DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

July 31, 2012

Mr. Matthew S. McCormick
Manager, Richland Operations Office
U.S. Department of Energy
P.O. Box 550, Mail Stop 7-50
Richland, Washington 99352

Dear Mr. McCormick:

The Defense Nuclear Facilities Safety Board (Board) has closely followed preliminary design activities and safety basis development for Phase I of the Sludge Treatment Project (STP), also known as the Engineered Container Retrieval and Transfer System (ECRTS), at the Hanford Site. The STP team submitted a Preliminary Safety Design Report (PSDR) to the Department of Energy's (DOE) Richland Operations Office (RL) on December 21, 2011. DOE-RL issued the Preliminary Safety Validation Report on July 5, 2012. The Board's staff reviewed the design and safety basis of the ECRTS and its associated Modified K West Basin Annex found in the PSDR. The project team is already addressing many of the Board's concerns identified during its review. In order to ensure the issues are resolved in a prompt manner, the Board has determined that two issues require DOE senior management attention:

- *Non-Bounding Spray Leak Consequence Analyses*—The STP team credited active engineered controls and made assumptions without sufficient technical justification about operator actions that limit the duration of spray leak accident scenarios. The project team also made assumptions without sufficient technical justification that limited the portion of radioactive material that would be involved in the seismic accident scenario. These practices are contrary to the methodology of DOE Standard 3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses,* for the calculation of unmitigated accident dose consequences. Additionally, the Board's staff found that atmospheric dispersion parameters used to calculate dose consequences for the collocated worker and the public receptors were not technically justified. Therefore, the calculated spray leak accident dose consequences are not bounding.

- *Safety Instrumented Systems*—The PSDR identifies instrumented systems as part of the safety control set. Title 10, Code of Federal Regulations Part 830, *Nuclear Safety Management*, requires the documented safety analysis to contain performance criteria for safety structures, systems, and components and that these items be designed to appropriate standards. DOE Standard 1189, *Integration of Safety into the Design Process*, states that specific codes and standards are expected to be identified during preliminary design. Contrary to the expectations of DOE Standard 1189, the PSDR does not specify DOE Standard 1195, *Design of Safety Significant Safety*

Instrumented Systems Used at DOE Nonreactor Nuclear Facilities, nor does it specify any industry consensus standards that will be applied to the design of safety instrumented systems.

The enclosure to this letter summarizes the Board's understanding of the status and safety posture of the ECRTS project and provides further detail on the above issues, as well as two additional issues that the STP team is on track to address. The Board will continue to follow these issues as the STP proceeds through final design. The interaction between the Board's staff and STP project personnel has been productive, and we look forward to continuing this dialogue as the project moves forward.

Sincerely,

Peter S. Winokur, Ph.D.
Chairman

Enclosure

c: Mr. David Huizenga
Mrs. Mari-Jo Campagnone

Enclosure
Summary of Sludge Treatment Project and Related Issues

Background. The scope of the Sludge Treatment Project (STP) includes the disposition of sludge contained in the six engineered containers within the 105-K West (KW) Basin at the Hanford Site. Phase I of the STP involves retrieval of the sludge from these engineered containers using the Engineered Container Retrieval and Transfer System (ECRTS) and transport to a yet-to-be-determined on-site facility. The Department of Energy (DOE) and its contractor, CH2M Hill Plateau Remediation Company (CHPRC), are currently evaluating storage facilities and treatment technologies for Phase II of the STP, which will allow final disposition of the sludge.

The STP team initially adopted a tailored approach to implement the requirements of DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*. This approach combined the Critical Decision-2 and -3 milestones for the ECRTS and cancelled the development of the Preliminary Safety Design Report (PSDR). In it's letter to DOE dated December 22, 2010, the Defense Nuclear Facilities Safety Board (Board) identified that DOE requirements for integrating safety into the design were not fully satisfied under this approach. Subsequently, the STP team submitted a PSDR to DOE's Richland Operations Office (RL) on December 21, 2011. The Board's staff reviewed the design and safety basis of the ECRTS and its associated Modified KW Basin Annex as found in the PSDR and associated preliminary design report.

The sludge located in the KW Basin sludge is a product of years of corrosion of N-Reactor spent fuel combined with debris from fuel storage racks and containers, windblown dust, and spallation from the KW and K East (KE) Basins' concrete walls and floors. The sludge from the basins' floors and pits was consolidated into five engineered containers while the sludge generated by the spent fuel cleaning activities was collected in settler tanks before retrieval to the sixth engineered container as shown in Table 1.

