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Alternatives
Introduction

The Alternatives for immobilization of SLAW are divided into three technologies: vitrification (baseline), steam reforming, and grouting. Each technology has advantages and disadvantages and all have been demonstrated at large scale on other waste streams. This section provides an overview of each of the technologies and their assumptions, with more detailed descriptions provided in the Appendix.

All LAW will be pretreated to remove ^{137}Cs equivalent to or beneath the WTP LAW vitrification facility criteria (<3.18E-5 Ci/mole Na^+ [Fiskum et al., PNNL-28958]) which is sufficient to permit contact-handled maintenance in all subsequent processes. This level is also assumed for these grouting alternatives. In all grouting alternatives, it is assumed that the liquid tank waste would be processed through the Tank Farm Pretreatment (TFPT) process. Treatment in WTP does not preclude the grout alternatives but may impact the waste classification of the product. The TFPT is the follow-on facility as described in the Hanford System Plan 9, and is similar to the Tank Side Cesium Removal (TSCR) system. Using TFPT removes ^{137}Cs, ^{90}Sr, and some actinides using Crystalline SilicoTitanate (CST)[1]. The concentration of the feed to the TFPT system will be as high as 6M, but selected feeds may be processed for cesium removal at lower concentrations (e.g. some feeds may be processed at ~2M sodium to maintain phosphates in solution). The extent of removal of ^{90}Sr and actinides by CST is not known for all feed stream compositions but is estimated to be 99% and 30%, respectively, unless the waste is a complexant waste. The estimate for non-complexant waste is based on limited testing of processing AW-102, AP-107, and AP-105 through columns of CST [Rovira et al., PNNL-28783, Fiskum et al., PNNL-27706; Fiskum et al., PNNL-30712]. These tanks contain blends of supernate from several tanks and is expected to be representative of the strontium chemistry in non-complexant wastes. Complexant waste could contain high soluble ^{90}Sr and actinides that may or may not be removed by CST. It is known that the $SrOH^+$ ion is the species removed by CST [Zheng Dissertation]. The distribution coefficient for ^{90}Sr is actually ten times higher than for Cs [Taylor-Pashow et al., SRNL-STI-2019-00678, Fiskum et al., PNNL-30185], which indicates that its removal will normally exceed that for Cs during the TFPT column operation. Note that this concentration would also be beneath NRC Class A low-level limits (1 Ci/m^3) for waste at 6 M [Na^+]. Further, the laboratory testing with AW-102, AP-105, and AP-107 indicated that the ^{90}Sr concentration in the column effluent (all were <1E-3 µCi/mL) would also be beneath the corresponding Class A limit (0.04 Ci/m^3), as well as the combined Pu isotope concentrations were beneath the Class A limit (100 nCi/g). Verification of the ability of CST to remove these isotopes to beneath the Class A limit could be part of the waste acceptance criteria for the grouting process. The prior NDAA17 report [SRNL-RP-2018-00687] indicated that 90% of waste would reach Class A if 99% of the ^{90}Sr was removed.

After TFPT, the liquid will be evaporated to remove excess water; with many of the organic species in the waste expected to partition to the condensate during that evaporation. The condensate containing the soluble organics will be sent to the Effluent Treatment Facility (ETF), which is permitted for destruction of the organics in tank farm evaporator condensate. The target sodium ion concentration for evaporation has not been specified but could be as high as 9M sodium for selected wastes. Concentrating the SLAW in an evaporator will also have the effect of potentially removing many of the Land Disposal Restricted (LDR) organic compounds to beneath the treatment standard [Nash et al., SRNL-STI-2020-00582]. If low volatility LDR organic compounds are also present, the concentrated SLAW will be processed further using methods to be identified during this study, such as low

[1] Spent TSCR/TFPT columns are stored onsite in interim storage and assumed vitrified with sludge in the HLW facility.

temperature oxidation. If some portion of the waste is resistant to these treatments to remove or destroy the organics, it is assumed that the waste can be diverted to the LAW melter for processing. Similar to that mentioned above for removal of Sr and Pu, all grouting alternatives assume that the liquid waste is sampled and analyzed and tested as necessary prior to processing to ensure pretreatment will produce an acceptable waste form.

The status of the technology maturation for pretreatment processes discussed here is mixed. A tank-side treatment system for cesium removal is currently deployed at SRS (TCCR) and is in startup testing at Hanford (TSCR), so is mature. Waste evaporation to both remove LDR organics and reduce waste volume and the grout formulation and production are relatively mature technologies, although the effectiveness of LDR organic removal of all species is yet to be completely demonstrated. Additional treatment may be necessary to destroy some organics, and this is low maturity level. Maturity of the iodine and technetium removal technologies are discussed in Section X.X of this report.

While not a specific technology, the ability of a SLAW immobilization process to have flexible processing rates and easy idling periods is important. The processing of HLW causes a wide range of flow rates for SLAW, depending on the need for washing and leaching cycles of a particular sludge. It is beneficial to have a capacity to process at higher-than-average flow rates or to turn off the process and readily resume processing.

The primary alternatives are shown in the Table X.x. These alternatives are described in the sections following the table. There are also variants on the primary alternatives also shown in the table and described along with the alternatives.

Grout Alternatives

A wealth of experience in using grout waste forms exists within the U.S. from federal and commercial applications and as the standard immobilization technology for low-level wastes across the international community. The required properties of the grout waste form in each alternative are dictated by the disposal location (e.g., zero groundwater pathway), the immobilization facility used (modular or centralized plant) and chemistry of the waste. A history of experience in grout waste forms both nationally and internationally, descriptions of immobilization facilities/technologies relevant to the alternatives, performance requirements and formulation considerations based on disposal locations, recent work since the prior NDAA17 report [SRNL-RP-2018-00687] and key assumptions is present in Section X.

The grouting process for each alternative may be different, depending on both the process selected and the supernatant composition. The basic components are ordinary Portland cement (OPC), blast furnace slag (BFS), and fly ash (FA), and other additives may be added or ratios may vary, depending on composition and disposal requirements. The ratio of the basic components and waste loading will vary, depending on whether the grout must be pumped long distances to a vault or would be dumped into a nearby container because the rheological properties and set-time needs would be different. The dry ingredients would likely be stored in silos exterior to the grout plant and fed into a dry mix blend tank inside the facility and then to a dry feed hopper.

The baseline for all grout options is to design all components of the disposal system to meet the criteria for disposal at the specified disposal site using the integrated retention properties of the waste form chemistry, container (if applicable), disposal environment (e.g. IDF or vault), and geotechnical cap. The intent is to design the entire system to be protective of the environment and retain the contaminants of concern to within the applicable limits. Additional measures, such as barriers and getters, may be taken as options to provide defense-in-depth of contaminant release. The details of those options are described in section X.X of this report.

Grout options for immobilization of treated LAW can benefit from addition of selective "getters" that improve sequestration of specific contaminants. Although BFS acts by chemical reduction to sequester many contaminants, such as regulated metals and technetium, it is a bulk grout-forming additive and is not usually referred to as a "getter". These selective getters are typically added in small amounts along with the bulk of the grout-forming materials to enhance retention of a specific contaminant, although there are also options to add them as a barrier beneath the bulk waste form so that they can hinder leaching of the contaminant to the environment. For the alternatives described in this section, it is assumed that getters are needed to meet the leaching performance criteria for onsite disposal of grout in containers for Alternatives 1-5. If other manipulations of the grout formulation are needed to reach the performance criteria or material properties, they are assumed to be included. The key contaminant of concern where getters are required/beneficial for onsite disposal of grouted waste forms is ^{129}I, and perhaps are also needed for the highest performing grouts to sequester ^{99}Tc.

The offsite grout disposal alternatives assume that getters are not needed for ^{129}I and/or ^{99}Tc and retention of these species is reliant on the integrated disposal system. However, if getters or manipulation of the grout formulation are ultimately needed to meet the Waste Acceptance Criteria of the offsite facility, they will be included, but are not assumed needed in cost estimates at this time for the primary alternatives.
Nitrate and nitrite are not destroyed or chemically stabilized in cement-based slag based grouts. These ions are concentrated in pore solution and have a sorption (liquid-solid partitioning coefficient - retardation factor of < 1) indicating very little retention under saturated conditions. Retention can be increased by reducing porosity of the waste form, but the technology to do this consistently at large scale is not mature.

Removal of ^{129}I and/or ^{99}Tc are considered variants for grout Alternatives 1B and 3C, where all other flow-sheet assumptions are consistent with options 1 and 3, respectively. Similarly, a "sample and send" approach is a variant for options 1 and 3. In these variants, 1C and 3D, the waste is sampled and analyzed for ^{129}I and/or ^{99}Tc. After grouting the waste, grout containers with lower than a threshold concentration of these radionuclides would be disposed onsite, and those with higher than threshold concentration would be disposed offsite.

General assumptions for the Alternatives are shown in Table X below.

Table X. Assumptions for Alternatives

LAW is pretreated in TFPT (~TSCR) to remove ^{137}Cs to <3.18E-5 Ci/mole Na^+ (but does not preclude treatment in WTP pretreatment facility)
TFPT treatment removes ^{90}Sr to <0.04 Ci/m^3 and Pu to <100 nCi/g for most (~90%) LAW feed (not complexant) WTP pretreatment facility would not reach these limits)
LAW is retrieved and staged for pretreatment in a DST (except for Grout 4 and 5)

LAW is sampled and analyzed (and tested, if required) to ensure a compliant waste form will be produced
Pretreated LAW will be evaporated to reach optimum Na^+ concentration
LDR organics will be removed from LAW by evaporation (and oxidation, if needed) to beneath regulatory levels (or will be sent for vitrification)
For grout alternatives, “Getters” for ^{129}I (and perhaps ^{99}Tc) are included in grout formulations for Alternatives Grout 1-5 but are not needed for offsite disposal
All debris/solid waste is disposed onsite in IDF except alternatives Grout-5A and B
All alternatives that include offsite shipment assume DOT compliant shipping containers are utilized

Alternatives Comparison Table

Alternative	Brief Description	Cross-site transfer required	Utilize existing DSTs	Disposal	Container
Vitrification	Vitrification	X	X	Onsite	X
Steam Ref-A	Steam Reform	X	X	Onsite	X
Steam Ref-B	Steam Reform	X	X	Offsite	X
Grout-1	Single plant	X	X	Onsite	X
Grout-2	Single plant	X	X	Offsite	X
Grout-3A	Separate plants East-West		X	Onsite	X
Grout-3B	Separate plants East-West		X	Offsite	X
Grout-4A	Individual plants (farms/tanks)			Onsite	X
Grout-4B	Individual plants (farms/tanks)			Offsite	X
Grout-5A	Offsite vendor			Onsite	X
Grout-5B	Offsite vendor			Offsite	X
Grout-6	Onsite monolith	X[2]	X	Onsite	
Variant Grout-1B.	Grout 1 + Tc/I removal	NA	NA	Onsite	X
Variant Grout 3C	Grout 3 + Tc/I removal		X	Onsite	X
Variant Grout 1C	Grout 1 + Sample Tc/I/send offsite/onsite	X	X	Onsite	X
Variant Grout 3D	Grout 3 + Sample Tc/I/send offsite/onsite		X	Onsite	X

[2] If monoliths are constructed in both East and West areas, a cross-site transfer line would not be required for G-6

Alternative: Single SLAW Vitrification plant

(Note: this description is duplicated from the NDAA17 report SRNL-STI-2018-00687, with updates for the current evaluation)

The vitrification Alternative considered in this assessment is shown in Figure X (from SRNL-STI-2018-00687). Disposal of the glass waste is assumed to be in the Integrated Disposal Facility (IDF) in containers. This scenario is comparable to the vitrification from the previous NDAA17 report [SRNL-RP-2018-00687].
In this Alternative, the existing Double Shell Tank system is assumed to be utilized to blend and stage the feed. To transport the liquid waste to the single SLAW vitrification facility, a cross-site transfer line would be needed, and some remote tank farms may require transfer capabilities. The waste is assumed to be sampled in the DST and analyzed and found to be compliant with the pretreatment system such that it would produce an acceptable glass waste form. Vitrification blends radioactive liquid waste with glass-forming materials at high heat in a ceramic-lined Joule-heated melter, forming a molten mixture that is poured into stainless steel containers to cool and solidify into a borosilicate glass wasteform that is highly stable in the expected conditions in a disposal facility. Vitrification technology has been used in the U.S. and other countries to treat high-level waste (HLW), (which is generally made up of metal oxides). Vitrification for supplemental treatment of Hanford Low Activity Waste is summarized below and detailed in Appendix TBD.

Waste vitrification technology consists of mixing a chemically characterized, aqueous waste stream with sugar, specific metal oxides, and metal carbonates to produce a slurry that is fed to a melter in which the slurry is incorporated into the melt pool. The volatile components are driven into offgas by heat, requiring a complex offgas system to treat the melter offgas prior to discharge and generating two secondary liquid waste streams as well as solid secondary waste that also requires treatment.

The molten glass is poured into a stainless steel container to cool. Vitrification unit operations are shown in Figure X.

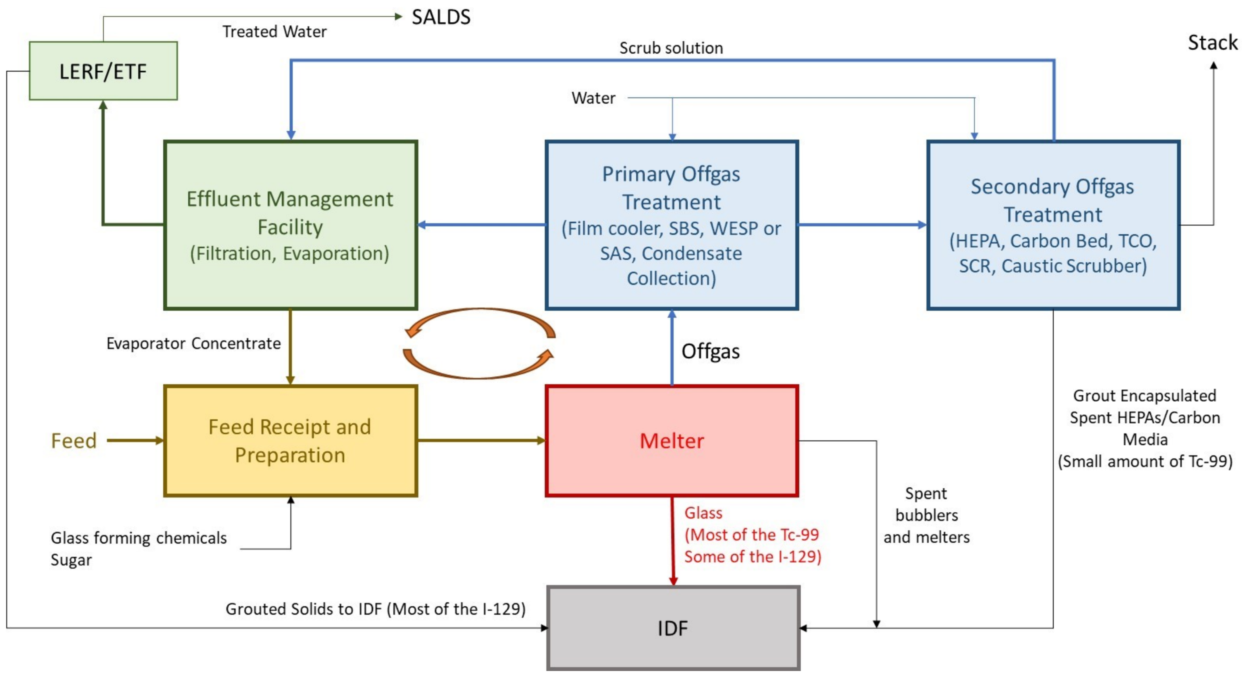

Figure X. Schematic Flow Diagram of Vitrification

The waste components are chemically bonded as part of the glass wasteform, the interaction of the waste components with the glass-forming chemicals defines the amount of waste that can be immobilized in glass. The concentration and interaction among these components define the glass properties, such as durability. For LAW and Supplemental LAW, the Glass Shell v3.0 (a collection of property models) is used to constrain the composition and loading of LAW glasses to control the sulfur tolerance of the melter feed to durability response, viscosity, and refractory corrosion. The models also consider component concentration limits for chromium, halides, and phosphate. The models use the chemical composition (measured) of the waste to be vitrified. Preliminary calculations use the concentrations of sodium, potassium, and sulfur, to develop a target glass composition. Then, using the property models and the twelve glass forming chemicals (GFCs) identified, the target glass composition is adjusted using the GFCs to maximize waste loading while meeting all the processing and performance constraints. The final properties and composition of the vitrified wasteform vary, but the models ensure that all the properties remain within acceptable processing and performance regions. The vitrified waste is poured using lifts into stainless steel containers. The canisters, filled to at least 90%, are cooled, sealed, and decontaminated, and are stored temporarily prior to IDF disposal.

