Topic: Cesium Management and Disposition Alternatives for the Low Activity Waste Pre-Treatment System
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Cesium Management and Disposition Alternatives for the Low Activity Waste Pretreatment System

Summary

The Hanford Advisory Board (HAB or Board), following lengthy discussions and reviews conducted by the Board's Tank Waste Committee with the U.S. Department of Energy (DOE) Office of River Protection (ORP), completed a review of the proposed Direct Feed Low Activity Waste (DFLAW) process and the Low Activity Waste Pretreatment System (LAWPS). Specifically, the committee's discussions centered on the proposed management and potential disposal paths of the High-Level Cesium Waste resulting from the LAWPS process. The committee performed this review at the request of the DOE-ORP Federal Project Director, LAWPS, as described in the Hanford Advisory Board 2015 and 2016 Work Plans. Specific areas to be discussed in this work plan item included:

- Are there alternate cesium removal, storage, and disposition technologies that should be considered under DFLAW scenarios?

- What would be the implications for long-term cleanup planning on the Central Plateau?

The goal of this document is to identify and review alternatives to the current baseline of removing the High-Level Cesium Waste and returning it back to the double shell tanks (DST). Specific consideration was made to assure that the selected alternative would not generate an additional waste form that may have to be stored, for the long term, on the Hanford Site, should associated technical or regulatory issues not be resolved. Alternatives that would have grouted the cesium for long-term disposable, were considered and discussed by the committee. Grout options were changed to non-grout disposal systems due to long-term destructive radiation effects on grout. Grout will only last one to ten years when radioactive cesium is incorporated into it at high Class C levels.

Related alternative options are considered and labeled as a subset of each option.

The following DFLAW Disposition Alternatives Process Flow Chart and the Disposition Alternatives Options Summary Table attempt to summarize the alternatives developed and discussed during presentations and on-site tours with DOE, and extended in-depth dialogue and analysis by members of the Board.

The DFLAW Disposition Alternatives Process Flow Chart attempts to represent in graphical form an extremely simplified DFLAW processes on the left side of the diagram. The process block labelled "Cs Removal & Disposition" is then expanded to show the potential cesium alternatives in the larger block in the center-left. Each major cesium disposition alternative that the Board considered is depicted as a

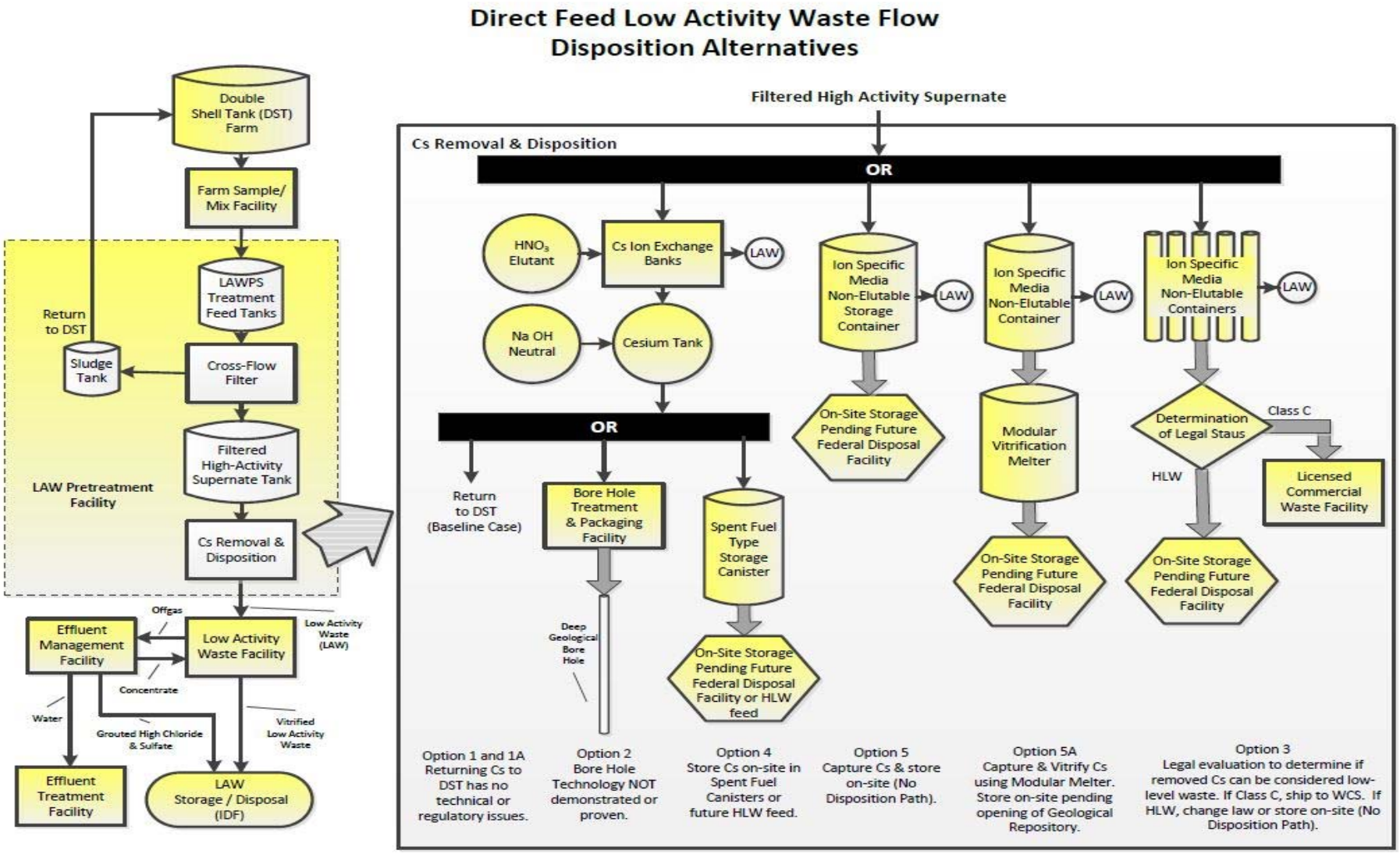
vertical process from the "Filtered High Activity Supernate" input at the top and the final cesium disposition at the bottom of the block. The Low-Activity Waste (LAW) stream with the cesium removed is labeled "LAW," and it flows to the LAW facility where is vitrified into glass logs.

