K Basins Sludge Treatment Project Phase 1

Technology Readiness Assessment Report

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The Review Team also acknowledges the excellent support provided by Dr. Sahid Smith, DOE-RL and Ms. Mary Cole, CH2M Hill PRC who were instrumental in the preparation of this report.

Executive Summary

A Technology Readiness Assessment of Phase 1 of the K Basins Sludge Treatment Project has concluded that all Critical Technology Elements of the Project are at TRL 4, the level that is appropriate for CD-1. Process Integration of the Project was found to be at a TRL of 4- because the final wasteform and disposal path for the sludge (Phase 2) has yet to be determined.

The Department of Energy Richland Operations Office (DOE-RL) is responsible for the Sludge Treatment Project (STP) at the Hanford Site in Washington State. The STP is a subproject of the K Basins Closure Project (KBCP). The sludge consists of material generated from the washing and packaging of spent nuclear fuel and material that was cleaned up from K East and K West Basin floors. The sludge is currently stored within Engineered Containers (ECs) and settler tanks (STs) located in the K West Basin. Sludge currently contained in the STs will be retrieved into empty ECs during FY 2010, and will be dispositioned along with the materials currently stored in ECs. The mission of the STP is to retrieve, treat, and package the sludge material for ultimate disposal at a national repository.

In order to achieve the Hanford 2015 Vision for the River Corridor, the project contractor, CH2M HILL Plateau Remediation Company (CHPRC) recommended a two phased approach. Phase 1 would remove the sludge from K Basins and relocate it to safe interim storage on the Hanford Central Plateau; Phase 2 would remobilize, treat, and package the sludge for transport and disposal at the Waste Isolation Pilot Plant (WIPP).

Phase 1 activities are diagramed in Figure ES-1, below. The retrieval process transfers the sludge from the ECs into Sludge Transport Storage Containers (STSCs). Excess transfer water will be decanted from the STSC, filtered and returned to the basin, resulting in filling the STSC with an optimal volume of sludge waste. The loaded STSCs will be transported to T Plant where they will be stored until Phase 2.

In accordance with the DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide[ES-1], the RL KBCP Federal Project Director requested a TRA for the STP Phase 1 activities to support Phase 1 CD-1 approval. The STP TRA scope includes all Phase 1 plus Phase 2 remobilization activities. Phase 2 activities after remobilization are not yet defined and are not within the scope of this TRA.

CHPRC will submit a CD-1 package for STP Phase 1 to DOE-RL for approval in the spring of 2010. Submission of a CD-2/3 package is scheduled for the end of 2011. Operations are scheduled to begin in the spring of 2013 and be completed by the end of CY 2014.

[ES-1] **U.S. Department of Energy.** *DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide.* 2008

Figure ES-1 depicts key Phase 1 process steps and systems identified from *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*[ES-2].

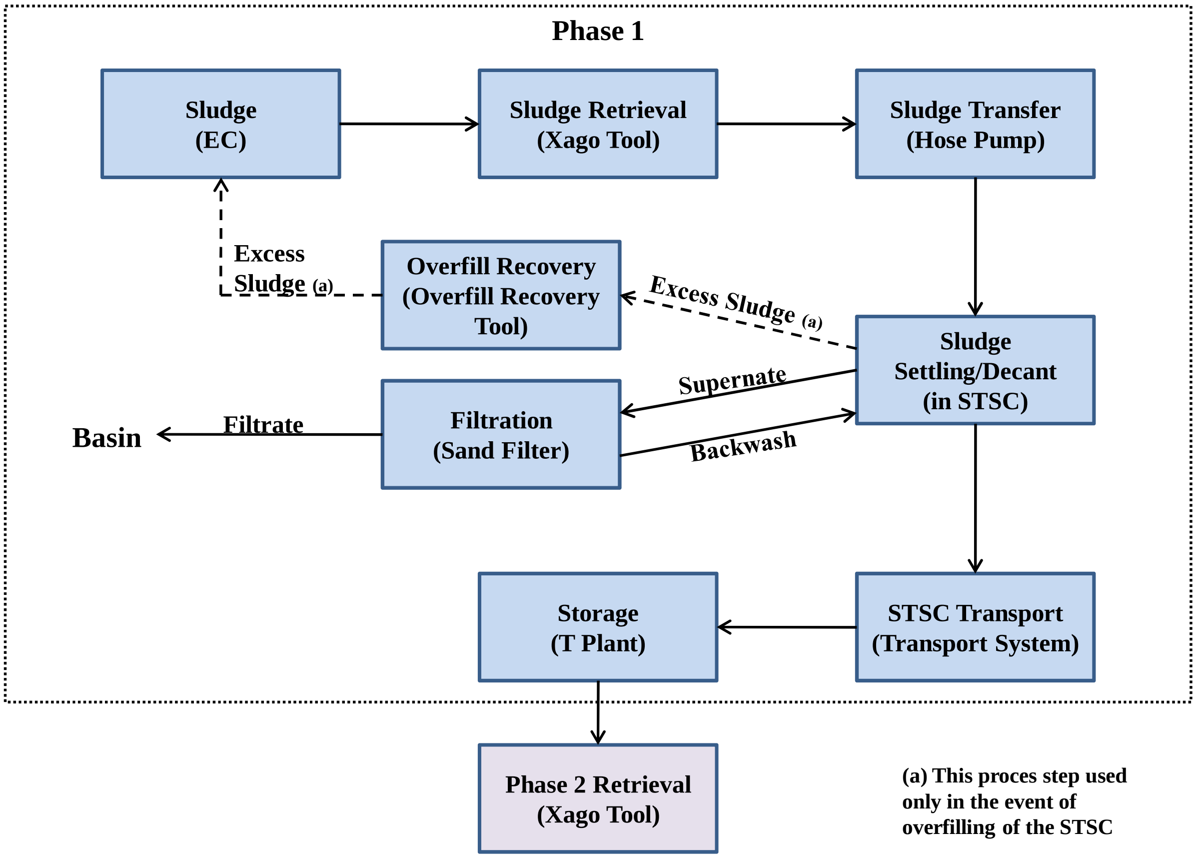

Figure ES-1 Key Process Steps/Systems for Phase 1 Sludge Treatment and Phase 2 Retrieval

The TRA process consists of: (1) identifying Critical Technology Elements (CTEs); (2) assessing the Technology Readiness Level (TRL) of each CTE and the overall integrated process; and (3) preparing the TRA report. If some of the CTEs are judged to be below the desired level of readiness, the TRA is followed by development of a Technology Maturation Plan (TMP) that identifies the additional development required to attain the desired level of readiness.

The seven-person Assessment Team (Team) was comprised of technical experts from DOE-EM national laboratories, field offices, and technical consultants that were independent of the K

[ES-2] **CH2M Hill Plateau Remediation Company.** *HNF-41051, Preliminary STP Container and Settler Sludge Process System Description and Material Balance.* 2009. Revision 2

Basins project. The Team evaluated the processes and mechanical systems of Phase 1 and the Phase 2 retrieval system. It did not evaluate the software systems used to control the processes and mechanical equipment because these software systems have not been sufficiently developed.

The Technology elements (TEs) identified by the Team and evaluated as potential CTEs are given in Table ES-1. The Team identified the Xago tool, Overflow Recovery Tool and the Pumps as CTEs.

Table ES-1 Results of the CTE Determination

TEs Evaluated	CTE ?	Notes
Xago Tool	Yes	The Xago tool was evaluated for use for Phase 1retrieval from ECs and Phase 2 retrieval from STSCs.
Overflow Recovery Tool (ORT)	Yes	The ORT is a direct suction retrieval lance with a mobilizing nozzle similar to the existing Settler Retrieval Tool currently being installed in the 105KW Basin.
Booster/Decant Pumps	Yes	The same pump will be used for both systems. The baseline, hose pump was assessed. An alternative pump by Hazelton that will be tested in the next few months was not assessed.
Settling and Decant Process	No	This is a physical process not a technology. Lab scale settling tests have been carried out on real sludge samples and simulants. Scaling of settling times is understood.
Filtration (Sand Filter)	No	Sand filter technology is well developed. A sand filter has been used to filter K Basin sludge.
Process Connector s	No	The connectors are similar to other connectors that have been used at Hanford and elsewhere in the nuclear industry. Plans exist to test the unique configuration connect/disconnect in a remote environment. A common operational concern, i.e., ensuring no spread of contamination on decoupling, has been successfully dealt with in a variety of applications,
STSC Remote Handling Equipment	No	The system includes cask and STSC handling equipment, and control technology such as truck scales, ENRAF level gauges, high level alarms, and leak detectors. The cask and STSC handling systems are almost identical to the Sludge Transfer System (STS) that was originally used to transfer sludge from K-East Basin North Loadout Pit to T Plant. The control technology is standard and has been used at Hanford and elsewhere.
Sludge and Process Chemistry	No	Not a separate technology. The adequacy of sludge characterization and simulant development is evaluated for each CTE. Process chemistry is included in the evaluation of process integration (Appendix C and Section 3.5.

The results of the TRL determinations for the three CTEs and the integrated Waste Processing System are given in Table ES-2

Table ES-2 Results of the TRL Determination

CTE	TRL	Notes
Xago Tool	4	A major item required to raise the TRLs of these three technologies is improved sludge characterization data needed to ensure that simulants used in testing are bounding. This deficiency should be remedied in the near future. Results from the recent sampling campaign carried out on the K Basins sludges currently stored in
Overflow Recovery Tool	4	

Pumps	4	ECs should be available early in 2010. Settler sludge will be sampled in the next few months as it is removed from the Settler Tanks and transferred to an EC. The baseline peristaltic hose pump must be modified for submerged service. Plans to modify and test the pump exist. The Project also intends to procure and test a centrifugal slurry pump that is designed to work underwater.
Waste Processing System	4-	Potential changes in sludge properties caused by long term storage in T Plant may complicate Phase 2 retrieval and represent a project risk. Phase 2 final treatment and disposition of the sludge has not yet been determined. Until the Phase 2 wasteform is known the final disposition path has a degree of uncertainty and represents a project risk. Full process integration from waste to disposal is incomplete at this time. Planned, integrated, prototypical tests with bounding simulants are critical to advancing the maturity of the Waste Processing System WPS.

Team Observations and Recommendations are given below.

Observations – TRA

1. The Project was very well prepared for the TRA. Its technology development plan was geared to developing information that would allow each technology to mature to at least TRL 3. It had also carried out a TRA self assessment that included completion of the TRA questions with detailed references.

2. Presentations given by Project personnel were clear, concise, informative, and contained sufficient detail. Project personnel were very frank and forthcoming during discussions and in response to questions.

Observations Sludge Transfer Project

The following observations generally support the development path being followed by the Project.

1. Improved characterization data and stimulant development efforts are critical to project success in a number of areas such as simulant and process design and validation. Results from the recent sampling campaign carried out on the KE and KW Basins sludges currently stored in the ECs should be available by early CY 2010. Settler Tank sludge will be sampled in the next few months as it is removed from the Settler Tanks and transferred to an EC. Acquisition of basic data appears to be on the right track.

2. Testing with real waste would be difficult and probably not cost effective due to ALARA considerations. However, the inability to test with real waste represents a risk. Use of a range of validated simulants is an appropriate strategy.

3. Simulant design will have to be reexamined in the light of additional characterization data; additional testing may be required if current simulants are not bounding.

4. Process integration from waste to disposal is incomplete at this time. Potential changes in sludge properties caused by long term storage in STSCs at T Plant may complicate Phase 2 retrieval and represent a project risk. Phase 2 final treatment and disposition of the sludge has not yet been determined. Until the Phase 2 wasteform is known, the final disposition path has a degree of uncertainty and represents a risk.

5. Based on testing accomplished to date by the STP, the Settler Tank sludge simulant has been the most challenging to mobilize and retrieve. Continued focus on understanding physical and chemical properties through ongoing characterization efforts is required. Validation of equipment through testing with simulants that have been verified to bound relevant sludge properties during mobilization and retrieval operations will ensure the technology is capable of performing required functions.

Recommendations

1. Continue the planned test programs including the MASF, full scale, prototypical tests and the planned submerged pump tests.

2. Continue sludge aging studies, including the effects of U metal oxidation and multi-year storage on sludge physical, chemical, and rheological properties. Carry out periodic sampling of STSCs while they are stored at T Plant. Develop a program/plan to monitor/predict sludge property changes during the storage period as necessary input to the phase 2 process.

3. Continue to search for new characterization methods that will aid in the evaluation of sludge transport.

4. Continue the program for process improvements, e.g., flocculants, turbidity, in-situ measurements.

5. Proceed with Phase 2 process development as soon as possible.

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Acronyms and Abbreviations

ALARA	As Low As Reasonably Achievable
CD	Critical Decision
CHPRC	CH2M HILL Plateau Remediation Company
CTEs	Critical Technology Elements
CY	Calendar Year
DoD	Department of Defense
DOE-EM	Department of Energy Office of Environmental Management
DOE-RL	Department of Energy Richland Operations Office
ECs	Engineered Containers
EM	Office of Environmental Management
FY	Fiscal Year
GAO	Government Accountability Office
IXM	Ion Exchange Module
KBCP	K Basins Closure Project
KE	K East
KW	K West
MASF	Maintenance and Storage Facility
NASA	National Aeronautics and Space Administration
ORT	Overfill Recovery Tool
STP	Sludge Treatment Project
STs	Settler Tanks
STS	Sludge Transport System
STSCs	Sludge Transport Storage Container
TEs	Technology Elements
TMP	Technology Maturation Plan
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
U	Uranium
WIPP	Waste Isolation Pilot Plant

Glossary

Term	Definition
Critical Technology Element	A technology element is "critical" if the system being acquired depends on the technology element to meet operational requirements (with acceptable development, cost, and schedule and with acceptable production and operations costs) and if the technology element or its application is either new or novel. Said another way, an element that is new or novel or being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operational utility.
Engineering Scale	A system that is generally greater than 1/10 of the size of the final application, but it is still less than the scale of the final application.
Full Scale	The scale for technology testing or demonstration that matches the scale of the final application.
Identical System	Configuration that matches the final application in all respects.
Laboratory Scale	A system that is a small laboratory model (usually less than 1/10 of the size of the full-size system).
Model	A functional form of a system generally reduced in scale, near, or at operational specification.
Operational Environment (Limited Range)	A real environment that simulates some of the operational requirements and specifications required of the final system (e.g., limited range of actual waste).
Operational Environment (Full Range)	Environment that simulates the operational requirements and specifications required of the final system (e.g., full range of actual waste).
Paper System	System that exists on paper (no hardware).
Pieces System	System that matches a piece or pieces of the final application.
Pilot Scale	The size of a system between the small laboratory or bench scale and a full-size system.
Prototype	A physical or virtual model that represents the final application in almost all respects that is used to evaluate the technical or manufacturing feasibility or utility of a particular technology or process, concept, end item, or system.

Glossary (Continued)

Relevant Environment	A testing environment that simulates the key aspects of the operational environment (e.g., range of simulants plus limited range of actual waste).
Similar System	The configuration that matches the final application in almost all respects.
Simulated Operational Environment	Environment that uses a range of waste simulants for testing of a real or virtual prototype.

1 Introduction

1.1 K Basins Background

The Department of Energy Richland Operations Office (DOE-RL) is responsible for the Sludge Treatment Project (STP) at the Hanford Site in Washington State. The STP is a subproject of the K Basins Closure Project (KBCP). The sludge is currently stored within Engineered Containers (ECs) and Settler Tank (STs) located in the K West Basin. Sludge currently contained in the STs will be retrieved into empty ECs during FY 2010, and will be dispositioned along with the materials currently stored in ECs. The mission of the STP is to retrieve, treat, and package the sludge material for ultimate disposal at a national repository.

The STP faces significant challenges to successfully retrieve, treat, package and dispose of K Basin sludge material. DOE has attempted several different technical approaches to disposition this material using different technologies and contracting approaches. None have proven mature enough to successfully deal with this unique material. Previous technical approaches failed to demonstrate technical feasibility and adequate technical maturity and were abandoned prior to detailed design.

In 2007 a TRA was jointly performed by DOE-RL and the performing contractor (Fluor Hanford) to determine whether the project had adequately developed needed technologies. The TRA team concluded that the critical technologies associated with the project plans were not at the maturity level needed to support a Critical Decision “3” (CD-3) to procure and construct the sludge treatment process. This conclusion supported the contractor’s recommendation and DOE-RL’s decision to re-baseline the STP to between CD-0 and CD-1.