The nitrate and nitrite salts in the LAW are converted to a mixture of nitrogen, ammonia, and NOx in the melter by reaction with sugar, also producing carbon dioxide and other gases. The melter is continuously bubbled by continuously forcing air through submerged pipes in the molten pool to increase the melt rate. The air and offgassed chemicals are processed through the primary and secondary offgas systems. The organic chemicals, including regulated organics, are largely destroyed by the high heat of the melter; although some other regulated organics are produced by the incomplete combustion of sugar in the melter. The sulfate in the waste has potential to form a separate phase in the melter, and has limited solubility in glass. Sulfate is normally the species that limits waste loading. Waste loading is typically 10-25 % (defined as waste sodium ion loading). The waste volume is reduced versus the aqueous waste, with the glass volume equivalent to ~40-50% of the liquid feed volume.

This alternative assumes a semi-continuous process, where a specific mass of each of the twelve dry-mix components, sugar, and a volume of liquid SLAW are blended and fed forward to a melter feed tank which is fed continuously into the melter. Molten glass is poured through a spout from the melter into the 564 gallon stainless steel container. When full, the pour stream is stopped. The filled container is moved, and the process repeats. The containers are decontaminated and sealed.

The feed rate, bubbling rate, and melter power are balanced in an attempt to maintain a cold cap on the melt pool, other than in the immediate vicinity of the 18 bubblers. The cold cap is produced by the melter feed slurry cooling the surface of the glass. Water and other volatile components (e.g. Hg) are boiled off from the cold cap. Reactions between the nitrate/nitrite and sugar generate CO, CO2, N2, N2O, NOx, ammonia as well as small amounts of organic products from incomplete combustion of the sugar also occur primarily in the cold cap. Cold cap reactions with nitrate/nitrite as well as reactions in the cold cap and plenum with oxygen result in destruction of most of the organics in the feed. Melter offgas condensate consists of components that are volatile and semi-volatile at melter temperatures. These species include Cl, F, I, Tc, Hg, As, S, and Se. In the absence of a cold cap or during operation with a reduced cold cap, these species vaporize more completely. These species are largely scrubbed out by the primary and secondary offgas processes.

All water fed to the system, and the water added during offgas treatment processes becomes liquid secondary waste. The liquid secondary waste generated during vitrification is collected and processed through the Effluent Management Facility (EMF). As generated, the primary waste condensate and scrubber stream is near neutral in pH. This is collected and processed using filtration and evaporation in the EMF. In EMF, the pH is raised to ~12, causing the ammonium in the waste stream to partition to the overheads as ammonia. The EMF evaporator bottoms are recycled to the melter for retreatment so that the radioactive and hazardous components, such as Tc-99, are forced into the glass at higher concentrations that a single pass system would achieve.

The EMF overhead condensate and secondary offgas system liquids are transferred to the Hanford Liquid Effluent Retention Facility/Effluent Treatment Facility (LERF/ETF) for collection and further treatment. The liquid secondary waste from the EMF evaporation process is expected to contain organics that require upgrades to the ETF treatment systems (in progress to treat condensate from the WTP-LAW facility) and the volume of waste generated could require additional upgrades or a new facility. The liquid secondary waste from the secondary offgas system will likely contain a large fraction of the I-129 in the SLAW waste feed and could require treatment prior to processing this effluent stream at LERF-ETF.

After treatment in ETF, the concentrated waste from ETF is primarily ammonium sulfate. The wasteform for the concentrated waste is currently under development, with the intent to grout the ETF concentrated waste and disposing it in the IDF. Treated water from ETF is disposed to a land disposal site (State Approved Land Disposal Site, SALDS).

Solid secondary waste from the vitrification facility (HEPA filters, carbon bed media, bubblers, etc.) will be placed in a container, encapsulated in grout, and disposed of in the IDF.

The technology parameters for the technology readiness for the Vitrification Alternative is estimated to be moderate for this type of waste stream. Additional research of formulations that have improved waste loading could further improve waste processing throughput.

Alternative: Steam Reforming Onsite (A) and Offsite (B) Disposal

NOTE: the description below was copied from SRNL-STI-2018-00687 with minor edits as a placeholder for more up-to-date input

STEAM REFORMING

Fluidized Bed Steam Reforming (FBSR) converts radioactive liquid waste to dry granular mineral particles with chemical structures that retain the radionuclides. FBSR has been researched, developed, and used commercially for over two decades for processing low level radioactive wastes. FBSR for supplemental treatment of Hanford Low Activity Waste is summarized below and detailed in Appendix TBD.

Fluidized Bed Steam Reforming Technology

FBSR is a high temperature process that operates at temperatures up to 725-750^{o} C to evaporate water in the waste, destroy organics, destroy nitrates, and convert the solid residue into a durable, leach-resistant wasteform. For the concept of treatment of Hanford SLAW, this process occurs in the Denitration and Mineralizing Reformer (DMR) vessel, which contains a bed of particles that are the right size and density to be continually fluidized by steam that flows upward through the bed. The steam is superheated to nominally 500-600^{o} C prior to entering the DMR. Coal and oxygen are fed into the DMR, where they react (also with steam) under stoichiometrically reducing (pyrolysis) conditions to heat the DMR to the target operating temperature and to produce hydrogen and other reduced gas species that react with the nitrates and nitrites in the waste feed, converting the nitrates and nitrites to nitrogen and water. Organics in the feed are efficiently pyrolyzed; nitrates in the feed are destroyed to below detectable levels in the mineralized wasteform; and about 95-99% of the gaseous nitrogen oxides (NOx) that are interim produced in the DMR are destroyed by subsequent reactions.

The remaining dissolved and undissolved components of the SLAW (such as sodium, aluminum, halogens, sulfur, hazardous metals, and radionuclides, if present) react with the clay that is premixed with the waste feed to form the desired mineralized waste form. This product includes highly durable mineral structures of nepheline, carnegieite, sodalite, or nosean. These structures can incorporate the nonvolatile and semi-volatile elements in the waste feed either into the nepheline or carnegieite mineral structures or inside sodalite or nosean "cages" of suitable sizes to contain halogens and radionuclides (Figure X).[3]

The relative proportions of these minerals in the waste form depend largely on the amounts of halides, sulfur, and radionuclides relative to the amounts of total sodium and potassium in the SLAW. Modeling calculations for representative SLAW compositions indicate that the mineral product can nominally contain mostly (60-80 weight per cent [wt%]) nepheline or carnegieite, 5-10 wt% sodalite, 6-12 wt% nosean, and 1-10 wt% silica (SiO2) and alumina (Al2O3). The relatively small amounts of the sodalite and nosean minerals compared to the larger amounts of nepheline and carnegieite minerals in the model result from the relatively small amounts of anions and radionuclides (ranging from about 3-14 mole% of the sodium) and the sulfur (ranging from about 0.4-1 mole% of the sodium) in the SLAW feed vector.

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[3] Jantzen, C.M., E.M. Pierce, C.J. Bannochie, P.R. Burket, A.D. Cozzi, C.L. Crawford, W.E. Daniel, K.M. Fox, SRNL, C.C. Herman, D.H. Miller, D.M. Missimer, C.A. Nash, M.F. Williams, C.F. Brown, N. P. Qafoku, J.J. Neeway, M.M. Valenta, G.A. Gill, D.J. Swanberg, R.A. Robbins, L.E. Thompson, 2015, "Fluidized Bed Steam Reformed Mineral Wasteform Performance Testing to Support Hanford Supplemental Low Activity Waste Immobilization Technology Selection," SRNL-STI-2011-00387.

FBSR Options for Treating Hanford SLAW

Two main FBSR cases were analyzed. Both produce a durable, mineralized primary waste form for storage and permanent disposal. The differences between the two options are the disposal sites—Integrated Disposal Facility (IDF) on the Hanford site (alternative "FBSR-A") and offsite (alternative "FBSR-B") —as well as the FBSR processing steps needed to meet the requirements of those disposal facilities.

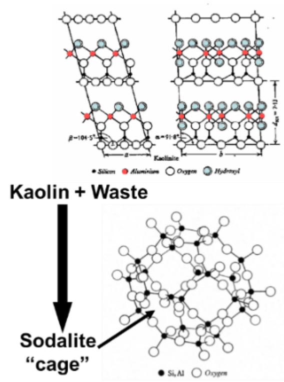

Figure X Sodalite "cage" contains halogens and radionuclides

In both FBSR cases, two process systems in parallel receive waste from a single feed system to provide the throughput and ability to vary the throughput needed to maintain the SLAW feed vector throughput. Case A (Figure Y) produces a monolithic primary waste form for storage and permanent disposal in the IDF on the Hanford site. Secondary wastes also are disposed of at IDF. A geopolymer process downstream of the FBSR converts the granular FBSR product to a monolith, which is needed to meet the expected IDF 500 pound per-square-inch compressive strength limit required for IDF disposal.

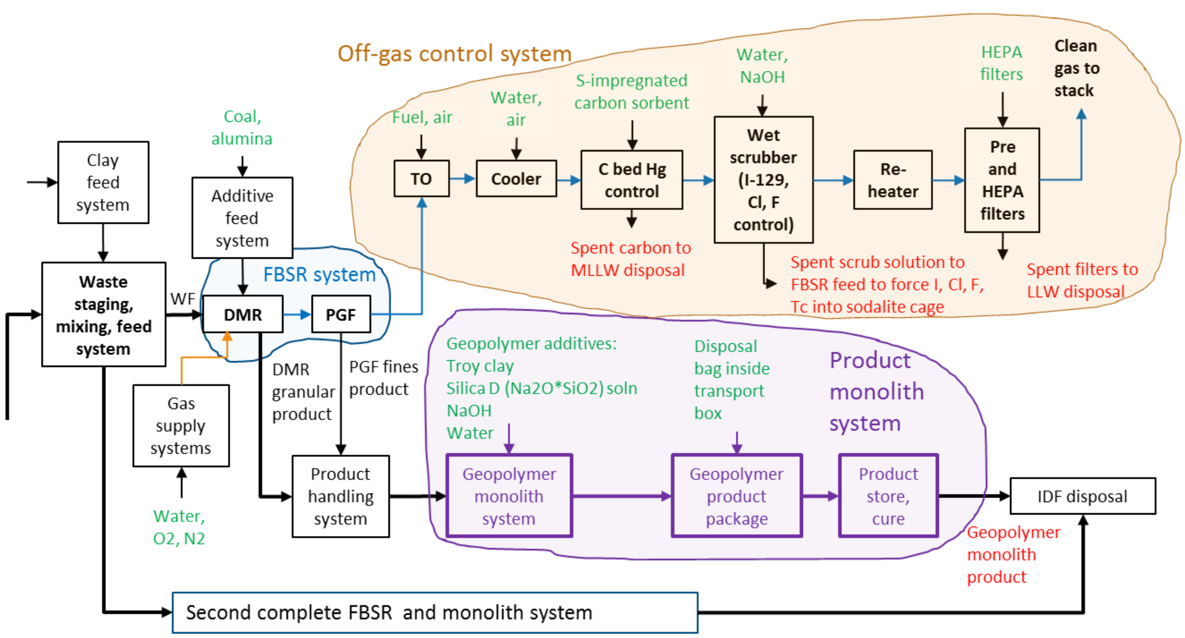

Figure Y FBSR Case A: Mineralized solid monolith product and secondary wastes disposed of at IDF

Case B (Figure Z) produces a solid granular primary waste form for storage and permanent disposal offsite. Secondary wastes also are assumed disposed offsite. Offsite disposal is assumed to not require a monolithic waste form, so the geopolymer monolith production system is eliminated, making the Case B FBSR process simpler. These two cases bound the potential disposal options considered in this alternative.

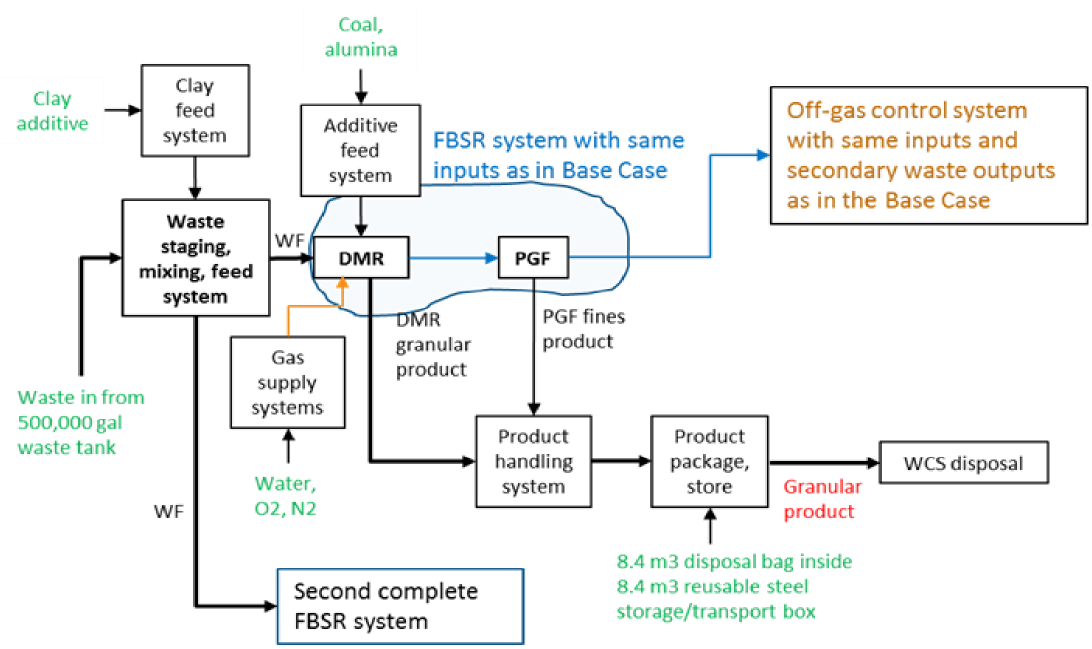

Figure Z FBSR Case B: Mineralized solid granular product and secondary wastes disposed of at WCS (WCS disposal is shown only as a placeholder offsite location)

In all steam reforming cases, the wet scrubber solution is entirely recycled back to the waste feed. This creates a "flywheel" of the more volatile isotopes such as Tc-99 and I-129; but the flywheel enables highly efficient capture of these isotopes in the mineralized product because the single pass capture of these isotopes is relatively high. Small fractions of these isotopes are captured in two secondary wastes—spent carbon (used for Hg control) and spent HEPA filters. The mass balance estimates and flywheel discussion are summarized in Appendix TBD. Since 100% of the spent scrub solution is recycled, there is no liquid secondary process waste from the offgas system.

Alternative: Grout 1; Single SLAW Grout Plant – On site Disposal

The grout immobilization Alternative #1 considered in this assessment is shown in Figure 1. Disposal of the grout is assumed to be in the Integrated Disposal Facility (IDF) in containers. This scenario is comparable to "Case 1" from the previous NDAA17 report [SRNL-RP-2018-00687].

In Alternative #1, the existing Double Shell Tank system is assumed to be utilized to blend and stage the feed, comparable to the plans for the Baseline case. To transport the liquid waste to the single large grout facility, a cross-site transfer line would be needed, and some remote tank farms may require transfer capabilities. The waste is assumed to be sampled in the DST and analyzed and found to be compliant with the pretreatment system such that it would produce an acceptable grout waste form, or it will be staged for vitrification.

The pretreated Supplemental Low Activity Waste (SLAW) would be transferred to the grout plant and accumulated in a 500,000-gallon tank for lag storage. The projected process flow rate for SLAW is eight gallons per minute, so the tank would accommodate about 40 days of lag storage.

This alternative assumes a semi-continuous batch process, where a specific mass of dry-mix feed and volume of liquid SLAW are blended as a single batch and poured into a container or containers. The filled containers are moved, and the process repeats. Between batches, the batch mixer would be cleaned with water, and any flush water is returned to a storage tank awaiting incorporation into the next batch.

The containers are assumed to be 8.4 m^3 steel frames, each with a heavy-duty polypropylene bag liner. The exact container size and bag type used in a final deployment may be somewhat different than assumed here, but assuming this size makes convenient comparisons to additional alternative scenarios. Minor variations in the container and liner would have minimal impact on the cost and schedule estimates developed here but will ultimately be consistent with the basis defined in the Performance Assessment.

