Topic: Cesium Management and Disposition Alternatives for the Low Activity Waste Pre-Treatment System
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Originating Committee: Tank Waste
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Summary

The Hanford Advisory 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 focused on the proposed management and potential disposal paths of the High Level Cesium Waste resulting from the LAWPS process. This review was performed at the request of DOE-ORP Federal Project Director, Low Activity Waste Pretreatment System, 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 Direct Feed Low Activity Waste scenarios?

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

The goal of this document was to identify and review alternatives to the current baseline of removing the High Level Cesium Waste and returning it to the double shell tanks. Specific consideration was made to assure that the alternative selected would not generate an additional waste form, which 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 1-10 years when radioactive cesium is incorporated in it at high Class C levels. Related alternative options were considered and labelled as a subset of each option.

The following Direct Feed Low Activity Waste Disposition Alternatives Process Flow Chart and the Disposition Alternatives Options Summary Table attempts to summarize the alternatives developed and discussed during presentations and on-site tours with DOE, represent an extended in-depth dialogue and analysis by members of the Board.

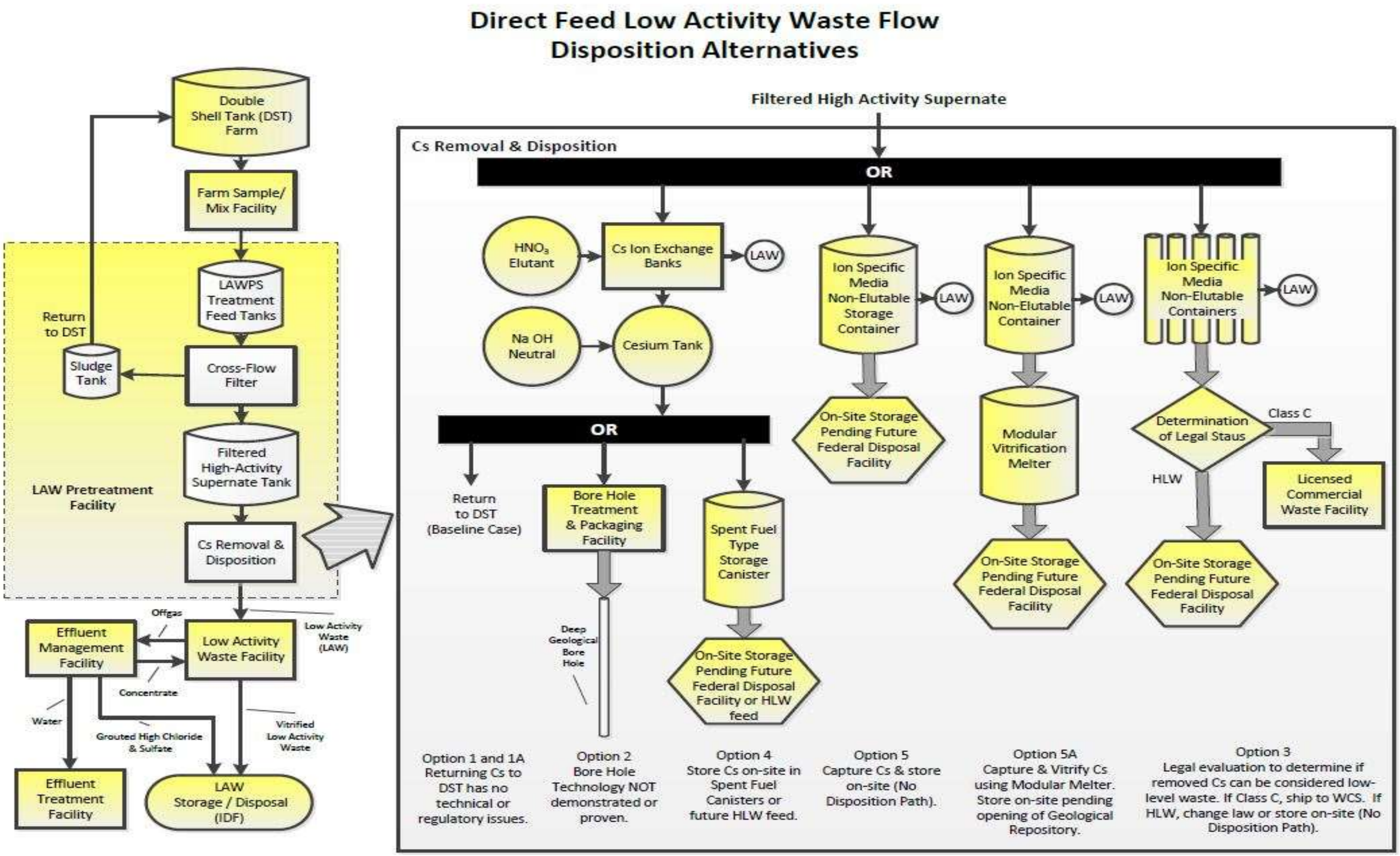
The Direct Feed Low Activity Waste Disposition Alternatives Process Flow Chart represents in graphical form an extremely simplified DFLAW processes on the left side of the diagram. The process block labelled "Cs Removal & Disposition" is expanded to show the potential cesium alternatives in the larger block in the center-left. Each cesium major disposition alternative that the committee 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 steam with the cesium removed is labeled "LAW" and flows to the Low Activity Waste Facility where it is vitrified into glass logs.

