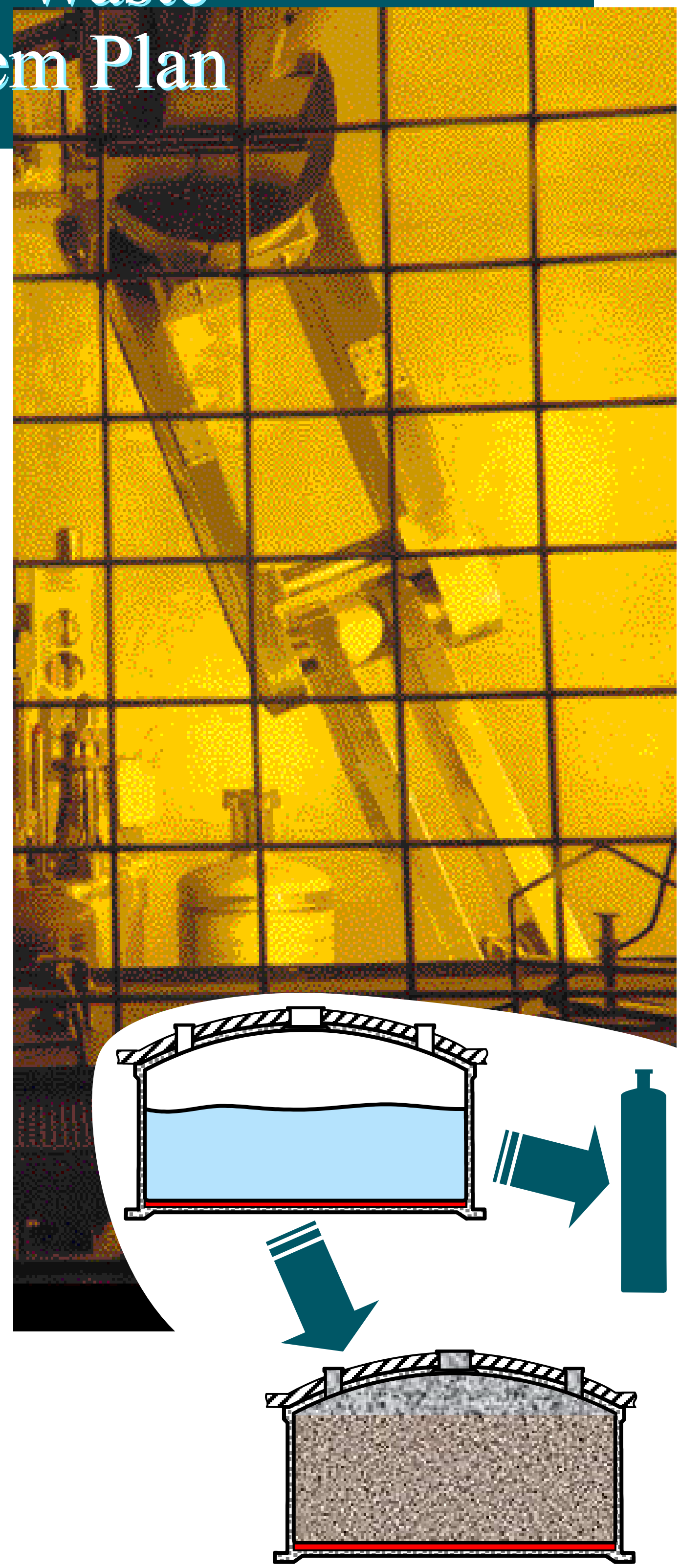
SRR-LWP-2009-00001

LIQUID Waste System Plan

Savannah River Site Liquid Waste Planning Process

An Integrated System at the Savannah River Site



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Liquid Waste System Plan
Revision 21

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1. Executive Summary

The last *Liquid Waste System Plan*, Revision 20[1] (LWSP–R20) was published in March 2016. This 21st Revision of the *Liquid Waste System Plan* (hereinafter referred to as the *Plan*) documents a scenario to allow continued progress in achieving the processing goals of the Department of Energy (DOE) at Savannah River Site (SRS) by Savannah River Remediation (SRR). It assumes the conditions extant in the beginning of Fiscal Year (FY) 2019. It also assumes continued 3H Evaporator operations as begun in mid-FY18. It further recognizes the outage for Melter replacement and the Salt Waste Processing Facility (SWPF) tie-ins that resulted in the Defense Waste Processing Facility (DWPF) resumption of operations in mid-FY18 with Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU) operations resuming shortly thereafter.

This *Plan* assumes aggressive performance of salt and sludge processing to forecast the best possible outcome for dispositioning the waste in the SRS High Level Waste (HLW) tank farms. This optimistic case assumes receipt of the funding required to: install removal equipment, process at stated rates, and maintain and replace (as necessary) the equipment. It assumes no major equipment failures other than the Melter replacement. It also assumes no major changes in safety requirements that would negatively affect the current planning basis for the removal, transfer, or processing of waste. As described in the Risk and Opportunity Management Plan[2] (ROMP), there are several risk events that, were they realized, could adversely affect the successful completion of the program goals in the time described.

The 3H Evaporator (242-25H) is required to volume reduce sludge wash decants and heel removal waste. In February 2016, however, waste was discovered in the 3H Evaporator cell having leaked from the evaporator vessel. In March 2017, the anomaly and failure mechanism were identified, and a path forward developed resulting in the resumption of operations in July 2018.

In February 2017, the second DWPF Melter was declared to have reached its End-of-Life (EOL) after fourteen years of operations, greatly exceeding its design life with more than double the life of the first melter. Melter replacement necessitated interruption of DWPF and MCU processing. Planned outages to make physical tie-ins for SWPF were accelerated to coincide with the melter replacement outage. These outage-related tie-ins were completed, the melter replaced, and DWPF operations resumed in December 2017.

One other feature of this *Plan* is incorporation of the provisions of the "*Agreement*"[3] executed in October 2016. That "*Agreement*" designates specific technology incorporation (*i.e.*, Tank Closure Cesium Removal [TCCR], Next Generation Solvent [NGS] in SWPF, and Sonar mapping demonstration) into the LW disposition matrix. Salt processing goals and deadlines are identified. Along with the goals and timing is a recognition of the challenges of operating a complex set of interdependent facilities, many of which are older such that documentation of *force majeure* events is allowed.

This *Plan* results in processing over 25 million gallons (Mgal) of salt waste in the "*Agreement*" period of FY16 through FY22. In addition to the 4,173 canisters that have been produced from FY96 through FY18, an additional 3,948 cans are projected for a total production of approximately 8,121 DWPF canisters over the lifetime of the project.

The completion of waste removal in F-Tank Farm (FTF), in this *Plan*, occurs in 2031 allowing the Inter-Area Line to be shut down also in 2031 and FTF closures complete by the end of 2033. LW treatment and disposition in DWPF and SWPF are completed by 2034. Of the 51 tanks, 44 tanks are closed by 2035 and the last of the H-Tank Farm (HTF) tanks, the DWPF feed tank, is closed in 2037.

Purpose

The purpose of this *Plan* is to integrate and document the activities required to disposition the existing and future HLW and remove from service radioactive LW tanks and facilities belonging to DOE at SRS (DOE-SR). It records a planning basis for waste processing in the LW System through the end of the program mission.

This twenty-first revision (Revision 21) of the *Plan*:

- Supports input to development of financial submissions to the complex-wide Integrated Planning, Accountability, & Budgeting System (IPABS)
- Provides a technical basis for LW Contract and Contract Performance Baseline changes
- Provides input to the development of regulatory agreements

Common Goals & Values

The overarching principles which govern strategic planning and execution of the SRS Liquid Waste Disposition Program are summarized in the seven "Common Goals and Values" that were agreed upon by key stakeholders over a decade ago (cf. *Progress in Implementation of Common Goals and Values* [4]). These remain the guiding goals and values for program execution and planning:

1. Reduce operational risk and the risk of leaks to the environment by removing waste from tanks and closing the tanks.
2. Remove actinides from waste expeditiously since their impact on the environment is the most significant if a leak occurs.
3. Maximize amount of waste ready for disposal in deep geologic repository. Make significant effort to ensure maximum amount of long-lived radionuclides are disposed in a deep geologic repository.
4. Remove as much cesium as practical from salt waste and dispose in parallel with vitrified sludge.
5. Dispose of cesium as soon as practical to avoid having cesium only waste when sludge vitrification is complete.
6. Limit disposal of radioactive waste onsite at SRS so that residual radioactivity is as low as reasonably achievable.
7. Ensure DOE's strategy and plans are subject to public involvement and acceptance.

Goals

The goals of previous revisions of this *Plan*, through Revision 17, were to meet *Federal Facility Agreement* (FFA)[5] and *Site Treatment Plan* (STP)[6] regulatory commitments. However, with the delays of SWPF beyond October 2014, as demonstrated in Revision 17, the following regulatory commitments have been adversely affected:

- Meet tank waste removal regulatory milestones in the currently-approved FFA
- Meet tank removal-from-service regulatory milestones in the currently-approved FFA
- Meet the waste treatment goals identified in the STP.

The goals (not necessarily the outcomes) of this *Plan* were to meet the following programmatic objectives:

1. Continual safe storage of liquid waste in tanks and vitrified canisters in storage.
2. Complete LW System operational closure by the end of FY33.
3. Complete operational closure of F Tank Farm by end of FY28.
4. Process liquid salt waste (e.g., dissolved salt solution, supernate) in FY16 through FY22 in accordance with the South Carolina Department of Health and Environmental Control (SCDHEC) *Dispute Resolution Agreement for Alleged Violations of Class 3 Industrial Solid Waste Landfill Permit Facility, Facility ID #025500-1603*[3] (referred to hereinafter as the "*Agreement*") (including consideration for *Force Majeure* conditions).
5. Remove the bulk of the waste in the Older Style H-Tank Farm tanks in the water table (i.e., Tanks 9, 10, 13, 14) by end of FY23.
6. Complete operational closure of the 1F Evaporator by the end of FY23.

Please note that some of these goals were not achievable within the constraints of the Plan.

Additional principles guiding the development of this *Plan* include:

- Conduct operations consistent with the Waste Determinations (WD): *Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*[7], the *Basis for Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*[8], the *Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site*[9], the *Basis for Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site*[10], the *Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site*[11], and the *Basis for Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site*[12]
- Comply with applicable permits and consent orders, including the Modified Class 3 Landfill Permit for the SRS Z-Area Saltstone Disposal Facility (SDF) (permit ID 025500-1603) and State-approved Consolidated General Closure Plan[13] (GCP)
- Minimize the quantity of radionuclides (as measured in curies) dispositioned in the SDF, keeping the total curies at or below the amount identified in *Savannah River Site – Liquid Waste Disposition Processing Strategy*[14] (SRS LW Strategy), as amended by letter from the SCDHEC to DOE-SR[15] and the *Basis for Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*[8] and the "*Agreement*"
- Support continued nuclear material stabilization of legacy materials in H-Canyon.

To enable continuation of risk reduction initiatives encompassed by the goals above, this *Plan* follows a processing strategy to provide the tank space required to support meeting, or minimizing impacts to meeting, programmatic objectives. During the period prior to startup of SWPF in 2020, near-term retrieval, treatment, and disposal of salt waste are required. The ARP/MCU facilities provide this treatment. Operation of these salt treatment processes frees up working space in the 2H and 3H Evaporators' concentrate receipt tanks (Tanks 38, 30, and 37). This provides support for near-term handling of waste streams generated from tank removals from service, DWPF sludge batch (SB) preparation, DWPF recycle handling, and H-Canyon processing.

Revisions

The significant updates from the previous version of this *Plan*, the *Liquid Waste System Plan, Revision 20*[1], include:

- **Major Equipment:**
  - Resolution of 3H Evaporator Pot leak and return to service
  - Replacement of DWPF EOL Melter 2
- **Salt Processing**:
  - SWPF startup moved to March 2020 from December 2018
  - Plan for installation of two TCCR units
- **DWPF**:
  - Resolve Hydrogen Generation Rate (HGR) Potential Inadequacy in Safety Analysis (PISA)
  - Convert to Glycolic Flowsheet

Results of the Plan

Table 1-1—Results *of Modeled Cases* describes the major results as compared to Revision 20 of the *Plan*:

Table 1-1—*Results of Modeled Cases*

Parameter	Rev 20, Case 1	Rev 21,
Date SWPF begins hot commissioning	Dec 2018	March 2020
Date last LW facility turned over to D&D	2041	2037
Final Type I and II tanks complete operational closure	2033	2030
Complete bulk sludge treatment	2031	2031
Complete bulk salt treatment	2032	2031
Complete heel treatment	2036	2034
TCCR for supplemental salt waste treatment	1 unit	2 units
Next generation solvent for increased SWPF throughput	Jan 2022	May 2021
Total number of canisters produced	8,170	8,121
Year supplemental canister storage required to be ready	2029	2030
Radionuclides (curies) dispositioned in SDF within the amended *SRS LW Strategy*	Yes	Yes
Total number of SDUs	14	13

Operational Closure: Supplemental salt processing via TCCR, as well as a quicker ramp up to the SWPF rate of 9 Mgal/yr, accelerates closure of old-style tanks with respect to Rev 20

SWPF Processing: This *Plan* assumes SWPF will implement NGS by the beginning of the second year of operation with no impact to the program schedule; the 9 Mgal/yr processing rate will be available after implementation of Enhanced Low Activity Waste Disposal and 24/7 shift operation at the Saltstone Production Facility (SPF)

Radionuclides Dispositioned in SDF: This *Plan* is consistent with *SRS LW Strategy* as amended by letter from the SCDHEC to DOE-SR[15] and the *Basis for Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*[8] concerning the total curies dispositioned at SDF.

Supporting Nuclear Material Stabilization: The Tank Farms have assumed receipt space of 200 thousand gallons (kgal) per year of H-Canyon waste through FY22 increasing to 300 kgal/yr from FY23 through FY30. Additionally, this *Plan* accommodates receipt of particular H-Canyon waste streams in Tank 50 or directly to sludge batches through FY30. (Note: after FY30, any H-Canyon waste will be dispositioned by H-Canyon)

Canister Storage: With the continued modification of Glass Waste Storage Building (GWSB) 1 to enable stacking two canisters in each storage location, this *Plan* forecasts the need for supplemental canister storage beginning in FY30. Shipment of canisters from SRS is not included in this *Plan* since a federal repository has yet to be identified.

Saltstone Disposal Units (SDU): SDU-2, SDU-3, and SDU-5 are dual cylindrical cell units with ~2.8 Mgal grout capacity (~1.6 Mgal of feed) per cell. SDU-2 and SDU-5 are filled. SDU-6 (currently in use) is a single cylindrical cell unit with ~32 Mgal grout capacity (~17 Mgal of feed). This *Plan* assumes future SDUs will have the same capacity as SDU-6. The last SDU will be sized as needed to complete the LW mission.

2. Introduction

This twenty-first revision of the Liquid Waste System Plan documents a strategy to operate the LW System at SRS to receive, store, treat, and dispose of radioactive LW and to close waste storage and processing facilities. The LW System is a highly integrated operation involving safely storing LW in underground storage tanks; removing, treating, and dispositioning the low-level waste (LLW) fraction in concrete SDUs; vitrifying the higher activity waste at DWPF; and storing the vitrified waste in stainless steel canisters pending permanent disposition. After waste removal and processing, the storage and processing facilities are cleaned and closed. This *Plan* assumes the reader has a familiarity with the systems and processes discussed. Section 6—*System Description* of this *Plan* provides an overview of the LW System.

The Tank Farms have received over 160 million gallons of waste from 1954 to the present. Having reduced the volume of waste via evaporation and dispositioned waste via vitrification and saltstone, the Tank Farms currently store approximately 35 million gallons of waste containing approximately 248 million curies (MCi) of radioactivity. As of December 31, 2018, DWPF had produced 4,179 vitrified waste canisters. (Note: All volumes and curies reported as current inventory in the Tank Farms are as of December 31, 2018 and account for any changes of volume or curies in the Tank Farms since Revision 20 of the *Plan* and the *Section 3116 Determination for Salt Waste Disposal at the Savannah River Site*[7].)

Successful and timely salt waste removal and disposal is integral to efforts to proceed with all aspects of tank cleanup and removal from service, extending well beyond permitted disposal of the solidified low-activity salt waste streams themselves. Removal of salt waste enables some tanks to be removed from service in anticipation of future closure. It also is necessary for the continued removal and stabilization of the high-activity sludge fraction of the waste. Preparing the sludge for processing in DWPF generates salt waste which must be stored or dispositioned. Operating ARP/MCU reduces the volume of stored salt waste and enhances salt waste processing so that vitrification of the sludge can continue more efficiently. Operating ARP/MCU also supports conversion of some tanks from storage to preparation of salt batches for processing in.

This *Plan* forecasts the best possible outcome for dispositioning the waste in the SRS tank farms via optimistic operation of waste removal, ARP/MCU, TCCR, SWPF, DWPF, and the Saltstone facilities. This optimistic case assumes timely receipt of the funding required to: install waste removal equipment, process at stated rates, and maintain and replace equipment, as necessary. It assumes no major equipment failures other than the one Melter replacement. It also assumes no major changes in safety requirements that would negatively affect the current planning basis for the storage, removal, transfer, or processing of waste. As described in the ROMP, there are several risk events that, were they realized, could adversely affect the successful completion of the program goals in the time described.

2.1 *Common Goals & Values*

The overarching principles which govern strategic planning and execution of the SRS Liquid Waste Disposition Program are summarized well in the seven "Common Goals and Values" that were agreed upon by key stakeholders over a decade ago[4]. These remain the guiding goals and values for program execution and planning:

1. **Reduce operational risk and the risk of leaks to the environment by removing waste from tanks, and closing the tanks**
   - Curie Workoff from ~550 MCi in 1995 to 248 MCi at the end of 2018 (dispositioning ~61 MCi in glass, 0.5 MCi in Saltstone grout, and the remainder due to radioactive decay).
   - Of the 14 SRS tanks with leakage history (all old-style tanks):
     - — 6 are operationally closed and grouted (Tanks 5, 6, 12, 16, 19, and 20)
     - — 2 are supporting the TCCR process (Tanks 10 and 11)
     - — 1 is awaiting heel removal activities to commence (Tank 15)
     - — 3 contain essentially dry waste, with little or no free liquid supernate (Tanks 1, 9, and 14)
     - — 2 contain liquid supernate at a level below known leak sites (Tanks 4 and 13)
   - Of the 24 SRS old-style tanks:
     - — 8 are grouted and operationally closed (Tanks 5, 6, 12, 16, 17, 18, 19, and 20)
     - — 5 have had bulk waste removal completed (Tanks 4, 7, 8, 11, and 15)
   - Approximately 66% of old-style tank space is currently empty or grouted and approximately 23% of new-style tank space is empty.

2. **Remove actinides (sludge) from waste expeditiously since they affect the environment most significantly if a leak occurs.**
   - Actinides and other high activity components are being immobilized in glass
   - To date, over 4,170 canisters of waste (~51 % of the projected lifecycle total) have been vitrified
   - Canister waste loading was raised from the originally planned ~28%, as appropriate
   - In August 2013, DWPF set a production record of 40 canisters produced in a single month.

3. **Maximize amount of waste ready for disposal in deep geologic repository. Make significant effort to ensure maximum amount of long-lived radionuclides are disposed in a deep geologic repository.**
   - To date, over 98% of the curies immobilized have been placed in glass in preparation for disposal in a deep geologic repository
   - At mission completion, over 99% of treated curies are projected to have been immobilized in glass.

4. **Remove as much cesium as practical from salt waste and dispose in parallel with vitrified sludge.**
   - A small portion of salt waste (~2%) was treated only via Deliquification, Dissolution, and Adjustment (DDA)
   - Extraction of cesium from salt waste through ARP/MCU began in 2008 and, through 2013, was ~10 times more efficient than the original projection (~3.4% of forecast salt production)
   - Deployment of NGS at MCU in 2014 improved cesium removal efficiency by more than 200 times, exceeding the original SWPF design; the cesium-laden MCU Strip Effluent (SE) stream is vitrified with sludge and disposed in canisters (~2.8% of forecast salt production)
   - TCCR is forecast to provide supplemental treatment capability to existing and future salt processing and improve confidence in supporting the desired acceleration of waste retrieval and tank operational closure efforts (~16%)
   - SWPF is forecast to treat the highest volume (~ 75%) and activity of the salt waste.

5. **Dispose of cesium as soon as practical to avoid having cesium only waste when sludge vitrification is complete.**
   - To date, over 9.8 million gallons (Mgal) of salt waste (approximately 8.4% of the projected lifecycle total) have been treated and dispositioned
   - Allocation of available resources is focused on maintaining the pace of risk reduction through waste treatment and immobilization
   - The contribution of ARP/MCU was enhanced by deploying NGS to increase cesium removal efficiency
   - This *Plan* utilizes TCCR to supplement SWPF to accelerate salt processing
   - This *Plan* forecasts completion of salt processing prior to completion of sludge processing.

6. **Limit disposal of radioactive waste onsite at SRS so that residual radioactivity is as low as reasonably achievable.**
   - Formal Performance Assessments (PA) of LLW disposal and operational closure of tanks, coupled with cost to benefit evaluations prior to cessation of tank waste removal activities, support that any residual future impacts from onsite waste disposal are within the requirements of applicable federal and state laws and regulations, and are as low as reasonably practical
   - Based on operational experience, over 95% of the radioactive inventory in a tank has been removed after bulk waste removal and heel dilution; over 99% of the radioactive inventory has been removed after final cleaning
   - At mission completion, over 99% of treated curies are projected to have been immobilized in glass and packaged for offsite disposal in a deep geologic repository
   - The originally agreed upon projection for onsite emplacement in engineered disposal units from LW treatment and disposition was 3 MCi (2.5 MCi from DDA-only; 0.3 MCi from ARP/MCU; and 0.2 MCi from SWPF). That agreement was reduced to 0.8 MCi in August 2011[15] based on progress as of 2011.

7. **Ensure DOE's strategy and plans are subject to public involvement and acceptance.**
   - The formal processes for evaluation, determination, and execution of all tank waste removal, disposal, and operational closure fully involves SCDHEC, the Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC)
   - Various formal hold points exist in these processes for public involvement and comment
   - All SRS LW disposition activities fall within the purview of the Defense Nuclear Facilities Safety Board (DNFSB) oversight, and DNFSB periodically issues publicly accessible reports of their evaluations and conducts periodic meetings to receive public input regarding their activities
   - The SRS Citizen's Advisory Board receives routine updates in a public venue regarding all SRS LW Disposition activities
   - Updates to this *Plan* are provided to all regulatory and oversight entities and made available for public review

- Quarterly updates of radiological inventory additions to SDUs are posted to a publicly accessible website
- SRR monthly and annual reports of progress towards disposition of SRS LW are available to the public.

2.2 ***System Planning Overview***

System Plan Rev. 21 Goals and Priorities

DOE's overarching priorities for development of this *Plan* are:

1. Continual safe storage of liquid waste in tanks and vitrified canisters in storage.
2. Complete LW System operational closure by the end of FY33.
3. Complete operational closure of F Tank Farm by end of FY28.
4. Process liquid salt waste (e.g., dissolved salt solution, supernate) in FY16 through FY22 in accordance with the SCDHEC "*Agreement*"[3] (including consideration for *Force Majeure* conditions).
5. Remove the bulk of the waste in the old-style H-Tank Farm tanks in the water table (i.e., Tanks 9, 10, 13, 14) by end of FY23.
6. Complete operational closure of the 1F Evaporator by the end of FY23.

