SRR-CWDA-2012-00044
Revision 1

Evaluation of Features, Events, and Processes in the H-Area Tank Farm Performance Assessment

October 30, 2012

Prepared by: Savannah River Remediation LLC
Closure and Waste Disposal Authority
Aiken, SC 29808

Prepared for U.S. Department of Energy Under Contract No. DE-AC09-09SR22505

APPROVALS

Author:

10/30/2012
Date

Steve Hommel
C&WDA Closure Assessments
Savannah River Remediation

Technical Review:

10/30/2012
Date

Mark Layton
C&WDA Closure Assessments
Savannah River Remediation

Management Review:

10/30/2012
Date

Kent Rosenberger
C&WDA Closure Assessments
Savannah River Remediation

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ACRONYMS/ABBREVIATIONS

ACP	Accelerated Closure Projects
ALARA	As Low As Reasonably Achievable
C&WDA	Closure and Waste Disposal Authority
CA	Composite Analysis
CAB	Citizen's Advisory Board
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CPT	Cone Penetration Test
DOE	U.S. Department of Energy
E_h	Reduction Potential
EPA	U.S. Environmental Protection Agency
FEPs	Features, Events, and Processes
FFA	Federal Facility Agreement
FMB	Fourmile Branch
FTF	F-Area Tank Farm
GCL	Geosynthetic Clay Liner
GSA	General Separations Area
GSAD	General Separations Area Database
HDPE	High Density Polyethylene
HRR	Highly Radioactive Radionuclide
HTF	H-Area Tank Farm
IHI	Inadvertent Human Intruder
K_d	Distribution Coefficient
LFRG	Low Level Waste Disposal Facility Federal Review Group
LLW	Low Level Waste
LW	Liquid Waste
MEP	Maximum Extent Practical
MOP	Member of the Public
NRMP	Natural Resources Management Plan
PA	Performance Assessment
pH	The measure of the acidity or basicity of an aqueous solution
PMP	Probable Maximum Precipitation
RAI	Request for Additional Information
RCRA	Resource Conservation and Recovery Act
QA	Quality Assurance
SCDHEC	South Carolina Department of Health and Environmental Control
SDF	Saltstone Disposal Facility
SRS	Savannah River Site
USDA	U.S. Department of Agriculture
UTR	Upper Three Runs

1.0 INTRODUCTION

At the Savannah River Site (SRS), Performance Assessments (PA) have been developed to support the closure of liquid waste (LW) facilities and to provide the technical basis for demonstrating compliance with performance objectives as defined in Department of Energy (DOE) Manual 435.1-1 and 10 Code of Federal Regulations (CFR) 61.

These PAs inform decisions related to facility designs and the methods of disposal or closure. They also model the capacity of the facility to limit contaminant release and transport of radionuclides and chemical contaminants from disposal sites within specific time periods. To ensure compliance with the performance objectives as related to protection of public health and safety, the H-Area Tank Farm (HTF) PA provides the necessary technical basis and assumptions to support development and calculation of the following: a) potential radiological doses to a hypothetical Member of the Public (MOP), b) potential radiological doses to a hypothetical inadvertent human intruder, and c) radiological dose to a human receptor via the air pathway, radon flux, and water concentrations.

Due to the complex nature of these models, a structured methodology is necessary to ensure that relevant components and assumptions are adequately addressed during model development. Therefore, PA models must be developed within defined boundaries and with appropriate consideration of the relevant features, events, and processes (FEPs).

1.1 Purpose and Scope

The purpose of this report is to evaluate whether or not the relevant LW FEPs have been adequately addressed within either the H-Area Tank Farm (HTF) PA (in either the Base Case or the alternate modeling scenarios of Revision 0) or other supporting documentation. By confirming that the HTF PA Revision 0 adequately addressed the LW FEPs, a formal list of applicable FEPs shall be established for future HTF PAs.

For the purpose of this report, FEPs are defined as follows:

- A **feature** is an object, structure, or condition that has the potential to affect disposal system performance;
- An **event** is a natural or human-caused phenomenon that has the potential to affect disposal system performance and that occurs during an interval that is short relative to the period of performance; and
- A **process** is a natural or human-caused phenomenon that has the potential to affect disposal system performance and that operates during all or a significant part of the period of performance.

FEPs analyses typically consist of three steps [SAND2010-3348 P]:

1. **FEPs Identification –** Identify and define a list of all potentially relevant FEPs, no matter how improbable or inconsequential.
2. **FEPs Screening –** Evaluate the potentially relevant FEPs using specific criteria to determine which FEPs should be included (screened in) or excluded (screened out) from PA modeling.

3. **PA Model Implementation –** Develop PA models (Base Case and alternate scenarios and sensitivities cases) that incorporate the included (screened in) FEPs.

This report documents an *ex post facto* FEPs analysis to evaluate the HTF PA against the relevant FEPs. Accordingly, this report deviates from the typical FEPs methodology described above (i.e., Step 3 was performed first). Steps 1 and 2 were performed and documented independently. [SRR-CWDA-2012-00011, Rev. 0] This report introduces a fourth step: "FEPs-to-PA Evaluation." Therefore, the FEPs analysis process for the HTF PA is applied as follows:

1. **PA Model Implementation –** Develop the HTF PA (SRR-CWDA-2010-00128, Rev. 0).
2. **FEPs Identification –** Identify and define a list of all potentially relevant FEPs (SRR-CWDA-2012-00011, Rev. 0).
3. **FEPs Screening –** Determine which FEPs should be included (screened in) or excluded (screened out) from PA modeling (SRR-CWDA-2012-00011, Rev.0).
4. **FEPs-to-PA Evaluation –** Evaluate whether the PA models (Base Case and alternate scenarios) appropriately incorporate the included (screened in) FEPs (as documented within this report).

Section 2 of this report provides a description of each of the relevant FEPs considered for this evaluation from SRR-CWDA-2012-00011, Rev. 0. Section 3 provides a crosswalk that maps each FEP to information within the HTF PA (SRR-CWDA-2010-00128, Rev. 0) or other supporting documentation. Finally, Section 4 summarizes the findings of this analysis.

1.2 Quality Assurance

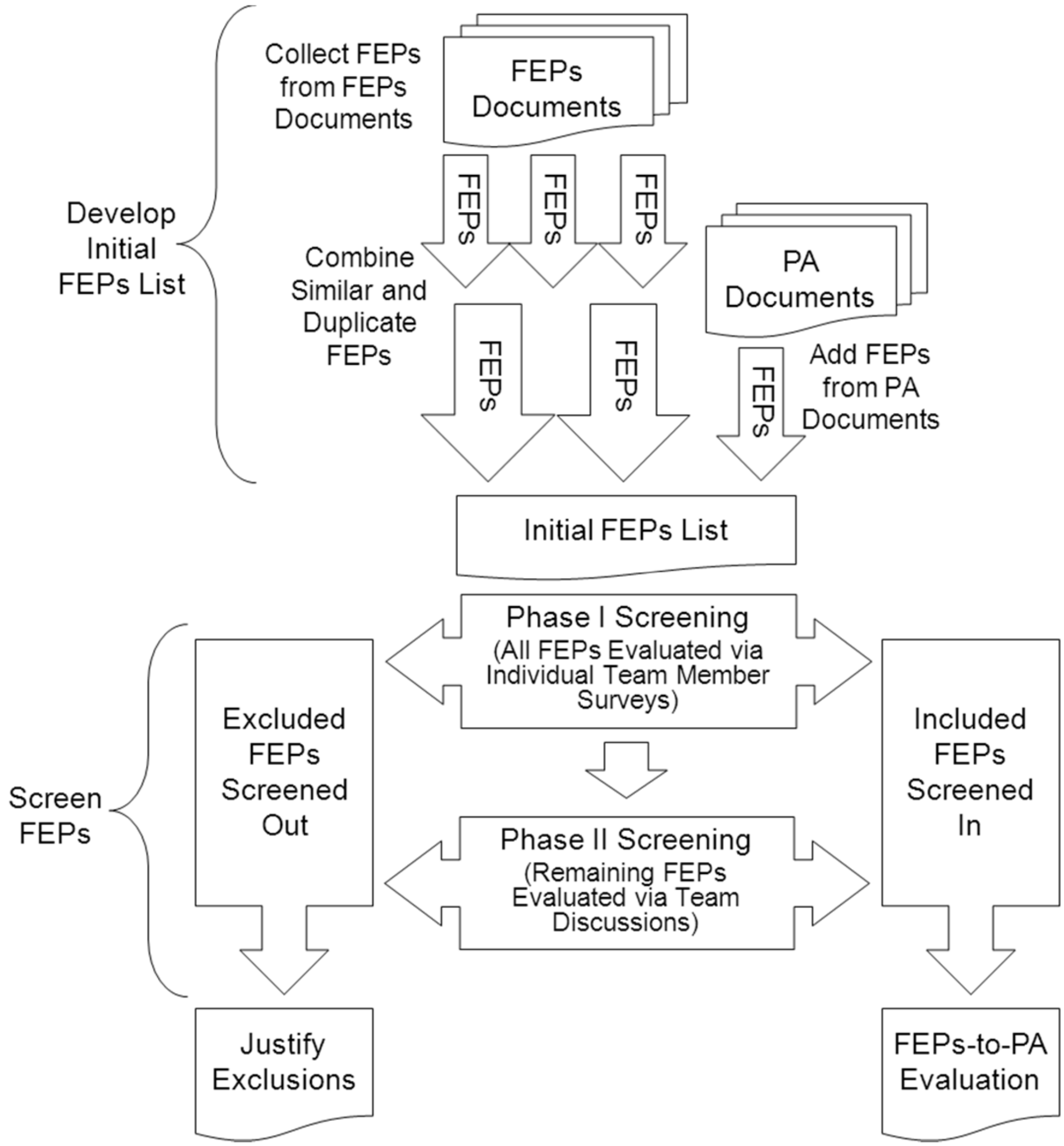
Development of this report and supporting analyses are subject to the quality assurance (QA) program and requirements as defined in Manual 1Q – *Quality Assurance Manual*. Consistent with this QA program, the information provided herein shall undergo technical and management review prior to approval and release.

2.0 LIQUID WASTE FEPs

The report *Features, Events, and Processes for Liquid Waste Performance Assessments* documented the screening process for LW FEPs. [SRR-CWDA-2012-00011, Rev. 0] That report developed an initial list of 262 FEPs from five FEPs documents and other sources. Of those 262 FEPs, 30 were systematically screened out.

Figure 2.0-1 provides a general overview of this screening process. Table 2.0-1 provides a description of the 232 FEPs that were screened in for further evaluation. Note that the FEP ID numbers provided in the table are not continuous as the FEPs that have been screened out are not included.

Figure 2.0-1: FEPs Methodology



[Source: SRR-CWDA-2012-00011, Rev.0]

Table 2.0-1: Descriptions of FEPs for Evaluation

FEP ID	FEP Name	FEP Description
1.1.01	Assessment Context Factors	Factors related to determining the scope or boundary conditions for the performance assessment of a waste closure facility. These include: a) factors related to the purpose for which the assessment is being performed, b) the regulatory requirements and criteria, c) the assessment philosophy that will be followed, and d) the overall framework within which the assessment will be performed.
1.1.02	Assessment Purpose	Consideration for the purpose of the performance assessment of a waste closure facility.
1.1.03	Assessment Conditions	Factors related to the conditions (or framework) under which the performance assessment of the waste closure facility and closure system will be performed.
1.1.04	Documentation and Presentation of Results	The effective documentation, presentation and communication of the performance assessment using a variety of techniques (such as written material, videos, presentations, CD-ROM, web pages) tailored to the needs of the various stakeholders.
1.1.05	Transparency of Assessment Approach	A transparent assessment approach ensures that all assumptions, constraints, and conditions imposed on the assessment and made within the assessment, are communicated or documented to all stakeholders. Such documentation includes scenario development and handling of expert judgment; model development decisions and justifications; input parameter values; and approaches with respect to the treatment of subjective uncertainties.
1.1.06	Assessment Timeframe (Phases of Disposal)	Factors related to the timeframe over which the waste closure facility may present human health or environmental hazards and be considered for the performance assessment. Examples of time periods to consider include: from closure to the end of institutional control; and the timing of the peak impact.
1.1.07	Safety Effects Beyond Periods of Control	Consideration for the effects of waste releases beyond the periods of facility controls. The continued isolation of the contaminants should not depend on actions by future generations to maintain the integrity of the closure system. The assessment should consider impacts on the health of future generations with respect to the relevant levels of impact that are acceptable today.
1.1.08	Spatial Domain of Concern	Factors related to the spatial domain over which the contaminants and the waste closure facility may present significant human health or environmental hazard and that will be considered in the post-closure performance assessment. This includes consideration for the level discretization to apply to the spatial domain.
1.1.09	Assessment Endpoints	Concentration, flux, or health impact (risk/dose) criteria used to quantify the impact of the contaminants released from the waste closure facility. The endpoints may include: a) the concentration in disposed material, b) the contaminant flux from the waste closure facility, c) contaminant concentration in environmental media (e.g., soil, sediment, groundwater, surface water, fauna and flora, and the atmosphere), and d) risks to human health.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
1.2.01	Regulatory Compliance	Factors related to the compliance of regulatory requirements, conditions, and criteria associated with all stages of the development, operation, and closure of the facility with respect to influences on the post-closure performance assessment or the permitting and/or licensing of the closure facility. This includes consideration for Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.
1.2.02	Protection of Human Health and the Environment	Factors related to the regulatory requirements, criteria, and standards for the protection of human health and the environment during the lifetime of the waste closure facility and that would have an influence on the post-closure performance assessment and the assessment endpoints.
1.2.03	Performance Requirements and Criteria	Factors related to performance requirements and criteria to be considered in the development of waste closure facility and the associated performance assessment. Closure systems are designed to satisfy a number of requirements to ensure the long-term safety of the closure facility. Criteria specific to closure system design can be performance driven (derived from site and facility-specific models) or prescriptive (i.e. regulatory criteria that apply to an entire class of facility).
1.2.04	Functional and Technical Requirements and Criteria	Factors related to functional and technical requirements to be considered in the development of a safety case for the waste closure facility. Examples of such factors include: a) minimizing infiltration of water into disposal units, b) ensuring the integrity of disposal unit covers, c) providing the structural stability of system components, d) minimizing contact of waste with standing water, e) providing adequate drainage, minimizing the need for long-term maintenance, and f) providing barriers against intrusion.
1.2.05	ALARA	Factors related to "As Low As Reasonably Achievable" (ALARA) requirements and goals. This is a requirement to ensure risks are minimized with respect to the radiological detriment to members of the public that may result from the disposal of wastes.
1.2.06	Administrative Control of the Waste Closure Facility	Factors related to failure of administrative control measures and responsibilities for these measures during the pre-operational, operational, and post-closure (institutional control) periods. Measures applicable for the institutional control period can be divided into: active institutional control measures (such as monitoring, surveillance and remedial work) and passive institutional control measures (such as land use controls, site markers, and record keeping).
1.2.07	Waste Acceptance Requirements and Criteria	Factors related to defining waste acceptance requirements and criteria and ensuring that waste(s) accepted for disposal or closure meet specific requirements and criteria, such that the waste(s) is/are consistent with the operational and long-term safety cases for the waste closure facility.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
1.3.01	Model and Data Issues	Factors related to modeling of the disposal system. Model and data issues are general (i.e., methodological) issues affecting the modeling process and data usage. Model issues include: a) the approach and assumptions associated with the selection of conceptual models, b) the mathematical implementation of conceptual models, c) spatial and temporal discretization, d) models of coupled processes, and e) boundary and initial conditions. Data issues include the derivation of data values, correlations, and dependence of parameter selection on model scale.
1.3.02	Software Codes	Factors related to software selection and software quality assurance practices for codes important to the performance and safety of the waste closure facility as they apply to modeling, model validation, calibration, and benchmarking.
1.3.03	Model Approaches	Factors related to the modeling approaches applied in the performance assessment. Some examples include: a) simple scoping calculations that can be computed using a hand calculator or spreadsheet, b) worst case (or bounding) calculations that deal with uncertainty, and c) conceptual and mathematical models. This also includes consideration for deterministic modeling versus probabilistic modeling approaches.
1.3.04	Systematic Assessment Approach	Different systematic or structured approaches can be followed to perform performance assessments of waste closure facilities, all aimed at improving the confidence in the assessment results. Factors to be considered in a systematic approach include: a) the necessary level of appropriate documentation, b) rigor and technical justification for decisions and methods used, c) use of multiple lines of reasoning to broaden result sets, d) use of iterations, e) development of system understanding and expertise, and f) demonstration of performance.
1.3.05	Iterative Assessment Approach	Performance Assessments, by their nature, require an iterative approach, aiming at continual improvement of the safety case. This implies that a performance assessment process will have to go through two or more consecutive iterations. The advantage of such an approach is that it allows one to use information from the previous assessment to refine the design of the system and the collection of additional data.
1.3.06	Realistic Assessment Approach	A realistic, or equitable, approach applies assumptions with respect to physical reality (including what is possible and likely to occur). This approach is typically used when some knowledge of the actual system or conditions are available. The disadvantage of applying realistic assumptions in the assessment is that results might be underestimated. Therefore, it is necessary to document and justify the nature of each assumption in the assessment.
1.3.07	Conservative Assessment Approach	Using a conservative, or cautious, approach applies assumptions that will not result in the end-point(s) being underestimated. In applying this approach, there is a danger that aggregation of conservative assumptions, each of which may be appropriate in its own right, may result in an unrealistic estimate of potential impacts. Therefore, it is necessary to document and justify the nature of each assumption in the assessment.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
1.3.08	Reasonable Assurance Assessment Approach	The reasonable assurance approach emphasizes that performance assessments are not exact reflections of reality. As such, the goal of a performance assessment is to determine the conditions for which reasonable assurance of regulatory compliance can be achieved. This approach is a more of a decision tool, rather than a method to predict the actual behavior of a disposal system into the future. The results are a function of the data, design, and assumptions used in the analysis.
1.3.09	Prospective Evaluation Assessment Approach	A prospective evaluation approach emphasizes that the intent of the performance assessment is not to predict actual system behavior but to improve system understanding such that appropriate emphasis may be directed towards specific system components (i.e., those with the greatest potential impact on regulatory compliance).
1.3.10	Uncertainties	Factors related to the identification and treatment of model/future uncertainties in the performance assessment. Such factors include: a) conceptual model uncertainty, b) mathematical model uncertainty, c) computer model uncertainty d) parameter/data uncertainty, and e) subjective uncertainties.
1.3.11	Sensitivity Analyses	Factors related to the performance of sensitivity analyses of the post-closure performance assessment. Sensitivity analyses help to establish a comprehensive and defensible safety case and provide insights into system behavior that may lead to design improvements.
1.3.12	Model Confidence	Factors related to activities that build confidence in the performance assessment modeling. Activities include verification of performance, calibration of performance, and validation of performance.
1.3.13	Alternative Simplified Modeling Approach	Supplement the sophisticated model with a less complex model for explanatory purposes and as a confidence-building tool. A well-designed simplified model may help foster public understanding and acceptance of the waste closure facility. While simplification may cause loss of detail, demonstration of equivalence of simple and complex methods may be possible if it can be shown that the simplifications focus on the critical factors related to system performance and safety.
1.3.14	Evaluate Multiple Endpoints	The use of multiple lines of reasoning and the calculation of multiple endpoints helps ensure that the varied interests of stakeholders are addressed and understood. Demonstration of the performance of individual system components and their expected time evolution increases confidence in the performance of the whole system. Presentation of a number of safety indicators over a range of timeframes allows stakeholders to focus attention on indicators and timeframes of the greatest interest.
1.3.15	Processing Limitations to Modeling	Factors related to the processing (computing) limitations to running the performance assessment models.
1.4.01	Development of Expertise	Develop expertise and understanding of the performance assessment process and determination of related strategic issues.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
1.4.02	Monitoring and Surveillance	Factors related to the monitoring and surveillance that is carried out during operations or following closure of individual disposal units or total the waste closure facility. This includes monitoring and surveillance for operational safety and parameters related to long-term safety and performance. Regulations, confidence building activities, or public pressure may determine the extent and requirement for such a monitoring and surveillance program.
1.4.03	Retrievability	Factors related to any design, emplacement, operational or administrative measures that might be applied or considered in order to enable or ease retrieval of radioactive wastes from the waste closure facility. An interim period might be planned between waste emplacement and final tank farm closure, during which time retrieval is possible.
1.4.04	Regulatory and Peer Reviews	A requirement that the performance assessment should be subject to a rigorous regulatory and peer review processes as part of developing a comprehensive and defensible safety case for a waste closure facility. Reviewers should be satisfied that good engineering practices are used in design, construction, operation, and closure of the facility and that good science has been applied in investigating and researching the site and related FEPS, and in evaluating and interpreting the resulting data and methodologies used.
1.4.05	Confidence Building (External to Modeling)	Activities, other than modeling, to address the concerns of stakeholders. Such as validation and analogue studies, as well as public hearings to maintain an open dialogue.
1.4.06	Target Audience (Stakeholders Involvement)	Factors related to the definition of the target audience and their involvement in the post-closure safety assessment process of the waste closure facility.
2.1.01	Definition of the Exposed Member of the Public	Factors related to the determination of the "Member of the Public" (MOP), the representative and reasonably or conservatively exposed individual for whom doses and results shall be evaluated. Defining the MOP shall consider regulatory stipulations, conservatisms, and group homogeneity (in terms of diet and habits, location).
2.1.02	Human Physiology (Metabolism, Diet, and Fluid Intake)	Factors related to intake human consumption and ingestion. Human diets can vary greatly, both qualitatively and quantitatively. In addition to food and fluid intake, humans may also consume other things such as medicines, drugs, soils, and minerals. Consideration could also be given to vegetarian and other special diets, and to changes in diet due to external factors.
2.1.03	Human Behavior and Habits (Non-Diet Related)	Factors related to non-diet related behavior and habits of humans to whom exposures from the waste closure facility are calculated. These factors include time spent in various environments, activities, and uses of materials and may be influenced by agricultural practices, technology, and societal factors (e.g., culture, religion, economics). Examples include: a) outdoor activities (e.g., fishing, logging, swimming, etc.), b) keeping of pets that could become contaminated, and c) agricultural practices (e.g., plowing, cultivation, harvesting, etc.).