After filling, the containers would be closed and the exterior decontaminated. The secondary waste generated by the decontamination process, and any contaminated hardware, would be transported and disposed in the IDF. The filled, closed containers would be staged prior to transport to IDF to allow time for curing. Once in IDF, the steel frame would be disassembled and returned to the grout plant for reuse, and the grout waste form would remain in the polypropylene liner and emplaced.

The technology parameters for the technology readiness for Alternative #1 is estimated to be high and could be deployed with existing technology, assuming the LDR-prohibited organics can be managed in compliance with the regulations. Additional research of formulations that have improved leachability versus previous grouts could further improve waste form performance.

Variants 1B and 1C

Removal of ^{129}I and/or ^{99}Tc are considered variant 1B, where all other flow-sheet assumptions are consistent with Alternative 1 (and would eliminate the need for getters). After TFPT and LDR treatment, iodine and technetium removal processes (described in section X.X) are used to remove these radionuclides prior to grouting and onsite disposal. Similarly, a "sample and send" approach is a variant for option 1C. In this variant, 1C, the waste is sampled and analyzed for ^{129}I and/or ^{99}Tc. After grouting the waste, grout containers with lower than a threshold concentration of these radionuclides would be disposed onsite, and those with higher than threshold concentration would be disposed offsite. The threshold limit has not yet been defined, but would be tied to the risk budget tool as related to the PA.

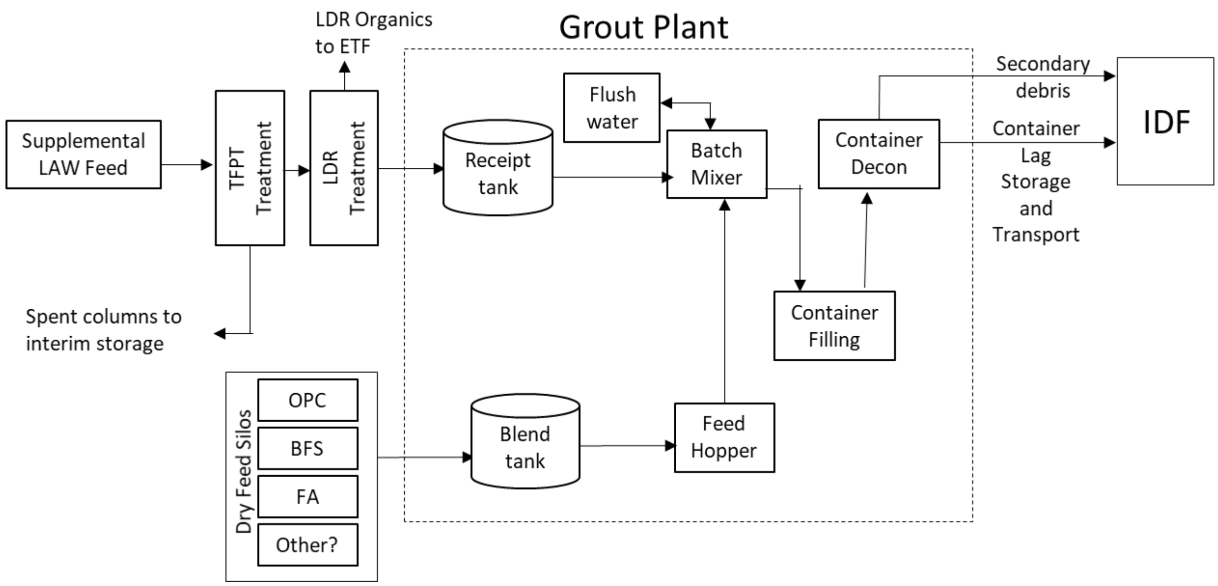

Figure 1. Schematic Flow Diagram of Alternative #1.

<u>Alternative: Grout 2; Single SLAW Grout Plant – Off site Disposal</u>

The grout immobilization Alternative #2 considered in this assessment is shown in Figure 2. Disposal of the grout is assumed to be in containers at an offsite facility. This scenario is comparable to "Case 2" from the previous NDAA17 report [SRNL-RP-2018-00687].

In Alternative #2, the existing Double Shell Tank system is assumed to be utilized to blend and stage the feed, comparable to the plans for the Baseline case. To transport the liquid waste to the single large grout facility, a cross-site transfer line would be needed, and some remote tank farms may require transfer capabilities. The waste is assumed to be sampled in the DST and analyzed and found to be compliant with the TFPT and LDR-removal systems such that it would produce an acceptable grout waste form or it will be staged for LAW vitrification.

The pretreated Supplemental Low Activity Waste (SLAW) would be transferred to the grout plant and accumulated in a 500,000-gallon tank for lag storage. The projected process flow rate for SLAW is eight gallons per minute, so the tank would accommodate about 40 days of lag storage.

This alternative assumes a semi-continuous batch process, where a specific mass of dry-mix feed and volume of liquid SLAW are blended as a single batch and poured into a container or containers. The filled containers are moved, and the process repeats. Between batches, the batch mixer would be cleaned with water, and any flush water is returned to a storage tank awaiting incorporation into the next batch.

The containers are assumed to be 8.4 m^3 steel frames, each with a heavy-duty polypropylene bag liner. The exact container size and bag type used in a final deployment may be somewhat different than assumed here, but assuming this size makes convenient comparisons to additional alternative scenarios. Minor variations in the container and liner would have minimal impact on the cost and schedule estimates.

After filling the containers would be closed and the exterior is decontaminated. The secondary waste generated by the decontamination process, and any contaminated hardware, would be transported and disposed in the IDF. The filled, closed containers would be staged prior to transport offsite to permit time for curing. Once in the offsite facility, the steel frame would be disassembled and returned to the grout plant for reuse, and the grout waste form would remain in the polypropylene liner and emplaced.

The technology parameters for the technology readiness for Alternative #2 is estimated to be high and could be deployed with existing technology, assuming the LDR-prohibited organics can be managed in compliance with the regulations.

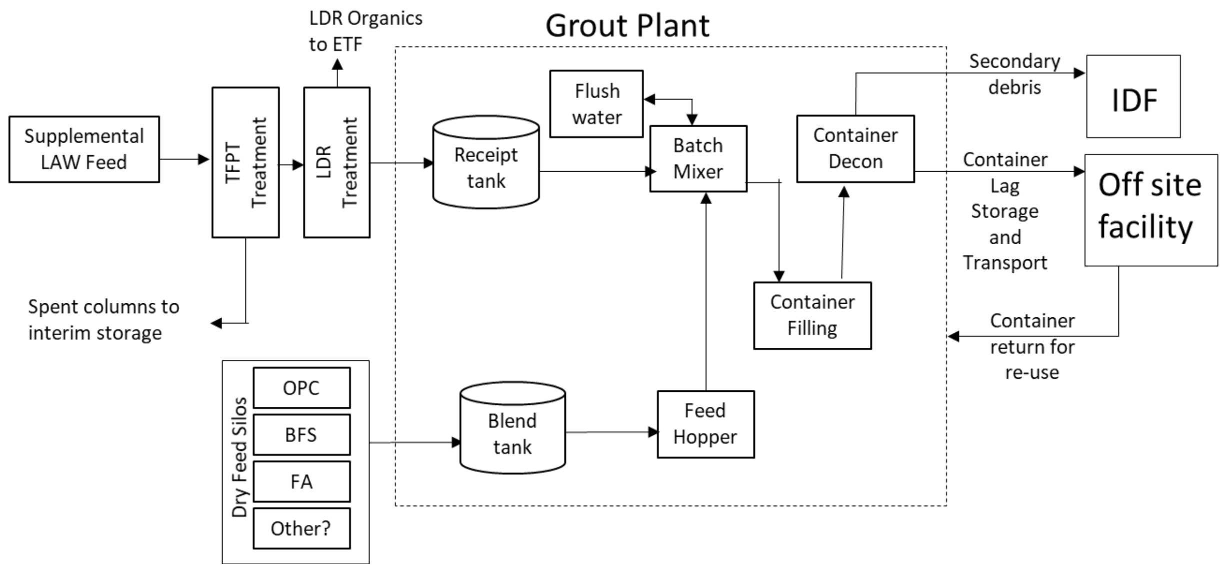

Figure 2. Schematic Flow Diagram of Alternative #2.

Alternative: Grout 3; Separate Grout Plants for East and West Areas

Alternative 3 considers two grouting plants, one each for the East and West areas, producing a containerized grout waste form. Its main intent is to reduce the cross-site transport of untreated waste, and as such it is intermediate between the single grouting plant alternatives (1 and 2) and the tank-by tank alternative (4).[4] The waste is assumed to be blended, staged, and sampled in the DST and analyzed and found to be compliant with the pretreatment system such that it would produce an acceptable grout waste form, or it will be staged for vitrification.

Alternative 3 is identical to other grout alternatives insofar as TFPT and LDR organic treatment operations are concerned and is essentially the same as Alternative 1 for all processing and container size parameters. The tank waste would still be pretreated through TFPT units and collected in a local tank to await grout processing. The pretreated SLAW would be transferred to the grout plant and accumulated in a lag storage tank. (In West area, a ~100,000 gallon lag storage tank is expected to be sufficient; in East area, a 500,000 gallon tank is assumed to accommodate surges in HLW effluent volumes) The containers are cured, decontaminated, and transported for disposal. Secondary waste disposal is the same as Alternative 1.

Alternative 3 evaporator and other operations may be somewhat different in that two smaller versions may be suitable for a two-plant scenario relative to a single large grout plant. Note that the East plant would have to be sized to handle SLAW from the HLW treatment at the WTP, while the West plant would likely be smaller and have a lower capacity requirement.[5] The condensate from West area would have to be transported to LERF/ETF by truck (where ETF is already equipped to receive waste by truck).

However, if some portion of the waste is resistant to the processes selected for LDR organic treatment [e.g., evaporator and low-temperature oxidation], it is assumed that it can be diverted to the LAW melter for processing. Presumably, this would be performed using the transfer lines used to transport supernatant to the East tank farm and the WTP.

Alternative 3 has the alternatives 3A and 3B, for disposal of the grout waste form onsite or offsite, respectively. It is assumed that the flowsheet schematics are the same as those shown in Alternatives 1 and 2 and as shown in Figure X.X and X.X for Alternatives 1 and 2; although with smaller equipment sizes. The slight difference in the shipping of the grouted SLAW containers from the West grouting plant to the IDF is insignificant. Note that these alternatives have the option of beginning treatment in the East or West areas, independent of the other.

<u>Variants 3C and 3D</u>

Removal of ^{129}I and/or ^{99}Tc is considered variant 3C, where all other flow-sheet assumptions are consistent with variant 3A (and would eliminate the need for getters). After TFPT and LDR treatment,

[4] To give a sense of scale, the "main" East (A and C) and West (S and U) clusters are separated from one another by about 6 miles; while the more "remote" East (B) and West (T) clusters are each about 1.3 miles from the main East and West clusters, respectively.

[5] Both grouting plants might even be relocatable. If relocatable, a single move of the West grouting plant, from the S farm to the T farm; and/or a single move of the East grouting plant from the A farm to the B farm, might be cost effective. If relocatable, a single move of the West grouting plant, from the S farm to the T farm; and/or a single move of the East grouting plant from the A farm to the B farm, might be cost effective.

iodine and technetium removal processes (described in section X.X) are used to remove these radionuclides prior to grouting and onsite disposal. Similarly, a “sample and send” approach is a variant for option 3A and 3B. In this variant, 3D, the waste is sampled and analyzed for ^{129}I and/or ^{99}Tc. Grout containers with lower than a threshold concentration of these radionuclides would be disposed onsite, and those with higher than threshold concentration would be disposed offsite. The threshold limit has not yet been defined, but would be tied to the risk budget tool as related to the PA.

Alternative: Grout 4; Individual Grout Plants for Each Tank Farm or Tank Farm Group

This Alternative utilizes mobile or multiple small batch TFPT, LDR treatment, and grout plants to treat supernate at each Tank Farm or Tank Farm grouping, disposing the immobilized waste either onsite (4A) or offsite (4B). This alternative does not require a cross-site transfer line for supernate that is compatible with grouting. The liquid is immobilized in mobile or multiple small batch grout plants and poured into containers. The containerized grouted waste could then be transported and disposed in the IDF (Alternative 4A) or sent to an offsite facility for disposal (Alternative 4B). If some portion of the waste is resistant to these treatments to remove the organics, it is assumed that it can be diverted to the LAW melter for processing.

Modular treatment units would be installed at the individual tank farms or tank farm groups. Waste is retrieved and fed directly to the pretreatment and grouting processes. The waste is assumed to be sampled in the tank and analyzed and found to be compliant with the pretreatment system such that it would produce an acceptable grout waste form or it will be staged for vitrification. The pretreated SLAW would be accumulated in an above-ground tank module on the order of 10,000 gallons for lag storage. The projected process flow rate for SLAW is eight gallons per minute, so the tank would accommodate about one day of lag storage. When the treatment of the targeted tanks has been completed, treatment modules could be redeployed to other Tank Farms or, where more economical, simply replaced, thus maximizing the investment made in the equipment.

This alternative assumes a semi-continuous batch process, where a specific mass of dry-mix feed and volume of liquid SLAW are blended as a single batch and poured into a container or containers. The filled containers are moved, and the process repeats. Between batches, the batch mixer would be cleaned with water, and any flush water is returned to a storage tank awaiting incorporation into the next batch.

The grout containers are assumed to be 8.4 m^3 steel frames, each with a heavy-duty polypropylene bag liner. The exact container size and bag type used in a final deployment may be somewhat different than assumed here, but assuming this size makes convenient comparisons to additional alternative scenarios. Minor variations in the container and liner would have minimal impact on the cost and schedule estimates.

After filling, the containers would be closed and the exterior is decontaminated. The secondary solid waste generated by the decontamination process, and any contaminated hardware, would be transported and disposed in the IDF. The filled, closed containers would be staged prior to transport to permit time for curing. Once in the disposal facility, the steel frame would be disassembled and returned to the grout plant for reuse, and the grout waste form would remain in the polypropylene liner and emplaced.

Technical maturity for the immobilization process is high and could be performed with existing technology. Portable grout plants have been deployed at SRS, though for use in facility stabilization and not immobilization of treated supernate. At least one mobile evaporator design has been fabricated and tested though has not been deployed in radioactive service, albeit not for technical reasons.

The process flowsheet is shown in Figure 3. Since treatment will be accomplished near the tanks, a cross-site transfer line for supernate is not necessary for waste that is compatible with the grouting process. All secondary waste generated by the immobilization process is assumed to be handled by the available site facilities such as ETF. Transportation to ETF will likely occur by truck. The ETF is already equipped with facilities to receive waste transported by truck. (note: receipt tank is smaller for this alternative vs. other alternatives)

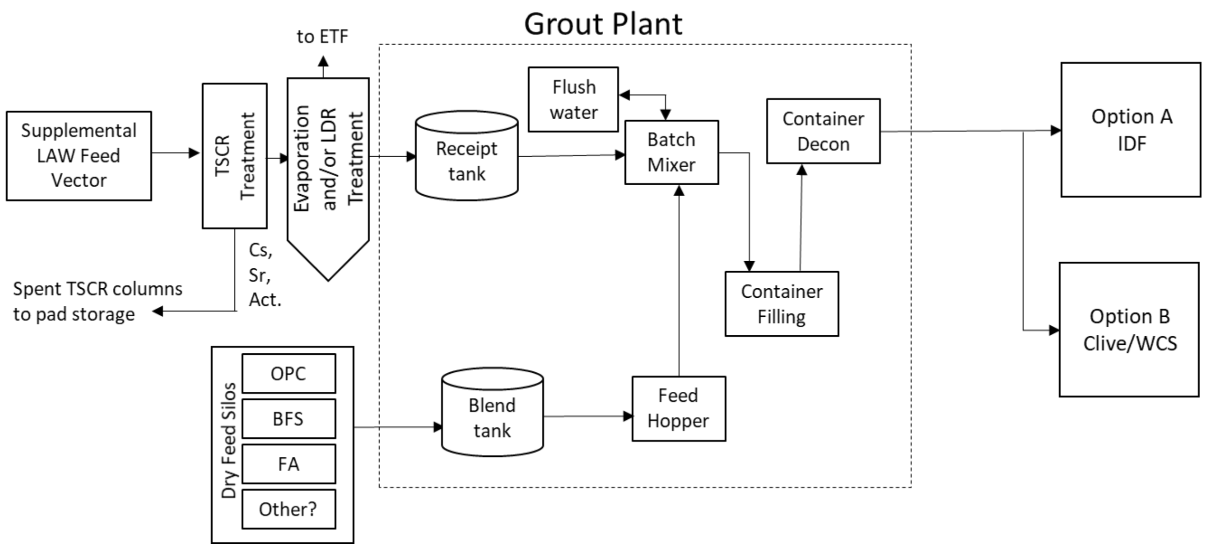

Figure 3. Schematic Flow Diagram for Alternative 4

Alternative 4A

Disposal of the grout is assumed to be in the Integrated Disposal Facility (IDF) in containers. This scenario is comparable to “Case 1” from the original FFRDC report. This option assumes that the grouted waste form will be packaged in a similar manner as option 1 (8.4 cubic meter polypropylene bags) and the grouting process will utilize the same formulations assumed in Alternative 1.