Subsequently, DOE-RL directed Fluor Hanford to develop a CD-1 package that would include alternative analyses for removal of the sludge stored in the K West Basins, in accordance with DOE Order 413.3A and DOE Standard 1189. DOE-RL also identified removal of the sludge from the K West Basin and its relocation away from the River Corridor as soon as possible as a key DOE objective [(1)]. A change in performing contractors from Fluor Hanford to CHPRC occurred in October 2008. CHPRC performed an alternative analysis and submitted the Sludge Treatment Project Alternative Analysis Summary Report, HNF-39744, Rev.0, on January 26, 2009 [(2)].

In order to achieve the Hanford 2015 Vision for the River Corridor, CHPRC recommended a two phased approach. Phase 1 would remove the sludge from K Basins and relocate it to safe interim storage on the Hanford Central Plateau; Phase 2 would remobilize, treat, and package the sludge for transport and disposal at the Waste Isolation Pilot Plant (WIPP).

In accordance with the DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide [(3)], the DOE-RL KBCP

Federal Project Director requested a TRA for the STP Phase 1 activities to support CD-1 approval.

CHPRC is preparing a CD-1 package for STP Phase 1, with submittal to RL for approval scheduled for the spring of 2010. Submission of a CD-2/3 package is scheduled for the end of calendar year (CY) 2011. Operations are scheduled to begin in the spring of 2013 and be completed by the end of CY 2014.

The scope of this STP TRA is given in the TRA Plan (K Basins Sludge Treatment Project Phase 1 Critical Decision (CD) -1 Technology Readiness Assessment Plan) (4) and includes all Phase 1 plus Phase 2 remobilization activities. (Although not part of Phase 1, Phase 2 remobilization of the sludge prior to Phase 2 treatment was included in the TRA. See Figure 1 of the TRA Plan (4). Remobilization is listed as Technology Element 10A.) The TRA Plan can be found in Appendix E. Phase 2 activities after remobilization are not yet defined and are not within the scope of this TRA.

1.2 K BASIN STP Phase 1 Process Description

Phase 1 activities, diagramed in Figure 1.1 below, include the retrieval of the sludge from the Engineered Containers (ECs). The ECs contain sludge generated from the washing and packaging of spent nuclear fuel and sludge that was cleaned up from K East Basin and K West Basin floors. Sludge contained in the STs will have been retrieved into an Engineered Container prior to the start of Phase 1 operations The retrieval process transfers the sludge from the ECs into Sludge Transport Storage Containers (STSCs). Excess transfer water will be decanted from the STSC, filtered and returned to the basin, resulting in filling the STSC with an optimal volume of sludge. The loaded STSCs will be transported to T Plant where they will be stored until Phase 2.

Figure 1.1 depicts key Phase 1 process steps and systems identified from *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* (5). Key steps and systems are discussed below.

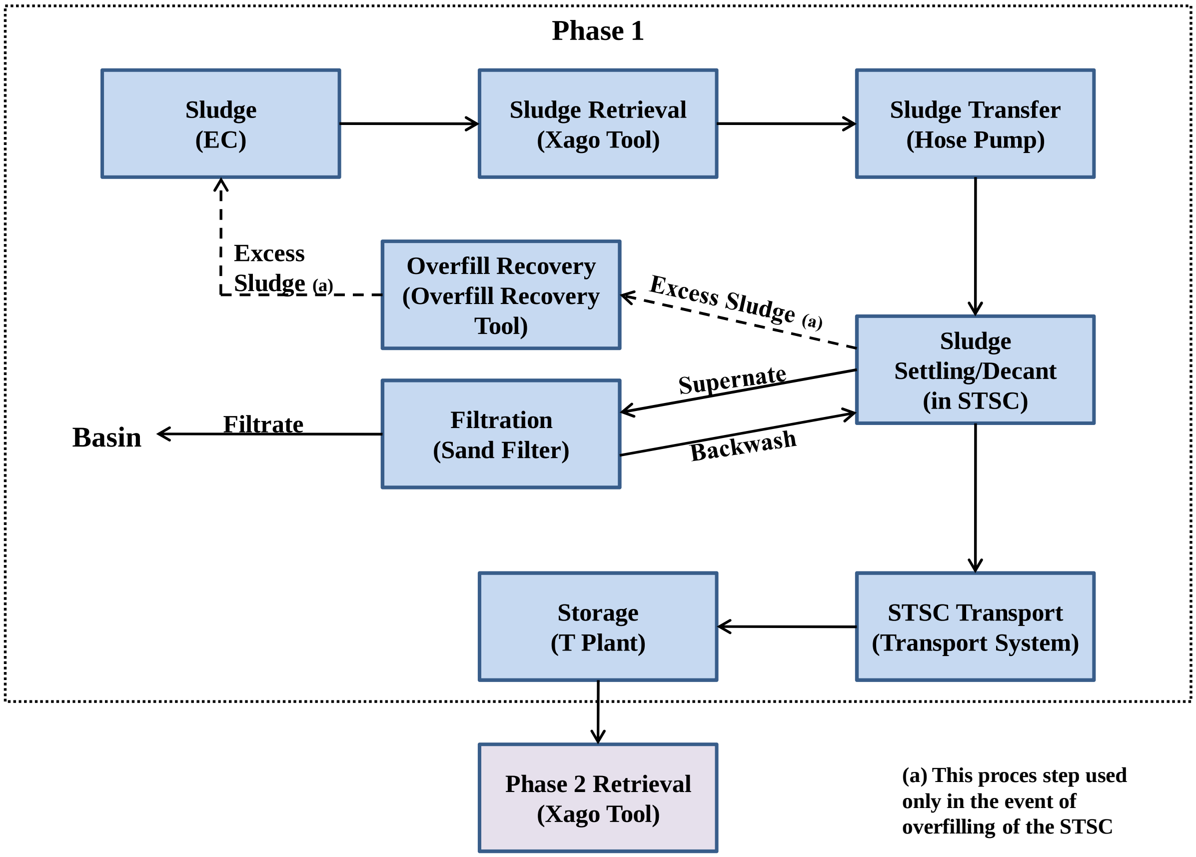

Figure 1.1 Key Process Steps and Systems for Phase 1 Sludge Treatment and Phase 2 Retrieval

1.2.1 Inventory

Table 1.1 gives the sludge volumes from the various sources along with a brief description of the composition of the sludges. Detailed chemical and physical properties of the sludges can be found in HNF-41051 [(5)], HNF-SD-SNF-TI-009, Vol.2 [(6)], and PNNL 14947 [(7)].

Table 1-1 Estimated K-Basins Sludge Inventory [(5)]

Sludge Source	Inventory	Notes
K East	18.4 m^3 stored in 3 ECs	K East/West sludge ranges in particle size from a few microns to 6,350 microns (1/4 inch). It is primarily iron and aluminum oxides, concrete grit, sand, dirt, paint chips, and operational and biological debris. It is contaminated with fuel corrosion products and small fragments of metallic uranium (~ 0.03 g/cm^3). More detailed characterization results from a recent EC sampling campaign will be available by early CY 2010.
K West	5.1 m^3 stored in 2 ECs	
Settler Tanks	5.4 m^3 to be stored in 1EC	Settler Tank sludge ranges in particle size from a few microns to **<600** microns. It is expected to be primarily uranium corrosion products and fission and activation products, with some remaining metallic uranium

		(~0.05 g/cm^3). Settler sludge may also contain lesser quantities of iron oxides, aluminum oxides, sand, Grafoil (graphite gasket material) fragments, concrete grit, dirt, and other operational debris Settler Tanks sludge will be sampled and characterized after it has been transferred to the ECs. Sampling will be completed in fiscal year (FY) 2010, and characterization completed in early FY 2011.

1.2.2 Sludge Retrieval

The Retrieval process extracts the sludge from the ECs and feeds it into the transfer line. The sludge retrieval system consists of the Xago Ltd. HydroLance™ (Xago) tool component, pumps to supply treated pressurized water from the basin ion-exchange system, ancillary instrumentation, and piping and hoses required to deliver the sludge-bearing stream to booster pump that will transfer it to the STSC. The Xago tool was developed specifically for sludge retrieval. It uses modified, existing, eductor technology packaged in a specialized tool that can be deployed and operated underwater in the KW Basin.

1.2.3 Sludge Transfer

Retrieved sludge will be transferred to the STSCs using a hose in hose transfer line, remote connectors, and a submerged slurry pump. The hose in hose transfer line is a standard designs that has been used at Hanford for a number of applications. The current baseline slurry booster pump is an industrial hose pump (peristaltic pump) designed for abrasive slurry applications. The pump will be modified to allow it to operate submerged.

1.2.4 Sludge Settling and Decant

The Sludge Settling and Decant process consists of the incremental filling of the STSC receiving vessel and intermittent decanting of excess mobilizing water. This operation loads the STSC with an optimal sludge volume and recovers the mobilizing water, recycling it back to the basin. The existing process flow allows sixteen hours for the sludge to settle. After settling the supernate will be drawn off and additional sludge will be loaded into the STSC. The settling/decant process will be repeated until the STSC is loaded with the desired amount of sludge. The sludge working volume of the STSC will depend on the characteristics of the sludge being processed. The maximum working volumes for settler and basin sludges are ~2.63 m^3 and 3.49 m^3 respectively [(5)]. The amount of sludge that will be loaded into each STSC will be determined by variety of factors including, fissile content, dose, gas generation and retention, heat generation, and sludge expansion caused by U oxidation. In the STSC, the sludge volume will be less than two thirds the working capacity. The rest of the volume will be supernate. Loading will be monitored using level indication (ENRAF gauge) and mass (modified truck scales).

1.2.5 Filtration

After decanting the supernate is filtered through a sand filter. Filtered supernate is returned to the basin. The filtrate is to contain less than 90 mg/L (ppm) solids, which is the present requirement to maintain K Basin water clarity. The solids accumulated on the filter are backwashed to the STSC at the end of the filling cycle.

1.2.6 Overfill Recovery

In the event that a STSC is overfilled, the excess sludge will be removed using the Overfill Recovery Tool (ORT) and returned to the ECs. The ORT is a direct suction retrieval lance with a mobilizing nozzle similar to the existing Settler Retrieval Tool currently being installed in the KW Basin. A flanged penetration on the STSC top will be opened and the tool will be inserted into the sludge. Mobilization and dilution water will be provided by pumps that supply treated pressurized water from the existing basin ion exchange module (IXM) system. The STSC decant pump will be utilized to provide the direct suction and motive force necessary to pump the sludge back to the engineered container. At the completion of the recovery action, the ORT, which is considered expendable, will remain in the STSC.

1.2.7 STSC Transport

The STSC Transport System includes the STSC & Transporter Loading Facility and the STS Transport System. The STSC & Transporter Loading Facility will be a remotely operated facility in the KW Basin annex that will facilitate direct loading of STSCs. The STSC Transport System is an existing, trailer based system. An empty STSC will arrive at the annex in a Sludge Transport System (STS) Cask on the STS Transporter. Transfer hoses and instrumentation will be manually connected to the STSC. Personnel will exit the annex during remote loading of sludge into the STSC. The STSC and STS Cask remain on the Transporter during sludge loading. After loading, personnel will enter the annex and manually disconnect transfer hoses and instrumentation from the STSC and decontaminate the transporter. The STS Cask and STSC will be transferred to T Plant. The STS Cask may require evacuation and backfill with inert gas to satisfy shipping safety requirements.

As shown in Table 1.2, the STP expects to load 20 STCs with sludge.

Table 1-2 Number of STSCs Produced

Sludge Source	Number of STSCs
K East Engineered Containers	9
K West Engineered Containers	4
Settler Tanks	7
Total	**20**

1.2.8 Sludge Storage at T Plant

Sludge Storage in STSCs at T Plant relies on existing systems with previously used equipment. Although loaded STSCs may impose new controls and requirements, the basic technologies required have been used for other similar waste packages.

1.2.9 Phase 2 Sludge Retrieval

Phase 2 plans to treat and dispose of the sludge have not yet been developed. The project intends to use the Xago tool to remobilize and retrieve the sludge from the STSCs prior to final treatment. However, the waste will reside in the STSCs for a number of years before treatment begins. There is some concern that the sludge may undergo physical/chemical transformations that will impact retrieval.

1.3 K BASINS STP TRA Objectives

The purpose of the STP TRA is to evaluate technology maturity for STP Phase 1 activities and Phase 2 retrieval, using the Technology Readiness Level (TRL) scale established in the DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide [(3)]. The results of the TRA will be used by the RL KBCP Federal Project Director to support DOE approval of CD-1 for STP Phase 1. After the TRA is completed and the final report is issued, KBCP will develop a Technology Maturation Plan (TMP) to guide future maturation of technologies to levels appropriate for CD-2.

2 Technology Readiness Assessment

A TRA is a systematic, metric-based process and accompanying report that assesses the maturity of certain technologies [called Critical Technology Elements (CTEs)] used in systems [(8)].

2.1 Background

A TRA measures technology maturity using the Technology Readiness Level (TRL) scale pioneered by the National Aeronautics and Space Administration (NASA) in the 1980s. The TRL scale ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations). The Department of Energy, Office of Environmental Management (DOE-EM), Department of Defense (DoD), and National Aeronautics and Space Administration (NASA) normally require a TRL of 6 for incorporation of a technology into the detailed design process.

In 1999 the Government Accountability Office (GAO) recommended that the DoD adopt NASA's TRLs as a means of assessing technology maturity [(9)]. In 2001, the Deputy Undersecretary of Defense for Science and Technology issued a memorandum that endorsed the use of TRLs in new major programs. Subsequently, the DoD developed detailed guidance for performing TRAs [(8)]. Recent legislation (2006) has specified that the DoD Milestone Decision Authority must certify to Congress that a technology has been demonstrated in a relevant environment (TRL 6) prior to transition of weapons system technologies to detailed design or justify any waivers.

In March of 2007 the GAO recommended that the DOE adopt the NASA/DoD methodology for evaluating technology maturity [(10)]. Language supporting the GAO recommendation was incorporated in the House version of the 2008 DOE-EM budget legislation. In 2006-2007, DOE-EM conducted pilot TRAs on a number of projects including Hanford's Waste Treatment Plant, Savannah River's Tank 48, and Hanford's K-Basins. In March 2008 DOE-EM issued its *Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide* which established the TRA process as an integral part of DOE-EM's Project Management's Critical Decision Process [(3)].

2.2 Description of TRA Process

The TRA process consists of three parts: (1) identifying the CTEs; (2) assessing the TRL of each CTE and the overall integrated process using an established readiness scale; and (3) preparing the TRA report. If some of the CTEs are judged to be below the desired level of readiness, the TRA is followed by development of a Technology Maturation Plan (TMP) that identifies the additional development required to attain the desired level of readiness. The TRA process is usually carried out by a group of experts that are independent of the project under consideration.

The CTE identification process involves breaking the project under evaluation into its component systems and subsystems and determining which of these are essential to project success, and either represent new technologies, are combinations of existing technologies in new or novel ways, or will be used in a new environment. Potential CTEs are evaluated against the two sets of questions presented in Table 2.1. A system is determined to be a CTE if a positive response is provided to at least one of the questions in each of the two sets of questions. Section 3.1 and Appendix A contain additional information on the CTE identification process and results for this TRA.

Table 2-1 Questions used to determine the Critical Technology Elements (CTEs)

First Set	1. Does the technology directly impact a functional requirement of the process or facility? 2. Do limitations in the understanding of the technology result in a potential schedule risk (i.e., the technology may not be ready for insertion when required)? 3. Do limitations in the understanding of the technology result in a potential cost risk (i.e., the technology may cause significant cost overruns)? 4. Are there uncertainties in the definition of the end state requirements for this technology?
Second Set	1. Is the technology (system) new or novel? 2. Is the technology (system) modified? 3. Has the technology been repackaged so that a new relevant environment is realized? 4. Is the technology expected to operate in an environment and/or achieve a performance beyond its original design intention or demonstrated capability?

The TRL scale used in this assessment is shown in Table 2.2. This scale requires that testing of a prototypical design in a relevant environment be completed before incorporation of the technology into the final design of the facility.

Table 2-2 Technology Readiness Levels Used in this Assessment

Relative Level of Technology Development	TRL	TRL Definition	TRL Description
System Operations	**9**	Actual system operated over the full range of expected conditions.	The technology is in its final form and operated under the full range of operating conditions. Examples include using the actual system with the full range of wastes.
System Commissioning	**8**	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning.
	7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing the prototype in the field with a range of simulants and/or actual waste and cold commissioning.
Technology Demonstration	**6**	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype with actual waste and a range of simulants.
	5	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity system in a simulated environment and/or with a range of actual waste and simulants.
Technology Development	**4**	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants.
Research to Prove Feasibility	**3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. Components may be tested with simulants.
	2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.
Basic Technology Research	**1**	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties.