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.1.04	Human Dwellings	The characteristics of the houses or other structures or shelters in which humans spend time. The dwelling location, materials used in construction, design elements (e.g., for improved energy efficiency and air tightness), dwelling size, heating sources, the likelihood of infiltration of water or gases, and the introduction of other contaminants into the dwelling may all affect human exposure to contaminants.
2.1.05	Demographics and Community	Factors related to demographic features and assumed urban development in the vicinity of the waste closure facility. In addition to population density and location, consideration should be given to the types of communities: hunter-gatherer/nomadic communities; agricultural communities; self-sufficient rural communities; other rural communities; and urban communities. Changes in any of these conditions may influence the performance of the facility.
2.2.01	Natural and Geological Resources and Land Use	Factors related to natural resources and land use, particularly those that might encourage investigation or excavation at or near the waste closure facility. Examples of natural resources include: water, lumber, oil and gas (such as methane), minerals, and geothermal energy. Examples of land use include: reclamation/extension, logging, agricultural activity, urbanization, and waste disposal.
2.2.02	Water Management	Factors related to groundwater and surface water management. Water management is accomplished through a combination of dams, reservoirs, canals, pipelines, and collection and storage facilities. Water management activities could have a major influence on the behavior and transport of contaminants.
2.2.03	Natural/Semi-Natural Land and Water Use	The use of natural or semi-natural tracts of land and water such as forest, bush and lakes. Uses include the gathering of special foodstuffs and resources (e.g., picking wild blueberries and gathering of peat and wood for household heating).
2.2.04	Rural and Agricultural Land and Water Use	The use of land and water for agriculture, fisheries, game ranching and similar practices. Practices include: a) fish hatcheries and fish farming, b) ranching of indigenous and imported animals, c) draining of wetlands for farming use, d) gardening, e) irrigation, f) plowing, g) other farming practices such as greenhouses or hydroponics, fertilization, and the use of herbicides, pesticides, fungicides and related products, h) recycling and composting, i) crop storage, and j) outdoor spraying of water to cool buildings and control dust. Consideration for the duration of land use may need to be considered.
2.2.05	Urban and Industrial Land and Water Use	The use of land and water for urban or industrial purposes. Water has a variety of industrial uses: mining, the pulp and paper industry, food preparation, and electricity generation. Establishment of large water-use systems could influence the behavior and transport of contaminants in the environment and introduce remote sources of contaminants to a large community (such as the concentration of effluent sewage at a single point of discharge). Additionally, produce from hobby gardens in urban areas might be more contaminated than agricultural crops because the amateur gardener might over-irrigate.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.2.06	Leisure and Other Uses of the Environment	Leisure activities, their effects on the surface environment, and implications for contaminant exposure pathways. Examples include: a) swimming and boating, b) hiking, c) camping, d) skiing, and e) sports activities. Many of these activities might influence which exposure pathways have significant impacts.
2.3.01	Future Human Actions (Active)	Factors related to human actions and regional practices associated with the post-closure period (future), which may affect the performance of the natural (geological) and/or engineered barriers, and consequently the waste closure facility.
2.3.02	Future Knowledge of the Facility	Factors related to the degree of knowledge of the existence, location and/or nature of the waste closure facility, including the retention of related records and the construction of markers to inform future humans of the location and contents of the facility. The loss of such records and markers may increase the likelihood of inadvertent intrusion.
2.3.03	Social and Institutional Developments	Factors related to changes in future social patterns and degree of local government, planning and regulation. Specific factors include: a) changes in planning controls and environmental legislation, b) demographic change and urban development, c) changes in land use, and d) loss of records or societal memory of the waste closure facility location and hazards.
2.3.04	Technological Developments	Factors related to future developments in human technology and changes in the capacity and motivation to implement technologies (i.e., research and development). Technological developments may affect the long-term performance of the waste closure facility. These include changes in the ability of humans to intrude the site, and changes that might affect contaminant exposure and its health implications. For example: Scientific and technological advances may lead to a total cure for cancer, thereby reducing the risks from radiation exposure.
2.3.05	No Technological Development	The conservative assumption that technological development will not occur, on the basis of uncertainty as to what types of developments may or may not occur. In these cases it is assumed that the past and present technological developments are a sufficient indication for future developments.
2.3.06	Retrograde Developments	The conservative assumption that technological capacities may be lost due to degradation of society or failure to pass on generational expertise.
2.4.01	Biomes	Factors related to the characteristics of biomes found on earth, and their evolution. A biome is a mixed community of plants and animals (a biotic community) occupying a major geographical area on a continental scale. Usually applied to terrestrial environments, each biome is characterized by similarity of structure or physiology rather than by species composition. Within a particular biome, plants and animals are regarded as being well adapted to each other and to broadly similar environmental conditions, especially climate. Important factors influencing biomes (excluding human activity) include temperature, precipitation, latitude, and altitude.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.4.02	Microbial Activity	Microbes exist naturally in soils and groundwater. Other microbes may be introduced on construction materials and in the air during excavation, operation and closure procedures. These microbes may affect chemical conditions and can affect the rates of some reactions. They may also directly affect contaminant transport by acting as organic colloids or by affecting redox potential and pH.
2.4.03	Vegetation	Factors related to the characteristics of terrestrial and aquatic vegetation both as individual plants and in mass, and their evolution.
2.4.04	Animal Populations	Factors related to the characteristics of the terrestrial and aquatic animals both as individual animals and as populations, and their evolution.
2.5.01	Geological Environment and Processes	Factors related to features and processes of the geological environment surrounding the waste closure facility.
2.5.02	Topography and Landforms	Factors related to the topography and surface morphology (relief and shape of the surface) of the waste closure facility region and its evolution over time. Topographical features include outcrops and hills, water-filled depressions, wetlands, recharge areas and discharge areas. Topography, precipitation, and surficial permeability distribution in the system will determine the flow boundary conditions (i.e., location and amount of recharge and discharge in the system).
2.5.03	Depositional Environments and Landforms	Factors related to landforms formed from the deposition of weathered and eroded surface materials. On occasion, these deposits can be compressed and/or altered by pressure, heat and chemical processes to become sedimentary rocks. This includes landforms with some of the following geomorphic features: beaches, deltas, flood plains, and glacial moraines.
2.5.04	Stratigraphy and Host Lithology	Factors related to the properties and evolution of the local stratigraphy and lithology. Stratigraphy is the succession of geological formations and rock structures and types that make up the region. The various units may help isolate the waste and influence where surface water infiltrates and where ground-waters eventually discharge. Lithology describes the relevant properties of the geological units, including: thermal and hydraulic conductivity, compressive and shear strength, porosity, tortuosity, thickness, etc. The inhomogeneity and uncertainty of these properties is also part of their characterization. These properties could change with time and temperature.
2.5.05	Geologic Discontinuities and Boundary Conditions (Fractures, Faults, and Cracks)	Factors related to the properties and characteristics of large scale discontinuities in the geosphere, such as faults, fractures, dykes, and folds. These geological discontinuities often form the boundaries of an aquifer.
2.5.06	Near-Surface Aquifers and Water-Bearing Features	Factors related to the characteristics and formation of aquifers and water-bearing features within a few meters of the land surface and their evolution. Aquifers are formed by the gathering of water between alternating layering of permeable and impermeable rock on a local or regional scale.
2.5.07	Unconsolidated Soft Zones	The presence of soft zones (e.g., the calcareous zone in the Santee Formation of the SRS) may influence stability of the waste closure facility and have an effect on flow.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.5.08	Undetected Geologic Features	Natural or man-made features that are not detected during site investigation, or even during excavation, construction, or operation. Examples of possible features are a) faults, b) fracture zones, c) induced fractures caused by excavation, and d) other discontinuities. These features could play a significant role in the transport of groundwater to and from the waste closure facility.
2.5.10	Soils and Sediment	The soils and sediments that overlie the rock of the geosphere, including their evolution in time. Soil type is determined by many different factors (e.g., formative process, geology, climate, vegetation, land use). The physical and chemical attributes of the surficial soils (such as organic matter content and pH) may influence the mobility of radionuclides. Feature includes overburden and aquatic and marine sediments.
2.5.11	Hydraulic Properties	Properties of the host rock and other rock units that affect the migration of fluids, including a) hydraulic conductivity in the context of flow through a porous medium, b) the presence of open fractures, c) capillary suction, and d) the gas-entry pressure. Changes of hydraulic properties due to changes in rock stress or fault movements.
2.6.01	Mechanical Effects on Geologic Features	Factors related to the mechanical processes and conditions that affect the geosphere and the overall evolution of conditions of the natural system with time. This includes the effects of changes due to the seismicity, excavation, and the long-term presence of the closure system.
2.6.02	Tectonic Activity and Processes	Factors related to tectonic movement at plate boundaries, the potential for tectonic movement, and its effects on the performance of the waste closure facility. Large-scale tectonic activity, such as regional uplift, subsidence, folding, mountain building, or other processes related to plate movements, could affect performance by altering the physical and thermohydrologic properties of the geosphere.
2.6.04	Deformation and Metamorphism	Factors related to the physical deformation (elastic, plastic, or brittle) or metamorphism of geological structures in response to geological forces such as tectonic movement and orogeny or in response to stress fields generated either at plate margins or in regions of anomalous stress. This includes a) faulting, b) fracturing, c) extrusion and, d) compression and folding of rocks. A fault is a large-scale discontinuity or fracture in the Earth's crust accompanied by displacement of one side of the fracture relative to the other. Fractures may be caused by compressional or tensional forces in the Earth's crust.
2.6.07	Deposition	Deposition is the geological process by which material is added to a landform or land mass. The process may change topography and thus affects local and regional hydrology. Deposition of surficial materials can occur by a variety of means, including fluvial, eolian, and lacustrine deposition and redistribution of soil through weathering and mass wasting processes.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.6.08	Erosion and Weathering	Erosion and weathering are processes which lead to the denudation of the land surface and a reduction in topography. Erosion and weathering may cause changes to the present day topography through denudation and are thus capable of affecting both local and regional hydrology. Weathering refers to physical and chemical processes that alter and degrade rocks and soil at and near the land surface. Erosion involves the transport of surficial material away from the site by various mechanisms including glacial, fluvial, eolian (involving wind), and chemical processes. Surficial materials, including weathering products, are also subject to gravity, and erosion can take place by mass wastage processes (e.g., landslides). The extent of denudation depends to a large extent on climate and the rate of local uplift.
2.6.09	Mass Wasting	Mass wasting is the geomorphic process by which materials move downslope under the force of gravity. Types of mass wasting include creep, slides, flow, topples, and falls, each with its own characteristic features, and taking place over timescales from seconds to years. Mass wasting occurs on both terrestrial and submarine slopes, and the largest and most disastrous mass wasting events may be related to some extraordinary activity or occurrences, including: a) earthquakes, b) slope modification (e.g., human activity), c) undercutting (typically along stream banks or by surf action along the coast), d) exceptional precipitation, and e) volcanic eruptions.
2.6.12	Hydrogeological Processes and Conditions	Factors related to the hydraulic and hydrogeological processes that affect the geosphere and the overall evolution of conditions due to the excavation, construction, and long-term presence of the closure facility. During hydrogeological investigations, efforts should describe the existing and projected water uses; location, extent and interrelationship of the important hydrogeological units in the region; recharge and discharge of the major hydrogeological units; regional and local water tables and their gradients and seasonal fluctuations; an estimate of groundwater flow velocities and direction; radionuclides travel times along most likely flow paths from the closure facility to the biosphere.
2.7.01	Atmosphere	The transport of radionuclides and chemical contaminants in the atmosphere as gas, vapor, or suspended fine particulate or aerosol. Contaminants may enter the atmosphere as a result of water evaporation, degassing from soils or water, transpiration from plants, suspension due to wind erosion, plowing, or fires. The atmosphere may provide a significant mechanism to transport, dilute, or remove these contaminants by advection and dispersion. This category provides for specific human and animal exposure pathways.
2.7.02	Climate and Weather	The characteristics of climate and weather including precipitation, temperature, pressure, and wind speed and direction, and their evolution. Climate and weather may have a major influence on transport of contaminants in the environment through recharging of surface-water bodies and leaching of soils, and affect human behavior of irrigation requirements for agricultural crops and the source of drinking water. The variability in the climate and weather (such as drought, flooding, storms, and duration of snow melt and their potential effects) can influence erosion, the accumulation and release of contaminants, and potential human exposure.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.7.03	Precipitation	Precipitation depends on climate and is an important control on the amount of runoff and infiltration, flow in the unsaturated zone, and groundwater recharge. It transports solutes with it as it flows downward through the subsurface or escapes as runoff. Precipitation influences agricultural practices of the receptor.
2.7.05	Warm Weather Effects	Factors related to warm tropical and desert climates and their effect on the performance of the waste closure facility. For example, warm weather may increase evapotranspiration thus reducing infiltration and eventual transport.
2.7.06	Cold Weather Effects	Factors related to cold weather effects (i.e., physical processes) and associated landforms. Permafrost and seasonal freeze/thaw cycles are characteristic of periglacial environments that may impact erosional processes. This FEP includes the effects of glaciers and ice sheets within the region of the waste closure facility. For example, frost heaving pushes the ground surface up and causes a downslope movement of rocks. Gelifluction occurs when the thawed layer becomes saturated with melt water and slowly moves downslope forming distinctive lobes and sheets of debris. Rock glaciers form as a tongue or lobe of ice-cemented rock debris that moves slowly downslope in a manner similar to glaciers.
2.7.07	Climate Change	Climate change includes the effects of long-term change in global climate (e.g., glacial/interglacial cycles) and shorter-term change in regional and local climate. Climate is typically characterized by temporal variations in precipitation and temperature and may affect the long-term performance of the waste closure facility. This includes the effects of greenhouse gases and potential for global warming.
2.7.08	Solar Radiation	Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis, which provides the energy for plant growth and metabolism, and the organic food for other forms of life.
2.8.01	Water	The characteristics of water, and its evolution. Water is the medium by which mineral nutrients enter and are translocated in plants and is required for photosynthetic chemical reactions. The original source of this water is precipitation from the atmosphere and plants and animals receive their water from the Earth's surface and soil.
2.8.02	Surface-Water Bodies	The characteristics of surface-water bodies such as rivers, lakes, wetlands and springs, and their evolution in time. These water bodies can indicate watershed boundaries and act as recharge zones for groundwater and, as such, can influence groundwater chemistry and contaminant transport. Contaminant transport and mixing can occur within the surface water bodies (such as dilution, sedimentation, aeration, stream flow, and river meander).
2.8.03	Evapotranspiration	Evapotranspiration removes water from soil and rock by evaporation and transpiration via plant root water uptake. Surface water runoff and evapotranspiration are components in the water balance, together with precipitation, infiltration, and change in soil water storage.
2.8.04	Surface Runoff	Surface runoff produces erosion, and can feed washes, arroyos, and impoundments, where flooding may lead to increased recharge. Surface water runoff and evapotranspiration are components in the water balance, together with precipitation, infiltration, and change in soil water storage.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
2.8.05	Capillary Rise	Capillary rise, or wicking, involves the drawing up of water, above the water table or above locally saturated zones through continuous pores, due to a net upward force produced by the attraction of the water molecules to a solid surface until the suction gradient is balanced by the gravitational pull downward.
2.8.06	Infiltration and Recharge	Infiltration into the subsurface provides a boundary condition for groundwater flow in the unsaturated zone. The amount and location of the infiltration influences the amount of seepage through the closure cap, and the amount and location of recharge influences the height of the water table, the hydraulic gradient, and the specific discharge. Mixing of these waters could result in mineral precipitation, dissolution, and altered chemical gradients in the subsurface.
2.8.07	Discharge Zones Within the Assessment Domain	Locations (within the assessment domain) where the water table intersects the surface allow ground waters to flow out onto the surface as springs, seepage lines, streams, wetlands or lakes. Discharge zones are often low-lying areas such as at the margin or bottoms of lakes and wetlands. Springs may also be found at various elevations depending on factors such as the lithology and stratigraphy of the geosphere and the location of outcropping geological units.
2.8.08	Discharge Zones Outside the Assessment Domain	Some contaminants could be released and discharged to the surface environment at locations beyond the assessment domain (or the reference biosphere). Radionuclides transported in groundwater as solutes or solid materials (colloids) from the far-field may discharge at specific "outcrops" that are outside the reference biosphere.
2.8.09	Hydrological Regime and Water Balance (Near-Surface)	Factors related to near-surface hydrology at a catchment scale and also soil water balance, runoff, the flushing rate of surface-water bodies, and their evolution. Extremes such as drought, flooding, storms and snow melt may be relevant. Changes to the hydrological regime could also induce changes in the behavior of the critical group.
3.1.01	Site Characterization and Investigations	Factors related to site characterization. Such factors include: a) determining which site investigations are needed (both prior and during construction and operation), b) evaluations of related assessments, c) defining the level of detail required (to support both a general understanding of the site, its past evolution, and likely future natural evolution over a period of time), and d) a specific understanding of the impact on safety of associated FEPs. These activities establish baseline conditions and data.
3.1.02	Site Development	Factors related to any type of human activities during site development that can potentially affect the performance of the waste closure facility or the exposure pathways after closure. Examples of site development include the following: construction of roads, residential buildings (urban), or industries. This includes earthmoving works such as leveling of the site, modifications of natural site drainage, and construction of dams).

