U.S. NUCLEAR REGULATORY COMMISSION
REVIEW OF THE DEPARTMENT OF ENERGY AT SAVANNAH RIVER
HIGH-LEVEL WASTE TANK CLOSURE METHODOLOGY

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I. INTRODUCTION

Background - High-Level Waste Tanks at the Savannah River Site

The Savannah River Site (SRS), a 310-square-mile area adjacent to the Savannah River, is owned by the U.S. Department of Energy (DOE) and operated by the Westinghouse Savannah River Company (WSRC). See Figure 1. The mission of SRS includes production of nuclear materials for national defense, environmental restoration, and the receipt and disposition of research reactor fuels. While separating plutonium from irradiated fuel, large volumes of liquid high-level waste (HLW) were generated. The HLW, which amounts to approximately 34 million gallons, is stored in 51 underground tanks located in F- and H-Area tank farms (See Figures 2 and 3). DOE is currently retrieving and processing the waste into low-level waste (LLW) forms through the saltstone process and into HLW glass through vitrification. Following bulk removal, the HLW tanks and ancillary equipment will be closed in accordance with South Carolina Department of Health and Environmental Control (SCDHEC) regulations. Twenty-four tanks are scheduled to be closed by 2022 (as of January 1999 [1]). These twenty-four were chosen because they do not meet Federal Facility Agreement (SCDHEC and Environmental Protection Agency [2]) secondary containment requirements. Two of the twenty-four tanks, numbers 17 and 20, have already been closed, and Tank 16 has been cleaned but not closed.

DOE plans to remove as much waste as possible from the tanks, and then fill each tank with layers of grout. A key part of their disposal plans is classification of the residual tank waste as "incidental." If DOE-SR classifies the residual waste as incidental, then DOE-SR believes it would be appropriate to conclude that neither the tank itself, nor the residual waste it contains is high-level.

Incidental Waste Classification

The incidental waste classification criteria were approved by the Commission in the Staff Requirements Memorandum (SRM) dated February 16, 1993, in response to SECY-92-391, "Denial of PRM 60-4 - Petition for Rulemaking from the States of Washington and Oregon Regarding Classification of Radioactive Waste at Hanford," and are described in the March 2, 1993, letter from R. Bernero, NRC, to J. Lytle, DOE [3].

(1) The waste has been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical.

(2) The waste will be incorporated in a solid form at a concentration that does not exceed the applicable concentration limits for Class C LLW as established in 10 CFR 61.55.

(3) The waste is to be managed, pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives in 10 CFR Part 61, Subpart C, are satisfied.

Figure 1: SRS map with F- and H-Areas highlighted [2].

Figure 2: General layout of F-Area Tank Farm [2].

Figure 3: General layout of H- Area Tank Farm [2].

The incidental waste classification criteria were originally developed for waste removal (and separation) from HLW tanks at the Hanford site. The review was generally based on these criteria and a performance-based analysis.

Review Approach

DOE and NRC established a Memorandum of Understanding [4] that provides a basic framework for NRC review. Under the terms and conditions of the Memorandum of Understanding, NRC is acting in an advisory capacity and is not providing regulatory approval.

The review is based on DOE's "Regulatory Basis for Incidental Waste Classification at the Savannah River Site High-Level Waste Tank Farms," (Regulatory Basis) [5]. After initial review of the Regulatory Basis and supporting documents like the Tank 17 Closure Module [6] and the F-tank farm performance assessment [7], we sent a Request for Additional Information (RAI) [8]. DOE-SR responded in September 1998 [9], but not all of the responses were sufficiently clear. NRC and DOE held a public meeting on April 1, 1999, to resolve some of the outstanding issues, and DOE submitted supplementary responses on April 22, 1999 [10].

II. CRITERION ONE

...the waste has been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical...[3]

Tank Inventory and Sampling

The F-Area tank farm has 22 waste tanks in a 22-acre area, while the H-Area tank farm has 29 tanks in a 45-acre area [2]. The tank farms also have evaporators, transfer piping, diversion boxes, and pump pits. The tanks were used to store liquid HLW from various SRS production and laboratory facilities, and contain supernatant, saltcake, and sludge. The supernatant consists of dissolved salts and is typically rich in sodium hydroxide and sodium nitrate, whereas saltcake is formed by evaporation of supernatant and contains predominantly sodium nitrate, carbonate, and sulfate. The sludge consists of insoluble metal hydroxides (manganese, iron, and aluminum) and various radionuclides (e.g., ^{99}Tc, ^{90}Sr, ^{239}Pu).

In general, SRS samples for radionuclides that are expected to be present in high concentrations, or that might have a significant impact on the performance evaluation. Estimated tank inventories are based on waste transfer records that specify the process (uranium or plutonium recovery from reactor fuel and target assemblies) that produced the waste. The masses of major chemical and major actinide components transferred to the tanks are documented [6]. Minor chemical constituents are calculated on the basis of a fixed ratio to the major constituent (ferric hydroxide). Fission and activation product inventories are calculated on the basis of reactor yield distributions and solubilities, and minor actinides are estimated from yield distributions. The total calculated inventories are divided by the total sludge volume to obtain concentrations.

Photographs and videos are used to estimate the volume of residual waste in each tank, and map its location. The operational history and visual evidence will be used to determine a representative sampling approach (i.e., the number of samples and their locations). Sample results are compared with estimated tank inventories.

For Tank 17, two samples were collected using a floater pump. This sampling was performed prior to transferring 280,000 gallons of water to Tank 6. The pump floated on top of the waste with a vacuum tube extending to the bottom of the waste. By means of an air hose the pump was able to move about the tank while the sample tube acquired samples from the bottom of the tank. Each sample was filtered to obtain a representative sample of the sludge [6]. Three different forms of tank sampling were used for Tank 20: an absorbent swipe, a "mud snapper," and a "scrape sampler." The absorbent swipe was lowered through the southeast riser to the tank bottom where the sample was obtained. The "mud snapper" was also lowered through a tank riser to collect a grab sample. Finally, a hinged fiberglass rod was used to maneuver a scraper across the bottom of the tank [16].

Economic Practicality of Waste Removal Options

DOE analyzed eight options for tank closure [5], ranging from water washing with no fill or cover (essentially the no-action alternative) to chemical and mechanical cleaning, followed by tank removal. The economic burden (not including bulk waste removal) ranged from $1.4 million per tank (no-action alternative) to greater than $100 million per tank (tank removal).

Evaluation of the options is dependent on radionuclide exposure to workers during closure and to the public during postclosure for the various options. Four of the eight closure configuration options use spray water cleaning as the only mode of removal of radionuclides, in combination with various options for filling the tanks and covering the tank areas. The combination of spray water wash and grout fill was selected as the base case option based on cost effectiveness and anticipated dose reduction. Tank closure may include a Resource Conservation and Recovery Act (RCRA) style cap, which will be contingent upon the closure requirements used (i.e., Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)).

Technical Practicality of Waste Removal Options

The base case removal strategy is bulk waste removal, followed by spray water washing. HLW is removed from the waste tanks and vitrified for disposal at the proposed HLW repository at Yucca Mountain. Other mechanical waste removal methods have also been evaluated by DOE-SR. See Table 1. Methods for intensive mechanical scrubbing, like robotic arms, pitbull pumps or remote controlled sluicing crawlers, have only been demonstrated in laboratory environments, and are not considered sufficiently technically developed at this time.

