ACCELERATING THE CLEANUP OF HANFORD’S TANK WASTE: MEETING THE 2028 COMMITMENT

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ABSTRACT

Over the past two years, the Department of Energy (DOE) Office of River Protection (ORP) has made significant advances in its planning and execution of the River Protection Project (RPP), charged with cleaning up the Hanford tank waste. The 149 single-shell tanks (SSTs), 28 double-shell tanks (DSTs), and 61 miscellaneous underground storage tanks (MUSTs) at Hanford contain approximately 200 million liters (53 million gallons) of mixed radioactive wastes, some of which dates back to the first days of the Manhattan Project. The RPP is the largest environmental cleanup project in the United States.

As we entered the new millennia the RPP faced substantial issues. Under the planned approach a Phase I waste treatment plant (WTP) was to be built and operated to treat 10% of the tank waste by mass, containing 25% of the total radioactivity by 2018. During Phase I additional WTP facilities were to be constructed to treat the remaining 90% of the waste. Although the Tri-Party Agreement (TPA) between DOE, the Washington Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) required treatment to be completed by 2028, the WTP throughput capacity necessary to treat the remaining 90% of the waste between 2018 and 2028 was unrealistic from a size perspective (roughly six times the size of the current waste treatment plant which, by itself, is the largest in the world) and cost perspective to actually be put into place. Consequently, the total time for cleanup extended into the second half of this century with a price tag of at least $56 billion, no clearly delineated plan leading to completion, and low confidence in the total projected cost.

As part of DOE’s initiative to accelerate the reduction of risk associated with the Environmental Management (EM) projects, the RPP developed a new philosophy and approach to cleanup. Rather than use a one-size-fits-all strategy to treatment as had been envisioned during privatization, we looked more closely at the waste and aligned our treatment and disposal approaches with the waste characteristics. This strategy identified some waste that could be treated outside of the WTP. We also reconfigured the WTP to quadruple the high-level waste (HLW) vitrification throughput at the on-set of treatment operations. We worked with Ecology, the EPA, and waste treatment technology experts from across the nation to identify supplemental technologies for treating much of the low-activity waste (LAW). Three technologies; bulk vitrification, cast stone, and steam reforming were subsequently evaluated with bulk vitrification being selected for testing at Hanford.

We also reconfigured our tank farm plans to accelerate SST waste retrieval and to start closing the SSTs a dozen years sooner than previously planned.

The result in terms of plans is a 20-year reduction in the mission completion date, a greater than $20 billion savings in life cycle costs, and alignment of the overall RPP with the dates committed to in the TPA. This strategy has been independently reviewed, approved, and is being managed as the lifecycle cost baseline for completing cleanup of Hanford's tank waste by 2028.

INTRODUCTION

The DOE ORP is responsible for the RPP including all management and cleanup activities associated with the radioactive tank waste inventory generated during the 50 years of nuclear materials production at the Hanford Site in Washington. This inventory includes more than 200 million liters (53 million gallons) of radioactive mixed waste stored in 177 large underground tanks and 61 smaller miscellaneous tanks. The waste contains greater than 7 million TBq (190 million curies) of radioactivity. Another 5.5 million TBq (148 million curies) of cesium-137 and strontium-90 and their daughter nuclides were removed from the tanks during active operations in the 60s and 70s, both to reduce the radioactive decay heat load and to provide those isotopes to government and industrial users with a need for irradiation or heat sources. Those isotopes are now in approximately 1900 double-wall stainless steel capsules stored at Hanford and approximately 30 glass logs that were produced for research purposes, also stored at Hanford.

Of the 177 large underground tanks, 149 are older SSTs that are decades beyond their design life. Sixty-seven of these tanks are known or assumed to have leaked approximately 2-4 million liters (0.5-1 million gallons) of waste into the surrounding soil. While most of the liquid waste has been removed from the SSTs under our Interim Stabilization initiative, the SSTs still contain approximately 114 million liters (30 million gallons) of mostly solid sludge and soluble salt cake. None of the newer 28 DSTs are known to have leaked and are in active storage service.