Cesium Management and Disposition Alternatives for LAWPS

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 paper.

Cesium Management and Disposition Alternatives for LAWPS



Disposition Alternatives Options Summary

Option	Description	Removal Process	DFLAW Cs Deposition	Technical	Legal / Regulatory	Comments
1	Return Cesium back to DST	Elutable[1] resin	DST then PT and HLW Vitrification		Acceptable	DFLAW baseline process
1A	Return Cesium to DST under optimized management plan and expedite Direct Feed HLW proposal	Elutable resin	DST then DFHLW Vitrification		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 of law – highly unlikely	If law is changed, send to WCS disposal facility
4	Place Cesium in Spent Fuel Type Storage Containers or in a Cs Tank for future high-level waste disposal	Elutable resin	On-site storage awaiting Deep Geological Repository	Eluted Cs for spent fuel type storage containers must be converted to solid form. Both process require a new facility or new DST	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

No options were identified 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 Double Shell Tank farms and not generate cesium in a form that would create a 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 to minimize cesium being extracted several times from tank waste, and also expedites the Direct Feed HLW proposal. 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 Direct Feed High Level Waste proposal DST solids are not processed by the Pretreatment 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 can be added directly into the HLW feed and vitrified into high level glass. DFHLW bypasses many of the Pretreatment unresolved 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 a lacks a detailed feasibility study and economic analysis. Projected potential savings of this option could range between $5-10 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 LLRW site located in Texas operated by Waste Control Specialists (WCS). Initially, it was felt this option would require a Waste Incidental to Reprocessing (WIR) determination to be Class C. However, upon looking at other regulatory requirements it was concluded that a controversial change in the law governing high-level waste would likely be needed. If the cesium were to be packaged as Class C waste in anticipation of modifying the law governing high level waste, and these regulatory requirements are 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

Background

Current DFLAW plans call for using an ion exchange process in the LAWPS to strip high level waste constituents, primarily highly radioactive cesium, from a waste stream from the tank farms creating a low activity waste feed for vitrification in the Low Activity Waste (LAW) facility. The cesium or high level waste would be returned to the existing waste tanks in the tank farms for later processing when the capability to process High Level Waste (HLW) in the Waste Treatment and Immobilization Plant (WTP) was available.

On September 24, 2013, the U.S. Department of Energy (DOE) released the Hanford Tank Waste Retrieval, Treatment, and Disposition Framework (Framework) document. This document describes a strategic framework for addressing the risks and challenges to completing the DOE Office of River Protection (ORP) mission by implementing a phased approach that would:

- Begin immobilization of the tank waste as soon as practicable through the Direct Feed Low Activity Waste (DFLAW) process.
- Process transuranic (TRU) tank wastes for disposal at the Waste Isolation Pilot Plant (WIPP).
- Resolve technical issues for the Pretreatment (PT) and High-Level Waste (HLW) Facilities, including determining how to adequately mix and sample the waste prior to processing, to enable design completion, and the 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 Waste Treatment and Immobilization Plant (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 facility (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, immobilization of any waste cannot occur per the current plan until the many technical issues involving the PT Facility are resolved. Therefore, an alternative approach for immobilizing waste as soon as practicable, while simultaneously resolving the remaining technical challenges, is identified. By adopting a DFLAW option in which the waste bypasses the PT Facility, waste immobilization could begin earlier than if treatment of the waste is delayed until all technical issues are resolved and the PT and HLW Facilities are completed.

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

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

The low-activity waste consists primarily of the supernate (liquid) portion of the tank waste with most of the solids and radioactivity removed before vitrification, low-activity waste will be the largest tank waste stream by volume (approximately 90% of the volume), but the lowest in radioactivity content (approximately 10% of the curies). Since the low-activity waste makes up approximately 90% of the total volume of waste to be treated, it 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. The low activity waste is also the tank waste 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 low-activity waste could be directly fed to the LAW Facility for glass immobilization.