Typical chemical methods used to treat HLW waste require that the waste be removed from the tank and transferred to a processing facility. Therefore, most chemical separations are not appropriate for in-situ applications, like residual waste left in a tank. Unlike most chemical separations, oxalic acid can be administered in-situ, and therefore is considered technically practical for waste removal. Oxalic acid cleaning has been demonstrated at SRS for Tank 16.

OPTION*	COST** ($/tank)	WORKER EXPOSURE (person-rem/ tank)	RADIOLOGICAL IMPACT† (mrem/yr)	TECHNICALLY PRACTICAL	ECONOMICALLY PRACTICAL
Spray Water Wash, No Fill	1,356,000	2-3	4.7 at 805 years	Yes, but ineffective	Yes
Spray Water Wash + Sand Fill + RCRA-style cap	3,800,000	10.2-11.2	4.1 at 1,645 years	Yes	Selected base case is more effective at comparable cost
[Base case] Spray Water Wash + Grout Fill (No cover)	**3,800,000**	**10.2-11.2**	**3.1 at 2,555 years**	**Yes**	**Yes, most cost-effective alternative**
Spray Water Wash + Grout Fill + RCRA-style cap	3,800,000	10.2-11.2	3.1 at 3,045 years	Yes	Yes (cost does not include RCRA-style cap)
Spray Water Wash + Oxalic Acid Wash + Grout Fill	4,600,000	10.2-12.2	< Selected base case	Yes, oxalic acid wash has been demonstrated for sludge, and will be used in some cases to meet other criteria (Complications down-stream)	No
Spray Water Wash + Saltstone Fill	6,300,000	10.5-11.5	> Selected base case	Yes, but higher source term since saltstone is already contaminated	No
Spray Water Wash + Oxalic Acid Wash + Chemical-Mechanical Cleaning + Grout Fill	>50,000,000	> Selected alternative	< Selected base case	No, technologies not demonstrated large-scale	No
Spray Water Wash + Oxalic Acid Wash + Chemical-Mechanical Cleaning + Tank Removal	>100,000,000	>93	< Selected base case	No, technologies not demonstrated large scale, and high worker doses	No

* Bulk waste removal assumed for all options.
** Costs are for comparison only and are not budget quality.
† Total dose at seepline.

Table 1: Options considered by DOE for removal of radionuclides [5]. (Note that dollar amounts are from 1997 and are not consistent with those reported elsewhere in this report.)

Unfortunately, it has consequences on subsequent processing of waste. Oxalic acid cleaning results in an additional waste stream requiring treatment, and impacts the chemistry of the feed stock for the Defense Waste Processing Facility (DWPF) (vitrification plant), resulting in additional expense and waste glass volume. Oxalic acid cleaning may also pose a criticality threat during removal by reducing the pH and thereby increasing the amount of fissionable material in the solution. Therefore, although oxalic acid is considered to be technically practical, it is not considered to be economically practical for use in all tanks.

Removal of Key Radionuclides

For tank closure, it should be noted that key radionuclides cannot be removed preferentially, since the residual wastes, by their very nature, cannot be removed from the tanks for further processing. No generic cut-off has been established for waste removed from each tank. Each tank will be cleaned to the maximum extent possible using water washing and pumping following bulk waste removal. Waste volume in emptied tanks has been estimated from visual inspections. This was accomplished by comparing the height of the waste to known height markers on the bottom of the tank such as tank welds or steel lifting plates of known thickness. At some locations the actual tank bottom could be seen. Performance of bulk waste removal and spray washing is expected to result in removal of 98 percent to 99 percent of the total radioactivity, and over 99 percent of the volume of the waste.

According to DOE's general methodology, and assumed in their performance modeling, approximately 1000 gallons of sludge are projected to remain in each tank. It is estimated that 14 tanks will be cleaned using standard waste removal to 1000 gallons. Thirty-seven are expected to be cleaned to approximately 100 gallons, (using oxalic acid). Even though oxalic acid cleaning is not considered to be economically practical, it is expected to be used for some tanks in order to meet the performance objectives specified in Criterion Three.

NRC Review and Conclusions

There is limited reference material available to independently verify DOE evaluations of economic and technical practicality. We have reviewed the general DOE methodology for removal of key radionuclides to the extent technically and economically practical. We have also examined further information on actual waste removal practices and efficiencies for Tanks 16, 17 and 20. From Table 1, the economic burdens for each closure methodology can be compared. The methodology chosen by DOE, water-wash and grout fill, provides adequate radiological protection at the most reasonable cost. As stated above, 37 tanks are expected to need additional oxalic washing. Due to the initial individual tank inventories not all tanks will need chemical cleaning. Because of the high removal efficiency of the chosen methodology other technologies would not be economically practical. More exotic cleaning technologies would cost approximately 46 million dollars more per tank and remove less than one percent of the original tank activity.

The following assumptions were made in assessing conformance with Criterion One.

- Cost/benefit assessments associated with different options are reasonable.

- DOE will follow the tank closure procedure outlined in the Industrial Wastewater Closure Plan [11]. Specific actions for cleaning will be developed for each tank (e.g., oxalic acid wash may be employed in selected tanks). The individual performance assessment for each tank will dictate what, if any, further cleaning is required.

The following recommendations are noted with respect to meeting Criterion One.

- A set tank sampling protocol should be developed. The method should involve enough samples to adequately represent the tank contents, and should be performed after bulk waste removal and tank cleaning. Without a cost estimate for sampling it is difficult to determine the minimum number of samples. Any large inconsistencies indicate the need for further sampling, or the use of a more conservative source term.

- If the source term changes significantly as a result of the cessation of the In-Tank Precipitation process, or as a result of any replacement process, the methodology for meeting Criterion One must be reevaluated.

The following conclusions are made with respect to Criterion One.

- The DOE methodology for sludge volume estimation appears technically adequate.

- DOE's methodology for removal of key radionuclides to the extent technically and economically practical is acceptable.

III. CRITERION TWO

...wastes will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR Part 61...[3]

Solid Physical Form

The DOE Closure Plan [2], which has already been implemented for Tanks 17 and 20, includes the addition of a reducing grout to the residual waste in the tank, followed by a layer of low-strength cement, and a layer of high-strength grout. See Figure 4.

DOE will pump reducing grout directly on to residual waste in the tank from seven tank risers, six around the circumference of the tank, and one in the center (Figure 5). The grout mixes partially with the residual waste, and surrounds it generally in a wagon wheel form (Figure 6). After the liquid grout is poured, dry grout is distributed on top to absorb any remaining liquid, and to fully cover the residual waste. The reducing grout alters the leachate chemistry, and reduces the mobility of certain radionuclides, by creating a reducing environment, with a high pH [5].

Controlled low-strength material (CLSM) is a self-leveling backfill material composed of sand and cement formers. It is pumped into the tank following the reducing grout application. CLSM fills most of the volume in each tank. It has several useful properties for this application. Its compressive strength will provide adequate support for the overbearing weight, it has a low heat of hydration, and it is relatively inexpensive.

The final layer is "strong grout." Strong grout is a low viscosity grout with compressive strengths in the normal concrete range (~2000 psi). This formulation is used near the top of each tank because its consistency is suited for filling voids created around risers and tank equipment. This strong grout will also discourage accidental penetration of the waste from the top (as from an inadvertent intruder) .