Table 1: Estimated Sludge Volume per Engineered Container

Origin	KW Basin		Settler Tanks	KE Basin		
Container ID	SCS-CON-210	SCS-CON-220	SCS-CON-230	SCS-CON-240	SCS-CON-250	SCS-CON-260
Sludge Volume (m^3)	4.2	1.0	3.5	2.6	7.7	8.1

ECRTS equipment is being designed to be located in the existing KW Basin building and the Modified KW Basin Annex. Modification of the existing KW Basin Fuel Transfer System Annex is required to accommodate the ECRTS process equipment and provide a loading bay to support sludge transfer and packaging. The ECRTS will transfer approximately 27 m^3 of sludge into Sludge Transport and Storage Containers (STSCs). The sludge will be retrieved from the engineered containers in multiple batches as slurry and pumped through a hose-in-hose transfer system to a STSC that will be located in the proposed Modified KW Basin Annex. The loaded STSCs will then be transported in Sludge Transport System (STS) casks to an interim storage location.

Design Basis Accidents. The STP team performed hazard and accident evaluation studies to determine the potential effects of operational events and natural phenomena hazards. The studies identified the following significant hazardous conditions in addition to the standard radiological and industrial safety hazards:

- Spray release
- Splash and splatter pool release
- Hydrogen explosion (deflagration or detonation)
- STSC over-pressurization

Based on these studies, the STP team identified two Design Basis Accidents (DBA) as bounding: spray releases and hydrogen explosions. Both of these DBAs can be initiated by operational events, external events, fires, or natural phenomenon.

Spray Release—The bounding spray release scenario is based on an undetected breach of primary containment that occurs while sludge is being transferred from the engineered container to the STSC. The amount of slurry released into the environment is a function of the breach dimensions, the fluid pressure, and the duration of the release. The complexity resulting from the multiple phenomena involved in a spray release necessitates the development of a suitable technical basis that likely requires supporting research and development. The STP team therefore identified concerns in the following areas during their evaluation:

- Uncertainty in slurry rheology, including properties such as viscosity and the effect of these properties on spray leak droplet formation
- Applicability of spray correlations for use with multiphase flows with solid particles
- Suitable choice of a droplet distribution for spray conditions
- Droplet characteristics such as the Sauter Mean Diameter and shape
- Determination of the distribution of solid particles in spray droplets
- Selection of appropriately conservative crack configurations

To compensate for these concerns associated with the spray leak analysis, the radiological consequences for the spray leaks events were estimated using two different methods:

1. Correlation-Independent Method, in which an analysis was performed that is independent of any spray parameter correlation. The STP team concluded that this approach provides conservative results that can be compared to the margin for the safety-class (SC) evaluation guideline, and justify the safety-significant (SS) designation of selected controls.

2. Correlation-Dependent Method, in which the Dombrowski and Johns correlation for the Sauter Mean Diameter was used together with Rosin-Rammler spray droplet distribution. This method allowed the quantity of respirable aerosol generated to be estimated using input parameters that the STP team considered to be conservative.

Table 2 summarizes the resulting dose consequences in terms of total effective dose (TED) to collocated workers and onsite and offsite members of the public for an operational spray leak. The onsite public receptor is located on the nearby bank of the Columbia River, 520 m from the KW Basin, while the offsite public receptor is located at the site boundary which is the distant Wahluke Slope.

Table 2: Operational Spray Leak Radiological Dose Consequences (rem TED)

Operation	Retrieval and Transfer	Overfill Recovery	Decant	Sand Filter Back-Flush
Correlation-Independent Method				
Collocated Worker	146	186	48	33
Onsite Public	132	168	43	30
Offsite Public	1.7	2.1	0.55	0.38
Correlation-Dependent Method				
Collocated Worker	26	9.5	13	10
Onsite Public	24	8.6	12	8.9
Offsite Public	0.3	0.11	0.15	0.11

The STP team used the correlation-independent method to calculate the consequences of a seismically induced spray leak, which was assumed to have a longer duration than an operational leak. Table 3 summarizes the resulting consequences.