The Disposition Alternatives Options Summary Table summarizes the result of the discussions and findings for each cesium disposition option considered.

A more detailed description and discussion of each option is included in the body of this white paper.

List of Abbreviations

Cs	Cesium
CH-TRU	Contact-Handled Transuranic Waste
DFHLW	Direct Feed High-Level Waste
DFLAW	Direct Feed Low-Activity Waste
DOE	Department of Energy
DST	Double Shell Tank
EMF	Effluent Management Facility
ETF	Effluent Treatment Facility
IDF	Integrated Disposal Facility
ISF	Interim Storage Facility
IX	Ion Exchange
HAB	Hanford Advisory Board
HLW	High-Level Waste
LAW	Low-Activity Waste
LAWPS	Low-Activity Waste Pretreatment System
LLW	Low-Level Waste
LLRW	Low-Level Radioactive Waste
ORP	Office of River Protection
PT	Pretreatment
SRNL	Savannah River National Laboratory
TRU	Transuranic
Vit.	Vitrification
WCS	Waste Control Specialists
WIPP	Waste Isolation Pilot Plant
WIR	Waste Incidental to Reprocessing
WTP	Waste Treatment and Immobilization Plant


Direct Feed Low Activity Waste Flow
Disposition Alternatives
Double Shell Tank (DST) Farm
Farm Sample/ Mix Facility
LAWPS Treatment Feed Tanks
Return to DST
Sludge Tank
Cross-Flow Filter
Filtered High-Activity Supernate Tank
LAW Pretreatment Facility
Cs Removal & Disposition
Offgas
Effluent Management Facility
Low Activity Waste Facility
Low Activity Waste (LAW)
Concentrate
Water
Grouted High Chloride & Sulfate
Vitrified Low Activity Waste
Effluent Treatment Facility
LAW Storage / Disposal (IDF)
Filtered High Activity Supernate
Cs Removal & Disposition
OR
HNO3 Elutant
Cs Ion Exchange Banks
LAW
Na OH Neutral
Cesium Tank
Ion Specific Media Non-Elutable Storage Container
Ion Specific Media Non-Elutable Container
Ion Specific Media Non-Elutable Containers
On-Site Storage Pending Future Federal Disposal Facility
Modular Vitrification Melter
Determination of Legal Staus
Class C
HLW
Licensed Commercial Waste Facility
Return to DST (Baseline Case)
Bore Hole Treatment & Packaging Facility
Spent Fuel Type Storage Canister
Deep Geological Bore Hole
On-Site Storage Pending Future Federal Disposal Facility or HLW feed
Option 1 and 1A Returning Cs to DST has no technical or regulatory issues.
Option 2 Bore Hole Technology NOT demonstrated or proven.
Option 4 Store Cs on-site in Spent Fuel Canisters or future HLW feed.
Option 5 Capture Cs & store on-site (No Disposition Path).
Option 5A Capture & Vitrify Cs using Modular Melter. Store on-site pending opening of Geological Repository.
Option 3 Legal evaluation to determine if removed Cs can be considered low-level waste. If Class C, ship to WCS. If HLW, change law or store on-site (No Disposition Path).

Disposition Alternatives Options Summary

Option	Description	Removal Process	DFLAW Cesium Deposition	Technical	Legal / Regulatory	Comments
1	Return cesium back to DST	Elutable[1] resin	DST then PT and HLW Vit.		Acceptable	DFLAW baseline process
1A	Return cesium to DST under optimized management plan and expedite Direct Feed HLW proposal	Elutable resin	DST then DFHLW Vit.		Acceptable	Return Cesium to DST, expedite DFHLW proposal
2	Dispose of cesium in deep geologic borehole	Elutable resin	Borehole	Many technical hurdles – highly uncertain	Borehole demonstration blocked by host State	Unproven technology, feasibility test not yet started - many years from being a viable option
3	Dispose of cesium as Class C Waste at a Licensed Commercial Disposal Facility	Non-elutable resin	WCS		Would require change to HLW law – highly unlikely	If law is changed, send to WCS disposal facility
4	Place cesium in Spent Fuel Type Storage Containers or in a cesium Tank for future high-level waste disposal	Elutable resin	On-site storage awaiting Deep Geological Repository	Organic resin destroyed by high radiation fields, explosion hazard	Requires permit for long term on-site storage until HLW operational	Radiation hazard no current path for permanent disposal till HLW operational
5	Store cesium in ion specific media for future federal disposal	Non-elutable resin	On-site storage awaiting Deep Geological Repository		Requires permit for long term on-site storage	No current path for permanent disposal Waste requires processing to meet repository requirements
5A	Vitrify cesium in Storage Container for Future Federal Disposal	Non-elutable resin	On-site storage awaiting Deep Geological Repository		Requires permit for long term on-site storage	Unproven technology, no current path for permanent disposal waste form may not meet repository requirements

[1] See explanation under the detailed discussion of Option 1 (footnote 2).

Conclusions

The Board did not identify any options that met all of the general criteria that were established at the start of this effort. The key criteria were to identify an alternative that would not return the cesium removed during the DFLAW process back to the DST farms and not to place the cesium in waste form that, due to regulatory or other factors, could disrupt the proposed disposal path and result in long-term storage of this waste form on the Hanford Site.