Please note that some of these goals were not achievable within the constraints of the Plan*.*

Constraints

Operations are planned within the boundaries established by applicable regulatory constraints and processing constraints. For more information regarding regulatory constraints, refer to Section 3.2.

Processing constraints are primarily addressed within the context of tank space management.

There is currently a premium on processing and storage space in the SRS radioactive LW tanks. Space is needed for safe storage of waste; volume reduction initiatives via evaporation; retrieval of waste from old-style tanks and subsequent cleaning of those emptied tanks; preparation of sludge and dissolution of salt prior to treatment in downstream facilities; and receipt of influent wastes from both DWPF and H Canyon. The Tank Farm space management strategy is based on a set of key assumptions involving projections of treatment facility throughput, Tank Farm evaporator performance, and influent stream volumes.

As the Liquid Waste program proceeds, the roles of some tanks will change to maximize efficient use of available space at that time. Currently, the 27 new-style tanks are deployed as follows:

- 5 (Tanks 38, 41, 43, 49, and 50) are dedicated to salt batching, qualification, and disposition (including DWPF recycle beneficial reuse, feeding the Saltstone Production Facility (SPF), and the 2H Evaporator);
- 2 additional tanks (Tanks 27 and 42) are planned for conversion to salt blend tanks to prepare salt batching
- 6 (Tanks 29, 30, 32, 37, 40, and 51) are dedicated to sludge batching, qualification, and disposition (including the 3H Evaporator)
- 1 (Tank 39) supports uninterrupted H-Canyon waste receipts
- 13 (Tanks 25, 26, 28, 31, 33, 34, 35, 36, 44, 45, 46, 47, and 48) are dedicated to safe storage of legacy LW pending retrieval and disposition.

These 27 new-style tanks represent a maximum storage capacity of 35 million gallons of space. However, not all that space is available for waste storage:

- 3.0 Mgal is margin as defense-in-depth operational control coupled with Safety Class or Safety Significant (SC/SS) structures, systems, or components (SSC) to facilitate reasonably conservative assurance of more than adequate dilution and ventilation of potentially flammable vapors
- 1.3 Mgal is procedurally-required minimum contingency space for recovery from the unlikely event of a large waste leak elsewhere in the system
- 3.9 Mgal is operational "working" space variously used to provide:
  - Additional contingency transfer space as operational excess margin above the procedurally-required minimum
  - Excess margin to preserve salt batch quality and maintain uninterrupted treatment and disposition through ARP/MCU and Saltstone
  - Excess margin to preserve sludge batch quality and maintain uninterrupted immobilization through DWPF
  - Excess margin to preserve uninterrupted support for H-Canyon.

2.3 *Risk Assessment*

The *PBS-SR-0014, Radioactive Liquid Tank Waste Stabilization and Disposition, Risk and Opportunity Management Plan* (ROMP) documents the comprehensive identification and analysis of technical risks and opportunities associated with the LW program. It identifies individual technical and programmatic risks and presents the strategies for handling risks and opportunities in the near-term and outyears.

The ROMP identifies over 100 risks associated with this *Plan* with a total outyear Technical and Programmatic Risk Assessment (T&PRA) of several billion dollars. After mitigation, overall risk level is reduced; however, some concerns remain:

- Funding—Adequate funding for PBS-SR-0014 throughout its life cycle to permit full execution of the System Plan is uncertain. This is a crosscutting risk for both major contractors at SRS and is addressed at the site level.
- Aging Infrastructure—The System Plan end date places significant stress on what will be an increasingly aging infrastructure. Recent infrastructure failures, such as the leak in the 3H Evaporator pot, provide insight into the problems that may be encountered with operating the HLW System for an additional 18 years.
- TCCR Spent Column Disposition—TCCR is forecast to produce over 120 cesium-laden ion exchange columns over the course of its mission. Interim Safe Storage (ISS) will be provided on-site for these columns, but the final disposition for these highly radioactive columns has not been selected.
- Infrastructure Capacity—The capacity of the existing Tank Farm infrastructure will be stretched close to its limits in supporting salt batch preparation. Choke points could easily be encountered if multiple use conflicts develop and planned availability of transfer routes and equipment are impacted.
- Emergent Changes to Requirements—Changes to Business, Project Management, or Technical requirements may adversely affect plans for the provision of necessary facilities (*e.g.*, SDUs), or performance of necessary activities (*e.g.*, transfers). This has the potential to interfere with normal operational expectations assumed in the *Plan*.
- DWPF Recycle—For every 1.0 gallon of sludge treated in DWPF, 1.3 gallons of dilute salt waste is returned to the Tank Farm. This System Plan assumes that in FY23, the DWPF recycle stream will be diverted for treatment outside of the Tank Farm, but a specific treatment path has not yet been selected.

3. Planning Bases

This *Plan* is based on DOE-SR and SRR agreed inputs, assumptions, and priorities. Dates, volumes, and chemical or radiological composition information contained in this *Plan* are planning approximations only. Specific flowsheets guide actual execution of individual processing steps. The activities described are summary-level activities, some of which have yet to be fully defined. The sequence of activities reflects the best judgment of the planners. The individual activity execution strategies contain full scope, schedule, and funding development. Upon approval of scope, cost, and schedule baselines; modifications of this *Plan* may be required.

3.1 *Funding*

Progress toward the ultimate goal of immobilizing all the LW at SRS is highly dependent on available funding. This *Plan* was developed assuming the availability of the funding required as specified in the inputs and assumptions referenced above. It supports justification for requesting necessary funding profiles. With any reduction from full funding, activities that ensure safe storage of waste claim priority. Funding above that required for safe storage enables risk reduction activities, i.e., waste removal, treatment—including immobilization—and removal from service, as described in this *Plan*.

3.2 *Regulatory Drivers*

Numerous laws, constraints, and commitments influence LW System planning. Described below are requirements most directly affecting LW system planning. This *Plan* assumes the timely acquisition of regulatory approvals.

South Carolina Environmental Laws

Under the South Carolina Pollution Control Act, S.C. Code Ann. §§ 48-1-10 *et seq*., SCDHEC is the delegated authority for air pollution control and water pollution control. The State has empowered SCDHEC to adopt standards for protection of water and air quality, and to issue permits for pollutant discharges. Further, SCDHEC is authorized to administer both the federal Clean Water Act and the Clean Air Act. Under South Carolina's Hazardous Waste Management Act, S.C. Code Ann. §§ 44-56-10 *et seq*., SCDHEC is granted the authority to manage hazardous wastes. With minor modifications, SCDHEC has promulgated the federal Resource Conservation and Recovery Act (RCRA) requirements, including essentially the same numbering system. The South Carolina Solid Waste Policy and Management Act, S.C. Code Ann. §§ 44-96-10 *et seq*., provides standards for the management of most solid wastes in the state. For example, SCDHEC issued to DOE-SR permits such as the Class 3 Landfill Permit for SDF. This landfill permit contains conditions for the acceptable disposal of non-hazardous waste in the SDF. This permit also contains provisions for fines and penalties. Other principal permits required to operate LW facilities pursuant to the state's environmental laws include:

- SCDHEC Bureau of Water:
  - Industrial wastewater treatment facility permits (e.g., Tank Farms, DWPF, ARP/MCU, Effluent Treatment Project [ETP], and the SPF)
  - National Pollutant Discharge Elimination System (NPDES) permit (H-16 Outfall discharges from ETP)
- SCDHEC Bureau of Air Quality:
  - Part 70 Air Quality Permit (one Site-wide Air Permit including the LW facilities).

Site Treatment Plan (STP)

The STP[6] for SRS describes the development of treatment capacities and technologies for mixed wastes and provides guidance on establishing treatment technologies for newly identified mixed wastes. The STP allows DOE, regulatory agencies, the States, and other stakeholders to efficiently plan mixed waste treatment and disposal by considering waste volumes and treatment capacities on a national scale. The STP identifies vitrification in DWPF as the preferred treatment option for appropriate SRS liquid high-level radioactive waste streams and solidification in Saltstone for low-level radioactive waste streams. In 1996, SRS committed that:

> *"Upon the beginning of full operations, DWPF will maintain canister production sufficient to meet the commitment for the removal of the backlogged and currently generated waste inventory by 2028."*

The commitment for the removal of the waste by 2028 encompasses bulk waste removal and heel removal scope of this *Plan*. Final cleaning, deactivation, and removal from service of storage and processing facilities are subsequent to the satisfaction of this commitment. *Note that with the changes in technology and challenges in implementing the various technologies this* Plan *does not meet this commitment, even with additional salt processing.*

Federal Facility Agreement (FFA)

The EPA, DOE, and SCDHEC executed the SRS FFA[5] on January 15, 1993, with an effective date of August 16, 1993. It provides standards for secondary containment, requirements for responding to leaks, and provisions for the removal from service of leaking or unsuitable LW storage tanks. Tanks scheduled for operational closure may continue to be used but must adhere to the FFA schedule for operational closure and the applicable requirements contained in the Tank Farms' industrial wastewater treatment facility permit. Several agreements since then have modified the original agreement recognizing the realization of previously identified risks (*e.g.*, delays in SWPF start-up date).

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to assess the potential environmental impacts of proposed actions. Seven existing NEPA documents and their associated records of decision directly affect the LW System and support the operating scenario described in this *Plan*:

- DWPF Supplemental Environmental Impact Statement (SEIS) (DOE/EIS-0082-S)
- Final Waste Management Programmatic Environmental Impact Statement (PEIS) (DOE/EIS-0200-F)
- SRS Waste Management Final Environmental Impact Statement (EIS) (DOE/EIS-0217)
- Interim Management of Nuclear Materials EIS (DOE/EIS-0220)
- SRS High-Level Waste Tank Closure Final EIS (DOE/EIS-0303)
- Environmental Assessment (EA) for the Closure of the HLW Tanks in F- and H Areas at SRS (DOE/EA-1164)
- SRS Salt Processing Alternatives Final SEIS (DOE/EIS-0082-S2).

Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005

The *Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005* (NDAA) Section 3116 (NDAA §3116) allows determinations by the Secretary of Energy, in consultation with the NRC, that certain radioactive waste from reprocessing is not high-level waste and may be disposed of in South Carolina pursuant to a State-approved closure plan or State-issued permit. For salt waste, DOE contemplates removing targeted fission products and actinides using a variety of technologies and combining the removed fission products and actinides with the metals being vitrified in DWPF. NDAA §3116 governs solidifying the remaining low-activity salt stream into saltstone for disposal in the SDF. For tank removal from service activities, NDAA §3116 governs the Waste Determinations for the Tank Farms that demonstrate that the tank residuals, the tanks, and ancillary equipment (evaporators, diversion boxes, etc.) at the time of removal from service and stabilization can be managed as non-high-level waste.

Conduct of operations are planned in accordance with the following applicable portions of the NDAA:

- Section 3116 Determination for Salt Waste Disposal at the Savannah River Site[7]
- Basis for Section 3116 Determination for Salt Waste Disposal at the Savannah River Site[8]
- Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site[9]
- Basis for Section 3116 Determination for Closure of F-Tank Farm at the Savannah River Site[10]
- Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site[11]
- Basis for Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site[12]

3.3 ***Revisions***

The significant updates from the previous version of this *Plan*, the *Liquid Waste System Plan, Revision 20*[1], include:

- **Major Equipment:**
  - Resolution of 3H Evaporator Pot leak and return to service
  - Replacement of DWPF EOL Melter 2
- **Salt Processing**:
  - SWPF startup moved to March 2020 from December 2018
  - SWPF early year production rates are increased
  - Plan for installation of two TCCR units
- **DWPF**:
  - Resolve HGR PISA
  - Convert to Glycolic Flowsheet

3.4 *Key Milestones*

Key Milestones are those major dates deemed necessary under this *Plan* to remove waste from storage, process it into glass or saltstone, and close the LW facilities. The *LW System Plan*, *Revision 20* milestones are provided for comparison.

Table 3-1—*Key Milestones*

Key Milestone	Rev 20 Case 1	Rev 21
Date SWPF begins hot commissioning	Dec 2018	March 2020
Date last LW facility turned over to D&D	2041	2037
Final Type I, II, and IV tanks complete operational closure	2036	2033
Complete bulk sludge treatment	2031	2031
Complete bulk salt treatment	2032	2031
Complete heel treatment	2036	2034
Total number of canisters produced	8,170	8,121
Year supplemental canister storage required to be ready	2029	2030
Initiate ARP/MCU Processing *(actual)*	*Apr 2008*	*Apr 2008*
Initiate TCCR Processing	2018	2019
Initiate SWPF Processing	Dec 2018	May 2020
– *Salt Solution Processed via DDA-solely (actual)*	*2.8 Mgal*	*2.8 Mgal*
– *Salt Solution Processed via ARP/MCU*	*10 Mgal*	*8.1 Mgal*
– *Salt Solution Processed via TCCR*	*0.8 Mgal*	*16.8 Mgal*
– *Salt Solution Processed via SWPF*	*110 Mgal*	*90 Mgal*
Number of SDU	14	13

Operational Closure: Supplemental salt processing via TCCR accelerates closure of old-style tanks with respect to Rev 20.
SWPF Processing: Hot commissioning begins in March 2020 with the deliberate introduction of radioactive materials into the several subprocesses of SWPF for two months. Beginning in the third month (May 2020) operations begin with a forecast capacity of 6 Mgal/year. The second year of operations is forecast to begin the 9 Mgal/yr operations through the end of the program, except for major process interruptions *e.g.*, the planned DWPF Melter change outage in 2029.
Vitrification of Sludge at DWPF: This *Plan* forecasts completion of salt processing concurrent with sludge processing, minimizing sludge simulant addition. Processing of the remaining heels will continue past the end of SWPF operations.
Canister Storage: This *Plan* recognizes the continued modification of GWSB 1 to allow storage of two canisters in each storage position. GWSB 1 and 2 are forecast to be full in 2029 requiring provision of supplemental canister storage beginning in FY30. Shipment of canisters from SRS is not included in this *Plan* since a federal repository has not yet been identified.
Saltstone Disposal Units (SDU): SDU-2, SDU-3, and SDU-5 are dual cylindrical cell units with ~2.8 Mgal grout capacity (~1.6 Mgal of feed) per cell. SDU-2 and SDU-5 are filled. SDU-6 (currently in use) is a single cylindrical cell unit with ~32 Mgal grout capacity (~17 Mgal of feed). This *Plan* assumes future SDUs will have the same capacity as SDU-6. The last SDU will be sized as needed to complete the LW mission.

4. Planning Summary and Results

This section summarizes the key attributes of this *Plan*. Detailed discussion on risks and associated mitigation strategies are included in other documents such as the ROMP and individual implementation activity risk assessments.

In addition, this *Plan* assumes receiving adequate funding to achieve the required project and operations activities. Failure to obtain adequate funding will have a commensurate impact on the programmatic objectives.

This section summarizes the *Plan*, based on the key assumptions and bases. Tabular results of the lifecycle, on a year-by-year basis, or graphical results of the lifecycle are included in:
Appendix A—*Salt Solution Processing*
Appendix B—*Tank Farm Influents and Effluents*
Appendix C—*Bulk Waste Removal Complete*
Appendix D—*Tank Removal from Service*
Appendix E—*LW System Plan—Revision 21 Summary*
Appendix F—*Sludge Processing*
Appendix G—*GWSB Utilization*
Appendix H—*Canister Storage*
Appendix I—*TCCR Columns Interim Safe Storage*
Appendix J—*Remaining Tank Inventory*

4.1 Sludge Processing

Sludge processing is paced by available canister storage, ability to fund sludge removal, accessibility of sludge below salt waste, and by tank storage space to prepare sludge batches. Each sludge batch is comprised of sludge from two or more source tanks. Sludge batch planning uses the estimated mass and composition of sludge and known processing capabilities to develop processing sequences. In addition, the need to integrate salt and sludge processing constrains canister production to meet salt processing requirement during some years.

The basic steps for sludge processing (Figure 4-1) are:
1. Sludge removal from tanks
2. Low-Temperature Aluminum Dissolution (LTAD), if needed (in Tank 51)
3. Blending and washing of sludge (in Tank 51)
4. Sludge feeding to the DWPF (from Tank 40)
5. Vitrification in DWPF.

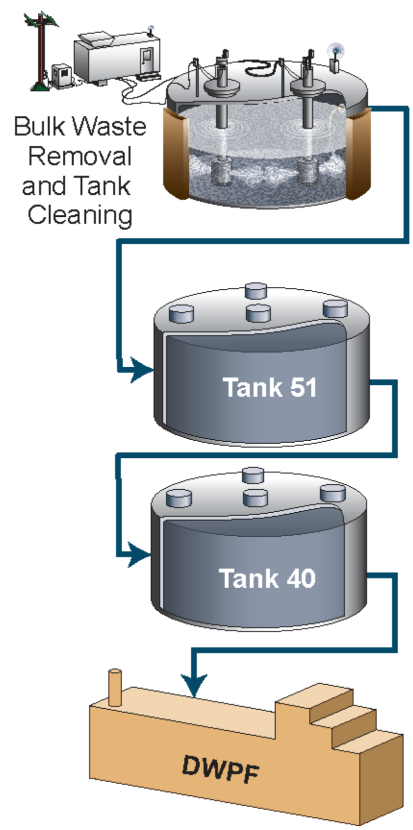


Figure 4-1—*Sludge Feed Preparation*

Low Temperature Aluminum Dissolution

High-heat sludge generated from the Canyon H-Modified (HM) process has high amounts of aluminum solids as gibbsite or boehmite. Some of this aluminum can be removed from the sludge by dissolution of the aluminum and subsequent removal by decanting of the liquid phase. This reduces the number of canisters needed to disposition the sludge, due to the lowered sludge solids mass and improved waste loading in the glass. Dissolution is achieved by application of added caustic, elevated temperature, mixing, and sufficient reaction time. “Low Temperature” refers to the use of a maximum temperature of around 75ºC to achieve the dissolution, as demonstrated for SB5, SB6, and SB10. The dissolved aluminum is processed with the salt waste. Sludge generated by the PUREX process does not require LTAD.

Sludge Washing

Sodium and other soluble salts (e.g., sulfates, nitrates, nitrites) in DWPF feed are reduced through sludge washing. Sludge washing is performed by adding water to the sludge batch, mixing with slurry pumps, securing the pumps to allow gravity settling of washed solids, and decanting the sodium-rich supernate to an evaporator system for concentration. This cycle is repeated until the desired molarity (typically 1.0 M Na) is reached. Some types of sludge settle slowly, extending wash cycles. Sludge settling and washing typically constitutes ~75% of batch preparation time. The total number of washes performed, and volume of wash water used are minimized to conserve waste tank space. Sludge batch size and wash volumes are also limited by the hydrogen generation rate associated with radiolysis of water. Tank contents are mixed on a periodic frequency to release hydrogen retained within the sludge layer, resulting in a limited window within operating constraints for gravity settling. Once sludge washing has achieved its chemical composition objective and the batch has been qualified for compliance with the DWPF Waste Acceptance Criteria (WAC), it is transferred to Tank 40 for feeding into DWPF in small (5 kgal– 10 kgal) batches.

4.2 ***DWPF Operations***

Washed sludge is transferred to the DWPF facility where it is combined with the high-level waste streams from salt processing (discussed below) for vitrification into glass canisters and stored on-site pending disposition.

Historically, melter performance has been the limiting factor for DWPF throughput. The DWPF melter had produced an average of 215 canisters/yr before melter bubblers were installed. When bubblers were installed in September 2010, however, the melter capacity improved such that, in FY12 a record 277 canisters were poured and a monthly record of 40 canisters were poured in August 2013. The feed preparation systems internal to DWPF have demonstrated a capacity of greater than 325 canisters/yr, e.g., the 337 canisters poured from July 2011 thru June 2012. In this *Plan*, the canister production rate is matched to ARP/MCU or SWPF production rate. The early years of the plan require fewer canisters to support the ARP/MCU or SWPF production of SE. DWPF, however, has a demonstrated capability of producing the maximum annual rate forecast in this *Plan* of 300 canisters/yr.

The declaration of the HGR PISA in February 2017 is currently limiting DWPF operations (see section 5.6 *Additional Technical Assumptions*, the *Nuclear Safety* subsection). Resolution of the limitation is expected upon full implementation of the glycolic flowsheet.

Total Canister Count

Total canister count is primarily based on the mass of sludge in a tank that must be emptied, the ability to perform aluminum dissolution, and the need to add sludge modifiers to meet physical and chemical requirements for DWPF processing. Providing tank space for SWPF and ongoing waste removal may require transfer of sludge to a temporary storage location (sludge hub tank). Limits on the mass of sludge that can be physically managed in a sludge batch may dictate an increase or decrease in both solids loading and canister generation rate. There is also a minimum practical operating rate (approximately five canisters per month) for keeping the DWPF processes functioning. Additionally, a minimum canister production rate is required to support salt processing, based on the amount of SE and monosodium titanate (MST) generated. SWPF processing of 9 Mgal/yr with NGS is anticipated to require over 275 canisters per year.

Two-step Production Improvement Approach

To support higher glass throughput, the DWPF melter was retrofitted with four bubbler systems and the melter off-gas system was optimized in September 2010. The second step of DWPF production capacity improvement program addresses streamlining the DWPF feed preparation system. Several process improvements are planned to streamline the DWPF feed preparation system which are required to support SWPF operations at a feed rate greater than 6 Mgal per year:

- Implementation of an alternate reductant, *i.e.*, the glycolic flowsheet
- Processing of cesium SE in the slurry mix evaporator (SME).

Reduction of liquid addition in DWPF supports receipt of SE from SWPF. Beneficial reuse of DWPF recycle for waste removal and tank cleaning, in lieu of water additions, supplements recycle reduction and supports maintenance of Tank Farm capacity (see §4.6 below).

Future estimated canister production, by year is shown in Appendix H—*Canister Storage*. The canister rates include two one-week outages every year to allow for routine planned maintenance and another two weeks for the site-wide steam outage each year.

Failed Equipment Storage Vaults and Melter Storage Boxes

The major component of the DWPF process is the Melter which has a finite operational life. While the original design of the DWPF facility forecast a melter replacement every two years, the first melter operated over eight and a half years before it reached its end of life. Melter 2 had operated fourteen years when it reached the end of life in 2017. This Plan assumes one additional melter change will be required in 2029, at which time Melter 3 will have been in service for twelve years.

Disposition of highly radioactive failed melters requires specially designed transport and storage Melter Storage Boxes (MSB) which are placed in underground Failed Equipment Storage Vaults (FESVs) for interim storage. The original DWPF design has two FESVs contained within one construction unit. Each FESV is designed to store one MSB containing a failed melter.

Melter 1 was placed in FESV 2 in December 2002. Melter 1 (inside MSB 1) had a relatively low external radiation field. It was placed in the northernmost vault since the next vault pair to be constructed would be adjacent to FESV 2. Melter 2 was placed in FESV 1 in May 2017. Space has been reserved for construction of up to ten FESVs, if needed.

This Plan assumes FESV 3 and 4 preparation begins in 2020 and requires two years for completion. Construction of MSB 3 is forecast to be completed in FY21. MSB 3 will not be required until Melter 3 is nearing end of life.