The testing requirements are compared to the TRLs in Table 2.2. These definitions provide a convenient means to further understand the relationship between the scale of testing, fidelity of testing system, testing environment, and the TRL. This scale requires that for TRL 6, testing must be completed at an engineering or pilot scale, with testing of the system fidelity that is similar to the actual application and with a range of simulated waste and/or limited range of actual waste, if applicable.

The assessment of the TRLs is aided by questions based on a TRL Calculator methodology that was originally developed by the U.S. Air Force [11] and modified for DOE-EM applications. The TRL Calculator questions used in this assessment can be found in Appendix B.

Table 2-3 Relationship of Testing Requirements to the TRL

TRL	Scale of Testing[1]	Fidelity[2]	Environment[3]
9	Full	Identical	Operational (Full Range)
8	Full	Identical	Operational (Limited Range)
7	Full	Similar	Relevant
6	Engineering/Pilot	Similar	Relevant
5	Laboratory	Similar	Relevant
4	Laboratory	Pieces	Simulated
3	Laboratory	Pieces	Simulated
2	Paper	Paper	Paper
1	Paper	Paper	Paper

1. Full Scale = Full plant scale that matches final application
   1/10 Full Scale < Engineering/Pilot Scale < Full Scale (Typical)
   Lab Scale < 1/10 Full Scale (Typical)

2. Identical System – configuration matches the final application in all respects
   Similar System – configuration matches the final application in almost all respects
   Pieces System – matches a piece or pieces of the final application
   Paper System – exists on paper (no hardware)

3. Operational (Full Range) – full range of actual waste
   Operational (Limited Range) – limited range of actual waste
   Relevant – range of simulants + limited range of actual waste
   Simulated – range of simulants

The TRA also evaluates process integration, i.e., whether the combination of individual technologies will produce a process that will accomplish project goals. Additional details on the evaluation of process integration including the set of process integration questions used in this assessment can be found in Section 3.5 and Appendix C.

2.3 K Basins Sludge Treatment Project TRA Process Description

The seven-person Assessment Team (Team) was comprised of technical experts from DOE-EM national laboratories, field offices, and technical consultants that were independent of the K Basins project. See Appendix D for resumes of the Assessment Team and identification of supporting contractor and vendor personnel.

The Team evaluated the processes and mechanical systems of Phase 1 and the Phase 2 retrieval system. It did not evaluate the software systems used to control the processes and mechanical equipment because these software systems have not been sufficiently developed.

During the working sessions Project personnel presented descriptions of STP treatment systems, described the technology research and testing results, and participated in the completion of the responses to the question sets used to determine CTEs and TRLs. The Team identified as potential CTEs the technology subsystems that are directly involved in Phase 1 processing and Phase 2 retrieval and evaluated them against the two sets of questions presented in Table 2.1. The team then evaluated each CTE against the TRL Calculator questions and evaluated the processing system against the process integration questions. The response to each TRL Calculator and process integration question was recorded along with references to the appropriate documents. The Team completed independent due-diligence reviews and evaluations of the testing and design information to validate the input obtained in the working sessions.

Appendix A contains the results of the CTE evaluations. Appendix B contains the TRL Calculator results for each CTE. Appendix C contains the results of the process integration questions.

3 K Basins Sludge Treatment Project TRA Results

3.1 CTEs

The Team identified the Xago tool, Overflow Recovery tool and the pumps as CTEs. The Technology elements (TEs) identified by the Team and evaluated as potential CTEs are given in Table 3.1. The responses to the two sets of questions for each CTE are provided in Appendix A.

Table 3-1 Results of the CTE Determination

TEs Evaluated	CTE ?	Notes
Xago Tool	Yes	The Xago tool was evaluated for use for Phase 1retrieval from ECs and Phase 2 retrieval from STSCs.
Overflow Recovery Tool (ORT)	Yes	The ORT is a direct suction retrieval lance with a mobilizing nozzle similar to the existing Settler Retrieval Tool currently being installed in the 105KW Basin.
Booster/Decant Pumps	Yes	The same pump will be used for both systems in order to reduce the need for spares. The baseline, hose pump was assessed. An alternative pump by Hazelton that will be tested in the next few months was not assessed.
Settling and Decant Process	No	This is a physical process not a technology. Lab scale settling tests have been carried out on real sludge samples and simulants. Scaling of settling times is understood.
Filtration (Sand Filter)	No	Sand filter technology is well developed. A sand filter has been used to filter K Basin sludge.
Process Connector s	No	The connectors are similar to other connectors that have been used at Hanford and elsewhere in the nuclear industry. Plans exist to test the unique configuration connect/disconnect in a remote environment. A common operational concern, i.e., ensuring no spread of contamination on decoupling, has been successfully dealt with in a variety of applications,
STSC Remote Handling Equipment	No	The system includes cask and STSC handling equipment, and control technology such as truck scales, ENRAF level gauges, high level alarms, and leak detectors. The cask and STSC handling systems are almost identical to the Sludge Transfer System (STS) that was originally used to transfer sludge from K-East Basin North Loadout Pit to T Plant. The control technology is standard and has been used at Hanford and elsewhere.
Sludge and Process Chemistry	No	Not a separate technology. The adequacy of sludge characterization and simulant development is evaluated for each CTE. Process chemistry is included in the evaluation of process integration (Appendix C and Section 3.5.

3.2 XAGO Tool

3.2.1 Function of XAGO Tool

The function of the Xago HydroLance is to retrieve KE and KW and Settler Tanks sludge from engineered containers in the KW Basin and transport the sludge through a hose to a booster pump that will transport the sludge to the sludge transport and storage containers (STSCs).

3.2.2 Description of XAGO Tool

The HydroLance is a combined fluidizer and jet pump system manufactured by Xago Nuclear Ltd [(12)]. It consists of an adjustable annular jet pump to provide both suction and motive force to move the slurry, a low pressure “Coanda” fluidizer head to entrain solids at the suction end of the HydroLance, and an optional set of high pressure nozzles used to break up high shear strength materials.

The HydroLance uses the Coanda fluidizer and jet pump to bore a hole through the sludge. After boring the hole, the HydroLance is positioned near the bottom of the container. The high pressure fluidizer jets mounted at the end of the HydroLance are pulsed to undercut the layers of sludge above the HydroLance. The sludge fluidized by the high pressure jets flows freely to the HydroLance suction. The weight of the sludge above the undercut sections causes the sludge bed to collapse down and toward the HydroLance suction. When no more fluidized sludge is available, the process is repeated.

Figure 3.1 shows a picture of the Xago HydroLance.

3.2.3 Relationship to Other Systems

The relationship of the Xago HydroLance to other systems is as follows:

- The feed to the Xago HydroLance is from the EC in which the device is placed.
- Additional feed streams to the Xago HydroLance are demineralized water that feeds centrifugal pumps supplying water to the fluidizing jets, the Coanda head, and the jet pump on the HydroLance.
- The primary process effluent is the slurried sludge that is removed from the EC and feeds the booster pump that will transport it to the sludge transport and storage containers (STSCs).
- The Xago HydroLance is connected to the booster pump by hoses.

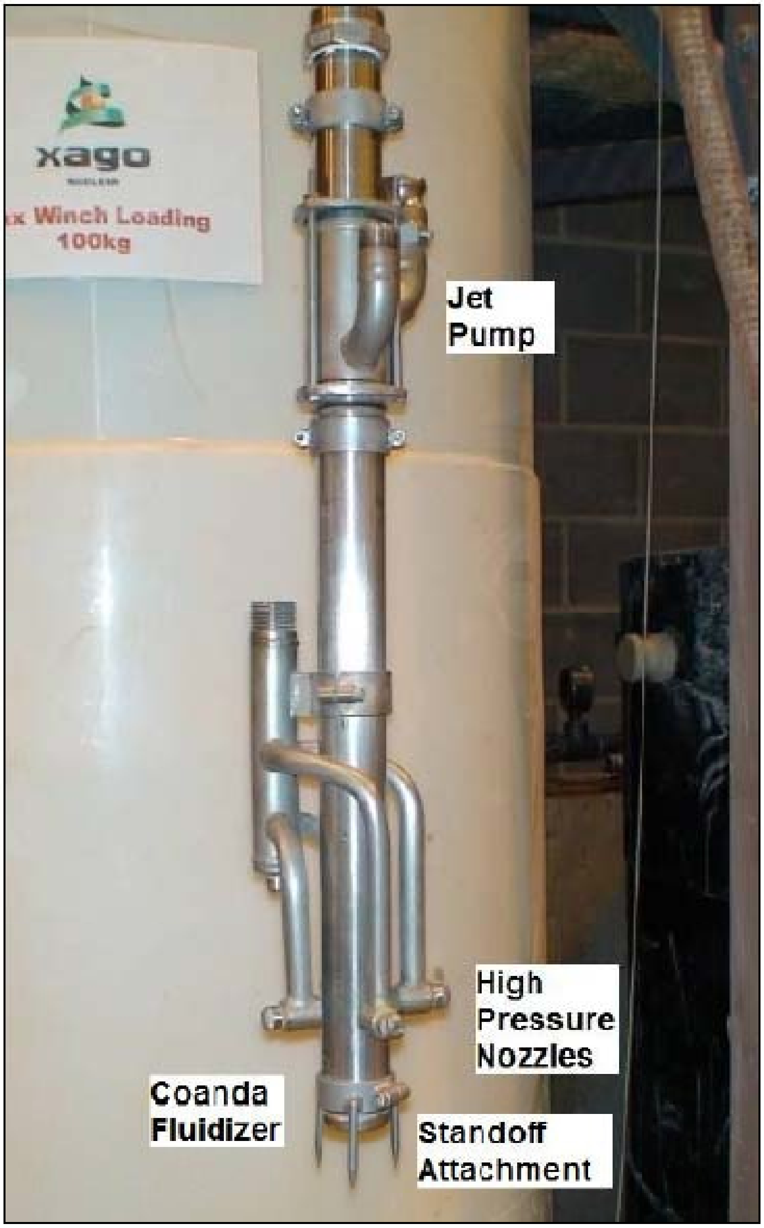

Figure 3.1 Xago HydroLance [12]

3.2.4 Development History and Status

The Xago HydroLance is a commercially available product A full-scale HydroLance supplied by Xago Nuclear Ltd and NuVision Engineering has been tested with simulated Hanford K-Basin sludge [12].

Xago Nuclear Ltd has a worldwide and exclusive license to use patented technology developed by Dynamic Processing Solutions Limited and now owned by Cooper Cameron Corporation. Xago's license allows it to apply and sub-license such technology outside the Oil & Gas sector.

3.2.5 Relevant Environment

The HydroLance will retrieve ~ 30 m^3 of K Basin and Settler Tanks sludges from ECs located in KW Basin. These containers are located under water, so many of the key components of the HydroLance must operate underwater. Because of the depth of the basins, the device must operate remotely. The pumps used to supply pressure and liquid to the HydroLance must operate under water or be located at a long distance from the device.

3.2.6 Comparison of the Relevant Environment and the Demonstrated Environment

The testing conducted by CHPRC simulated the sludge bed and container environment only. It did not simulate hose management, tool deployment, and Electrical Control and Instrument interfaces [(12)].

Test engineered containers replicated full height.

Because the Xago HydroLance is a commercially available device, testing was conducted at full-scale. Full-scale testing requires a large volume of feed material. Using simulated sludge reduces the cost of testing and eliminates the radiation dose received by the workers performing the test. Conducting the test with actual K-Basin sludge would require a very large sample of the sludge, a large, shielded facility in which to conduct the test, a large dose to the workers conducting the test, and significant cost to dispose of the radioactive sludge at the conclusion of the test.

The radionuclides present in the sludge do not have a direct impact on the performance of the HydroLance. The relevant parameters affecting the HydroLance performance are the particle size, particle density, and slurry rheology. If these parameters can be matched or bounded, simulant testing will enable a thorough evaluation of the technology.

The simulant tests performed to date are based on older, limited characterization data. New characterization data is needed to confirm that the simulants used in testing bound the physical properties of the sludge.

3.2.7 Technology Readiness Level Determination

The Xago HydroLance was determined to have a technology readiness level of 4. The reasons for the Xago HydroLance not being a level 5 were the following.

- Settler Tank sludge and Engineering Container sludge characterization is not complete.
- The impact of aging on the sludge physical properties is not complete.

The Xago HydroLance was given a technology readiness level of 4, even though laboratory-scale tests on real waste have not been completed. The testing performed to date has been with a full-scale unit rather than laboratory-scale or pilot-scale. The team believes that real waste tests are not practical with the full-scale unit because of cost, dose to worker, and the amount of radioactive waste that would be generated from the tests. In addition, the team believes that the simulants have been selected to match the physical properties of the sludge that are important in evaluating the Xago HydroLance.

3.3 Overfill Recovery Tool

3.3.1 Function of the Overfill Recovery Tool (ORT)

Phase I of the Sludge Treatment Project (STP) is to hydraulically retrieve sludge from the engineered containers located in KW Basin, and transfer it to the Sludge Transport and Storage Container (STSC). In the event that excess sludge is loaded into the STSC, it will be necessary to remove the excess sludge to meet requirements for shipping and storage. The STSC Overfill Recovery Tool (ORT) is being developed to meet the functional requirement to retrieve excess sludge from the STSC and transfer it back to an engineered container in the KW basin (13).

3.3.2 Description of the Overfill Recovery Tool

The sludge retrieval technology of the ORT is a direct suction lance with a mobilizing spray nozzle similar to the existing Settler Retrieval Tool currently being installed in the KW Basin Settler Tanks (5; 14). A flanged penetration on the STSC top will be opened and the ORT will be inserted into the sludge. Treated pressurized water pumped from an existing KW basin system is supplied to the nozzle for dilution and mobilization. The STSC decant pump is utilized to provide the direct suction and motive force necessary to pump the sludge back to an engineered container. At the completion of the recovery action, the ORT is considered expendable and will remain in the STSC (5).

3.3.3 Relationship to Other Systems

The ORT will utilize the decant pump system to provide the motive force for suction at the lance and pressure to transfer the sludge back to an KW basin engineered container (5). The ORT serves as a contingency tool in the off normal event that the STSC is overfilled during a transfer. It is not planned to be installed or used during normal operations. Design is at the conceptual phase but it is likely that a remote connection on the STSC to the decant system would need to be made, if the ORT is required (5).

The ORT will also require connection to the existing water source in the KW annex for the mobilizing spray operation (5).

Figure 3.2 Overfill Recovery Tool

3.3.4 Development History and Status

The ORT utilizes a pressurized water spray nozzle for dilution and mobilization of the sludge and a suction pipe for removal of the sludge slurry. The design is similar in concept to the Settler Retrieval Tool [14] and the Xago Inc. Hydrolance retrieval tool [12; 15]. All utilize a water spray for mobilization and dilution and some suction method to transfer the material. The Xago is an engineered system designed to remove sludge efficiently. It is significantly more complex than the ORT. The ORT is better approximated by the settler retrieval tool albeit a somewhat simplified version. Both the settler retrieval tool and Xago have undergone extensive testing with settler tank sludge and engineered container sludge simulants, and have been shown to be effective [12; 14]. Nominal testing has been completed for the ORT, but testing of the other retrieval tools provides some confidence that it will work as intended. Efficiency of performance is not as critical as it is for the other retrieval tools because the ORT is not planned for use if the STSC loading system performs as designed [5].

3.3.5 Relevant Environment

The relevant environment for STSC ORT is as follows [13]:

- The K-Basin sludge is composed of corrosion products from aluminum clad and Zircaloy clad irradiated uranium metal fuel, dirt, sand, organic material, ion exchange resins, spalled concrete, paint chips, pieces of Grafoil, small sections of aluminum wire, sand filter material, and hydroxides of iron, aluminum, and uranium.

- The KE EC sludge is assumed to settle in a STSC to 25 volume percent solids. The KW EC sludge is assumed to settle in a STSC to 26 volume percent solids. Settler sludge is assumed to settle in a STSC to 30 volume percent.

3.3.6 Comparison of the Relevant Environment and the Demonstrated Environment

The specific design for the STSC ORT has not been and is not planned to be demonstrated with actual waste. Testing with actual waste is not considered practical; however tools operating on similar principles have been used in the past in actual sludge transfer evolutions. The function and operation of the ORT tool will be further substantiated by testing with a full size ORT [16] in simulants developed from a range of sludge characterization data selected to bound actual tool operations. Completion of the KW EC and Settler sludge characterization is still in progress and current simulants were developed based on historic sludge characterization data [17]. Until the sludge characterization results are completed verification that current simulants bound expected sludge properties cannot be confirmed.