Option 1A, which initially returns cesium to the DSTs, uses an optimized management plan that minimizes the need to extract cesium from tank waste several times and expedites the Direct Feed High-Level Waste (DFHLW) proposal. The cesium management plan would process low-cesium waste first to return less total cesium to DSTs and free up DST capacity for cesium waste that would then be sent to HLW without further cesium removal. In the DFHLW proposal, DST solids are not processed by the Pretreatment (PT) facility to any significant extent for the vast majority of tank waste. The unwashed solids are sent directly to HLW for vitrification. Once the DFHLW process is operational, the cesium eluent in the DSTs would be added directly into the HLW feed and vitrified into high-level glass. DFHLW bypasses many of the unresolved PT technical issues.

While this approach does not fully satisfy our primary goal of not returning the DFLAW cesium back to the DSTs, it does not create a new waste form and, with the DFHLW approach, does have an acceptable regulatory and technical path forward. This option appears to be the most acceptable from an economic, regulatory, and stakeholder perspective. DFHLW is currently only in the proposal stage, and the strategy currently lacks a detailed feasibility study and economic analysis. Projected potential savings of the DFHLW option could range between $5billion to $10 billion.

One alternative that did not return the cesium to the DSTs is Option 3, dispose of the removed cesium as Class C Waste in a Licensed Commercial Disposal Facility. This option would place the cesium in waste containers that would be designed to meet Class C waste requirements and then shipped to and disposed of at the Federal Low-Level Radioactive Waste (LLRW) site located in Texas and operated by Waste Control Specialists (WCS). Initially, the Board felt that this option would require a Waste Incidental to Reprocessing (WIR) determination to be Class C. However, upon looking at other regulatory requirements, the Board concluded that a controversial change in the law governing HLW would likely be needed. If ORP packaged the cesium as Class C waste in anticipation of modifying the federal law governing HLW, and these regulatory requirements were not successfully resolved, the cesium waste canisters could end up stored, long term, on the Hanford Site. This disposal path also requires an additional cost of $200 to $340 million to package, ship, and dispose of cesium waste at WCS.

Discussion of Cesium Disposition Alternatives

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Background

Current DFLAW plans call for using an ion exchange process in the LAWPS to strip HLW constituents, primarily highly radioactive cesium, from a waste stream from the tank farms creating a LAW feed for vitrification in the LAW facility. The cesium or HLW would be returned to the existing DSTs for later processing, once the Waste Treatment and Immobilization Plant (WTP) has the capability to process HLW.

On September 24, 2013, DOE released the Hanford Tank Waste Retrieval, Treatment, and Disposition Framework (Framework) document. This document described a strategic framework for addressing the risks and challenges to completing the ORP mission by implementing a phased approach that would:

- Begin immobilization of the tank waste as soon as practicable through the DFLAW process.
- Process transuranic (TRU) tank wastes for disposal at the Waste Isolation Pilot Plant (WIPP).
- Resolve technical issues for the PT facility and the HLW facility, including determination of how to adequately mix and sample the waste prior to processing, to enable design completion, and safe completion of construction, startup, and operations of these facilities.

Immobilization of the approximately 56 million gallons of radioactive and chemical wastes stored in 177 underground tanks located on Hanford's Central Plateau will occur in the WTP. The complexity of both the waste itself as well as the WTP facilities has led to difficult and, to date, unresolved technical issues for the portions of the PT facility and, to a much lesser extent, the HLW facility) that will process the solid portions of the waste. Because the current design of WTP anticipates that all waste will be processed through the PT facility, no immobilization of any waste could occur per the current plan until the many technical issues involving the PT facility are resolved. Therefore, ORP identified DFLAW as an alternative approach for immobilizing waste as soon as practicable while simultaneously resolving the remaining technical challenges. By adopting a DFLAW option in which the waste bypasses the PT facility, waste immobilization could begin significantly earlier than if treatment of the waste is delayed until all technical issues are resolved and the PT facility and the HLW facilities are completed.

The Framework document divided the 56 million gallons of tank waste into three major categories for treatment:

(1) LAW;
(2) Potential contact-handled transuranic waste (CH-TRU); and
(3) HLW, which is further subdivided into waste not requiring special handling (easier to process) and waste requiring special handling (harder to process).

LAW consists primarily of the supernate (liquid) portion of the tank waste with most of the solids and radioactivity removed before vitrification. LAW will be the largest tank waste stream by volume (approximately 90% of the total volume), but the lowest in radioactivity content (approximately 10% of

the total curies). Since the LAW makes up approximately 90% of the total volume of waste to be treated, it also has the greatest influence on the total duration of the Hanford tank waste mission. The liquid form of this waste makes it susceptible to leakage. LAW is also the tank waste that is most easily processed through the WTP. In particular, at the present time it is felt that there are no significant technical risks associated with vitrifying this waste stream in the LAW Facility.

Beginning LAW facility operations before the PT facility is operational would require a capability to remove the cesium and small amounts of transuranic and strontium-90 solids from the liquid supernatant waste stream so that LAW could be directly fed to the LAW facility for glass immobilization.

ORP's analyses of this approach indicated that a standalone Interim Pretreatment System Facility would best address this need. It would be located between the tank farms and the LAW Facility and would remove the solids and cesium from the liquid waste stream. In addition, some space was set aside to possibly remove other radioactive elements or test improvements in currently planned separation techniques. This facility would provide the processing capability to support a DFLAW operation prior to the completion of the PT facility. As this option uses mature technologies, DOE felt that the technical risks associated with this alternative were low.

Disadvantages of Returning Radioactive Cesium to the Waste Tanks

The current baseline for the DFLAW process is to return the high-level cesium waste removed from the waste stream back to the DSTs. The focus of this paper is to identify and discuss potential alternate cesium removal, storage, and disposition technologies to this baseline approach.

Cesium is present in HLW mostly in salt cake and supernatant as stable cesium-133 and radioactive cesium-134, cesium-135, and cesium-137. Cesium-134 has mostly decayed away, leaving cesium-135 and cesium-137. Cesium-137 decays to barium-137m which decays to barium-137. This is the principle gamma source in tanks. There is approximately three to four times more total cesium than radioactive cesium-137 in the tank waste.