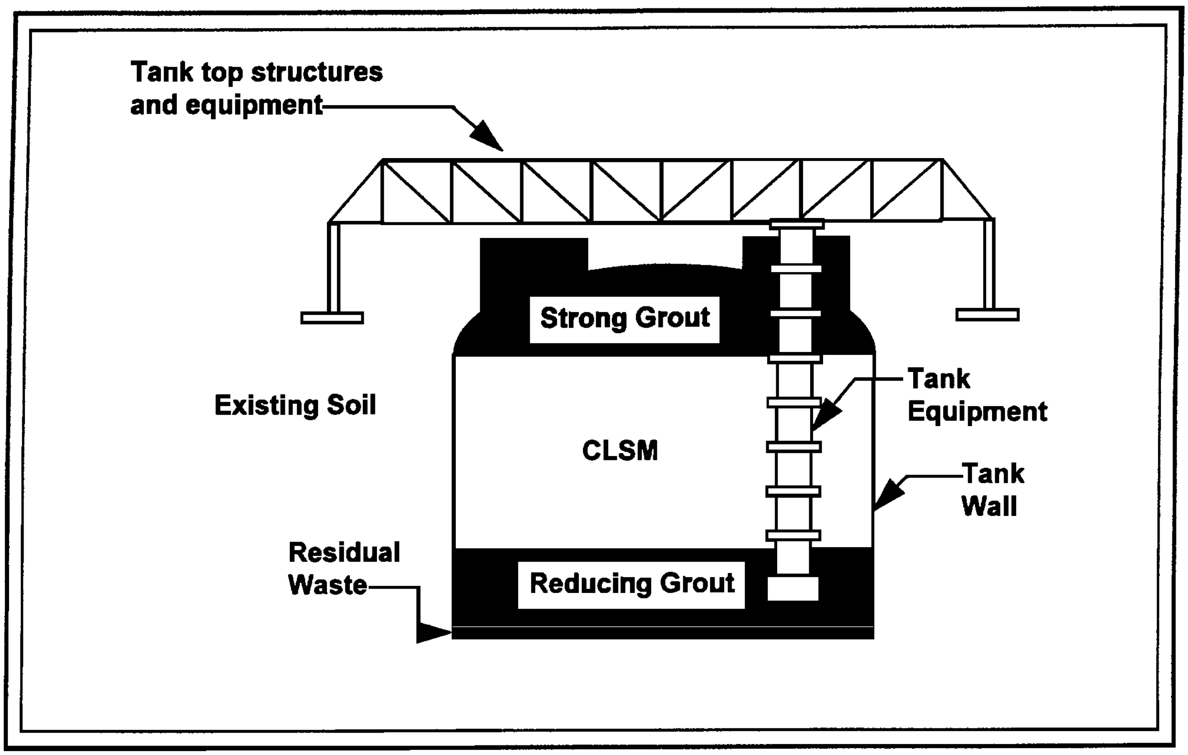

Figure 4: Tank closure showing layers of fill material [5].

The Regulatory Basis [5] addresses the stability of the grout-filled tanks based on three factors (derived from 10 CFR 61.56): (i) resistance to subsidence, (ii) resistance to dispersion, and (iii) reduction of the likelihood of inadvertent intrusion. Assuming that DOE fills the tanks according to the procedures outlined in the Industrial Wastewater Closure Plan [11], the waste will be immobilized in cementitious materials at least 10 m below the ground surface, with the topmost layer consisting of a strong grout.

Class C Concentration Limits

For approximately 14 of the 51 tanks, the Branch Technical Position (BTP) on Concentration Averaging [12] will be applied to meet the concentration limits specified in 10 CFR Part 61. These 14 tanks require between 0 and 31 inches of grout to meet the Class C limits. In general, they contain low-heat, second-cycle wastes, and the remaining 37 contain first-cycle extraction wastes. The actual number of tanks that can meet the concentration limits with application of the BTP will depend on source, volume, and concentration of residual waste.

The BTP on Concentration Averaging is based on 10 CFR Part 61.55(a)(8), that, “the concentration of a radionuclide [in waste] may be averaged over the volume of the waste, or weight of the waste if the units [on the values tabulated in the concentration tables] are expressed as nanocuries per gram.” One of the principal considerations is “whether the distribution of radionuclides within the waste can be considered to be reasonably homogeneous.... A homogeneous waste type is one in which the radionuclide concentrations are likely to approach uniformity in the context of the intruder scenarios used to establish the values included in Tables 1 and 2 of 10 CFR 61.55" [12]. Homogeneity in this context does not necessarily assume uniform mixing.

DOE used Section 3.2 of the BTP to perform the concentration averaging calculations. Section 3.2, “solidified and absorbed liquids,” states that “[c]lassification of evaporator concentrates, filter backwashes, liquids, or ion-exchange resins solidified in a manner to achieve homogeneity or meet the stability criteria of 10 CFR 61.56 should be based on solidified nuclide activity divided by the volume or weight of the solidified mass.”

The volume of reducing grout, along with the residual waste, is used as the volume of the “waste form” for concentration averaging purposes. The entire tank volume (filled with CLSM and strong grout) is not used. The volume of reducing grout added to each tank will depend on the concentration of the remaining radionuclides.

Tests have been performed at Construction Technology Laboratories, Inc. (CTL) to determine the degree of mixing between the reducing grout and simulated tank waste [13]. DOE has determined the thickness or amount of reducing grout needed to comply with the Class C concentration limits. A safety factor will also be included; an additional 50 percent (by volume) of grout will be added beyond that needed to meet the Class C concentration limits.

Figure 5: Tank 20 riser locations [14].

Figure 6: Sludge and grout in "wagon-wheel" formation [14].

Alternatives to 10 CFR Part 61 Waste Classification

In the remaining 37 tanks, additional cleaning before grouting would be required to satisfy the Class C requirements, even with the application of concentration averaging. For these tanks, DOE determined that additional cleaning to the degree necessary to meet Class C concentration limits in all tanks would lead to substantial increase in the cost of tank closure. (Oxalic acid cleaning would add $1,050,000 per tank, or an additional $38,850,000 for 37 tanks.) Consequently, DOE has requested that NRC apply the provisions in 10 CFR 61.58, which recognize the acceptability of alternative considerations for the classification of waste, provided there is reasonable assurance that the performance objectives in 10 CFR Part 61, Subpart C, are met. Tanks will therefore be cleaned to meet the performance objectives, but will not necessarily be cleaned to the degree necessary to meet Class C concentration limits through application of the BTP.

Recent calculations for F-Tank Farm [15] indicate that using oxalic acid to clean all tanks will not significantly reduce maximum annual dose to the public or to an inadvertent intruder. The maximum annual drinking water doses for the current calculated baseline case (which includes oxalic acid cleaning in 10 of 22 tanks to meet performance objectives) are 130 mrem/year for an intruder at 1-meter from the tank, and 1.9 mrem/year at the seepline for a member of the public. When oxalic acid cleaning is applied to all of the tanks, the 1-meter maximum annual drinking water dose to an intruder drops to 110 mrem/year, and the seepline drinking water dose drops to 1.7 mrem/year. There are ten tanks in F-Tank Farm, which are expected to meet Class C limits with application of concentration averaging; using oxalic acid to clean these tanks would add approximately $10,500,000 for limited, or no, benefit.