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3.3.7 Technology Readiness Level Determination

The ORT was determined to be TRL 4 because full characterization of the KW EC and Settler Tank sludges is still being completed. The TRA team initially evaluated the ORT at a TRL of 5 but it did not meet the requirements related to testing in a relevant environment. The TRA subsequently evaluated the ORT against the criteria of TRL 4 to ensure all criteria were addressed. The current maturity level of the ORT is based on testing of similar equipment and the review of the TRL was therefore limited to test data and operational history of that equipment. As discussed previously the Xago Inc. Hydrolance retrieval tool and the sludge settler retrieval tool have both been tested extensively at full scale with simulants [12; 14; 15].

It is noted that, based on discussion during the presentations to the TRA team, the project plans to continue full scale testing of the ORT with simulants and that initial testing has taken place, however test results were not officially issued under the project documentation system and therefore were not included as part of the review by the TRA team.

The conclusions reached relate to demonstration of the technology by which the ORT will operate. The potential manufacturing and quality impacts at both TRL 4 and 5 have been overcome by the successful manufacturing of a full scale ORT. Additional programmatic requirements have been addressed by the current maturity level of the project. The technology could easily reach TRL 5 with completion of sludge characterization work and verification of the bounding properties for simulants used in testing. The results of the characterization may result in additional simulant development (17). The project is aware of this and it is anticipated the latest characterization data will be available and the proper simulants selected prior to completing full scale testing of the ORT. The results summarized in the referenced test reports confirm the settler sludge is the most difficult sludge to mobilize and retrieve and must continue to be a point of focus in the test program as part of the TMP to raise the TRL level of the ORT (12; 14; 15).

3.4 Booster and Decant Pumps

3.4.1 Function of the Pumps

The critical technology elements are pumps. There are two pumps in the system the booster and the decant pump, but they have been lumped for this evaluation. The same pump type will be used for both services as the process needs are very similar. The pump must pump aqueous sludges of varying compositions and consistencies. Only the booster pump is unique in that it must be completely submerged in the basin water. Actual run times on the pumps to deliver the waste to its next process step will be short.

3.4.2 Description of the Pumps

Pumping of waste is common to the Hanford complex and has been used in the K Basin area for transferring sludges from the K E Basin to the KW Basin. The most common pump used at K Basins is a long shaft submersible centrifugal pump. In this case the contractor has chosen to look at an alternate pump the peristaltic hose pump and use the long shaft pump as a contingency. The hose pump was chosen because it is believed to be superior in handling abrasive slurries and can transport rather larger pieces of trash such as pieces of wire or bolts. (See Figure 3.3)

Figure 3.3 Pieces of Aluminum Basket Wire, Nuts, and Bolts Added to Pump Test Simulant

3.4.3 Relationship to Other Systems

The booster pump will be used to transfer sludge mobilized by the Xago Tool from the ECs to the STSCs. The other pump will pump decant liquid from the STSC to the sand filter and may be used to pump sludge back to an EC in the case of an over-filled STSC.

3.4.4 Development History and Status

Peristaltic hose pumps are very robust for handling a range of slurry properties. They show little wear because of the elastomeric nature of the hose and can pass large solids because of the lack of constriction. Such pumps have been used in radioactive waste service [(18)]. A drawing and specification of the pump is given in Watson Marlow Bredel SPX-80 Engineering and Technical Data.

3.4.5 Relevant Environment

The peristaltic hose pump must pump aqueous sludges of varying compositions and consistencies that include pieces of trash such as grafoil, bits of aluminum wire, nuts, and bolts. This capability has been demonstrated with simulants ranging from thick non-Newtonian slurries to thin Newtonian settling slurries to bound actual waste properties. These simulants were based on actual waste historical samples obtained from previous basin operations. Characterization of actual EC and Settler Tank sludge is still being completed. Ongoing sludge characterization and verification of the bounding properties of the current simulants needs to be completed. Comparison of the Relevant Environment and the Demonstrated Environment

3.4.6 Comparison of the Relevant Environment and the Demonstrated Environment

A full scale pump test has been run with the hose pump. The line size and flow rates were the same as was the current design. Static head and horizontal and vertical lengths were similar to those expected and losses were similar. A variety of simulants were pumped including some rather large pieces of simulated trash such as wires and bolts that are known to exist in the basin. The ability of the pumps to restart after a shutdown was also demonstrated. The pumps were run approximately 7 times longer than expected by the process. Only minor wear was found. The testing demonstrated the ability of the pumps to deliver the process result. However, yet to be demonstrated is the ability of the pump to work fully submerged. Such pumps have been run submerged but not the type tested. This will be the chief mechanical challenge [(19; 20)].

Pulsation dampening is required. The projected pressure drop at the desired flow rate was estimated using reviewed standard methods for both thick and settling slurries at 70 gallons per minute in 1.5 inch hose [(21)].

The simulant sludges represent a reasonable range of sludge types. Further sample analysis and characterization of actual waste will verify that the simulant properties are bounding or will be used to develop bounding simulants which will then be used in future acceptance tests.

3.4.7 Technology Readiness Level Determination

The TRL determined was 4 based on the extensive full scale test. It was limited by the need to demonstrate the mechanical reliability of a submerged pump of this type to operate under water for a long time and by the need for additional characterization data that validates the assumption that the simuants are bounding.

The chief uncertainty is the mechanical reliability of a submerged hose pump. If this should not be accomplished successfully then the backup is the standard long shaft, submersible, centrifugal pump. Use of the backup pump would probably increase maintenance and down time.

3.5 Process Integration

3.5.1 Function of Process Integration

The function of process integration is to ensure that:

1. the full waste processing system is designed to treat the full range of wastes it will receive and produce a final product that can be disposed;
2. the waste processing system can start up, operate, and finish processing in accordance with project schedules;
3. individual process systems and operating modes are compatible and can be successfully mated;
4. all recycle and secondary waste streams are identified and accounted for in the process flow, and all secondary wastes can be treated and disposed; and
5. all external interfaces have been identified and are being managed.

3.5.2 Description of the Integrated Process

The STP process has been described in Section 1.2, above. A full description can be found in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* (5) and PRC-STP-00059, *Sludge Loading Options – Operations and Maintenance Evaluation* (22). Estimated system operating duration is forty six weeks. Phase 1 completion which will occur when all the loaded STSCs are placed in the T Plant cells is currently scheduled for 11/25/14.

3.5.3 Relationship to Other Site Systems

The interface with Phase 2 retrieval of sludge from STSCs stored at T Plant is described in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* (5)(Section 3.2.6). System external interfaces are described in PRC-STP-00006, *KW Basin and Sludge Treatment Project Interface Control* (23). The major interface is with T Plant.

3.5.4 Evaluation of Process Integration

The process is designed to treat KE and KW Basins and Settler Tank sludges in accordance with the overall STP Project schedule (24). All individual process systems and operating modes appear to be compatible and should be successfully mated. All recycle and secondary waste streams are identified and accounted for in the process flow, and all secondary wastes can be treated and disposed. All external interfaces have been identified and are being managed.

However, process integration of the project was determined to be less than that normally required for TRL 4. Phase 1 will be complete when all the sludge is loaded into STSCs and all STSCs have been stored in T Plant. The sludge will be stored in T Plant for an undetermined number of years. If sludge properties change during storage, retrieval may become difficult. Although such a change has not been observed while the sludge has been in K Basins and preliminary testing has shown that aging will not radically affect sludge properties, long term storage represents a project risk. Additionally, Phase 2 final treatment and disposition of the sludge has not yet been decided upon. Until the Phase 2 wasteform is known the final disposition path faces some degree of uncertainty and represents a risk.

4 Conclusions

4.1 Conclusions on Technology Readiness

The results of the TRL determination are given in Table 4-1.

Table 4-1 Results of the TRL Determination

CTE	TRL	Notes
X ago Tool	4	A major item required to raise the TRLs of these three technologies is improved sludge characterization data needed to ensure that simulants used in testing are bounding. This deficiency should be remedied in the near future. Results from the recent sampling campaign carried out on the K Basins sludges currently stored in ECs should be available by early 2010. Settler sludge will be sampled in the next few months as it is removed from the Settler Tanks and transferred to an EC. The baseline peristaltic hose pump must be modified for submerged service. Plans to modify and test the pump exist. The Project also intends to procure and test a centrifugal slurry pump that is designed to work underwater.
Overflow Recovery Tool	4	
Pumps	4	
Waste Processing System	4-	Potential changes in sludge properties caused by long term storage in T Plant may complicate Phase 2 retrieval and represent a project risk. Phase 2 final treatment and disposition of the sludge has not yet been determined. Until the Phase 2 wasteform is known the final disposition path has a degree of uncertainty and represents a project risk. Full process integration from waste to disposal is incomplete at this time. Planned, integrated, prototypical tests with bounding simulants are critical to advancing the maturity of the Waste Processing System WPS.

4.2 Observations and Recommendations

4.2.1 Observations – TRA

1. The Project was very well prepared for the TRA. Its technology development plan was geared to developing information that would allow each technology to be determined to be at least TRL3. It had also carried out a TRA self assessment that included completion of the TRA questions with detailed references.

2. Presentations given by Project personnel were clear, concise, informative, and contained sufficient detail. Project personnel were very frank and forthcoming during discussions and in response to questions.

4.2.2 Observations Sludge Transfer Project

1. Improved characterization data and simulant development efforts are critical to project success in a number of areas such as simulant and process design and validation. Results from the recent sampling campaign carried out on the KE and KW Basins sludges currently stored in the ECs should be available by early CY 2010 Settler sludge will be sampled in the next few months as it is removed from the Settler Tanks and transferred to an EC. Acquisition of basic data appears to be on the right track.

2. Testing with real waste would be difficult and probably not cost effective due to ALARA considerations. However, the inability to test with real waste represents a risk. Use of a range of validated simulants is an appropriate strategy.

3. Simulant design will have to be reexamined in the light of additional characterization data; additional testing may be required if current simulants are not bounding.

4. Process integration from waste to disposal is incomplete at this time. Potential changes in sludge properties caused by long term storage in STSCs at T Plant may complicate Phase 2 retrieval and represent a project risk. Phase 2 final treatment and disposition of the sludge has not yet been determined. Until the Phase 2 wasteform is known, the final disposition path has a degree of uncertainty and represents a risk.

5. Based on testing accomplished to date by the STP, the Settler Tank sludge simulants have been the most challenging to mobilize and retrieve. Continued focus on understanding physical and chemical properties through ongoing characterization efforts and validating equipment through testing with simulants verified to bound the sludge properties in mobilization and retrieval operations will ensure the technology is efficiently utilized.

4.2.3 Recommendations

1. Continue the planned test programs including the MASF, full scale, prototypical tests and the planned submerged pump tests.

2. Continue sludge aging studies, including the effects of U metal oxidation and multi-year storage on sludge physical, chemical, and rheological properties. Carry out periodic sampling of STSCs while they are stored at T Plant. Develop a program/plan to monitor/predict sludge property changes during the storage period as necessary input to the phase 2 process.

3. Continue to search for new characterization methods that will aid in the evaluation of sludge transport.

4. Continue the program for process improvements, e.g., flocculants, turbidity, in-situ measurements.

5. Proceed with Phase 2 process development as soon as possible.

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Appendix A Determination of the Critical Technology Elements

The Xago Tool, Overflow Recovery Tool (ORT), and Booster/Decant Pumps were determined to be CTEs. The CTE evaluation results for these three technologies are given in Tables A.1-3. One Yes in each of the two sets of questions is sufficient to determine that a TE is a CTE.

Table A.1 Technology Element: Xago Tool

CTE Questions: Xago Tool			
Yes	**No**	**Set 1**	**Notes**
X		• Does the technology directly impact a functional requirement of the process or facility?	
		• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?	
		• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?	
		• Are there uncertainties in the definition of the end state requirements for this technology?	
Yes	**No**	**Set 2**	
X		• Is the technology new or novel?	
		• Is the technology modified?	
		• Has the technology been repackaged so a new relevant environment is realized?	
		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?	

Table A.2 Technology Element: Overfill Recovery Tool

CTE Questions: Overfill Recovery Tool			
Yes	**No**	**Set 1**	**Notes**
X		• Does the technology directly impact a functional requirement of the process or facility?	
		• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?	
		• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?	
		• Are there uncertainties in the definition of the end state requirements for this technology?	
Yes	**No**	**Set 2**	
	X	• Is the technology new or novel?	
X		• Is the technology modified?	
		• Has the technology been repackaged so a new relevant environment is realized?	
		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?	

Table A.3 Technology Element: Booster/Decant Pump

CTE Questions: Booster/Decant Pump			
Yes	**No**	**Set 1**	**Notes**
X		• Does the technology directly impact a functional requirement of the process or facility?	
		• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?	
		• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?	
		• Are there uncertainties in the definition of the end state requirements for this technology?	
Yes	**No**	**Set 2**	
	X	• Is the technology new or novel?	
	X	• Is the technology modified?	
X		• Has the technology been repackaged so a new relevant environment is realized?	The baseline booster pump (hose pump) will be engineered/modified for submerged service.
X		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?	The baseline booster pump (hose pump) will be engineered/modified for submerged service. Suitable performance of the hose pump will need to be demonstrated in a fully submerged environment.

Appendix B Technology Readiness Level Summary for K BASINS Critical Technology Elements

Appendix B summarizes the responses to the TRL questions for each of the critical technology elements (CTEs). The following were evaluated:

Xago Tool

- Table B.1 Technology Readiness Level 4 Summary for the Xago Tool
- Table B.2 Technology Readiness Level 5 Summary for the Xago Tool

Overflow Recovery Tool

- Table B.3. Technology Readiness Level 4 Summary for the Overflow Recovery Tool

Booster/Decant Pumps

- Table B.4 Technology Readiness Level 4 Summary for the Booster/Decant Pumps

Table B.1 Technology Readiness Level 4 Summary for the Xago Tool			
CTE: Xago Tool for EC Retrieval & STSC Retrieval			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	Y	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	(25)
M	Y	2. Laboratory components tested are surrogates for system components	Full scale item exists. (12)
T	Y	3. Individual components tested in laboratory/ or by supplier	Full scale item exists. (12)
T	Y	4. Subsystems composed of multiple components tested at lab scale using simulants	(12; 15)
T	Y	5. Modeling & Simulation used to simulate some components and interfaces between components	(12; 15)
P	Y	6. Overall system requirements for end user's application are known	(5)
T	Y	7. Overall system requirements for end user's application are documented	(5; 13)
P	Y	8. System performance metrics measuring requirements have been established	(5; 13)
P	Y	9. Laboratory testing requirements derived from system requirements are established	Full scale item exists. (12)
M	Y	10. Available components assembled into laboratory scale system	Full scale item exists. (12)
T	Y	11. Laboratory experiments with available components show that they work together	Full scale item exits. (12)
T	Y	12. Analysis completed to establish component compatibility (Do components work together)	Full scale item exists. (12)
P	Y	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	(26)
T	Y	14. Technology demonstrates basic functionality in simulated environment	(12; 15)
M	Y	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Full scale item exists. (12)

Table B.1 Technology Readiness Level 4 Summary for the Xago Tool

CTE: Xago Tool for EC Retrieval & STSC Retrieval

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	Y	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	(5; 13)
M	Y	17. Equipment scale-up relationships are understood/accounted for in technology development program	Full scale item exists. (12)
T	Y	18. Controlled laboratory environment used in testing	(12; 15)
P	Y	19. Initial cost drivers identified	Full scale item exists. (12)
M	Y	20. Integration studies have been started	Full scale item exists. (12)
P	Y	21. Formal risk management program initiated	(27)
M	Y	22. Key manufacturing processes for equipment systems identified	Full scale item exists. (12)
P	Y	23. Scaling documents and designs of technology have been completed	Full scale item exists. (12)
M	Y	24. Key manufacturing processes assessed in laboratory	Full scale item exists. (12)
P/T	Y	25. Functional process description developed. (Systems/subsystems identified)	(5)
T	Y	26. Low fidelity technology "system" integration and engineering completed in a lab environment	(12; 15)
M	Y	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Full scale item exists. (12)
T	Y	28. Key physical and chemical properties have been characterized for a range of wastes	(28; 17; 29)
T	Y	29. A limited number of simulants have been developed that approximate the range of waste properties	(17)
T	(N)	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Not necessary or appropriate to do a prototype of in the hot cell laboratory. Not practicable.
T	Y	31. Process/parameter limits and safety control strategies are being explored	(30)

Table B.1 Technology Readiness Level 4 Summary for the Xago Tool

CTE: Xago Tool for EC Retrieval & STSC Retrieval

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	32. Test plan documents for prototypical lab- scale tests completed	(12; 15)
P	Y	33. Technology availability dates established	Full scale item exists. (12)

Table B.2 Technology Readiness Level 5 Summary for the Xago Tool			
CTE: Xago Tool EC Retrieval & STSC Retrieval			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	Y	1. The relationships between major system and sub-system parameters are understood on a laboratory scale.	(5)
T	Y	2. Plant size components available for testing	(12; 15)
T	Y	3. System interface requirements known (How would system be integrated into the plant?)	(5)
P	Y	4. Preliminary design engineering begins	(12; 15)
T	Y	5. Requirements for technology verification established	(12; 15; 26; 31)
T	Y	6. Interfaces between components/subsystems in testing are realistic (bench top with realistic interfaces)	(12; 15)
M	Y	7. Prototypes of equipment system components have been created (know how to make equipment)	Have purchased a full scale Xago tool. (12)
M	Y	8. Tooling and machines demonstrated in lab for new manufacturing processes to make component	Full scale item exists. (12)
T	Y	9. High fidelity lab integration of system completed, ready for test in relevant environments	Full scale item exists. (12)
M	Y	10. Manufacturing techniques have been defined to the point where largest problems defined	Full scale item exists. (12)
T	Y	11. Lab-scale, similar system tested with range of simulants	(12; 15)
T	Y	12. Fidelity of system mock-up improves from laboratory to bench-scale testing	Full scale item exists. (12)
M	Y	13. Availability and reliability (RAMI) target levels identified	Procurement Specification
M	Y	14. Some special purpose components combined with available laboratory components for testing	Full scale item exists. (12)
P	Y	15. Three dimensional drawings and P&IDs for the prototypical engineering-scale test facility have been prepared	Test facility exists (MASF).