The return of radioactive cesium to the tanks has numerous disadvantages. These include:

- Cesium gamma emissions are the principle radiation hazard to the work force.
- Cesium makes up about 50% of hydrogen generated in tanks/PT. Seven of twelve tanks scheduled for DFLAW treatment have high hydrogen generation rates.
- Cesium places more radiation/heat stress on tanks, some of which are nearing their design life.
- Cesium return to the DSTs is more expensive and creates more waste. It is cheaper in the short run and costlier in the long run.
- Cesium return takes up tank space and creates less free DST space.

DFLAW impacts on DST Capacity

The actual space taken up by returning neutralized cesium eluted off the LAWPS cesium resin back into the DSTs is approximately 9% of the supernatant volume removed. This does not include concentration by evaporation, which is probably not the choice operation for many reasons. The approximate remaining 24% volume returned to the DSTs (for every three-parts volume removed from DSTs, approximately one-part volume is retuned to DSTs using DFLAW) is from LAWPS resin pretreatment, LAWPS resin post cesium elution reactivation, LAW off gas processes, and ETF (Effluent Treatment Facility) brine volume from all sources. This 24% of volume returned to the tanks includes significant reduction by evaporation of a factor of approximately 2.5 or slightly more. The large majority of liquids returned to DSTs are from LAW off gas.

Cesium Disposition Alternatives

As requested by DOE in the HAB FY2015 and FY2016 Work Plans, the Board conducted an in-depth review of the preliminary design associated with the DFLAW and possible alternate cesium removal, storage, and disposition technologies that might be considered for use in the DFLAW.

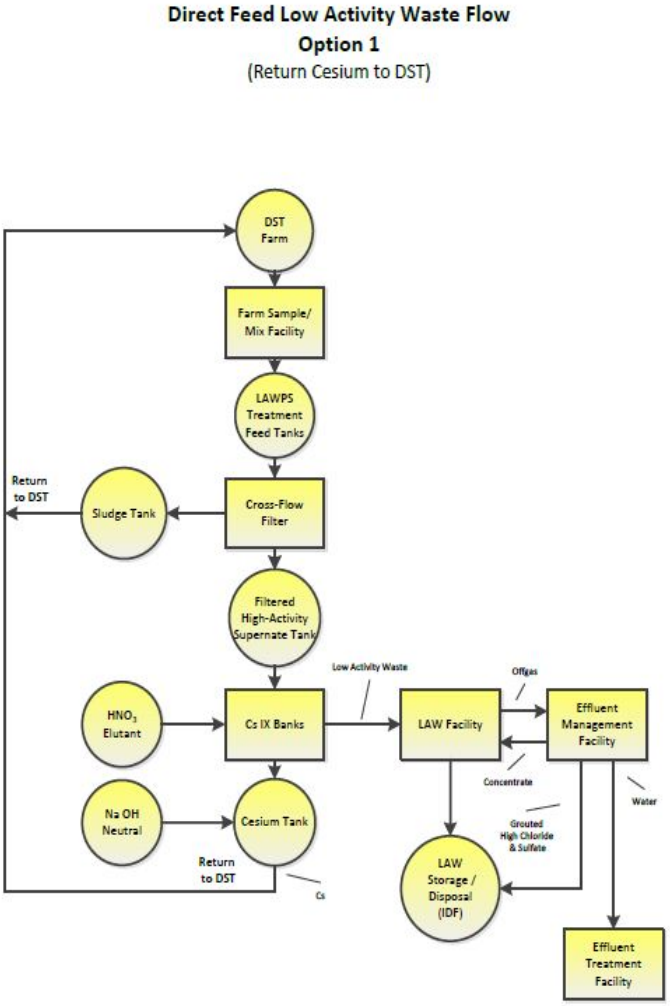
The Board developed and considered the following alternatives for the disposition of the cesium removed from the waste steam as part of the DFLAW process.

Option 1 - Return Cesium Back to the DSTs (current DOE baseline alternative)

This represents the current Baseline DFLAW cesium disposition path.

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW facility. The cesium is captured using ion exchange resin media, eluted[2] with nitric acid, neutralized, and returned to the DST farms to await vitrification in the HLW facility.

Secondary liquid wastes generated from the LAW facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.



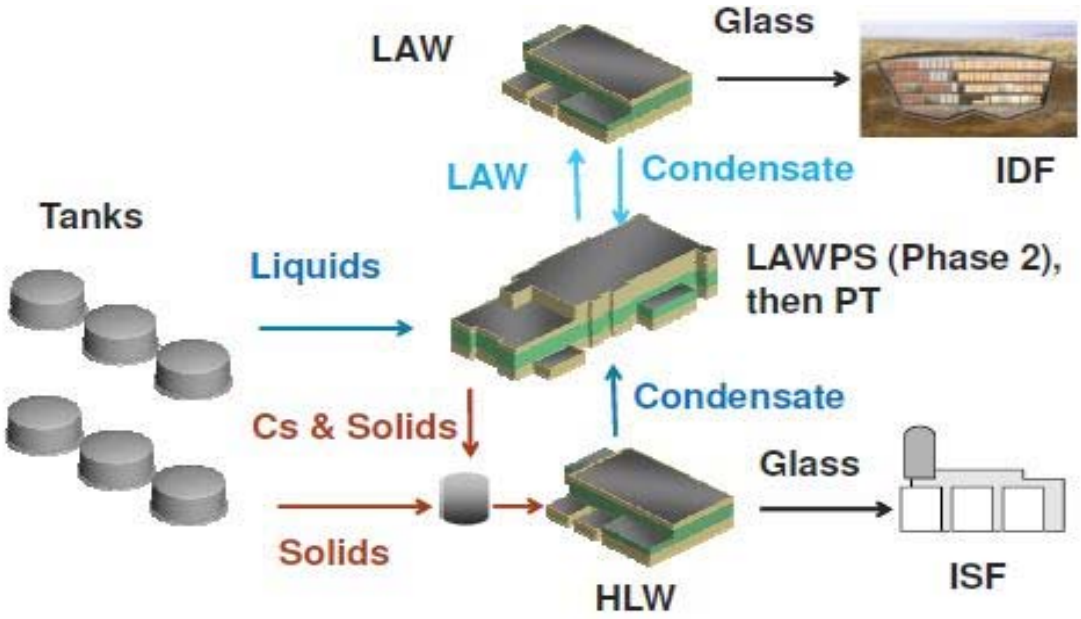
[2] To elute means to remove by dissolving, such as removing absorbed material from an adsorbent, in this case cesium from ion exchange or ion capture material. Elution is the action of eluting a material from a substance. Elutable means that it is practical and possible to remove a material. Non-elutable means that it is not. As used in ion exchange media, elution is generally accomplished using acids or caustics where one ion is traded for another when the chemical reaction is easily reversible. In non-elutable media the ion is generally either held too tightly to be exchanged, or it is irreversibly bound in or to the media. In other uses, elution is often accomplished using solvents; however, that would not apply in this case.