Currently, the FESV 200-ton gantry crane is designed to interface only with an MSB designed primarily to contain failed melters. The placement of other large failed DWPF equipment (which do not have disposal paths) in FESVs has been considered but the complete engineered system to move large contaminated equipment from the 221-S Canyon to the FESV has not been designed or constructed. Alternative methods for disposal of large contaminated equipment from DWPF (not including melters) are being evaluated.

Glass Waste Canister Storage

The canisters of vitrified HLW glass produced by DWPF are currently stored on-site in dedicated interim GWSBs. A Shielded Canister Transporter moves one canister at a time from the Vitrification Building to a GWSB. The schedule for filling the GWSBs is found in Appendix H—*Canister Storage.* The schedule assumes that starting in FY20 all current production canisters are double stacked in GWSB 1 (Figure 4-2—*Double Stacking*) within the guidelines of *Heat Transfer Analysis of Double Stacking of Canisters in the Glass Waste Storage Building #1*[16].

GWSB 1 consists of a below-grade seismically qualified concrete vault containing support frames for vertical storage of 2,262 standard canisters. In FY15, GWSB 1 began conversion for stacking two canisters in each storage location for a total capacity of 4,524 standard canisters. As of January 1, 2019, GWSB 1 contained 1,912 radioactive canisters and two archived non-radioactive canisters.

GWSB 2, with a similar design to GWSB 1, has 2,340 standard storage locations. The first radioactive canister was placed in GWSB 2 on July 10, 2006. One archived non-radioactive canister is in GWSB 2. As of January 1, 2019, GWSB 2 stored 2,251 radioactive canisters. See Appendix G—*GWSB Utilization* for current utilization of the GWSBs

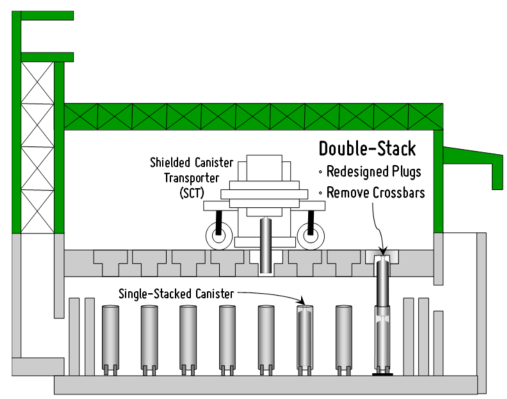


Figure 4-2—*Double Stacking*

Additional glass waste storage capacity will be required, with availability beginning in FY30 as current storage capacity is 6,861 and the total projected storage requirement is 8,121 for a shortfall of 1,260 canisters. The schedule for shipment of the canisters from SRS is not included in this *Plan*. It will be developed upon availability of a permanent federal repository.

4.3 ***Salt Processing***

As highlighted in the Introduction, this *Plan* includes the use of a series of salt treatment processes over the life of the program, including ARP/MCU, TCCR, and SWPF. *Appendix A—Salt Solution Processing* reflects the breakdown of the volumes treated from each of the processes by year. Using the input assumptions for this Plan, over 100 Mgal of salt solution from the Tank Farms will have been processed over the life of the program; over 9.8 Mgal were processed by December 2018. SWPF is planned to process most of this salt solution waste.

Salt preparation capability is limited by the number of blend tanks available to prepare salt batches. A single tank is capable of preparing 4 Mgal/yr. In the first year of SWPF operations, Tank 21 (Type IV) and Tank 41(Type III) serve as blend tanks. Thereafter, two Type III tanks, Tank 27 and Tank 42, will be equipped for blend tank service allowing the Tank 21 to be converted for TCCR service. The three blend tanks will support the planned SWPF operating rate of 9 Mgal/yr after the initial year of operation. When FTF is ready for closure, Tank 24 (Type IV) will replace the FTF blend tank, Tank 27, for the last two years of SWPF operations.

Other factors limiting salt processing capacity with the strategy to compensate for the limitation:

- **SE & MST processing in DWPF at the planned rates:** Achieving greater than 7.2 Mgal/yr of SWPF processing will require reducing the SE volume through implementation of NGS at SWPF in addition to other facility enhancements
- **Decontaminated Salt Solution (DSS) processing in SPF at the planned rates:** Enhanced Low Activity Waste Disposal (ELAWD) Phase II, along with 24/7 operations are required to ensure SPF's ability to process the DSS stream from SWPF when SWPF operates at rates greater than 6 Mgal/yr.
- **Equipment Reliability Upgrades:** Equipment upgrades such as Tank Farm East Hill Utilities and Saltstone Mixer re-design will provide increased attainability rates
- **Salt Dissolution Efficiency:** Increasing the salt dissolution efficiency enhances reliability of salt batch preparation. Revise safety basis requirements to maximize the salt dissolution rate utilizing commercial submersible mixing pumps (CSMPs)
- **Salt Batch Qualification:** Part of the salt batch preparation time is for qualification analysis and documentation. The salt batch qualification process can be streamlined through analyte reduction and the automatic electronic Waste Acceptance Criteria (eWAC)
- **Transfer Line Integrity:** Occasionally, transfers are delayed due to Out of Service (OOS) transfer lines from failed pressure tests. Devise improved transfer line integrity assurance
- **Offsite Dry Feed Preparation:** Dry feed preparation at SPF requires the use of the existing silos to mix the components of the dry feed. An offsite dry feeds mixing plant would allow pre-mixing the dry feeds before reaching the Saltstone facility to increase dry feeds capacity and enable use of all four silos
- **Pre-Transfer Flammability Calculations:** Currently engineering calculations are required prior to transfer to ensure the integrity of the flammability control program. Revision of the Tank Farm flammability program could minimize Engineering calculations and evaluations prior to performing transfers
- **Frit Development:** Current frit recipes are not adequate to support the higher SWPF throughput projected in this *Plan*. Develop new Frit recipes to handle the increased amount of MST sent to DWPF from SWPF

4.3.1 Actinide Removal Process / Modular CSSX Unit (ARP/MCU)

Salt waste is currently processed through ARP/MCU. A summary of the process is shown in Figure 4-3—*Schematic of the ARP/MCU Process*.

The ARP decontaminates salt solution via adsorption of strontium-90 (Sr-90), actinide, and entrained sludge solids in the salt solution onto MST followed by filtration or settling. The actinides, Sr-90, and MST-laden sludge waste stream are transferred to DWPF for vitrification and the remaining clarified salt solution is transferred to the MCU process. In 2016, a demonstration of ARP was initiated to demonstrate that, with the correct salt batch makeup, MST addition is not necessary to meet the SPF WAC for the ARP/MCU batches.

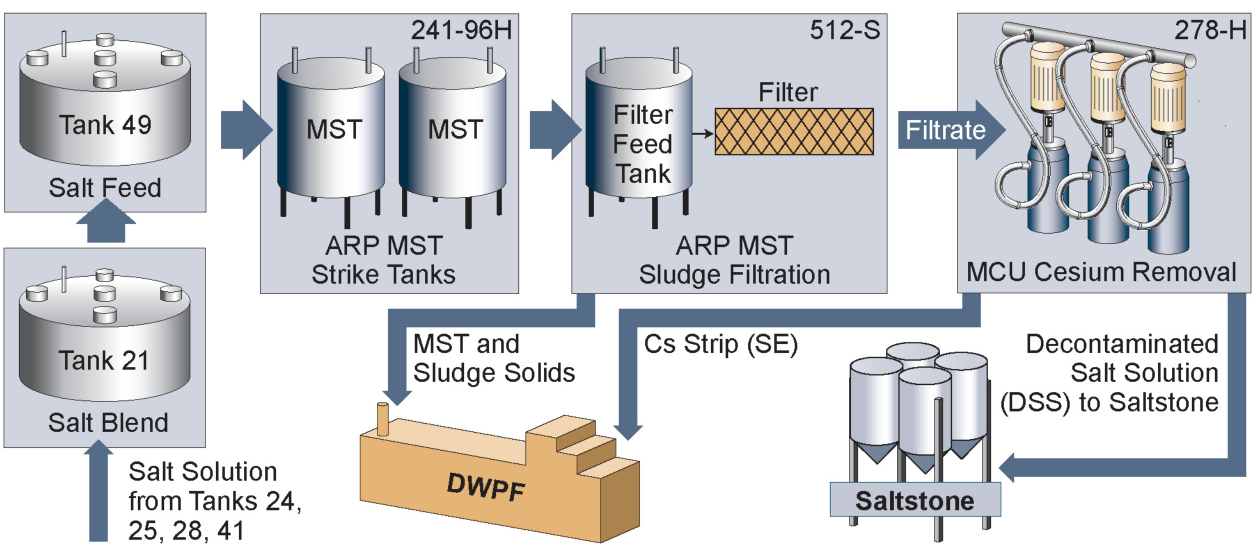


Figure 4-3—*Schematic of the ARP/MCU Process*

The MCU process extracts Cs from the clarified salt solution using CSSX chemistry. The DSS is subsequently transferred to Tank 50 for feed to the SPF, and the SE solution from the CSSX process is transferred to the DWPF for vitrification.

The ARP/MCU process was constructed and initially permitted for a three-year service period, bridging the crucial period before the startup of the SWPF. With the delay of SWPF, however, ARP/MCU has been enhanced and improved to provide a longer-term option for salt disposition. The original goals of the ARP/MCU process were *first* treat salt solution prior to the start of SWPF; and *second* provide operational experience and lessons learned for the SWPF project.

Actions taken since startup of ARP/MCU have demonstrated an increased processing rate from the original design of 1 million gallons per year to approximately 1.4 million gallons per year. Enhancements and improvements include chemistry adjustments at Tank 49, reduced cycle-times, and redesign and replacement of the secondary filter at 512-S. Efforts continue to improve equipment reliability, reducing unexpected downtime to improve overall attainment.

Improved Decontamination

In the fourth quarter of FY13, the original solvent formula was replaced with NGS. Operation of ARP/MCU with NGS results in more efficient removal of cesium from the treated salt solution than the original solvent formula. This increased cesium removal efficiency (decontamination factor or DF) allows ARP/MCU to produce a DSS stream with a residual cesium concentration much less than previously achieved. The improved DF will enable continued operation of ARP/MCU while minimizing the curies disposed in the SDF. ARP/MCU will continue to be operated at a nominal 6 gpm until the facility is shut down for final SWPF tie-ins.

4.3.2 Tank Closure Cesium Removal (TCCR)

The TCCR initiative consists of an ion exchange process for the removal of cesium from liquid salt waste to provide a supplemental treatment capability and improved confidence in supporting the desired acceleration of waste retrieval and tank operational closure efforts. Building on the experience of modular commercial nuclear plant decontamination and following the disaster response associated with Fukushima, the technology exists in industry to accomplish larger scale, selective removal of the cesium component of the bulk salt waste effectively and efficiently. A commercial supplier designed, fabricated, tested, and delivered a modular cesium removal system which has been deployed at Tank 10 for the treatment of liquid salt waste.

This *Plan* assumes successful demonstration of the initial TCCR unit (TCCR-1) in HTF to treat dissolved salt waste from Tank 10. The configuration consists of temporary process structures located near Tank 10 and Tank 11, so the cesium removal process takes place outside of the tank. The DSS is temporarily stored in Tank 11 before transfer to Tank 50 and then to SPF for disposal. After Tank 10 is complete, the TCCR-1will process Tank 9 salt. After two years of processing Tank 9 materials, the TCCR-1 is planned for relocation to Tank 21 to continue processing while Tanks 9, 10, and 11 are closed. Tank 23 is planned to hold the DSS from the Tank 21 TCCR operation for periodic transfer to Tank 50 and ultimate disposition in Saltstone.

A second TCCR unit (TCCR-2) is planned for FTF to treat dissolved waste from F-Area tanks. Tank 4 and Tank 7 are used to support salt dissolution and feed batch preparation. The temporary process structures would be located near Tank 4 with the cesium removal process taking place outside the tank. After four years of operations, when TCCR-2 has completed processing the suitable salt in FTF allowing the closure of the old-style tanks, it will be relocated to Tank 21 as well.

Once the ion exchange media in a column becomes loaded with cesium to the extent practical ("spent"), the column (with media) will be removed from the system and replaced with a new ion exchange column loaded with fresh media. The spent column will be transported to an ISS location within the tank farm. While the spent resin is designed to be able to be dispositioned via DWPF, the ISS concept reduces initial process facilities and costs while also allowing for identification and evaluation of potential future disposal alternatives. For planning purposes, this Plan assumes an alternate disposal option is approved by regulatory authorities and implemented. The current projection is that over 120 TCCR columns will be moved to ISS prior to final disposition (Appendix I—*TCCR Columns Interim Safe Storage*)

The water used to support heel removal and prepare sludge batches at the end of the program will be treated with a TCCR unit relocated to be near Tank 51; the decontaminated wash water will be sent to Tank 50 and then Saltstone for treatment and disposition. This plan assumes any required changes to the Saltstone WAC or regulatory permits will be made.

4.3.3 Salt Waste Processing Facility (SWPF)

The SWPF processing rate is based on an assumed 100% availability for the Tank Farm feed as well as DWPF and SPF receipt of the SWPF discharge streams. The SWPF treatment process is planned to produce DSS that meets the SPF WAC limit.

Currently, factors limiting SWPF production to 6 Mgal/yr include:

- Transfer lines and equipment for transferring feed from the Tank Farms to SWPF and the effluents from SWPF to Tank 50 (the SPF feed tank) and DWPF
- Provision of blend tanks to provide feed to support feeding SWPF at the rated capacity
- Total cycle time in SWPF
- SE & MST processing in DWPF at the planned rates. Achieving greater than 7.2 Mgal/yr of SWPF processing will require reducing the SE volume by increasing the concentration factor to 20 or greater
- DSS processing in SPF at the planned rates. ELAWD Phase II, along with 24/7 operations, are required to ensure SPF's ability to process more than 6 Mgal/yr of DSS from SWPF.

To mitigate these limitations, modifications to the facilities are planned, including:

- **Infrastructure**: Completion of Salt Disposition Initiative (SDI) activities for physical tie-in to SWPF
- **Tank Farms**: Salt dissolution, blending, batching, and qualification at a pace sufficient to provide feed at design rates and enable additional tanks to enter blend tank service
- **DWPF**: Improvements described in Section 4.2 (above) enhance the ability to process SE to support an SWPF feed rate greater than 6 Mgal/yr
- **SPF**: ELAWD II improvements described in Section 4.4 (below) enhance SPF's ability to process the DSS stream from SWPF to support an SWPF feed rate greater than 6 Mgal/yr.

Additionally, storage for the resultant waste streams must be provided, including:

- Construction of future SDUs to support disposition of saltstone from SWPF DSS stream processing at design rates
- Construction of future glass waste storage capability to support canister storage for SWPF SE & MST stream processing at design rates

Blend Tank Selection

"Source" and "Hub" tanks supply and collect the source material to be used in compiling the salt batch. "Blend" tanks receive and mix the source material to create the salt batch. The "Feed" tank receives the batch from the Blend tank and feed it to ARP/MCU or SWPF, when it becomes operational. To support SWPF's maximum throughput of 9 million gallons per year, three blend tanks are planned to be operated simultaneously.

There are three basic requirements for a tank to be eligible for use as a blend tank. The tank must be able to:

- Accept material from other tanks (receiving capabilities).
- Blend the material from the Source tanks (mixing capabilities)
- Send 1 million gallons of prepared feed to the Feed tank (transfer capabilities to Tank 49).

Additionally, the salt dissolution campaigns are planned according to the following priorities:

1. Continual safe storage of liquid waste in tanks and vitrified canisters in storage.
2. Complete LW System operational closure by the end of FY33.
3. Complete operational closure of F Tank Farm by end of FY28.
4. Process liquid salt waste (e.g., dissolved salt solution, supernate) in FY16 through FY22 in accordance with the South Carolina Department of Health and Environmental Control (SCDHEC) "*Agreement*" (including consideration for *Force Majeure* conditions).
5. Remove the bulk of the waste in the old-style H-Tank Farm tanks in the water table (i.e., Tanks 9, 10, 13, 14) by end of FY23.

6. Complete operational closure of the 1F Evaporator by the end of FY23.

It should be noted that the remaining Type IV tanks in H-Tank Farm are integral in closing F-Tank Farm as it provides much needed usable tank space. Therefore, the priority to close Type IV tanks is low despite them also being old-style tanks.

Tank 49 is the current Feed tank for ARP/MCU and will remain as the Feed tank for SWPF. This *Plan* requires Tanks 41, 42, and 27 to become blend tanks once SWPF is operational. As infrastructure improvements occur and demands change, however, the selection of blend tanks will change accordingly to operate as safely and efficiently as possible.

Tank 41 (Type IIIA) is currently undergoing salt dissolution, which once completed, will leave the tank ready for conversion to blend tank service. The residual solids are not expected to interfere with batch compilation. Flammability and corrosion controls regarding these solids will be managed. A mixing pump will be installed making Tank 41 the second blend tank.

Current efforts in modifying piping within the 2H evaporator cell to reduce transfer conflicts would result in Tanks 41 and 42 having direct transfer paths to Tank 49. This also makes Tank 42 (Type IIIA) a reasonable blend tank candidate. The concentrated supernate currently within Tank 42 is planned to be both transferred and used in SWPF batches. Additionally, the old mixing pumps within Tank 42 will be tested and if needed, replaced to ensure mixing capabilities.

Tank 27 (Type IIIA) was identified as a future Blend tank as it is in F-Area Tank Farm which provides multiple transfer paths to the other F-Area Tank Farm tanks. This reduces the number of inter-area transfers required to remove salt from F-Area Tank Farm. The tank is currently planned to go through salt dissolution, which would, once completed, provide adequate tank space for batch compilation. Like Tank 41, the residual solids are not expected to interfere with batch compilation and controls are manageable. Mixing device(s) will also need to be installed.

4.4 ***Saltstone Operations***

The Saltstone operation consists of two main components. The SPF contains the tanks and equipment necessary to receive the feed and treat and process it into saltstone grout. The grout is pumped from SPF into the SDF, consisting of several SDUs for final disposition.

Saltstone Production Facility

SPF receives and treats the salt solution to produce grout by mixing the liquid feed stream with cementitious materials (cement, flyash, and slag). A slurry of the components is pumped into the SDUs, located in SDF, where the saltstone grout solidifies into a monolithic, non-hazardous, solid LLW form.

To enable SPF to accommodate the increases in feed volume from SWPF, the SPF dry feed preparation system must be streamlined. This will be accomplished in the second phase of ELAWD. Additionally, to support SWPF processing rates above 6 Mgal/yr, SPF operations will be conducted on a 24/7 schedule requiring increased staffing over the current 4/10 schedule. ELAWD Phase II and the staffing increase are forecast to be available after the first year of SWPF operations.

ELAWD Phase II (SPF Dry Feed Mods)

Several operations and equipment reliability improvements are required to enhance the operation of SPF feeding SDF:

- **Silo bin discharge**—Rework existing silo bin discharge system to allow silos to operate at full capacity. Implement software changes that will allow air to be pulsed through the silo during downtimes to prevent packing and bridging
- **Knife gate valve or equivalent**—Install knife gate valve assembly at each silo to enhance the system's abilities to handle inconsistencies with bulk materials and aid in dry material recipe accuracy
- **Screw feeder**—Replace the existing obsolete screw feeder
- **Weather protection**—Enclose the Premix Feed Bin and Loss-In-Weight hopper to protect the many flexible couplings and joints that are susceptible to water intrusion
- **Flexible couplings**—Upgrade each flexible coupling to provide improved sealing and weather resistance
- **Dust collectors—**Update Silo 2 dust collector to improve simultaneous truck unloading capacity for Silos 1, 2, and 3.

Saltstone 24/7 Operations

Operations and equipment reliability improvements are required to enable 24/7 operation of SPF feeding SDF:

- **Lightning protection upgrades** – Install lightning protection throughout the Saltstone facility to minimize process equipment damage during inclement weather and to maximize critical process equipment availability
- **Process air compressor replacement** – Replace outdated process air compressors to support dry feed system operations and serves as a backup supply to the 210-Z instrument air system.

Saltstone Disposal Facility

SDU-2 and SDU-5 (both of which are full) and SDU-3 each consist of two cells nominally 150 feet diameter by 22 feet high. After accounting for interior obstructions (support columns, drainwater collection systems, etc.), the nominal useable volume of a cell is approximately 2.8 Mgal. Nominally, 1.76 gallons of grout is produced for each gallon of DSS feed, yielding a nominal cell capacity of approximately 1.5 Mgal of feed. SDU-6, which is currently the active SDU, consists of a single cell 375 feet in diameter by 43 feet high. SDU-6 has the capacity to disposition over 32 Mgal of saltstone containing approximately 18.7 Mgal of feed. Future SDUs will have the same capacity as SDU-6. The last SDU will be sized as needed to complete the LW mission.

4.5 *Waste Removal and Tank Closure*

4.5.1 Waste Removal and Tank Cleaning

The first step in the disposition of sludge and salt waste is bulk waste removal. Sludge is removed from the waste tank and sent to a hub tank, a tank set up to receive and transfer sludge to the feed preparation tank, or directly to the feed preparation tank ensuring sludge waste is continuously available for treatment at DWPF. Salt is dissolved, removed, and staged for treatment at ARP/MCU or SWPF.

Waste Removal

If permanent infrastructure is available, sludge removal planning maximizes the use of this infrastructure to most effectively remove waste. This planning includes the use of structural steel, cable trays, existing mixer pumps, transfer pumps, and ventilation. If permanent infrastructure is not available, then temporary equipment may be used on some waste tanks to perform waste removal (see Figure 4-4). Portable and temporary equipment would then meet tank infrastructure needs.

The primary components of a temporary system include:

- Reusable mixing pumps
- Portable field operating station containing pump drives and controls
- Portable substation to provide 480-, 240- and 120-volt power
- Disposable commercial transfer pumps.

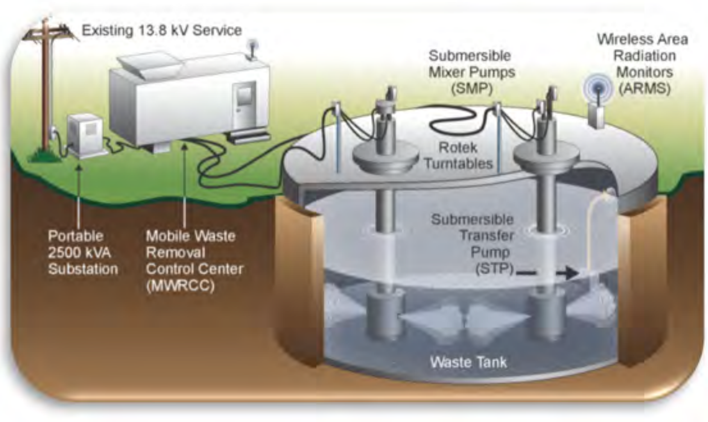


Figure 4-4—*Temporary Waste Removal*

The temporary equipment is deployed at the tank as a field operating station, providing temporary power and control for waste removal equipment. When waste removal is completed on one tank, the equipment can be reconfigured to support waste removal on the next tank. Pumps are sized to fit through the existing 24-inch riser openings in the waste tanks. To the extent that risers are available, pumps are set in optimal configurations within the waste tanks. For submersible mixer pumps (SMP), product-lubricated bearings and motor cooling eliminate the need for bearing and seal water supply. These pumps have exterior fittings and fixtures, so the pumps can be decontaminated, minimizing radiation exposure to personnel during relocation to another tank. CSMPs, however, have demonstrated preferable performance to SMPs and are currently planned for sludge removal as well as salt removal. Disposable transfer pumps transfer the waste to a receipt or hub tank using existing underground transfer lines and diversion boxes. If the transfer system is degraded or non-existent, above-grade transfer lines may be deployed, rather than investing in costly repairs. Temporary shielding is supplied as necessary to minimize exposure to personnel.