Table 3: Seismically Induced Spray Leak Radiological Dose Consequences (rem TED)

Receptor Location	Radiological Dose Consequences
Collocated Worker	326
Onsite Public	294
Offsite Public	3.7

Based on the radiological consequences to the co-located worker derived with the correlation-independent method, the STP team identified engineered controls that are classified as SS structures, systems, and components (SSCs) to mitigate the consequences of spray leak events. These include transfer lines, rupture disks, valves, hard piping, leak detection instruments, a timer, the auxiliary ventilation system, the inert gas system, casks, STSCs, sludge quantity instruments, the Modified KW Basin Annex structure, and a seismic shutdown switch. To address the accident consequences for onsite members of the public, the STP team chose to develop and will implement the ability to control public access to the Columbia River during sludge transfers.

Hydrogen Explosion—A significant hazardous component of the K Basins containerized sludge is uranium metal. This metal reacts exothermally with water to generate uranium oxide and hydrogen. As a result of this reaction and the radiolytic decomposition of water, the hydrogen concentration in the STSC could reach levels that can support combustion. This could occur as the result of a loss of ventilation flow through the STSC or hydrogen generation over time in an isolated STSC. The potential also exists for the accumulation of hydrogen within the sludge in the STSC leading to an episodic release of that hydrogen into the STSC headspace.

The STP team analyzed hydrogen explosion/deflagration events for the sludge transfer process and concluded that the radiological consequences of these events do not exceed the evaluation guidelines for collocated workers and public receptors. However, the STP team evaluated a hydrogen explosion in a STSC, STS cask, or the transfer line service box as requiring SS controls due to the potential for serious injury or death to a facility worker. The control strategy selected for this hazard is to prevent an explosion by maintaining the hydrogen concentration in the STSC headspace below 25 percent of the lower flammability limit (LFL). This is achieved with a SS auxiliary ventilation system that automatically actuates upon a loss of flow through the general service process ventilation system. It uses pressurized nitrogen tanks to provide ventilation at a flow rate through the STSC sufficient to maintain the hydrogen concentration below 25 percent of the LFL.

Previous Issues from Conceptual Design. The Board's December 22, 2010, letter to DOE identified four issues that the Board believed should have been addressed during the preliminary design process; *Design Information*, *Tailoring of Requirements*, *Site Boundary Definition*, and *Spray Leak Methodology*.

The STP team submitted a PSDR that contains a documented safety control set with sufficient design information for evaluating the ability of the safety SSCs to perform their safety functions. As a result of this submittal and DOE-RL's plans to review the PSDR, the Board's staff considers the *Design Information* and *Tailoring of Requirements* issues raised in the Board's letter to have been adequately addressed.

The STP team has devoted significant resources to controlling public access to the Columbia River, as noted above in the discussion of controls for spray leak accidents. These efforts culminated in the STP team demonstrating a successful river closure exercise in March 2012. Therefore, the Board's staff considers the *Site Boundary Definition* issue from the Board's December 22, 2010, letter to have been adequately addressed.

In response to the Board letter's *Spray Leak Methodology* issue, the STP team developed the correlation-independent methodology discussed above to address the uncertainty of sludge spray leak parameter values. The STP team used the accident dose consequences calculated using this methodology to select and classify controls, resulting in the SS classification for spray leak controls for worker protection. The spray leak parameter values used in the correlation-dependent analysis lack sufficient technical basis to support their use for conservative accident analysis and classification of controls. Further spray leak testing would be required to demonstrate adequate safety margin should the results of the correlation-dependent accident analysis be used for classifying the safety control set. The Board's staff understands that the STP team intends to continue the use of the correlation-independent methodology for spray leak parameter values. Therefore, the Board's staff considers this issue to have been adequately addressed.

New Issues. The Board's staff identified the issues detailed below, which the Board believes must be addressed as the project progresses through final design.

Non-Bounding Spray Leak Consequence Analyses —The Board's staff found that the unmitigated spray leak accident scenarios were developed using practices that are contrary to the methodology of DOE Standard 3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*. During operational events, the safety analysis relies on active engineered features, such as a sludge transfer timer, and assumptions (without sufficient technical justification) about operator actions to limit the leak duration time, and therefore incorrectly limit the amount of radioactive material involved in the unmitigated accident scenario. This safety analysis relies on operator action to terminate each sludge transfer after a presumed time interval, but this time interval is not assured in the safety basis. The PSDR assumes that operators will eventually notice the longer transfer times if a leak is occurring and decide to stop the transfer within the presumed time interval. During the unmitigated seismic accident scenario, the safety analysis incorrectly assumes that only 1.36 m^3 out of the available 3.5 m^3 of sludge is released. This value is based on crediting the performance of non-seismically qualified process equipment and an assumption that the sludge will not reposition as a result of the seismic event.