Alternative 4B

This option also assumes that the grouted waste form will be packaged in a similar manner as option 1 (8.4 cubic meter polypropylene bags) and the grouting process will utilize the same formulations assumed in Alternative 1. The grouted forms would be transported for disposal to an existing permitted offsite facility.

Alternative: Grout 5; Off-site Vendor for Grouting

This alternative utilizes an offsite vendor to immobilize the treated supernate. The grouted waste could then be sent to an offsite facility for disposal or returned to Hanford for disposal in the IDF. After removal of ^{137}Cs and ^{90}Sr in TFPT and LDR organic treatment, the treated supernate is shipped offsite in liquid form.[6] A variant is for the offsite vendor to treat LDR organics instead of treating onsite.

In Alternative #5, the existing Double Shell Tank system is assumed to be utilized to blend and stage the feed. A cross-site transfer line would not be needed. The waste is assumed to be sampled in the DST and analyzed and found to be compliant with the pretreatment system such that it would produce an acceptable grout waste form, or it will be staged for vitrification. This alternative could provide an early start and/or supplemental capacity for grout stabilization of the SLAW. An early start for SLAW treatment using this alternative, with eventual replacement/supplement with on-site grout facilities could potentially reduce overall mission costs and duration.

The process flowsheet is shown in Figure 4 (possible LDR treatment by the vendor is not shown). This alternative can be used for both a centralized facility that pretreats the supernate or for modular facilities at each tank farm, but it should be acknowledged that this option is more suited for at tank or at tank farm systems. A cross-site transfer line for supernate is not necessary assuming the pretreatment is not centralized. All secondary waste generated by the immobilization process is assumed to be handled by the offsite vendor and included in the contract for immobilization of the pretreated supernate. The pretreated Supplemental Low Activity Waste (SLAW) would be transferred to a small tank for lag storage. The projected process flow rate for SLAW is eight gallons per minute, so the tank would accommodate a to-be-determined days of lag storage.

This alternative assumes a semi-continuous batch process performed by the vendor, where a specific mass of dry-mix feed and volume of liquid SLAW are blended as a single batch and poured into a container or containers. The filled containers are moved, and the process repeats.

Consistent with the other alternatives for containerized grout, the containers are assumed to be 8.4 m^3 steel frames, each with a heavy-duty polypropylene bag liner. The exact container size and bag type used in a final deployment by the vendor may be somewhat different than assumed here, but assuming this size makes convenient comparisons to additional alternative scenarios. Minor variations in the container and liner would have minimal impact on the cost and schedule estimates developed here but will ultimately be consistent with the basis defined in the Performance Assessment for the onsite disposal alternative or WAC for offsite disposal.

Technical maturity for the immobilization process is high and could be performed with existing technology, assuming that the LDR organics can be removed by a separate process.

[6] the ability to ship pretreated liquid tank waste at a small scale was demonstrated during the Test Bed Initiative

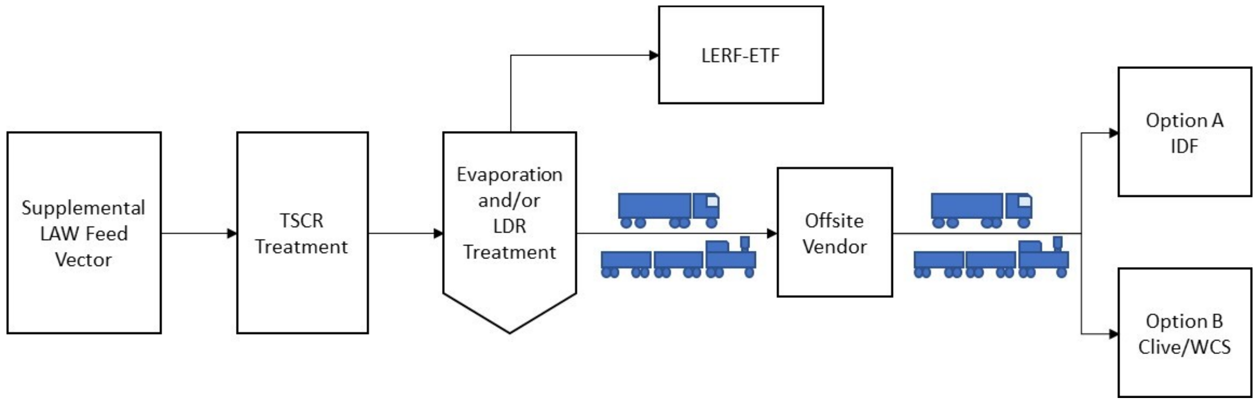

Figure 4. Schematic Flow Diagram for Alternative 5

Alternative 5A

This option postpones the cost of a grout plant (capitol, operating, and disposition); instead, a fee is paid per gallon for immobilization of the waste. If used to provide an early start, it delays the costs of an onsite grout plant which could be advantageous to avoid exceeding yearly spending limits. It is assumed that the grouted waste form will be packaged in a similar manner as option 1 (8.4 cubic meter polypropylene-lined containers) and the grouting process will utilize the same formulations assumed in Alternative 1. The immobilization fee is not expected to include shipping costs, the grouted waste form would be free-on-board at the immobilization facility.

Alternative 5B

This option postpones the cost of a grout plant (capitol, operating, and disposition); instead, a fee is paid per gallon for immobilization and disposal of the waste. If used to provide an early start, it delays the costs of an onsite grout plant which could be advantageous to avoid exceeding yearly spending limits. The shipping and disposal costs for the grouted waste form would likely be included in the treatment cost such that only one fee and contract needs to be awarded. It is noted that the treatment facility and the disposal site could be one entity.

Since the offsite contractor is handling both immobilization and disposal, the contractor would choose both the immobilization technique and the final packaging size and type.

Alternative: Grout 6; Onsite disposal improvement – large monolith and vault with engineered liners

The grout immobilization Alternative #6 considered in this assessment is outlined in Figure 5. Disposal of the grout is assumed to be in monoliths in large vaults analogous to the newest, mega-volume Saltstone Disposal Units (SDUs) at the Savannah River Site [SRR].[7] This scenario would reduce the interaction of the grouted waste form with the surrounding environment because of its large size and engineered controls and, thereby, reduce the potential for leaching, release, and transport of constituents of concern to the environment.

In Alternative #6, the existing Double Shell Tank system would be used to blend and stage the supernatant and would be followed by TFPT and LDR organic treatment; however, this alternative could support on-site disposal for any of the previous five alternatives (see above). For example, if large vaults were only to be constructed in 200-East Area (where both the WTP and IDF are located), then a cross-site supernatant transfer line and transfer capabilities for the remote tank farms would be required. Thus, if one or more large vaults were constructed in both 200-East and 200-West Areas; this scenario would not require a cross-site supernatant transfer line but would require grout plants in both 200-East and 200-West Areas.[8]

The waste is assumed to be sampled in the DST and analyzed and when found to be compliant with the pretreatment system such that it would produce an acceptable grout waste form, the waste would be pretreated via TFPT to remove ^{137}Cs (with ^{90}Sr and some actinides also removed), evaporated, and any fraction requiring additional treatment for LDR organics would be treated.[9] The resulting pretreated Supplemental Low Activity Waste (SLAW) would be transferred to the grout plant. If a large grout facility (like the SPF) is constructed to support the large vault, then the treated waste would be accumulated in a tank up to 500,000-gallons for lag storage (see Alternative #1).[10] The projected process flow rate is eight gallons per minute (see Alternative #1), so a 500,000-gallon tank (for the large grout facility) would accommodate approximately 40 days of lag storage.

This alternative assumes a semi-continuous batch grout process, where the liquid SLAW is mixed with cementitious materials (e.g., cement, fly ash, and slag) and then pumped (preferably in lifts) to the large, SDU-like vault where the grout solidifies into a monolithic, solid low-level waste form. Between batches, the batch mixer would be cleaned with water, and any flush water returned to a storage tank awaiting incorporation into the next batch.

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[7] Construction of the first mega-volume SDU 6 at the Savannah River Site was completed in May 2017 and began receiving waste in August 2018. SDUs 7 through 12 have been approved with two under construction.

[8] An additional consideration for this option entails whether a large vault necessarily requires a large grout facility (e.g., the Salt Processing Facility | SPF at the Savannah River [Lorier and Langton, 2019, SRNL-STI-2019-00009]) or could smaller (and perhaps also mobile) grout facilities provide sufficient process capacity (with projected process flow rate of eight gallons per minute) needed to efficiently and effectively fill a large vault. This consideration is not included as a formal option in this alternative; it would be a possible consideration for the waste form team.

[9] There should be a provision that if after cesium removal, evaporation, and LDR organic treatment the sampled waste does not satisfy LDR that the waste be ultimately transferred (in a method to be determined) to the LAW vitrification facility for immobilization.

[10] Alternatively, a relocatable (and perhaps mobile) grout facility (please see Alternative #4) would require different lag storage requirements (at a volume or volumes and configuration to be determined).

The large SDU-like vault (assumed constructed of concrete using a water tank design like for the newest SDUs at SR) is assumed to be 375 feet in diameter, 43 feet high, and can hold approximately 33 million gallons (125,000 m^3) of grout.[11] The concrete floor of the vault sits atop a multilayer foundation, including a specially engineered geosynthetic clay liner and a high-density plastic liner (similar to that used in commercial landfill applications) sandwiched between two concrete layers called "mud mats." The mud mats serve as the foundation for the concrete structural base slab and to protect the leakage detection system. In this alternative, the vault and engineered liners work together to further limit release and environmental migration of contaminants. Additional defense-in-depth measures (both internal and external[12]) could be added as needed to ensure meeting the criteria in the Performance Assessment. These defense-in-depth measures are not formally evaluated as alternatives or options in the decision framework.

The secondary waste generated by the decontamination process, and any contaminated hardware, would be transported to and disposed of in the IDF.

The technology readiness for Alternative #6 is estimated to be high and could be deployed with existing technology.

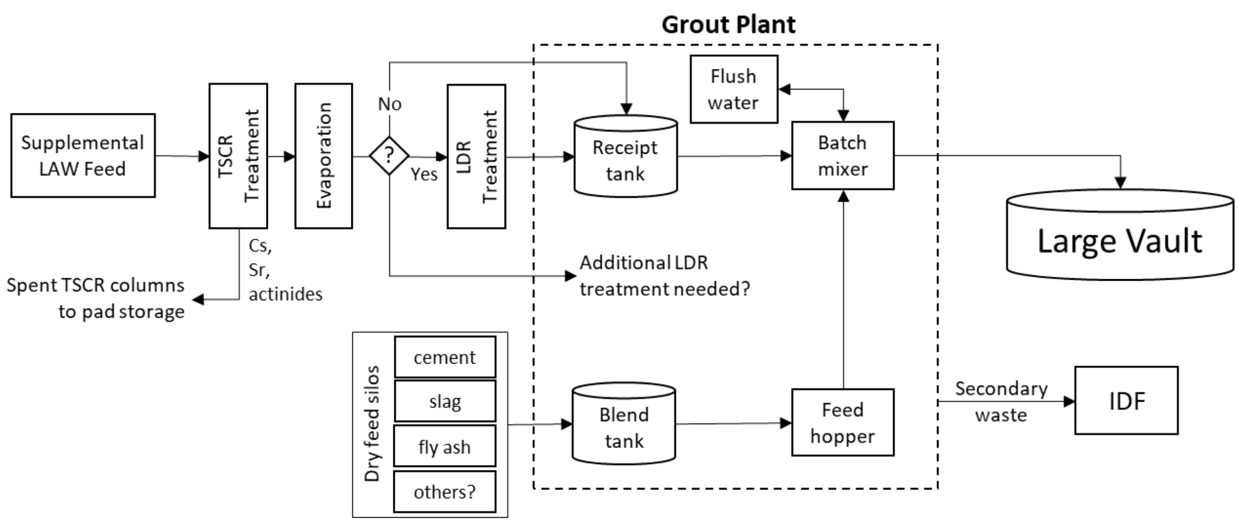

Figure 5. Schematic Flow Diagram of Alternative #6

[11] These are the dimensions of the SDU 6 and later large (or mega) water tank design saltstone vaults at Savannah River [SRR].

[12] In addition to using a large monolith (low surface area to volume ratio) to reduce potential interaction of the bulk of the grouted waste form with the surrounding environment, other types of coatings, liners, and grout applications may reduce impacts even further. For example, a coating was applied to SDU 6 at SR to provide sufficient water tightness. Furthermore, the application of clean, reducing grout layers (acting as diffusion barriers and additional reductive capacity) could significantly improve overall vault system performance. Additional research of grout formulations that have improved leachability versus previous grouts could further improve waste form performance. Options external to the vault itself include getters in the backfill material and closure cap or engineered covers.

References

SRR "Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site," SRR-CWDA-2019-00001, Rev. 0, 2019.

Alternative Vitrification 1: Single SLAW Vitrification Plant – On site Disposal

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	No
2	Expected pretreatment system	None
3	Immobilization process Feed system	Blend 12 glass former chemicals and sugar with waste
4	Immobilization system	Joule-Heater Slurry Fed melter
5	Auxiliary systems for immobilization	Air for Bubblers and pressure control; Cooling water for melter electrodes and melter components; Temperature monitoring for melter components, power supplies for electrodes, feed compositional control modules, air lift system for pouring
6	Immobilization temperature	1150° Celsius
7	Gasses emitted by immobilization process	Gas species that are volatized from the feed or produced during vitrification[13] including steam, NO_x, N_2, CO, CO_2, NH_3, H_2, and incompletely oxidized organic compounds (such as acetonitrile[14]), other acid gases (including chlorides, fluorides, and SO_x), and higher volatility elements including Hg, Tc-99, I-129, and Cs-137 that are not efficiently captured in a single pass in the melter. The melter offgas also contains entrained particulate matter and small amounts of Cr, B, and Na ions.
8	Offgas system	Film Cooler, Submerged Bed Scrubber, Steam Atomized Scrubber, Heater, HEPA, Activated Carbon Bed, Heat Exchanger, Thermal Oxidizer, Selective Catalytic Reducer, Caustic Scrubber, Blower, Stack (Effluent Management Facility to filter, evaporate, and recycle condensate)
9	Offgas or effluent liquid handling tanks	Hold Tank Caustic Adjustment Tank Evaporator Concentrate Hold Tank Evaporator Condensate Hold Tank Bypass Line to Tank Farm with Inhibitor Addition Systems
10	Secondary liquid waste	Primary offgas liquids are filtered evaporated in a new facility (EMF) and recirculated to the melter to improve retention of Tc in glass; secondary offgas system liquids (caustic scrubber) are sent to ETF along with EMF primary offgas liquid evaporator condensate; after ETF treatment, they are disposed in grout waste form in IDF; Total liquid secondary waste ~3X feed volume (reference needed) Expansion of LERF/ETF required for this alternative.

[13] Many species are appreciable volatile at the high temperatures of a vitrification process; not all are listed here for simplicity.

[14] Acetonitrile is thought to be a product of incomplete sugar combustion and has been noted in condensate from pilot scale melter tests conducted at the Vitreous State Laboratory. The acetonitrile levels noted are above the concentrations that the Hanford ETF can treat.

11	Secondary solid waste	Rad-con control waste, Failed equipment, Spent bubblers[15], Spent melters[16], Spent carbon absorbent, Spent HEPA filters, Solids from liquid secondary waste, all disposed in IDF
12	Assumed Primary waste disposal site	Containers to IDF
13	Projected primary waste volume	~0.4X feed volume
14	Primary waste form packaging	Molten glass poured into stainless steel containers and cooled to harden
15	Primary waste form interim handling	Inert Fill System, Capping Station, Container Decontamination and swabbing, Buffer Storage
16	Tc-99 assumed on HEPA filters[17]	8 Ci
17	I-129 assumed on Carbon Bed	3 Ci[18]
18	Impact of cold shut down	Feed line flush; allow melter to cool; replace and discard melter. Restart new melter.
19	Impact of idling	Semi-volatiles lost (Sulfur, halides, I-129, Tc-99, Cs-137, Hg), Increased loading on HEPA filters; lower glass waste loading during turn down and upon resumption
20	Impact of feed turn down	Increased loss of semi-volatiles if cold cap coverage cannot be maintained; increased loading of challenging species in Recycle stream and possibly on HEPA filters; lower waste loading
21	Immobilization unit operation vessel size	31' x 22' x 16' per melter (melt pool: 16' x 6.8' x 2.5'); 2 melters for WTP-LAW; TBD number for SLAW
22	24-hour ops req'd to meet rate or prevent adverse impacts?	yes
23	Single pass retention of Tc-99/I-129	40/10
24	Waste form density	2800 kg/m^3
25	Iodine control	Iodine vaporizes in melter; likely captured in secondary offgas system (caustic scrubber solution sent to LERF-ETF); immobilized as secondary waste in IDF; high partitioning uncertainty. NOTE: WTP-LAW will likely have a process added to remove iodine from caustic scrubber solution prior to transfer to LERF-ETF to prevent hazards category change for ETF.