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.1.03	Facility Factors	Factors related to decisions taken and events occurring during the life cycle of the waste closure facility that may influence the performance of the facility. These include those features, events, and processes occurring during pre-operational, operational, and post-closure periods of the waste closure facility whose principal effect is to determine the evolution of the physical, chemical, biological, and human conditions of the waste closure facility with the purpose to estimate the release and migration of contaminants and the consequent exposure to human beings and the environment.
3.1.04	Multi-Barrier Safety Function	Consideration for applying a multi-barrier closure system (using both natural and engineered barriers) that is designed to ensure long-term safety by means of multiple safety functions.
3.2.01	Design Basis for Engineered Components	Factors related to the design of the waste closure facility and facility components (and associated design documentation) and the ways in which the design contributes to long-term performance. The performance assessment must account for design features, material characteristics, design influences on the environment, and assumptions regarding the design of the waste closure facility (i.e., the safety concept and the engineering specifications for excavation, construction, operation and closure). Design should ensure that the functional requirements and criteria are met.
3.2.02	Schedule and Planning	A detailed description of the major activities associated with the construction, the operation, the closure of the waste closure facility, and the schedule and resources required for that purpose. Relevant events may include monitoring activities to provide data on the transient behavior of the system or to provide input to the final assessment. The sequence of events and time between events may have implications for long-term performance.
3.2.03	Procurement of Items and Services	Factors related to quality assurance that will be applied during the procurement of items and services important to the safety of the waste closure facility.
3.2.05	Construction	Factors related to the excavation, stabilization, and the installation and assembly of structural elements according to the assessed design and approved schedule and planning. The major tasks of construction of waste closure facility include: a) excavation, testing, and preparation of soil material, b) placement of monitoring systems, c) placement of engineered barrier systems, d) installation of drainage control features, e) revegetation, and f) quality control.
3.2.06	Operation	Factors related to the operation (waste emplacement, backfilling, monitoring and surveillance, remedial activities) of the waste closure facility, according to the approved schedule and planning for the facility.
3.2.07	Removal or Stabilization of Waste	Factors related to the waste storage, removal, and stabilization of waste tanks and disposal units at the waste closure facility. Distinction can be made between qualitative and quantitative requirements for the removal and stabilization of radioactive waste from waste tanks at the waste closure facility.
3.2.08	Disposal Unit and/or Facility Closure	Factors related to the end of waste disposal operations and the closure of individual waste tanks. These closure activities are undertaken mainly to prevent human access into and limit the migration of contaminants from the individual waste tanks. This includes planning, preparation, decommissioning of components, and confirmation activities.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.3.01	Closure System Features and Materials	Features related to the closure operations of the waste closure facility and the materials used for that purpose, according to the approved schedule and planning for the facility. A wide variety of materials can be used in combination to provide the overall system with the required properties to prevent human access into and limit the migration of contaminants from the waste closure facility.
3.3.02	Manufacturing and Commissioning of Components	Factors related to the commissioning and manufacturing of components and subcomponents activities important to the safety of a waste closure facility (such as the possibility and impacts of manufacturing defects).
3.3.03	Consolidation of System Components	Factors related to the consolidation of engineered barrier system components. Such consolidation may affect the development of the chemical environment and, therefore, the radionuclide transport out of the closure system.
3.3.04	Waste Tank, Container, or Package Characteristics	**Physical characteristics** of the container include: a) dimensions and geometry, b) permeability and porosity, c) density, d) void space, e) surface finish and level of cleanliness, and f) external or internal coatings or linings. **Chemical characteristics** of the container include: a) chemical composition of container, b) chemical stability and confinement in the near-field, c) reactivity, and d) gas generation. **Mechanical characteristics** of the container include: a) tensile and compressive strengths, b) abrasion resistance, and c) ductility. Considers materials that may have been used, such as: a) carbon steel, b) stainless steel, c) polymers and polymer impregnated concrete, d) asbestos cement, e) reinforced concrete, f) cast steel, g) modular cast iron, h) spheroidal graphite cast iron, i) polyethylene, j) lead, k) titanium, l) ceramics, m) stainless steel, and n) High Density Polyethylene (HDPE). Considers function (the role of the waste container) and repackaging capabilities.
3.3.05	Closure System Buffer (Closure Cap, Backfill, and Near-Field Soil) Properties	The backfill and other soil mineralogy will affect the buffering of geochemical conditions in response to perturbation by the cementitious materials and residual wastes, and provide a substrate for sorption of contaminants. Used to inform the selection of distribution coefficients that describe contaminant mobility. Mineralogical dehydration reactions release water affecting hydrologic conditions. Dehydration of zeolites may lead to large-scale volume changes affecting flow and/or waste tank stability. The likelihood of geothermal fluids might cause changes in mineralogical composition.
3.3.06	Bentonite and Vermiculite Effects	Bentonite/Vermiculite layers provide a barrier to groundwater flow and act as a mechanical barrier to protect the waste tank. The material will degrade over time by physical and chemical processes and thus its barrier functions will diminish. This will have an impact on radionuclide release processes and rate. For example, in a ground or pore water containing suspended bentonite/vermiculite clay particles, there is sometimes a tendency for the bentonite/vermiculite clay particles to coagulate and form larger aggregates, and may settle to form clay-rich sediment. This process is promoted by an increase in the salinity of the solution.
3.3.07	Closure Cap Thickness and Material Properties	The vertical distance between the top of the closure cap and the top of the waste closure facility.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.3.08	Disposal Unit and/or Facility Wall and Roof Thicknesses	The thicknesses of the walls and roof of the disposal unit or closure facility.
3.3.09	Disposal Unit or Facility Floor Thickness	The thickness of the floor of the disposal unit or closure facility.
3.3.10	Ancillary Equipment and Piping/Transfer Lines	Factors related to ancillary equipment and transfer lines (including evaporators, mixers, robotics, cooling coils, etc.) and their effects on other system components and processes.
3.4.01	Hydrological Processes and Conditions	The hydrological and hydrogeological processes (including coupled effects) that affect the wastes, tanks, and other engineered features, and the overall hydrological evolution of the closure system with time.
3.4.02	Hydrostatic Pressure on the Closure System	Waste and system components within the saturated zone will be subjected to hydrostatic pressure (or suction head) in addition to stresses associated with the evolution of the waste and cementitious materials.
3.4.03	Condensation on Closure System Surfaces	Condensation of water on engineered system components may affect the hydrologic and chemical environment. Emplacement of waste can create thermal gradients that can lead to cold traps (locations characterized by transferal of latent heat). This can create condensation, leading to enhanced moisture at the site of engineered system components. Waste emplacement geometry and thermal loading may affect the scale at which condensation occurs.
3.4.04	Resaturation and Desaturation	After closure, groundwater may flow from the near-field into the engineered system and from far-field materials into near-field materials causing these environments to hydraulically saturate or resaturate. Groundwater may cause materials to expand, resulting in a general homogenization of physical and chemical characteristics. This resaturation will impact thermal, hydraulic, mechanical, and chemical properties. For example, metals may corrode and temperatures may cool.
3.5.01	Chemical/Geochemical Processes and Conditions	The chemical and longer-term geochemical processes that affect the system and the overall chemical evolution over time. This includes the effects of chemical and geochemical influences on and degradation of a) wastes, b) containers and engineered components, c) backfill, and d) host material by groundwater entering from the surrounding geology. Properties that may be affected include permeability and sorption.
3.5.02	Evolving Water Chemistry in the Engineered System and Waste Form	Factors related to the chemical properties of water in the engineered system components and the waste form. Chemistry of water flowing into the engineered system components and the waste form is affected by initial water chemistry in the rock, mineral and gas composition in the rock, and thermal-hydrological-chemical processes in the rock. Chemical effects on the engineered system components and the waste form (e.g., dissolution) may be enhanced or altered in a system where metals, waste, rock minerals, and water are all in physical contact with one another. This water will react with the various metals and cementitious materials (e.g., grout) causing considerable changes to the chemistry of the intruding water. When radionuclides are released, this will result in further changes to the water chemistry.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.5.03	Evolving Water Chemistry in the Near-Field	Factors related to the chemical properties of water in the backfill and near-field environment. The water chemistry in the near-field materials is controlled by the composition of the ambient natural groundwater and the composition of waters leaving the engineered system. The water chemistry in the near-field controls transport and retardation processes related to contaminants released from the engineered system.
3.5.04	Evolving Water Chemistry in the Far-Field	Factors related to the chemical properties of water in the backfill and far-field environment. The initial chemistry of the far-field environment reflects the natural, present-day system. This far-field groundwater chemistry is controlled largely by rock- and soil-water interactions and by mixing with waters from the near-field and from the surface. However, perturbations can occur due to climate change which can cause infiltration of sea-water or glacial melt waters.
3.5.05	pH Conditions	The pH conditions in water owing to interactions between the water and the cementitious materials. pH (along with Eh and chloride and sulphate conditions) is an important determinant in the chemical behavior, which in turn affects the release and transport of contaminants in groundwater and gas.
3.5.06	Eh Conditions	The Eh conditions in water owing to interactions between the water and the cementitious materials. Eh (along with pH and chloride and sulphate conditions) is an important determinant in the chemical behavior of any waste closure facility, which in turn affects the release and transport of contaminants in groundwater and gas. An oxygen-deficient environment (anaerobic) promotes the formation of lower, and often less soluble, oxidation states of radioelements, promotes relatively slow corrosion and microbial processes, and minimizes the rate of gas generation.
3.5.07	Colloid Generation	Colloids may be generated by chemical, physical, and microbiological processes. Contaminants can sorb onto these colloids which may affect their subsequent transport through the system.
3.5.08	Chemical Effects of Waste-Rock Contact	Waste and rock may be placed in direct contact by mechanical failure of the waste packages. Chemical effects on the waste (e.g., dissolution) may be enhanced or altered in a system where waste, rock minerals, and water are all in physical contact with one another, relative to a system where only waste and water are in physical contact.
3.5.09	Rind (Chemically Altered Zone) Forms in the Near-Field	Thermal-chemical processes involving precipitation, condensation, and re-dissolution could alter the properties of the adjacent materials. These alterations may form a rind, or altered zone with hydrological, thermal, and mineralogical properties different from the initial conditions.
3.5.10	Complexation in the Natural System	Effects on the physical and chemical environment due to complexing agents such as carbonate, fluoride, and humic and fulvic acids present in natural ground waters could affect radionuclide transport in the natural system.
3.5.11	Reaction Kinetics	Chemical reactions, such as radionuclide dissolution/precipitation reactions and reactions controlling the reduction-oxidation state, may not be at equilibrium within the closure system.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.5.13	Osmotic Effects	Osmosis is the flow of water through a semi-permeable membrane so that the molecular concentration solutions on either side of the membrane become equal. Water deposited on the surface of concrete (by condensation or through incoming groundwater) and the pore water would eventually have the same ionic compositions, with osmosis playing a role in achieving this if the pore structure of the concrete acted like a semi-permeable membrane.
3.5.14	Leaching	Leaching is the removal by water of minerals from the solid materials (i.e., concrete, bentonite and asphalt) that could affect waste closure facility performance.
3.6.03	Thermo-Chemical Alteration, Near-Field	Thermal effects may influence chemical alterations and radionuclide transport directly (such as radionuclide speciation and solubility in the natural system) or indirectly (such as changes in the mineralogy along the flow path). Relevant processes include: a) volume effects associated with silica phase changes, b) precipitation and dissolution of fracture-filling minerals (such as silica and calcite), and c) alteration of zeolites and other minerals to clays.
3.6.07	Temperature and Thermal Gradient Effects on the Geosphere	Factors related to the thermal processes that affect the geosphere and the overall evolution of conditions with time due to the long-term presence of the closure facility. The variety of materials in the near-field barriers will have different thermal expansion coefficients. Thus, if the temperature of the near-field changes, the barriers may expand or contract at different rates, causing changes to the stresses acting on them, and may cause minor physical effects on some barriers. The temperature of the far-field is largely controlled by the natural geothermal gradient, although it may be influenced by changing climate at the surface. The temperature in the far-field will be a control on the rates of chemical and microbiological processes, and can influence the stress field, groundwater flow, diffusion rates, and radionuclide transport.
3.7.01	Chemical Degradation of Engineered System Metals	Degradation of the metal materials used in the engineered system may occur by chemical or microbial processes, and may affect long-term system performance.
3.7.02	Corrosion	The corrosive effect of water on metals in the engineered barrier system. Corrosion includes generalized, localized, and galvanic processes. This also includes chemical interactions related to corrosion products and processes related to corrosion enhanced by microbial influences and radiolysis.
3.7.03	Stress-Corrosion Cracking and Hydride Cracking of Engineered System Metals	Stress-corrosion cracking, or hydride embrittlement and cracking, may mechanically weaken the container and promote subsequent failure or other corrosion mechanisms. The process might be accelerated if hydrogen is attracted to and accumulates at a defect or crack site, forming metal hydrides that promote degradation.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.7.06	Waste Container, Package, or Over-Pack Failure	The outer shell of the waste canister provides long lifetimes because of the very slow corrosion rate in the waste closure facility environment. However, corrosion will eventually cause the canister to fail, although early failure could be caused by manufacturing defects, mechanical impacts or creep. The mechanical strength of the waste canister is largely provided by the type of metal alloy and a reduction of the mechanical strength can occur due to a number of physical and chemical processes. The effect will be to limit the canister’s resistance to failure by mechanical impact. Waste packages may fail prematurely because of manufacturing defects, improper sealing, or other factors related to quality control during manufacture and emplacement.
3.7.07	Degradation of Non-Metal Solids: Backfill, Rock, Grout, Cement, etc.	Factors related to the degradation of non-metal solids within the engineered closure system (e.g., backfill, rock, grout, cementitious materials, etc.). These will be affected by physical and chemical degradation processes. These processes will affect the pore water chemistry, the solubility and sorption of radionuclides, and the mechanical stability of the waste tanks. Degradation of backfill by flowing groundwater, either by erosion of particulate matter or by dissolution, may occur by a combination of physical and chemical processes, and their degradation may impact on other parts of the closure system.
3.7.08	Swelling of Backfill and Emplacement Materials	The backfill may be a mixture of partially dried bentonite and an inert filler material. The bentonite or vermiculite will take-up water during the resaturation phase and swell as the clay minerals adsorb water into their lattice structure. Swelling of the bentonite will affect properties which are important for water and gas transport through the backfill and for radionuclide transport and release.
3.7.09	Concrete Shrinkage/Expansion	Concrete shows volume changes during the curing phase and during aging which can impact the integrity and hydraulic properties of the material.
3.7.10	Sulfate and Chloride Attack	Sulfate attack and chloride attack: The chloride and sulphate conditions and chemical processes owing to interactions between the water and the cementitious materials and engineered features. Chloride and sulphate concentrations, along with pH and Eh, are important in affecting the chemical behavior of any cementitious material, which in turn affects the release and transport of contaminants in groundwater and gas. The presence of organic complexants could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Chemical complexing agents include inorganic ions such as the chloride, fluoride and sulphate anions, and organic-based species such as humic and fulvic acids which occur naturally in soils and in the geosphere.
3.7.11	Carbonation	The carbonate conditions and chemical processes owing to interactions between the water and the cementitious materials and engineered features. Carbonate and carbon dioxide concentrations, along with pH and Eh, are important in affecting the chemical behavior of any cementitious material, which in turn affects the release and transport of contaminants in groundwater and gas.
3.7.12	Polymer Degradation	The chemical effect of water in the waste closure facility on polymeric materials.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.8.01	Alternatives to Pre-Closure Activities	Factors related to alternative waste closure facility design, construction, operation, and closure conditions rather than those in the approved schedule and planning. Included are the poor design, construction, operation, and closure conditions and the effects on long-term safety and performance.
3.8.02	Incomplete Closure	Factors related to incomplete filling, construction, and/or closure (premature abandonment) of the waste closure facility.
3.8.03	Error in Waste Removal and Stabilization	Deviations from the design and/or errors in waste removal and stabilization that could affect long-term performance of the waste closure facility.
3.8.04	Inadequate Quality Assurance/Control and Deviations from Design	Quality assurance and control procedures and tests during the design, construction, operation, and closure of the waste closure facility. Factors related to the failure or poor implementation of quality assurance and quality control procedures during the life cycle of the waste closure facility.
3.8.05	Remedial Actions	Factors related to actions taken to remediate problems or issues related to the performance of the waste closure facility. This FEP addresses the concern that remedial actions may worsen the situation, possibly because it was incorrectly determined that performance was impaired, or because remedial actions are improperly undertaken or unknowingly defeat important barriers. Another possibility is that contaminated materials from remedial activities may not be adequately stored or disposed.
3.8.06	Void Space Formation	If waste packages and/or canisters are not completely filled, then the unfilled inert gas or air-filled volume could influence water-chemistry calculations. Diffusion-controlled cavity growth is a possible creep rupture mechanism that could occur under the temperature and pressure conditions that prevail during dry storage of spent fuel. It might also occur during disposal.
3.8.07	Material Volume Changes	The effects of volume changes in materials used in the waste closure facility. This includes the effects of volume growth from corrosion products, which have a higher molar volume than the intact, non-corroded material. Increases in volume could change the stress state in the material leading to additional system degradation.
3.8.08	Electrochemical Effects in the Closure System (Including Anion Exclusion)	Electrochemical effects (or gradients) may establish an electric potential within or between closure system materials, particularly where two different metals occur close together in saturated conditions or in response to natural electrical currents in far-field rock. Migration of ions within such an electric field could affect corrosion of metals and could also have a direct effect on the dissolution and transport of radionuclides as charged ions. Anion exclusion refers to the overlapping of electrical double layers within a pore and the subsequent exclusion (full or partial) of anions and cations from the pore. Neutral species and water itself may migrate through such a pore unimpeded.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
3.8.09	Mechanical Effects at EBS Component Interfaces	Factors related to the mechanical effects that occur at the interfaces between the engineered components of the closure system and the near-field environment. These factors include: a) the physical effects of steady-state contact (such as mechanical and static loading) at these interfaces, b) the effects of backfill and grouting for resisting to rockfall and structure collapse, c) the effects of physical impacts to the backfill and grout itself, and d) the effects of drilling and excavating at or near the closure facility. These factors may also be caused by forces such as rockfall and seismic-induced impacts, and internal and external stresses. These stresses will act on the engineered components and can be partially responsible for failure of the engineered barriers.
4.1.01	Waste Type Classification	Classification of the radioactive waste into exempt waste, low and intermediate level waste (short lived and long lived) or any other country-specific waste classification scheme. A variety of waste forms and waste types may be disposed of within the closure system. Some of types may have initial degradation characteristics. Therefore, the effectiveness of each waste form as a barrier to radionuclide mobilization should be considered.
4.1.02	Waste Form Characteristics	Contaminant characteristics are related to the physical, chemical (organic and inorganic) and radiological properties of the contaminant(s) contained in the residual waste of the closure facility. Chemical characteristics of the waste form include: a) chemical composition, b) chemical stability and confinement in the near-field, c) reactivity, d) gas generation, e) toxicity, and f) decomposition of organic wastes Physical characteristics of the waste form include: a) permeability and porosity, b) homogeneity (distribution of waste and matrix constituents within the waste form, c) density, d) voidage, e) preferential pathways in waste form.
4.1.03	Waste Inventory	A description of the total radionuclide content in the waste (total activity in units of curies, or mass in grams) and a description of the content of individual radionuclides (radionuclide composition) and chemicals (chemical composition, typically in units of density or concentration) in the waste. A description of the physical content of the waste material in its untreated form (i.e. as generated). A description of the physical size of the waste and/or waste containers used to dispose the waste material in its untreated or treated (stabilized) form.
4.1.04	Waste Allocation and Emplacement	Describes the assumptions regarding the allocation of wastes (i.e. variance between waste tanks), including waste type(s) and amount(s). Some waste types and inventories may require special waste emplacement arrangements to simplify the disposal practice, to ensure safety, or to ensure structure stability in the disposal zone.
4.1.05	Waste Homogeneity	A description of the homogeneity of the waste in the closure facility. Different categories of heterogeneity are possible in a waste closure facility: a) heterogeneity in the disposal concepts, b) heterogeneity in the waste stream, and c) heterogeneity in the distribution of the radionuclides in the waste or waste form.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
4.1.06	Highly Radioactive Radionuclides (HRRs)	Identification of HRRs, selection of radionuclides characterized in residual waste, selection of treatment technologies to remove HRRs to the Maximum Extent Practical (MEP), and screening of radionuclides for the purpose of performance assessment calculations.
4.1.07	Metallic Wastes	The physical, chemical, and biological characteristics of the metallic wastes and any conditioning material at the time of disposal are important for the definition of contaminant release rates (source term); gas generation rate; and geochemical conditions in the waste closure facility.
4.1.08	Non-Metallic, Inorganic Wastes	The physical, chemical and biological characteristics of non-metallic, inorganic wastes and solutes at the time of disposal are important for the definition of: contaminant release rates (source term); gas generation rate; and geochemical conditions in the waste closure facility.
4.1.09	Organic Wastes	Factors related to the characteristics of radionuclides or chemical contaminants that are organic or have the potential to form organics under prevailing waste closure facility and environmental conditions. Organic compounds may include stable organic complexes which may form compounds with other contaminants (usually metals). The resulting organic forms may be more or less mobile or toxic than the original form. Conditioning material at the time of disposal are important for defining contaminant release rates (source term), gas generation rates, and geochemical conditions in the waste closure facility
4.1.10	Volatiles and Potential for Volatility	Factors related to the characteristics of radiotoxic and chemotoxic species that are volatile or have the potential for volatility under prevailing waste closure facility and environmental conditions.
4.2.01	Radioactive Decay and In-Growth	Radioactive decay is a fundamental process that affects all radioactive (unstable) nuclides. Radioactive decay will change the inventory of radionuclides in the waste, and the heat generation will affect the temperature in the near-field and the stability of the wasteform and other cementitious materials.
4.2.02	Activity Limits in Disposed Waste	The radionuclide specific activity limits that can be disposed in a waste closure facility to ensure that human health and the environment are not adversely affected by the disposal waste material. As part of defining waste acceptance criteria for a waste closure facility, quantitative nuclide specific activity limits can be derived to ensure adequate protection to human health and the environment as a function of time. These activity limits can be expressed as total activity limits (Bq of waste disposed) or activity concentration limits (Bq per Kg of waste material). In addition, activity limits for each waste package can also be defined.
4.2.03	Contaminant Solubility, Solubility Limits, and Speciation	Speciation and solubility processes, including their evolution in time, occurring in the accessible environment that effect the dissolution/precipitation of contaminants. Large solubility limits increase the mobility of contaminants, but low solubility limits may lead to larger exposures when precipitation occurs. Small concentrations of complexing agents could form stable dissolved species, enhancing the dissolution of contaminants from the waste form and increasing their solubility. Conversely, solubility limits will be smaller when complexing agents have low concentrations or where the chemical environment decreases the stability of dissolved species or enhances the stability of a solid phase.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