The tank wastes are maintained at a high pH to protect the carbon steel tanks from corrosion. The combination of high pH and extensive evaporation campaigns during nearly 50 years of active operations to free up tank capacity resulted in concentrated chemical wastes in three phases; sludge, salt cake, and supernatant (liquid). The sludge is primarily insoluble metal hydroxides. The salt cake is primarily soluble sodium nitrate and sodium nitrite salts. The supernatant is caustic liquid saturated with the sodium salts. All three waste phases also contain varying quantities of phosphates, carbonates, oxides sulfates. All-in-all, over 1600 chemical compounds have been identified in the wastes. Approximately 98% of the radioactivity (curies) is attributable to cesium-137 and strontium-90 and their secular equilibrium daughter products, barium-137m and yttrium-90.

Mission and Drivers

In 1989 the DOE, EPA, and Ecology entered into an agreement on how to bring Hanford facilities into compliance with the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This agreement, commonly known as the TPA, established enforceable milestones for cleaning up the Hanford Site. The TPA provides the basic framework for the Hanford cleanup. Along with DOE Orders and other State and Federal laws and regulations, the TPA establishes various criteria, milestones, and schedules for the RPP. For the tank farms, Ecology is the lead regulatory agency, which results in the cleanup actions being conducted under RCRA. Under RCRA, the State has regulatory authority over the hazardous constituents in the wastes as well as RCRA permitted facilities where wastes are stored, treated, and disposed. DOE has regulatory authority for radioactive materials under the Atomic Energy Act of 1954 as amended and several other laws that speak to DOE's authority.

The RPP mission is to store, retrieve, treat, and dispose of the tank waste in an environmentally sound, safe, and cost-effective manner. The plan to accomplish this mission includes the following steps:

(1) Retrieve at least 99% of waste in accordance with the TPA.

(2) Pretreat the retrieved waste to separate it into a decontaminated LAW fraction that contains nearly all of the chemical constituents and a HLW fraction that contains approximately 93% of the radioactivity currently remaining in the tanks[a]. Pretreatment is accomplished via a variety of standard industrial chemical and mechanical separations techniques customized to Hanford tank waste characteristics.

(3) Immobilize both the HLW and the LAW fractions using borosilicate glass as the waste form.

(4) Dispose of the LAW near-surface on-site at Hanford in mixed waste disposal cells permitted by the State of Washington.

(5) Store the HLW glass logs in secure on-site facilities until the HLW can be shipped to the federal geologic repository for disposal.

(6) Stabilize the residue waste remaining in the tanks after retrieval using techniques approved by the State of Washington and then close the tanks and tank farms using a defense-in-depth closure approach wherein multiple natural and engineered barriers mitigate potential long-term groundwater and human intrusion risks.

(7) Turn the closed RPP facilities over to the Office of Legacy Management for long-term monitoring and institutional control.

Project Acceleration

As we entered the new millennia the RPP faced substantial issues. The Tank Waste Remediation System (TWRS) plan was headed towards failure due to continued price growth including a $15 billion price tag for the Phase I waste treatment demonstration. Under that plan, a Phase I waste treatment plant (WTP) was to be built and operated to treat 10% of the tank waste by mass and 25% of the total radioactivity. That treatment was to be completed by 2018. During Phase I additional WTP facilities were to be constructed to treat the remaining 90% of the waste in the 10-year Phase II period between 2018 and 2028 when all treatment was required to be completed under the TPA. Cramming 90% of the treatment into a 10-year period required the initial WTP to expand by a factor of six; to greater than 150,000 metric ton of glass throughput per day. Building new facilities to reach that throughput capacity and then running the facilities for only 25% of their design life was logistically and fiscally unrealistic. Consequently, the expectation was cleanup would not be completed until the second half of this century and the price tag would be at least $56 billion. There was, however, no clearly delineated plan leading to mission completion and there was low confidence that the total projected cost would be sufficient.

The new millennia also brought a new Administration with a strong commitment to accelerate the reduction of risk associated with all DOE Environmental Management (EM) projects. Over the past three years, the ORP has made significant advances in its planning and execution of the tank waste cleanup. Consistent with the Administration’s directives to accelerate risk reduction, the RPP developed a new philosophy and strategy for cleanup.

One pivotal change was that, rather than use a one-size-fits-all strategy for treatment as had been envisioned, to look more closely at the waste and align our treatment and disposal approaches with the waste characteristics. This was an important change because of substantial tank-to-tank differences in the Hanford tank wastes that resulted from the Hanford operations history. Hanford was the pioneer site where spent fuel reprocessing techniques were developed and deployed starting with the Bismuth Phosphate process in the 40s and 50s, to the REDOX process in the early-50s, and finally to the PUREX process in the late 50s, the standard process that was then used at the other DOE sites as well as in commercial industry. Similarly, fuel designs evolved during the same period. Fuel claddings evolved from aluminum to zircalloy, resulting in chemistry changes, and fuel burn-up levels increased substantially. Finally, various campaigns were conducted to remove specific radioisotopes from the tanks for research and other purposes which resulted in additional chemical wastes being created.