[15] Spent bubblers are captured separately from other failed equipment as the design life is very short (6 months) required replacement of large numbers of bubblers during SLAW operation. In addition, these bubblers may require a platinum coating to achieve the specified design life. A loss of air would result in bubbler failure and required changeout of all bubblers in a melter

[16] Design life of a melter is five years, much shorter than the mission duration.

[17] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

[18] Removal of iodine by the activated carbon bed is currently under review and will likely differ from the assumptions made during the IDF PA. The evaluations of waste form performance made during this study utilized the same methods in the PA as the review of iodine removal in the LAW melter offgas is not complete.

26	Tc control	Most Tc vaporizes from melter but is eventually retained by recycling; most Tc is disposed in glass waste form; some Tc will be immobilized as secondary waste from offgas streams/equipment
27	Se-79 control	Se-79 sequestered in primary waste form; 2% disposed as secondary waste from ETF solids per IDF PA
28	LDR organics control	LDR organics in tank waste are largely destroyed in melter; melter produces other LDR organics; some secondary LDR organics are partitioned to the offgas condensate where they will be treated in ETF; TCO unit in melter offgas destroys organics that remain in melter offgas after scrubbers
29	Nitrate/nitrite control	Nitrate/nitrite are destroyed in the melter; offgas contains NOx, which is destroyed in catalytic reducer by reaction with ammonia; any remaining is capture in caustic scrubber.
30	RCRA metal control	Hg vaporizes and sorbs into scrubber streams and GAC bed; other RCRA metals are mostly incorporated into glass
31	Ammonia control	Melter evaporates ammonia in waste and produces additional ammonia from reactions of sugar with nitrate/nitrite, which is partially scrubbed in the offgas scrubbers and then evaporates in the EMF, where it is sent to ETF for incorporation into a grout waste form using a new process specific for ammonia immobilization; ammonia is also introduced into the secondary melter offgas system to destroy NOx, where some is lost to the stack.
32	Viscosity/pumping	Rheology of LAW mixed with glass formers in the melter feed tanks is controlled as needed by water additions, Viscosity of glass controlled by GFC formulation
33	Potential new tank leaks	Baseline schedule
34	Long term immobilization	Primary glass waste form is in compliance with DOE requirements based on PA calculations; secondary wastes contain small amounts of radionuclides; Some Tc is in secondary offgas equipment (e.g. HEPA filters) is grouted and disposed in IDF. I is only partially retained in glass and partially in equipment and secondary wastes grouted and disposed in IDF
35	Technology Risks; executability/maturity	Vitrification of radioactive tank waste salt solution is first-of-a-kind. Simulant testing has been performed for many years, but an integrated melter system with all off-gas system components has not been tested at any scale with simulants or radioactive materials. Prior to SLAW, the initial WTP-LAW is expected to be commissioned and begin processing LAW. Operation of that facility will aid in design and operation of a vitrification option for SLAW.
36	Process Complexity	The melter system incorporates multiple integrated unit operations, including glass former blending, pumping, melting, bubbling (in melt pool), offgas scrubbing, offgas filtration, offgas sorption, offgas catalytic reactions, and container decontamination. Radioactive and non-radioactive species removed by scrubbing are processed and returned to the melter in a recycle loop. Secondary wastes are handled in multiple locations. Once melter is started, the melter and offgas system must remain in continuous operation until melter is retired.
37	Required facilities/Infrastructure	TFPT system; Large vitrification and offgas facility, offgas scrubber filter and evaporator (EMF), and upgrades to ETF. In addition, large

		amounts of steam, cooling water, electricity, compressed air, and 24/7 laboratory support for samples.
38	Cross site transfer line needed?	Required; baseline
39	Utilize existing DSTs?	Existing DSTs used; baseline plan
40	B & T farm WRFs?	Required
41	Treated LAW Staging tank	DST in AP farm assumed as staging tank (continues use of AP-106 from DFLAW processing)
42	Effectiveness/robustness	Twelve glass formers and sugar are added to the waste in varying amounts, depending on waste composition, to optimize waste loading and destroy nitrate/nitrite and prevent sulfur layer formation in melter. Resulting glass is environmentally robust. Offgas system consists of multiple unit operations that must work in a continuous and integrated system. Vitrification has limited ability to handle feed volume turn-downs and hot idling can lead to increased partitioning of species to the secondary waste streams. Restarting a melter after a cold shutdown is not practical.
43	Adaptability/flexibility	Formulation of glass former additives can be tailored to the waste chemistry; process operability challenging (production resumption challenging to perform after outages; melter remains molten; offgas system must remain operational continuously); Complex, integrated, one-of-a-kind melter and offgas system, turn-down capability is limited.
44	Number and Levels of Safety Control Mitigation	38 high consequence hazards for workers are identified for WTP-LAW operations.
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	Baseline

<u>Alternative Steam Reforming Onsite: Single FBSR Plant – On site Disposal</u>

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	
2	Expected pretreatment system	
3	Immobilization process Feed system	
4	Immobilization system	
5	Auxiliary systems for immobilization	
6	Immobilization temperature	

7	Gasses emitted by immobilization process	
8	Offgas system	
9	Offgas or effluent liquid handling tanks	
10	Secondary liquid waste	
11	Secondary solid waste	
12	Assumed Primary waste disposal site	
13	Projected primary waste volume	
14	Primary waste form packaging	
15	Primary waste form interim handling	
16	Tc-99 assumed on HEPA filters	
17	I-129 assumed on Carbon Bed	
18	Impact of cold shut down	
19	Impact of idling	
20	Impact of feed turn down	
21	Immobilization unit operation vessel size	
22	24-hour ops req'd to meet rate or prevent adverse impacts?	
23	Single pass retention of Tc-99/I-129	
24	Waste form density	
25	Iodine control	
26	Tc control	
27	Se-79 control	
28	LDR organics control	
29	Nitrate/nitrite control	
30	RCRA metal control	
31	Ammonia control	
32	Viscosity/pumping	
33	Potential new tank leaks	
34	Long term immobilization	
35	Technology Risks; executability/maturity	
36	Process Complexity	
37	Required facilities/infrastructure	
38	Cross site transfer line needed?	

39	Utilize existing DSTs?	
40	B & T farm WRFs?	
41	Treated LAW Staging tank	
42	Effectiveness/robustness	
43	Adaptability/flexibility	
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	
46	Compatibility with HLW	
47	Compliance	

Alternative Steam Reforming Offsite: Single FBSR Plant – Off site Disposal

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	
2	Expected pretreatment system	
3	Immobilization process Feed system	
4	Immobilization system	
5	Auxiliary systems for immobilization	
6	Immobilization temperature	
7	Gasses emitted by immobilization process	
8	Offgas system	
9	Offgas or effluent liquid handling tanks	
10	Secondary liquid waste	
11	Secondary solid waste	
12	Assumed Primary waste disposal site	
13	Projected primary waste volume	
14	Primary waste form packaging	
15	Primary waste form interim handling	
16	Tc-99 assumed on HEPA filters	
17	I-129 assumed on Carbon Bed	
18	Impact of cold shut down	
19	Impact of idling	
20	Impact of feed turn down	
21	Immobilization unit operation vessel size	
22	24-hour ops req'd to meet rate or prevent adverse impacts?	
23	Single pass retention of Tc-99/I-129	
24	Waste form density	
25	Iodine control	
26	Tc control	
27	Se-79 control	

28	LDR organics control	
29	Nitrate/nitrite control	
30	RCRA metal control	
31	Ammonia control	
32	Viscosity/pumping	
33	Potential new tank leaks	
34	Long term immobilization	
35	Technology Risks; executability/maturity	
36	Process Complexity	
37	Required facilities/infrastructure	
38	Cross site transfer line needed?	
39	Utilize existing DSTs?	
40	B & T farm WRFs?	
41	Treated LAW Staging tank	
42	Effectiveness/robustness	
43	Adaptability/flexibility	
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	
46	Compatibility with HLW	
47	Compliance	
48	Stakeholder acceptability	

Alternative Grout 1: Single SLAW Grout Plant – On site Disposal

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics removal/destruction
2	Expected pretreatment system	evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[19]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of feed volume collected as condensate from LDR organic removal evaporation is sent to ETF. Condensate would be similar to 242-A evaporator condensate already treated by ETF.
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	Containers to IDF
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	Liquid feed with grout formers poured into polybag lined container
15	Primary waste form interim handling	Decontaminate; interim store for curing
16	Tc-99 assumed on HEPA filters[20]	0.8 Ci

[19] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.

[20] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[21]	0.03 Ci
18	Impact of cold shut down	System flush/pig on shut down; process resumption is ~immediate
19	Impact of idling	None
20	Impact of feed turn down	Slower operation; limited impact
21	Immobilization unit operation vessel size	18' x 4' x 4' grout mixer[22]
22	24-hour ops req'd to meet rate or prevent adverse impacts?	No
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary; non-compatible tanks diverted to Vitrification
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity and IDF cap performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Minimal impact; Containerized grout does not require pumping grout mixture over long distances during production
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements based on PA calculations; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed

[21] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

[22] Grout mixer is identical to NDAA17 report and is based on size of a 10" Readco mixer, similar to the grout mixer used at the SRS Saltstone facility. Saltstone can process waste at 85 GPM, ~10X the maximum rate estimated for SLAW.

36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility; waste form interim storage/curing facility
38	Cross site transfer line needed?	Required; comparable to baseline
39	Utilize existing DSTs?	Existing DSTs used similar to baseline plan
40	B & T farm WRFs?	Required
41	Treated LAW Staging tank	DST in AP farm assumed as staging tank (continues use of AP-106 from DFLAW processing)
42	Effectiveness/robustness	The grout process is generally robust to changes in the waste feed composition and volume. The ability to shut down and restart allows the facility to handle low volume periods without impacting performance.
43	Adaptability/flexibility	Formulation of grout former additives can be tailored to the waste chemistry; process operability highly flexible (production resumption readily performed after outages); Simple commercial equipment
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	Grout disposal in the IDF is not compliant with the current IDF permit. Modifications to the IDF permit must be approved prior to disposal of grouted waste in IDF.

Alternative Grout 2: Single SLAW Grout Plant – Off site Disposal

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics removal/destruction
2	Expected pretreatment system	evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[23]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of waste volume collected as condensate from LDR organic removal evaporation is sent to ETF. Condensate would be similar to 242-A evaporator condensate already treated by ETF.
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	Containers to offsite
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	Liquid feed with grout formers poured into polybag lined container
15	Primary waste form interim handling	Decontaminate; interim store for curing
16	Tc-99 assumed on HEPA filters[24]	0.8 Ci

[23] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.
[24] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[25]	0.03 Ci
18	Impact of cold shut down	System flush/pig on shut down; process resumption is ~immediate
19	Impact of idling	None
20	Impact of feed turn down	Slower operation; limited impact
21	Immobilization unit operation vessel size	18' x 4' x 4' grout mixer[26]
22	24-hour ops req'd to meet rate or prevent adverse impacts?	No
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary; non-compatible tanks diverted to Vitrification
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity and disposal site performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Minimal impact; Containerized grout does not require pumping grout mixture over long distances during production
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed

[25] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

[26] Grout mixer is identical to NDAA17 report and is based on size of a 10" Readco mixer, similar to the grout mixer used at the SRS Saltstone facility. Saltstone can process waste at 85 GPM, ~10X the maximum rate estimated for SLAW.

36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility; waste form interim storage/curing facility
38	Cross site transfer line needed?	Required; comparable to baseline
39	Utilize existing DSTs?	Existing DSTs used similar to baseline plan
40	B & T farm WRFs?	Required
41	Treated LAW Staging tank	DST in AP farm assumed as staging tank (continues use of AP-106 from DFLAW processing)
42	Effectiveness/robustness	The grout process is generally robust to changes in the waste feed composition and volume. The ability to shut down and restart allows the facility to handle low volume periods without impacting performance.
43	Adaptability/flexibility	Formulation of grout former additives can be tailored to the waste chemistry; process operability highly flexible (production resumption readily performed after outages); Simple commercial equipment
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	Grout disposal offsite will be in compliance with the disposal facility permit. Modifications to the permit, if needed, must be approved prior to disposal of grouted waste in the facility.

Alternative Grout 3. Separate Grout Plants for East and West Areas

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics removal/destruction
2	Expected pretreatment system	evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[27]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of waste volume collected as condensate from LDR organic removal evaporation is sent to ETF. Condensate would be similar to 242-A evaporator condensate already treated by ETF.
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	3A: Containers to IDF; 3B: Containers to offsite
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	Liquid feed with grout formers poured into polybag lined container
15	Primary waste form interim handling	Decontaminate; interim store for curing
16	Tc-99 assumed on HEPA filters[28]	0.8 Ci

[27] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.

[28] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[29]	0.03 Ci
18	Impact of cold shut down	System flush/pig on shut down; process resumption is ~immediate
19	Impact of idling	None
20	Impact of feed turn down	Slower operation; limited impact
21	Immobilization unit operation vessel size	18’ x 4’ x 4’ grout mixer[30]
22	24-hour ops req’d to meet rate or prevent adverse impacts?	No
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary; non-compatible tanks diverted to Vitrification
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity and IDF cap performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Minimal impact; Containerized grout does not require pumping grout mixture over long distances during production
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements based on PA calculations; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed

[29] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

[30] Grout mixer is identical to NDAA17 report and is based on size of a 10” Readco mixer, similar to the grout mixer used at the SRS Saltstone facility. Saltstone can process waste at 85 GPM, ~10X the maximum rate estimated for SLAW.

36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility; waste form interim storage/curing facility
38	Cross site transfer line needed?	Not required
39	Utilize existing DSTs?	Existing DSTs used; West area SY tank would be selected for staging untreated waste
40	B & T farm WRFs?	Required
41	Treated LAW Staging tank	East Area: DST in AP farm assumed as staging tank (continues use of AP-106 from DFLAW processing); West Area: Staging tank needed
42	Effectiveness/robustness	The grout process is generally robust to changes in the waste feed composition and volume. The ability to shut down and restart allows the facility to handle low volume periods without impacting performance.
43	Adaptability/flexibility	Formulation of grout former additives can be tailored to the waste chemistry; process operability highly flexible (production resumption readily performed after outages); Simple commercial equipment
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	3A: Grout disposal in the IDF is not compliant with the current IDF permit. Modifications to the IDF permit must be approved prior to disposal of grouted waste in IDF. 3B: Grout disposal offsite would be in compliance with permits (after modification, if required)

Alternative Grout 4. Individual Grout Plants for Each Tank Farm or Tank Farm Group

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics removal/destruction
2	Expected pretreatment system	evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[31]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of waste volume collected as condensate from LDR organic removal evaporation is sent to ETF. Condensate would be similar to 242-A evaporator condensate already treated by ETF.
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	4A: Containers to IDF; 4B: Containers to offsite disposal
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	Liquid feed with grout formers poured into polybag lined container
15	Primary waste form interim handling	Decontaminate; interim store for curing
16	Tc-99 assumed on HEPA filters[32]	0.8 Ci

[31] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.

[32] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[33]	0.03 Ci
18	Impact of cold shut down	System flush/pig on shut down; process resumption is ~immediate
19	Impact of idling	None
20	Impact of feed turn down	Slower operation; limited impact
21	Immobilization unit operation vessel size	18’ x 4’ x 4’ grout mixer[34]
22	24-hour ops req’d to meet rate or prevent adverse impacts?	No
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary; non-compatible tanks diverted to Vitrification
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity and IDF cap performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Minimal impact; Containerized grout does not require pumping grout mixture over long distances during production
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed

[33] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

[34] Grout mixer is identical to NDAA17 report and is based on size of a 10” Readco mixer, similar to the grout mixer used at the SRS Saltstone facility. Saltstone can process waste at 85 GPM, ~10X the maximum rate estimated for SLAW. Modular facilities could use a smaller mixer, but this size retained for this review.