ORP's analyses of this approach indicates that a stand-a-lone Interim Low Activity Waste Pretreatment System Facility (LAWPS) would best address this need. Located between the tank farms and the LAW Facility, the LAWPS would remove the solids and cesium from the liquid waste stream. In addition, some space has been 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 PT. 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 that is removed from the waste stream back to the double shell tanks. 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 Cs-133 and radioactive Cs-134, Cs-135, and Cs-137. Cs-134 has mostly decayed away, leaving Cs-135 and Cs-137. Cs-137 decays to Ba-137m which decays to Ba-137. This is the principle gamma source in tanks. There is ~3 to 4 times more total cesium than radioactive Cs-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/Pretreatment. 7 of 12 tanks scheduled for DFLAW already have high hydrogen generation rates.
- Cesium places more radiation/heat stress on tanks; some are nearing their design life.

- Cesium return to the DSTs is more expensive and creates more waste; the approach is cheaper in the short run and costlier in the long run.
- Returning cesium takes up tank space; less free DST space therefore is available.

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 ~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 3 parts volume removed from DSTs, ~1 part volume is retuned to DSTs using DFLAW) is from LAWPS resin pretreatment, LAWPS resin post cesium elution reactivation, and from LAW off gas processes, and ETF brine volume from all sources. This 24% of volume returned to the tanks includes significant reduction by evaporation by a factor of ~2.5 or slightly more. The large majority of this is from LAW off gas.

Cesium Disposition Alternatives

As requested by DOE in the Hanford Advisory Board (Board) 2015 and 2016 Work Plan, the Board has conducted a review of the preliminary design associated with the DFLAW and the possible alternate cesium removal, storage, and disposition technologies that may be considered for use in the DFLAW.

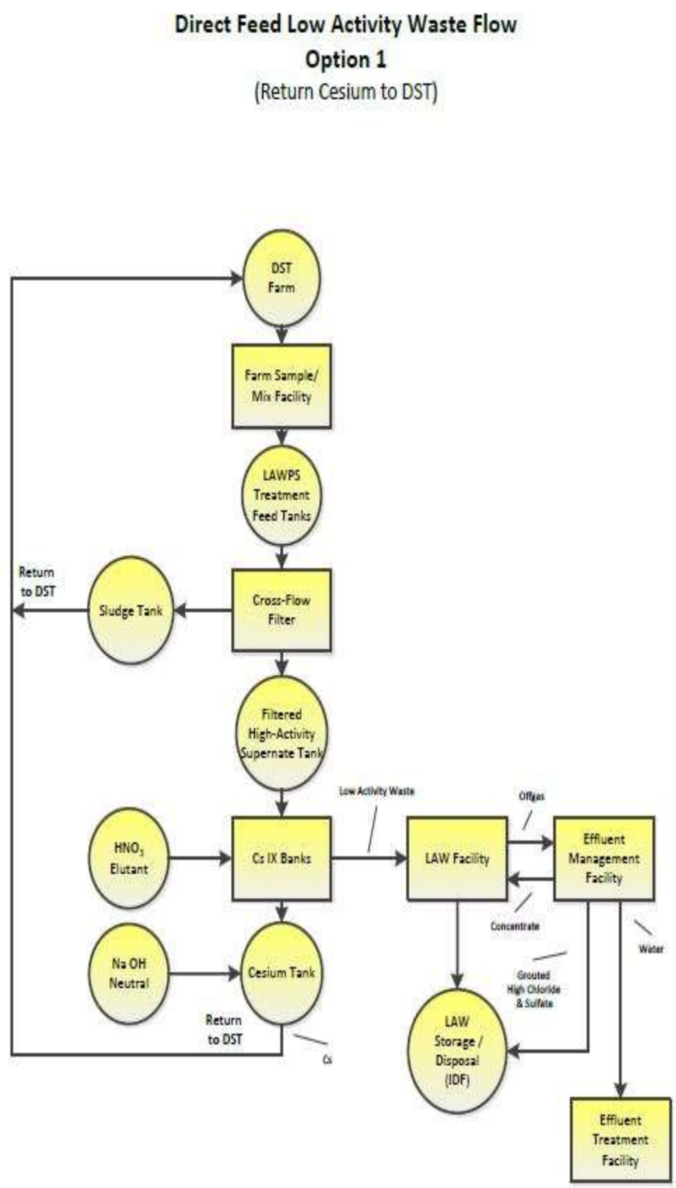
The following alternatives were developed and considered for the disposition of the Cesium removed from the waste steam as part of the DFLAW process.

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, then eluted[2] with nitic acid, neutralized and returned to the Double Shell Tank farms to a wait vitrification in the High Level Waste 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.