NRC Review and Conclusions

We reviewed the DOE Closure Plan [2], the Regulatory Basis [5], the actual grouting procedures used in Tanks 17 [6] and 20 [16], and the CTL report [13], to evaluate the solid physical form portion of this criterion. We also reviewed additional information provided in the form of photographs of the CTL reducing grout test pours, cylindrical samples taken from solidified test pours, and videotapes of the grout pours. The filled tanks are expected to provide a stable waste form.

We have also considered the appropriateness of applying concentration averaging for the 14 second-cycle/low-heat waste (LHW) tanks. It is not readily apparent where the cut-off between the "14" tanks and the "37" tanks is, i.e., it is not clear which tanks will have concentration averaging applied to meet the Class C concentration limits, and which will need "enhanced waste removal actions" (oxalic acid cleaning). The staff has determined that concentration averaging in accordance with the BTP is generally acceptable in this context to meet Class C limits, however, NRC recommends that a definitive cut-off be established to select eligible tanks and to distinguish them from tanks which require enhanced waste removal actions. For example, eligible tanks might be LHW only, and require less than a specified amount of grout to meet Class C limits.

10 CFR 61.58 recognizes the acceptability of alternative considerations for the classification of waste, "if after evaluation, of the specific characteristics of the waste, disposal site, and method of disposal, [the Commission] finds reasonable assurance of compliance with the performance

objectives of [10 CFR Part 61] Subpart C." The waste will be solidified in layers of grout, 10m below the surface of the ground; the disposal site is considered to be stable, and staff has concluded that the tank closure methodology is consistent with meeting the performance objectives of Part 61. (See Section IV). In addition, the public dose limit is well below the limit, inadvertent intruder doses are expected to be below the limit, and additional effort (i.e. oxalic acid cleaning) will be very costly and result in little, if any, reduction in risk. However, in order to bound the associated analyses, and provide a specific benchmark for satisfactory cleaning of the tanks, staff recommends that DOE consider developing site-specific concentration limits for residual waste in the SRS HLW tanks.

The following assumptions were used in assessing conformance with Criterion Two.

- The grouts and other cementitious materials used to fill the tanks will be appropriately chosen on a tank-specific basis to ensure chemical and physical stability and minimize void space.

- The radionuclide inventory and the chemical composition of the residual waste will be adequately characterized for each tank.

The following recommendations are made with respect to Criterion Two.

- A clear distinction should be made between tanks where concentration averaging can be applied to meet Class C limits, and those where enhanced waste removal activities to meet the performance objectives of 10 CFR Part 61 will be applied.

- Individual tank characterization efforts are appropriately conservative in adopting the greater of sampling or estimation concentrations. Discrepancies in radionuclide inventories for ^{99}Tc and ^{79}Se in tank characterization reports and closure performance assessment models, while not significantly affecting model results, may suggest a need for better data tracking.

- DOE should consider developing site-specific concentration limits for residual waste in the SRS HLW tanks to bound the associated analyses and provide a specific benchmark for satisfactory cleaning of the tanks.

The following conclusions are made with respect to Criterion Two.

- The filled tanks will provide an acceptably stable waste form in conformance with the structural stability requirements of 10 CFR 61.56(b)(1).

- Application of the BTP on Concentration Averaging is an acceptable means of meeting the waste classification criteria of Part 61.

- The administration of alternative waste classification does not supersede the need to meet all aspects of Criterion One and Three.

IV. CRITERION THREE

...the waste is to be managed, pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61 are satisfied....[3]

§ 61.41 Protection of general population from releases of radioactivity

"Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable."

The 25 mrem/yr limit applies throughout the operating and post-closure periods of a disposal facility. The other radiological control limits of 10 CFR Part 20, "Standards for Protection Against Radiation," apply during facility operation, except for the 25 mrem limit from the pathways defined above.

§ 61.42 Protection of individuals from inadvertent intrusion

"Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after institutional controls over the disposal site are removed."

Although a particular dose limit is not specified in this performance objective, compliance with the technical requirements of 10 CFR Part 61 and, in particular, with the classification system of 10 CFR 61.55, is considered to provide adequate protection to intruders at a near surface land disposal facility. In the Draft Environmental Impact Statement for 10 CFR Part 61 [17], NRC used a 500 mrem/yr dose limit to an inadvertent intruder to establish the concentrations limits and other aspects of the waste classification system. In addition, 10 CFR Part 61 does not specify a time for institutional controls in the performance objectives, but does require in 10 CFR 61.59(b) that "...controls may not be relied upon for more than 100 years."

§ 61.43 Protection of individuals during operations

"Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by §61.41 of this part. Every reasonable effort shall be made to maintain radiation exposures as low as reasonably achievable."

This performance objective applies to both the public and to LLW disposal facility workers.

§61.44 Stability of the disposal site after closure

"The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required."

The stability performance objective is consistent with a major premise of 10 CFR 61 that the facility must be sited, designed, used, operated, and closed with the intention of providing permanent disposal. A disposal facility should not require long-term maintenance and care. Stability is particularly important considering the requirements in 10 CFR 61.59(b) that "...institutional controls must not be relied upon for more than 100 years following transfer of control of the disposal site to the owner."

Performance Assessment to Demonstrate Performance Objectives

Fate and Transport Modeling

The Multimedia Environment Pollutant Assessment System (MEPAS), Version 3.1, is the source term, transport, and dose conversion code used for the SRS tank closure performance assessment (PA). This program uses analytical methods to model the transport of contaminants from a source unit to any point at which the user wishes to calculate the concentration. DOE performed a separate MEPAS calculation for each grouping of tanks in the F-Area Tank Farm. (See Figure 2). For each calculation, DOE entered the source term data (in both source volume and total inventory) for the grouping, distributed over a square area equal to that of the tank bottoms in the grouping. For instance, for the Type I tanks, the source term for the MEPAS calculation consisted of the total inventory of the affected tanks and the concentration of contaminants in the grouping (i.e., the total inventory of the affected tanks divided by sludge volume in these tanks) distributed over a square area equal to the area of the eight Type I tanks. To account for overlapping of the contaminant plumes from the three separate groupings of tanks within the tank farm, DOE also performed the calculations with the three groupings at the same initial physical location. In addition, DOE summed the centerline concentrations from each plume at the point of exposure to ensure that the highest concentration was assessed.

Assumptions were made to allow meaningful calculations to be performed by the code, that would provide an upper bound to the potential impact that could be realized at the point of exposure. Table 2 provides a comparison of major modeling assumptions with actual conditions in the F-Area Tank Farm. In addition, DOE has performed tank-specific modeling for the closure of Tanks 17 and 20. Future tank closures will also be individually modeled.

Initially, limited uncertainty and sensitivity analyses were performed for the MEPAS model assumptions and parameter choices. The sensitivity analysis [7] identified the following principal parameters that affect modeling results: radionuclide inventory, hydraulic conductivity, distribution coefficients (K_d), vadose zone thickness, dispersion coefficient (for plume), and distance downgradient to receptor location. In response to NRC requests [8], [18], further sensitivity analyses were performed on infiltration rate, engineered barrier lifetime, time dependence of hydraulic conductivity of concrete basemat, location of water table in relation to tank bottoms, merged aquifers, horizontal conductivity, basemat integrity, water budget percentages, and dispersivity [9, 10]. Model uncertainty in relation to the groundwater transport segment (GTS) construct, and a fluctuating water table have also been addressed [9, 10] in response to NRC requests [8, 18]. Sensitivity and uncertainty analysis results are discussed in the applicable technical sections of this paper.