36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility; waste form interim storage/curing facility
38	Cross site transfer line needed?	Not required for compatible LAW processing
39	Utilize existing DSTs?	Not required; waste retrieved, treated, and immobilized from each tank; staging tank(s) for untreated waste will be needed. DSTs would be used where applicable/practical
40	B & T farm WRFs?	No
41	Treated LAW Staging tank	Yes
42	Effectiveness/robustness	The grout process is generally robust to changes in the waste feed composition and volume. The ability to shut down and restart allows the facility to handle low volume periods without impacting performance.
43	Adaptability/flexibility	Formulation of grout former additives can be tailored to the waste chemistry; process operability highly flexible (production resumption readily performed after outages); Simple commercial equipment
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	4A: Grout disposal in the IDF is not compliant with the current IDF permit. Modifications to the IDF permit must be developed and approved prior to disposal of grouted waste in IDF. 4B: Grout disposal offsite would be performed in compliance with permits (after modification, if required)

Alternative Grout 5. Off-site Vendor for Grouting

This option assumes grouting is performed by a vendor using a similar grouting process that would be used for an on-site grout facility. However, the vendor may determine a different method depending on waste class and disposal site, therefore actual equipment and methods could differ. In addition, it is expected that the vendor will handle all secondary and job control wastes.

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics; could be performed by vendor and included in contract price.
2	Expected pretreatment system	Evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[35]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of waste volume collected as condensate from LDR organic removal evaporation is sent to ETF
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	5A: Containers to IDF; 5B: Containers to offsite disposal
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	TBD by vendor.
15	Primary waste form interim handling	N/A
16	Tc-99 assumed on HEPA filters[36]	0.8 Ci

[35] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.

[36] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[37]	0.03 Ci
18	Impact of cold shut down	None
19	Impact of idling	None
20	Impact of feed turn down	N/A
21	Immobilization unit operation vessel size	Not applicable – existing vendor facilities used.
22	24-hour ops req'd to meet rate or prevent adverse impacts?	N/A
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary. This option assumes the vendor will provide a treatment system that can handle all feeds
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity and IDF cap performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Minimal impact; Containerized grout does not require pumping grout mixture over long distances during production
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed
36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility; waste form interim storage/curing facility

[37] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

38	Cross site transfer line needed?	Not required
39	Utilize existing DSTs?	Retrieval and initial treatment expected to be small modular systems. Staging could include some amount of lag storage capacity for untreated feed, but this option does not preclude staging of untreated feed in existing DSTs prior to Cs removal.
40	B & T farm WRFs?	Not required
41	Treated LAW Staging tank	Retrieval and initial treatment expected to be small modular systems. Staging could include some amount of lag storage capacity for untreated feed, but this option does not preclude staging of treated feed for shipment in existing DSTs after Cs removal.
42	Effectiveness/robustness	The contract with the offsite vendor should allow treatment of a wide range of feeds and allow the process to accommodate changes in volume and composition during the mission.
43	Adaptability/flexibility	The contract with the offsite vendor should allow treatment of a wide range of feeds and allow the process to accommodate changes in volume and composition during the mission.
44	Number and Levels of Safety Control Mitigation	N/A
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	5A: Grout disposal in the IDF is not compliant with the current IDF permit. Modifications to the IDF permit must be developed and approved prior to disposal of grouted waste in IDF. Immobilization process used by the offsite vendor constrained by disposal requirements for IDF. 5B: Grout disposal offsite would be performed in compliance with permits (after modification, if required). The vendor would be able to choose the applicable immobilization method and disposal site depending on the characterization of each batch of feed.

Alternative Grout 6. Onsite disposal improvement – large monolith and vault with engineered liners

#	Criterion	Status
1	Pretreatment required (TFPT assumed for all)	Yes – LDR organics removal/destruction
2	Expected pretreatment system	evaporation; perhaps followed by chemical oxidation
3	Immobilization process Feed system	Blend 4 dry mix ingredients; mix with tank waste liquid in grout mixer
4	Immobilization system	Grout mixer
5	Auxiliary systems for immobilization	None
6	Immobilization temperature	~Ambient temperature; grout warms during curing (<100^{o} C)
7	Gasses emitted by immobilization process	Minor amounts of ammonia
8	Offgas system	Heater (prevent moisture on HEPA); HEPA filter; Activated Carbon Bed[38]; Blower; Stack
9	Offgas or effluent liquid handling tanks	Flush hold tank
10	Secondary liquid waste	None from grouting (returns to process in subsequent batch); ~30% of waste volume collected as condensate from LDR organic removal evaporation is sent to ETF
11	Secondary solid waste	Minimal amount of spent HEPA filters, carbon beds, failed equipment; minimal inventory of radionuclides
12	Assumed Primary waste disposal site	Monolith in engineered vault
13	Projected primary waste volume	~1.8X feed volume
14	Primary waste form packaging	Grout slurry poured into vault and allowed to harden
15	Primary waste form interim handling	None
16	Tc-99 assumed on HEPA filters[39]	0.8 Ci

[38] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation, it is not definitive that a carbon bed would be needed for this process.
[39] The amounts shown are the values used in the waste form performance evaluation conducted during the NDAA17 study.

17	I-129 assumed on Carbon Bed[40]	0.03 Ci
18	Impact of cold shut down	System flush/pig on shut down; process resumption is ~immediate
19	Impact of idling	None
20	Impact of feed turn down	Slower operation; limited impact
21	Immobilization unit operation vessel size	18' x 4' x 4' grout mixer[41]
22	24-hour ops req'd to meet rate or prevent adverse impacts?	No
23	Single pass retention of Tc-99/I-129	100/100
24	Waste form density	1770 kg/m^3
25	Iodine control	Iodine disposed in grout waste form; sequestered with getter
26	Tc control	Tc disposed in grout waste form; sequestered by redox with slag; unproven for non-pertechnetate
27	Se-79 control	TBD
28	LDR organics control	Characterization, evaporation, oxidation assumed necessary; non-compatible tanks diverted to Vitrification
29	Nitrate/nitrite control	Nitrate/nitrite disposed in grout; leachability controlled by waste form porosity, limited surface area, and vault performance
30	RCRA metal control	All metals partition 100% to waste form; sequestered by redox rxn with slag and caustic environment; passes TCLP test
31	Ammonia control	Small amount of ammonia in liquid waste would be vented during evaporation (for volume reduction and LDR organics removal); condensate contains some ammonia, which is sent to LERF/ETF (identical to current practice in 242-A evaporator)
32	Viscosity/pumping	Limited impact; Concept requires pumping grout mixture over long distances during production but has been demonstrated at scale at SRS for >30 years
33	Potential new tank leaks	No change from baseline
34	Long term immobilization	Primary waste form would be developed to be in compliance with DOE requirements based on PA calculations; secondary wastes contain minimal radionuclides; Tc and I are retained in waste form during production
35	Technology Risks; executability/maturity	Immobilization viable with existing technology; iodine getter development needed; LDR organics treatment development needed

[40] Although a carbon bed and capture of I-129 on the bed was applied to the grout process during the waste form performance evaluation in the NDAA17 report, it is not definitive that a carbon bed would be needed for this process.

[41] Grout mixer is identical to NDAA17 report and is based on size of a 10" Readco mixer, similar to the grout mixer used at the SRS Saltstone facility. Saltstone can process waste at 85 GPM, ~10X the maximum rate estimated for SLAW.

36	Process Complexity	Few unit operations, ambient to low temperature processing, limited offgas treatment required
37	Required facilities/infrastructure	TFPT system; LDR processing system; Grout production facility
38	Cross site transfer line needed?	Required; comparable to baseline
39	Utilize existing DSTs?	Existing DSTs used similar to baseline plan
40	B & T farm WRFs?	Required
41	Treated LAW Staging tank	DST in AP farm assumed as staging tank (continues use of AP-106 from DFLAW processing)
42	Effectiveness/robustness	The grout process is generally robust to changes in the waste feed composition and volume. The ability to shut down and restart allows the facility to handle low volume periods without impacting performance.
43	Adaptability/flexibility	Formulation of grout former additives can be tailored to the waste chemistry; process operability highly flexible (production resumption readily performed after outages); Simple commercial equipment
44	Number and Levels of Safety Control Mitigation	
45	Cost/affordability	TBD
46	Compatibility with HLW	Expected to be compatible
47	Compliance	Grout disposal in a new vault is not compliant with the current permit. A new permit must be developed and approved prior to disposal of grouted waste in a vault.

Selection Criteria assessment template 1

Color key:

- Criteria to be assessed
- Assumptions and ground rules; measures of effectiveness (MOEs)
  - Note MOEs are being developed and refined
- Assessments and scoring (to be added by assessment team)
- Action items and reminders

1. Long-term effectiveness of the proposed alternative: Grout Alt 1

1.1. ***Residual threat to health and environment upon successful completion***

Assumption: Only alternatives assessed as likely to comply with anticipated regulations and applicable standards for mobility and toxicity of wastes at project completion will be fully evaluated in the Report. Alternatives unlikely to comply with one or the other will be screened out.

1.1.1. Residual toxicity of wastes

1.1.1.1. Nitrates/nitrites

1.1.1.2. RCRA metals: No reduction in inherent toxicity; No MOE needed since all are equivalent

1.1.1.3. LDR organics: [be sure to cost any assumed infrastructure]

1.1.1.4. Ammonia [especially for VIT alternatives]

1.1.1.5. ~~Greenhouse gas emissions~~

No residual greenhouse gas / carbon footprint differences across alternatives; non-discriminatory [No MOE needed for long term]

1.1.2. Mobility of primary and secondary wastes to a groundwater source (given intended disposal site(s))

1.1.2.1. Radionuclides

MOEs: estimated concentration over ~1K years (to DOE O 435.1); delay to peak is when peak occurs and differs between scenarios; identify peak to 10K years for information only (i.e. compliance vs. post-compliance periods)

1.1.2.1.1. Iodine

1.1.2.1.2. Technetium

1.1.2.1.3. Se-79

1.1.2.1.4. [Cesium and strontium half-lives make them short-term only issue; no MOE needed here]

1.1.2.2. Nitrates / nitrites

1.1.2.3. Ammonia [especially for VIT alternatives]

1.1.2.4. RCRA metals

MOE is leachate TCLP compliance

1.1.2.4.1. Mercury
1.1.2.4.2. Chromium
1.1.2.4.3. Other

1.1.3. Total volume of primary and secondary waste forms

1.2. Long-term risks upon successful completion

Exogenous risks (earthquake, catastrophic flood, volcano, etc.) are assessed as indistinguishable across all technologies and disposal locations.

MOEs: error bars in 1.1. estimates above vs. margin under health/regulatory standards

1.2.1. Confidence in estimated residual toxicity
1.2.1.1. LDR organics
1.2.1.2. Nitrates/nitrites
1.2.1.3. Ammonia / ammonium ion.
1.2.1.4. RCRA metals
1.2.1.4.1. Mercury
1.2.1.4.2. Chromium
1.2.1.4.3. Other RCRA metals

1.2.2. Confidence in immobilization wrt groundwater
1.2.2.1. Iodine
1.2.2.2. Technetium (including non-pertechnetates)
1.2.2.3. Selenium-79
1.2.2.4. Nitrates/nitrites
1.2.2.5. Ammonia / ammonium ion
1.2.2.5.1. RCRA metals
1.2.2.5.2. Mercury
1.2.2.5.3. Chromium
1.2.2.5.4. Other RCRA metals

1.2.3. Confidence in total volume of primary and secondary waste forms produced

2. Short-term effectiveness of the proposed alternative

2.1. Risks to humans

2.1.1. Worker safety
2.1.1.1. Radiation
2.1.1.2. Chemical exposure
2.1.1.3. Particulate exposure
2.1.1.4. Physical injury

2.1.2. Transportation risks

MOEs: Number and distance of trips, health risks of material being transported

2.2. Risks to the environment

2.2.1. Wastewater discharges (intentional)
2.2.2. Atmospheric discharges

2.2.3. Transfer/process tank (onsite) spills
2.2.4. Offsite transportation spills
2.2.5. Secondary waste streams generated
2.2.6. Greenhouse gas emissions

2.3. Time needed to implement

2.3.1. Time to hot startup (years)
2.3.2. Time to full capacity (additional years)
2.3.3. Duration of operations (additional years)
2.3.4. Potential for early start

2.4. Risk of delay

3. Implementability of the proposed alternative

3.1. Likelihood and consequences of failing to complete for technical reasons

3.1.1. Technology and engineering risk

3.1.1.1. Technology failure modes

3.1.1.1.1. [Failure mode #1]
3.1.1.1.2. [Failure mode #2]
3.1.1.1.3. [Failure mode #3]
3.1.1.1.4. …
3.1.1.1.5. Process complexity

MOE: unit operations involved and their complexities (1 = low complexity to 10 = high complexity, total number of unit operations)
(Considers static versus moving components, temperature, reactions, gas phase formation/processes, mixed phase streams, number of process chemicals added, etc)

3.1.1.1.5.1. Unit operations
3.1.1.1.5.2. Accuracy of controls needed
3.1.1.1.5.3. Commercially available vs. bespoke systems
3.1.1.1.5.4. Overall flowsheet integration complexity

3.1.1.2. Required facilities / infrastructure

[(i.e., construction execution risk; system integration; including failure risk of existing infrastructure needed) melters, transport lines, pumping facilities, TSCR, evaporator, LAW VIT, …]

3.1.1.3. Required demolition / removal / modification
3.1.1.4. Technology readiness levels for CTEs

(Subsumed under 3.1.1.6)

3.1.1.5. Demonstrated effectiveness including Test Bed Initiative

(Subsumed under 3.1.1.6)

3.1.1.6. Analogous DOE experience

3.1.2. Robustness to known technical risks (ability to recover from things that go wrong in above 3.1.1.1 list)
[take credit for optional / conditional handling aspects of the alternative]

3.1.3. Adaptability to a range of waste compositions
[high heavy metals; high non-pertechnetate; ionic strength levels; phosphates; non-RCRA organics; etc.]

3.1.4. Ability to incorporate future advances
[Modular vs. big bang, ability to use multiple processes in parallel, …]

3.1.5. Expected progress at failure point

3.1.6. Worst plausible case progress at failure point

3.2. Likelihood and consequences of failing to complete due to resource constraints

3.2.1. MOE: Annual spending requirements against constrained annual SLAW budget

3.2.2. MOE: Peak spending level (SLAW only)

3.2.3. Schedule flexibility – ability to adapt to changes in workload / pace / budget
MOE: Ability to start and stop operations in response to external factors

3.2.4. Expected progress at failure point

3.2.5. Worst plausible case progress at failure

3.3. Likelihood and consequences of failing to complete due to external factors

3.3.1. Availability of key services and materials
[E.g., Offsite vendors; special ingredients; sole source providers…]

3.3.2. Stability of DOE / congressional support for Supplement LAW treatment

3.3.3. Securing and maintaining necessary permits/authorities

3.3.4. Expected progress at failure point

3.3.5. Worst plausible case progress at failure

3.3.6. ~~Risk of delaying HLW or other Hanford operations~~

3.3.7. ~~Availability of disposal site~~ (obviated by ground rule)

4. Life Cycle Costs

Costs must include any optional or conditional operations or processes assumed in performance and performance risk assessments above.

4.1. Capital project costs (including demo/mod of existing infrastructure and R&D)

4.2. Commissioning costs

4.3. Operations costs at Hanford

4.4. Offsite treatment, transportation and/or disposal costs

4.5. Shutdown and decommissioning costs

5. Community/Public Acceptance

[Current intent is to leave this section blank. For the Report, the FFRDC team will consider public meeting and draft report comments but will characterize alternatives with respect to the other criteria.]

5.1. State, Local, and Tribal government acceptance (non-regulatory)

5.2. Community and public acceptance

Selection Criteria assessment for Grout Alternative 1

Color key:

- Criteria to be assessed
- Assumptions and ground rules; measures of effectiveness (MOEs)
- Assessments and scoring notes
- Assessment scores/ratings
- Action items and reminders

1. Long-term effectiveness of the proposed alternative: Grout Alt 1

1.1. ***Residual threat to health and environment upon successful completion***

Assumption: Only alternatives assessed as likely to comply with anticipated regulations and applicable standards for mobility and toxicity of wastes at project completion will be fully evaluated in the Report. Alternatives unlikely to comply with one or the other will be screened out.