Sludge Removal

Sludge removal operations are typically conducted with several mixing pumps. Sufficient liquid is added to the tank to suspend sludge solids. Existing supernate is used, when practical, to minimize introduction of new liquids into the system. Operation of the mixing pumps suspends the solids, which are then transferred as a slurry from the tank. This operation is repeated, periodically lowering the mixer pumps, until the remaining contents of the tank can no longer be effectively removed by this method.

Sludge batches were originally configured to preferentially remove sludge from Type I and II tanks. Most of the sludge has been successfully removed from the old-style tanks. Tank 13, a Type II tank in HTF is being used to store and transfer sludge heels from other Type I and II tanks. Final Tank 13 heel removal is planned for 2025. Tanks 33, 34, 35, and 39, Type III tanks, are planned for use as sludge hub tanks, as needed.

Salt Removal

Salt waste removal strategy is developed on a tank-specific basis and may employ a variety of approaches. Some general approaches are briefly discussed here.

Tanks that are full of salt and at the beginning of the salt waste removal process may be approached using a Drain, Add, Remove (DAR) method (see Figure 4-5—*Drain, Add, Remove Method for Salt Waste Removal*). The dissolution liquid may be added in small batches or may be added at a very slow rate while simultaneously removing dissolved salt solution. The Add step is the most effective if the dissolution media can be sprayed onto the salt surface. Care must be taken to minimize the formation of preferential flow channels during the dissolved salt solution removal. The process ends with the removal of the dissolved salt solution.

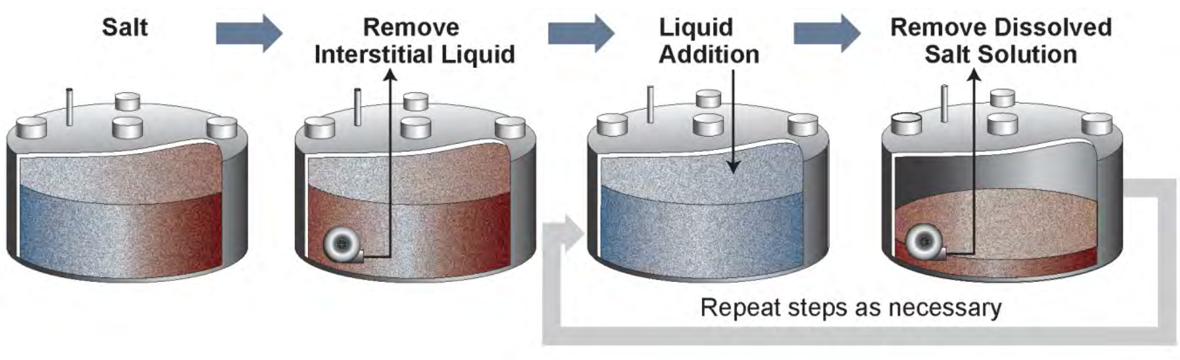


Figure 4-5—*Drain, Add, Remove Method for Salt Waste Removal*

Salt waste dissolution using Drain, Add, Remove eventually becomes inefficient. At this point the approach changes to Mechanical Agitation which will likely be active mixing using long shaft pumps. The dissolution liquid (e.g., inhibited water [IW], well water [WW], DWPF recycle) is added and then the mixing pumps are used to create contact between the salt and the dissolution liquid. The dissolved salt solution is removed from the tank in several batches. This approach is best suited to tank configurations with a large vapor space relative to the volume of salt remaining (see Figure 4-6—*Mechanical Agitation Salt Removal*)

Figure 4-6—*Mechanical Agitation Salt Removal*

Heel Removal

After completion of waste removal using the technologies discussed above, heel removal is performed. Heel Removal can consist of a combination of mechanical heel removal and chemical cleaning. In general, mechanical heel removal is done prior to chemical cleaning, and is discussed below in some detail. Depending on tank conditions, however, chemical cleaning may be performed prior to mechanical heel removal or some mechanical heel removal and some chemical heel removal may be performed iteratively to provide removal to the extent technically practicable from an engineering perspective and the highly radioactive radionuclides removed to the maximum extent practical.

Mechanical Heel Removal

For mechanical heel removal, this *Plan* assumes vigorous mixing continues, using mixing pumps, until reaching a point of diminishing returns. Additional mechanical removal may be achieved through directing pump discharges in specific patterns to impact remaining material.

Chemical Cleaning

Chemical cleaning may be performed on sludge tanks when mechanical heel removal has not removed the material to the extent technically practicable from an engineering perspective and the highly radioactive radionuclides removed to the maximum extent practical. In bulk oxalic acid (OA) cleaning, the tank is modified to address chemical compatibility concerns and OA is added to the tank and mixing pumps operated. The contents of the tank are agitated for a short period and then transferred to a receipt tank for neutralization. In caustic cleaning, a sludge heel is subjected to LTAD conditions (see § 4.1) to dissolve a significant amount of aluminum solids. This process is repeated one to three times based on chemical flowsheet projections.

Tanks with Documented Leak Sites

Several Type I, II, and IV tanks have documented leak sites. All Type IV tanks having documented leak sites have been operationally closed; however, waste removal operations on some of the Type I and II tanks could potentially reactivate old leak sites or expose new leak sites in those tanks. Contingency equipment and procedures will be utilized to contain leakage and prevent release to the environment. Specific plans will avoid liquid levels above known leak sites, when feasible, and focused monitoring will be employed where these levels cannot be avoided. Because of program progress to date, of the 14 SRS tanks (all old-style tanks) with leakage history:

- 6 are operationally closed and grouted (Tanks 5, 6, 12, 16, 19, and 20)
- 2 are supporting the TCCR process (Tanks 10 and 11)
- 1 is awaiting heel removal activities to commence (Tank 15)
- 3 contain essentially dry waste, with little or no free liquid supernate (Tanks 1, 9, and 14)
- 2 contain liquid supernate at a level below known leak sites (Tanks 4 and 13).

Annulus Cleaning

Some Type I and II tanks have waste in the annular spaces, typically a soluble form of salt appearing as dried nodules on tank walls at leak sites and at the bottom of the annulus pan. These tanks will be inspected to determine if Annulus Cleaning is required. For those tanks requiring annulus cleaning, this waste will be removed from the annulus to the extent technically practicable from an engineering perspective and the highly radioactive radionuclides removed to the maximum extent practical before declaring the tank ready for grouting.

4.5.2 Tank Operational Closure and Stabilization

Type I, II, and IV tanks are planned for operational closure in accordance with a formal agreement between the DOE, Region IV of the EPA, and SCDHEC as expressed in the SRS currently approved FFA. Eight of these tanks were operationally closed and stabilized (grouted): FTF Tanks 17 and 20 in 1997, Tanks 18 and 19 in 2012, Tanks 5 and 6 in 2013, and HTF Tank 16 in 2015 and Tank 12 in 2016.

Operational closure and stabilization consist of those actions following waste removal that bring liquid radioactive waste tanks and associated facilities to a state of readiness for final closure of the Tank Farms complex, including:

- Sampling and Characterization
- Developing tank-specific regulatory documents
- Isolating the tank from all operating systems in the surrounding Tank Farm (e.g., electrical, instruments, steam, air, water, waste transfer lines, and tank ventilation systems)
- Stabilizing by grouting of the primary tank, remaining equipment, annulus, and cooling coils
- Capping of select tank risers.

This *Plan* assumes thirty-six months from the last removal of any material until completion of grouting.

Sampling and Characterization

Before declaring a tank ready for grouting, the tank and annulus are inspected, the residual volume is estimated, and the residual is sampled in accordance with a sample plan. Laboratory analysis of the samples yields concentrations of radiological and non-radiological constituents in the remaining material. The SCDHEC-approved Sampling Analysis Program Plan and associated Quality Assurance Program Plan currently recognizes the Savannah River National Laboratory (SRNL) as the laboratory that performs residual characterization analysis. Concentration and volume data are used to characterize the residual material to produce radiological and non-radiological inventories for the Closure Module (CM). Tank-specific closure documents and other regulatory documentation are prepared to demonstrate compliance with State and DOE regulatory requirements as well as NDAA §3116.

Tank Isolation

Tank isolation is the physical process of isolating transfer lines and services from the tank. Isolating the tank from tank farm systems and services prohibits chemical additions or waste transfers into or out of the tank. Further isolation of a tank, after filling with grout, is planned to include cutting and capping or blanking mechanical system components (air piping/tubing, steam piping, etc.) and disconnecting electrical power to process components on the tank.

Closure Documentation Development

An area-specific WD approach ensures the NDAA §3116 tank operational closure process is implemented as efficiently as possible. PA and NDAA §3116 Basis Documents have been generated for each Tank Farm—one for FTF and one for HTF. The NDAA §3116 Basis Documents include the waste tanks as well as ancillary structures located within the boundary of the respective Tank Farm. The GCP was developed and approved by SCDHEC.

DOE Radioactive Waste Management Manual 435.1-1 mandates a Tier 1 Closure Plan and associated Tier 2 Closure Plans. The Tier 1 plans are area-specific and provide the bases and process for moving forward with tank grouting. This document is approved at the DOE-Headquarters level. The Tier 2 documents are tank-specific, follow the approved criteria established in the Tier 1 documents, and are locally approved by DOE-SR.

Development of a tank-specific CM, per the State-approved GCP, follows completion of tank cleaning activities. The CM describes the waste removal and cleaning activities performed and documents the proposed end state. Final characterization data supports the performance of a Special Analysis which determines if final residual inventories continue to support the conclusions of the area-wide PA.

Figure 4-7—*Grout Placement*

Grout Selection and Manufacture

A reducing grout provides long-term chemical durability and minimizes leaching of residual waste over time. The reducing grout selected is self-leveling, and encapsulates the equipment remaining inside the tank and annulus. The grout also provides for intruder prevention in tanks that do not have a thick concrete roof. Grouting activities include field modifications, temporary ventilation installation, grout plant mobilization, and grout procurement.

Grout Placement

Grout fill operations, including site preparation, pumper truck set up, grout plant set up (if required), grout delivery lines, and grout equipment setup are established around the tanks (see Figure 4-7). A sequence for tanks with an annulus will be developed so that voids are filled and the structural integrity of the tank is maintained. Generally, grouting the annulus and primary tank in alternating steps provides structural support for the tank wall.

Equipment Grouting

For tanks with installed equipment or cooling coils, internal voids are filled with a flowable grout mixture. In those tanks where the cooling coils have broken, alternative techniques are used to minimize voids in the grout matrix.

Riser Grouting and Capping

The final step, after filling the tank, may include encapsulating select risers. When necessary, forms are built around the risers and grout is used to encapsulate the risers providing a final barrier to in-leakage and intrusion. The final grouted tank configuration is an integral monolith with minimal voids and ensuring long-lasting protection of human health and the environment (see Figure 4-8).

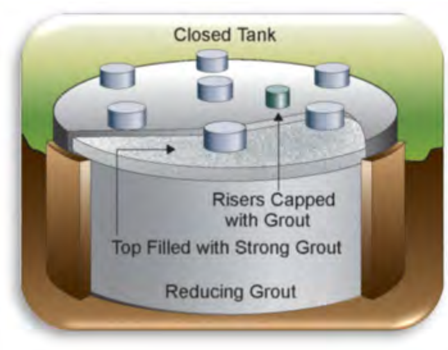


Figure 4-8—*Grouted Tank*

4.6 *Base Operations*

4.6.1 Supporting Nuclear Material Stabilization

A continuing portion of the mission of the Tank Farms, especially HTF, is safe receipt, storage, and disposition of waste yet to be received from H-Canyon and HB Line. This *Plan* supports nuclear material stabilization in H-Canyon through 2030. Tank 39 will continue to receive H-Canyon waste through FY30. The 3H Evaporator system will continue to operate without the need to replace the evaporator pot through FY26. This *Plan* assumes Tank 39 can receive 200 kgal/yr from H-Canyon in FY19 through FY22. Beginning in FY22, HTF is forecast to receive up to 300 kgal/yr from H-Canyon through FY30.

An alternate disposal path for some waste (e.g., U, Pu, or Np bearing waste) allows insertion into a DWPF sludge batch "just-in-time" via receipt into the sludge processing tank (Tank 51) or the DWPF feed tank (Tank 40). Plutonium discards from H-Canyon through FY30 will be supported to the extent allowable without negatively impacting planned canister waste loadings or failing to comply with canister fissile material concentration limits. Additionally, some of the LLW from H-Canyon may be received into Tank 50 for direct disposal in SDF through FY30.

4.6.2 DWPF Recycle Handling

DWPF recycle is the largest influent stream received by the Tank Farm. In this *Plan*, disposition of the recycle stream is handled through evaporation in the 2H Evaporator System and through the beneficial reuse of the low sodium molarity (less than 1.0 molar sodium) recycle stream. The DWPF recycle rate will remain between 1.5 and 1.9 Mgal/yr prior to SWPF operations. The rate depends on canister production rate and Steam Atomized Scrubbers (SAS) operation as well as DWPF recycle reduction initiatives. The rate could increase to as high as 3.2 Mgal/yr after the startup of SWPF because of extra water in the SE stream and MST slurry and because the higher Cs-137 concentrations could require the operation of two SAS stages in the DWPF melter offgas system; currently, only one SAS stage is operated. DWPF recycle is exclusively evaporated in the 2H Evaporator System due to chemical incompatibility with other waste streams. It may, however, be beneficially reused for salt solution molarity adjustment, salt dissolution, heel removal, etc. Beneficial reuse minimizes the utilization of the 2H Evaporator. DWPF recycle will be supplemented by inhibited water (IW), as required, for salt dissolution and adjustment.

As an optimistic strategy, this *Plan* models the diversion of the DWPF recycle stream to ETP beginning in FY23. The recycle stream will require pretreatment prior to transfer to ETP. A Systems Engineering Alternative Analysis will be performed in FY19 to identify the type and method of pretreatment necessary to enable this diversion.

The decision to discontinue DWPF recycle to the Tank Farm provides several opportunities. The effect is to add two tanks and an evaporator for general purpose use. This allows the 3H Evaporator to shut down in FY26 and undergo waste removal without the need to restore evaporator operations. Sludge removed from the 3H feed tank (Tank 32) can be sent directly to sludge batches as needed instead of being removed to other HTF tanks. This is a significant simplification of the plan and avoids the cost of putting the 3H back in service following Tank 32 sludge removal.

Moving the evaporator support function from the HTF West Hill to the HTF East Hill allows the waste removal and closure of the West Hill tanks (Tanks 29 thru 37, except 33 and 34 which are in FTF).

It is assumed that the 2H Evaporator will undergo a cleaning prior to being put in service as a general-purpose evaporator. Tank 22 will be depleted of the silica rich solution sent from the DWPF. The spent wash water from Tank

51 will be decanted to Tank 22 and either used for salt dissolution or sent for evaporation. Tank 22 contents will undergo evaporator feed qualification before processing in the evaporator. Since the system will no longer be receiving silica there should not be any concerns regarding sodium-aluminum-silicate formation within the evaporator vessel and there should not be any solids formation related criticality concerns.

4.6.3 Transfer Line Infrastructure

Although efforts will continue to be made to keep transfers between tanks to a minimum, executing this *Plan* requires more frequent transfers than have historically occurred in the Tank Farm, especially after the startup of SWPF, when large volumes of salt solution will be delivered to SWPF. Because of the greatly increased pace of transfers after the startup of SWPF, short downtimes due to unexpected conditions requiring repair will be more difficult to accommodate without impact because the idle time of transfer lines will be reduced.

New infrastructure is required to accomplish transfers to support SWPF, while also continuing activities such as waste removal and evaporation. Discoveries of unexpected conditions in existing transfer systems could impact the installation of new transfer lines and equipment.

The transfers in this *Plan* are generally based on the known current infrastructure, modifications planned in the SWPF transfer line tie-ins, and in projects for new facilities. The actions described can be executed as long as the planned modifications are made, and significant failures of key transfer equipment do not occur or can be mitigated quickly enough to allow activities to proceed as planned. This *Plan*, however, does not attempt to explain all the modifications needed or anticipate the failure of specific pieces of transfer equipment.

4.6.4 Tank 48 Treatment

Tank 48 contains legacy organic from previous salt treatment processes. Several technologies have been considered, including Fluidized Bed Steam Reforming and Copper Catalyzed Peroxide Oxidation, to treat the organic components and enable the waste to be dispositioned as saltstone or vitrified glass. Systems Engineering Evaluations will select an appropriate technology to allow Tank 48 treatment to begin in FY26 followed by operation closure.

4.6.5 Effluent Treatment Project

The ETP, located in H-Area, collects and treats process wastewater that may be contaminated with small quantities of radionuclides and process chemicals. The primary sources of wastewater include the 2H and 3H Evaporator overheads and H-Canyon contaminated water. The wastewater is processed through the treatment plant and pumped to Upper Three Runs Creek for discharge at an NPDES permitted outfall. Tank 50 receives ETP residual waste for storage prior to treatment at SPF and final disposal at SDF. A 35-kgal Waste Concentrate Hold Tank provides storage capacity at ETP to minimize transfer impacts directly to Tank 50 or SPF during SWPF operations. Beginning in FY23, ETP is planned to process DWPF Recycle.

4.6.6 Managing Type III Tank Space

Type III tank space is essential to all the processes described in this *Plan*. Limited waste storage space exists in Type III/IIIA tanks in both FTF and HTF. There is a risk (cf. ROMP) that a leak in a primary tank or other adverse event could occur that might impair execution of this *Plan.*

In the 3H Evaporator System, space is needed for evaporator concentrate receipt to support periodic salt dissolutions and storage of high-hydroxide waste that does not precipitate into salt. This “boiled-down” liquid is commonly referred to as “liquor” or “concentrate” and removing the “liquor” from an evaporator system is referred to as “deliquoring.” Evaporator effectiveness is diminished when the concentrate receipt tank salt level is 330″ or greater—at this point, the evaporator system is said to be “salt bound.” Deliquoring both the 2H and 3H Evaporators and salt removal from Tank 37, a 3H Evaporator concentrate receipt tank, are planned on a regular basis to ensure continued viability of the Evaporators.

In addition, this *Plan* incorporates contingency when allowable to provide the best opportunity for success. Lack of evaporator working space would hinder tank removals from service, canister production rate at the DWPF, or H-Canyon support.

This *Plan*, as did previous revisions of the *Plan*, utilizes Type I, II, and IV tanks to meet program objectives:

- Tank 8 stores aluminum-laden supernate from LTAD of Sludge Batches 5, 6, 10, 11, 12, 13, and 14
- Tank 4 is a blend and feed tank for TCCR-2
- Tank 7 stores dissolved salt solution
- Tank 7 will support waste removal activities from Tanks 1, 2, and 3

- Tank 11 stores DSS from TCCR operation for transfer to Tank 50 for disposition in Saltstone
- Tank 11 will support waste removal activities from Tanks 9 and 10
- Tank 13 serves as a hub for Sludge Removal from Tanks 14 and 15, supports Heel Removal from Tanks 9, 10, 11, 14 and 15, and supports Tank 14 salt dissolution
- Tank 21 will serve as a salt blend tank for ARP/MCU and SWPF before conversion to TCCR service
- Tank 22 will receive DWPF recycle and then support sludge washing
- Tank 23 will stage dissolved salt solution for salt batch preparation before conversion to TCCR service
- Tank 24 will continue to store evaporator concentrate. It replaces FTF Tank 27 as an SWPF blend tank supporting FTF closure.

4.7 ***Closure Sequence for the Liquid Waste System***

After the HTF and FTF tanks and ancillary equipment have been closed, the LW facilities outside the Tank Farm—DWPF, SWPF, ARP/MCU, SPF, SDF, and associated ancillary equipment—will be available for beneficial reuse, if required. Otherwise, these facilities will be available for final removal from service.

While the general priority is to close geographically proximate equipment and facilities, thus minimizing long-term cost, the actual sequence of the shutdowns is predicated on the capability of the facilities to process the particular blends required by the salt and sludge treatment processes. The priority (but not necessarily the sequence) for shutdowns as modeled is:

1. Type I and II tanks
2. F-Area waste tanks, the 2F Evaporator, and ancillary equipment (including 1F Evaporator and the concentrate transfer system)
3. H-Area West Hill waste tanks, the 3H Evaporator, and ancillary equipment (including 1H Evaporator)
4. H-Area East Hill waste tanks, the 2H Evaporator, and ancillary equipment (including any remaining ARP/MCU equipment)
5. Major remaining processing facilities (e.g., DWPF, SWPF, SDF/SPF, ETP).

Following the end of salt processing there remains a large volume of liquid used for completion of heel removal from sludge and salt tanks. Additionally, washing the sludge heels prior to processing through the DWPF will generate spent wash water. This *Plan* assumes a TCCR unit relocated to the HTF East Hill will process approximately 3 Mgal of water that will need to be dispositioned to support heel removal after SWPF and the 2H Evaporator are removed from service. This liquid stream, however, will not be as salty as the feed streams processed through SWPF. The saltstone WAC will need to accommodate this more dilute stream into saltstone. Additionally, the NDAA must be addressed as this stream is not in the WD.

The key elements of the systematic closure sequence for shutting down and closing the LW System are:

- 3H Evaporator shut down (FY26)
- Waste removal is complete from all Type I and II tanks (FY28)
- All Type I and II tanks are operationally closed (FY30)
- H-Canyon processing influents cease (FY30)
- 2H Evaporator shut down (FY30)
- FTF waste removal is completed (FY31)
- Inter-Area Line (IAL) removed from service (FY31)
- SWPF shut down (FY31)
- HTF (West Hill) waste removal is complete (FY33)
- FTF Type III tanks are operationally closed (FY33)
- HTF (East Hill) waste removal is complete (FY34)
- DWPF shut down (FY34)
- SPF shut down (FY35)
- All tanks are operationally closed (FY37)

Once closure activities are complete, any remaining facilities may be chemically cleaned and flushed as necessary.

5. Description of Assumptions and Bases

The following inputs and assumptions provided initial guidance to develop Revision 21 of the LW System Plan. The targets described in these assumptions are the overall goals of the various facilities. Modeling of the LW system, however, may indicate that the targets are not achievable given the constraints of the updated Salt Waste Processing Facility (SWPF) schedule, limits to funding, or other system constraints.

- **Priorities for Scenario Development (these are goals, not necessarily outcomes):**
  1. Continual safe storage of liquid waste in tanks and vitrified canisters in storage.
  2. Complete LW System operational closure by the end of FY33.
  3. Complete operational closure of F Tank Farm by end of FY28.
  4. Process liquid salt waste (e.g., dissolved salt solution, supernate) in FY16 through FY22 in accordance with the SCDHEC "*Agreement*"[3] (including consideration for *Force Majeure* conditions).
  5. Remove the bulk of the waste in the old-style H-Tank Farm tanks in the water table (i.e., Tanks 9, 10, 13, 14) by end of FY23.
  6. Complete operational closure of the 1F Evaporator by the end of FY23.