ACTUAL CONDITIONS	MODELING ASSUMPTION
22 Individual Tanks • 8 Type I tanks • 10 Type III tanks • 4 Type IV tanks	3 Area Sources • One source with area of 45, 396 ft^2 (Type I tanks) • One source with area of 56, 745 ft^2 (Type III tanks) • One source with area of 22, 698 ft^2 (Type IV tanks)
Each tank has a unique inventory and concentration of contaminants	Each area source can be represented as follows: • The inventory for each area source is equal to the total inventory of all tanks within the grouping • The concentration for each area source is equal to the total inventory in the area source divided by the total solids in the area source
Each tank has a unique plume with regard to space that may overlap other plumes in the vicinity; plume centerlines do not necessarily overlap	The 3 area sources are located at essentially the same initial physical location and travel the same path to the seepline so that the centerline of the plumes is forced to overlap
Each plume is time-dependent and plumes may overlap in time	The plumes from each area source are time-dependent and are added for each point in time
Future tank failures (i.e., failure of the grout) will occur at varying times	All tanks (the area sources) fail simultaneously (at t=1000)
Radiation dose from all radiological constituents is additive	Radiation dose from all radiological constituents is additive

Table 2: Comparison of F-Tank Farm modeling assumptions to actual conditions [5].

Risk Assessment

There are five factors to risk assessment: source, release, transport, uptake, and health effects. The source, release, transport and exposure aspects of the DOE Performance Assessment (Fate and Transport Modeling) will be discussed below, along with our evaluation. Uptake and health effects are not included in this evaluation, as they have been accounted for in the development of exposure limits for 10 CFR Part 61 performance objectives.

Source Term

Earlier in this paper we discussed tank sampling and estimated inventories. In the closed tanks, the bulk of the radionuclide inventory is sandwiched between two layers of reducing grout. To determine the inventory of contaminants after cleaning of each tank is accomplished, DOE assumes that the concentration of constituents in the solids remains unchanged. DOE considers this assumption to be realistic based on the fact that the presence of constituents in the solids indicates that the constituents are relatively insoluble and would be expected to remain insoluble throughout the tank cleaning process, which includes bulk removal of solids followed by spray water washing. Thus, the cleaning actions are expected to remove the more soluble constituents and reduce the volume of solids in the tanks; however, the cleaning will not substantially change the concentration of insoluble radionuclides in the sludge.

As each individual tank is prepared for closure, DOE will prepare a closure module that will be based on actual sampling results for that tank. Before any closure activities occurred DOE calculated anticipated doses that would result from each tank. These doses were based on assumptions/expectations that DOE believed it could accomplish, i.e., inventory and sludge removal efficiency. These preclosure calculations were therefore referred to as *a priori* calculations ("made before or without examination" [19]). If substantial deviations from the *a priori* modeling calculations are discovered such that actual sample measurements indicate a greater projected impact at the point of exposure, DOE will perform additional cleaning at that time to reduce the source term inventory. If additional cleaning is technically or economically infeasible, DOE may take credit for previously completed tank closures where actual sampling results indicated a lower impact at the point of exposure than predicted by the *a priori* modeling calculations.

In addition to modeling the tank contents, MEPAS runs were performed to determine the impacts of residual pollutants contained in ancillary equipment and piping. DOE models ancillary piping and equipment inventory as being equal to 20 percent of the total tank radionuclide inventory.

NRC Evaluation - Source Term

DOE can obtain a representative source term by analysis of historical records of processes resulting in waste generation. Confirmation of this source term will be accomplished through actual tank sampling, provided that the samples are taken from several different areas of well mixed sludge. NRC staff believe that if this source term identification protocol is followed the tank inventory will be well characterized.

The *a priori* calculation may be a useful tool in anticipating the predicted dose from each tank or groups of tanks. However, the *a priori* calculation should not be used as justification to limit the amount of tank cleanup.

Release

In their Fate and Transport Modeling (FTM) [7], DOE assumes that the grout and basemat will fail at 1000 years. The period of time claimed for the performance of engineered barriers should be supported by suitable information and justification [20]. The 1000 year lifetime assumed in the DOE methodology is based on an analysis performed at SRS for E-Area Vaults [21], which were projected to last 1400 years. The extended lifetime is partly due to environmental factors at SRS; freeze-thaw cycles and high chloride and sulfate ion concentrations, which are damaging to concretes, are not present. Sensitivity studies of engineered barrier lifetime revealed little sensitivity to these environmental factors.

In terms of release, the soil and grout layers above the source layer are primarily important in terms of restricting the flux of water through the waste. The hydraulic conductivity of the grout is much less than typical soil so that water infiltration into the source layer is substantially limited. However, grout cannot be assumed to be intact for an indefinite period of time. In the FTM, DOE assumes that when the grout develops catastrophic cracks in all tanks at 1000 years post-closure, the hydraulic conductivity increases by six orders of magnitude (from 9.6×10^{-9} cm/s to 6.6×10^{-3} cm/s). This change in conductivity is modeled as a step function rather than a gradual increase over time. Breakthrough time is sensitive to this parameter, but dose is not.

In addition, DOE anticipates that the reducing grout will alter the chemistry of the water that flows through the contaminated zone. The reducing grout will increase the pH and decrease the oxidation potential of the infiltrating water. A high pH and reducing environment will significantly reduce the solubility of the radionuclides contained in the contaminated zone. The reducing grout is projected to affect the water chemistry for a minimum of 500 years, and could extend into the future. Even after the grout develops cracks, there is no reason to believe that the chemistry will vary.

NRC Evaluation - Release

Although cracking and degradation of the reducing grout covered by a high-strength grout used for tank closure may be comparable to degradation of E-Area vault cement, it is the integrity of the basemats beneath the tanks that may be weak. Sensitivity analyses were performed assuming basemat failure at time = 0, 50, 100, 200, 500, 1000 and 2000 years. Dose appears to be insensitive to this parameter, but time of peak dose does change as basemat failure time varies. Basemat failure does not contribute to dose, therefore it is not considered to be an issue. In addition, the rationale for grout/cement lifetimes of 1000 years appears to be plausible, particularly with regard to chemical effects.

One tank group (17-18-19-20) in F-Area Tank Farm is located just above the water table. At times, these tanks may become partially submerged due to seasonal fluctuations of the water table. Some tanks in the H-Area are also in or near the water table. Partially submerged tanks may affect the manner that MEPAS models the release and transport of radionuclides. For tanks where the contaminated zone is beneath the water table, the release may be dominated by the horizontal flux of water rather than the vertical flux of water one would usually assume for tanks in the vadose zone. DOE attempted to show that the most conservative manner to model submerged tanks is to use the base case vertical flux model. Due to the small projected cross-sectional area perpendicular to horizontal flux the release rate is greatly limited. This is characteristic of the MEPAS code, and may be non-conservative, as changes in volume do not change leach rate estimates for the unsaturated zone leach rate model.