1.1.1. Residual toxicity of wastes [MOE Scoring: 1 All material destroyed to non-toxic constituents – 7 all retained – 10 – amount increased by treatment]

1.1.1.1. Nitrates/nitrites: No reduction in inherent toxicity vs. feed vector; MOE is nitrate/nitrite (as nitrogen) DWS for leaching during disposal in IDF PA (7)

1.1.1.2. RCRA metals: No reduction in inherent toxicity; No MOE needed since all are equivalent (7)

1.1.1.3. LDR organics: (1)

Negligible; any waste not sufficiently treated by evaporators/oxidation will be sent to vit. MOEs related to individual toxicity? Organics removed from waste treatable at LERF-ETF.

1.1.1.4. Ammonia (1)

No significant amount of residual ammonia in grouted tank wastes over long term

1.1.1.5. Greenhouse gas emissions No residual greenhouse gas / carbon footprint differences across alternatives for long term; non-discriminatory [No MOE needed for long term]

1.1.2. Mobility of primary and secondary wastes to a groundwater source (given intended disposal site(s))

1.1.2.1. Radionuclides

[MOEs: estimated concentration over ~1K years (to DOE O 435.1); delay to peak is when peak occurs and differs between scenarios; identify peak to 10K years for information only (i.e. compliance vs. post-compliance periods)]

1.1.2.1.1. Iodine: Sequestered by getter; projected ~100X below standard per NDAA17 report (but testing is preliminary and lab scale) MOE will be projected concentration in groundwater

1.1.2.1.2. Technetium: BFS sequesters; High performing for Tc; ~10X below DWS per NDAA17 report; without Tc getter; reduced by BFS; (NP will be evaluated below in confidence) MOE will be projected concentration in groundwater

1.1.2.1.3. Se-79 Sequestered by waste form

1.1.2.1.4. Cs & Sr [Cesium and strontium half-lives make them short-term only issue; no MOE needed]

1.1.2.2. Nitrates / nitrites

Retained only by diffusion barrier (physical entrapment); Recent diffusivity testing shows some formulations are beneath compliance standard, but those were in a saturated environment, which would be much higher than unsaturated actual environment. Data is bounding conservative case. (ref. PNNL-28992, Fig 4-3) (MOE is nitrate/nitrite (as nitrogen)). Drinking Water Standard for leaching during disposal as calculated for compliance point in IDF PA.

1.1.2.3. Ammonia

No significant amount of residual ammonia in grouted tank wastes. No MOE needed; no differences between alternatives

1.1.2.4. RCRA metals waste form has reduced toxicity. MOE is leachate TCLP compliance; grout waste form will be compliant

1.1.2.4.1. Mercury: Sequestered by sulfide rxn w BFS. MOE is retention of Hg in primary vs. secondary waste form

1.1.2.4.2. Chromium: Cr(VI) sequestered by redox w reductants in BFS and precipitation as hydroxide with alkali. MOE is retention of Cr in waste form (grout redox chemistry)

1.1.2.4.3. Other: Projected concentration of other RCRA metals (e.g. lead) appear not to exceed DWS limits and are significantly beneath concentration of Cr. No MOE needed

1.1.3. Total volume of primary and secondary waste forms -

Primary waste form is high with 1:1.8 volume increase (same as in NDAA17 report). secondary solid waste volume is minimal. [MOE is volume of primary and all secondary waste forms.]

1.2. Long-term risks upon successful completion

[Exogenous risks (earthquake, catastrophic flood, volcano, etc.) are assessed as indistinguishable across all technologies and disposal locations.]

[MOEs: error bars in estimates vs. margin under health/regulatory standards]

1.2.1. Confidence in estimated residual toxicity (MOE Scoring: 1 high confidence in value – 10 low confidence)

1.2.1.1. LDR organics (5)

Moderate confidence LDR organics can be removed/destroyed; additional evaluations, analyses, and testing planned; alternative is sending to LAW Vit

1.2.1.2. Nitrates/nitrites (1)
High confidence in no change to toxicity.

1.2.1.3. Ammonia / ammonium ion (2)
High confidence that ammonia will not be significant in grouted tank waste. Tank waste only contains small amounts of ammonium ion which will be vented during evaporation and/or grout formation.

1.2.1.4. RCRA metals

1.2.1.4.1. Mercury - (1) high confidence in ability to sequester

1.2.1.4.2. Chromium – (3) Temporal uncertainty in long-term sequestration of Cr, depending on oxidation rate. Uncertainty in duration of remaining in reduced form in the grout. Once Cr is in subsurface, high confidence in mobility predictions. Function of both oxidation and Kd in the soil.

1.2.1.4.3. Other RCRA metals (1)
High confidence in sequestration and limited solubility in waste form

1.2.2. Confidence in immobilization with respect to groundwater

1.2.2.1. Iodine - (4) Moderate confidence in reduction of mobility; limited data to support getter performance parameters

1.2.2.2. Technetium (including non-pertechnetates) (4 - TENTATIVE)
High confidence in reduction of mobility; high confidence in ability to reduce pertech to insoluble species; moderate confidence in re-oxidation/mobilization rate because of absence of oxidation rate data in Hanford subsurface, availability of oxygen in the specific disposal site, and waste form dimensions; high uncertainty in non-pertechnetate inventory, distribution, grout retention, and PA impact (note: all DST supernates are scheduled for processing through DFLAW; percentage of non-pertech in non-complexant tanks is uncertain but a small fraction is likely to be marginally compliant with high performing (low diffusivity) grout) in IDF

1.2.2.3. Selenium-79 Expect to act like sulfur and remain soluble in grout; retained by diffusion barrier

1.2.2.4. Nitrates/nitrites (6 - TENTATIVE)
Low-Moderate confidence that compliance standard can be met with high performing grout; total inventory is just over DWS with existing formulations and assumptions so minimal improvement is needed; laboratory test data used in calculations are bounding case and very conservative due to saturated experimental conditions vs. unsaturated disposal condition. (need to score based on probability that this will not meet the compliance limit?)

1.2.2.5. Ammonia / ammonium ion (1)
High confidence that grouted tank waste will not be a source of significant leaching of ammonium ion due to low concentration.

1.2.2.5.1. RCRA metals

1.2.2.5.2. Mercury – (1) high confidence in ability to sequester due to Hg sulfide formation

1.2.2.5.3. Chromium – (2-3) Moderate uncertainty in re-oxidation/solubilization rate, high confidence in knowledge of subsurface mobility; chromate is slow moving in subsurface and expected to be compliant with DWS.

1.2.2.5.4. Other RCRA metals (2) – depends on metal
High confidence in sequestration and limited solubility in waste form and slow movement in the subsurface

1.2.2.6.

1.2.3. Confidence in total volume of primary and secondary waste forms produced
High confidence in predicted total volume of primary waste and minimal secondary waste volumes

2. Short-term effectiveness of the proposed alternative

2.1. Risks to humans

2.1.1. Worker safety [MOE Scoring: 1 no hazards requiring mitigation to 10 multiple hazards requiring mitigation methods]

2.1.1.1. Radiation (3)
No vaporizing of radionuclides. Some construction is near an operating radioactive facility (LAW Vit); this single plant construction would be shorter duration in comparison to other alternatives.

2.1.1.2. Chemical exposure (2)
Negligible hazardous offgas; no toxic volatile or liquid chemicals. Minimal ammonia released during LDR removal. Strong caustic solution.

2.1.1.3. Particulate exposure (3)
High volume of fine powder with various transport mechanisms has potential risk of worker exposure to silica and other particulates. (Saltstone demonstrates viable and safe performance.)

2.1.1.4. Physical injury (2)
Low temperature; simple construction; largely offsite prefab hardware components. Some construction is near congested construction sites.

2.1.2. Transportation risks (2)
[MOEs: Number and distance of trips, nature of shipment – hazardous vs non-hazardous, non-rad vs rad. (MOE Scoring: 1 = few trip/shipments; 10 = highest number of shipments)]
Large number of transports of raw materials onto site and wasteform boxes onsite; no hazardous liquids shipped onsite; no rad liquid transport; no offsite transport of radioactive materials

2.2. Risks to the environment

2.2.1. Wastewater discharges
Minimal; all LAW/flush water is recycled into next batch; evaporator condensate collected to LERF/ETF (~30% of feed volume) Planned: MOE: 1. volume of wastewater discharged, 2. Composition (chem and rad), 3. are upgrades to ETF needed?)

2.2.2. Atmospheric discharges
[MOE: fraction of radionuclides and COCs converted to vapor in offgas system] Minimal releases possible; evaporator condensate is collected; HEPA/GAC filtered PVV. Low risk of inadvertent loss of contaminants to environment through evaporator.

2.2.3. Transfer/process tank (onsite) spills
Minimal risk, few tanks and process unit operations. Unplanned discharges MOE: volume, composition

2.2.4. Offsite transportation spills
None. Only possible is material transport truck/railcar accident

2.2.5. Secondary waste streams generated
[MOE: volume of waste (liquid and solids and equipment)] Minimal; evaporator condensate to LERF; some equipment, HEPA/GAC filters, and job control waste

2.2.6. Greenhouse gas emissions
Minimal (TBD for trucks) (see 2.1.2 above)

2.3. Time needed to implement

2.3.1. Time to hot startup (years) 8-13 years per NDAA17 report (revisit?)
2.3.2. Time to full capacity (additional years) 1 year
2.3.3. Duration of operations (additional years) as needed to support HLW
2.3.4. Potential for early start – No – Start tied to HLW processing

2.4. Risk of delay (low risk)
Minimal risk to delay operations; technology is well understood and demonstrated successfully at full scale in DOE complex.

3. Implementability of the proposed alternative

3.1. Likelihood and consequences of failing to complete for technical reasons
NEED MOEs

3.1.1. Technology and engineering risk

3.1.1.1. Technology failure modes [MOE – Perceived likelihood of failure; 1 = low likelihood and minimal consequences to 10 high likelihood and high consequences]

3.1.1.1.1. Can't produce and handle specified grout recipe (including getters) at scale (1) - low likelihood of failure

3.1.1.1.2. Suitable getter (iodine and potentially Tc) not identified / long term performance inadequate (7) - medium likelihood and high consequence

3.1.1.1.3. Transport lines become blocked/congested or leak (1) - low likelihood – small number of lines and lines are short, ambient temperature process

3.1.1.1.4. Evaporation/oxidation does not adequately reduce LDR organics (4) - low risk for most identified organics, medium risk for organics expected to be recalcitrant to evaporation or oxidation; alternative is vitrification, medium consequence

3.1.1.1.5. Sample analysis inadequate to allow sufficient LDR treatment (3) - low risk – assumed to addressed by batch qualification methods and detection limits can be reached

3.1.1.2. Process complexity

(flowsheet complexity risk) top level view of flowsheet moving parts for large non-modular option]

[MOE: unit operations involved and their complexities (MOE Scoring: 1 – low complexity to 10 – high complexity, total number of unit operations) (Consider: static versus moving components, temperature, reactions, gas phase formation/processes, mixed phase streams, number of process chemicals added, etc.)]

3.1.1.2.1 Unit Operations

- LDR organics evaporation/treatment (5) – assumes a recirculating vacuum evaporator – 50C operation with phase change and condensate handling
- Evaporator Condensate system (3) – collection tanks, sampling, and pumps
- Oxidative treatment (4) – metered additions, mechanical mixing, potential offgas generation
- Receipt tank (agitated, cooled?) (2) – CSTR vessel with pumps)
- Silos (4) with pneumatic conveyance (3) – Solids handling systems with weight recorders
- Dry feeds blender/feed hopper (3) Solids handling systems with weight recorders and pneumatic or mechanical blending
- Batch Mixer/Container filling (3) – Slurry mixing system
- Vessel vent offgas system (3) – Simple offgas system with HEPA filtration – may include a carbon bed for Hg
- Container decontamination (4) – Robotic? contamination measurement and decontamination system
- Container shipment (1) Hoist and forklift operations
- Container box disassembly and emplacement at IDF (2) Forklift and crane operations

3.1.1.2.2 Accuracy of controls needed (2-3)

- Sampling / measurements needed to control process - Batch qualification gives composition for grout / number of additions
- Modelling needed to control process – Grout process driven by water content – relatively simple and easy to measure
- Failure modes for improper operation – Either sets too slow or not at all, or does not flow

3.1.1.2.3 Commercially available / Similar (of a type) to Available / bespoke systems (2-3)

Most unit operations for grout use commercially available systems. Container sealing/closure for contamination control may be only bespoke system

3.1.1.2.4 Overall flowsheet integration complexity – (10 unit operations identified) (2) – unit operations are sequential, easily decoupled, few feedback loops)

3.1.1.3. Required facilities / infrastructure (2)

(i.e., construction execution risk; system integration; including failure risk of existing infrastructure needed)

- Construction risk is low – mostly commercially available equipment, experience with saltstone. Small construction site size reduces amount of soil disturbance needed, impact of and on collocated processes.
- Utility usage (electrical, cooling water, steam, etc. is low)
- Integration is simple - feed line to facility all that is needed except for feeds with LDR organics that require diversion

3.1.1.4. Required demolition / removal / modification (1)

Not expected to be an issue; no demolition needed. Small size for grout facility makes siting easier.

3.1.1.5. Technology readiness levels for CTEs

[subsume under 3.1.1.6]

3.1.1.6. Demonstrated effectiveness including Test Bed Initiative [MOE Scoring: 1 -being completely ready to 10 requiring development to make process work] (3-4)

Grout in general is demonstrated; saltstone at Savannah River (similar process, scale, and waste operating since 1991) Idaho, etc. (including containerized grout). Long-term performance predicted by modeling/theory/simulation and followed up with core sampling. Adding iodine getters has not been demonstrated at scale. Shipping of containerized grout has been done (NNSS). Evaporation of alkaline tank waste has been done for decades at Hanford and SRS, but demonstration of LDR organics has not been done at scale. Low-temperature oxidation not demonstrated at scale on Hanford waste, but has been tested at other sites (glycolate destruction at SRS for DWPF effluents, etc.)

3.1.1.7. Analogous DOE experience

[Subsume under 3.1.1.6]

3.1.2. Robustness to known technical risks (ability to recover from things that go wrong in above list) [MOE Scoring: 1 – very robust to 10 very fragile] (2-3)

Process and equipment are robust; failure of equipment well understood; grout formulations well understood and can be optimized; iodine getter is not well understood but can be developed. Failed equipment or plugged lines quickly replaceable.

3.1.3. Adaptability to a range of waste compositions (Waste form team assessment in progress – Scoring TBD)

[high heavy metals; high non-pertechnetate; ionic strength levels; phosphates; non-RCRA organics; etc.]

Grout formulations can be adapted to accommodate wide range of compositions; if a waste cannot be accommodated by grouting, it will be diverted for vitrification (including if untreatable for LDR organics, possibly for high non-pertechnetate, etc.)

3.1.4. Ability to incorporate future advances [MOE Scoring: 1 – easily incorporate to 10 impossible] (2)

Improvements to grout formulations could be accommodated relatively easily (e.g. additional dry feed component). Systems and unit operations are modular and relatively inexpensive. Updates to grout formulation easily incorporated.

Ability to expand capacity would be challenging but expect that system would be oversized to handle variability in flow rates so expansion unlikely to be needed.

3.1.5. Expected progress at failure point [MOE Scoring: 1 – low impact of failure (easily mitigated) to 10 – failures result in unmitigatable issues] (2) (there are decades of experience with grout waste forms at other DOE sites and worldwide)
The process is simple and does not contain complicated unit operations. Failures of the grout formulation during operation (e.g. improper setting or flowability) are expected to be resolved with waste loading or grout formulation changes. Failure of unit operation equipment would be easily replaceable. Sizing of the grout facility is expected to be far in excess of needed capacity; therefore, inability to meet throughput is not likely.

Failure to achieve sufficient organic removal/destruction on a batch of waste during operation to allow grout to stabilize the waste would result in inability to utilize the facility to treat the SLAW. Alternative is to divert that waste to LAW Vitrification.

Although low probability, failure caused by long-term performance issues after project completion and all waste is disposed have potential to result in release of contaminants in excess of projections; which may not be known until the release is measured from the disposal site in the distant future. Note: Containerized grout is expected to be retrievable and remediation would consist of additional barriers or removal of the grout from the disposal site followed by mitigation (e.g. disposal at a different site or additional treatment).

3.1.6. Worst plausible case progress at failure point [MOE Scoring: 1 – no long term impacts to 10 – non-mitigatable long term impacts] (4-5)
Immobilization of tank waste would be complete. Although low probability, long-term performance issues of the disposed waste have potential to result in release of contaminants in excess of projections; which may not be known until the release is measured from the disposal site in the distant future. Note: Containerized grout is expected to be retrievable and remediation could consist of installation of additional barriers at disposal site or removal of the grout from the disposal site and disposal at a different site or additional treatment.