Table B.2 Technology Readiness Level 5 Summary for the Xago Tool

CTE: Xago Tool EC Retrieval & STSC Retrieval

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	16. Laboratory environment for testing modified to approximate operational environment	MASF is engineering scale. Test completed (12)
T	Y	17. Component integration issues and requirements identified	P&ID (5)
P	Y	18. Detailed design drawings have been completed to support specification of engineering-scale testing system	Full scale item exists. (12)
T	Y	19. Requirements definition with performance thresholds and objectives established for final plant design	(12; 15; 26; 31)
P	Y	20. Preliminary technology feasibility engineering report completed	(12; 15)
T	Y	21. Integration of modules/functions demonstrated in a laboratory/bench-scale environment	Full scale item exists. (12)
T	Y	22. Formal control of all components to be used in final prototypical test system	Full scale item exists. (12)
P	Y	23. Configuration management plan in place	(32)
T	N	24. The range of all relevant physical and chemical properties has been determined (to the extent possible)	Settler sludge and engineered container sludge characterization and aging not yet complete.
T	N	25. Simulants have been developed that cover the full range of waste properties	Settler sludge and engineered container sludge characterization and aging not yet complete.
T	N	26. Testing has verified that the properties/performance of the simulants match the properties/performance of the actual wastes	Settler sludge and engineered container sludge characterization and aging not yet complete.
T	N	27. Laboratory-scale tests on the full range of simulants using a prototypical system have been completed	Settler sludge and engineered container sludge characterization and aging not yet complete.
T	(N)	28. Laboratory-scale tests on a limited range of real wastes using a prototypical system have been completed	Not necessary or appropriate to do a prototype of in the hot cell laboratory.
T	N	29. Test results for simulants and real waste are consistent	(5)
T	Y	30. Laboratory to engineering scale scale-up issues are understood and resolved	(12; 15)
T	Y	31. Limits for all process variables/parameters and safety controls are being refined	(5)

Table B.2 Technology Readiness Level 5 Summary for the Xago Tool			
CTE: Xago Tool EC Retrieval & STSC Retrieval			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
P	Y	32. Test plan for prototypical lab-scale tests executed – results validate design	(12; 15)
P	Y	33. Test plan documents for prototypical engineering-scale tests completed	(12; 15; 26; 31)
P	Y	34. Risk management plan documented	(12; 15)

Table B.3 Technology Readiness Level 4 Summary for the Overflow Recovery Tool

CTE: Overfill Recovery Tool

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	(25)
M	Y	2. Laboratory components tested are surrogates for system components	Full scale item exists and tooling which operates on similar principles has been successfully tested.
T	Y	3. Individual components tested in laboratory/-or by supplier	Full scale item exists and tooling which operates on similar principles has been successfully tested.
T	Y	4. Subsystems composed of multiple components tested at lab scale using simulants	(14; 12; 15)
T	Y	5. Modeling & Simulation used to simulate some components and interfaces between components	Full scale item exists and tooling which operates on similar principles has been successfully tested.
P	Y	6. Overall system requirements for end user's application are <u>known</u>	(13)
T	Y	7. Overall system requirements for end user's application are <u>documented</u>	(13)
P	Y	8. System performance metrics measuring requirements have been established	(5)
P	Y	9. Laboratory testing requirements derived from system requirements are established	(33; 34)
M	Y	10. Available components assembled into laboratory scale system	Full scale item exists and tooling which operates on similar principles has been successfully tested.
T	Y	11. Laboratory experiments with available components show that they work together	Full scale item exists and tooling which operates on similar principles has been successfully tested.
T	Y	12. Analysis completed to establish component compatibility (Do components work together)	Full scale item exists and tooling which operates on similar principles has been successfully tested.
P	Y	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	(5; 13)
T	Y	14. Technology demonstrates basic functionality in simulated environment	(14; 12; 15)

Table B.3 Technology Readiness Level 4 Summary for the Overflow Recovery Tool			
CTE: Overfill Recovery Tool			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
M	Y	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Full scale item exists.
P	Y	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	(5)
M	Y	17. Equipment scale-up relationships are understood/accounted for in technology development program	Full scale item exists.
T	Y	18. Controlled laboratory environment used in testing	(14; 12; 15)
P	Y	19. Initial cost drivers identified	Full scale item exists.
M	Y	20. Integration studies have been started	Full scale item exists.
P	Y	21. Formal risk management program initiated	(27)
M	Y	22. Key manufacturing processes for equipment systems identified	Full scale item exists.
P	Y	23. Scaling documents and designs of technology have been completed	Full scale item exists.
M	Y	24. Key manufacturing processes assessed in laboratory	Full scale item exists.
P/T	Y	25. Functional process description developed. (Systems/subsystems identified)	(5)
T	Y	26. Low fidelity technology “system” integration and engineering completed in a lab environment	(14; 12; 15)
M	Y	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Full scale item exists.
T	Y	28. Key physical and chemical properties have been characterized for a range of wastes	(28; 17; 29)
T	Y	29. A limited number of simulants have been developed that approximate the range of waste properties	(17)
T	(N)	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Not practicable to do a prototype of in the hot cell laboratory. Similar tools have been used on K Basins sludge.
T	Y	31. Process/parameter limits and safety control strategies are being explored	(30)

Table B.3 Technology Readiness Level 4 Summary for the Overflow Recovery Tool

CTE: Overfill Recovery Tool			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	Y	32. Test plan documents for prototypical lab- scale tests completed	(14)
P	Y	33. Technology availability dates established	Full scale item exists.

Table B.4 Technology Readiness Level 4 Summary for the Booster/Decant Pumps

CTE: Booster/Decant Pump

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	(25)
M	Y	2. Laboratory components tested are surrogates for system components	Full scale test exist. (19)
T	Y	3. Individual components tested in laboratory/or by supplier	Full scale test exist. (19) A21C-STP-TR-0015, Test Report for Sludge Treatment Project Slurry Transfer Testing for Direct Hydraulic Loading (Hose Pump)
T	Y	4. Subsystems composed of multiple components tested at lab scale using simulants	Full scale test exist. (19)
T	Y	5. Modeling & Simulation used to simulate some components and interfaces between components	Full scale test exist. (19)
P	Y	6. Overall system requirements for end user's application are known	(5) HNF-41051, Preliminary STP Container and Settler Sludge Process System Description and Material Balance
T	Y	7. Overall system requirements for end user's application are documented	(5) HNF-41051, Preliminary STP Container and Settler Sludge Process System Description and Material Balance
P	Y	8. System performance metrics measuring requirements have been established	(19) A21C-STP-TR-0015, Test Report for Sludge Treatment Project Slurry Transfer Testing for Direct Hydraulic Loading (Hose Pump)
P	Y	9. Laboratory testing requirements derived from system requirements are established	Full scale test exist. (19)
M	Y	10. Available components assembled into laboratory scale system	Full scale test exist. (19)
T	Y	11. Laboratory experiments with available components show that they work together	Full scale test exist. (19)
T	Y	12. Analysis completed to establish component compatibility (Do components work together)	Full scale test exist. (19)

Table B.4 Technology Readiness Level 4 Summary for the Booster/Decant Pumps

CTE: Booster/Decant Pump

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	Y	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	(19)
T	Y	14. Technology demonstrates basic functionality in simulated environment	(19)
M	Y	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Full scale test exist. (19)
P	Y	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	(19; 5)
M	Y	17. Equipment scale-up relationships are understood/accounted for in technology development program	Full scale test exists. (19)
T	Y	18. Controlled laboratory environment used in testing	(19)
P	Y	19. Initial cost drivers identified	Full scale unit procured
M	Y	20. Integration studies have been started	Full scale item exists and preliminary full-scale testing completed. (19)
P	Y	21. Formal risk management program initiated	(27)
M	Y	22. Key manufacturing processes for equipment systems identified	Full scale item exists. (19)
P	Y	23. Scaling documents and designs of technology have been completed	Full scale item exists. (19)
M	Y	24. Key manufacturing processes assessed in laboratory	Full scale item exists. (19)
P/T	Y	25. Functional process description developed. (Systems/subsystems identified)	(5)
T	Y	26. Low fidelity technology “system” integration and engineering completed in a lab environment	(19)
M	Y	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Possible alternative exists and will be tested.
T	Y	28. Key physical and chemical properties have been characterized for a range of wastes	(28; 17; 29)

Table B.4 Technology Readiness Level 4 Summary for the Booster/Decant Pumps

CTE: Booster/Decant Pump

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	29. A limited number of simulants have been developed that approximate the range of waste properties	(17)
T	(N)	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Not necessary or appropriate to do a prototype of in the hot cell laboratory. Not practicable.
T	Y	31. Process/parameter limits and safety control strategies are being explored	(30)
T	Y	32. Test plan documents for prototypical lab- scale tests completed	(19)
P	Y	33. Technology availability dates established	Full scale item exists. (19)

Appendix C Process Integration Summary

The completed TRL 4 Process Integration Questionnaire is included below. A Y response indicates that the requirement has been met at a level appropriate for conceptual design. Questions D.1 and D.3-5 that deal with disposition of the final wasteform cannot be answered affirmatively because the final wasteform produced during Phase 2 has not yet been determined. All other TRL 4 process integration questions received Y answers.

Table C.1 Responses to TRL 4 Questions for the Waste Processing System (WPS)

Table C.1 Technology Readiness Level 4 Summary for the Waste Processing System (WPS)			
	Y/N	**Criteria**	**Basis and Supporting Documents**
Processing P.1	Y	Is the WPS, as it appears in the conceptual design, intended to accept the full range of wastes to be processed?	The WPS is designed to accept the full range of sludge to be processed as established by the requirements documented in HNF-40475, *Functional Design Criteria Sludge Treatment Project – Phase 1* and HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* The range of sludge properties is described in HNF-SD-SNF-TI-009 (*105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities*) and HNF-SD-SNF-TI-015 (*Spent Nuclear Fuel Sludge Technical Databook, Vol. 2, Sludge*), and SNF-7765 (*Supporting Basis for Spent Nuclear Fuel Project Sludge Technical Databook*). (5; 13; 6; 35; 36)
P.2	Y	Is the WPS capable of meeting targets for startup and completion of waste processing?	All activities for the WPS are integrated into the overall *Sludge Treatment Project Field Execution Schedule, 10/11/09*. The design basis process throughput as described in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*, is capable of meeting the target mission completion date of 11/25/14. Technology maturation activities are scheduled to achieve TRL 6/7 by January, 2011(PRC-STP-00059, *Sludge Treatment Project Phase 1Technology Development Plan)*. The estimated operating schedule for the transfer of sludge is 46 weeks. (PRC-STP-00059, *Sludge Loading Options – Operations and Maintenance Evaluation*, 9/8/09*)* (5; 24; 37; 22)
P.3	Y	Have the target operational and performance requirements for the WPS been determined?	Target operational and performance requirements have been determined and are documented in HNF-40475, *Functional Design Criteria Sludge Treatment Project – Phase 1*. (13)
P.4	Y	Have all TEs that require an increase or change in capability been identified as CTEs.	The Team is satisfied that all CTEs have been properly identified.
P.5	Y	Has the WPS process flow been modeled?	The WPS process flow has been modeled as documented in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance.*

Table C.1 Technology Readiness Level 4 Summary for the Waste Processing System (WPS)

	Y/N	Criteria	Basis and Supporting Documents
			(5)
P.6	Y	Have WPS single point failures been identified?	The WPS single point failures have been identified and analyzed in the following documents: PRC-STP-00012, *What-If/Checklist Hazard Analysis for the Sludge Treatment Project Direct Load Alternative Draft Conceptual Design* and PRC-STP-00008, *Failure Modes and Effects Analysis, Sludge Retrieval and Transport Design*. (25; 38)
P.7	Y	Can TEs be sized to meet WPS throughput requirements?	TEs can be sized to meet the WPS throughput requirements found in HNF-40475, *Functional Design Criteria Sludge Treatment Project – Phase 1*. The process model in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* shows that conceptual equipment sizing is adequate to meet throughput requirements. The *Preliminary Hydraulic Analysis for Direct Loading of Sludge Transport and Storage Containers*, PRC-STP-00021, provides sizing requirements for hydraulic transfer equipment. (5; 13; 21)
P.8	Y	Have all new or novel operating modes of the WPS been modeled and/or tested at lab scale?	All new or novel operating modes of the WPS have been modeled and/or piloted. Modeling of operating modes is found in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance.* The following novel operating modes (i.e. sensitivity analyses) have been identified and modeled in HNF-41051, Section 4.0: (1) retrieved slurry solids concentration variation, (2) Lower Settled Solids Limit for Settler Sludge / No Annular STSC, (3) Particle Size Distribution variation for Settler sludge, (4) Settling Duration, (5) Settled Solids Volume Fraction, (6) Sludge Volume Variability, and (7) Under-filled Sludge Retrieval Containers. Pilot scale and prototype testing of TEs in the WPS is described in PRC-STP-00046, *Sludge Treatment Project Phase 1 Technology Development Plan.* Modeling in the *Preliminary Hydraulic Analysis for Direct Loading of Sludge Transport and Storage Containers*, PRC-STP-00021 provides sizing requirements for hydraulic transfer equipment. Pilot test results are found in the following test reports for individual CTEs: A21C-STR-TR-0001, *Test Report for Settler Tank Sludge Filtration Development Test*; A21C-STP-TR-0009, *Test Report for Direct Suction Top Retrieval Development Test*; A21C-STP-TR-0011, *Test Report for Sludge Container Retrieval Development Test, XAGO Top Retrieval*; A21C-STP-TR-0012, *Test Report for Sludge Treatment Project Engineered Container Retrieval Campaign Test (XAGO Follow-on)*; A21C-STP-TR-0014, *Qualification and Acceptance Test Report for the 105-KW Settler Tank Retrieval System*; A21C-STP-TR-0015, *Test Report for Sludge Treatment Project Slurry Transfer Testing for Direct Hydraulic Loading (Hose Pump)*;

Table C.1 Technology Readiness Level 4 Summary for the Waste Processing System (WPS)

	Y/N	Criteria	Basis and Supporting Documents
			KBC-37619, *Test Report for IWTS Settler Tank Retrieval Equipment Development Test*; PRC-STP-00044, *Test Report for Sludge Treatment Project Settling and Filtration Testing for STSC Loading* (5; 37; 21; 39; 40; 12; 15; 14; 19; 41)
P.9	Y	Have all recycle streams have been identified and included in conceptual design process flow models?	Recycle streams are shown in the Process Flow Diagram SK-4K-P-001 . Excess water from the settle/decant step is returned to the basin. Off-normal recovery from overfilling a transport container will return excess sludge to the engineered container it came from. (42)
Disposal D.1	(N)	Will the WPS produce a product or products that can be dispositioned?	The Phase 1 "product" is sludge placed into containers for interim storage at T Plant (Reference Engineering White Paper PRC-STP-00018, *Shielded Storage of KW Container and Settler Sludge at T Plant Sludge Treatment Project*. However, Phase 2 final treatment and disposition of the sludge have not yet been decided upon and, along with retrieval of the sludge after long term storage, represent a risk. (43)
D.2	Y	Are all WPS waste streams identified and tentatively characterized to the extent necessary for conceptual design?	All WPS waste streams have been identified and fully characterized. No new liquid or hazardous waste streams will be generated per HNF-40475, *Functional Design Criteria Sludge Treatment Project – Phase 1*, Section 4.1. Technical wastes (HEPA filters, PPE, process filter media) will be disposed in accordance with HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*. Spent equipment, basin water and the basin structure will be managed as part of the deactivation and demolition of the basin. Any residual sludge in these materials is currently characterized in HNF-SD-SNF-TI-009 (*105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities*), HNF-SD-SNF-TI-015 (*Spent Nuclear Fuel Sludge Technical Databook*), and SNF-7765 (*Supporting Basis for Spent Nuclear Fuel Project Sludge Technical Databook*). (13; 44; 6; 35; 36)
D.3	(N)	Can all WPS waste streams, including process liquids, off gases, and solids in the conceptual design be treated and disposed	All WPS waste streams, including process liquids, off gases, and solids can be treated and disposed. No new liquid or hazardous waste streams will be generated per HNF-40475, *Functional Design Criteria Sludge Treatment Project – Phase 1*, Section 4.1. Air vented from process vessels is discharged through HEPA filters as described in PRC-STP-00024, *Sludge Treatment Project STSC Loading Facility HVAC Conceptual Design Description*. HEPA filters, PPE, and process filter media will be disposed in accordance with HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*. Spent equipment, basin water and the basin structure will be managed as part of the deactivation and demolition of the basin. However, Phase 2 final treatment and disposition of the sludge have not yet been decided upon and, along with retrieval of the sludge after long term storage, represent a risk.