The combination of evolving reprocessing and reactor/fuel designs led to substantial radiological and chemical differences in the wastes from tank-to-tank. Some tanks contain sludge waste that, if loaded into 208 liter (55-gallon) drums today, would be contact-handled while others contain salt cake and liquids with dose rates greater than 100,000mGy (10,000 rad) per hour. The highest radionuclide inventory tanks contain over 20,000 times as much radioactivity as these lowest radionuclide tanks. Since treatment facilities must be designed to handle the worst of the waste, separating the waste on the basis of its radiological characteristics enabled us to design facilities and disposal pathways that made sense for various categories of waste. Abandoning the one-size-fits-all approach opened up new options for not only treatment, but also retrieval and disposal.

Waste Retrieval

We completed our SST interim stabilization program in 2004. This multi-year program removed the pumpable liquids from the SSTs and transferred the liquids to the newer, more leak resistant DSTs. Completing interim stabilization was an important milestone because without liquids, the potential for leakage during storage is greatly reduced. Interim stabilization does not eliminate risks from the SSTs, however. The SSTs are all at two or three times their design lives and, at some point, we will need to reintroduce liquids into those tanks to retrieve the wastes. At that time we will face the risk of leakage through new or existing leak pathways, a foreseeable situation which gave impetus to devising new ways to retrieve wastes using techniques that lessened driving forces leading to leakage.

At the millennium change, the focus was on conducting retrieval demonstrations using different retrieval techniques that would allow us to meet our 99% or more retrieval goals while also reducing the water head in the tanks during retrieval. We modified our focus from simply testing techniques on a few tanks to retrieving as many tanks as soon possible, learning as we go to apply the most appropriate retrieval method or methods to each tank.

We face several challenges during retrieval.

First, retrieval disturbs wastes, some that have been relative quiescent for decades. As the wastes are broken up during retrieval, potentially hazardous vapors are released at accelerated rates, thereby increasing worker protection challenges and worker concerns. We have brought in national expert toxicologists and risk assessment people in the nation to analyze and mitigate these risks and will continue to do so until we and our workers have full confidence that all risks are understood and all workers are fully protected. Our objective is to understand and mitigate vapor risks in the areas that workers will or may occupy. This is an ongoing initiative.

Second, much of the waste is like metallic peanut butter. It is insoluble, difficult to get to, and as we strive to remove the last few percent, it is difficult to sluice or suck it from the tank. When we are approaching the volumes the TPA allows to remain, there is roughly 2-3 cm (~1 inch) of waste depth distributed across a tank that is over 20 meters (75 feet) in diameter and 9 – 12 meters (30 – 40 feet) in height. Moreover, the tanks were designed for putting wastes in; not for getting wastes out. The typical SST has a few small openings through which pumps and other retrieval equipment can be inserted, which gives rise to situations analogous to getting the ship into and out of the bottle. We have developed retrieval techniques that use low-head sprays to dissolve and remove wastes as well as vacuum, hydraulic, and robotic techniques that enable us to move wastes within a tank to locations where greater retrieval is possible. We used multiple modified low-head sluicing and oxalic acid leaching cycles to retrieve our first tank, C-106. Roughly 1.5 million liters (400,000 gallons) of water and acid were used in sequential batch operations to retrieve the last 68,000 liters (18,000 gallons) of sludge from C-106. Our TPA goal was to leave no more than 10.1 cubic meters (360 cubic feet) of residue in the tank. Our analyses indicated a mean value that was 0.3% below the TPA goal, however, given uncertainties in volume measure methods, we were unable to reach consensus with Ecology that the goal was met. Instead, we were required to go through a TPA Appendix H process to obtain Ecology agreement on an alternate end point. That process is still ongoing. Meanwhile, we are proceeding with the retrieval of several other SSTs, some salt cake and some sludge.

A third challenge is that the wastes are not only radioactive; they are also chemically and physically hostile. The wastes tend to eat up pumps and equipment leading to failures and expensive replacements during retrieval. We continue to seek better pump designs and materials to reduce equipment failures, however, since worker protection protocols typically result in abandoning high radiation dose rate equipment in tanks once retrieval is complete, we also must balance equipment costs against projected service life.