4.2.04	Reduction-Oxidation Potential (Redox Fronts)	The generation and propagation of a redox front influence contaminant transport due to variations in solubilities and concentrations at the interfaces between waters with varying redox potentials. This geochemical instability may also result in the generation of colloids.
4.2.06	Degradation of the Inorganic Waste	Degradation and failure processes: The waste form type and associated characteristics will determine the dominant waste form degradation processes including: a) physical degradation processes (e.g., physical stress), b) chemical degradation processes (e.g., sulfate attack), and c) biological degradation processes (e.g., notifying bacteria and heterotrophic organisms), together with the physical, chemical, hydrological and biological conditions in the waste closure facility and environment. Consequently, degradation of inorganic wastes may impact on the release and transport of radionuclides from the near-field.
4.2.07	Degradation of the Organic Waste	Degradation and failure processes: The waste form type and associated characteristics will determine the dominant waste form degradation processes including: a) physical degradation processes (e.g., physical stress), b) chemical degradation processes (e.g., sulfate attack), and c) biological degradation processes (e.g., notifying bacteria and heterotrophic organisms), together with the physical, chemical, hydrological and biological conditions in the waste closure facility and environment. Consequently, degradation of organic wastes may impact on the release and transport of radionuclides from the near-field.
4.3.01	Contaminant Concentrations in Water and Other Media	Factors related to the concentrations of contaminants in: a) environmental media; b) drinking water, foodstuffs or drugs that may be consumed by humans; c) environmental media other than drinking water, foodstuffs or drugs; and d) human manufactured materials or environmental materials used by humans for special uses, e.g., clothing, building materials, peat. This includes groundwater concentrations.
4.3.02	Dissolution and Precipitation	Dissolution and precipitation processes, including their evolution in time. Most contaminants are released from the residual waste when they dissolve into the groundwater that has entered the waste tank, and many contaminants could re-precipitate as different compounds. Precipitation could also occur if there is an abrupt change in the chemical environment (including groundwater composition and pH) or if ingrowth from radioactive decay produces a local increase in concentration.
4.3.03	Solubility and Sorption Changes From Chemical and Temperature Interactions	Factors related to release of the various contaminants, by desorption and solubility influences, into the invading pore waters. For example, radionuclides in secondary uranium mineral phases, such as neptunium in schoepite and uranium silicates, could affect radionuclide concentrations (during radionuclide alteration, the radionuclides could be chemically bound to immobile compounds and result in a reduction of available radionuclides for mobilization).
4.3.04	Dilution of Radionuclides in Groundwater	Dilution due to mixing of contaminated and uncontaminated water may affect radionuclide concentrations in groundwater during transport in the saturated zone and during pumping at a withdrawal well. For example: Mixing or dilution of the radioactive species from the waste with species of the same element from other sources (i.e., stable and/or naturally occurring isotopes of the same element) could lead to a reduction of the radiological consequences.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
4.3.05	Radionuclide Accumulation (Recycling) in Soils	Radionuclide accumulation in soils may occur as a result of upwelling of contaminated groundwater (leaching, evaporation at discharge location), deposition of contaminated water or particulates (irrigation water, runoff), and/or atmospheric deposition. Radionuclides that have accumulated in soils (e.g., from deposition of contaminated irrigation water) may leach out of the soil and be recycled back into the groundwater as a result of recharge (either from natural or agriculturally induced infiltration). The recycled radionuclides may lead to enhanced radionuclide exposure at the receptor.
4.4.01	Human Exposure Pathways	Ingestion, inhalation, and external exposure pathways.
4.4.02	Food Preparation and Water Processing	Factors related to human diet and fluid intake of dietary foodstuffs and water between its original (raw) form and consumption by human beings and animals. Other influences include water filtration, diet of uncontaminated food, and food preparation techniques.
4.4.03	Radon and Radon Daughter Exposure (Noble Gas Contamination)	Radon and radon progeny exposure is considered separately from exposure to other radionuclides because the behavior of radon and its progeny, and their modes of exposure, are somewhat different. Radon is mobile and readily enters different components of the biosphere. Exposure to radon almost always implies exposure to its progeny which are relatively immobile and reactive. The principal mode of exposure to humans is inhalation of radon progeny attached to dust particles.
4.4.04	Animal, Plant, and Microbe Uptake and Migration of Contaminants	Factors related to migration of radionuclides and chemical contaminants as a result of animal, plant and microbial activity. Radionuclides may be transported and transferred through and between different compartments of the biosphere. Temporally and spatially dependent physical and chemical environments in the biosphere may lead to alteration of both the physical and chemical properties of the radionuclides as they move through or between the different compartments of the biosphere. Uptake and accumulation of contaminants by plants could affect potential exposure pathways. Uptake and bioaccumulation of contaminants in aquatic organisms could affect potential exposure pathways. These plants and aquatic organisms may be used as feed for livestock and/or consumed directly by humans.
4.4.05	Radiological Dose Effects/Risks	The radiation dose is calculated from exposure rates (external, inhalation, and ingestion) and dose coefficients. The latter are based upon radiation type, human metabolism, metabolism of the element of concern in the human body, and duration of exposure. Includes consideration of annual, lifetime, individual, and collective doses. Also includes sensitization to radiation so that its effects are more severe.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
4.4.06	Radiological and Chemical Toxicity/Effects	A description of the total toxic content in the waste (organic, inorganic, chemical), and a description of the content of individual toxic elements in the waste. The effects of radiation and chemical contaminants on man and other organisms can be classified in several different ways: somatic or genetic, occurring in the exposed individual or in the offspring of the exposed individual, respectively; and stochastic or non-stochastic, where the probability of the effect is a function of dose received, or the severity of the effect is a function of dose received and no effect may be observed below some threshold, respectively.
4.5.02	Radiation Effects on the Waste Closure System	When radionuclides decay, the emitted high-energy particle could result in the production of radicals in the water or air and they may then enhance the degradation/corrosion rate of the cementitious materials. Strong radiation fields could lead to radiation damage to the residual waste and surrounding waste tank. This effect would increase the dissolution rate and transport of radionuclides from the residual waste into the groundwater.
4.5.03	Radionuclide Interaction with Corrosion Products	Corrosion of materials will generate a range of possible solid secondary alteration products which depend on the groundwater chemistry. Radionuclides released from the source term may interact with these alteration products by a range of processes such as sorption/desorption or (co-)precipitation/dissolution reactions. These interactions have the potential for significantly controlling radionuclide release rates from the near-field.
4.5.04	Natural or Background Radiation	Factors related to radiation exposure and risks due to naturally occurring or background radiation.
4.5.05	Medical Radiation	Factors related to radiation exposure and risks due to medical procedures.
4.5.06	Contaminants from Other Man-Made Sources or Facilities	Factors related to radiation exposure and risks due to interactions or cumulative effects from man-made sources (such as other burial grounds or waste closure facilities) in the vicinity of the waste closure facility.
4.5.07	Radiolysis Effects	Alpha, beta, gamma, and neutron irradiation of water can cause disassociation of molecules, leading to gas production and changes in chemical conditions (potential, pH, and concentration of reactive radicals). Radiation emitted during radioactive decay of unstable nuclides can cause radiolysis of the groundwater and of water-bearing solid materials. This radiolysis can lead to the formation of oxidants and free hydrogen gas which will impact on the redox conditions in the near-field, leading to a change in radionuclide solubilities.
5.1.01	Groundwater Flow and Movement (Near-Field)	Unsaturated and saturated flow may occur along preferential pathways in and surrounding the waste tanks. Physical and chemical properties of the cementitious materials, in both intact and degraded states, should be considered in evaluating pathways. Preferential pathways for groundwater flow and diffusion may exist within the transfer lines. Backfill, plugs, and seals may not preclude hydrological, chemical, and thermal interactions between the various system components. Water outflows are responsible for the transport of dissolved radionuclides away from the waste tanks and ancillary equipment.
5.1.02	Groundwater Flow and Movement (Far-Field)	Groundwater flow in the saturated zone below the water table may affect long-term performance of the closure system. The location, magnitude, and direction of flow under present and future conditions and the hydraulic properties of the rock are all relevant.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
5.1.03	Episodic Or Pulse Flow and Release	Episodic flow could occur as a result of episodic infiltration. Episodic or pulse release of radionuclides from the waste tanks and radionuclide transport in the groundwater may occur both because of episodic flow into the waste tanks, and because of pulse releases from failed waste tanks.
5.1.04	Water Influx at the Closure Facility	An increase in the water flux at the tank closure facilities may affect thermal, hydrologic, chemical, and mechanical behavior of the system. The cause of the increase is not an essential part of the FEP.
5.1.05	Focusing of Flow Along Preferred Flow Paths (Fingers, Weeps, Faults, Fractures, etc.)	Development of preferential flow paths and/or the alteration of preferential flow paths. Heterogeneities in rock properties, including fractures and faults, may contribute to focusing of unsaturated flow into zones of greater and lower saturation that may persist as preferential flow paths. Fractures or other analogous channels may act as conduits for fluids to move into the subsurface to interact with the waste tanks and as conduits for fluids to leave the vicinity of the waste tanks and be conducted to the saturated zone. Water may flow through only a portion of the fracture network, including flow through a restricted portion of a given fracture plane.
5.1.07	Flow Diversion and Bypass Flow	Flow in unsaturated rock tends to be diverted by the closure cap. The resulting diversion of flow could have an effect on seepage into the waste tanks. Flow diversion could also lead to the development of a zone of lower flow rates and low saturation beneath the closure cap. The movement of water through the soil along a pathway other than that provided by the microscopic pore spaces within the soil matrix (such as shrinkage cracks, faunal burrows, and voids left following the decay of plant roots). Bypass flow can transmit water through soils whose matrix is not saturated faster than under laminar flow.
5.1.08	Film/Laminar Flow	Water may enter the waste tanks by a film flow process. This differs from the traditional view of flow in a capillary network where the wetting phase exclusively occupies capillaries with apertures smaller than some level defined by the capillary pressure. A film flow process could allow water to enter a waste tank at non-zero capillary pressure.
5.1.09	External Flow Boundaries	The external flow boundary conditions of the hydrogeological system control the location and amount of recharge and discharge, and are a control on the geometry of the flow system. The external flow boundary conditions are, thus, important to define for modeling groundwater flow and radionuclide transport in the far-field.
5.1.10	Alteration and Chemical Weathering Along Flow Paths	Chemical (water-rock) reactions between groundwater and the rock and any fracture minerals will lead to progressive changes to the solid phases along the flow path and to its hydraulic properties. Ongoing chemical reactions (precipitation and dissolution) between groundwater and rock and fracture minerals lead to weathering of the migration path resulting in increased groundwater flow and channeling. Weathering may alter the mineral composition and physical composition of the fractures and pores, as well as the groundwater chemistry and generation of colloids. These water-rock reactions can impede or enhance radionuclide transport depending on their nature.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
5.2.01	Hydrological Response to Geological Changes	Effects on regional groundwater flow and pressures arising from large-scale geological changes. Effects include changes in groundwater flow and pressures caused by erosion, and changes to hydraulic properties of geological units caused by changes in rock stress or fault movements. Within and underlying low-permeability geological formations, the hydrogeological conditions may have characteristics that reflect past geological conditions and are in a state of disequilibrium.
5.2.03	Hydraulic Potentials and Gradients	Hydraulic gradients drive fluid flow through the host rock and other rock units. The near-surface hydraulic gradients are topographically controlled and are in equilibrium with the current surface conditions. Hydraulic gradients will evolve with time due to changes in climate and landform, but more significantly due to glacial cycles.
5.2.04	Interfaces Between Different Waters	There is potential for the development of interfaces between ground waters of different composition in the near and far-field rock. At these interfaces, changes may occur in radionuclide solubilities and groundwater flow which could affect radionuclide transport and release.
5.2.05	Effects Related to Air and Vapor Flow and Evaporation within the System	FEP addresses the effects of dry-out within the rocks. Natural convective air circulation transfers energy between a hot and a cold region (source and sink, respectively) using the heat of vaporization and movement of the vapor as the transfer mechanism. Two phase circulation continues until the heat source is too weak to provide the thermal gradients required to drive it. Alteration of the rock may include dissolution that maintains the permeability necessary to support the circulation.
5.2.06	Perched Water Develops	Zones of perched water may develop above the water table which may affect flow between the surface and the waste tanks. If these zones develop within the disposal units, a "bath tub" effect may occur (i.e., water "pooling" and possibly filling the unit prior to degradation of the disposal unit walls and/or liner). If they develop below the waste tanks, they may affect flow pathways and radionuclide transport between the waste tanks and the saturated zone.
5.3.01	Contaminant Release and Migration Factors	The Contaminant Release and Migration category is related to the physical, chemical, and radiological processes that directly affect the release (i.e. that will result in the contaminants being available for migration into the environment) and migration of contaminants in the disposal system domain that will result in a contaminant concentration in environmental media.
5.3.02	Contaminant Release Pathways	Factors related to the pathways as well as the associated processes and conditions for the release of radiotoxic and chemotoxic species from its physical state of the waste closure facility. Factors related to the properties and characteristics of smaller discontinuities and features within the geosphere (saturated and unsaturated) that are expected to be the main paths for contaminant migration, and as they may evolve after closure.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
5.3.03	Multiphase Transport Processes	Contaminant migration in the disturbed zone could be influenced by: a) the development of a fractured/cracked system caused by the construction of the waste closure facility, b) an alteration of the flow regime caused by a changes in porosity or permeability, c) changes in the sorption properties of the disturbed zone, or d) gaseous (or diffusive) release of contaminants generated in the near-field. Pore water may flow into, and gas out of, the waste tanks in a complex process governed by hydraulic gradients, geosphere gas and liquid flow parameters, gas pressure, and relative saturations in the geosphere.
5.3.04	Contaminant Release from the Waste Form and Engineered Barrier System	Radionuclides will be released from the waste forms by a variety of mechanisms either into solution, to secondary solid alteration phases, as colloids, or in the gaseous phase. The nature and abundance of the released species will depend on the chemistry of the near-field pore-waters and the degradation rate of the wasteform. Radionuclides in the form of solutes or colloids released from the residual waste can migrate by diffusion or by water exchange from inside the waste tank to the groundwater, after the waste tank has been breached. Radionuclides can also migrate in the gas phase. Release and transport of radionuclides and other solute species from the waste tank will affect the groundwater chemistry (radionuclide content) inside the waste tank and in the surrounding soil. Radionuclides released from the waste tank can be transported through the backfill in solution or as a gas, and possibly also in colloidal form. The mechanisms and rate of radionuclide transport through the backfill are determined largely by the physical properties of the backfill materials. Transport through the backfill controls the release rate to the near-field environment.
5.3.05	Solid-Mediated Migration of Contaminants	The transport of radionuclides and chemical contaminants in large-scale solid phase movement (such as large-scale erosion processes) or smaller-scale processes (such as rinse mechanisms or colloidal transport) can also occur, leading to movement of contaminants.
5.3.06	Gas-Mediated Migration of Contaminants	The transport of radionuclides and chemical contaminants in gas or vapor phase, or as fine particulate or aerosols suspended in gas or vapor. Radioactive and chemically toxic gases may be generated by degradation of waste closure facility components, generated from the wastes, microbial degradation of organic material, or naturally occurring, and transported in the gas phase into the geosphere. The gas generated may form a free gas phase that could impact on the transport and release of radionuclides. In some cases, radionuclides may be directly associated with the gas molecules whilst, in other cases, the gas phase will impact on the movement of ground waters containing dissolved radionuclides. Pressure variations due to gas generation may affect flow patterns and contaminant transport in the natural system. Issues such as dwelling location, which could affect seepage of gases such as radon into basements, and heating source, could involve biogas production.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
5.3.07	Water-Mediated Migration of Contaminants	Transport of radionuclides and chemical contaminants in groundwater and surface water. Water-mediated transport processes include: a) advection or movement with the bulk movement of the fluid, b) percolation or convection, where the movement of the fluid is driven by gravity and heat, respectively, c) dispersion, or the spread in the spatial distribution of contaminants with time because of differential rates of advective or convective transport, d) molecular diffusion, or the random movement of individual atoms or molecules within the fluid; matrix diffusion or diffusion into stagnant pores, and e) multiphase transport processes including unsaturated flow.
5.3.08	Diffusion (Molecular Diffusion and Matric)	Diffusion is the process whereby chemical species move through water-filled cracks and voids under the influence of a chemical potential gradient (usually a concentration gradient). Radionuclides can migrate by diffusion from inside the tank to the backfill, after the tank has been breached. In addition, dissolved species in the ground waters outside the tank can be transported into the tank by diffusion. Both inward and outward diffusion of species will affect the groundwater chemistry and the release of solubility controlled species. Matrix diffusion is the process by which radionuclides and other species in the water flowing along fractures migrate into the non-flowing micro-fractures and into the micro-porosity of the surrounding rock mass. Matrix diffusion can provide an efficient retardation mechanism for both sorbing and non-sorbing contaminants.
5.3.09	Dispersion and Imbibition	Dispersion is the collective name for the consequences of a number of processes that cause ‘spreading-out’ of a contaminant plume in all directions, superimposed on the bulk movement predicted by a simple advection model. It results in a spatially distributed contaminant plume. Water flowing in fractures or other channels in the unsaturated zone may be imbibed into the surrounding rock matrix. This may occur during steady flow, episodic flow, or into matrix pores that have been dried out during the thermal period.
5.3.10	Advection	Transport of fluids and dissolved contaminants by advection with the flowing groundwater may occur. Physical and chemical properties of the system and system components, in both intact and degraded states, should be considered in evaluating advective transport.
5.3.11	Sorption and Desorption of Dissolved Contaminants (Kd Retardation)	Sorption and desorption of radionuclides and chemical contaminants describes the physicochemical interactions of a dissolved species with a solid phase to remove the species from solution. Desorption is the opposite process. Sorption and desorption are often described by a simple partition coefficient (Kd), also called the distribution constant. Sorption of radionuclides from the waste occurring on the cementitious materials, their degradation products, and on surfaces of fractures and matrix in rock or soil will retard the migration of those species. Sorption may be reversible or irreversible, and it may occur as a linear or nonlinear process.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
5.3.12	Radionuclide Fluxes to the Biosphere	Radionuclide fluxes from the closure facility into environmental media as an indicator of barrier performance. Care should be taken to define appropriate areas and volumes over which the fluxes are to be defined in order to make comparisons between those derived from the waste closure facility and fluxes of naturally occurring radionuclides.
5.3.13	Fast Transport Pathways	Fast pathways for water and radionuclide transport between the surface and depth can occur in the form of highly transmissive natural features (such as large fractures) or as poorly sealed shafts and boreholes. The presence of such fast pathways could potentially bypass large regions of the far-field rock and lead to early and large releases to the surface.
5.3.14	Long-Term Release of Radionuclides	The release of radionuclides to the environment may occur over a long period of time, as a result of the timing and magnitude of the waste tanks/waste packages degradation, and radionuclide transport.
5.3.15	Radionuclide Release Outside The Reference Biosphere	Radionuclide releases and accumulations outside the reference biosphere can occur. This could include: a) areas surrounding distant springs and surface water bodies, b) remote natural outfalls, and c) discharge areas such as playas, forests, grasslands, or wetlands that occur in isolated areas in the region. This might also include withdrawal from wells in remote areas. Sediment transport and redistribution may cause concentration or dilution of radionuclides. Flora and fauna in these areas may be exposed and radionuclides be bioaccumulated and enter the food chain. Intermittent use of these areas by humans may also lead to exposure.
5.3.16	Vadose Zone Depth	The vertical distance between the bottom of the floor of the disposal unit or closure facility and the top of the saturated zone.
5.3.17	Saturated Zone Depth	The vertical distance between the top of the saturated zone and the bottom point (or intake) of the assessment well.
5.3.18	Depth of Assessment Well	The depth from which the assessment well draws water.
5.3.19	Horizontal Distance to Points of Assessment	The horizontal distance between the waste closure facility and the assessment well or stream.
6.1.01	Inadvertent Human Intrusion	Humans without knowledge or awareness of the existence of the waste closure facility could accidentally intrude into the system and experience exposures to contaminants. In addition, activities may result in damage to containment, increasing contaminant release rates. An example of an inadvertent action includes an archeological or scientific study of the site. Note: other intrusions (such as meteorite impacts, drilling, and excavating) are discussed in other FEPs.
6.1.02	Deliberate Human Intrusion	Humans could deliberately intrude into the waste closure facility although without appropriate precautions, and experience exposures to contaminants. In addition, activities may result in damage to containment, increasing contaminant release rates. Motivation for deliberate human intrusion includes: a) mining and waste retrieval, b) site remediation/improvement activities, c) facility sabotage, and d) acts of war. Note that other intrusions (such as meteorite impacts, drilling, and excavating) are discussed in other FEPs.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
6.1.03	Drilling Activities	Factors related to any drilling activities in the vicinity of the waste closure facility. This includes: a) exploratory boreholes (for minerals or natural gas and oil), b) boreholes drilled for water-supply wells, c) boreholes drilled before construction of the facility, and d) boreholes drilled after the existence or the purpose of the closure facility has been forgotten. Other drilling activities might include: a) the production of geothermal energy, b) the injection of liquid wastes, and c) other scientific studies.
6.1.04	Excavating and Mining Activities	Factors related to any excavation and mining activities in the vicinity of the waste closure facility (excluding drilling). This includes: a) mining for natural resources (ore, oil, gas, etc.), b) mining to retrieve or extract components of the waste or of the closure facility, c) tunneling for the purpose of constructing subterranean dwellings, and d) tunneling for the purpose of additional waste storage or disposal. Activities may include: a) open excavation, b) tunneling, c) solution mining, d) digging, e) blasting, f) breaking, and g) loading and hauling of material. Some of these activating may result in the production of tailings, which may subsequently release contaminants.
6.1.05	Animal/Plant Intrusion	Factors related to the intrusion of animal and plant into the waste closure facility, leading to the disruption in performance.
6.1.06	Igneous or Seismic Event Precedes Human Intrusion	An igneous or seismic event (e.g., a dyke) could intersect the waste closure facility and alter the material and structural properties of the closure system (engineered and natural barriers). Because of the change in properties of these materials resulting from an igneous intrusion, an intruder using groundwater exploration drilling techniques may not be able to recognize that something other than naturally-occurring material has been encountered.
6.2.01	Seismicity	Factors related to the effects of seismic events on the closure system. Such factors include: a) liquefaction of the backfill materials and soils, b) shaking and damage to the waste form or engineered components, c) rockfalls, and d) extension or creation of fractures or faults. External effects also include: a) tidal waves (tsunamis), b) liquefaction of soil, c) formation of new discharge areas, d) alteration of river courses, and e) destruction of dams. Multiple events occurring close together in time might have effects that are not simply additive.
6.2.02	Seismic-Induced Damage or Changes to System Components	Factors related to physical damage or property changes to components of the waste closure system due to seismic events. Types of damage include: a) damage from repeated vibration, b) damage from physical contact between components, c) damage from rockfall, d) damage from stress resulting in dynamic or static loading, and e) damages related to movement or displacement of components or materials. Such damage mechanisms could lead to degraded performance. This includes changes to system chemistry, hydrology, and thermo-hydrology. Consider effects on porosity and permeability, fault and fractures, and effects to perched water and aquifers.
6.2.03	Effects of Subsidence	Subsidence at or near the closure facility may affect the properties of the natural system materials and surface topography. Changes in rock and soil properties, such as enhanced permeability, may alter flow paths from the surface to the waste closure facility. Changes in surface topography may alter run-off and infiltration, and may create impoundments.