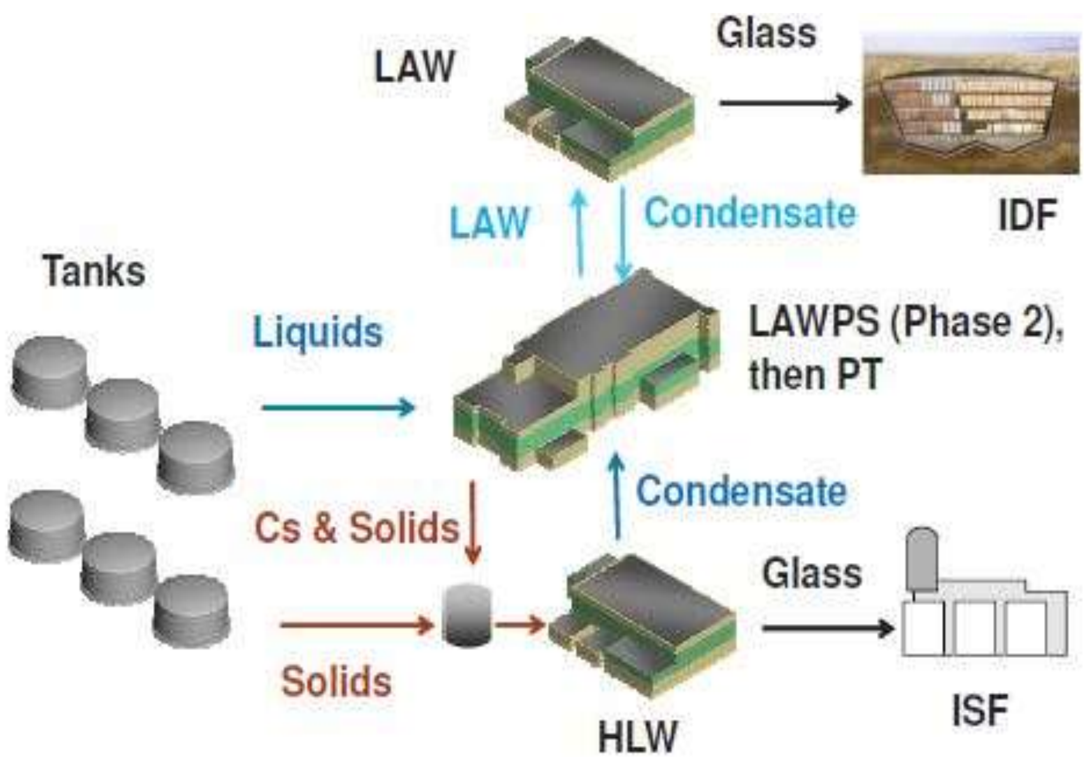
[2] To elute means to remove by dissolving, such as removing absorbed material from an adsorbent, in this case cesium from ion exchange or ion capture material. Elution is the action of eluting a material from a substance. Elutable means that it is practical to and can be removed. Non-elutable means 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 is irreversibly bound in or to the media. In other uses, elution is often accomplished using solvents. That would not apply here.

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 a cesium management to minimize cesium being extracted several times, and expedite Direct Feed HLW.

The cesium management plan will process low cesium waste first to return less total cesium to DSTs and thus free up DSTs capacity for cesium waste, which would be sent to HLW without further cesium removal. In the Direct Feed High Level Waste proposal, DST solids are not processed by the Pretreatment 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 will be added directly into the HLW feed and vitrified into high level glass. DFHLW bypasses many of the Pretreatment unresolved technical issues.

Initial runs of the DFLAW would process low concentration cesium supernatant only (no saltcake in initial runs). Initial process sequence for DFLAW tanks is: 1st tank AP-104, 2nd tank AP-106, 3rd tank AP-103, and 4th tank AP-108, and 5th tank AP-102). Total supernatant processed is 3 million gallons. Designate several DSTs as cesium eluent storage tanks as soon as practical. Expedite Direct Feed HLW process by installing a 100,000 gallon below ground DST tank with some solids/liquid separation capability, large single (replaceable) mixing impeller, hard installed sampling ports, small sampling and ventilation support building, and related underground piping. All tank sludge solids and some related saltcake retain in sludge transfers are to be process by Direct Feed HLW without any pretreatment extraction of any kind for the life of the mission. Once Direct Feed HLW is operational direct all cesium from LAWPS process and cesium eluent previous in DSTs to HLW glass. Once Pretreatment Facility is



complete integrate off gas of all glass plants and processes. Expose Pretreatment Facility to minimal entrained solids; only if absolutely necessary for some select HLW glass batches use Pretreatment 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, with the DFHLW approach does have an acceptable regulatory and technical path forward.

The DFHLW concept is currently only in the proposal stage, and a lacks a detailed feasibility study and economic analysis. Projected potential savings of this option could range between $5-10 billion.