Option 1A – Return Cesium to DSTs with Cesium Management Plan, and Expedite Direct Feed High Level Waste

Process DFLAW baseline with cesium returned back to DSTs using cesium management to minimize cesium being extracted several times, and expedite Direct Feed HLW.

The cesium management plan would process low cesium waste first to return less total cesium to DSTs and to free up DSTs capacity for cesium waste which would be sent to HLW without further cesium removal. In the DFLAW proposal DST solids are not processed by the PT facility to any significant extent for the vast majority of tank waste. The unwashed solids are sent directly to HLW for vitrification. Once the DFHLW process is operational, the cesium eluent in the DSTs would be added directly into the HLW feed and vitrified into high level glass. DFHLW bypasses many of the PT facility's unresolved technical issues.

Initial runs of DFLAW would process low concentration cesium supernatant only (no saltcake in initial runs). The initial process sequence for DFLAW tanks is: first tank AP-104, second tank AP-106, third tank AP-103, fourth tank AP-108, and fifth tank AP-102. Total supernatant anticipated to be processed is three million gallons. Several DSTs would be designated as cesium eluent storage tanks as soon as practical. This strategy could expedite the DFHLW process by installing a 100,000 gallon below-ground DST tank with some solids/liquid separation capability, a large single (replaceable) mixing impeller, hard installed sampling ports, a small sampling and ventilation support building, and related underground piping. All tank sludge solids and some related saltcake retained in sludge transfers are to be processed by DFHLW without any pretreatment extraction of any kind for the life of the mission. Once DFHLW is operational, direct all cesium from the LAWPS process and cesium eluent previous in DSTs to HLW glass. Once the PT facility is complete, integrate off gas of all glass plants and processes. Expose PT facility to minimal entrained solids; only if absolutely necessary for some select HLW glass batches use PT facility to process sludge solids.



While this approach does not fully satisfy our primary goal of not returning the DFLAW cesium back to the DSTs, it does not create a new waste form and, coupled with the DFHLW approach, it does have an acceptable regulatory and technical path forward.

The DFHLW concept is currently only in the proposal stage, and it lacks a detailed feasibility study and economic analysis. Projected potential savings of this option could range between five billion to ten billion dollars.

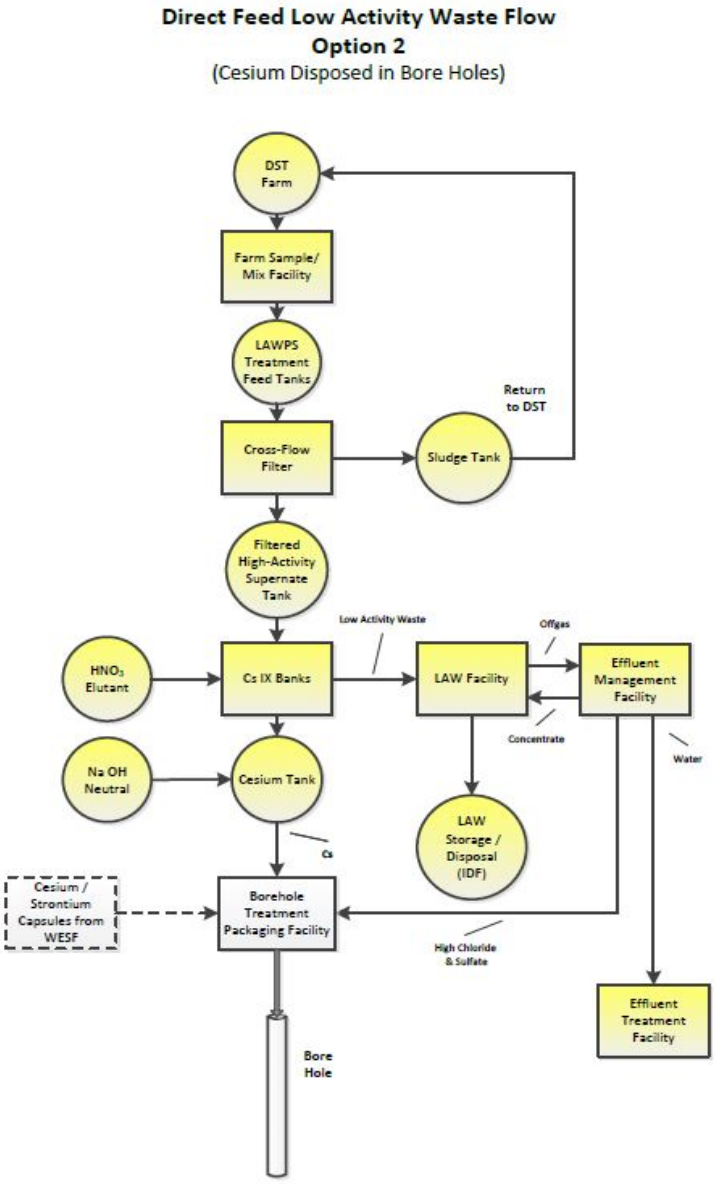
Option 2 - Dispose of Cesium in Deep Geologic Boreholes

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW facility. The cesium is captured using ion exchange resin media, eluted with nitric acid, neutralized, treated, and packaged for disposition in a deep geologic borehole.