Table 2.0-1: Descriptions of FEPs for Evaluation (Continued)

FEP ID	FEP Name	FEP Description
6.4.02	Flooding or Drainage System Failure	Factors related to flooding (or drainage system failures) of the site or facilities during construction, operation, or post-closure that could introduce additional water into the system, which could affect the long-term performance of the waste closure facility.
6.4.03	Movement of the Waste Form	Backfill provides a stable physical and chemical environment for the wasteform, and isolates the engineered system components from the near-field natural environment and flowing ground waters. The effectiveness may be diminished if the waste moves within the backfill. This could occur as a result of sinking, uneven swelling of clays and backfill materials, expansion of engineered system materials, or movement of the near-field geosphere via slumping or stresses.
6.4.04	Cave-In, Collapse, or Rockfall	Partial or complete collapse or cave-in of the engineered components or discrete rockfall could occur as a result of thermal effects, stresses related to excavation, or other mechanisms (including seismic activity). Cave-ins and rockfalls could affect the stability of the engineered components or result in static loading from rock overburden, as well as altering flow paths.
6.4.05	Accidents and Unplanned Events	Factors related to accidents and unplanned events, which might have an impact on long-term performance or safety of the waste closure facility.
6.4.06	Explosions and Crashes	Factors related to deliberate or accidental explosions and crashes that might impact the waste closure facility. Examples include: a) underground nuclear testing, b) aircraft crash on the site, c) acts of war or sabotage, and d) accidental equipment or chemical explosions.