Please note that some of these goals were not achievable within the constraints of the Plan.

5.1 *Funding*

This *Plan* assumed the FY19 funding guidance for FY19. Subsequent years were modeled assuming reasonable funding increases required to support the priorities would be made available that align with the budget outlook in the near term.

5.2 *Salt Waste Disposition*

- **Modular CSSX Unit (MCU)**
  - MCU will cease operations approximately three and a half (3½) months prior to SWPF hot commissioning (i.e., mid-November 2019)
  - MCU processing rates (for modeling purposes) will be:
    - approximately 50 kgal/mo from January 15, 2019 through the end of March 2019
    - approximately 130 kgal/mo through September 2019
    - approximately 50 kgal during the last two months (October and November 2019) for feed materials inventory reduction
  - MCU will have no major modifications to increase capacity

- **Salt Waste Processing Facility Integration (SWPF)**
  - SWPF begins hot commissioning March 1, 2020
  - SWPF will begin operations on May 1, 2020, two months after hot commissioning
  - The required all-inclusive Readiness Assessment (RA) for the LW Program, including Tank Farms, DWPF and Saltstone operating facilities, will be completed prior to the execution of SWPF Hot Commissioning activities.
  - SWPF will implement NGS by the beginning of the second year of operation with no impact to the program schedule
  - The SWPF feed chemistry is per SWPF Feed Specification Radionuclide Limits of the SWPF *Waste Acceptance Criteria*[17]
  - SWPF processing rates (for modeling purposes) will be:
    - approximately 6 Mgal/yr for the first twelve months of operation
    - approximately 9 Mgal/yr thereafter
  - Initial year SWPF restrictions:
    - The initial year of feed is at ≤ 1.0 Ci/gal at 6.44M Na per the WAC; subsequent feed to SWPF will be ≤ 2.0 Ci/gal at 6.44M Na[18]
    - The initial year of feed has a total Sr^{90} feed limit of 0.112 wt%
    - SE produced is less than 16.5 Ci/gal
    - MST/sludge solids limit is 6 wt%
    - These restrictions may be lifted and SWPF return to design basis upon Final Glycolic/SWPF DSA implementation

- **Saltstone Production Facility (SPF)**
  - SPF capacity is forecast to support combined salt processing rates from ARP/MCU, TCCR, and SWPF of up to:
    - 3 Mgal/year until August 2019
    - 6 Mgal/year from August 2019 through July 2021
    - 11 Mgal/year after March 2021
    - Placement of ^{129}I inventory in SDUs does not exceed limits in SRR-CWDA-2017-00042[19] while minimizing the total number of SDUs
  - Fill height limitations on SDUs due to the HGR PISA will be resolved upon implementation of the Interim Glycolic DSA.

- **Tank Closure Cesium Removal (TCCR)**
    - TCCR-1 becomes available for operations beginning January 2019
      - When processing Tank 10 material, TCCR-1 does not have a dedicated batch preparation tank, which means throughput is limited to that which can be prepared in the source tank
    - After the first operations, an evaluation will be performed to determine if TCCR should continue. For purposes of this exercise it is assumed:
      - TCCR-1 continues operation using Tank 9 dissolved salt as the feed after Tank 10 salt is depleted, no sooner than October 2020
      - A second TCCR unit (i.e., TCCR-2) is pursued.
    - The TCCR-1 nominal operational capacity after the initial Tank 10 demonstration period is 1 Mgal/year
    - TCCR-2 becomes available for operations beginning October 2021
      - Tank 4 will be used as a blend/feed tank for TCCR-2 operations
      - DSS will be transferred directly to Tank 50 using the 2F Evaporator (now out of service) overheads system after necessary modifications
      - TCCR-2 batches will be prepared with material from old-style or new-style tanks as appropriate to achieve the best overall salt processing plan.
      - TCCR-2 does not qualify as a "Major Modification"
    - The TCCR-2 assumed operational capacity is 1 Mgal/year until feed is exhausted
    - TCCR units may be relocated as best suits program needs and continue to operate. A 12-month outage is assumed for relocation.

5.3 *Sludge Processing*

- Modeling will determine the number of canisters and waste loading required to support salt processing
  - this assumes canister production below 100 in a given fiscal year is acceptable
- DWPF will be in outage during the final SWPF tie-ins until SWPF needs to begin transferring Strip Effluent (SE) to DWPF
- DWPF will be in outage during glycolic acid flowsheet implementation
- Full glycolic acid flowsheet implementation is required prior to processing SB 10
- DWPF canisters will maintain a fissile material concentration limit of no more than 897 g/m^3 of glass[20]
- Normal discards (including plutonium, neptunium, etc.) directly into sludge batches from H-Canyon will be supported to the extent allowable through FY30
- Modeling will determine the need date for additional glass waste storage, assuming completion of modification of Glass Waste Storage Building 1 to provide maximum additional canister storage capacity via "double-stacking"
- Shipment of canisters off-site for final disposition is not in the scope of this *Plan*.

5.4 *Tank Closures*

- DOE will obtain SCDHEC and EPA approval such that tanks that have completed bulk waste removal are allowed to be reused for:
  - TCCR operations support regardless of the source of feed from either old-style tanks or new-style tanks
  - movement of waste from old-style tanks
  - storage of other material previously approved by the SCDHEC and EPA (e.g., Low Temperature Aluminum Dissolution (LTAD) aluminum rich leachate)

5.5 *Tank Farm Operations*

- Tank Farm feed preparation infrastructure modifications are assumed to support salt processing rates including:
  - Blend tanks readiness for salt solution preparation
  - Feed tanks readiness for salt solution preparation, excepting:
    - Tank 31 salt dissolution capabilities are not available until April 2022
    - Tank 2 salt dissolution capabilities are not available until November 2022
    - Tank 34 sludge removal capabilities are not available until January 2022
  - Mixing capabilities
  - Enhanced transfer capabilities
  - Transfer routes provided
- Assumes no significant infrastructure failures
- Assumes no new Documented Safety Analysis (DSA) modifications or PISA resolutions that will impose significant restrictions on production
- H-Canyon is forecast to transfer up to 200 kgal per year through FY22 and 300 kgal per year through FY30 with small discards of Pu or Np directly into sludge batches to the extent allowable through FY30.

5.6 *Additional Technical Assumptions*

The following technical assumptions were used as input to the modeling of this *Plan*:

Waste Removal

- Heel Removal is assumed to take six months of operations using a combination of available technologies as needed:
  - Mechanical Cleaning uses mechanical agitation
  - Chemical Cleaning uses LTAD, OA, or advanced/specialized mechanical or chemical technology
  - For some tanks with high waste turnover, e.g. Tanks 4, 40, or 51, mechanical cleaning may not be required; however, flushing could be required
  - Monitoring during any cleaning process will inform the decision to utilize additional cleaning processes.

Annulus Cleaning

- All tanks that have experienced leaks will undergo inspection and, potentially, sampling and analysis to determine the necessity for annulus cleaning. The amount and type of material used for annulus cleaning depends on the quantity and type of waste present.

Tank Removal from Service

- Stabilization of a waste tank (i.e., grouting of primary tank, annulus space, and cooling coils) as specified in the applicable CM is to be completed within 30 months of receipt of concurrence to enter the residual waste sampling and analysis phase
  - Sampling (6 months on critical path): including Tank Drying, Sample Prep Documents, Volume Determination, and Sampling
  - Sample Analysis (9 months on critical path): including Lab Analysis and Sample Analysis Report (SAR)
  - Closure Documentation (12 months on critical path): including Data Quality Assessment (DQA), Inventory Determination, Special Analysis, Final Removal Report, Class C Calculation, CM, and Tier 2 Documentation
  - Grouting (3 months on critical path)
- SRNL infrastructure will be enhanced or additional labs will be qualified to enable the receipt, analysis, and report for as many tanks as needed
- Within six months of stabilization, tank waste systems will be removed from the *F and H Area High Level Radioactive Waste Tank Farms Construction Permit No. 17424-IW* in accordance with the applicable and approved Interim Record of Decision.

Regulatory Approvals

- SCDHEC will approve activities associated with waste removal, stabilization, and operational closure. Maintenance and monitoring of waste tank systems will be performed and completed as described in the GCP. Operational closure activities will be performed and completed as described in tank-specific CMs which are generated per the approved GCP
- EPA will approve the agreement to cease waste removal

- DOE will maintain NEPA documentation necessary to support this *Plan*.

Nuclear Safety

- It was determined in February 2017 that the LW facilities' DSA method for predicting the HGR had not addressed all the potential sources of hydrogen. It did not address the potential effect of organic compounds regarding radiolytic and thermolytic hydrogen production, nor was there supporting documentation demonstrating the organic contributions as negligible. This resulted in the declaration of a PISA in each LW facility due to the potential for build-up of flammable gases and inadequate controls. While performing testing to gain understanding of the potential contribution from organic compounds, interim resolution of the PISAs require processing restrictions based upon conservative estimates. The general impacts for each facility are:
  - Saltstone—SDU fill heights have been significantly reduced to account for thermolytic impacts. Initial testing suggests thermolysis is present and significant relief from the current basis is unlikely. Longer-term testing, once completed, is expected to support an increase in allowable SDU fill heights. If testing results are not effective in increasing SDU fill heights, alternate Safety Basis approaches may need to be explored. This could include use of actual field measurements for hydrogen and/or inclusion of a new preventive control strategy (e.g., forced ventilation)
  - DWPF—DWPF processing (primarily via feed stream restrictions) is currently limited. Testing being performed in conjunction with the glycolic flowsheet implementation is expected to address this issue and expand DWPF processing capabilities.
  - Tank Farms—Response times for various Limiting Condition for Operation actions related to waste tank ventilation are more restrictive, HGR limits for waste transfers were established, and evaporator operations are restricted. Additional research and development is planned to further the understanding of the hydrogen generation phenomenon.

DWPF Production

- The current sludge washing plan assumes washing to 1.0 M Na
- The canister heat load will be less than 834 watts per canister for a canister in a single stack location. Canisters will be double stacked in accordance with the guidance of *Heat Transfer Analysis of Double Stacking of Canisters in the Glass Waste Storage Building #1*[16] which permits storage of canisters up to 500 watts per canister.
- DWPF Recycle will be diverted from 2H Evaporator to ETP
- 10,600 gal of SE per SRAT Batch for MCU
- 12,800 gal of SE per SRAT/SME Batch for SWPF

Base Operations

- *Evaporation*

  The primary influents into the Tank Farms are DWPF recycle and H-Canyon waste receipts. In addition, sludge batch preparation produces a large internal stream of spent washwater. To continue to maintain space in the Tank Farms to support these missions, these streams must be evaporated. There are two operational evaporators in H-Area.

  DWPF recycle has a high concentration of silica due to the vitrification process. When this stream is mixed with aluminum streams from Plutonium Uranium Reduction Extraction (PUREX) and H Modified (HM) canyon processing, there is a potential for forming sodium aluminosilicate. Experience has shown that sodium aluminosilicate can co-precipitate sodium diuranate in the evaporator, causing a potential criticality concern. To prevent the potential for criticality, a feed qualification program is in place to minimize the formation of a sodium aluminosilicate scale in the 3H Evaporator and to prevent accumulation of enriched uranium in the 2H Evaporator. It is assumed that scale may accumulate in the 2H Evaporator, but periodic cleaning maintains uranium enrichments and masses will be well below criticality concerns.

- *2H Evaporator*
  - The 2H Evaporator System is currently used to evaporate DWPF recycle. The evaporator system feed and concentrate receipt tanks configuration is:
    - Feed – Tank 43; Receipt – Tank 38
  - After diversion of DWPF recycle to ETP, the 2H Evaporator will be cleaned and begin service as the general-purpose evaporator allowing the 3H Evaporator to be removed from service
  - Evaporator Capacity based on historical experience is 200 kgal/mo

- *3H Evaporator*
  - — The 3H Evaporator is used to process streams that minimize scale production, i.e., canyon wastes and sludge batch decants. The evaporator system feed and concentrate receipt tanks configuration is:
    - – Feed – Tank 32; Receipt – Tanks 30 and Tank 37
  - — Evaporator capacity based on historical experience is 100 kgal/mo
  - — The 3H Evaporator System experienced a leak in the evaporator pot in 2016. After repair and discovery of an additional anomaly, it was determined to be operable with certain administrative controls. This *Plan* assumes the 3H Evaporator continues to operate under the current conditions without a lengthy outage through FY26.

- *General Assumptions*
  - — A minor influent is the 299-H Maintenance Facility. The influents mainly consist of a dilute nitric acid stream, decontamination solutions, and steam condensate. These waste streams are produced when equipment is decontaminated. They are collected in the 299-H pump tank, neutralized and sent to Tank 39.
  - — Tank Farm infrastructure is maintained to support SWPF, DWPF, and SPF processing rates and tank operational closure schedules.

- *TCCR*

  Of necessity, tank farm operations will continue beyond the end of salt processing. The SWPF process support tanks will need final waste removal and cleaning. Likewise, the sludge processing tanks, including the 2H Evaporator system, must be de-inventoried and cleaned. Remaining sludge will require washing to be acceptable for DWPF processing into glass. This *Plan* includes an allowance for treatment and disposition of final heel and sludge washing solutions using a TCCR and SPF disposal. The waste generated from heel removal and sludge washing will not be high in sodium and can likely be treated with a TCCR unit to remove cesium, so that it can be sent to SPF. The WAC for SPF will need to be modified to handle this lower sodium material. Other options to handle these streams may be developed prior to the end of the program.

- *Effluent Treatment Project*

  ETP is assumed to receive an average of 11 Mgal/yr from FY19 through FY22:
  - — LW Evaporators: 5 Mgal/yr
  - — DWPF Recycle: 3 Mgal/yr (beginning FY24)
  - — Savannah River Nuclear Solutions (SRNS) Facilities: 6 Mgal/yr

    Note: The Agreement between SRNS and SRR for LW Receipt Services provides that the total maximum allocation for waste generated from SRNS facilities including H-Canyon, F-Canyon, and miscellaneous smaller contributors is 15 Mgal/yr.

Dismantlement and Decommissioning (D&D)

- LW Areas will be transferred to Area Closure on an area-by-area basis upon closure of their included facilities.

6. System Description

6.1 *History*

The LW System is the integrated series of facilities at SRS that safely manage the existing waste inventory and disposition waste stored in the tanks into a final glass or grout form. This system includes facilities for storage, evaporation, waste removal, pre-treatment, vitrification, and disposal.

Since it became operational in 1951, SRS, a 300-square-mile DOE Complex located in the State of South Carolina, has produced nuclear material for national defense, research, medical, and space programs. The separation of fissionable nuclear material from irradiated targets and fuels resulted in the generation of over 160 Mgal of radioactive waste. As of December 2018, approximately 35 Mgal[21] of radioactive waste are currently stored onsite in large underground waste storage tanks at SRS. Most of the tank waste inventory is a complex mixture of chemical and radioactive waste generated during the acid-side separation of special nuclear materials and enriched uranium from irradiated targets and spent fuel using the Plutonium Uranium Reduction Extraction (PUREX) process in F-Canyon and the modified PUREX process in H-Canyon (HM process). Waste generated from the recovery of Pu-238 in H-Canyon to produce heat sources for space missions is also included. The waste was converted to an alkaline solution; metal oxides settled as sludge, and supernate evaporated to form saltcake.

The variability in both nuclide and chemical content occurred because waste streams from the 1st cycle (high heat) and 2nd cycle (low heat) extractions from each Canyon were stored in separate tanks to better manage waste heat generation. When these streams were neutralized with caustic, the resulting precipitate settled into four characteristic sludges presently found in the tanks where they were originally deposited. The soluble portions of the 1st and 2nd cycle waste were similarly partitioned but have and continue to undergo blending during waste transfer and staging of salt waste for evaporative concentration to supernate and saltcake. Historically, fresh waste receipts were segregated into four general categories in the SRS Tank Farms: PUREX high activity waste, PUREX low activity waste, HM high activity wastes and HM low activity wastes. Because of this segregation, settled sludge solids contained in tanks that received fresh waste are readily identified as one of these four categories. Fission product concentrations are about three orders of magnitude higher in both PUREX and HM high-activity waste sludges than the corresponding low-activity waste sludges.

Because of differences in the material processed by PUREX and HM processes, the chemical compositions of principal sludge components (iron, aluminum, uranium, manganese, nickel, mercury, and noble metals) also vary over a broad range between these sludges. Combining and blending salt solutions has tended to reduce soluble waste into blended salt and concentrate, rather than maintaining four distinct salt compositions. Continued blending and evaporation of the salt solution deposits crystallized salts with overlying and interstitial concentrated salt solution in salt tanks located in both Tank Farms. More recently, with transfers of sludge slurries to sludge washing tanks, removal of saltcake for tank removal from service, receipts of DWPF recycle, and space limitations restricting full evaporator operations, salt solutions have been transferred between the two Tank Farms. Intermingling of PUREX and HM salt waste will continue through the end of the program.

Continued long-term storage of these radioactive wastes poses a potential environmental risk. Therefore, since 1996, DOE and its contractors have been removing waste from tanks, pre-treating it, vitrifying it, and pouring the vitrified waste into canisters for long-term disposal in a permanent canister storage location (see Figure 6-2—*Process Flowsheet*). As of January 1, 2019, DWPF had poured 4,179 vitrified waste canisters (see Figure 6-3—*Liquid Waste Program—Current Status*).

6.2 *Tank Storage*

SRS has 51 underground waste storage tanks, all of which were placed into operation between 1954 and 1986. There are four types of waste tanks—Types I through IV. Type III tanks are the newest tanks, placed into operation between

1969 and 1986. There are 27 Type III tanks. Type I tanks are the oldest tanks, constructed in 1952 through 1953. Type II waste tanks were constructed in 1955 through 1956. There are eight Type IV tanks, constructed in 1958 through 1962. Four Type IV tanks, Tanks 17 through 20; three Type I tanks, Tank 5 and Tank 6 in FTF and Tank 12 in HTF; and one Type II tank, Tank 16 in HTF have been isolated, grouted, and operationally closed. Fourteen tanks without full secondary containment have a history of leakage[22]. Because of program progress to date, of these 14 SRS tanks (all old-style tanks) with leakage history:

- 6 are operationally closed and grouted (Tanks 5, 6, 12, 16, 19, and 20)
- 2 are supporting the TCCR process (Tanks 10 and 11)
- 1 is awaiting heel removal activities to commence (Tank 15)
- 3 contain essentially dry waste, with little or no free liquid supernate (Tanks 1, 9, and 14)
- 2 contain liquid at a level below known leak sites (Tanks 4 and 13)

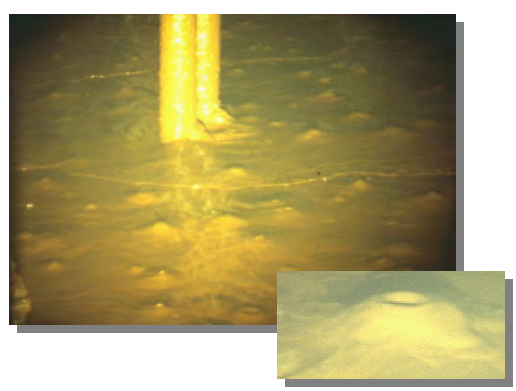
Of the remaining 10 old-style tanks (none of which have any known leakage history):

- 2 are operationally closed and grouted (Tanks 17 and 18)
- 2 contain essentially dry waste, with little or no free liquid supernate (Tanks 2 and 3)
- 6 contain liquid supernate. (Tanks 7, 8, and 21 through 24)

Salt waste is dissolved in the liquid portion of the waste. It can be in normal solution as Supernate (top picture) or, after evaporation, as salt cake (bottom picture) or concentrated supernate. The pipes in all the pictures are cooling coils.

When waste disposition began in 1996, the inventory of waste in the SRS tank system contained approximately 550 Million curies. Currently, 35 Mgal of radioactive waste, containing 248 million curies (MCi)[21] of radioactivity, are stored in 43 active waste storage tanks located in two separate locations, H-Tank Farm (27 tanks) and F-Tank Farm (16 tanks). This waste is a complex mixture of insoluble metal hydroxide solids, commonly referred to as sludge, and soluble salt supernate. The supernate volume is reduced by evaporation, which also concentrates the soluble salts to their solubility limit. The resultant solution crystallizes as salts. The resulting crystalline solids are commonly referred to as saltcake. The saltcake and supernate combined are referred to as salt waste.

The sludge component of the radioactive waste represents approximately 2.8 Mgal (8% of total) of waste but contains approximately 116 MCi (47% of total). The salt waste makes up the remaining 32.2 Mgal (92% of total) of waste and contains approximately 132 MCi (53% of total). Of that salt waste, the supernate accounts for 16.2 Mgal and 120 MCi and saltcake accounts for the remaining 16.0 Mgal and 12 MCi[21]. The sludge contains the majority of the long-lived (half-life > 30 years) radionuclides (e.g., actinides) and strontium. The sludge is currently being stabilized in DWPF through a vitrification process that immobilizes the waste in a borosilicate glass matrix. The salt is being separated in the ARP/MCU process into a higher-level component being stabilized in DWPF and a lower level component being dispositioned in SDF.

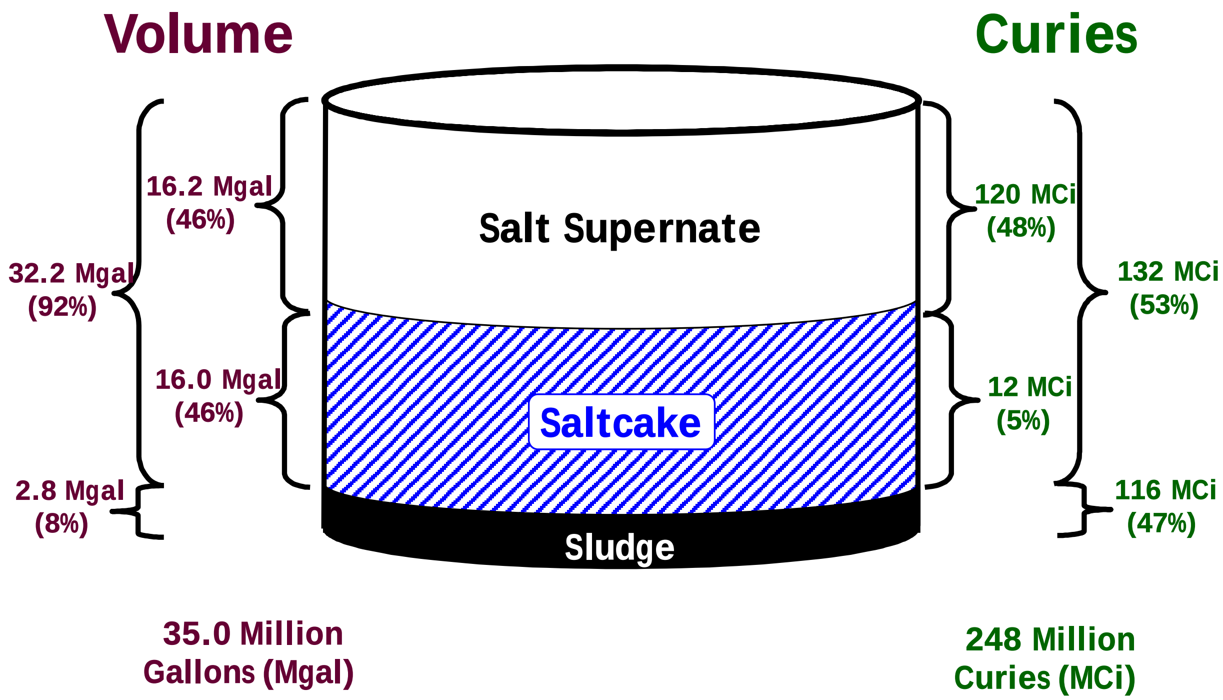


Sludge consists of insoluble solids that settle to the bottom of a tank. Note the offgas bubbles, including hydrogen generated from radiolysis.