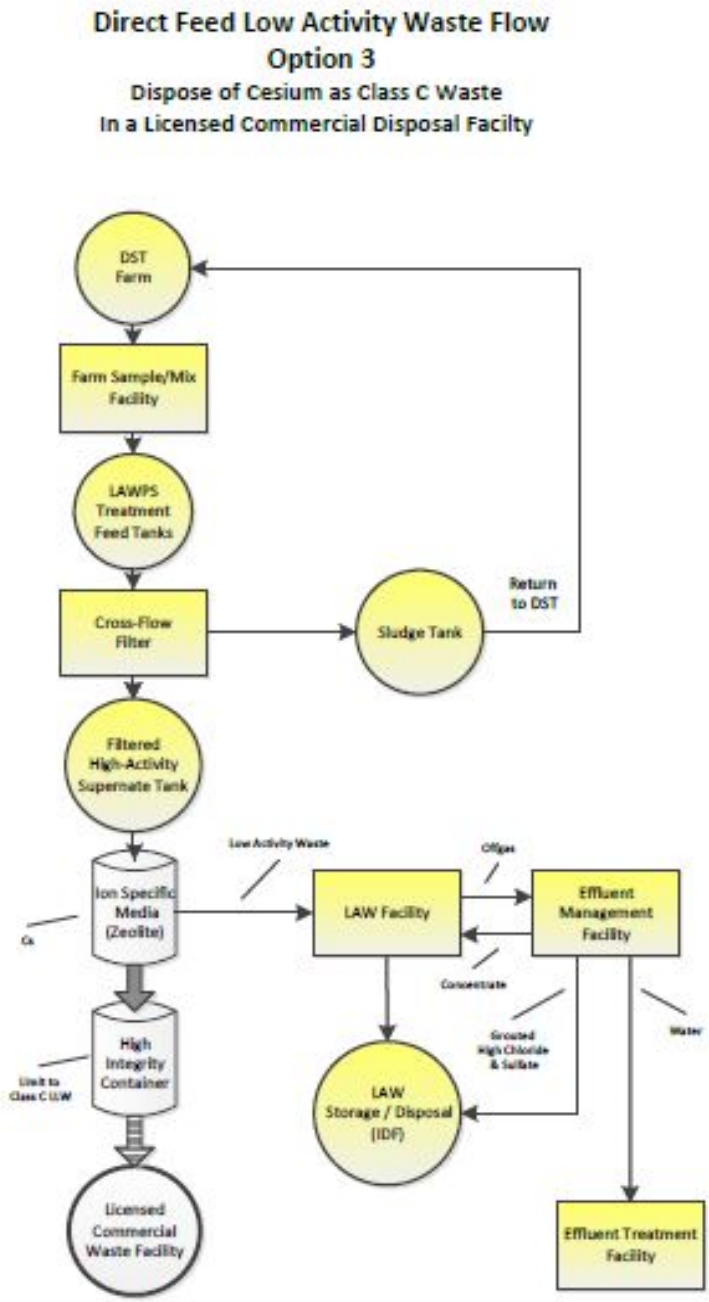
Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.

The borehole approach has many technical hurdles to overcome. It is an unproven technology. Feasibility tests of the concept have not yet started and is the strategy is, at best, many years from being a viable option.

Recently, use of the Borehole Demonstration Project Site was blocked by the host state leaving the viability of this option highly uncertain.



Option 3 - Dispose of Cesium as Class C Waste in a Licensed Commercial Disposal Facility



The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste using a non-elutable media. The resulting LAW stream is then vitrified in the LAW facility.

The cesium is captured in LAWPS using zeolite ion-specific media and dried and packaged in a High Integrity Container for disposition in a Licensed Commercial Waste Disposal facility.

This option places the cesium in waste containers that would be designed to meet Class C waste requirements and then shipped to and disposed of at the Federal LLRW site located in Texas which is operated by WCS.

Secondary liquid wastes generated from the LAW facility off gas system would then be treated and volume-reduced through the new Effluent Management Facility and existing Effluent Treatment Facility and 242-A Evaporator in the tank farms.

The Federal LLRW site at Texas WCS has a current maximum curie limit of 5.6 MCi. WCS can currently accept approximately 2.8 MCi of cesium-137 due to barium-137m progeny. This equates to 608 cubic meters of Class C waste at maximum cesium-137 concentration low level waste (LLW) Class C. Furthermore, an unknown, low percentage (approximately 5-30%) of the Class C containers may be TRU waste due to high concentrations of TRU radionuclides binding to the zeolite media.

This option would likely require a controversial change in the law governing the definition of HLW. If the cesium were to be packaged as Class C waste in anticipation of modifying the federal law governing

HLW, and then regulatory requirements were not successfully resolved, the cesium waste canisters could end up stored, long term, on the Hanford Site as orphan waste[3].