[Source: SRR-CWDA-2012-00011, Rev.0]

3.0 FEPs CROSSWALK TO THE HTF PA

Table 3.0-1 provides the crosswalk that documents the evaluation of the LW FEPs considered in the HTF PA. In most cases, the document referenced is the HTF PA (SRR-CWDA-2010-00128, Rev. 0); however, some of the FEPs have been addressed through supporting technical reports or through regulatory-related documents.

Table 3.0-1: LW FEPs to HTF PA Evaluation

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.01	Assessment Context Factors	SRR-CWDA-2010-00128, Rev. 0	1.0, 2.1	The PA approach and process state the performance objectives to be addressed. “This Performance Assessment (PA) for the Savannah River Site (SRS) was prepared to support the eventual removal from service of the H-Area Tank Farm (HTF) underground radioactive waste tanks and ancillary equipment. This PA provides the technical basis and results to be used in subsequent documents to demonstrate compliance with the pertinent requirements … for removal from service and eventual final closure of the HTF.”
1.1.02	Assessment Purpose	SRR-CWDA-2010-00128, Rev. 0	2.1	The PA approach and process state the performance objectives to be addressed. “PAs are used to assess the long-term fate and transport of residual contamination in the environment and provide the DOE with reasonable assurance that the removal from service of the SRS tank farm underground radioactive waste tanks and ancillary equipment will meet defined performance objectives for the protection of human health and the environment into the future.”

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.03	Assessment Conditions	SRR-CWDA-2010-00128, Rev. 0	2.1	The PA approach and process state the assessment conditions to be addressed. "The HTF PA was completed to support multiple decision documents, including the HTF IWW GCP and tank-specific closure modules. These documents support the closure of waste tanks to meet the FFA commitments. [WSRC-OS-94-42] The HTF PA development process included a public scoping meeting with the interface agencies in the input development stage. The purpose of the scoping meeting held during the development/planning phase of HTF PA inputs was to identify potential issues early, assess the reasonableness of key modeling assumptions, and reduce the risk of significant rework and remodeling after the HTF PA is finalized."
1.1.04	Documentation and Presentation of Results	SRR-CWDA-2010-00128, Rev. 0	1.0, 2.1, 2.4	The PA results and related documents are available for review by stakeholders. "This HTF PA provides the technical basis that will be used to demonstrate compliance with 10 CFR 61.41 … and 61.42 …. performance objectives that will be presented in the Basis for Section 3116 Waste Determination for Closure of HTF document."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.05	Transparency of Assessment Approach	SRR-CWDA-2010-00128, Rev. 0	1.0, 2.1	The inputs and basis for assumptions used are available for review by stakeholders. "The HTF PA development process included a public scoping meeting with the interface agencies in the input development stage. The purpose of the scoping meeting held during the development/planning phase of HTF PA inputs was to identify potential issues early, assess the reasonableness of key modeling assumptions, and reduce the risk of significant rework and remodeling after the HTF PA is finalized."
1.1.06	Assessment Timeframe (Phases of Disposal)	SRR-CWDA-2010-00128, Rev. 0	2.6.1, 2.6.5	The PA approach and process state the performance objectives to be addressed. "…The 100-year period of institutional control is assumed to begin in year 2032."
1.1.07	Safety Effects Beyond Periods of Control	SRR-CWDA-2010-00128, Rev. 0	2.6.1, 2.6.5	The PA evaluates safety effects well beyond the 100-year period of control. (See technical basis for FEP 1.1.06.)