Future PA studies should model all submerged tanks or tanks within the fluctuating water table as submerged tanks, using a physically based geochemical and fluid transport leachate model, since the MEPAS code does not conservatively model submerged tanks. The release rate model for MEPAS uses only cross-sectional area and the radionuclide concentration to determine rate of release. Future modeling needs to consider the effects of increasing the volume of waste, and should include a shorter expected life time for the grout, due to submersion.

Transport

DOE used a construct for apportioning performance objectives, called the ”groundwater transport segment." The GTS consists of a physically defined area of the aquifers directly underlying the tank closure configuration. By definition, each GTS contains all HLW tanks and the other contaminant sources that lie within its boundaries. The nominal width of the GTS is determined by the size of the tank closure configuration footprint perpendicular to the groundwater flow direction at the tank farm area.

The F- and H- Area Tank Farms are modeled with one GTS each. Due to the three-dimensional nature of groundwater flow and leakage between the stacked aquifer layers beneath the general separations area (GSA), each GTS contains three aquifer layers. (See Figures 7 and 8.) Once contaminants reach the Water Table aquifer, they may follow one of three possible routes: (1) they will be transported through the water table and outcrop at the seepline and Fourmile Branch; (2) they will leak vertically from the Water Table aquifer through the underlying, confining Tan Clay layer into the Barnwell-McBean aquifer which also outcrops at the seepline and Fourmile Branch; (3) they will continue downward from the Barnwell-McBean aquifer through the confining Green Clay layer, into the Congaree, and appear in the Upper Three Runs. A downward flow that partitions the contaminant in the ratio of the water budget for the three aquifers is assumed at the contaminant source (e.g., for Tank 17, percentages of 31 for the water table, 65 for Barnwell-McBean, and 4 for Congaree aquifers).

For each of the eight layers modeled (contaminated zone, concrete, vadose zone, Water Table aquifer, Tan Clay layer, Barnwell-McBean aquifer, Green Clay layer, and Congaree aquifer), distribution coefficients, K_ds, were selected for each radionuclide and chemical compound. As contaminants are transported from the contaminated zone to the seepline, they are dispersed longitudinally (along the streamline of fluid flow), vertically, and transversely, by the transporting medium. MEPAS incorporates longitudinal dispersivity of pollutants moving downward through the unsaturated zone layers (i.e., concrete basemat and vadose zone). In the saturated zone, concentration calculations include three-dimensional dispersion along the length of travel.

DOE methodology includes two types of calculations for each GTS pertaining to the high-level waste tanks:

- an *a priori* calculation of the projected impact of the entire GTS using assumptions on the degree of the tank cleaning achievable

- a tank-specific calculation for each module of the closure plan using sampling results available following cleaning

The calculated *a priori* results are used to project whether the GTS will meet the overall performance objectives. This process helps to address the cumulative effect of all the tanks in the tank farm whose plumes may intersect. As individual tanks are prepared for closure, the tank contents are sampled, and the sampled source inventory of the tank will be compared to the estimated source term used as part of the *a priori* calculation. The sampling results will also be used to perform the tank-specific calculation on impacts at the point of exposure to ensure that the performance objective “budget” is not exceeded based on calculations using actual tank inventories.

NRC Evaluation - Transport

The MEPAS code has been used to model the groundwater system at SRS, although the presence of three aquifers and zones of high conductivity make the system difficult to model. The MEPAS code assumes an infinite lateral boundary for the aquifers. Therefore, DOE has submitted sensitivity analyses that quantify the effect of these parameters/conditions. To reflect the impact of vertical flow and transport through the aquifers on dose, DOE combined the top two aquifers and eliminated the bottom Congaree aquifer (the Congaree only receives approximately 4 percent of the water/radionuclides from the water table at this point in the ground water system). This resulted in a potential increase in dose to the public at the seepline of one µrem. By reducing the transverse dispersivity by a factor of ten, hence limiting the lateral boundary, the highest aquifer dose increased by approximately 3 times, to 0.21 mrem/yr, which is well below the dose limit to the public.

Another scenario DOE performed was to verify the sensitivity of dose to the K_d coefficients. The manner in which water chemistry in the basemat and contaminant zone affect the K_d's was also considered in a separate sensitivity analysis. The sensitivity analysis allowed for increased concentrations and mobility, which resulted in an increased dose of approximately 4 over the base case. These trials showed that there is little sensitivity to K_d's within the range of conditions investigated.

Even though the MEPAS code may not be able to fully model this complicated flow field it can be shown that the entire system may be appropriately assessed through conservative assumptions. These conservative assumptions help to simplify the transport model as well as add confidence in the output.

Exposure

Exposure is a function of the scenario used, worker, public or intruder.

Protection of Worker

The worker is defined as an adult who has authorized access to, and works at, the tank farm and surrounding areas but is considered to be a member of the public for compliance purposes. This analysis assumes that the worker remains on the shores of Fourmile Branch or Upper Three Runs during working hours, and is exposed to radionuclide releases through: direct irradiation from shoreline deposits, incidental ingestion of soil from shoreline deposits, and dermal contact with dust from shoreline deposits.

Figure 7: Aquifer layers underlying the F-Area Tank Farm [6].

Figure 8: Sample calibrated potentiometric surface for the Water Table Aquifer [6].

NRC Evaluation - Protection of Worker

The worker is protected by DOE regulations (10 CFR Part 835) which are analogous to 10 CFR Part 20, and which require disposal facility safety analysis reports, which are issued as required [22]. Therefore the worker protection performance objective is considered to be met and will not be addressed here.

Protection of Public

The public is represented by a nearby adult resident, and a nearby child resident. They live in a dwelling 100 meters downstream of the groundwater outcropping in Fourmile Branch, on the side opposite the F-Area Tank Farm. The seepline at Fourmile Branch, where groundwater outcrops to the surface approximately 1 mile from the tanks, is the chosen point of exposure. DOE has committed to following a 4 mrem/yr total effective dose equivalent (TEDE) drinking water dose rate, although the NRC staff evaluation is in accordance with the 25 mrem/yr TEDE (all pathways) limit of 10 CFR Part 61.

The resident is assumed to use Fourmile Branch for recreational purposes; to grow and consume produce irrigated with water from Fourmile Branch; to obtain milk from cows raised on the residential property; and to consume meat from cattle that were fed contaminated vegetation from the area. The major parameters used in assigning characteristics to the receptors used in the calculations were taken from ICRP 23, "Report of the Task Group on Reference Man" [23], NRC Regulatory Guide 1.109 [24], and "Soil Concentration Guidelines for the Savannah River Site Using the DOE/RESRAD Methodology" [25]. Drinking water doses provide the limiting cases, specifically, the seepline concentrations for the Barnwell-McBean aquifer [5]. For Tank 17 of the F-Area Tank Farm, the maximum total dose modeled for the adult resident from contaminant transport in the Barnwell-McBean aquifer is 2.7×10^{-2} mrem/yr at 805 years. As each tank is closed, the potential dose to public from the Barnwell-McBean aquifer at the seepline is calculated, and added to the values for all previous tank closures. The total for the F-Area Tank Farm is intended to meet the 4 mrem/yr drinking water standard, which is well within the 10 CFR Part 61 limit of 25 mrem to the whole body.