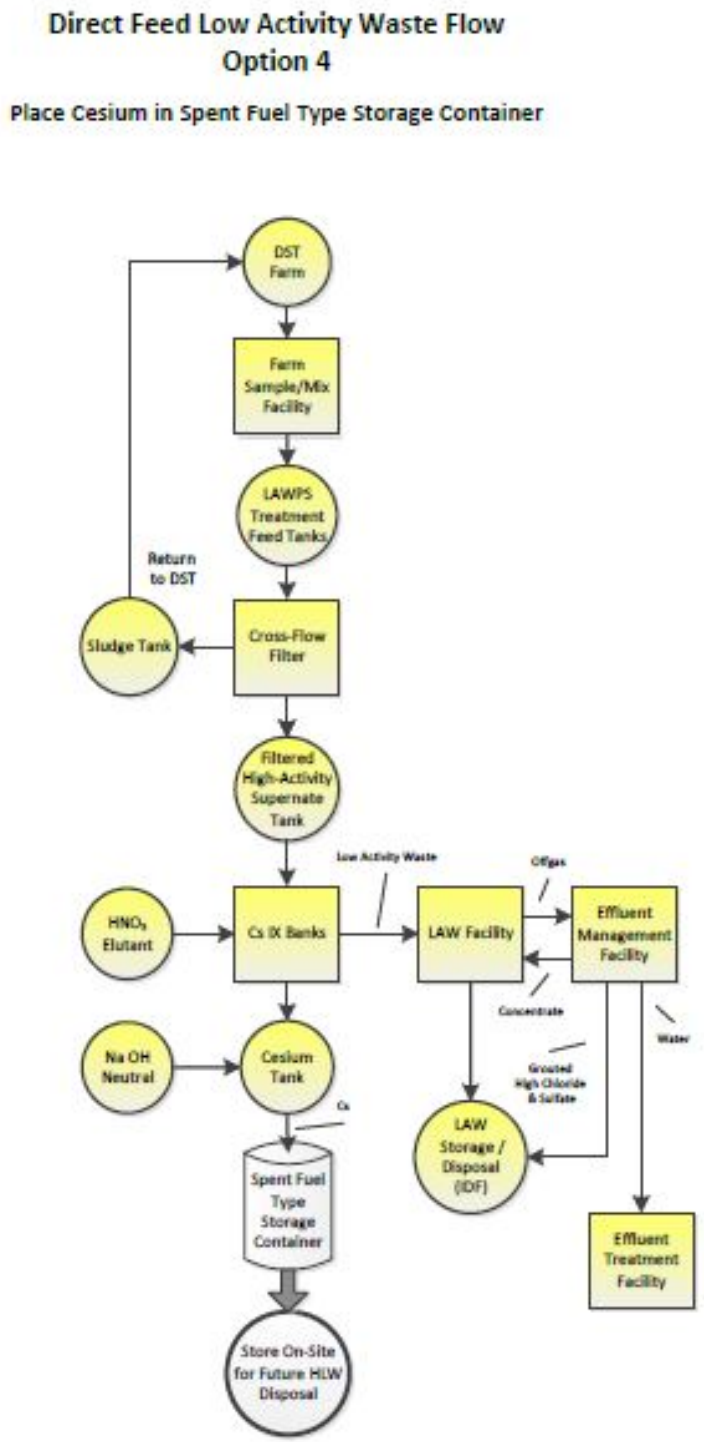
This disposal path would also require an additional cost of $200 to $340 million to package, ship, and dispose of cesium waste at WCS.

[3] Orphan wastes do not easily fit into the current waste classifications and therefore have no current existing long –term disposal options and potentially less future options than categorized wastes. Some examples of orphan waste are: cesium and strontium capsules, excess weapons grade plutonium, greater-than-Class-C LLW, depleted uranium, some special nuclear materials, and some mixed LLW.

Option 4– Place Cesium in Spent Fuel Type Storage or a Cesium Specific Storage Container for Future High Level Waste Disposal

Place cesium eluted from the current LAWPS resorcinol formaldehyde baseline resin process with HLW from LAW off gas in a spent nuclear fuel storage container. This would then be placed in a spent fuel type storage container for future HLW disposal or as future feed to the HLW facility.

An alternative would be to build a purpose-built DST to store eluted and neutralized cesium from LAWPS for future treatment in the HLW facility. The cesium tank needed would be about 1.5 million gallons in size and cost approximately $150-200 million to design and construct.