Table C.1 Technology Readiness Level 4 Summary for the Waste Processing System (WPS)			
	Y/N	**Criteria**	**Basis and Supporting Documents**
			A disposition path has been determined for the waste streams. Process waste (spent filter media) will be disposed as RH-TRU, CH-TRU, or LLW, according to its waste designation. The disposition of the equipment and systems deployed in the 105-K West Basin used for the retrieval and removal of sludge will be managed as part of the deactivation and demolition of the basin. The removal of sludge from the basin is defined in the 1999 CERCLA Record of Decision (ROD) (99-SFD-190) and 2005 ROD amendment (05-AMCP-0314) and includes: Treatment of water and transfer to the Effluent Treatment Facility, treatment of debris and transfer to a disposal or storage facilities in the 200 Area, and deactivation of the basins. Removed material will be managed as debris. The equipment and systems deployed in the basin will be considered debris at the end of the sludge removal mission and managed per the requirements in the RODs, End Point Criteria (HNF-20632) and approved (DOE-RL and EPA) remedial design for deactivation of the basin. The specific implementation for 105-K West basin is in development but will be comparable to what was approved for the 105-K East Basin (DOE/RL-2007-41), consistent with the 1999 CERCLA ROD (99-SFD-190) and 2005 ROD amendment (05-AMCP-0314). (13; 45; 44; 46; 47; 48; 49)
D.4	(N)	Will the waste streams meet the waste acceptance criteria of the proposed disposition facilities/sites?	Debris, structural waste, and process waste designated as LLW will be disposed at the Environmental Restoration Disposal Facility (ERDF) in accordance with WCH-00191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*. Basin water will be disposed at the Liquid Effluent Treatment Facility in accordance with *HNF-3172, Liquid Waste Processing Facilities Waste Acceptance Criteria*. Process waste designated as TRU will be disposed at WIPP in accordance with the *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant (WIPP WAC)* (DOE/WIPP-02-3122). However, Phase 2 final treatment and disposition of the sludge have not yet been decided upon and, along with retrieval of the sludge after long term storage, represent a risk. (50; 51; 52)
D.5	(N)	Have the disposition facilities/site been contacted to ensure that projected waste forms are compatible with facility/site **<u>operations, procedures, and regulations</u>**?	The disposition facilities/site have been contacted to ensure that the waste forms are compatible with facility/site <u>operations, procedures, and regulations</u>. Debris, structural waste, and process waste designated as LLW will be disposed at the Environmental Restoration Disposal Facility (ERDF) in accordance with *WCH-00191, Environmental Restoration Disposal Facility Waste Acceptance Criteria*. Basin water will be disposed at the Liquid Effluent Treatment Facility in accordance with *HNF-3172, Liquid Waste Processing Facilities Waste Acceptance Criteria*. Process waste designated as TRU will be disposed at WIPP in accordance with the

Table C.1 Technology Readiness Level 4 Summary for the Waste Processing System (WPS)			
	Y/N	**Criteria**	**Basis and Supporting Documents**
			Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant (WIPP WAC) (DOE/WIPP-02-3122). However, Phase 2 final treatment and disposition of the sludge have not yet been decided upon and, along with retrieval of the sludge after long term storage, represent a risk. (50; 51; 52)
Interfaces I.1	Y	The WPS requires no new relationships among systems. (If new relationships are required, the interfaces among the systems are possible CTEs.)	The WPS is not dependent on new relationships among systems within the K Basin, transportation, and T Plant. There are no new relationships with systems outside the scope of the STP Phase 1 project. The interface with Phase 2 retrieval of sludge from STSCs stored at T Plant is described in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance*, Sections 3.1.8 and 3.2.6. (5)
I.2	Y	Are all WPS technology interfaces and dependencies determined and understood at the conceptual level?	All WPS technology interfaces and dependencies have been determined and are understood. No external technology interfaces exist outside the scope of the STP project. The internal WPS critical technologies and their interfaces are described in PRC-STP-00010, *Technology Testing Plan for the Sludge Treatment Project – Phase 1 CD-1* and PRC-STP-00046, *Sludge Treatment Project Phase 1 Technology Development Plan.* Other interfaces are managed as described in PRC-STP-00006, *KW Basin and Sludge Treatment Project Interface Control*. (20; 37; 23)
I.3	Y	Have all TEs that have to be modified to be integrated into the WPS have been identified as CTEs? (If the answer is no, the modified TEs are probably CTEs.)	The Team is satisfied that all CTEs have been properly identified. All modified TEs that are integrated into the WPS have sub-elements that are identified as CTEs in PRC-STP-00010, *Technology Testing Plan for the Sludge Treatment Project – Phase 1 CD-1*. (20)
I.4	Y	Can all WPS components be successfully mated?	All WPS TE interfaces <u>can</u> be successfully mated. The design provides details on interfaces between TEs. System external interfaces are described in PRC-STP-00006, *KW Basin and Sludge Treatment Project Interface Control*. TE interfaces are shown in SK-TE-001, *CTEs Hydraulic Transfer to STSC* (23; 53)
I.5	Y	Are the processing modes of the TEs (e.g., batch, continuous) compatible?	The processing modes of the TEs are compatible. The design basis processing mode is sequential batch processing as described in HNF-41051, *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* (5)

Appendix D Technology Readiness Assessment Meeting Attendees and Team Resumes

Dr. Herbert Sutter: Dr. Sutter holds an A.B. in Chemistry from Hamilton College, a Ph.D. Physical Chemistry from Brown University and carried out Post Doctoral Research in Theoretical Chemistry at Cambridge University, UK. He has more than thirty years experience in the fields of separations science, high and low level radioactive waste treatment, waste water treatment, vitrification, and analytical chemistry. For the past nineteen years he has provided technical and programmatic support to DOE's Office of Environmental Management (EM). Dr. Sutter has provided technical assistance to the DOE programs at Hanford, Savannah River, and other sites in: (1) separation technologies; (2) technology development; (3) high level waste disposal; (4) nuclear waste characterization; (5) vitrification; and (6) analytical laboratory management. From 2007 through the present Dr, Sutter has supported EM's Office of Project Recovery working on technology aspects of Hanford's Waste Treatment Plant. During that time he helped develop the EM Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide (March 2008). From 2005 to 2006, Dr. Sutter assisted EM in the development of a long-term, complex-wide Project Plan for Technology Development and Demonstration. From 2002-2004, he was a senior scientist for Kenneth T. Lang Associates, Inc. and provided support to EM in several areas including the evaluation of HLW vitrification technologies at Hanford and pretreatment and separation technologies at Savannah River. He has also been a consultant to private industry on separation technologies. From 1990-2002, as a scientist for Science Applications International Corporation, he supported EM in the areas of nuclear waste treatment and characterization and analytical chemistry. From 1982-1990, Dr. Sutter was Vice President and Chief Scientist at Duratek Corporation and responsible for technical direction of all research and development and commercialization programs in ion exchange, filtration and separation techniques. Relevant experience includes: waste water treatment, bench and pilot testing, and waste treatment studies. Dr. Sutter has authored or co-authored over 30 journal articles and technical reports and is a member of the American Chemical Society and the American Nuclear Society.

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Dr. Michael Poirier: Dr. Poirier is a Senior Fellow Engineer at the Savannah River National Laboratory (SRNL). He has 20 years of experience in filtration, solid-liquid separations, mixing, slurry transport, and waste retrieval. His experience includes work with simulants and actual waste. Dr. Poirier conducted test programs with actual SRS and Hanford High Level Waste sludge and supernate to measure filter performance and evaluate alternative filtration technologies. He has led SRNL's technical support for the Actinide Removal Process (a filtration process) and the Modular Caustic Side Solvent Extraction Unit (a solvent extraction process) startup. These processes successfully started in 2008 and are currently treating SRS Liquid Radioactive Waste. Dr. Poirier has led the team that is developing the rotary micro-filter for DOE applications. This team has tested the rotary filter at bench-scale with actual waste, at pilot-scale with simulant, and at full-scale with simulant. The team has improved the commercial design to make the unit suitable for deployment at DOE sites. Dr. Poirier has been studying mixing in high level waste tanks at SRS. He developed mixing models for sludge and precipitate tanks. He compared the models with results from SRS operating experience, showed they modeled mixing in the waste tanks, and then applied the models to mixing in high level waste tanks to recommend operating parameters to optimize mixing. He performed a slurry transport study to determine the properties and characteristics of sludge and precipitate slurries at SRS. The results of the study were used to develop guides for transporting slurries between areas at SRS. He conducted a laboratory-scale, pilot-scale, and full-scale test program with ITT-Flygt to evaluate shrouded axial impeller mixers for heel removal in SRS waste tanks. The program developed methods to scale mixing requirements to 85 foot diameter tanks and showed that shrouded axial impeller mixers could mobilize very high shear strength sludge. Dr. Poirier received a Ph. D. in chemical engineering from the University of Illinois in Urbana, Illinois in 1989. Dr. Poirier received a B. S. in chemical engineering from the University of Notre Dame in 1984.

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Dr. Arthur W. Etchells III: Dr. Etchells is a world recognized authority in the field of mixing for the process industries. He is a chemical engineer with BS and MS from University of Pennsylvania and doctorate from University of Delaware. For thirty nine years he worked for the DuPont Company and for thirty years as an internal consultant for the many diverse DuPont businesses in the field of fluid flow with emphasis on mixing and slurry transport. He has achieved the highest technical level of DuPont Fellow and the highest technical award, the Lavoisier Medal. His outside activities such as teaching in universities and continuing education courses, publications, and lectures and his leadership in the world technical community have made him widely known and highly respected. He has contributed two chapters to the recent Handbook of Industrial Mixing (Wiley 2003) and is now working as an editor for a new supplemental edition. He is a past president of the North American Mixing Forum and winner of their award for contribution to mixing technology. He retired from DuPont in November 2002 and now works as an independent contract consultant. He is currently working for DuPont Safety Resources Business helping the Bechtel Company develop a facility for immobilizing radioactive waste at the Hanford site in the state of Washington along with other consulting for a number of companies outside of DuPont.

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Dr. Gary Smith: Dr. Smith is a staff scientist with the Pacific Northwest National Laboratory (PNNL) and is currently on assignment to the Office of Waste Processing, Engineering & Technology within the Office of Environmental Management, U.S. Department of Energy. Dr. Smith has been involved with all aspects of the nuclear waste flow sheet for a number of years, taking on roles of increasing responsibility in both a technical capacity and in management. He has extensive project management experience, most recently serving as PNNL's Deputy Program Manager for the River Protection Project – Waste Treatment Plant Project Support Program. This program contributes significantly to the characterization, retrieval, pretreatment, and vitrification of Hanford tank waste for the Waste Treatment and Immobilization Plant (WTP) project. Prior to this role, Dr. Smith served as a technical advisor, directly supporting the WTP contractor. He has managed and acted as principal investigator on projects ranging from vitrification and glass product testing to examining the process-ability of slurry feeds as a function of batch chemistry for laboratory-, bench- and pilot-scales. Dr. Smith has published more than 70 refereed journal articles, technical reports, and conference papers as well as numerous classified documents. He has co-edited three volumes of *Ceramic Transactions*, dealing with "Environmental and Waste Management Issues in the Ceramic Industry." He is a fellow of the American Ceramic Society (ACerS) and ASTM International. Dr. Smith is chair of ASTM International Committee C-26 on the Nuclear Fuel Cycle and chair of Subcommittee C26.13 on Spent Fuel and High Level Waste, committees that develop consensus standards for the international nuclear community. He also is vice chair of the U.S. Nuclear Technical Advisory Group and past chair of the ACerS Nuclear and Environmental Technology Division. He holds a Ph.D. in Materials Science & Engineering from the University of Arizona.

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Kris Thomas: Mr. Thomas has a B.S., Mechanical Engineering from the University of Idaho - with an emphasis in design, fluid flow, material properties and selection. He joined ORP in 2007 and prior to that, he worked at the Puget Sound Naval Shipyard as a Nuclear Engineer. He currently performs duties and responsibilities of the Mechanical SSO Engineer for the WTP

Engineering Division. He has led and participated in design review assessments of contractor designs on safety-related systems including application of design codes and standards.

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Jim J. Davis: Mr. Davis has over 21 years of nuclear experience including 17 years with the Department of Energy (DOE), predominately in the field of radioactive waste management at the Hanford, WA site. Currently he works for DOE-EM, Office of Standards and Quality Assurance (EM-64) in the area of quality assurance related to environmental management projects. Prior to that he worked for DOE as a project manager on Tank Farm (TF) waste retrieval projects and programs for over 12 years which included oversight of technology development, engineering design, procurement, construction and operations. He qualified as a Safety System Oversight (SSO) for transfer systems in the TF project and on mechanical systems for the Waste Treatment and Immobilization Plant (WTP), at which he supported engineering design and construction for 4 years. Prior to coming to the department, Jim worked 4 years in Naval nuclear refueling operations at Puget Sound Naval Shipyard. He received a Bachelor of Science in Engineering degree from the University of Washington in 1985.

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Paul Macbeth: Mr. Macbeth has a Master of Science degree in Nuclear Physics from Brigham Young University, and completed most of the course work for the Ph.D. degree in Nuclear Engineering from the University of Utah. Mr. Macbeth has over 30 years of direct professional experience in nuclear safety and waste management, dealing with diverse topics and complex issues, including assessment of environmental impacts from waste management activities, cryogenic storage of radioactive krypton, remediation of uranium mill tailings sites and contaminated Federal facilities, waste classification and associated risk assessment, as well as design and operational experience at a commercial nuclear power plant. Mr. Macbeth currently provides senior level expertise in transportation and packaging, nuclear safety and documented safety analyses, as well as radioactive and mixed waste management in review and oversight functions for DOE/RL. His reviews and oversight have helped ensure compliance with applicable DOE, EPA, State of Washington, NRC, and DOT regulatory requirements and guidelines through review and assessment of design, safety, NEPA, RCRA and budgetary documentation. His responsibilities have included preparation, review, assessment, and validation of safety analysis and authorization basis documents for High-Level, Low-Level and Transuranic Waste and Spent Nuclear Fuel treatment, storage and disposal facilities and transportation methods, documents for submittal to regulators covering RCRA permitting and remediation site closure activities, Tri-Party Agreement milestone progress, project design, NEPA activities, budget input reports, operational readiness reviews, and findings, observations and surveillances on Solid Waste and Transportation programs. He served as team member on RL's Readiness Assessment for startup of Mixed Waste Disposal Trench 31 in the Low-Level Waste Burial Grounds and on the Operational Readiness Review teams for restart of intrusive activities at N Basin and the Aging Waste Facility Ventilation System Upgrade. He was lead reviewer for Solid Waste Operations Interim Safety Bases (ISBs), the WRAP FSAR, the WESF BIO, the K Basins SAR, and the Solid Waste Master DSA, and performed Tier 3 reviews for DOE/RL's ESH Division on the Salt-Well Pumping and Aging Waste Facility Ventilation System Upgrade safety analysis and approval documents. Mr. Macbeth participated in the recent DOE review of the CH2M Hill Plateau Remediation Contractor's readiness to implement their Integrated Safety Management/Environmental Management program. He also documented bases for DOE approval of the foregoing Authorization Basis documents in Safety Evaluation Reports.