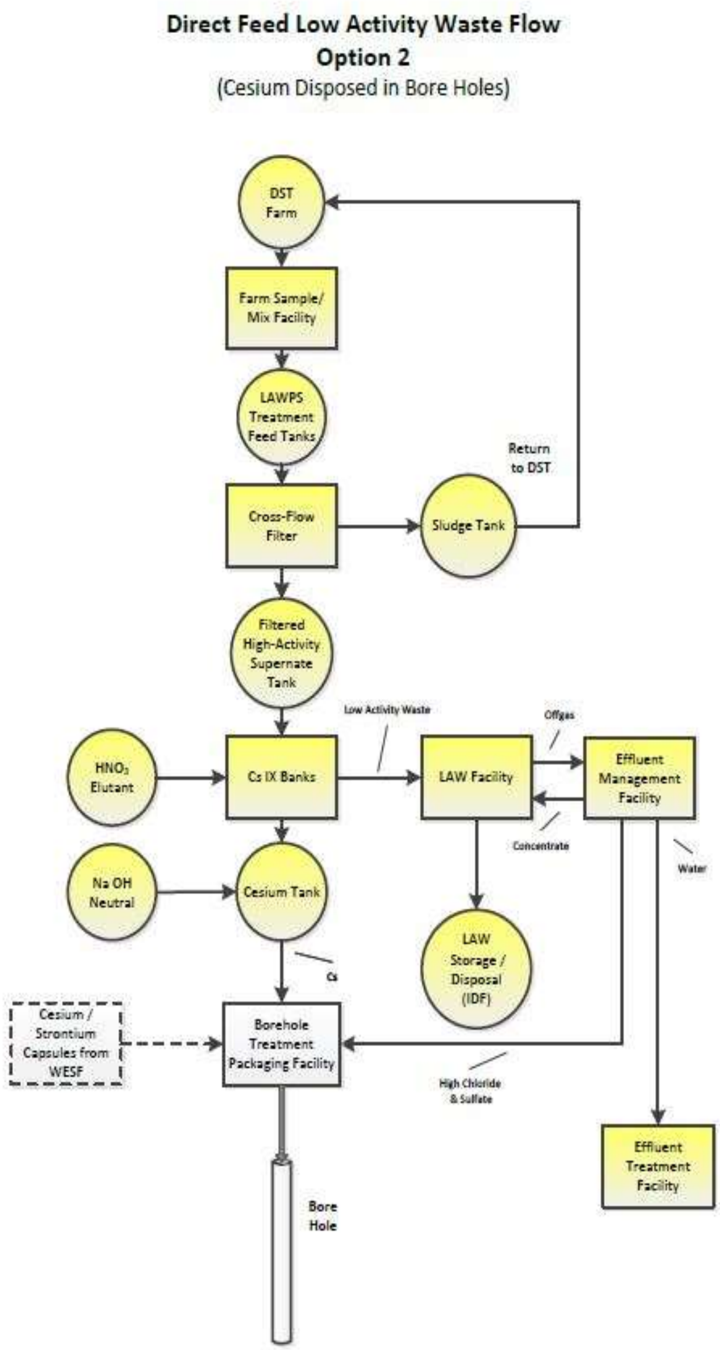
Option 2 - Dispose of Cesium in Deep Geologic Bore Holes

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, then eluted with nitic acid, neutralized, and treated and packaged for disposition in a deep geologic Bore Hole.

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 Bore Hole approach has many technical hurdles to overcome. It is an unproven technology. Furthermore, feasibility tests of the concept have not yet started and are, 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 approach highly uncertain.