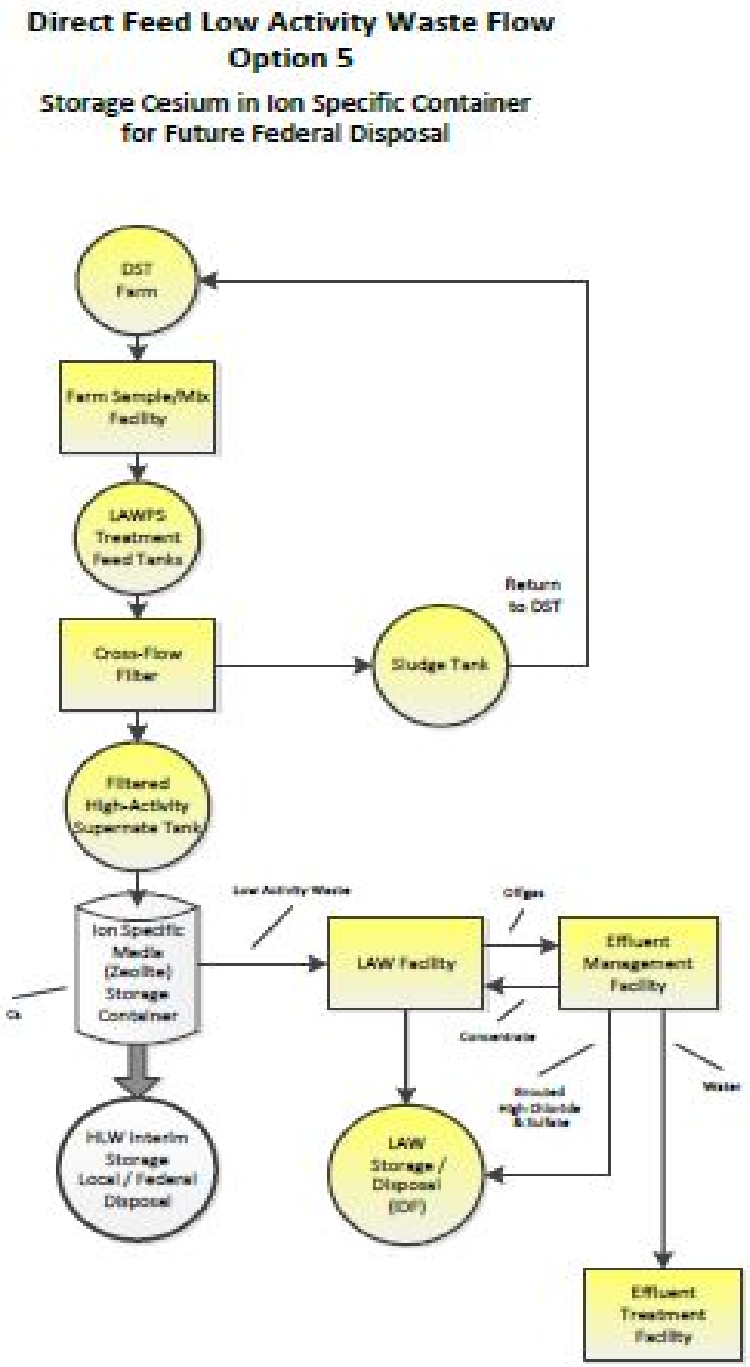


Option 5 - Store Cesium in Ion Specific Media for Future Federal Disposal

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW facility. The cesium would be captured using a non-elutable ion specific media such as zeolite or crystalline silicotitanate. The non-elutable media containing the cesium could then be stored on site in high integrity containers.

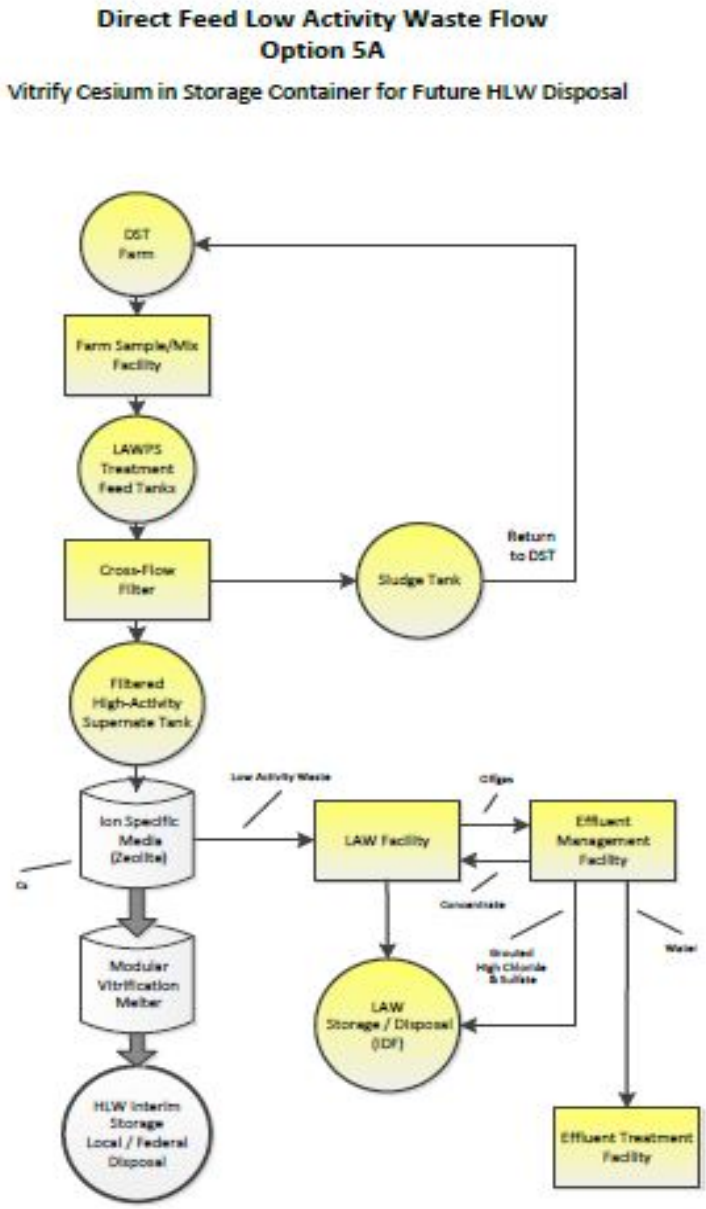
Secondary liquid wastes generated from the LAW Facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.

This process was developed and used extensively by Kurion[4] for removing the cesium contamination the water used for emergency cooling of the Fukushima Daiichi Nuclear Power Plant after it suffered major damage from the magnitude 9.0 earthquake and tsunami that hit Japan on March 11, 2011. Current photos of the plant site show row after row of these cesium containers stored for future treatment and disposal. There is currently no existing disposal path for these containers.



[4] Kurion is a corporation headquartered in Irvine, California with facilities in the United States, the United Kingdom and Japan. Kurion provides equipment, services and technology to address a variety of nuclear waste processing needs.

Option 5A - Vitrify Cesium Using Non-elutable Media, Place in Spent Fuel Storage Containers for Future High Level Waste Disposal



Kurion and Savannah River National Laboratory (SRNL) have proposed a modified Kurion system for cesium removal and interim storage in support of DFLAW; likely a zeolite or crystalline silicotitanate exchange media that is easily incorporated into glass- a Geo Melter.

The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste prior to vitrification in the LAW facility. The cesium is captured using a non-elutable ion specific media, the module containing the cesium is then vitrified in a modular vitrification melter and stored for future disposal in the federal deep geologic repository.

Secondary liquid wastes generated from the LAW facility off gas system would then be treated and volume-reduced through evaporation activities using the existing 242-A Evaporator in the tank farms.

Extensive research would have to be completed to verify that the modular vitrification could be performed on the cesium extraction media. Kurion is currently investigating a modular melter approach to address Japan's Fukushima Daiichi Nuclear Power Plant cesium contamination issues. If the modular melter option is found to be a viable option, this process could be used to vitrify the cesium in these containers. Until this process is proven and commercially available, these containers of cesium would have to be stored on the Hanford Site.

Even after a viable commercial modular melter process is available, the vitrified glass container must be in a form to meet the unknown waste acceptance criteria for the deep geological repository.