Radioactive waste volumes and radioactivity inventories reported herein are based on the Waste Characterization System (WCS) database, which includes the chemical and radionuclide inventories on a tank-by-tank basis. WCS is a dynamic database frequently updated with new data from ongoing operations such as decanting and concentrating of free supernate via evaporators, preparation of sludge batches for DWPF feed, waste transfers between tanks, waste sample analyses, and influent receipts such as H-Canyon waste and DWPF recycle.

Well over 95%[21] of the salt waste radioactivity is short-lived (half-life ≤ 30 years) Cs-137 and its daughter product, Ba-137m, along with lower levels of Sr^{90} actinide contamination. Depending on the waste stream (e.g., canyon waste, DWPF recycle waste), the cesium concentration may vary. The precipitation of salts following evaporation can also change the cesium concentration. The concentration of cesium is significantly lower than non-radioactive salts in the waste, such as sodium nitrate and nitrite, therefore, the cesium does not reach its solubility limit and only a small fraction precipitates[23]. As a result, the cesium concentration in the saltcake is much lower than that in the liquid supernate and interstitial liquid fraction of the salt waste.

Figure 6-1—*Waste Tank Composite Inventory (as of December 31, 2018)*[21]



6.3 *Waste Tank Space Management*

To make better use of available tank storage capacity, incoming LW is evaporated to reduce its volume. This is important because most of the SRS Type III waste storage tanks are already near full capacity. Since 1954, the Tank Farms have received over 160 Mgal of LW, of which over 110 Mgal have been evaporated, leaving approximately 35 Mgal in the storage tanks. Projected available tank space is carefully tracked to ensure that the Tank Farms do not become "water logged," meaning that so much of the usable Type III tank space has been filled that normal operations and waste removal and processing operations cannot continue. A contingency allotment of 1.3 Mgal is not included as working space. This amount is equivalent to the size of the largest tank and is reserved for the unlikely event that a full tank failed such that all its material had to be removed. Waste receipts and transfers are normal Tank Farm activities as the Tank Farms receive new or "fresh" waste from the H-Canyon stabilization program, LW from DWPF processing (typically referred to as "DWPF recycle"), and wash water from sludge washing. The Tank Farms also make routine transfers to and from waste tanks and evaporators. Since initiation of interim salt waste treatment (DDA and ARP/MCU), the working capacity of the Tank Farms has been maintained. Two evaporator systems are currently operating at SRS—the 2H and 3H systems.

Space in new-style tanks is used for various operations for waste processing and disposal. Tank space is recovered through evaporator operations, DWPF vitrification, ARP/MCU treatment, and Saltstone disposal. This valuable space has been used to: (1) retrieve waste from and clean old-style tanks; (2) prepare, qualify, and treat sludge waste for disposal; (3) prepare, qualify, treat, and dispose salt waste; and (4) support nuclear materials stabilization and disposal in H-Canyon through 2030. The Tank Farm space management strategy is based on a set of key assumptions involving projections of DWPF canister production rates, influent stream volumes, Tank Farm evaporator performance, and space gain initiative implementation. The processing of salt and sludge utilizes existing tank space to retrieve and prepare waste. Sludge processing through DWPF removes the highest risk material from the old-style tanks. However, for every gallon of sludge processed, 1.3 gallons of salt waste is formed due to sludge washing and DWPF processing operations to return the resulting low-level salt waste to the Tank Farm. Similarly, salt waste retrieval, preparation, and batching typically require the use of three gallons of tank space per gallon of salt waste treated. Given these parameters, the "key to reducing the overall risk is processing high-level waste as expeditiously as possible and managing the total tank space efficiently," as recognized by the DNFSB letter dated January 7, 2010[24].

New-style tank space is a currency used to prepare for permanent immobilization and disposition of HLW in a vitrified waste form and low-level waste in a grouted waste form. Additionally, several "old-style" tanks support immobilization and disposition of high-level waste. The tank space management program maintains sufficient space to allow continued DWPF operations. The tank space management program also provides the necessary tank space to support staging of salt solutions to sustain salt waste disposition currently through ARP/MCU and subsequently through SWPF. Of the 27 new-style tanks (with a total nominal volume of 35.1 million gallons) in the SRS LW System:

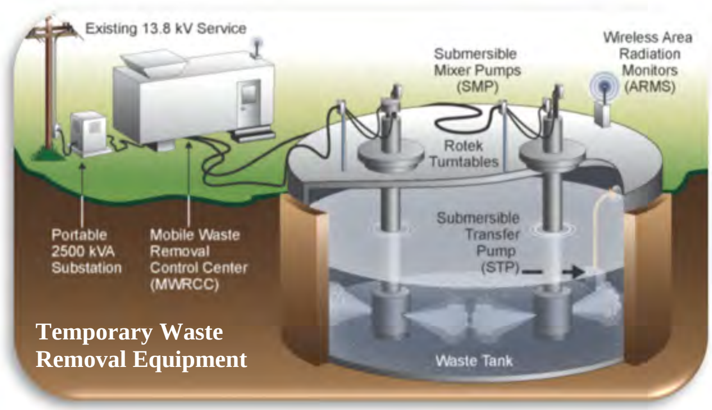
- 5 (Tanks 38, 41, 43, 49, and 50) are dedicated to salt batching, qualification, and disposition (including DWPF recycle beneficial reuse, feeding the Saltstone Production Facility (SPF), and the 2H Evaporator);
- 2 additional tanks (Tanks 27 and 42) are planned for conversion to salt blend tanks to prepare salt batching
- 6 (Tanks 29, 30, 32, 37, 40, and 51) are dedicated to sludge batching, qualification, and disposition (including the 3H Evaporator)
- 1 (Tank 39) is dedicated to uninterrupted H-Canyon waste receipts
- 13 (Tanks 25, 26, 28, 31, 33, 34, 35, 36, 44, 45, 46, 47, and 48) are dedicated to safe storage of legacy LW pending retrieval and disposition.

As the *Plan* progresses, the tank function changes.

There are currently ~8.2 Mgal of empty space (~23%) in these new-style tanks:

- 3.0 Mgal is margin as defense-in-depth operational control coupled with Safety Class or Safety Significant (SC/SS) structures, systems, or components (SSC) to facilitate reasonably conservative assurance of more than adequate dilution and ventilation of potentially flammable vapors
- 1.3 Mgal is procedurally-required minimum contingency space for recovery from the unlikely event of a bulk waste leak elsewhere in the system
- 3.9 Mgal is operational "working" space variously used to provide:
    - Additional contingency transfer space as operational excess margin above the procedurally-required minimum
    - Excess margin to preserve salt batch quality and maintain uninterrupted treatment and disposition through ARP/MCU and Saltstone
    - Excess margin to preserve sludge batch quality and maintain uninterrupted immobilization through DWPF
    - Excess margin to preserve uninterrupted support for H-Canyon.

6.4 *Waste Removal from Tanks*



Temporary Waste Removal Equipment

The first step in the disposition of sludge and salt waste is waste removal. Sludge is removed from the tank and transferred to a sludge hub tank or feed preparation tank ensuring sludge waste is continuously available for treatment at DWPF. Salt is dissolved, removed, and staged for treatment at ARP/MCU, TCCR, or SWPF.

If permanent infrastructure is available, sludge removal planning maximizes the use of this infrastructure to most effectively remove waste. This planning includes the use of structural steel, cable trays, existing slurry pumps, transfer pumps, and ventilation. However, to reduce the two-to-four-year period required for installation of substantial structural steel and large mixing and transfer pumps—with their attendant infrastructure—required for waste removal, a temporary waste removal equipment innovation was developed. This concept minimizes new infrastructure. Portable and temporary equipment meet tank infrastructure needs. Additional purchased pumps and equipment perform accelerated waste removal operations concurrently in both Tank Farms. The primary components of the temporary system are:

- Reusable mixing pumps
- A portable field operating station containing pump drives and controls
- A portable substation to provide 480-, 240- and 120-volt power
- Disposable commercial transfer pumps

The equipment is deployed at the tank as a field operating station, providing temporary power and control for waste removal equipment. When waste removal is completed on one tank, the equipment may be reconfigured to support waste removal on the next tank. Pumps are sized to fit through existing 24-inch riser openings in the waste tanks. To the extent that risers are available, pumps are set in optimal configurations within the waste tanks. Product lubricated bearings and motor cooling eliminate the need for bearing and seal water supply. These pumps have exterior fittings and fixtures, so the pumps can be decontaminated, minimizing radiation exposure to personnel during relocation to another tank. Disposable transfer pumps transfer the waste to a receipt or hub tank using existing underground transfer lines and diversion boxes. If the transfer system is degraded or non-existent, above-grade hose-in-hose technology is deployed, rather than investing in costly repairs. Temporary shielding is supplied as necessary to reduce exposure to personnel.

6.5 *Safe Disposal of the Waste*

The goal is to convert the majority of the waste into one of two final waste forms: glass, which will contain over 99% of the radioactivity, and saltstone, which will contain most of the volume. Each of the waste types at SRS needs to be treated to accomplish disposal in these two waste forms. The sludge must be washed to remove non-radioactive salts that would interfere with glass production. The washed sludge can then be sent to DWPF for vitrification. The salt must be treated to separate the bulk of the radionuclides from the non-radioactive salts in the waste. Starting in 2020, this separation will be accomplished in SWPF. However, until the startup of SWPF, ARP/MCU accomplishes this separation. ARP/MCU and SWPF will be supplemented with TCCR processing to accelerate the disposition of salt waste

6.6 *Salt Processing*

Five different processes treat salt:

- **Deliquification, Dissolution, and Adjustment** (DDA) –**D**eliquification (i.e., extracting the interstitial liquid) is an effective decontamination process because the primary radionuclide in salt is Cs-137, which is highly soluble. To accomplish the process, the salt was first deliquified by draining and pumping. The deliquified salt was then **D**issolved by adding water and pumping out the salt solution. The resulting salt solution was aggregated with other Tank Farm waste to **A**djust batch chemistry for processing at SPF. For salt in Tank 41 as of June 9, 2003, which was relatively low in radioactive content, treatment using DDA-solely was sufficient to meet the SPF WAC. Tank 41 has since received additional salt dissolution from Tank 25 and there is no longer any qualified feed for the DDA-solely process. No further DDA-solely treatment is planned.
- **Actinide Removal Process** (ARP) – For salt, even though extraction of the interstitial liquid reduces Cs-137 and soluble actinide concentrations, the Cs-137 or actinide concentrations of the resulting salt are too high to meet the SPF WAC. In ARP, MST may be added to the waste as a finely divided solid. Actinides are sorbed on the MST and then filtered out of the liquid to produce a low-level waste stream that is sent to MCU. The solids, containing the MST with the actinides, are dispositioned at DWPF. In 2016, a demonstration of ARP was initiated to demonstrate that, with the correct salt batch makeup, MST addition is not necessary to meet the SPF WAC for the ARP/MCU batches.
- **Modular CSSX Unit** (MCU) – The ARP low-level waste stream requires reduction in the concentration of Cs-137 using the CSSX process. MCU is a solvent extraction process for removal of Cs-137 from caustic salt solutions. The solvent used is a four-part solvent with the key ingredient being the cesium extractant (previously BoBCalix but, beginning September 2013, the NGS is MaxCalix). This solvent is fed to a bank of centrifugal contactors while the waste is fed to the other end in a counter-current flow. The solvent extracts the cesium, with each successive contactor stage extracting more, resulting in a DSS stream and a cesium-laden solvent stream. The solvent stream is stripped of its cesium, washed, and the solvent is reused. The cesium-laden SE is transferred to DWPF. MCU has a dual purpose:
  - demonstrating the CSSX flowsheet
  - treating salt waste to enable accelerated closure of Type I, II, and IV tanks and uninterrupted vitrification of HLW at DWPF

- **Salt Waste Processing Facility** (SWPF) – This is the full-scale CSSX process. This planned facility will incorporate both the ARP and CSSX processes in a full-scale shielded facility capable of handling salt with higher levels of radioactivity.
- **Tank Closure Cesium Removal** (TCCR) – This consists of an ion exchange process for the removal of cesium from liquid salt waste to provide supplemental treatment capability. Building on the experience of modular commercial nuclear plant decontamination and following the disaster response associated with Fukushima, technology exists to efficiently accomplish large scale, selective removal of the cesium component of the bulk salt waste. The configuration is an "at-tank" modular arrangement. The configuration consists of temporary process structures located near a tank, so the cesium removal process would take place outside of the tank. The DSS will be transferred to Tank 50 for disposition via SPF. Once the ion exchange media in a column becomes loaded with cesium to the extent practical ("spent"), the column (with media) will be removed from the system and replaced with a new ion exchange column loaded with fresh media. The spent column will be transported to an ISS location within the tank farm.

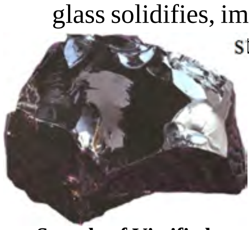
6.7 *Sludge Processing*

Sludge is washed to reduce the amount of non-radioactive soluble salts remaining in the sludge slurry. During sludge processing, large volumes of wash water are generated and must be volume-reduced by evaporation or beneficially reused. Over the life of the waste removal program, the sludge currently stored in tanks at SRS will be blended into separate sludge batches to be processed and fed to DWPF for vitrification.

6.8 *DWPF Vitrification*


Canisters being received
(prior to being filled with radioactive glass)

Final processing for the washed sludge and salt waste occurs at DWPF. This waste includes MST/sludge from ARP or SWPF, the cesium SE from MCU or SWPF, and the washed sludge slurry. In a complex sequence of carefully controlled chemical reactions, this waste is blended with glass frit and melted to vitrify it into a borosilicate glass form. The resulting molten glass is poured into stainless steel canisters. As the filled canisters cool, the molten glass solidifies, immobilizing the radioactive waste within the glass structure. After a canister has cooled, it is sealed with a temporary plug, the external surfaces are decontaminated to meet United States Department of Transportation requirements, and the canister is then permanently sealed. The canister is then ready to be stored on an interim basis on-site. A low-level recycle waste stream from DWPF is returned to the Tank Farms. DWPF has been operational since 1996.


Sample of Vitrified Radioactive Glass

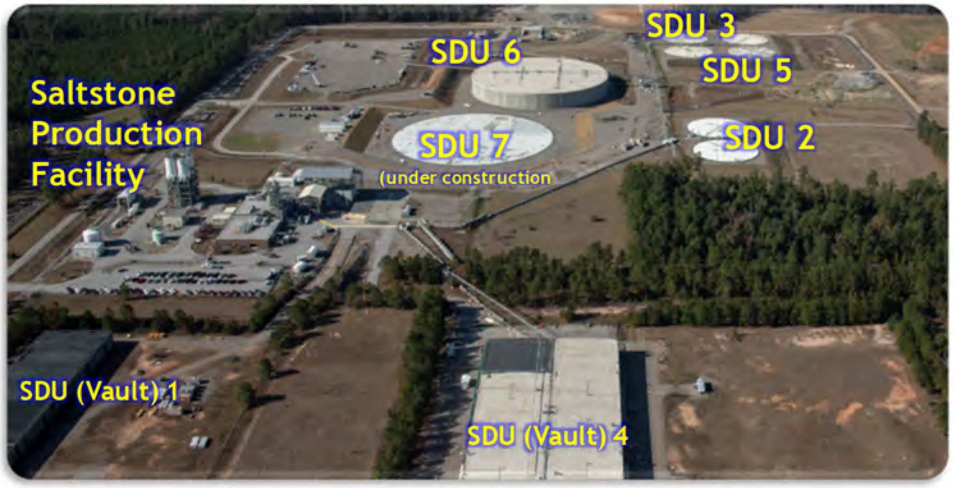
6.9 *Saltstone Disposition*

The Saltstone Facility, located in Z-Area, consists of two facility segments: the Saltstone Production Facility (SPF) and the Saltstone Disposal Facility (SDF). SPF is permitted as a wastewater treatment facility per SCDHEC regulations. SPF receives and treats the salt solution to produce grout by mixing the LLW liquid stream with cementitious materials (cement, flyash, and slag). A slurry of the components is pumped into Saltstone Disposal Units (SDU), located in SDF, where the grout solidifies into a monolithic, non-hazardous, solid LLW form known as saltstone. SDF is permitted as an Industrial Solid Waste Landfill site.


View of the Saltstone Production Facility

Future salt waste processing will impose significantly greater production demands. After SWPF startup, feed of DSS to the SPF could reach as high as 12.8 Mgal/yr. In anticipation of this future demand, SRS completed installation of Enhanced Low Activity Waste Disposal (ELAWD) improvements. The ELAWD Phase 1 improvements provided equipment modifications to increase operating margins, reliability, and controls. Also, during the ELAWD Phase 1 outage, the Mixing and Transfer System was modified to connect SPF to SDU-2.

ELAWD Phase 2 will modify the dry feeds system and connect SPF to new larger capacity salt solution feed receipt tanks. Lastly, modifications that support converting from the present day-shift staffing to 24/7 operations are planned.



The SDF will contain several large concrete SDUs. Each of the SDUs will be filled with saltstone. The grout itself provides primary containment of the waste, and the walls, floor, and roof of the SDUs provide secondary containment.

Approximately 15 feet of overburden were removed to prepare and level the site for SDU construction. All SDUs will be built at or slightly below the grade level that exists after the overburden and leveling operations are complete. The bottom of the saltstone monoliths will be at least five feet above the historic high-water table beneath the Z-Area site, thus avoiding disposal of waste in a zone of water table fluctuation. Run-on and run-off controls are installed to minimize site erosion during the operational period.

The first SDU (Vault 1), ~100 feet by 600 feet by 25 feet high, is divided into six cells. The second SDU (Vault 4), ~200 feet by 600 feet 26 feet high, has twelve cells. No more waste disposal is planned for these SDUs.

SDU-2 and SDU-5 (which are full), and SDU-3 have two cells, each being 150 feet diameter by 22 feet high. This design is used commercially for storage of water. After accounting for interior obstructions (support columns, drainwater collection systems, etc.), the nominal useable volume of a cell is 2.8 Mgal. Recent operating experience averages 1.76 gallons of grout produced for each gallon of feed, yielding a nominal cell capacity of approximately 1.6 Mgal of feed.

The next generation of units, beginning with SDU-6 (which is in use) are of a 375-foot diameter 43-foot tall single-cell design. SDU-6, can hold 32 Mgal of contaminated grout or 18.7 Mgal of feed. Future SDUs will have the same capacity as SDU-6. The last SDU will be sized as needed to complete the LW mission.

Closure operations will begin near the end of the active disposal period in the SDF, i.e., after most or all the SDUs have been constructed and filled. Backfill of native soil will be placed around the SDUs. The present closure concept includes two moisture barriers consisting of clay/gravel drainage systems along with backfill layers and a shallow-rooted bamboo vegetative cover.

Construction of the SDF and the first two vaults were completed between February 1986 and July 1988. The SDF started radioactive operations June 12, 1990. SDU-2, construction complete it June 2012, began filling in September 2012 and completed filling in July 2014. SDU-3 and SDU-5 were construction complete in September 2013. SDU-5 began filling in December 2013 and completed filling in February 2017. SDU-3 began filling in February 2017. The large SDU-6 construction began in December 2013, was completed in June 2018 and began filling in August 2018. Future SDUs will be constructed on a "just-in-time" basis in coordination with salt processing production rates.