NRC Evaluation - Protection of Public

DOE has used an all pathway dose assessment to show conformance with the performance objectives established for the public. Drinking water doses provide the limiting cases. The total for the F-Area Tank Farm is intended to meet 4 mrem/yr for drinking water, which is expected to be well within the 10 CFR Part 61 limit of 25 mrem/yr to the whole body.

DOE has selected the nearest public dose receptor to be approximately one mile from the F-Area Tank Farm. This selection of receptor location allows for a one mile buffer zone between the HLW waste tanks and the public. Due to the large number and types of facilities located at SRS this buffer zone distance appears to be conservative. Within the general area of the F-Area and H-Area Tank Farms there are also five production reactors, two chemical reprocessing canyons, the DWPF, a liquid low-level waste effluent treatment facility, and a solid low-level waste burial ground. At locations between the F-Area Tank Farm and the seepline where it can not satisfy the 4-mrem/yr drinking water standard, DOE plans to institute active and passive institutional controls [5], although the NRC evaluation assumed no dependence on extended institutional controls. (See discussion below.) If combined doses from all pathways are less than the 25 mrem/yr requirement of 10 CFR Part 61.41, adoption of additional protective measures is optional.

As indicated by the performance assessment, combined doses to the public from all pathways are projected to be below the 25 mrem/yr limit, therefore, staff considers that there is reasonable assurance that safety requirements comparable to §61.41 can be satisfied, as well as the provisions of ALARA (as low as reasonably achievable).

Protection of Intruder

DOE has used two different intruder scenarios to show that their methodology meets the incidental waste criteria. The first scenario was intended to justify the use of the alternative waste classification requirements of 61.58. This scenario depicts an intruder who drills through the tank and is then exposed to the drill cuttings. The separate intruder scenario analysis was provided to demonstrate compliance with the provisions of 10 CFR 61.58. However, Section 61.58 references all of the performance objectives in Section 61.40. Therefore, it is inappropriate to focus the rationale for alternative provisions on intruder protection, and this intruder scenario will not be discussed further.

The second intruder scenario, designed to show compliance with §61.42, defines the intruder as "a teenager who gains unauthorized access to the F-Area Tank Farm and is potentially exposed to contaminants" [7]. This scenario is analyzed as if institutional controls have ceased. Because the intruder will not have residential habits, he will not have exposure pathways similar to those of a resident (the intruder does not build a house, grow produce, etc); rather, the intruder could be exposed to the same pathways as the seepline worker but for a shorter duration (4 hours per day). All calculated doses to this intruder are less than 0.001 mrem/yr.

NRC Evaluation - Protection of Intruder

The traditional agriculture scenario consists of a farmer who lives at the tank farm, and drills a well near the tank farm and then uses the well water to irrigate his crops and feed his livestock as well as himself. The original intruder scenarios provided did not include the agriculture scenario. In response to the NRC request [18] for sensitivity of dose to a resident farmer, DOE-SR has provided calculated drinking water doses (only). DOE's intruder PA showed that the maximum drinking water dose the farmer would receive via the ground-water pathway was 130 mrem/year at a well distance of 1 meter from the tank farm, at approximately 700 years. For these analyses, all the tanks in F-tank farm were modeled on a centerline, and doses from drinking water wells for the resident farmer were modeled downgradient on the centerline of groundwater transport at 1m, 25m, 50m, and 100m. According to DOE-SR, the drinking water dose pathway is expected to be the highest dose contributor, and therefore provides reasonable assurance that the 500 mrem/year limit, used as a basis for waste classification, to show protection of individuals from inadvertent intrusion, can be met. The DOE-SR analysis assumes all activity is contained within the reducing grout layer located at the bottom of each tank, and that this contaminant zone is not disturbed. This then implies that there is no activity in any vertical component of the tank structure, and therefore, a typical construction scenario (with a 10 foot deep basement) would not disturb any contaminated portion of the tank structure. The scenarios used do not include other dose contributors such as ingestion of contaminated food, inhalation, or direct irradiation; however, drinking water dose is expected to be the highest contributor. Since DOE anticipates drinking water to be the largest contributor to the total dose, staff considers that there is reasonable assurance that safety requirements comparable to §61.42 can be satisfied.

Staff recommends that future performance assessments for SR tank closures, including individual tank closure modules, and the H-Tank Farm Fate and Transport Modeling, include the full agriculture scenario (all pathways) as well as the discovery scenario, as described in the Draft Environmental Impact Statement for 10 CFR Part 61 [17].

The highest drinking water dose of 130 mrem/yr is attributed to ancillary equipment and piping, rather than the actual tanks. For the PA calculations, DOE assumed an additional 20 percent of the radioactive contaminants remaining in each tank after bulk waste removal and spray washing would be distributed in the ancillary equipment and piping associated with the tank system. PA runs were performed to determine the impacts of residual waste contained in the ancillary equipment and piping (which were assumed to be filled with grout where possible) [7]. However, the modeling does not appear to have considered degraded piping and ancillary equipment in the context of an inadvertent intruder. Prior to in-situ closure of above-ground and near-surface ancillary equipment and piping, an intruder scenario should be modeled considering degraded and disturbed ancillary equipment and piping, which in addition to tank sources, must not exceed the 500 mrem per year (all pathways, total effective dose equivalent) for the discovery and agricultural scenarios. That is, the scenario should include the traditional agricultural intruder assumptions, which in this case could mean digging a basement, contacting the waste, and inhaling and/or ingesting it. Furthermore, the staff recommends that all external components of the HLW tanks (e.g., piping) meet Class C concentration limits without the application of concentration averaging, unless DOE-SR can demonstrate that closed external components provide protection to an inadvertent intruder (similar to that provided for the HLW residual contained in the closed tanks). This is important because the current PA shows that the external components contribute the most significant dose prior to 1000 years.

Institutional Controls

DOE's policy is to maintain institutional control of the site in perpetuity. The "Savannah River Site Future Use Plan," issued in March of 1998, states as policy the following points: (1) SRS boundaries shall remain unchanged, and the land shall remain under the ownership of the federal government, consistent with site's designation as a National Environmental Research Park; (2) residential uses of all SRS land shall be prohibited; and (3) an Integral Site Model which incorporates three planning zones (industrial, industrial support, and restricted public uses) will be utilized. The land around the F- and H- Areas (i.e., between Upper Three Runs Creek and Four Mile Branch) will be considered in the industrial use category. DOE considers that these provisions for institutional controls are comparable to or exceed those for Part 61.

NRC Evaluation - Institutional Controls

The institutional requirements of 10 CFR Part 61 state that active institutional controls may not be relied upon for more than 100 years. The NRC evaluation assumed no dependence on extended institutional controls. It appears from the performance assessments performed by

DOE in the FTM [7], and from subsequent modeling performed in response to questions from NRC, that there is reasonable assurance that tanks closed in accordance with the stated tank closure methodology can meet the performance objectives of 10 CFR Part 61, without dependence on institutional controls.

Site Stability

DOE plans to fill each tank with 30 or more feet of grout and cement. In addition to the steel and concrete structure of the tanks, this is predicted to create a solid, stable configuration for more than 1000 years. Final remediation of the tank farm areas under CERCLA may include capping the area, which would further isolate the waste by sealing the areas above each tank grouping. Such a configuration would help provide long-term assurance of stability and strength of the closure area.

NRC Evaluation - Site Stability

DOE's plans to fill the tanks with multiple layers of grout and concrete appear sufficient to indicate that safety requirements comparable to §61.44 can be met. Note that estimation of engineered barrier lifetime (i.e., duration of grout/cement fill) has been addressed above.