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U.S. Department of Energy, Richland Operations Office, Safety and Engineering,

Appendix E TRA Plan

K Basins Sludge Treatment Project

Phase 1
Critical Decision (CD) -1

Technology Readiness Assessment

Plan

Federal Project Director: ______________________
Tom Teynor (DOE-RL)

EM-20: ______________________
Mark Gilbertson (EM-20)

TRA Team Lead: ______________________
Herb Sutter (Consultant to EM)

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1.0 INTRODUCTION

The Federal Project Director (FPD) for the U.S Department of Energy (DOE), Richland Operations Office (RL) K Basins Closure Project (KBCP) requested a Technology Readiness Assessment (TRA) for the Sludge Treatment Project (STP) at the Hanford Site in Washington State. The KBCP is responsible for conducting the STP TRA with assistance from the DOE Office of Environmental Management (EM). The STP is configured in two phases. Phase 1 retrieves the sludge from K-basin and transports it to the Central Plateau for interim storage. In Phase 2 the sludge is treated, packaged and shipped offsite for disposal. The technologies that will be assessed are those necessary to support Phase 1 of the STP which will remove sludge from the K West Basin on the Hanford River Corridor and place the sludge in safe interim storage on the Hanford Central Plateau. The technologies used to perform the Phase 1 activities are being developed at the STP Test Facility located in the 400 Area on the Hanford Site and are described in Section 3, Technologies.

2.0 PURPOSE

The purpose of the STP TRA is to evaluate technology maturity for STP Phase 1 activities, using the Technology Readiness Level (TRL) scale established in the DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide (March 2008). The results of the TRA will be used by the RL KBCP Federal Project Director to support DOE approval of CD-1 for STP Phase 1. After the TRA is completed and the final report is issued KBCP will develop a Technology Maturation Plan (TMP) to guide future maturation of technologies to levels appropriate for CD-2.

3.0 TECHNOLOGIES

The DOE-RL is responsible for the STP at the Hanford Site in Washington State. The STP is a subproject of the KBCP. Sludge is currently stored within Engineered Containers (EC) located in the K West Basin. The mission of the STP is to retrieve, treat, and package the sludge material for ultimate disposal at a national repository.

3.1 Background

The STP faces significant challenges to successfully retrieve, treat, package and dispose of K Basin sludge material (DOE, January 2005). To date, no known technology has been developed and successfully demonstrated that addresses all the issues associated with the K Basins sludge. DOE has attempted several different technical approaches to disposition this material using different technologies and contracting approaches. None have proven mature enough to successfully deal with this unique material. Previous technical approaches have been abandoned prior to demonstration of technical feasibility and adequate technical maturity to proceed to detailed design, construction, and operation of the needed sludge treatment and packaging facilities.

In 2007, a TRA was jointly performed by DOE-RL and the performing contractor to determine whether the project had adequately developed the needed technologies. The TRA was modeled on previously conducted DOE TRAs and the Department of Defense TRA Desk-book using a methodology that was tailored by the TRA team to apply to the STP activities. The TRA team concluded that the critical technologies associated with the project plans at that time were not at the maturity level needed to support a Critical Decision “3” (CD-3) to procure and construct the sludge treatment process. This conclusion supported the contractor’s recommendation and subsequent DOE-RL decision to re-baseline the STP to between CD-0 and CD-1 (Reference: RL letter 07-KBC-0048, 7/3/07).

Subsequently, DOE-RL directed the performing contractor to develop a Critical Decision-1 (CD-1) package that includes alternative analyses for removal of the sludge stored in the K West Basins, in accordance with DOE Order 413.3A and DOE Standard 1189. DOE-RL also identified removal of the sludge from the K West Basin and its relocation off the River Corridor as soon as possible as a key DOE objective (Reference: RL letter 08-AMCP-0151, 3/28/08). In response, the performing contractor, CHPRC performed an alternative analysis and submitted the Sludge Treatment Project Alternative Analysis Summary Report, HNF-39744, Revision 0, on January 26, 2009 [Reference: letter CHPRC-09-00009].

In order to achieve the Hanford 2015 Vision for the River Corridor, the CHPRC recommended a two phased approach which expedites removal of the sludge off the River Corridor. Phase 1 removes the sludge from the River Corridor and relocates it to safe interim storage on the Hanford Central Plateau, and Phase 2 remobilizes the sludge for subsequent treatment and packaging for transport and disposal at the Waste Isolation Pilot Plant (WIPP).

The scope of this STP TRA is the Phase 1 activities. The Phase 2 activities are not sufficiently defined at this point with methodologies that can be relied on to establish the preferred alternatives and as such, are not within the scope of this TRA Plan.

In accordance with the DOE Office of Environmental Management (EM) Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide (March 2008), the RL KBCP Federal Project Director has requested a TRA on the STP Phase 1 activities to support CD-1 approval. CHPRC is preparing a CD-1 package for STP Phase 1, with submittal to RL for approval expected to occur in FY2010.

3.2 Technology Descriptions

Phase 1 activities, diagramed in Figure 1 below, include the retrieval of the sludge from the Engineered Containers (ECs) currently located in the K West Basin. The ECs contain sludge generated from the washing and packaging of spent nuclear fuel and which was subsequently cleaned up from K East Basin and K West Basin floors. The retrieval process transfers the sludge from the ECs into Sludge Transport Storage Containers (STSC). Excess transfer water will be decanted from the STSC and returned to the basin, resulting in filling the STSC with an optimal volume of sludge waste. Note that two methods are being considered for STSC loading: Direct Loading and Small Canister Loading. Each method has its own set of Technology Elements (TEs). Developing parallel processing options early in the project is a risk management strategy.

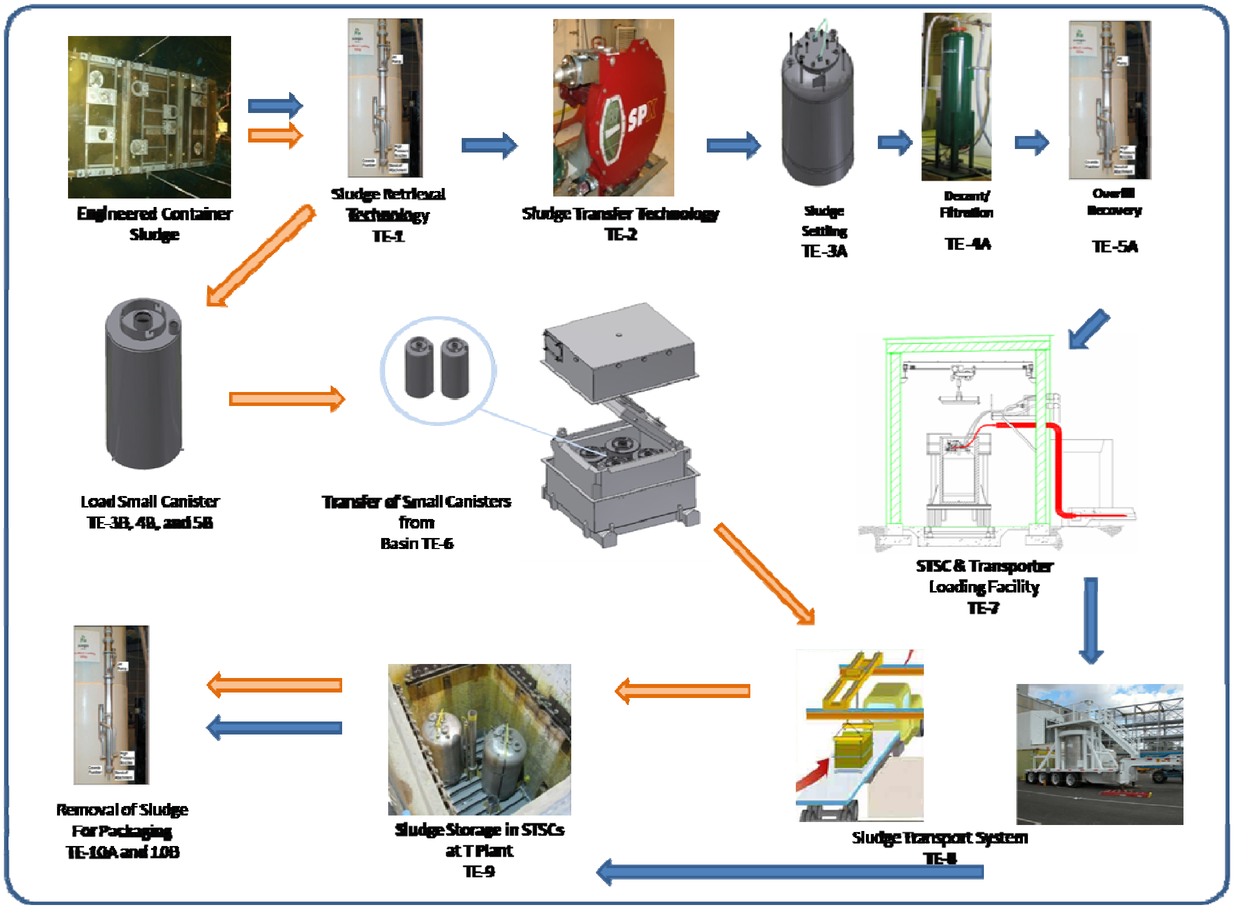

Figure 1. Phase 1 Sludge Treatment Process Diagram

The Phase 1 process involves a total of seven sludge handling functions that are identified in HNF-41051 Revision 0, Preliminary STP Container and Settler Sludge Process System Description and Material Balance. These functions are Retrieval, Solids Settling, Supernate Filtration, Transfer Canisters, STSC / STS Transporter Loading, Sludge Transport and Sludge Storage in STSC or Small Canisters at T Plant, and are discussed further below.

3.2.1 Retrieval

The Retrieval function extracts the sludge from the ECs currently located in the basin. The project has developed two TEs for this function. The Sludge Retrieval Technology (TE-1) addresses the tools and techniques needed to mobilize the sludge and remove it from the ECs and the Sludge Transfer Technology (TE-2) which would only be used for Direct Loading STSCs. Direct Loading STSCs requires the additional in-line transfer pumping capability because of the distances between the EC and the STSC.

3.2.2 Solids Settling

The Solids Settling function of the process allows for the incremental filling of the receiving vessel and intermittent decanting of excess mobilizing water. This operation loads the receiving vessel with an optimal sludge volume and recovers the mobilizing water, recycling it back to the basin. Because there are two optional process paths for this function which use different receiving vessels, the project has developed two TEs, the Sludge Settling - STSCs (TE-3A) and the Sludge Settling - Small Canisters (TE-3B). While the function for each of these TEs is similar, the technology and equipment that support Direct Loading STSCs is located outside of the basin whereas loading Small Canisters is done within the basin under water. These methods are sufficiently different to warrant the feasibility demonstration for both.

3.2.3 Supernate Filtration

The Supernate Filtration function is further broken down into a decanting / filtration operation and an overfill recovery system. The project has developed four TEs that address this function which are individually designed to support the loading of the two different receiving vessels. For the Direct Loading STSCs, the Decant / Filtration system (TE-4A) and the Overfill Recovery system (TE-5A) are used to dewater the STSC as it is held on the Sludge Transport System (STS) Transporter in the Annex. Solids are filtered from the decanted water before returning it back to the basin.

For the Small Canister Loading, the separation of settled solids uses a Settling Chamber when filling the Small Canisters (TE-3B). The Decant / Filtration - Canisters (TE-4B) loading occurs underwater in K-Basin which increases radiation protection. Other features include that smaller canisters are easier to handle and spillage that occurs when disconnecting transfer lines stays in the basin and is retrieved. This option also employs a control mechanism to drain the settled solids from the bottom of the Settling Chamber into the Canister. An operation for Overfill Prevention & Recovery - Canisters (TE-5B) has also been developed to support the Small Canister Loading operations.

3.2.4 Transfer Canisters

The Transfer Canisters function only applies to the Small Canister Loading process. The project has developed the Small Canister Transfer system (TE-6), which moves the canister that is filled with sludge from beneath the Settling Chamber to the Fuel Transfer System (FTS) Cask which is loaded under water in the basin. The FTS Cask, loaded with Small Canisters of sludge, is lifted out of the basin water using the FTS, deconned by rinsing and placed into the Cask Transport Overpack (CTO). The CTO is then transferred, using the overhead crane to the annex where the CTO is placed on a transport trailer for transfer to T Plant.

3.2.5 STSC / STS Transporter Loading

The STSC / STS Transporter Loading function takes place in the annex which has been modified to facilitate loading STSCs designed for Direct Loading. The project has developed the STSC & Transporter Loading Facility (TE-7) which addresses this function with remote operated equipment. Empty STSCs arrive in the annex on the STS Transporter and remain on the Transporter while being loaded one at a time. For the Direct Loaded STSCs, sludge transfer /

decant equipment connections are made, which include confinement controls and the sludge is pumped directly into the STSC.

3.2.6 Sludge Transport

The Sludge Transport function takes into consideration two different transport options. In order to address the options, the project has developed two TEs for this function. The STS Transport System (TE-8, Option 1) is an existing system with previously used equipment. Because the STSC and the sludge contained within may impose new requirements, this system is being evaluated for changes necessary to support the loading configuration as discussed in the preceding descriptions. This system would be used for delivery of the Direct Loaded STSC to T Plant where they will use existing processes and equipment with any necessary modifications to accommodate the loaded STSCs as they are handled and monitored in this facility. The Small Canisters transport option uses the Fuel Transfer System (FTS) cask and Overpack (TE 8, Option 2), to transfer the Small Canisters to T Plant.

3.2.7 Sludge Storage in STSC or Small Canisters at T Plant

The Sludge Storage function takes into consideration the two different transport options and also considers the differences in STSC loading configurations. In order to address the options, the project has developed two TEs for this function. Sludge Storage in STSCs at T Plant (TE-9, Option 1), uses the STS Transport System, which is described in 3.2.6 above. This method relies on an existing system with previously used equipment. Because the STSC and the sludge contained within may impose new requirements, this system is being evaluated for changes necessary to support the loading configuration as discussed in the preceding descriptions. These systems would be used for receipt and storage of the Direct Loaded STSC at T Plant. The results from the evaluations will identify any necessary modifications to accommodate the sludge loaded STSCs as they are handled and monitored in this facility. Sludge Storage using Small Canisters in STSCs (TE-9, Option 2), uses the Fuel Transfer System (FTS) cask and over-pack (TE 8, Option 2), to transfer the Small Canisters to T Plant. This optional method includes using remote handling equipment to unload the canisters from the FTS cask and transferring them into the STSC at T Plant.

This storage function also includes the technologies necessary to remobilize the sludge for Phase 2. There are major differences with handling the sludge in the STSCs that have been loaded in the two loading configurations. Remobilizing the sludge in the two different storage technologies is addressed by two TEs. For remobilizing the sludge in the Direct Loaded STSCs, the Removal of Sludge for Packaging - Phase 1 Retrievability Demonstration from Direct Loaded STSCs (TE-10A) ensures that sludge removal can be accomplished using tools and techniques that are effective in the Direct Loaded STSC. For remobilizing the sludge in the STSCs loaded with Small Canisters, the Removal of Sludge for Packaging – Phase 1 Retrievability Demonstration from Underwater Loaded Small Containers (TE-10B) ensures that sludge contained in the Small Canisters can be removed from the STSC and handled safely as it is input into the Phase 2 operations.

4.0 TRA TEAM

The K Basins STP Phase 1 / CD-1 TRA will be performed by a team selected by the Team Leader in collaboration with the KBCP FPD and EM-20. The TRA Team will include subject matter and technical experts having experience in sludge waste process operations, process engineering and system design who are independent of the KBCP.

STP TRA Team Members

Assignment - Organization	***Name***	***Area of Expertise***
Team Lead - Consultant	Herb Sutter	Decant / Filtration
Team member - SRNL	Mike Poirier	
Team member - Consultant	Art Etchells	Sludge Retrieval & Transfer
Team member – EM-20 / PNNL	Gary Smith	
Team member – EM-60	Jim Poppiti	
Team member – DOE ORP	Kris Thomas	Mechanical Handling
Team member – EM-64	Jim J. Davis	
Team member – DOE RL	Paul Macbeth	Packaging / Transport / Storage

5.0 TRA SCHEDULE and COST

5.1 Schedule

The TRA on-site assessment is planned for early October 2009. The TRA Final Report will be issued in mid-November. Key dates are given below.