Figure 6-2—*Process Flowsheet*

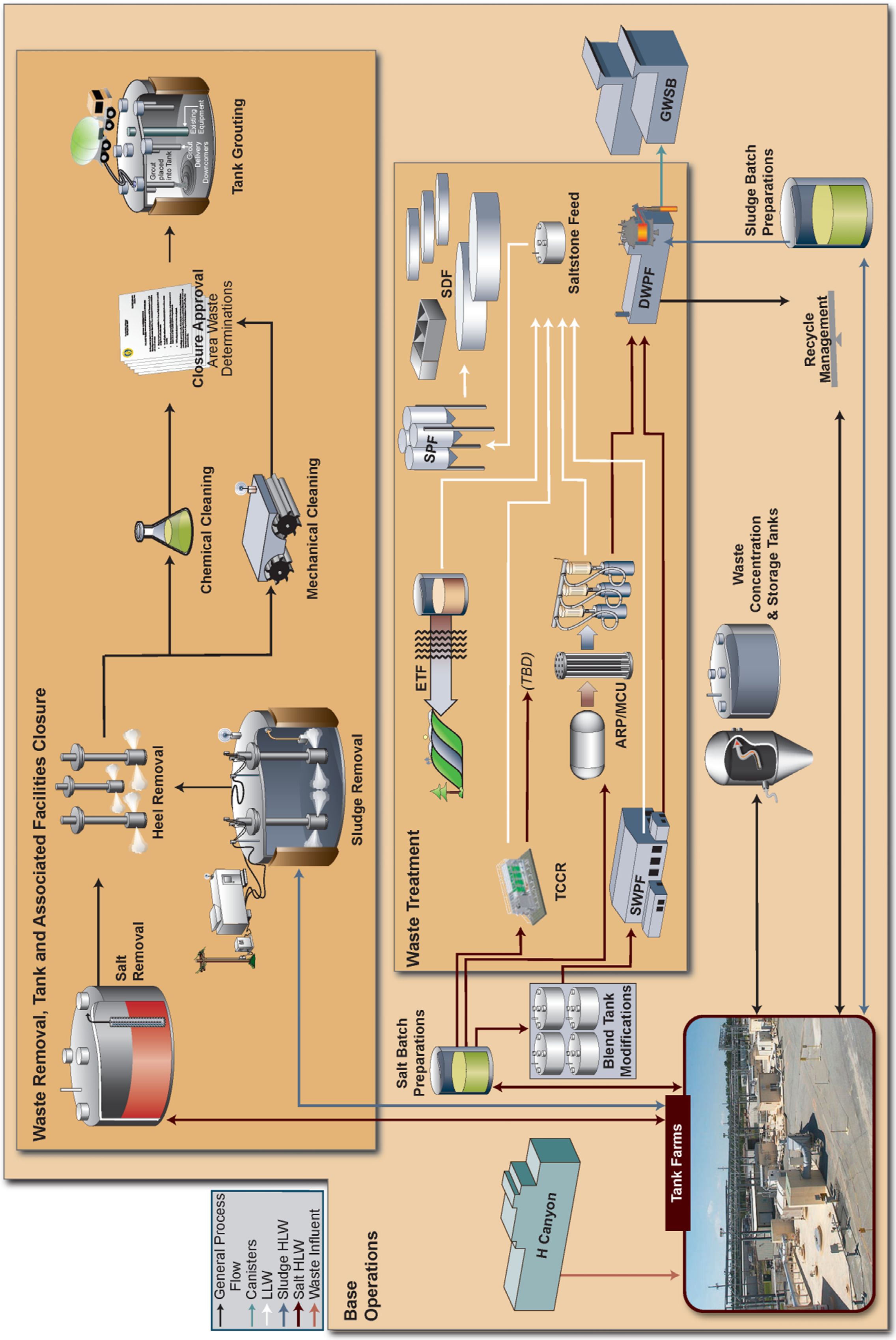


Figure 6-3—*Liquid Waste Program—Current Status*

w

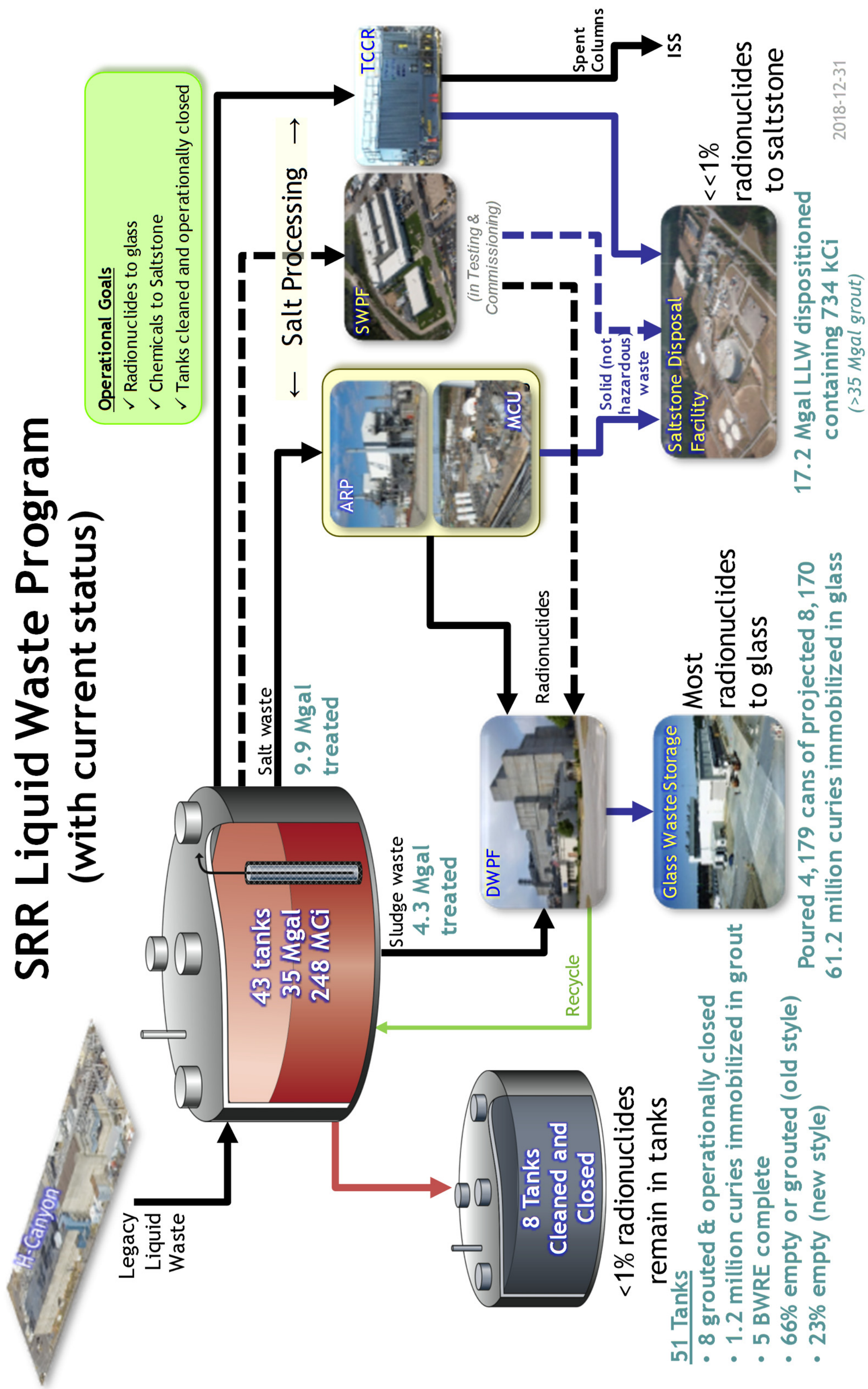
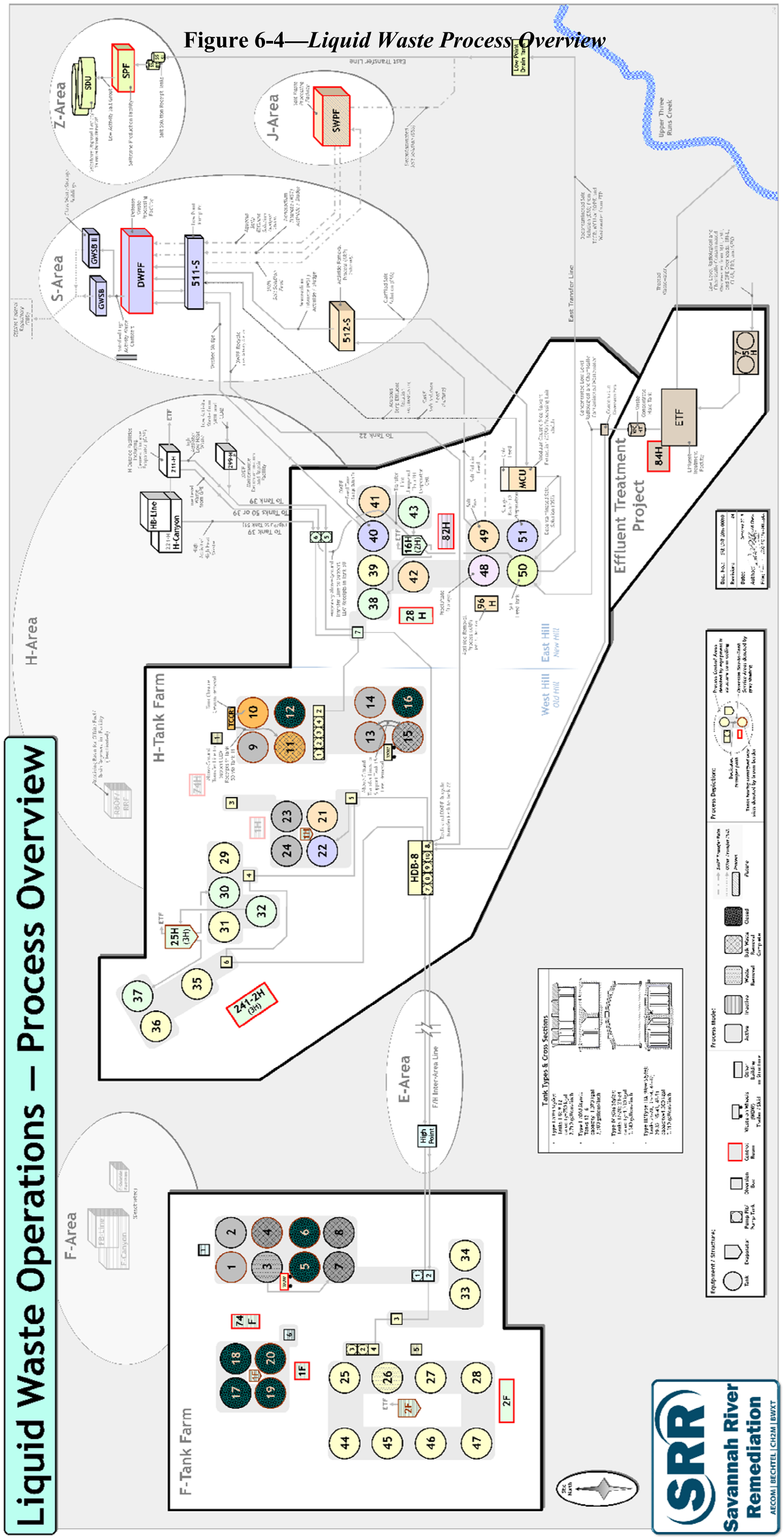


Figure 6-4—*Liquid Waste Process Overview*



Appendix A—*Salt Solution Processing*

End of	Salt Solution (kgal)						Saltstone Feed to Tank 50 (kgal) [b]				Feed	SDU
Fiscal Year	DDA-solely	ARP/MCU	TCCR-1	TCCR-2	SWPF	Total [a]	DSS	H-Can	512-S	ETP	to SPF	Numbers [c]
Total as of end of FY10	*2,800*	*985*				*3,785*	*3,151*	*682*		*3,019*	*3,881*	*4*
FY11		*1,064*				*1,064*	*1,487*	*200*		*64*	*1,487*	*4*
FY12		*705*				*705*	*901*	*19*		*24*	*1,252*	*4 & 2*
FY13		*1,320*				*1,320*	*1,566*	*24*	*65*	*69*	*2,005*	*2*
FY14		*551*				*551*	*697*	*15*	*12*	*47*	*1,167*	*2 & 5*
FY15		*753*				*753*	*919*	*12*	*18*	*45*	*828*	*5*
FY16		*1,126*				*1,126*	*1,429*	*11*	*9*	*42*	*1,506*	*5*
FY17		*397*				*397*	*442*	*5*	*5*	*46*	*500*	*5*
FY18		*149*				*149*	*171*	*11*	*3*	*19*	*384*	*5–6*
FY19		900	625			1,525	1,767	15	10	50	1,842	5–6
FY20		100			2,500	2,600	3,331		2	50	3,383	6
FY21		-	1,000		7,250	8,250	10,291			50	10,341	6
FY22			1,000	1,000	9,000	11,000	13,534			50	13,584	6–7
FY23				1,000	9,000	10,000	12,534			50	12,584	7–8
FY24			1,000	1,000	9,000	11,000	13,534			188	13,721	8
FY25			1,000	1,000	9,000	11,000	13,534			188	13,721	8–9
FY26			1,000		9,000	10,000	12,534			188	12,721	9–10
FY27			1,000	1,000	9,000	11,000	13,534			188	13,721	10
FY28			1,000	1,000	9,000	11,000	13,534			188	13,721	10–11
FY29			1,000	1,000	6,000	8,000	9,689			147	9,836	11–12
FY30			500	500	9,000	10,000	12,534			188	13,132	12
FY31					2,250	2,250	2,883			155	3,038	12–13
FY32							-			144	144	13
FY33										140	140	13
FY34									-	95	95	13
Total	**2,800**	**8,050**	**9,125**	**7,500**	**90,000**	**117,475**	**143,990**	**994**		**5,430**	**148,736**	

[a] *Salt Solution* is a total of salt solution treated via the DDA-solely, ARP/MCU, TCCR, and SWPF processes. Each gallon of salt solution treated via ARP/MCU yields ~1.26 gal of DSS, ~1.28 gallons for SWPF and ~1 gallon for TCCR.

[b] LLW receipts to Tank 50 include the DSS from salt processing, LLW from H-Canyon, ARP (512-S) filter cleaning discards, and the ETP low level stream.

[c]
- SDU-2 and SDU-3 (being full), SDU-1, and SDU-4, are no longer planned to receive contaminated grout
- SDU-5 has two ~2.8-Mgal cylindrical cells, each capable of receiving ~1.5 Mgal of feed
- SDU-6 is a single 32 Mgal cylindrical cell, capable of receiving ~18.7 Mgal of feed
- Future SDUs are assumed to have a similar design to SDU-6. The last SDU will be sized for the remaining production.
- Each gallon of Tank 50 feed, when added to the cement, flyash, and slag, generates approximately 1.76 gallons of grout
- Bleed water recycling consumes 5% of the vault space, reducing the available space for feed solution.

Note Dates, volumes, and chemical or radiological composition information are planning approximations only.

Appendix B—*Tank Farm Influents and Effluents*

End of Fiscal Year	Influents (kgal)						Effluents (kgal)		Total Inventory[e]
	H-Canyon[a]			DWPF				Sludge to	
	HLW	LLW	Other Mat'l[b]	Recycle[c]	299-H	ETP	Feed to SPF	DWPF	
FY19	200	15	11	728	12	50	1,842	50	**33,270**
FY20	200	-	-	1,022	12	50	3,383	74	**32,252**
FY21	200	-		2,171	12	50	10,341	202	**29,913**
FY22	200	-		2,752	12	50	13,584	309	**28,041**
FY23	300	-		1,376	12	50	12,584	307	**24,481**
FY24	300	-			12	188	13,721	307	**21,938**
FY25	300	-			12	188	13,721	317	**20,795**
FY26	300	-			12	188	12,721	312	**18,929**
FY27	300	-			12	188	13,721	308	**16,406**
FY28	300				12	188	13,721	301	**11,828**
FY29	300				12	147	9,836	206	**9,358**
FY30	300				12	188	13,132	313	**4,367**
FY31					d	155	3,038	373	**2,875**
FY32						144	144	393	**2,636**
FY33						140	140	356	**544**
FY34						95	95	104	**406**
FY35						-	-	-	**-**

a H-Canyon receipts consist mainly of: HLW, received into Tank 39 and LLW, received in Tank 50

b Various nuclear materials, including plutonium, uranium, neptunium, etc., from H-Canyon may be introduced directly into sludge batches, via either the sludge preparation tank (Tank 51) or the DWPF feed tank (Tank 40) to the extent allowable without negatively impacting planned canister waste loadings while continuing to comply with the canister fissile material concentration limits. The H-Canyon forecast for these materials will be included in future versions of this *Plan*, as it is made

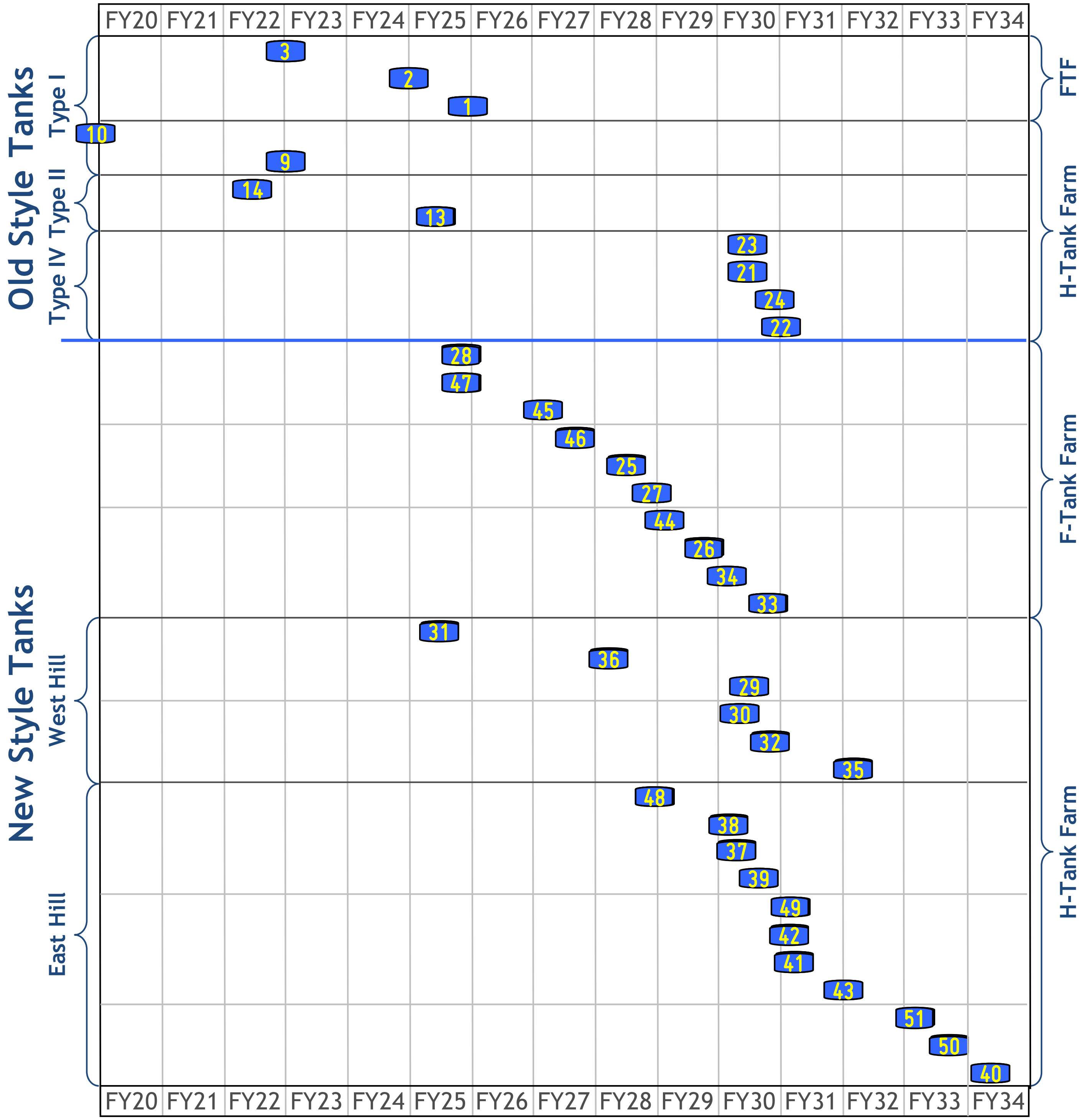
c DWPF Recycle receipts may be received into Tank 22 or used for Beneficial Reuse in salt dissolution or sludge washing. After FY23 DWPF recycle is planned to be treated by ETP.

d Maintenance Facility (299-H) receipts mainly consists of dilute nitric acid stream, decontamination solutions, and steam condensate. Waste streams from decontaminating equipment are collected in the 299-H pump tank, neutralized, and sent to Tank 39. Beginning in FY31, 299-H services supported by H-Canyon will cease and maintenance activities will be performed in the DWPF maintenance cell.

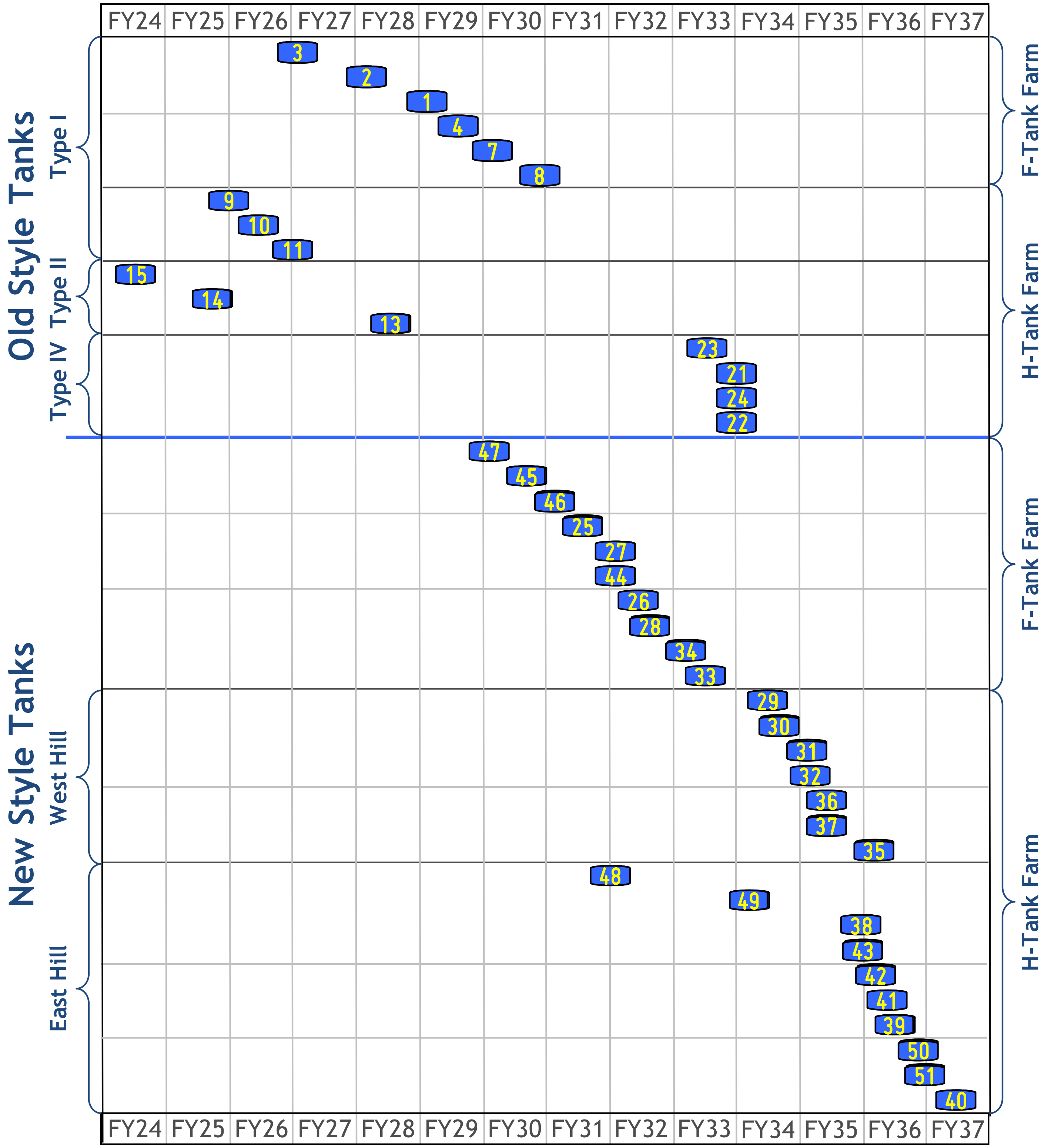
e Volumes are not additive after accounting for jet dilution, expansion of sludge during sludge slurrying operations (sludge becomes less dense), and other volume changes during the processing of waste. During a transfer, steam eductor jets are used to transfer LW from tank to tank. Volume from the transfer steam accounts for 4% of the volume being transferred for intra-area transfers and 6% for IAL. Additionally, mixing waste forms of different compositions are not mathematically additive.

Note Dates, volumes, and chemical or radiological composition information are planning approximations only.