NRC Review and Conclusions

The following assumptions were used in assessing conformance with Criterion Three.

- Institutional controls in perpetuity were not assumed, rather, the institutional controls used for 10 CFR Part 61, specifically, 100 years (maximum) active institutional controls, were assumed.
- Drinking water dose to an intruder is the dominant exposure pathway.
- Drinking water dose to the public is the dominant exposure pathway.
- The doses are expressed as total effective dose equivalents.
- 1000 year lifetime for the grout/cement tank fill.
- 1000 year lifetime for the chemistry effects of reducing grout.

The following recommendations are made with respect to Criterion Three.

- Institutional controls in perpetuity should not be assumed when the H-Area tank farm is modeled.
- For H-Area tank farm modeling, the period of cement integrity and the reducing conditions imposed from the grout should be shorter for those tanks partially submerged.
- An all pathways dose assessment should be performed.

- If the source term changes significantly as a result of the cessation of the In-Tank Precipitation process, or as a result of the replacement process, the performance assessments must be reevaluated.

- Prior to in-situ closure of ancillary equipment and piping, an intruder scenario should be modeled considering degradation of any ancillary equipment and piping.

- Staff recommends that future performance assessments for SR tank closures, including individual tank closure modules, and the H-Tank Farm Fate and Transport Modeling, include the full agricultural intruder scenario (all pathways) as well as the discovery (intruder) scenario, as described in the Draft Environmental Impact Statement for 10 CFR Part 61.

- All external components of the HLW tanks (e.g., piping) should meet Class C concentration limits without the application of concentration averaging, unless DOE-SR can demonstrate that closed external components provide protection to an inadvertent intruder (similar to that provided for the HLW residual contained in the closed tanks).

The following conclusions are made with respect to Criterion Three.

- As indicated by the DOE performance assessment, combined doses to the public from all pathways are projected to be below the 25 mrem/yr limit, therefore, staff considers that there is reasonable assurance that safety requirements comparable to §61.41 can be satisfied.

- Staff considers that there is reasonable assurance that safety requirements comparable to §61.42 (protection of individuals from inadvertent intrusion) are satisfied for tank closure only. Further analysis must be performed to show that closure of ancillary piping and equipment can protect the inadvertent intruder.

- The worker is protected by DOE regulations which are analogous to 10 CFR Part 20. Therefore the worker protection performance objective (§61.43) is considered to be met.

- DOE's plans to fill the tanks with multiple layers of grout and concrete appear sufficient to indicate that safety requirements comparable to §61.44 can be met.

V. CONCLUSIONS AND RECOMMENDATIONS

NRC staff has concluded that the DOE methodology for incidental waste classification of residual HLW tank waste can meet the objectives of incidental waste Criteria One and Three specified in the Bernero to Lytle letter of March 2, 1993, for tank closure. Although the waste form concentration limits associated with Criterion Two cannot be met for all tanks, the performance objectives of 10 CFR Part 61, Subpart C can be met with enhanced cleaning, similar to the provisions in 10 CFR 61.58, "Alternative Requirements for Waste Classification and Characteristics." Adequate protection of the public health and safety should be provided by meeting the first and third criteria. No conclusion can be made at this point regarding ancillary equipment. Institutional controls in perpetuity have not been approved, but do not appear to be necessary in the performance assessment to assure protection of the public health and safety.

The analysis performed regarding the proposed tank closure methodology for the HLW tanks located at the DOE Savannah River Site was performed according to the terms and conditions of the established Memorandum of Understanding [4]. Under those terms and conditions, NRC is acting in an advisory capacity, and is not providing regulatory approval. DOE is responsible for determining whether the waste is incidental.

The analysis and resulting conclusions are specific only to the 51 tanks located at the DOE-SRS F and H Area Tank Farms and related piping and equipment. NRC judgment as to the adequacy of the methodology is dependent on verification that the assumptions underlying the analysis are correct. The NRC assessment is a site-specific evaluation, and is not a precedent for any future decisions on waste classification scenarios at other sites, particularly sites under NRC jurisdiction.

NRC Recommendations for Future DOE Tank Closure Activities at DOE-SR

The following recommendations apply to future activities at the Savannah River site, including the H-Area fate and transport modeling, and the individual tank closure modules.

- Rigorous sensitivity and uncertainty analyses should be performed in conjunction with future modeling, including, but not limited to:
  - Early degradation of grout/cement fill for submerged tanks or tanks within the fluctuating water table zone
  - Combined aquifer scenario (for both public and intruder)
  - Horizontal vs vertical flux (particularly in the saturated zone)
  - Conservative distribution coefficient analysis
  - Dispersive solute flux for submerged scenarios
  - A revised leachate model for submerged tanks which incorporates geochemical and fluid transport effects

- 500 year resident farmer intruder scenario should be included, including dose from all pathways (and assuming maximum of 100 year active institutional controls).

- An all pathways dose assessment for public receptors.

- A set tank sampling protocol should be developed. The method should involve enough samples to adequately represent the tank contents, and should be performed after bulk waste removal and tank cleaning. Any large inconsistencies indicate the need for further sampling, or the use of a more conservative source term.

- The radionuclide inventory and the chemical composition of the residual waste will be adequately characterized for future tank closures .

- As the tank closure process will continue for at least the next 20 years, technical feasibility of waste removal options and tank grouting/cementing techniques should continue to be evaluated.

- DOE should consider developing site-specific concentration limits for residual waste in the SRS HLW tanks to bound the associated analyses and provide a specific benchmark for satisfactory cleaning of the tanks.

- DOE should perform sensitivity analyses on key parameters that could be impacted by natural phenomenon changes.

- Prior to in-situ closure of ancillary equipment and piping, an intruder scenario should be modeled considering degradation of any ancillary equipment and piping.

- Staff recommends that future performance assessments for SR tank closures, including individual tank closure modules, and the H-Tank Farm Fate and Transport Modeling, include the full agricultural intruder scenario (all pathways) as well as the discovery (intruder) scenario, as described in the Draft Environmental Impact Statement for 10 CFR Part 61.

- All external components of the HLW tanks (e.g., piping) should meet Class C concentration limits without the application of concentration averaging, unless DOE-SR can demonstrate that closed external components provide protection to an inadvertent intruder (similar to that provided for the HLW residual contained in the closed tanks).

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LIST OF ABBREVIATIONS AND ACRONYMS

BTP	Branch Technical Position
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLSM	Controlled Low-strength Material
CTL	Construction Technology Laboratories, Inc.
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
DOE-SR	U.S. Department of Energy Savannah River
DWPF	Defense Waste Processing Facility
FTM	"Fate and Transport Modeling of Residual Contaminants and Human Health Impacts from the F-area High-Level Waste Tank Farm"
GSA	General Separations Area
GTS	Groundwater Transport Segment
HLW	High-level Waste
LHW	Low-heat Waste
LLW	Low-level Waste
MEPAS	Multimedia Environment Pollutant Assessment System
NRC	Nuclear Regulatory Commission
PA	Performance Assessment
RCRA	Resource Conservation and Recovery Act
RAI	Request for Additional Information
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site
TEDE	Total Effective Dose Equivalent
WSRC	Westinghouse Savannah River Company