A fourth challenge is that the space within the DSTs where the retrieved wastes are sent is limited and will continue to be limited until the waste treatment plant comes on line and starts removing wastes from the DSTs. To overcome the shortage of free DST storage space to store the retrieved SST wastes, a number of changes are being implemented to make additional space available in the DSTs. These include increasing the working capacity of some DSTs, consolidating waste, and realigning operational emergency reserved space requirements to the current cleanup project needs. We have also identified some tank waste that can be treated outside the WTP using techniques we should be able to bring on-line earlier with minimal need for DST space.

Finally, accelerating waste retrieval enables us to work with our regulators, stakeholders, and Tribal Nations to address difficult value issues such as leak detection and the acceptability of any leakage during retrieval and legal and regulatory issues such as whether the TPA waste retrieval goals are sufficient to declare retrieval complete. A voter initiative that passed in Washington State last November, Initiative 297, while ostensibly directed at keeping out of state waste from coming to Hanford, also appears to have replaced the TPA's quantitative retrieval goals with subjective criteria that could make retrieval completions elusive for indeterminate times into the future. We believe it is better to address these issues by moving forward with specific tanks and dealing with the issues as they arise rather than reverting back to paralysis by analysis.

Waste Treatment

Waste treatment is on the critical path to project completion and is the highest cost element. The $5.8 billion WTP that is now under construction and scheduled for hot startup in 2010 is the cornerstone. However, as previously mentioned, the WTP cannot treat all the waste by 2028. Our approach to this issue is two-fold.

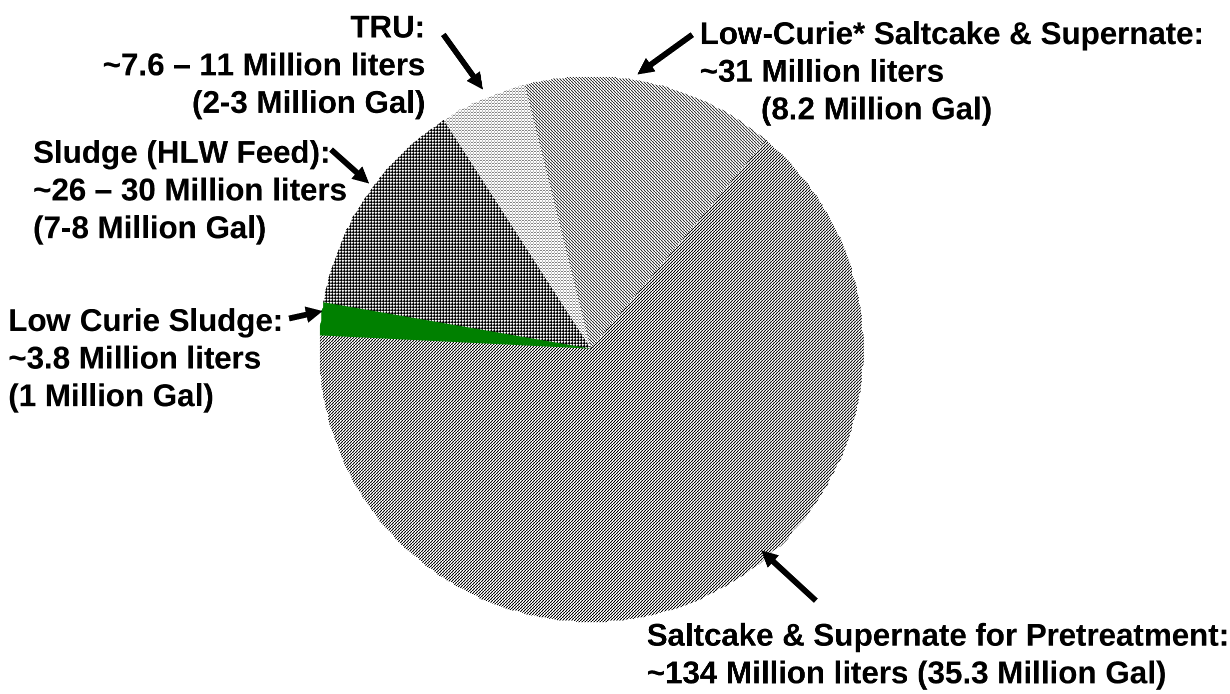
First, rather than following the two phase TWRS paradigm, we elected to make our WTP as productive as possible from the start. Second, we looked more closely at the characteristics of the waste in each tank to determine the most appropriate treatment and disposal pathway.