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

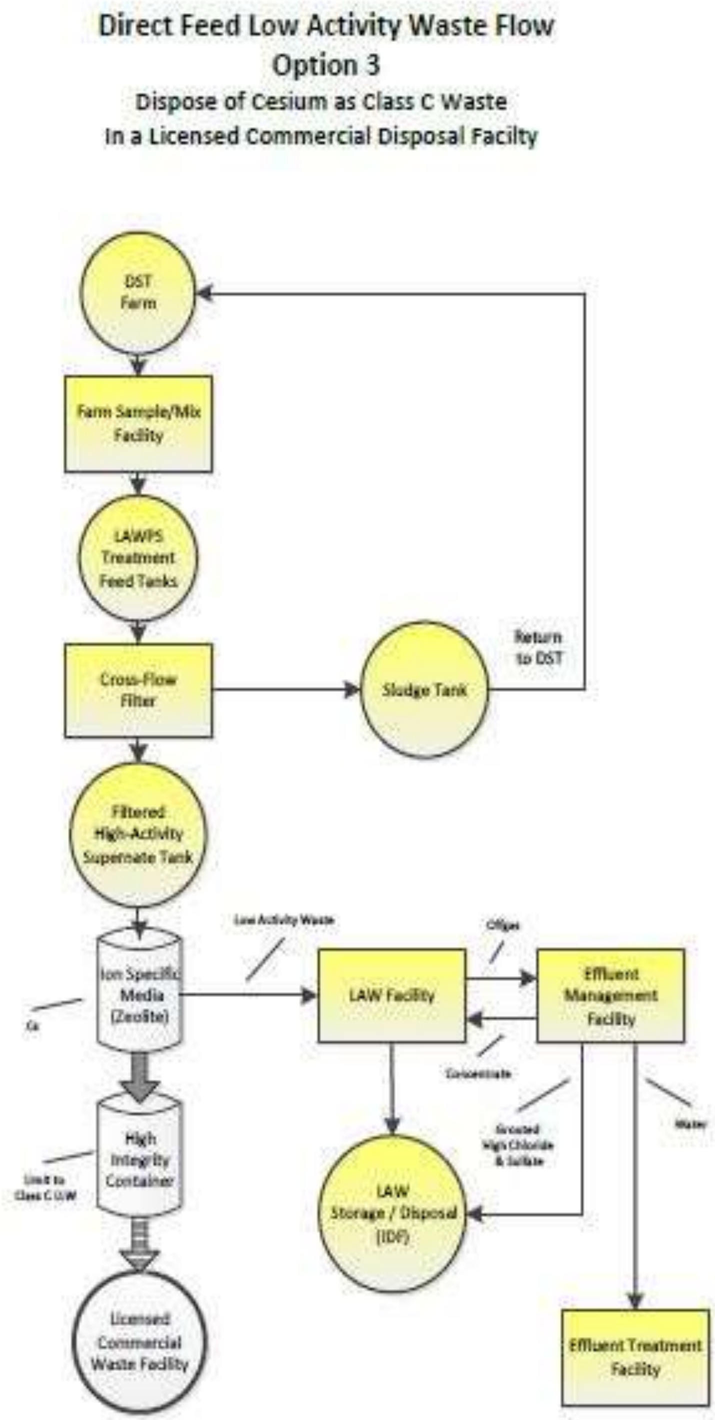
The solids and cesium and possibly other radioactive elements will be removed from the liquid waste stream from the tank waste using a non-elutable media. The resulting low activity waste stream is then vitrified in the LAW Facility.

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 Texas Federal LLRW site located in Texas which is operated by Waste Control Specialists (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 Texas Federal LLRW site at Texas WCS has a current maximum Curie limit of 5.6 MCi. WCS can currently accept ~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 LLW Class C. The current Curie restriction at WCS will allow at best the ability to free up ~4 million gallons of DST space and accept 20-40% of LAWPS operational life cesium output.



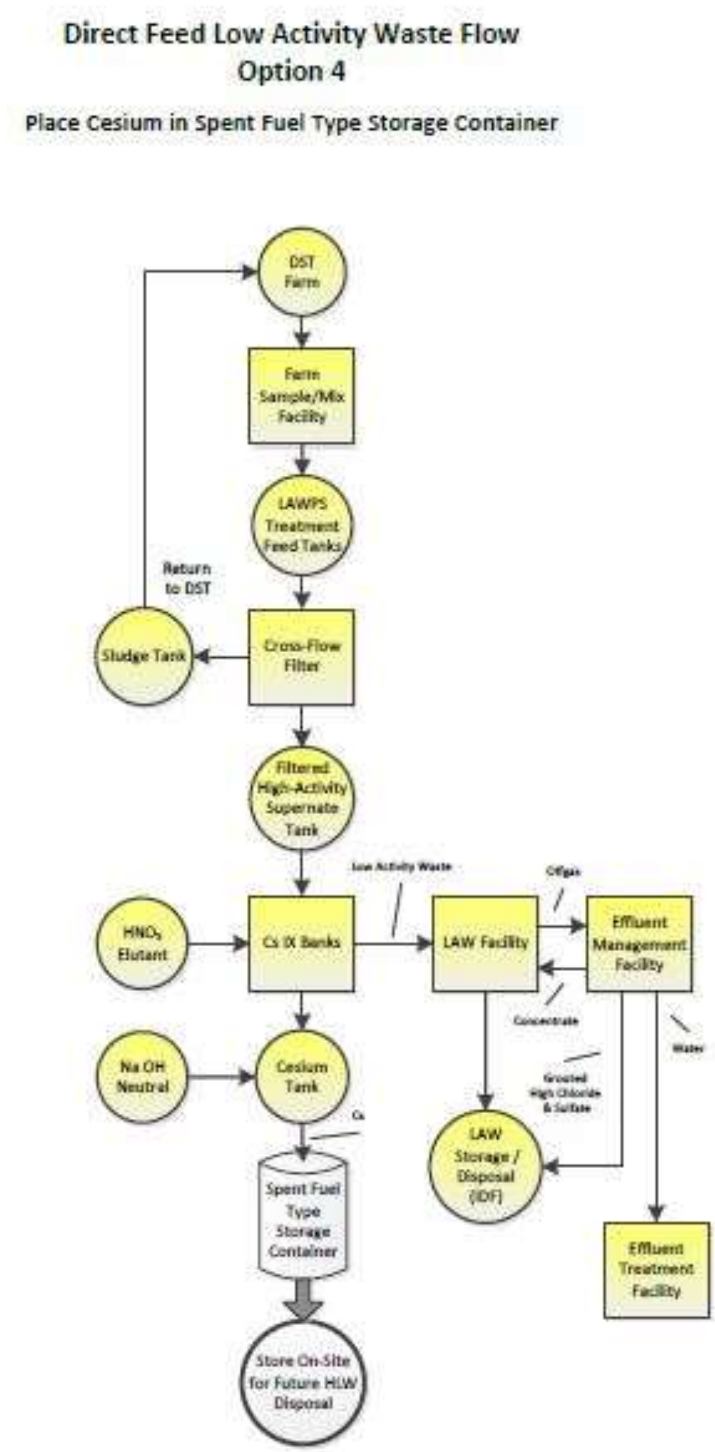
This option would likely require a controversial change in the law governing the definition of high-level waste. If the cesium were to be packaged as Class C waste in anticipation of modifying the law governing high level waste, and these regulatory requirements were not successfully resolved, the cesium waste canisters could end up stored, long term, on the Hanford Site.