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.08	Spatial Domain of Concern	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.4, 4.4.4.1.1	The referenced section provides a detailed description of the modeled area. Near-field and far-field (seepline) domains are described. "The GSA boundary conditions are graphically displayed in Figure 4.2-14." "The area resolution of the GSA aquifer model is 200 square feet except in peripheral areas. There are 108 grid blocks along the east-west axis, and 77 blocks along the north-south axis. The vertical resolution varies depending on hydrogeologic unit and terrain/hydrostratigraphic surface variations as depicted in Figure 4.2-15. ... The 3-D grid comprises 102,295 active cells as depicted in Figure 4.2-16." "Regional GSA modeling in PORFLOW was developed using a 200 foot x 200-foot grid with primary focus on seepline concentration (Figure 4.4-13)." "The HTF modeling was developed from the GSA scale model using a 50 foot x 50-foot grid refinement, with the primary focus being on the 1-meter and 100-meter concentrations (Figure 4.4-14). To avoid excessive numerical dispersion at the 100-meter scale, a grid resolution finer than 200 feet x 200 feet was required ... The HTF velocity field includes the entire vertical extent of the GSA model within the horizontal confines of the HTF domain."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.09	Assessment Endpoints	SRR-CWDA-2010-00128, Rev. 0	2.5.1, 2.5.2	LLW disposal performance assessment endpoints to be addressed are identified and defined within the regulatory framework. For example, as described in Section 2.5.1: "The NRC acknowledged that using a performance objective of 25 mrem/yr effective dose is acceptable versus considering individual organ doses ... [and] that using a whole body dose equivalent limit of 500 mrem/yr effective dose is appropriate to assess intruder scenarios."
1.2.01	Regulatory Compliance	SRR-CWDA-2010-00128, Rev. 0	2.5.1, 2.5.2, 8.1	PA results with respect to regulatory compliance are discussed. For example, Section 2.5.1 states that "Subpart C of 10 CFR 61 lists the five performance objectives…"
1.2.02	Protection of Human Health and the Environment	SRR-CWDA-2010-00128, Rev. 0	2.5.1, 2.5.2, 5.0	Performance objectives to be addressed are identified and defined. Section 5.0 discusses the results of the PA analysis and impacts on human health and the environment. For example, Section 2.5.1 states that "Subpart C of 10 CFR 61 lists the five performance objectives…"
1.2.03	Performance Requirements and Criteria	SRR-CWDA-2010-00128, Rev. 0	1.0, 2.5.1, 2.5.2	Table 1.0-1 provides Key Limits from Regulatory Requirements. Performance requirements and criteria are discussed.
1.2.04	Functional and Technical Requirements and Criteria	SRR-CWDA-2010-00128, Rev. 0	2.4.4, 2.5, 3.1, 3.2, 4.3.2	Various requirements are discussed and considered throughout the PA. For example, Section 3.2.3 discusses the chemical and mechanical grout quality requirements.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.2.05	ALARA	SRR-CWDA-2010-00128, Rev. 0	5.8	This section provides a detailed ALARA analysis. "The ALARA process is applied to HTF in several ways, 1) making conservative assumptions when modeling tank farm waste inventory, releases, and dose to receptors, 2) by evaluating waste tank cleaning and stabilization alternatives, and 3) by implementing cleaning processes prior to waste tank closure that remove the highly radioactive radionuclides to the maximum extent practical."
1.2.06	Administrative Control of the Waste Closure Facility	SRR-CWDA-2010-00128, Rev. 0	2.3, 2.4.2, 2.4.3	PA identifies the mission, vision, and responsibilities for monitoring. Administrative controls have been considered. For example Section 2.3 states: "for the purpose of this PA, a 100-year period of institutional control is assumed to begin after the closure cap is installed… [and the] … cap will be monitored, maintained, and repaired as necessary during the institutional control period."
1.2.07	Waste Acceptance Requirements and Criteria	SRR-CWDA-2010-00128, Rev. 0	2.4.5, 3.4, 3.4.1	Process history and waste transfer data collected and used to determine residual waste inventories.
1.3.01	Model and Data Issues	SRR-CWDA-2010-00128, Rev. 0	2.1.2, 2.6.4, 2.6.5, 2.6.6, 4.0	Various model and data issues are discussed and considered throughout the PA. For example, Figure 2.1-1 provides an overview of the various modeling relationships between various parameters and modeling components of the HTF PA.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.3.02	Software Codes	SRR-CWDA-2010-00128, Rev. 0	4.3	Software is thoroughly discussed in this section. "The purpose of this section is to present the modeling codes used and describe the modeling code integration. A brief description is provided for each modeling code, which includes the function of the code, available code manuals or technical documents for the applicable code revision, reasons for selection of the particular code, and available QA documentation for the code."
1.3.03	Model Approaches	SRR-CWDA-2010-00128, Rev. 0	2.1.2, 4.2, 4.3	ISCM, PORFLOW, and GoldSim approaches and processes are discussed. For example, Figure 2.1-1 provides an overview of the various modeling relationships between various parameters and modeling components of the HTF PA.
1.3.04	Systematic Assessment Approach	SRR-CWDA-2010-00128, Rev. 0	2.1, 4.3, 5.6.2	Integration of PORFLOW and GoldSim models are discussed and benchmarked.
1.3.05	Iterative Assessment Approach	SRR-CWDA-2010-00128, Rev. 0	2.1.2, 5.6.2, 8.2	Section 2.1.2 discusses "preliminary model runs" that led to refinement. Section 5.6.2 discusses benchmarking used to adjust the GoldSim model. Section 8.2 states that as additional data becomes available, additional modeling will be required.
1.3.06	Realistic Assessment Approach	SRR-CWDA-2011-00054, Rev. 1	2.6	Although the referenced RAI response document is in response to a PA for a different facility (F-Area Tank Farm; FTF), this response is also applicable to the modeling approach applied to the HTF PA. The response to RAI-PA-1 provides a discussion of how "realistic" versus "conservative" approaches have been considered for the PA.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.3.07	Conservative Assessment Approach	SRR-CWDA-2011-00054, Rev. 1	2.6	Although the referenced RAI response document is in response to a PA for a different facility (F-Area Tank Farm; FTF), this response is also applicable to the modeling approach applied to the HTF PA. The response to RAI-PA-1 provides a discussion of how "realistic" versus "conservative" approaches have been considered for the PA.
1.3.08	Reasonable Assurance Assessment Approach	SRR-CWDA-2010-00128, Rev. 0	2.6.5, 5.6.2	The deterministic Base Case of the PA includes a combination of reasonably conservative and best-estimate assumptions. Benchmarking provides confidence in model results.
1.3.09	Prospective Evaluation Assessment Approach	SRR-CWDA-2010-00128, Rev. 0	5.6	The combination of deterministic, probabilistic, and alternative modeling provides confidence in the Base Case and provides appropriate insights to system functionality that may lead to system design improvements.
1.3.10	Uncertainties	SRR-CWDA-2010-00128, Rev. 0	5.6, 5.6.4	Section 5.6.4 provides a description of the uncertainty analyses. "This section describes the uncertainty analyses, which is concerned with how the uncertainty in model input parameters is propagated through the model to the selected model results, or endpoints."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.3.11	Sensitivity Analyses	SRR-CWDA-2010-00128, Rev. 0	5.6, 5.6.5, 5.6.7	Section 5.6.5 provides a description of a parameter-specific sensitivity analysis. "... the maximum dose to the MOP will have different sensitivities at different times, since it is driven by the presence of different radionuclides... Extracting the important model inputs for results of interest is the subject of the sensitivity analyses." Section 5.6.7 provides a description of a configuration-specific sensitivity analysis. "This section presents the sensitivity of the HTF closure system to alternative waste tank cases, and the sensitivity of the system to the nominal waste tank conditions with no closure cap (referred to as the No Cap Case)."
1.3.12	Model Confidence	SRR-CWDA-2010-00128, Rev. 0	5.6, 5.6.2	The benchmarking analysis developed in GoldSim provides an alternative model approach that gives greater confidence in the modeled results.
1.3.13	Alternative Simplified Modeling Approach	SRR-CWDA-2010-00128, Rev. 0	5.6, 5.6.2	The benchmarking analysis developed in GoldSim uses simplified assumptions to implement flow data. "… the HTF GoldSim Model is necessarily a simplification of the HTF PORFLOW Model."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.3.14	Evaluate Multiple Endpoints	SRR-CWDA-2010-00128, Rev. 0	5.2, 5.5	The PORFLOW release and transport model, coupled with the GoldSim dose calculator, provides results for multiple endpoints. Section 5.2 provides groundwater concentrations for various contaminants at key locations: “Maximum groundwater concentrations are presented for two exposure points, 1) 100 meters from the HTF and 2) the seeplines (UTR and Fourmile Branch). Results are presented for the three distinct aquifers modeled (UTR-UZ, UTR-LZ, and Gordon Aquifer)..” Section 5.5 provides dose results for various contaminants at key locations. For example, the “… groundwater pathway peak doses for the six 100-meter sectors are calculated … for each radionuclide in the sector…”
1.3.15	Processing Limitations to Modeling	SRR-CWDA-2010-00128, Rev. 0	4.3	Modeling limitations were handled during model development and implementation.
1.4.01	Development of Expertise	SRR-CWDA-2010-00128, Rev. 0	9.0	PA preparers have numerous years of experience developing, revising, and analyzing the PA.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.4.02	Monitoring and Surveillance	SRR-CWDA-2010-00128, Rev. 0	2.3, 2.4.1, 2.4.3, 2.4.5, 2.5.1	Various sections of the PA discuss future activities and monitoring and surveillance programs. These will be discussed in greater detail in maintenance and monitoring program documentation. "The closure cap will be monitored, maintained, and repaired as necessary during the institutional control period." "The plan for protection of groundwater at SRS is documented in the *Savannah River Site Groundwater Protection Program* (SRNS-TR-2009-00076)."
1.4.03	Retrievability	SRR-CWDA-2010-00128, Rev. 0	2.4.4	HTF waste is residual after tank cleaning. The fill with grout option chosen prevents waste retrievability.
1.4.04	Regulatory and Peer Reviews	SRR-CWDA-2010-00128, Rev. 0	Revision History, 1.0, 8.1	The Revision Summary indicates that Revision 0b of the PA was submitted for review to the DOE Low Level Waste (LLW) Disposal Facility Federal Review Group (LFRG), followed by an initial issue (Rev. 0) of the PA four months later. Rev. 0 incorporated review comments from the technical/peer review from the LFRG. The regulatory process to complete closure of the HTF requires the development of multiple detailed technical documents with reviews and approvals by multiple state and federal agencies.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.4.05	Confidence Building (External to Modeling)	SRR-CWDA-2010-00128, Rev. 0	2.1, 2.4.3, 8.2	Workshops were held with stakeholders to discuss end-state vision and long-range plans. Section 8.2 addresses additional studies to build confidence in the Maintenance Program Implementation Plan. "Because this HTF PA is considered a living document for the closure of the HTF facility, it will be reviewed as additional studies are conducted to verify that it still bounds the HTF model inputs. As additional data become available and the PA needs to be revised, additional modeling will be required." "Future work is also planned in the area of input refinement and confirmation. For example, further work will be conducted to refine and confirm the existing radionuclide inventories that will be present in HTF at site closure."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.4.06	Target Audience (Stakeholders Involvement)	SRR-CWDA-2010-00128, Rev. 0	2.1, 2.1.1, 2.4.2, 2.4.3	Stakeholder involvement included public meetings as well as a formal review process with the Citizen's Advisory Board (CAB). "The HTF PA development process included a public scoping meeting with the interface agencies in the input development stage." "The purpose of the scoping meeting was to facilitate candid technical discussion on input parameters related to the HTF PA modeling. To accomplish this goal, on April 20 through 22, 2010, a public meeting with representatives from SCDHEC, EPA, and the NRC was held to discuss and review individual input packages. [ML100970781] This scoping meeting (and the HTF PA process in general) also incorporated improvements from previous PA developments, in particular lessons learned from the FTF PA."
2.1.01	Definition of the Exposed Member of the Public	SRR-CWDA-2010-00128, Rev. 0	4.2.3.1, 5.6.3.11	Although the PA does not explicitly define the MOP, consideration for the MOP characteristics and exposure pathways was given during the PA development.
2.1.02	Human Physiology (Metabolism, Diet, and Fluid Intake)	SRR-CWDA-2010-00128, Rev. 0	4.6.2, 5.6.3.12	Diet and ingestion properties are used to define various dose factors.
2.1.03	Human Behavior and Habits (Non-Diet Related)	SRR-CWDA-2010-00128, Rev. 0	4.2.3.1	Although the PA does not explicitly define the MOP, consideration for the MOP characteristics and exposure pathways was given during the PA development.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.1.04	Human Dwellings	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2.6	Although the PA does not explicitly define the features of MOP dwellings, consideration for such was given during the development of Section 4.2.3.2.6.
2.1.05	Demographics and Community	SRR-CWDA-2010-00128, Rev. 0	3.1.1.1, 3.1.1.3, 4.2.3.2, 5.6.3.12	Various human health exposure parameters were developed through the consideration of human demographics and community.
2.2.01	Natural and Geological Resources and Land Use	SRR-CWDA-2010-00128, Rev. 0	3.1.7, 4.2.3.2, 5.6.3.12	Factors related to land and water use was considered during the development of the human health exposure parameters. "Natural resources at SRS are managed under the Natural Resources Management Plan for the Savannah River Site (NRMP) prepared for the DOE by the U.S. Department of Agriculture (USDA) Forest Service - Savannah River. [NRMP-2005]"
2.2.02	Water Management	SRR-CWDA-2010-00128, Rev. 0	3.1.7.1, 4.6.2, 5.6.3.10	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.2.03	Natural/Semi-Natural Land and Water Use	SRR-CWDA-2010-00128, Rev. 0	4.6.2, 5.6.3.12	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.2.04	Rural and Agricultural Land and Water Use	SRR-CWDA-2010-00128, Rev. 0	4.2.4, 4.6.2, 5.6.3.12	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.2.05	Urban and Industrial Land and Water Use	SRR-CWDA-2010-00128, Rev. 0	4.6.2, 5.6.3.12	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.2.06	Leisure and Other Uses of the Environment	SRR-CWDA-2010-00128, Rev. 0	4.2.4, 4.6.2, 5.6.3.12	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.3.01	Future Human Actions (Active)	SRR-CWDA-2010-00128, Rev. 0	6.0	The PA makes conservative assumption about future human actions via the IHI analysis.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.3.02	Future Knowledge of the Facility	SRR-CWDA-2010-00128, Rev. 0	2.6.1, 6.4	For human intruder scenarios, the PA assumes that future knowledge of the FTF is lost immediately after the 100-year period of institutional control. "The Long Range Comprehensive Plan assumes that the entire site will be owned and controlled by the federal government in perpetuity. [PIT-MISC-0041] However, for the purpose of this PA, no federal protection is assumed beyond the 100-year period of institutional control."
2.3.03	Social and Institutional Developments	SRR-CWDA-2010-00128, Rev. 0	6.0	The human intruder scenario conservatively addresses the impact of future changes to social patterns.
2.3.04	Technological Developments	SRR-CWDA-2010-00128, Rev. 0	6.0, 8.2	The PA assumes that technology remains unchanged throughout the simulated period. As additional data becomes available, additional modeling may be required.
2.3.05	No Technological Development	SRR-CWDA-2010-00128, Rev. 0	6.0, 8.2	The PA assumes that technology remains unchanged throughout the simulated period. As additional data becomes available, additional modeling may be required.
2.3.06	Retrograde Developments	SRR-CWDA-2010-00128, Rev. 0	6.0, 8.2	The PA assumes that technology remains unchanged throughout the simulated period. As additional data becomes available, additional modeling may be required.
2.4.01	Biomes	SRR-CWDA-2010-00128, Rev. 0	3.1.3, 4.2.3, 4.6	Factors related to biome impacts were considered during the development of the human health exposure parameters.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.4.02	Microbial Activity	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2, 3.2.4.7	Factors related to microbial activity were considered during the evaluation of chemical and physical impacts on construction materials and human health exposure parameters. For example, the geosynthetic clay liner (GCL) of the closure cap is considered "insensitive to microbial (i.e., fungi or bacteria) biodegradation." [WSRC-STI-2007-00184, Rev. 2]
2.4.03	Vegetation	SRR-CWDA-2010-00128, Rev. 0	3.1.3, 3.1.5.4, 4.6	Factors related to vegetation were considered during the development of the human health exposure parameters.
2.4.04	Animal Populations	SRR-CWDA-2010-00128, Rev. 0	3.1.3, 3.1.5.4, 4.6	Factors related to animal populations were considered during the development of the human health exposure parameters.
2.5.01	Geological Environment and Processes	SRR-CWDA-2010-00128, Rev. 0	3.1.4, 3.1.5	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.02	Topography and Landforms	SRR-CWDA-2010-00128, Rev. 0	3.1.4.1	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.03	Depositional Environments and Landforms	SRR-CWDA-2010-00128, Rev. 0	3.1.4.1	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.04	Stratigraphy and Host Lithology	SRR-CWDA-2010-00128, Rev. 0	3.1.4.1, 3.1.4.2	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.05	Geologic Discontinuities and Boundary Conditions (Fractures, Faults, and Cracks)	SRR-CWDA-2010-00128, Rev. 0	3.1.4.3, 3.1.5, 3.1.5.1	Various geologic and environmental processes were considered during the development of the flow and transport parameters.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.5.06	Near-Surface Aquifers and Water-Bearing Features	SRR-CWDA-2010-00128, Rev. 0	3.1.5.1, 4.2.3, 4.2.2.1.5	Various geologic and environmental processes were considered during the development of the flow and transport parameters. Particular attention was given to aquifers.
2.5.07	Unconsolidated Soft Zones	SRR-CWDA-2010-00128, Rev. 0, SRR-CWDA-2011-00054, Rev. 1	4.2.2, 4.4.4.1.4	Calibrations of the GSA/PORFLOW transport model implicitly reflect consideration for "soft-zone" effects. The response to RAI-FF-1 also addresses this FEP.
2.5.08	Undetected Geologic Features	SRNL-STI-2010-00734	3.1.5.2, 4.2.2.2, 4.4.4.1.4	The report "Mineralogical, Hydrogeochemical, and Environmental Isotope Data Supporting the E-Area Low-Level Waste Facility Performance Assessment" describes extensive studies of the GSA. The large number and wide distributions of data collection points supports the assumption that undetected geologic features would likely have a minimal impact on results.
2.5.10	Soils and Sediment	SRR-CWDA-2010-00128, Rev. 0	3.1.4.2, 4.2.2.2	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.11	Hydraulic Properties	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.2, 4.2.2.1.3, 4.2.2.1.4, 4.2.2.2.2, 4.2.2.2.7	Various geologic and environmental processes were considered during the development of the flow and transport parameters. Hydraulic properties are addressed for the vadose and saturated zones.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.6.01	Mechanical Effects on Geologic Features	WSRC-STI-2007-00184, Rev. 2 and K-CLC-F-00073, Rev. 2	3.2.1.6, 3.2.4	The report "Static Settlement of F-Area Waste Storage Tanks 18 and 19" examined waste tank stability and other mechanical effects. In addition, the report "FTF Closure Cap and Infiltration Estimates" discusses stability considerations for the closure cap. These reports both apply to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.6.02	Tectonic Activity and Processes	SRR-CWDA-2010-00128, Rev. 0, SRR-CWDA-2011-00054, Rev. 1	3.1.4, 4.4.2.4	Local and regional tectonic and seismic activity are considered; however studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities. Additionally, although the alternate tank configurations (B, C, D, and E) were not explicitly linked to seismic events, the types of cracks caused by credible seismic events at the HTF are assumed to be bounded by these alternate configurations.
2.6.04	Deformation and Metamorphism	SRR-CWDA-2010-00128, Rev. 0	3.1.4.1, 3.1.4.3, 3.2.4.7	Local and regional tectonic and seismic activity are considered; however studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities. Further, these processes generally require high heat and high pressure that may exist at great depths; however the HTF wastes will be buried in shallow conditions that are not conducive to these processes.
2.6.07	Deposition	SRR-CWDA-2010-00128, Rev. 0	3.1.4.2	The SRS is located in the Upper Coastal Plain depositional environment. Soil and environmental properties inherently incorporate such depositional characteristics.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.6.08	Erosion and Weathering	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap and Infiltration Estimates" discusses stability considerations for the closure cap, including the effects of erosion and weathering. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.6.09	Mass Wasting	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap and Infiltration Estimates" discusses stability considerations for the closure cap, including the effects of erosion and weathering, which captures the effects of any potential mass wasting events. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.6.12	Hydrogeological Processes and Conditions	SRR-CWDA-2010-00128, Rev. 0	3.1.5	Various geologic and environmental processes were considered during the development of the flow and transport parameters. Hydrogeological processes and conditions are addressed for the vadose and saturated zones.
2.7.01	Atmosphere	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4	The report "FTF Closure Cap and Infiltration Estimates" considered relevant atmospheric and climate conditions when developing the infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.7.02	Climate and Weather	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4, 4.4.2.5	The report "FTF Closure Cap and Infiltration Estimates" considered relevant atmospheric and climate conditions when developing the infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.7.03	Precipitation	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4	The report "FTF Closure Cap and Infiltration Estimates" considered relevant atmospheric and climate conditions (including precipitation) when developing the infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.7.05	Warm Weather Effects	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4	The report "FTF Closure Cap and Infiltration Estimates" considered relevant atmospheric and climate conditions (including weather) when developing the infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.7.06	Cold Weather Effects	SRR-CWDA-2010-00128, Rev. 0and SRR-CWDA-2011-00044, Rev. 1	3.1.2.3, 3.2.4, 3.2.4.7	Table 3.2-13 indicates that freeze-thaw cycles were considered as a potential degradation mechanism on the closure cap. Further, the RAI response VP-2 to the Saltstone Disposal Facility (SDF) PA discusses additional consideration of cold weather effects on cementitious material that may be applied to the HTF PA.
2.7.07	Climate Change	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4	The report "FTF Closure Cap and Infiltration Estimates" considered relevant atmospheric and climate conditions when developing the infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.7.08	Solar Radiation	WSRC-STI-2007-00184, Rev. 2	3.1.2.3, 3.2.4	As noted in the screening decision, solar radiation is only expected to impact PA results with respect climate change. [SRR-CWDA-2012-00011, Rev. 0] Therefore, this FEP is implicitly considered through the infiltration sensitivities as discussed in the Climate Change FEP. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
2.8.01	Water	SRR-CWDA-2010-00128, Rev. 0	3.1.7.1, 4.2.2.1	Water is a primary transport mechanism considered throughout the PA.
2.8.02	Surface-Water Bodies	SRR-CWDA-2010-00128, Rev. 0	3.1.1.1, 3.1.1.2, 3.1.3, 3.1.5, 3.1.7.1.1, 4.2.2.1	The PA looks at projected dose from water usage from both groundwater and surface streams (FMB and UTR) sources. FMB and UTR and their associated wetlands are the discharge point for radionuclide migration from the closure facilities.
2.8.03	Evapotranspiration	SRR-CWDA-2010-00128, Rev. 0	3.2.4.5.1, 3.2.4.5.3	The PA considers the entire water cycle (water balance) associated with the closure facilities (i.e. precipitation, runoff, evapotranspiration, lateral drainage, soil water storage, infiltration/aquifer recharge, groundwater flow, and groundwater discharge to surface streams (FMB and UTR)).
2.8.04	Surface Runoff	SRR-CWDA-2010-00128, Rev. 0	3.1.3, 3.1.5.1, 3.1.5.4, 3.1.7.1, 3.2.4.5.3, 4.2.2.1	The PA considers the entire water cycle (water balance) associated with the closure facilities (i.e. precipitation, runoff, evapotranspiration, lateral drainage, soil water storage, infiltration/aquifer recharge, groundwater flow, and groundwater discharge to surface streams (FMB and UTR)). Additionally the PA has taken into consideration erosion associated with runoff.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.8.05	Capillary Rise	SRR-CWDA-2010-00128, Rev. 0, WSRC-STI-2007-00184, Rev. 2	3.2.4.6	A conservative value was used for the maximum evaporative zone depth to account for the anticipated capillarity of the surficial soils.
2.8.06	Infiltration and Recharge	SRR-CWDA-2010-00128, Rev. 0	3.2.4, 4.2.2.1.3, 4.2.2.1.4	The PA considers the entire water cycle (water balance) associated with the closure facilities (i.e. precipitation, runoff, evapotranspiration, lateral drainage, soil water storage, infiltration/aquifer recharge, groundwater flow, and groundwater discharge to surface streams (FMB and UTR)).
2.8.07	Discharge Zones Within the Assessment Domain	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.3, 4.2.2.1.4	The PA looks at projected dose from water usage from both groundwater and surface streams (FMB and UTR) sources. FMB and UTR and their associated wetlands are the discharge point for radionuclide migration from the closure facilities.
2.8.08	Discharge Zones Outside the Assessment Domain	SRNL-STI-2009-00512, Rev. 0	2.4, 4.2.2.1	The SRS Composite Analysis shall assess contaminant discharge outside the HTF boundary.
2.8.09	Hydrological Regime and Water Balance (Near-Surface)	SRR-CWDA-2010-00128, Rev. 0	3.2.4.1.3, 4.2.2.1.1	The PA considers the entire water cycle (water balance) associated with the closure facilities (i.e. precipitation, runoff, evapotranspiration, lateral drainage, soil water storage, infiltration/aquifer recharge, groundwater flow, and groundwater discharge to surface streams (FMB and UTR)). Additionally the PA has taken into consideration erosion associated with runoff.
3.1.01	Site Characterization and Investigations	SRR-CWDA-2010-00128, Rev. 0	2.1, 3.1	The PA approach, process, and methods state the performance objectives and site characteristics to be addressed.
3.1.02	Site Development	SRR-CWDA-2010-00128, Rev. 0	3.2	The PA discusses the construction and functions of the various HTF facilities.
3.1.03	Facility Factors	SRR-CWDA-2010-00128, Rev. 0	3.2	The PA discusses the construction and functions of the various HTF facilities.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.1.04	Multi-Barrier Safety Function	SRR-CWDA-2010-00128, Rev. 0	3.2.1, 3.2.3, 3.2.4, 5.6.6	The PA discusses the construction and functions of the various HTF facilities. The PA also describes and analyzes multiple barriers to demonstrate the robustness of the closure system.
3.2.01	Design Basis for Engineered Components	SRR-CWDA-2010-00128, Rev. 0	3.2, 3.2.1, 3.2.2, 3.2.3, 3.2.4	The PA discusses the construction and functions of the various HTF facilities. The PA also describes and analyzes multiple barriers to demonstrate the robustness of the closure system.
3.2.02	Schedule and Planning	SRR-CWDA-2010-00128, Rev. 0	2.1, 2.3, 2.4.2, 3.2, 3.2.4.1.2	Schedule and planning is broadly discussed and considered throughout the PA.
3.2.03	Procurement of Items and Services	SRR-CWDA-2010-00128, Rev. 0	3.2.1, 3.2.2, 3.2.3, 3.2.4	Facility design implies that items and services shall be procured to quality-controlled specifications.
3.2.05	Construction	SRR-CWDA-2010-00128, Rev. 0	3.2	The PA describes the construction of waste tanks and facilities in significant detail.
3.2.06	Operation	SRR-CWDA-2010-00128, Rev. 0	2.3	This section describes the Facility Life Cycle that includes facility operation.
3.2.07	Removal or Stabilization of Waste	SRR-CWDA-2010-00128, Rev. 0	2.3	This section describes the Facility Life Cycle that includes removal and stabilization of waste.
3.2.08	Disposal Unit and/or Facility Closure	SRR-CWDA-2010-00128, Rev. 0	2.3	This section describes the Facility Life Cycle that includes closure.
3.3.01	Closure System Features and Materials	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 3.2.4	Facility design implies that various features and materials have been or shall be considered.
3.3.02	Manufacturing and Commissioning of Components	SRR-CWDA-2010-00128, Rev. 0	3.2.1, 3.2.2, 3.2.3, 3.2.4	Facility design implies that components have been or shall be manufactured and commissioned under quality-controlled specifications.
3.3.03	Consolidation of System Components	SRR-CWDA-2010-00128, Rev. 0	3.2.1, 3.2.2, 3.2.3, 3.2.4	Facility design implies that consolidation of system components have been or shall be considered.
3.3.04	Waste Tank, Container, or Package Characteristics	SRR-CWDA-2010-00128, Rev. 0	3.2.1	These characteristics are important parameters considered during the development of the waste release model.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.3.05	Closure System Buffer (Closure Cap, Backfill, and Near-Field Soil) Properties	WSRC-STI-2007-00184, Rev. 2	3.2.4, 4.2.2.2	The report "FTF Closure Cap and Infiltration Estimates" provides significant consideration of closure cap and soil properties to determine infiltration estimates. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.3.06	Bentonite and Vermiculite Effects	WSRC-STI-2007-00184, Rev. 2	3.2.4, 4.2.2.2	The report "FTF Closure Cap and Infiltration Estimates" included a Geosynthetic Clay Layer (GCL) formed from a bentonite clay (or a clay with similar properties). Bentonite effects are considered along with closure cap degradation. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.3.07	Closure Cap Thickness and Material Properties	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.1, 4.2.2.2.2	The material properties of the closure cap parameters are explicitly considered in the PA.
3.3.08	Disposal Unit and/or Facility Wall and Roof Thicknesses	SRR-CWDA-2010-00128, Rev. 0	3.2.1	The material properties of the waste tank parameters are explicitly considered in the PA.
3.3.09	Disposal Unit or Facility Floor Thickness	SRR-CWDA-2010-00128, Rev. 0	3.2.1	The material properties of the waste tank floor and basemat are explicitly considered in the PA.
3.3.10	Ancillary Equipment and Piping/Transfer Lines	SRR-CWDA-2010-00128, Rev. 0	3.2.2	Ancillary equipment and transfer lines are modeled as contaminant sources in the PA.
3.4.01	Hydrological Processes and Conditions	SRR-CWDA-2010-00128, Rev. 0	3.1.5, 4.2.2.1.3, 4.4.4.1.2	Various geologic and environmental processes were considered during the development of the flow and transport parameters. Hydrological processes and conditions are addressed for the vadose and saturated zones.
3.4.02	Hydrostatic Pressure on the Closure System	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.2	The moisture characteristic curves indirectly account for hydrostatic pressure in the system.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.4.03	Condensation on Closure System Surfaces	SRR-CWDA-2010-00128, Rev. 0	4.4.4.1.2	The PA shows that the waste tanks are assumed to be very saturated (i.e., more than 99%). Therefore, condensation would not impact results.
3.4.04	Resaturation and Desaturation	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for desiccation (wet-dry cycles) impacts on the closure cap. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.5.01	Chemical/ Geochemical Processes and Conditions	SRR-CWDA-2010-00128, Rev. 0	3.1.6, 4.2.1.1, 4.2.1.8, 4.2.2, 5.2.1, 6.1	Various geologic and environmental processes were considered during the development of the flow and transport parameters. Chemical and geochemical processes and conditions are addressed extensively.
3.5.02	Evolving Water Chemistry in the Engineered System and Waste Form	SRR-CWDA-2010-00128, Rev. 0	3.1.6, 4.2, 4.2.1, 4.2.2	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.03	Evolving Water Chemistry in the Near-Field	SRR-CWDA-2010-00128, Rev. 0	4.2.2, 6.1	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.04	Evolving Water Chemistry in the Far-Field	SRR-CWDA-2010-00128, Rev. 0	4.2.2, 5.2.1	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.05	pH Conditions	SRR-CWDA-2010-00128, Rev. 0	4.2, 4.2.1, 4.2.2	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.06	Eh Conditions	SRR-CWDA-2010-00128, Rev. 0	4.2, 4.2.1, 4.2.2	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.5.07	Colloid Generation	SRNL-STI-2011-00498, Rev. 0	4.2.2, 8.2	The report "Mobilization and Characterization of Colloids Generated from Cement Leachates Moving Through a SRS Sandy Sediment" examines the potential for colloid generation within the native environment. The conclusion of the report indicated "that very little colloidal materials were generated ... " and "What little that was precipitated, was too large to move through porous media."
3.5.08	Chemical Effects of Waste-Rock Contact	SRR-CWDA-2010-00128, Rev. 0	3.1.6, 4.2.1.2, 4.2.1.8, 5.2.1, 6.1	Chemical effects of waste-rock contact that can influence water chemistry and the related transport and release mechanisms are addressed.
3.5.09	Rind (Chemically Altered Zone) Forms in the Near-Field	SRR-CWDA-2010-00128, Rev. 0	4.2.1	The leaching of cementitious materials into the soil and the effects this material has on the chemistry of this soil, as related to contaminant transport, was considered.
3.5.10	Complexation in the Natural System	SRR-CWDA-2010-00128, Rev. 0	4.2.1.7	The effects of carbonation and calcite are discussed.
3.5.11	Reaction Kinetics	SRR-CWDA-2010-00128, Rev. 0	4.2.1	The PA model assumes equilibrium state for various reactions.
3.5.13	Osmotic Effects	WSRC-STI-2007-00184, Rev. 2	3.2.4	Flow through the GCL, prior to closure cap degradation, is an osmotic process.
3.5.14	Leaching	SRR-CWDA-2010-00128, Rev. 0	4.2.1	The leaching of cementitious materials into the soil and the effects this material has on the chemistry of this soil, as related to contaminant transport, was considered.
3.6.03	Thermo-Chemical Alteration, Near-Field	WSRC-STI-2007-00184, Rev. 2	3.2.4, 4.2.2.2	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for temperature and thermal effect on the near-field. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.6.07	Temperature and Thermal Gradient Effects on the Geosphere	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for temperature and thermal effect on the near-field. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.7.01	Chemical Degradation of Engineered System Metals	SRR-CWDA-2010-00128, Rev. 0	2.6.5.1, 4.2.2.2.6	Waste tank liner failure is a significant modeling parameter included in the PA. "Degradation of the waste tank steel encased in grouted conditions was estimated due to carbonation of the concrete leading to low pH conditions, or the chloride-induced depassivation of the steel leading to accelerated corrosion."
3.7.02	Corrosion	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.6, 4.4.2, 4.4.3	Waste tank liner failure is a significant modeling parameter included in the PA. "…studies developed estimates for corrosion-induced failure of the steel liners. These estimates considered general and localized corrosion mechanisms…"
3.7.03	Stress-Corrosion Cracking and Hydride Cracking of Engineered System Metals	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.6, 4.4.2, 4.4.3, 5.6.3.7	Waste tank liner failure is a significant modeling parameter included in the PA. "The waste tank steel life estimates assume general corrosion and pitting (leading to stress corrosion cracking) are the primary corrosion mechanisms…"
3.7.06	Waste Container, Package, or Over-Pack Failure	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.6, 5.6.3.7	Tank liner failure is explicitly modeled and discussed throughout the PA. "…studies developed estimates for corrosion-induced failure of the steel liners.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.7.07	Degradation of Non-Metal Solids: Backfill, Rock, Grout, Cement, etc.	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2, 3.2.4.7, 4.2.2.2.4	Degradation of non-metal solids is explicitly modeled and discussed throughout the PA.
3.7.08	Swelling of Backfill and Emplacement Materials	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for swelling of materials. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.7.09	Concrete Shrinkage/Expansion	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.4	The PA Model assumes concrete shrinkage will have a negligible effect on the grout and does not model this process. “Two areas bounded by the carbonation front mechanism and therefore not explicitly simulated in the sub-model are shrinkage and thermal cracking of the grout.”
3.7.10	Sulfate and Chloride Attack	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2, 4.2.2.2.6	Various chemical degradation mechanisms (such as sulfate attack and carbonation) have been considered during the development of degradation modeling. “Sulfate attack represents a complex set of chemical and physical processes…” “Degradation of the waste tank steel encased in grouted conditions was estimated due to carbonation of the concrete leading to low pH conditions, or the chloride-induced depassivation of the steel leading to accelerated corrosion. Chloride-induced corrosion was determined to be the more aggressive phenomenon.”