3.2. Likelihood and consequences of failing to complete due to resource constraints [MOE Scoring: 1 – no possibility of failure to 10 – failure assured] (2-3)

3.2.1. [MOE: Annual spending requirements against constrained annual SLAW budget]

3.2.2. [MOE: Peak spending level (SLAW only)]

3.2.3. Schedule flexibility – ability to adapt to changes in workload / pace / budget
[MOE: Ability to start and stop operations in response to external factors]

3.2.4. Expected progress at failure point [TBD]

3.2.5. Worst plausible case progress at failure [TBD]

3.3. Likelihood and consequences of failing to complete due to external factors

3.3.1. Availability of key services and materials [MOE Scoring: 1 no possibility of materials or services not available to 10 likely that limited resources will impact production] (2)
(eg. Offsite vendor; special ingredient; sole source provider…)
Slag and fly ash are typically qualified and sourced from a single supplier; but alternates could be developed, qualified, and readied for deployment to substitute if the need arises.
Limited use of sampling and utilities.

3.3.2. Stability of DOE / congressional support for Supplement LAW treatment [MOE Scoring: 1 – Funding for SLAW assured to 10 Funding likely to be restricted]
The lower cost for a grout option will minimize impact of budget constraints.

3.3.3. Securing and maintaining necessary permits/authorities [TBD]

3.3.4. Expected progress at failure point [TBD]
Failure to get permission to dispose grouted waste form at IDF means process cannot start.

3.3.5. Worst plausible case progress at failure [TBD]
Failure to get permission to dispose grouted waste form at IDF means process cannot start.

3.3.6. ~~Risk of delaying HLW or other Hanford operations~~

3.3.7. ~~Availability of disposal site~~ (obviated by ground rule)

4. Life Cycle Costs

Costs must include any optional or conditional operations or processes assumed in performance and performance risk assessments above.

4.1. Capital project costs (including demo/mod of existing infrastructure and R&D)

(To be provided by Cost team)

4.2. Commissioning costs

(To be provided by Cost team)

4.3. Operations costs at Hanford

(To be provided by Cost team)

4.4. Offsite treatment, transportation and/or disposal costs

(To be provided by Cost team)

4.5. Shutdown and decommissioning costs

(To be provided by Cost team)

5. Community/Public Acceptance

5.1. State, Local, and Tribal government acceptance (non-regulatory)

5.2. Community and public acceptance

Vitrification Selection Criteria Scoring– 9/30/2021

Color key:

- Criteria to be assessed
- Assumptions and ground rules; measures of effectiveness (MOEs)
- Assessments and scoring
- Action items and reminders
-

1. Long-term effectiveness of the proposed alternative:

1.1. *Residual threat to health and environment upon successful completion*

Assumption: Only alternatives assessed as likely to comply with anticipated regulations and applicable standards for mobility and toxicity of wastes at project completion will be fully evaluated in the Report. Alternatives unlikely to comply with one or the other will be screened out.

1.1.1. Residual toxicity of wastes (MOE Scoring: 1 All material destroyed to non-toxic constituents – 7 all retained – 10 – amount increased by treatment)

1.1.1.1. Nitrates/nitrites: Nitrate/nitrite are nearly completely destroyed by vitrification and offgas processes – small residuals in caustic scrub solution that is sent to ETF and end up grouted for disposal in IDF. (2)

1.1.1.2. RCRA metals: RCRA metals are contained in the primary wasteform except Hg. Final partitioning of Hg has high uncertainty. All primary offgas components will have mercury contamination and secondary offgas components will have Hg contamination up to the GAC. Hg captured on the GAC will be micro-encapsulated in grout. Some Hg will partition to the LERF-ETF facility and end up in a grouted wasteform disposed in IDF. (7 no destruction; Hg is vaporized to secondary stream)

1.1.1.3. LDR organics: Most organics are destroyed by the vitrification and secondary offgas process. Some organics are generated by incomplete combustion of sugar, captured in the SBS condensate and partitioned to LERF-ETF for destruction. Some organics will be captured by the GAC and grouted for disposal in IDF. (4 – organics in waste largely destroyed, melter produces some; remaining organics partition to secondary waste)

1.1.1.4. Ammonia The vitrification process generates ammonia which will be partitioned to the LERF-ETF facility for treatment. In addition, ammonia is added to the secondary offgas system (to destroy NOx) and emitted from the vitrification facility stack. Ammonia in ETF will be precipitated and incorporated into a grout waste form disposed in IDF. (10)

1.1.1.5. ~~Greenhouse gas emissions~~ No residual greenhouse gas / carbon footprint differences across alternatives; non-discriminatory (none in waste form)

1.1.2. Mobility of primary and secondary wastes to a groundwater source (given intended disposal site(s))

1.1.2.1. Radionuclides

MOEs: estimated peak ratio to DWS over ~10k years; duration of peak hazard; delay to peak – Primary glass wasteform is modeled/predicted to have very small release rates; some radionuclides will partition to secondary wastes and will be grouted.

1.1.2.1.1. Iodine – Iodine is expected to partition predominately to components and secondary wastes (liquid/solid/gas). Release rates for macro-encapsulated components expected to be higher than microencapsulation of iodine in secondary solids waste stream from ETF; both are disposed in IDF (without getters).

1.1.2.1.2. Technetium (Non-TcO_4 will be evaluated below in 1.2.2.2) Most (~99%) Tc-99 will be retained in the primary waste form which exhibits very low leach rates. A small fraction will be captured on the HEPA filters which are crushed and macro-encapsulated in grout. Leach rates from the spent HEPAs is evaluated in the current PA, but predicted quantities of Tc on HEPAs are assumed to be extremely low but do not accurately account for system full performance.

1.1.2.1.3. Se-79 - Assumed to partition like Sulfur with most ending up in the primary waste form with very low leach rates. Like Tc-99, a small portion could be captured on the spent HEPA filters that are microencapsulated and disposed in IDF.

1.1.2.1.4. [Cesium and strontium half-lives make them short-term only issue]

1.1.2.2. Nitrates / nitrites (need MOEs) N/A – destroyed in melter

1.1.2.3. Ammonia Ammonia is generated by the melter process and is added during secondary offgas treatment to destroy NOx. Ammonia from the melter process is typically partitioned to LERF-ETF while excess ammonia added during secondary offgas treatment is exhausted from the vitrification facility stack. Ammonia in ETF is precipitated and encapsulated in grout waste form disposed in IDF. Release from waste form at some TBD rate is likely.

1.1.2.4. RCRA metals – Leach rates of RCRA metals from the glass are predicted to be very low.

1.1.2.5. Mercury – Hg will not be retained in glass and will end up in a grouted waste form for all options.

1.1.2.5.1. Chromium – Cr will be captured in the primary waste form with very low leach rates. Like Tc, a small fraction could be partitioned to the spent HEPA filters that are macro-encapsulated in grout and disposed in IDF.

1.1.2.5.2. Other

1.1.3. Total volume of primary and secondary waste forms - For 1 gallon of LAW feed: 0.33 gallons of primary waste glass, 0.05 gallons of spent equipment, 0.05 of grouted solids from ETF, and 1.8 gallons of liquid effluent disposed at SALDS. (Note: Flush volumes not included in water effluent totals)

1.2. Long-term risks upon successful completion

Exogenous risks (earthquake, catastrophic flood, volcano, etc.) are assessed as indistinguishable across all technologies and disposal locations.

MOEs: error bars in estimates vs. margin under health standards

1.2.1. Confidence in estimated residual toxicity (MOE Scoring: 1 high confidence in value – 10 low confidence)

1.2.1.1. LDR organics Destruction of organics. Uncertainty exists in the speciation of the organics in the waste feed, the amount and speciation of organics that will be vaporized, destroyed, or produced by the melter and scrubbed from the offgas in the primary offgas system and subsequently sent to LERF-ETF, and the amount and type of organics that will be captured on the GAC, which is microencapsulated and disposed in IDF. (7)

1.2.1.2. Nitrates/nitrites High confidence that nitrate and nitrite will be nearly completely destroyed by the immobilization process. (1)

1.2.1.3. RCRA metals

1.2.1.3.1. Mercury Low confidence that the partitioning of Hg will be as expected. (10)

1.2.1.3.2. Chromium – High confidence that chromium will be effectively immobilized in primary waste form. (1)

1.2.1.3.3. Other

1.2.2. Confidence in immobilization wrt groundwater

1.2.2.1. Iodine Low confidence that partitioning of iodine through process will proceed as expected. High confidence that the amount of iodine in secondary wastes will be higher than assumed in IDF PA. Partitioning significantly impacted if melter idles frequently. (8)

1.2.2.2. Technetium (including non-pertechnetates) High confidence that partitioning of Tc through process will proceed as expected, including non-pertechnetate (converts to pertechnetate in melter). (Note: also it is expected that the amount of Tc-99 in secondary wastes will be higher than assumed in IDF PA due to model simplifications that did not incorporate all known impacts on Tc-99 partitioning.) Partitioning to offgas is significantly impacted if melter idles frequently or WESP deluge frequency/time is higher than expected or if its scrubbing efficiency is lower than expected. (4)

1.2.2.3. Selenium Medium-low confidence that selenium will behave similar to sulfur and be incorporated into primary waste form with low leach rates. (7)

1.2.2.4. Nitrates/nitrites High confidence that nitrate/nitrite will not impact groundwater due to destruction during process (1)

1.2.2.5. RCRA metals High confidence that RCRA metals (except Hg) will be effectively immobilized in primary waste form with low leach rates. Hg is partitioned entirely to secondary waste streams (1)

1.2.3. Confidence in total volume of primary and secondary waste forms produced High confidence in volume reduction of primary waste form. Medium confidence in amount of secondary waste generated – low TOE would lead to higher secondary waste volume per liter of feed, which would lead to larger amounts disposed in IDF. (4)

2. Short-term effectiveness of the proposed alternative

2.1. Risks to humans

2.1.1. Worker safety [MOE Scoring: 1 no hazards requiring mitigation to 10 multiple hazards requiring mitigation methods]

2.1.1.1. Radiation TBD.

2.1.1.2. Chemical exposure TBD.

2.1.1.3. Particulate exposure

TBD

2.1.1.4. Physical injury – TBD.

2.1.2. Transportation risks – [MOEs: Number and distance of trips, nature of shipment – hazardous vs non-hazardous, non-rad vs rad. (MOE Scoring: 1 = few trip/shipments; 10 = highest number of shipments)]

TBD.

2.2. Risks to the environment

2.2.1. Wastewater discharges - MOE: 1. volume of wastewater discharged, 2. Composition (chem and rad), 3. are upgrades to ETF needed?) TBD.

2.2.2. Atmospheric discharges – [MOE: fraction of radionuclides and COCs converted to vapor in offgas system] TBD.

2.2.3. Transfer/process tank (onsite) spills – TBD.

2.2.4. Offsite transportation spills – TBD.

2.2.5. Secondary waste streams generated – [MOE: volume of waste (liquid and solids and equipment)] TBD.

2.2.6. Greenhouse gas emissions (see 2.1.2 above) – TBD

2.3. Time needed to implement

2.3.1. Time to hot startup (years) TBD.

2.3.2. Time to full capacity (additional years) TBD

2.3.3. Duration of operations (additional years) TBD.

2.3.4. Potential for early start TBD

2.4. Risk of delay - TBD

3. Implementability of the proposed alternative

3.1. Technical executability (risk of failing to complete for technical reasons)

3.1.1. Technology and engineering risk

3.1.1.1. Technology failure modes modes [MOE – Perceived likelihood of failure; 1 = low likelihood and minimal consequences to 10 high likelihood and high consequences] TBD.

3.1.1.1.1. TBD failure mode

3.1.1.1.2. TBD failure mode

3.1.1.1.3. TBD failure mode

3.1.1.2. Process complexity

[flowsheet complexity risk; top level view of flowsheet moving parts for large non-modular option]

[MOE: unit operations involved and their complexities (MOE Scoring: 1 – low complexity to 10 – high complexity, total number of unit operations) (Consider: static versus moving components, temperature, reactions, gas phase formation/processes, mixed phase streams, number of process chemicals added, etc)] TBD.

3.1.1.2.1. Unit Operations

- Feed Preparation Tasks
  - Receipt of feed and recycle (#)
  - Melter Feed Preparation (#)
  - GFC Batching (#)
  - GFC Blending and Transfer (#)
  - Melter Feed System (#)
- Melter (#)
- Primary Offgas
  - Film Cooler (#)
  - Submerged Bed Scrubber (#)
  - Wet ElectroStatic Precipitator or Steam Atomized Scrubber (#)
  - Condensate Collection (#)
- Secondary Offgas
  - Heater (#)
  - HEPA (#)
  - Activated Carbon Bed (#)
  - Heat Exchanger (#)
  - Heater (#)
  - Thermal Catalytic Oxidizer (#)
  - Selective Catalytic Reduction Unit (#)
  - Caustic Scrubber (#)
- Effluent Management
  - Melter Offgas Condensate Receipt and pH adjustment (#)
  - Evaporation (#)
  - Evaporator Condensate collection and transfer to LERF-ETF (#)
  - Evaporator Concentrate collection and return to Feed Preparation process (#)
- Container handling Line
  - Pour Cave (#)
  - Fill height verification and inert fill station (#)
  - Lidding Station (#)
  - Container swabbing and decon station (#)
  - Container load out station (#)

3.1.1.2.2. Accuracy of controls needed

- Sampling / measurements needed to control process - TBD
- Modelling needed to control process – TBD

- TBD

3.1.1.2.3. Commercially available / Similar (of a type) to Available / bespoke systems
TBD

3.1.1.2.4. Overall flowsheet integration complexity
TBD

3.1.1.3. Required facilities / infrastructure
(i.e., construction execution risk; system integration; including failure risk of existing infrastructure needed) TBD.

3.1.1.4. Required demolition / removal / modification
TBD.

3.1.1.5. Technology readiness levels for CTEs
(subsume under 3.1.1.6)

3.1.1.6. Demonstrated effectiveness including Test Bed Initiative
[MOE Scoring: 1 -being completely ready to 10 requiring development to make process work] TBD.

3.1.1.7. Analogous DOE experience
(Subsume under 3.1.1.6)

3.1.2. Robustness to known technical risks (ability to recover from things that go wrong in above list) [MOE Scoring: 1 – very robust to 10 very fragile]
TBD.

3.1.3. Adaptability to a range of waste compositions
[high heavy metals; high non-pertechnetate; ionic strength levels; phosphates; non-RCRA organics; etc.] TBD.

3.1.4. Ability to incorporate future advances
[MOE Scoring: 1 – easily incorporate to 10 impossible] TBD.

3.1.5. Expected progress at failure point [MOE Scoring: 1 – low impact of failure (easily mitigated) to 10 – failures result in unmitigatable issues] (TBD)

3.1.6. Worst plausible case progress at failure point [MOE Scoring: 1 – no long term impacts to 10 – non-mitigatable long term impacts]
TBD.

3.2. Likelihood and consequences of failing to complete due to resource constraints [MOE Scoring: 1 – no possibility of failure to 10 – failure assured] (#)

3.2.1. [MOE: Annual spending requirements against constrained annual SLAW budget]

3.2.2. [MOE: Peak spending level (SLAW only)]

3.2.3. Schedule flexibility – ability to adapt to changes in workload / pace / budget
[MOE: Ability to start and stop operations in response to external factors]

3.2.4. Expected progress at failure point [TBD]

3.2.5. Worst plausible case progress at failure [TBD]

3.3. Likelihood and consequences of failing to complete due to external factors

3.3.1. Availability of key services and materials [MOE Scoring: 1 no possibility of materials or services not available to 10 likely that limited resources will impact production] (#)

(eg. Offsite vendor; special ingredient; sole source provider…)
TBD

3.3.2. Stability of DOE / congressional support for Supplement LAW treatment [MOE Scoring: 1 – Funding for SLAW assured to 10 Funding likely to be restricted]
TBD

3.3.3. Securing and maintaining necessary permits/authorities [TBD]

3.3.4. Expected progress at failure point [TBD]
TBD.

3.3.5. Worst plausible case progress at failure [TBD]
TBD.

4. Life Cycle Costs

Costs must include any optional or conditional operations or processes assumed in performance and performance risk assessments above.

4.1. Capital project costs (including demo/mod of existing infrastructure and R&D)
(To be provided by cost team)

4.2. Commissioning costs
(To be provided by cost team)

4.3. Operations costs at Hanford
(To be provided by cost team)

4.4. Offsite treatment, transportation and/or disposal costs
(To be provided by cost team)

4.5. Shutdown and decommissioning costs
(To be provided by cost team)

5. Community/Public Acceptance

5.1. State, Local, and Tribal government acceptance (non-regulatory)

5.2. Community and public acceptance