Relative to the first part of our approach, we redesigned to replace the single 1.5 metric ton of glass per day (MTGD) HLW melter with two 3 MTGD HLW melters. On the LAW side, we replaced the three 15 MTGD LAW melters with two 20-plus MTGD LAW melters. We were constrained from adding a third higher capacity LAW melter due to other limitations in the LAW melter building design that could not deal with throughput rates greater than 40 – 45 MTGD.

Unfortunately, the LAW throughput must be 10 to 15 times greater than the HLW melter capacity due to a roughly 10:1 ratio of LAW to HLW when the wastes proceed through pretreatment as well as extra burden placed on the LAW melters due to process chemicals added during pretreatment and internal recycles. Unless the full LAW capacity is provided, the HLW melters cannot run at full capacity and full HLW melter capacity is required to complete treatment 2028 as required by the TPA.

Relative to the second part of the approach, we broke down the wastes into categories based upon their origins, history, and radiological characteristic. By looking at the waste characteristics more closely, we determined that the wide variations in radionuclide and chemical content opened potential pathways to use alternate treatment and disposal approaches for some wastes as identified in Figure 1.

For example, we determined that it was economically desirable to treat and dispose of 8-11 million liters (2-3 million gallons) of sludge that was created outside the actual reprocessing of the spent nuclear fuel as TRU waste rather than HLW. Although it has been known for decades that the waste did not meet the strict definition of HLW, under the previous strategy it was believed that it would be less expensive to combine that sludge with HLW than it would be to create a parallel treatment path as TRU. Our analysis indicated the opposite; processing that sludge through the HLW melters would not only require 3 – 4 years of HLW melter time, it would also create an additional 1000 – 2000 HLW canisters that are expensive to store and tough to dispose of given the limitations at Yucca Mountain. Using nearly dry retrieval techniques, we can retrieve, dry and package that sludge far more cost effectively. Moreover, much of the sludge is contact handled and should not take up valuable repository space. We face regulatory challenges with State of Washington treatment permits and a State of New Mexico Class 3 WIPP Hazardous Waste Facility permit modification, both of which are required. Nonetheless, this is such a clear cut pathway to accelerate risk reduction by isolating those wastes via deep geologic disposal decades before previous plans allowed, we will continue to meet the challenges and I believe we will persevere.



* <0.05 Ci/liter Cs-137 @ 5 molar Na concentration. Not "highly radioactive" based on radionuclide content. Only requires liquid/solids separation prior to immobilization and disposal as a low-level waste (based on analysis concurred in by NRC).

Fig. 1. Hanford tank waste based on radioactive constituents

As previously noted, our LAW waste immobilization capacity needed to be increased significantly to complete waste treatment by 2028. This could be accomplished by constructing additional WTP type LAW vitrification facilities; or, to find a supplemental immobilization method that was separate from but running in parallel with WTP. We worked with Ecology, the EPA, and waste treatment technology experts from across the nation to identify supplemental technologies for treating the massive volume of LAW. Together, we identified three technologies that we subsequently evaluated in detail: bulk vitrification, cast stone, and steam reforming.

Cast stone (grout) is no longer being pursued for the LAW, although it might have use for secondary wastes, because that waste form is not as good as that produced by either bulk vitrification or steam reforming. ORP is testing bulk vitrification as its primary candidate for LAW supplemental treatment due to process simplicity and stakeholder and regulatory preferences for glass, however, steam reforming is being tested in parallel at other DOE sites and is a backup should bulk vitrification not prove out or issues arise with secondary waste. Bulk vitrification also fits within the Record of Decision (ROD) issued for the TWRS Environmental Impact Statement (EIS), which indicated that the LAW would be vitrified, as well as agreements reached with the U.S. Nuclear Regulatory Commission in the late 1990s that stipulated that the LAW would be vitrified.