Additionally, the Board's staff found that the atmospheric dispersion parameters used to calculate the dose consequences for the collocated worker and the public receptors were not technically justified. The project team estimated the airborne release fraction (ARF) for the spray leak event by assuming that the aerosol mist concentration resulting from vaporization of the sludge spray was 100 mg/m^3. The STP team then assumed this aerosol concentration to be the maximum sustainable loading of respirable droplets in air at the onsite receptor, 100 m away from the spray leak. This value was normalized with the atmospheric dispersion factor for the onsite receptor to generate an ARF of 0.022. This ARF value was then used for calculating both onsite and offsite dose consequences. The project team provided no justification for using this ARF value, which could actually range from a low value of about 0.01 to its maximum value of 1. While the project team's approach may produce a bounding ARF value for collocated receptors, it has not been technically justified that extrapolating this method to more distant receptors is defensible or conservative. Given the strong dependence of the offsite dose consequences on the chosen ARF value, the potential exists for offsite dose consequences to challenge or exceed the evaluation guideline if a more technically justified value of ARF is used.

The project team's current spray leak analysis is not bounding and requires further technical justification to meet DOE's requirements. The Board's staff believes that the amount of uncertainty in the accident dose consequences prevents the current spray leak analysis from serving as the basis for determining the safety classification of the safety control set.

Safety Instrumented Systems—The ECRTS PSDR credits instrumented systems with the performance of SS safety functions. Specific examples include, but are not limited to the leak detection system, the nuclear safety shutdown interlock, and the control portions of the auxiliary ventilation and inert gas systems. Title 10, Code of Federal Regulations (CFR) Part 830, *Nuclear Safety Management* (10 CFR Part 830), requires the documented safety analysis to contain performance criteria for safety SSCs that will ensure their functional requirements are met. 10 CFR Part 830 also requires that items be designed to appropriate standards. DOE Standard 1189, *Integration of Safety into the Design Process* (DOE Standard 1189), provides expectations on how the design process should meet the requirements of 10 CFR Part 830 as well as the nuclear safety design criteria of DOE Order 420.1B, *Facility Safety*. DOE Standard 1189 states that specific codes and standards to be used for the design of safety SSCs are expected to be identified during the preliminary design phase.

Contrary to these expectations, the PSDR does not specify how the design of safety instrumented systems (SIS) will meet the requirements of DOE Order 420.1B for safety SSCs, nor does it specify DOE Standard 1195, *Design of Safety Significant Safety Instrumented Systems Used at DOE Nonreactor Nuclear Facilities*, or any industry consensus standards that will be applied to the design of SISs. These design criteria are required in order to provide adequate assurance that SISs can reliably perform their safety functions and that the documented safety analysis can meet the requirements of 10 CFR Part 830.

Protection of the Public on the Columbia River—The STP team has devoted significant resources to developing the ability to control public access to the Columbia River. However, this capability is not included in the PSDR. This administrative control relies on Emergency Management programs for protection of the public and is not included in the safety control set for the ECRTS at the KW Basin. Since this safety function would otherwise have been accomplished through use of a SC SSC, DOE Standard 1186, *Specific Administrative Controls,* requires identification of a Specific Administrative Control (SAC) to govern the implementation of this capability. The Board's staff discussed this issue with the STP team, which is taking actions to address it. The staff understands that the ECRTS Preliminary Documented Safety Analysis will utilize SACs to include the river closure capability as part of the final safety control set.

Modified KW Basin Annex Design—The Board's staff reviewed the preliminary design of the Modified KW Basin Annex structure. The structure is classified as SS and rated to Seismic Design Category 2. The Board's staff raised issues related to the design of the structure's floor slab, which the STP team is taking actions to address. The staff found that the weight of the STSC trailer on the floor grating and supporting structural steel members could cause bending and punching shear of the annex's floor slab, compromising the structural integrity of the building. This potential impact was not analyzed as part of the preliminary design. After discussing this issue with the project team, the Board's staff understands that the 90 percent design package for the Modified KW Basin Annex will include a new analysis evaluating the potential for bending and punching shear failure of the annex floor slab and identify any potential design changes required by this new analysis. Additionally, the staff found that the project team used the Portland Cement Association's (PCA) slab-on-grade design charts for portions of the floor slab where discontinuities exist, and hence moments can be generated. The PCA specifies that its design charts are applicable only for continuous slab construction. The Board's staff understands that the project team has conducted an additional analysis to justify the use of the PCA charts at slab discontinuities and will include this justification in the 90 percent design package.