Appendix C—*Bulk Waste Removal Complete*



Appendix D—*Tank Removal from Service*



Appendix E—*LW System Plan—Revision 21 Summary*

(see attached foldout chart)

Appendix F—*Sludge Processing*

Sludge Batch	Source Tanks [a]	Projected SOL (weight %)	Actual Cans @ Projected SOL	Date Batch Finished @ Projected SOL[b]
Actual canisters poured through December 2018 (SB 1 through 9):			4,179	
SB9 (con't)	13, 12 Chemical Cleaning, 22 (solids from DWPF)	32%	272	Jun 2021
SB10	15 via 13 (HM HAW), LTAD, 26 (PUREX), AFS-2 (Pu)	36%	500	Feb 2023
SB11	15 via 13 (HM HAW), 35 (HM HAW), LTAD, 26, 34 (PUREX)	36%	450	Aug 2024
SB12	35, 39 (HM HAW), LTAD 34 (PUREX)	36%	425	Jan 2026
SB13	35, 39 (HM HAW), LTAD, 33 (PUREX), 11 &14 via 13 (MIXED HM/PUREX)	36%	450	Jul 2027
SB14	35 & 39 (HM HAW), LTAD, 47 via 33 (PUREX)	36%	425	Dec 2028
DWPF Melter Replacement — January 2029 thru April 2029				
SB15	35, 39, 32 (HM HAW), LTAD, 43 (MIXED HM HAW/LAW), 4, 7, 8, & 47 via 33 (PUREX)	36%	300	Apr 2030
SB16	32, 33, 35, 39 (HM HAW)	40%	375	Jul 2031
Heel Batch 1 [c]	39, 32 (HM HAW)(incl 23 Solids), 33 (PUREX)	40%	375	Oct 2032
Heel Batch 2 [c]	35 (HM HAW plus DWPF Solids), 39 (Incl 32 HM HAW, 24 Zeolite, 23 Solids), 43H (HM LAW)	40%	260	Sep 2033
Heel Batch 3 [c]	43, 35, 39 including Heels (Mixed HM HAW, HM LAW)	32%	60	Mar 2034
Heel Batch 4 [c]	40 Heel Material	28%	50	Sep 2034
		Total:	**8,121**	

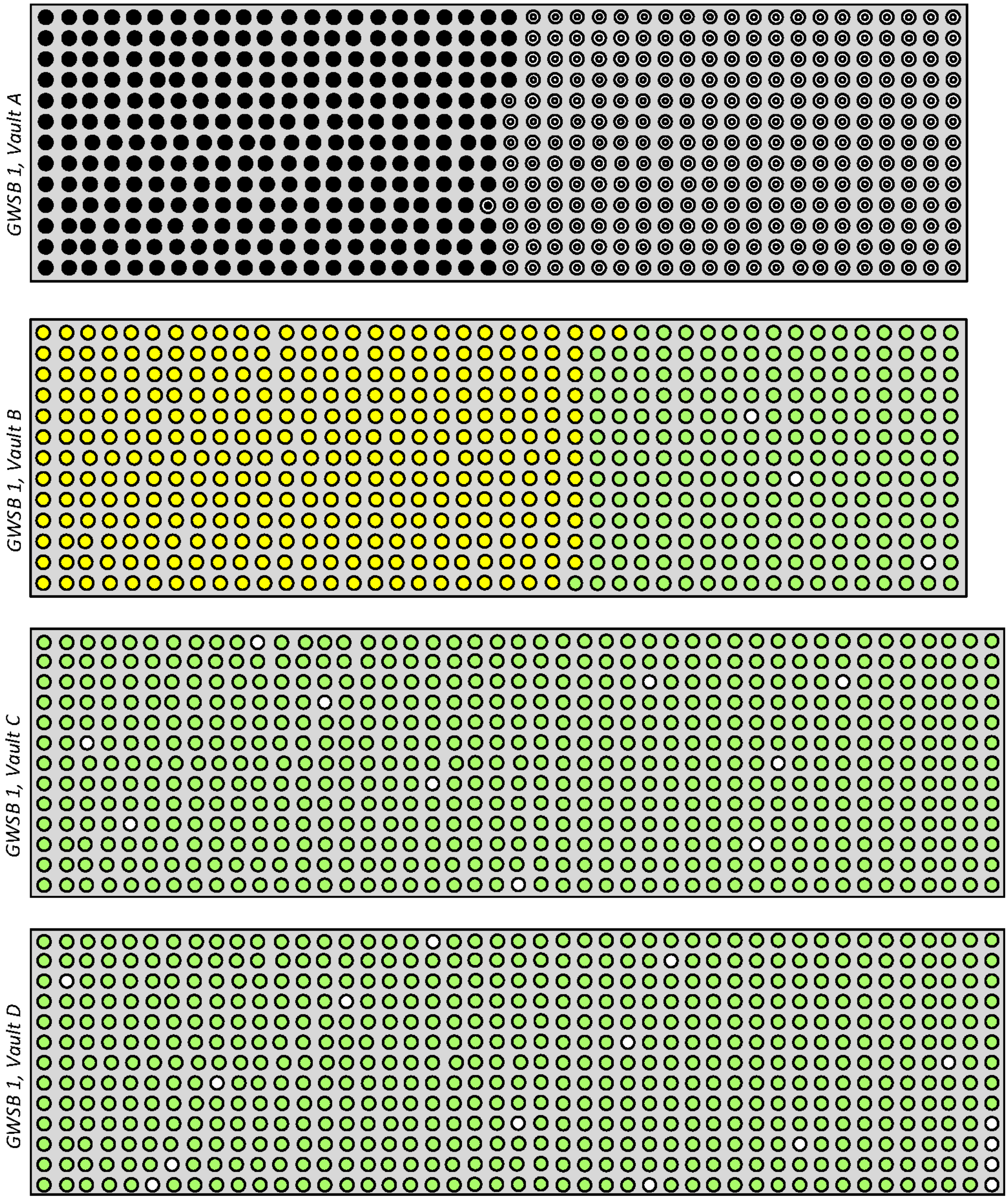
[a] The indicated tanks are the sources of the major components of each sludge batch, not necessarily the sludge location just prior to receipt for sludge washing. Tanks 33 and 35, for example, are also used to stage sludge that is removed from other tanks. Some BWRE may be accelerated with respect to this table as conditions dictate.

[b] Dates are approximate and represent when Tank 40 gets to heel level. Actual dates depend on canister production rates

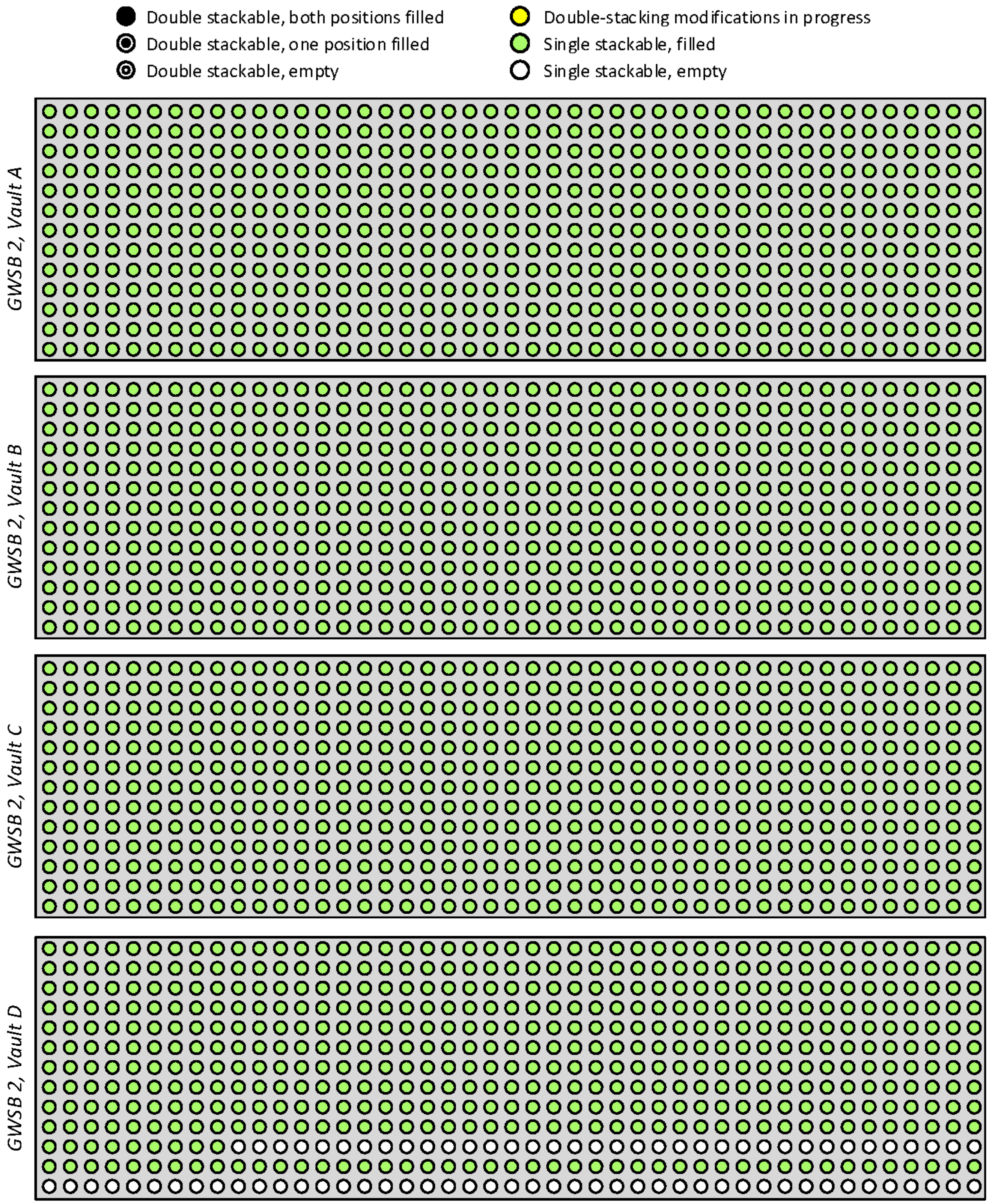
[c] Longer processing assumed for dilute heel processing

Note: Dates, volumes, and chemical or radiological composition information are planning approximations only.

Appendix G—*GWSB Utilization*



GWSB utilization presents the current conditions, as of December 31, 2018, of the two GWSBs showing which canister storage positions have been converted to double-stack capability and which storage positions are empty, have a single canister, or have two canisters.



Appendix H—*Canister Storage*

End of Fiscal Year	SRS Cans Poured		SRS Cans in GWSB 1 (4,522 capacity)[a]		SRS Cans in GWSB 2 (2,339 capacity)[b]		SRS Cans in Supplemental Storage [c]	
	Yearly	Cum.	Added	Cum.	Added	Cum.	Added	Cum.
FY96	64	64	64	64				
FY97	169	233	169	233				
FY98	250	483	250	483				
FY99	236	719	236	719				
FY00	231	950	231	950				
FY01	227	1,177	227	1,177				
FY02	160	1,337	160	1,337				
FY03	115	1,452	115	1,452				
FY04	260	1,712	260	1,712				
FY05	257	1,969	257	1,969				
FY06	245	2,214	244	2,213	1	1		
FY07	160	2,374	28	2,241	132	133		
FY08	225	2,599		2,241	225	358		
FY09	196	2,795		2,241	196	554	[d]	
FY10	192	2,987	3	2,244	183	737		
FY11	264	3,251		2,244	260	997		
FY12	277	3,528		2,244	277	1,269		
FY13	224	3,752		2,244	224	1,493		
FY14	125	3,877		2,244	125	1,629		
FY15	93	3,970	(193)	2,051	281	1,910		
FY16	136	4,106	(139)	1,912	277	2,201		
FY17	52	4,158		1,912	48	2,235		
FY18	15	4,173		1,912	15	2,251		
FY19	49	4,222		1,912	49	2,300		
FY20	84	4,306	84	1,996		2,300		
FY21	220	4,526	220	2,216		2,300		
FY22	300	4,826	300	2,516		2,300		
FY23	300	5,126	300	2,816		2,300		
FY24	300	5,426	300	3,116		2,300		
FY25	300	5,726	300	3,416		2,300		
FY26	300	6,026	300	3,716		2,300		
FY27	300	6,326	300	4,016		2,300		
FY28	300	6,626	300	4,316		2,300		
FY29	200	6,826	200	4,516		2,300		
FY30	300	7,126	6	4,522	39	2,339	255	255
FY31	300	7,426		4,522		2,339	300	555
FY32	300	7,726		4,522		2,339	300	855
FY33	285	8,011		4,522		2,339	285	1,140
FY34	110	8,121		4,522		2,339	110	1,250
FY35		8,121		4,522		2,339	10[f]	1,260

Numbers in italics are actuals — through FY18. FY19 and future are forecast based on modeling assumptions

[a] GWSB 1 filling began in May 1996. In FY15, conversion of GWSB 1 was initiated for stacking two canisters in each storage location. When conversion is complete, canisters will be moved from GWSB 2 to GWSB 1 until it is full, retaining about 5 GWSB №1 locations unused for contingency in case GWSB 2 is temporarily unavailable. The total capacity of GWSB 1 will be 4,524 when conversion is complete with two positions filled with non-radioactive archive canisters.

[b] GWSB 2 was built with 2,340 standard storage locations. One archived non-radioactive canister is stored in GWSB 2 yielding a usable storage capacity of 2,339 standard canisters. GWSB 2 received its first radioactive canister in June 2006. It is expected to reach maximum capacity in FY30. Note: its design does not accomodate stacking canisters similar to GWSB 1.

[c] This *Plan* assumes supplemental canister storage is available in FY30.

[d] Typically, several canisters are in the vitirification building pending transfer to canister storage. All canisters will be transferred to canister storage before the DWPF is cleaned and flushed.

[e] This *Plan* assumes that, beginning in FY20, future production canisters are placed in double stack locations within the guidance of the double stack heat transfer calculation, M-CLC-S-00819, until GWSB 1 reaches capacity.

[f] Remaining canisters in the vitrification buliding are moved to storage during DWPF Clean & Flush.

Note: Dates, volumes, and chemical or radiological composition information are planning approximations only.

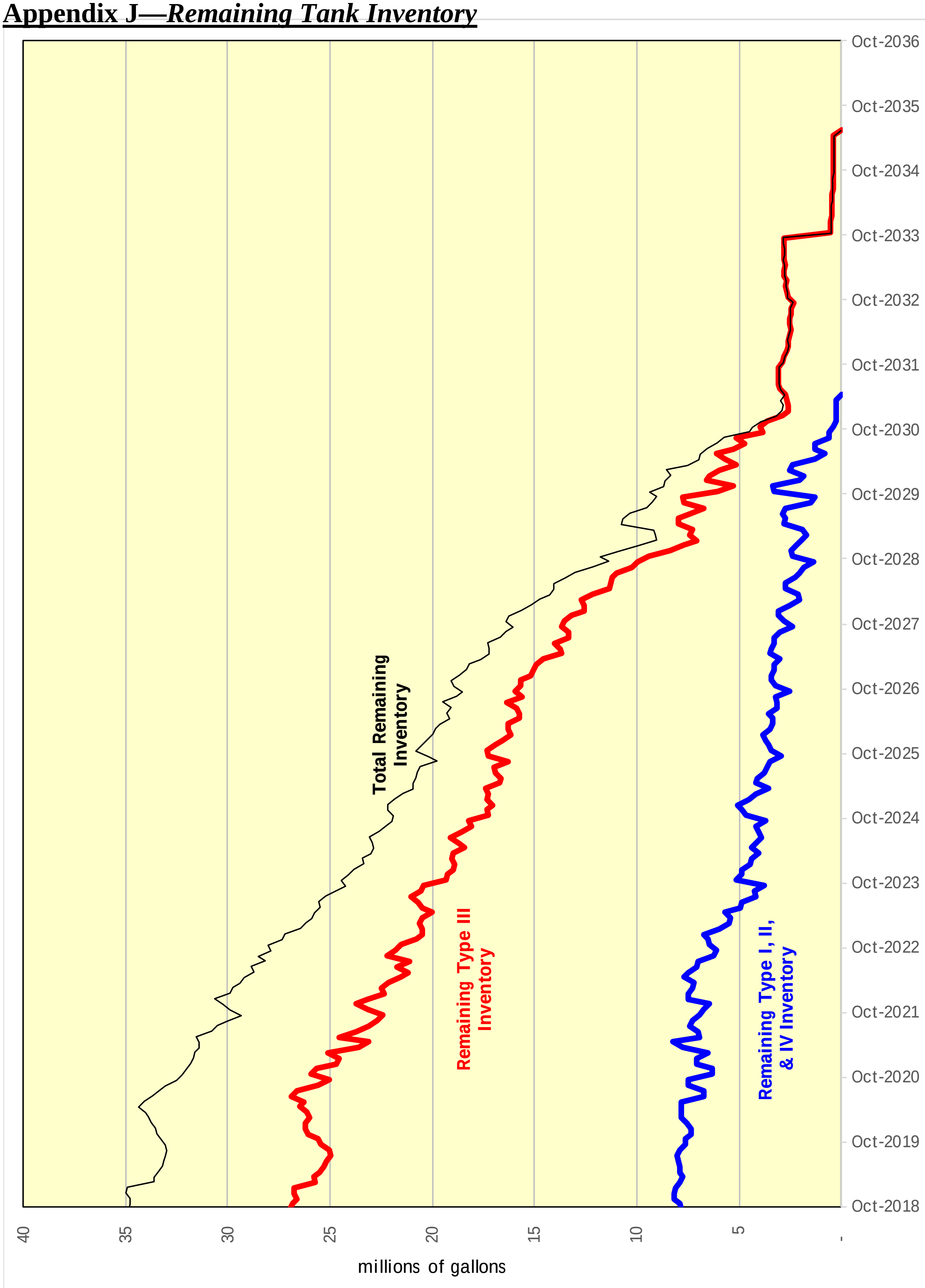
Appendix I—*TCCR Columns Interim Safe Storage*

End of Fiscal Year	TCCR Ion Exchange Columns produced for storage in the ISS	
	Yearly	Cum.
FY19	1	1
FY20	6	7
FY21	9	16
FY22	16	32
FY23	7	39
FY24	14	53
FY25	14	67
FY26	6	73
FY27	13	86
FY28	14	100
FY29	15	115
FY30	5	120
FY31		120
FY32	1	121
FY33	1	122
FY34		
FY35		

TCCR Ion Exchange Column Assumptions

- TCCR IX column design remains the same (mass of CST is ~515 kg)
- Adsorption kinetics supports a loading of 75,000 Ci of Cs-137 per IX column
- The capacity of CST for cesium adsorption is unaffected by salt solution makeup or UOP manufacturing process
- Columns are filled to the 75,000 Ci Cs-137/column limit (i.e. no partially used columns)
- Salt solution curie content and volume processed is that of System Plan Rev. 21 Volume Balance
- Temperature of salt solution/columns is maintained constant so CST resin kinetics/capacity is constant
- Resulting decontaminated salt solution meets the Saltstone Waste Acceptance Criteria

Appendix J—*Remaining Tank Inventory*



Acronyms

ARP **Actinide Removal Process** –process that removes actinides and Strontium-90 (Sr-90), both soluble and insoluble, from Tank Farm salt solution using MST and filtration
Ci/gal **Curies per gallon**
CM **Closure Module**
CSMP **Commercial Submersible Mixing Pumps**
CSSX **Caustic Side Solvent Extraction** – process for removing cesium from a caustic (alkaline) solution. The process is a liquid-liquid extraction process using a crown ether. SRS plans to use this process to remove Cesium-137 (Cs-137) from salt wastes.
D&D **Dismantlement and Decommissioning**
DAR **Drain, Add, Remove**
DDA **Deliquification, Dissolution, and Adjustment**
DF **decontamination factor**
DNFSB **Defense Nuclear Facilities Safety Board**
DOE **Department of Energy**
DOE-SR The **DOE Savannah River** Operations Office
DQA **Data Quality Assessment**
DSA **Documented Safety Analysis**
DSS **Decontaminated Salt Solution** – the decontaminated stream from any of the salt processes – DDA, ARP/MCU, or SWPF
DWPF **Defense Waste Processing Facility** – SRS facility in which LW is vitrified (turned into glass)
EA **Environmental Assessment**
EIS **Environmental Impact Statement**
ELAWD **Enhanced Low Activity Waste Disposal**
EOL **End-of-Life**
EPA **Environmental Protection Agency**
ETP **Effluent Treatment Project –** SRS facility for treating contaminated wastewaters from F & H Areas
eWAC **Electronic Waste Acceptance Criteria**
FFA **Federal Facility Agreement** – tri-party agreement between DOE, SCDHEC, and EPA concerning closure of waste sites. The currently-approved FFA contains commitment dates for closing specific LW tanks
FESV **Failed Equipment Storage Vault**
FTF **F-Tank Farm**
FY **Fiscal Year**
GWSB **Glass Waste Storage Building** – SRS facilities with a below-ground concrete vault for storing glass-filled HLW canisters
HLW **High Level Waste**
HM **H Modified** – the modified PUREX process in H-Canyon for separation of special nuclear materials and enriched uranium
HTF **H-Tank Farm**
IAL **Inter-Area Line**
IPABS **Integrated Planning, Accountability, & Budgeting System**
ISS **Interim Safe Storage**
IW **inhibited water** – well water to which small quantities of sodium hydroxide and sodium nitrite have been added to prevent corrosion of carbon steel waste tanks
kgal **thousand gallons**
LTAD **Low Temperature Aluminum Dissolution**
LLW **Low Level Waste**
LW **Liquid** (Radioactive) **Waste** – broad term that includes the liquid wastes from the canyons, HLW for vitrification in DWPF, LLW for disposition at SDF, and LLW wastes for treatment at ETP
MCi **Million Curies**
MCU **Modular CSSX Unit** – small-scale modular unit that removes cesium from supernate using a CSSX process similar to SWPF
Mgal **million gallons**
MSB **Melter Storage Box**
MST **monosodium titanate**
NCSE **Nuclear Criticality Safety Evaluations**
NDAA Ronald W. Reagan **National Defense Authorization Act** for Fiscal Year 2005, Public Law 108-375
NDAA §3116 **Section 3116** – Defense Site Acceleration Completion—of the **NDAA**
NEPA **National Environmental Policy Act**
NGS **Next Generation Solvent**
NPDES **National Pollution Discharge Elimination Systems**
NRC **Nuclear Regulatory Commission**
OA **Oxalic Acid**
OOS **Out of Service**
PA **Performance Assessment**
PEIS **Programmatic Environmental Impact Statement**
PISA **Potential Inadequacy in the Safety Analysis**
PUREX **Plutonium Uranium Reduction Extraction**
RA **Readiness Assessment**

RCRA **Resource Conservation and Recovery Act**
ROMP **Risk** and **Opportunity Management Plan**
SAR **Sample Analysis Report**
SAS **Steam Atomized Scrubber**
SB **Sludge Batch**
SC **Safety Class**
SCDHEC **South Carolina Department of Health and Environmental Control** – state agency that regulates hazardous wastes at SRS
SDI **Salt Disposition Initiative**
SDF **Saltstone Disposal Facility** – SRS facility containing Saltstone Disposal Units
SDU **Saltstone Disposal Units** – Disposal Units that receive wet grout from SPF, where it cures into a solid, non-hazardous Saltstone
SE **Strip Effluent**
SEIS **Supplemental Environmental Impact Statement**
SME **Slurry Mix Evaporator**
SMP **Submersible Mixer Pump**
SOL **Solids Oxide Loading**
SPF **Saltstone Production Facility** – SRS facility that mixes decontaminated salt solution and other low-level wastes with dry materials to form a grout that is pumped to SDF
SRNL **Savannah River National Laboratory**
SRNS **Savannah River Nuclear Solutions**
SRR **Savannah River Remediation** LLC
SRS **Savannah River Site**
SS **Safety Significant**
SSC **Structure, System, or Component**
STP **Site Treatment Plan**
SWPF **Salt Waste Processing Facility** –facility that will remove Cs-137 from Tank Farm salt solutions by the CSSX process and Sr-90 and actinides by treatment with MST and filtration
T&PRA **Technical and Programmatic Risk Assessment**
TCCR **Tank Closure Cesium Removal** –process that will remove Cs-137 from Tank Farm salt solutions by the ion exchange process
WAC **Waste Acceptance Criteria**
WCS **Waste Characterization System** – system for estimating the inventories of radionuclides and chemicals in SRS Tank Farm tanks using a combination of process knowledge and samples
WD **Waste Determination**
wt% **weight percent**
WW **well water**

References

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Liquid Waste System Plan
Revision 21

Appendix E—LW System Plan—Rev 21 Summary

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