Among the perceived advantages associated with bulk vitrification is that it is modular in nature and substantially less complex than the WTP LAW melter system. This opens potential opportunities to bring bulk vitrification on-line sooner than other LAW immobilization approaches. Also, as indicated in Figure 1, a significant fraction of the waste is low curie salt that has Cs-137 concentrations below those that the NRC agreed were practical to use cesium ion exchange on. That opens the door to using liquids/solids separations techniques only to pretreat those wastes which makes deployment possible before the WTP pretreatment facilities come on-line. We anticipate demonstrating bulk vitrification later this year on 780,000 liters (~200,000 gallons) of low curie tank waste under a Research Development and Demonstration permit issued by Ecology.

Waste Disposal and Closure

The HLW canisters will be stored on site until the federal geologic repository at Yucca Mountain in Nevada is ready to accept them. We will utilize two cells in the Canister Storage Building for the first 880 canisters and then build additional storage modules as needed. We currently estimate that ~9,000, 0.6 meter diameter x 4.6 meter long (2 ft. x 15 ft.) HLW canisters will be produced through mission completion.

LAW and secondary waste will be disposed on-site in an Ecology-permitted mixed low-level waste landfill known as the Integrated Disposal Facility (IDF). The IDF will ultimately have a capacity of 0.9 million cubic meters of waste. The facility will have double-lined trenches and a leak detection and collection system that exceed RCRA hazardous waste and DOE low-level waste disposal requirements. It is estimated that ~350,000 cubic meters of containerized LAW will be disposed in this facility. Figure 2 is a conceptual view of the IDF.

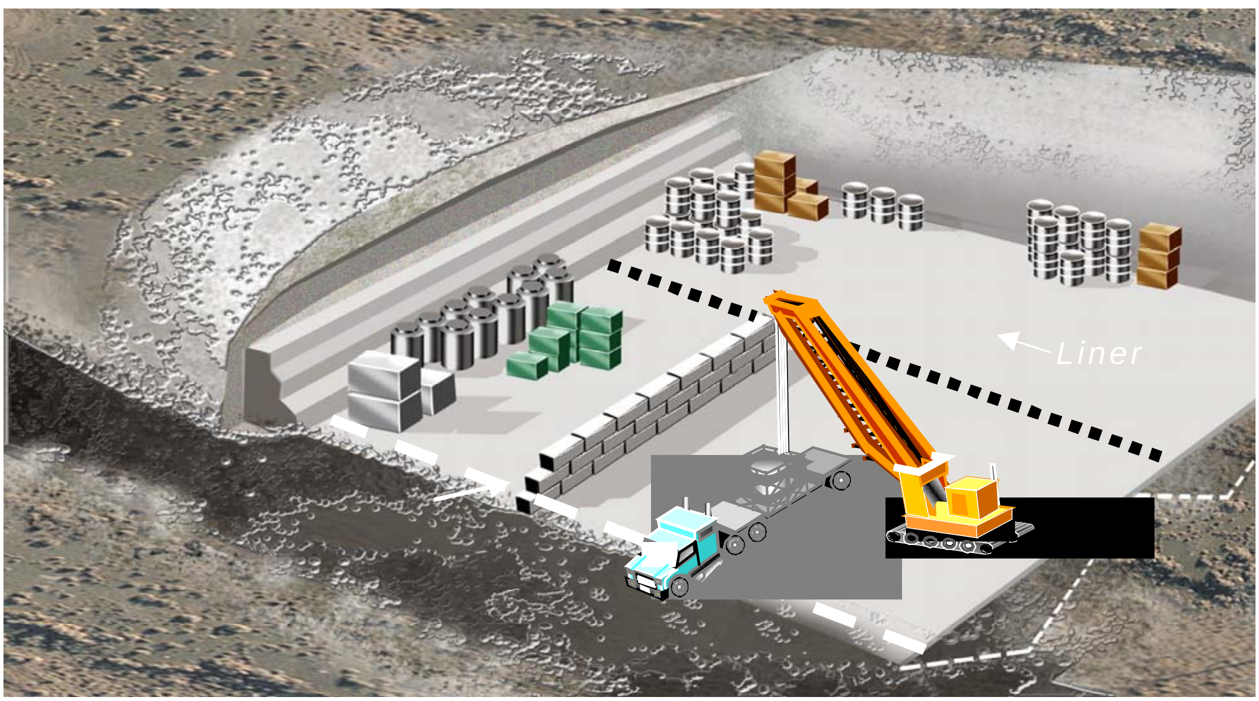


Fig. 2. Integrated disposal facility

Assuming we are successful in receiving the required Class 3 permits from the State of New Mexico, the TRU tank waste will be inspected and certified at Hanford and then shipped to WIPP for disposal. We anticipate at least 2 Class 3 permit requests. The first, which could be transmitted at any time, would be for waste in 8 tanks that are contact-handled and cannot reasonably be confused with HLW on the basis of origin or content. At least three other tanks contain radiologically similar wastes while the remainder, there are 20 tanks in all, contain waste that may or may not be remote-handled depending upon our success in washing the sludge. The total estimated volume of TRU tank waste that could be shipped to WIPP following drying and packaging should be less than 10,000 cubic meters (2.6 million gallons) including the dried sludge and contaminated failed equipment and secondary waste materials that are generated during cleanup operations.