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

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

Place cesium eluted from current LAWPS resorcinol formaldehyde baseline resin process and possibly also the high level off gas waste from LAW in a spent nuclear fuel storage containers. The cesium eluent and possible off gas liquid would have to be solidified to place in spent fuel or high integrity container. A likely method to convert these liquids into solids would be evaporator concentration and absorbing on silica gel to make a granular powder. Place in a spent fuel type storage container for future high level waste disposal or as future feed to the High Level Waste Facility. Disposal costs are estimated at $320 million. (Note WRPS disposal costs are estimated at $626 million because of an inflated Federal Depository costs and not taking advantage of rail shipment savings.)

Another alternative would be to build a purpose built DST to store eluted and neutralized cesium from LAWPS of future disposal in HLW. The cesium tank needed would be about 1.5 million gallons in size and cost approximately $150-200 million.

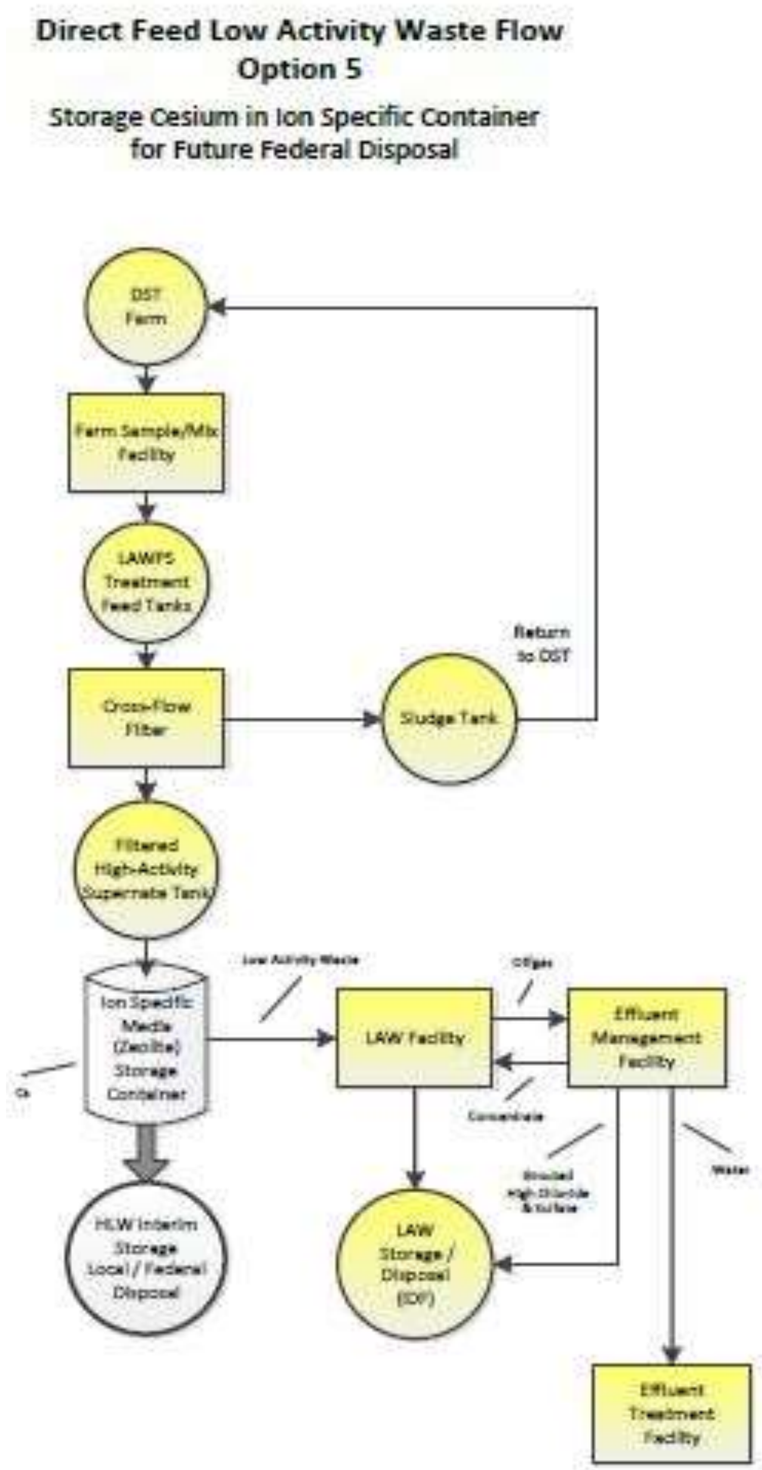


Option 5 - Store Cesium in Ion Specific Media for Future Federal Disposal

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[3] 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 current existing disposal path for these containers.



[3] 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.

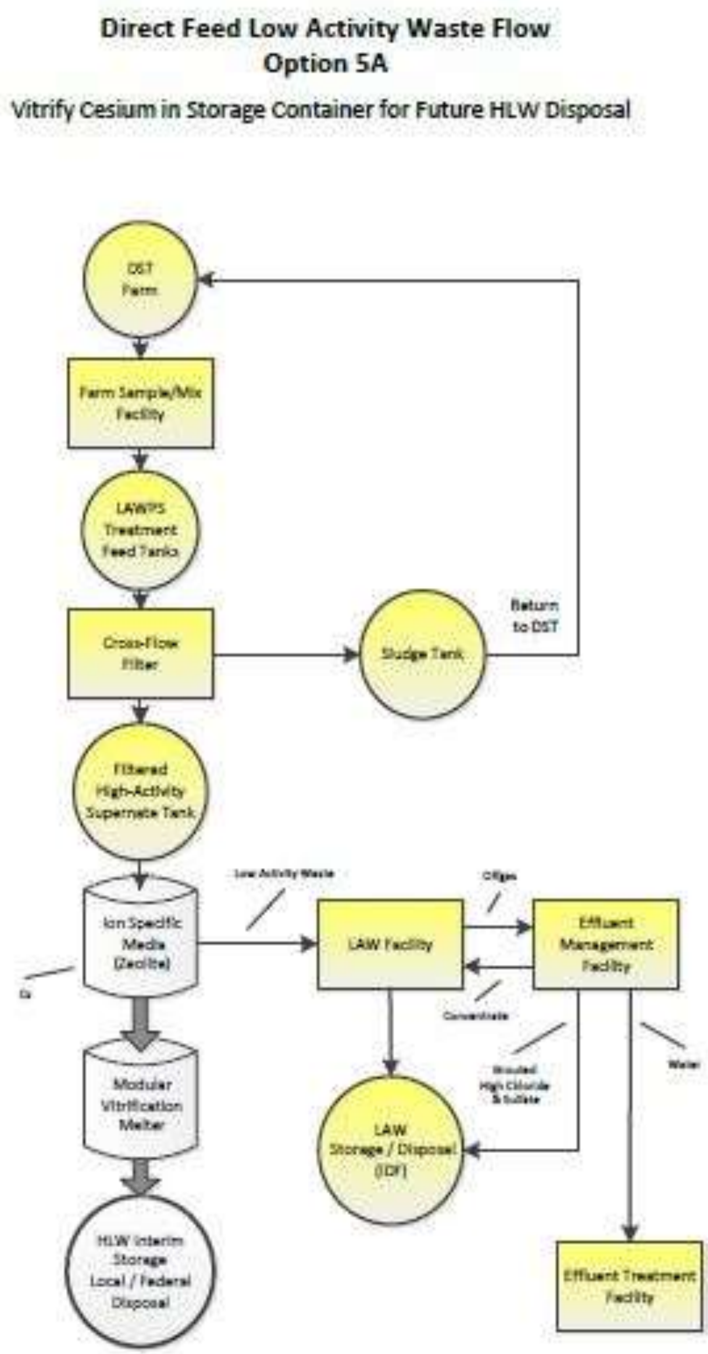
Option 5A - Vitrify Cesium using non-elutable media, place in spent fuel storage containers for future high level waste disposal

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, 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 Cs resins. 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 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.