Activities	***Start Date***
Submit TRA Request to EM-20	25 May 2009
Submit TRA Plan to EM-20	12 June 2009
Establish TRA Team & Approve TRA Plan	10 August, 2009
Complete DOE-RL LMR	24 August 2009
Distribute relevant documents to TRA Team	31 August 2009
Perform On-site Assessment	October 5-9, 2009
Issue draft TRA Report for FAC	28 October 2009
FAC completed	4 November 2009
Issue Final TRA Report	13 November 2009

Key tasks are provided below that indicate the estimated durations.

Task	Duration	Task Description
1. Develop TRA Plan	4 weeks	Draft TRA Plan, conduct internal RL review, submit draft to EM-20 for comment, incorporate comments, conduct final RL review
2. Pre-assessment Activities	6 weeks	The Team will be assembled and contractual arrangements completed. The project will prepare an Orientation Documentation Package for the TRA Team. Regular tele - cons involving the Team and Project personnel will be held. The Team will develop requests for any additional documentation desired prior to the on-site visit as well as briefings and tours to be conducted during the on-site. The Team and the Project will also develop a list of facilities and support required for the on-site.
3. Conduct TRA	1 week	On-site TRA review period where TRA Team reviews the performing contractor's objective evidence files, interviews the project staff and observes equipment and operational demonstrations. TRA Team will provide a TRA in-brief to project and establish protocols for documents, interviews and demonstrations as necessary. At the conclusion of the TRA review, the TRA Team will provide a TRA out-brief and provide a summary of its observations.
4. Prepare Draft TRA Report, FAC	4 weeks	TRA Team prepares the TRA draft report, conducts their internal review and provides its final draft to DOE RL for review and Factual Accuracy Check (FAC). DOE RL will forward the final draft to the project for input into the FAC and provide review comments back to the TRA Team.
5. Finalize TRA Report	2 weeks	TRA Team incorporates feedback into the Final TRA Report and transmits it to DOE RL and EM-20. The TRA Team will brief EM-20, DOE-RL, and the performing contractor on the TRA observations, findings and recommendations.

5.2 Cost

Assuming an eight-person TRA Team with a one week on-site TRA review duration, man-hours for this TRA are estimated to be approximately 1572 MH. Using individual rates of $175 per hour, project support of $150 per hour and expenses at $2200 per person per trip (1 week), an approximate cost of $291,200 is projected. However, labor (930 hours) for five of the team members is not a direct cost to the project because they are DOE federal employees. In addition, three members reside at RL and incur no travel expenses. Therefore, $169,350 [$162,750 + $6600] is deducted from the projected cost to result in a $121,850 estimated cost. A breakdown of the projected cost is provided in the Cost Basis below.

Cost Basis

	Man Hours By Tasks					Total MHs	Costs
	1	2	3	4	5		
Leader (1)	10	60	60	60	20	210	$36,750
Members (7)	14	420	420	420	28	1302	$227,850
Project Support						60	$9,000
					Sub-totals	1572	$273,600
						Travel	$17,600
					Projected		$291,200
					Deduction		- $169,350
					Estimated Cost		$121,850

The funding for this TRA is included in the PBS-12 scope.

6.0 DEFINITIONS

Technology Elements (TEs): Technology elements of the STP Project that have been identified and are further evaluated to determine if they are Critical Technology Elements.

Critical Technology Elements (CTEs): Technology components which are essential to the successful function and operation the STP. A CTE may be comprised of a single component, a subsystem, a system, or a concept of use or function.

A technology element is “critical” if the functionality, operability, reliability or maintainability of the system depends on this technology element and/or if the technology element or its application is either new or novel. An element that is new or novel or is being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operation utility.

Technology Readiness Level (TRL): Numerical value/ranking system describing the maturity of a given technology element relative to the intended application in the deployment and operation of the STP project.

Technology Maturation Plan (TMP): Planned activities, including estimated costs, schedule and predecessors/successors required to mature a given technology element to an acceptable level for deployment in the proposed environment.

7.0 REFERENCES

Hose-in-Hose Sludge Transfer System, Technical Assessment of Fluor Hanford Inc.KE/KW Basins, January 20-March 14,2005, A-05-SED-SNF-011, U. S. Department of Energy Office of Environmental Management, Washington, DC

U.S. Department of Energy, Office of Environmental Management, *Technology Readiness Assessment (TRA)/ Technology Maturation Plan (TMP) Process Guide*, , March 2008

Sludge Treatment Project Alternatives Analysis Summary Report, HNV-39744 Rev. 0 (Volumes 1 & 2) delivered to DOE RL, 26 January 2009.

K Basins Sludge Treatment Process Technology Readiness Assessment Final Report, A-07-SED-017, dated June 2007

Functional Design Criteria, Sludge Treatment Project – Phase 1, Project A-21-C, HNF-40475, Rev 0A dated June 2009

External Technical Review of the Hanford K Basins Sludge Treatment Project, May 2009

8.0 TRA TEAM DELIVERABLES

The TRA Team will provide a final report within 5 weeks of completion of the on-site review. A draft of the report will be available to support Contractor follow-on activities, if needed. The following items will be developed:

- On-site out-brief
- Draft TRA Report
- DOE and PRC Management Presentation
- Final Report

Appendix

Sludge Treatment Project
Technology Readiness Assessment
Team Member
Biographies

Dr. Herbert Sutter: Dr. Sutter holds an A.B. in Chemistry from Hamilton College, a Ph.D. Physical Chemistry from Brown University and a Post Doctoral Theoretical Chemistry from Cambridge University, UK. He has more than thirty years experience in the fields of separations science, high and low level radioactive waste treatment, waste water treatment, vitrification, and analytical chemistry. For the past nineteen years he has provided technical and programmatic support to DOE's Office of Environmental Management (EM). Dr. Sutter has provided technical assistance to the DOE programs at Hanford, Savannah River, and other sites in: (1) separation technologies; (2) technology development; (3) high level waste disposal; (4) nuclear waste characterization; (5) vitrification; and (6) analytical laboratory management. From 2007 through the present Dr, Sutter has supported EM's Office of Project Recovery working on technology aspects of Hanford's Waste Treatment Plant. During that time he helped develop the EM Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide (March 2008). From 2005 to 2006, Dr. Sutter assisted EM in the development of a long-term, complex-wide Project Plan for Technology Development and Demonstration. From 2002-2004, he was a senior scientist for Kenneth T. Lang Associates, Inc. and provided support to EM in several areas including the evaluation of HLW vitrification technologies at Hanford and pretreatment and separation technologies at Savannah River. He has also been a consultant to private industry on separation technologies. From 1990-2002, as a scientist for Science Applications International Corporation, he supported EM in the areas of nuclear waste treatment and characterization and analytical chemistry. From 1982-1990, Dr. Sutter was Vice President and Chief Scientist at Duratek Corporation and responsible for technical direction of all research and development and commercialization programs in ion exchange, filtration and separation techniques. Relevant experience includes: waste water treatment, bench and pilot testing, and waste treatment studies. Dr. Sutter has authored or co-authored over 30 journal articles and technical reports and is a member of the American Chemical Society and the American Nuclear Society.

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Dr. Michael Poirier: Dr. Poirier is a Senior Fellow Engineer at the Savannah River National Laboratory (SRNL). He has 20 years of experience in filtration, solid-liquid separations, mixing, slurry transport, and waste retrieval. His experience includes work with simulants and actual waste. Dr. Poirier conducted test programs with actual SRS and Hanford High Level Waste sludge and supernate to measure filter performance and evaluate alternative filtration technologies. He has led SRNL's technical support for the Actinide Removal Process (a filtration process) and the Modular Caustic Side Solvent Extraction Unit (a solvent extraction process) startup. These processes successfully started in 2008 and are currently treating SRS Liquid Radioactive Waste. Dr. Poirier has led the team that is developing the rotary micro-filter for DOE applications. This team has tested the rotary filter at bench-scale with actual waste, at pilot-scale with simulant, and at full-scale with simulant. The team has improved the commercial design to make the unit suitable for deployment at DOE sites. Dr. Poirier has been studying mixing in high level waste tanks at SRS. He developed mixing models for sludge and precipitate tanks. He compared the models with results from SRS operating experience, showed they modeled mixing in the waste tanks, and then applied the models to mixing in high level waste tanks to recommend operating parameters to optimize mixing. He performed a slurry transport study to determine the properties and characteristics of sludge and precipitate slurries at SRS. The results of the study were used to develop guides for transporting slurries between areas at SRS. He conducted a laboratory-scale, pilot-scale, and full-scale test program with ITT-Flygt to evaluate shrouded axial impeller mixers for heel removal in SRS waste tanks. The program developed methods to scale mixing requirements to 85 foot diameter tanks and showed that shrouded axial impeller mixers could mobilize very high shear strength sludge. Dr. Poirier received a Ph. D. in chemical engineering from the University of Illinois in Urbana, Illinois in 1989. Dr. Poirier received a B. S. in chemical engineering from the University of Notre Dame in 1984.

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Dr. Arthur W. Etchells III: Dr. Etchells is a world recognized authority in the field of mixing for the process industries. He is a chemical engineer with BS and MS from University of Pennsylvania and doctorate from University of Delaware. For thirty nine years he worked for the DuPont Company and for thirty years as an internal consultant for the many diverse DuPont businesses in the field of fluid flow with emphasis on mixing and slurry transport. He has achieved the highest technical level of DuPont Fellow and the highest technical award, the Lavoisier Medal. His outside activities such as teaching in universities and continuing education courses, publications, and lectures and his leadership in the world technical community have made him widely known and highly respected. He has contributed two chapters to the recent Handbook of Industrial Mixing (Wiley 2003) and is now working as an editor for a new supplemental edition. He is a past president of the North American Mixing Forum and winner of their award for contribution to mixing technology. He retired from DuPont in November 2002 and now works as an independent contract consultant. He is currently working for DuPont Safety Resources Business helping the Bechtel Company develop a facility for immobilizing radioactive waste at the Hanford site in the state of Washington along with other consulting for a number of companies outside of DuPont.

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Dr. Gary Smith: Dr. Smith is a staff scientist with the Pacific Northwest National Laboratory (PNNL) and is currently on assignment to the Office of Waste Processing, Engineering & Technology within the Office of Environmental Management, U.S.

Department of Energy. Dr. Smith has been involved with all aspects of the nuclear waste flow sheet for a number of years, taking on roles of increasing responsibility in both a technical capacity and in management. He has extensive project management experience, most recently serving as PNNL's Deputy Program Manager for the River Protection Project – Waste Treatment Plant Project Support Program. This program contributes significantly to the characterization, retrieval, pretreatment, and vitrification of Hanford tank waste for the Waste Treatment and Immobilization Plant (WTP) project. Prior to this role, Dr. Smith served as a technical advisor, directly supporting the WTP contractor. He has managed and acted as principal investigator on projects ranging from vitrification and glass product testing to examining the process-ability of slurry feeds as a function of batch chemistry for laboratory-, bench- and pilot-scales. Dr. Smith has published more than 70 refereed journal articles, technical reports, and conference papers as well as numerous classified documents. He has co-edited three volumes of *Ceramic Transactions*, dealing with "Environmental and Waste Management Issues in the Ceramic Industry." He is a fellow of the American Ceramic Society (ACerS) and ASTM International. Dr. Smith is chair of ASTM International Committee C-26 on the Nuclear Fuel Cycle and chair of Subcommittee C26.13 on Spent Fuel and High Level Waste, committees that develop consensus standards for the international nuclear community. He also is vice chair of the U.S. Nuclear Technical Advisory Group and past chair of the ACerS Nuclear and Environmental Technology Division. He holds a Ph.D. in Materials Science & Engineering from the University of Arizona.

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Dr. James A. Poppiti: Dr. Poppiti holds a PhD in Chemistry and is a Certified Health Physicist (CHP) and has worked for DOE for almost 20 years. Dr. Poppiti spent 4 years at Hanford (1996 – 2000) as the Manager for the Tank Waste Characterization Project, the Manager of the Vadose Zone Project, and Manager of Waste Retrieval Engineering. During that time Dr. Poppiti supervised DOE's efforts to close DNFSB Recommendation 93-5 (Tank Waste Characterization), which was closed in 1999. He worked for the NNSA Chief of Defense Nuclear Safety (CDNS) for 3 years in the areas of Radiation Protection and Process Chemistry. Areas of expertise include chemical processing and health physics. He is a qualified Software Quality Assurance (SQA) assessor and has performed SQA reviews for chemical processing facilities. He has participated in nuclear safety and chemical process safety reviews for several projects including the waste treatment plant at Hanford, the new Uranium Processing Facility at Y-12, the Liquid Waste Treatment Facility at Los Alamos, spent fuel, and depleted uranium hexafluoride.

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Kris Thomas: Mr. Thomas has a B.S., Mechanical Engineering from the University of Idaho - with an emphasis in design, fluid flow, material properties and selection. He joined ORP in 2007 and prior to that, he worked at the Puget Sound Naval Shipyard as a Nuclear Engineer. He currently performs duties and responsibilities of the Mechanical SSO Engineer for the WTP Engineering Division. He has lead and participated in design review assessments of contractor designs on safety-related systems including application of design codes and standards.

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Jim J. Davis: Mr. Davis has over 21 years of nuclear experience including 17 years with the Department of Energy (DOE), predominately in the field of radioactive waste management at the Hanford, WA site. Currently he works for DOE-EM, Office of Standards and Quality Assurance (EM-64) in the area of quality assurance related to environmental management projects. Prior to that he worked for DOE as a project manager on Tank Farm (TF) waste retrieval projects and programs for over 12 years which included oversight of technology development, engineering design, procurement, construction and operations. He qualified as a Safety System Oversight (SSO) for transfer systems in the TF project and on mechanical systems for the Waste Treatment and Immobilization Plant (WTP), at which he supported engineering design and construction for 4 years. Prior to coming to the department, Jim worked 4 years in Naval nuclear refueling operations at Puget Sound Naval Shipyard. He received a Bachelor of Science in Engineering degree from the University of Washington in 1985.

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Paul Macbeth: Mr. Macbeth has a Master of Science degree in Nuclear Physics from Brigham Young University, and completed most of the course work for the Ph.D. degree in Nuclear Engineering from the University of Utah. Mr. Macbeth has over 30 years of direct professional experience in nuclear safety and waste management, dealing with diverse topics and complex issues, including assessment of environmental impacts from waste management activities, cryogenic storage of radioactive krypton, remediation of uranium mill tailings sites and contaminated Federal facilities, waste classification and associated risk assessment, as well as design and operational experience at a commercial nuclear power plant. Mr. Macbeth currently provides senior level expertise in transportation and packaging, nuclear safety and documented safety analyses, as well as radioactive and mixed waste management in review and oversight functions for DOE/RL. His reviews and oversight have helped ensure compliance with applicable DOE, EPA, State of Washington, NRC, and DOT regulatory requirements and guidelines through review and assessment of design, safety, NEPA, RCRA and budgetary documentation. His responsibilities have included preparation, review, assessment, and validation of safety analysis and authorization basis documents for High-Level, Low-Level and Transuranic Waste and Spent Nuclear Fuel treatment, storage and disposal facilities and transportation methods, documents for submittal to regulators covering RCRA permitting and remediation site closure activities, Tri-Party Agreement milestone progress, project design, NEPA activities, budget input reports, operational readiness reviews, and findings, observations and surveillances on Solid Waste and Transportation programs. He served as team member on RL's Readiness Assessment for startup of Mixed Waste Disposal Trench 31 in the Low-Level Waste Burial Grounds and on the Operational Readiness Review teams for restart of intrusive activities at N Basin and the Aging Waste Facility Ventilation System Upgrade. He was lead reviewer for Solid Waste Operations Interim Safety Bases (ISBs), the WRAP FSAR, the WESF BIO, the K Basins SAR, and the Solid Waste Master SAR, and performed Tier 3 reviews for DOE/RL's ESH Division on the Salt-Well Pumping and Aging Waste Facility Ventilation System Upgrade safety analysis and approval documents. Mr. Macbeth participated in the recent DOE review of the CH2M Hill Plateau Remediation Contractor's readiness to implement their Integrated Safety Management/Environmental Management program. He also documented bases for DOE approval of the foregoing Authorization Basis documents in Safety Evaluation Reports.

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