Although we are nearing the point where tank closures should be imminent, there are procedures and issues to be addressed. First, on the procedural side, the Single-Shell Tank Closure EIS, currently in preparation, must go through public comment and issuance of the Final EIS and record of decision before Ecology will issue a permit to proceed. Second, Initiative 297, which I mentioned earlier, substantially increases the difficulty Ecology faces in issuing a closure permit. Finally, although the 9th Circuit Court of Appeals reinstated the waste incidental to reprocessing provisions in DOE O 435.1, those who oppose leaving any waste in a tank for whatever reasons are free to try to block our efforts in the courts. To proceed will take a great deal of discussion and cooperation among the regulators, stakeholders, Tribal Nations, and the involved DOE offices.

Overall, our plan is aggressive, success orientated, and offers the fastest path to reducing public risk that we are aware of. We have made substantial progress over the past 3 years and we believe it is a good deal for U.S. taxpayers and the Hanford stakeholders. It will complete the mission 20 years sooner than thought possible at the millennium change, save greater than $20 billion relative to the previous plan, and it brings the overall RPP into alignment with the dates committed to in the TPA. Our current baseline plan completes waste treatment by 2028 and closes all facilities by 2033 at a total cost of $28 billion. This plan has been independently reviewed, approved, and is being managed as the life-cycle cost baseline.

SAFETY

While it should go without saying that, "Safety is our number priority", I will say it anyway for emphasis. Working safely enables progress. Not working safely shuts us down. It is that simple. We must have an attitude and commitment to safety at all levels and in all organizations. Managers must set policy and expectations, and then monitor and take enforcement action to ensure compliance. Our approach to working safely is to:

- Identify hazards at the task level,
- Maintain strict discipline and Conduct of Operations
- Conduct pre-job planning, training, and briefings
  - Know control limits – review potential "what ifs" and unexpected conditions
  - Maintain jobs in safe condition—STOP WORK if not safe
- Conduct post-job reviews to incorporate "lessons learned" into future planning and work

Two major safety issues we have been addressing are protection of workers from hazardous vapors released from the tanks, as I mentioned earlier, and near misses during WTP construction. We are steadfastly addressing both. Although our safety record is excellent when measured against national industrial norms, we can and will do better.

Challenges

The RPP is the largest environmental cleanup project in the United States. It is highly complex from technical, regulatory, legal, political, and logistical perspectives. Some of the near-term challenges are:

- Working safely.
- Constructing and starting up the WTP on schedule and within budget.
- Implementing supplemental treatment for LAW and TRU waste.
- Determining TRU and residual tank waste classification.
- Obtaining closure permits.
- Integrating tank farms and WTP into one optimized system.
- Re-bidding the tank farm contract, which expires in FY-06.

Path to Success

Our view of the path to success includes:

- Never relinquishing our commitment to always perform safely or not at all,
- Maintaining a positive can-do attitude regardless of the issues that arise,
- Maintaining open and honest relations with Regulators, Stakeholders, and Tribal Nations,
- Maintaining a technically competent DOE and contractor workforce,
- Meeting our commitments, while always
- Maintaining our work ethic and integrity.

This project is important to the Northwest and to this nation. Hanford helped the U.S. win the Cold War and now it is the Nation’s turn to leave Hanford in a cleaned up state that is compatible with the agrarian economy in the Hanford region and the area’s economic dependence on and love for the Columbia River. It is challenging, exciting, and rewarding to those of us on the team to conduct our cleanup in a manner that is consistent with our regulatory commitments and stakeholders’ values. We will do it!

FOOTNOTES

[a]As previously mentioned, approximately 5.5 million TBq (148 million curies) (Cs-137, Sr-90, and their daughters) were removed from the tanks during the 60s and 70s and are currently stored in stabilized forms.