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.7.11	Carbonation	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2, 4.2.2.2.4, 4.2.2.2.6	Various chemical degradation mechanisms (such as sulfate attack and carbonation) have been considered during the development of degradation modeling. "The most extensive attack comes from carbonation."
3.7.12	Polymer Degradation	WSRC-STI-2007-00184, Rev. 2	3.2.4	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for polymer degradation for the GCL. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
3.8.01	Alternatives to Pre-Closure Activities	DOE/EIS-0303	2.4.4, 3.2.1.6, 3.2.3, 4.2.3	The "High-Level Waste Tank Closure Final Environmental Impact Statement" discusses alternatives for waste tank cleaning and stabilization.
3.8.02	Incomplete Closure	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 4.4.2	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities.
3.8.03	Error in Waste Removal and Stabilization	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 4.4.2	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities.
3.8.04	Inadequate Quality Assurance/Control and Deviations from Design	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 4.4.2	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities.
3.8.05	Remedial Actions	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 4.4.2	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.8.06	Void Space Formation	SRR-CWDA-2010-00128, Rev. 0	3.2.3, 4.2.2.2, 4.4.2, 5.6.3.6	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities. "…some uncertainty was applied to represent void spaces forming all the way through the basemat…"
3.8.07	Material Volume Changes	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2	This section discusses the effects of volumetric expansion of degraded materials. "…continued expansion results in more cracking and spalling of the concrete cover…"
3.8.08	Electrochemical Effects in the Closure System (Including Anion Exclusion)	SRR-CWDA-2010-00128, Rev. 0	4.2.1	Reduction potential (or E*h*) is an electrochemical property that influences radionuclide release and transport.
3.8.09	Mechanical Effects at EBS Component Interfaces	K-CLC-F-00073, Rev. 2	3.2.1.6, 3.2.4	The report "Static Settlement of F-Area Waste Storage Tanks 18 and 19" examined waste tank stability and other mechanical effects. This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
4.1.01	Waste Type Classification	SRR-CWDA-2010-00128, Rev. 0	2.5, 2.6.4, 3.3.1	Waste properties and features are explicitly modeled in the PA.
4.1.02	Waste Form Characteristics	SRR-CWDA-2010-00128, Rev. 0	3.3, 4.2.2, 4.5.2.2	Waste properties and features are explicitly modeled in the PA.
4.1.03	Waste Inventory	SRR-CWDA-2010-00128, Rev. 0	3.3.1, 3.3.2, 3.3.3, 3.4	Waste properties and features are explicitly modeled in the PA.
4.1.04	Waste Allocation and Emplacement	SRR-CWDA-2010-00128, Rev. 0	3.3.1, 3.3.2, 3.3.3	Waste properties and features are explicitly modeled in the PA.
4.1.05	Waste Homogeneity	SRR-CWDA-2010-00128, Rev. 0	3.3	Waste properties and features are explicitly modeled in the PA.
4.1.06	Highly Radioactive Radionuclides (HRRs)	SRR-CWDA-2010-00128, Rev. 0	5.2.2	Results discussed in the PA focus on the impacts from the HRRs. The PA refers to these as "Sensitivity Run Radionuclides."
4.1.07	Metallic Wastes	SRR-CWDA-2010-00128, Rev. 0	3.3, 3.4	Implicit in the description of the waste inventory is consideration of the properties of metallic wastes.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.1.08	Non-Metallic, Inorganic Wastes	SRR-CWDA-2010-00128, Rev. 0	3.3, 3.4	Implicit in the description of the waste inventory is consideration of the properties of non-metallic, inorganic wastes.
4.1.09	Organic Wastes	SRR-CWDA-2010-00128, Rev. 0	3.3, 3.4	Implicit in the description of the waste inventory is consideration of the properties of organic wastes.
4.1.10	Volatiles and Potential for Volatility	SRR-CWDA-2010-00128, Rev. 0	4.2.1.2.1, 4.2.2.1, 7.2.9	Volatiles and potential volatility are conservatively handled within the PA.
4.2.01	Radioactive Decay and In-Growth	SRR-CWDA-2010-00128, Rev. 0	3.3.1, 3.3.2, 3.4	Waste properties and features are explicitly modeled in the PA.
4.2.02	Activity Limits in Disposed Waste	SRR-CWDA-2010-00128, Rev. 0	3.4	Waste properties and features are explicitly modeled in the PA.
4.2.03	Contaminant Solubility, Solubility Limits, and Speciation	SRR-CWDA-2010-00128, Rev. 0	4.2.1.2	Waste properties and features are explicitly modeled in the PA. "An independent conceptual waste release model was used to simulate stabilized contaminant release from the grouted waste tanks based on various chemical phases in the waste tank controlling solubility..."
4.2.04	Reduction-Oxidation Potential (Redox Fronts)	SRR-CWDA-2010-00128, Rev. 0	4.2.1, 4.2.1.2, 4.4.2	Redox fronts are an important modeling parameter for contaminant transport in the PA. "…contaminants begin to leach from the degraded system based on changes to the pH and redox potential of the residual contamination on the floor of the waste tank system."
4.2.06	Degradation of the Inorganic Waste	SRR-CWDA-2010-00128, Rev. 0	3.2.3.2, 4.2.2.2.4	Waste properties and features are explicitly modeled in the PA.
4.2.07	Degradation of the Organic Waste	SRR-CWDA-2010-00128, Rev. 0	3.3.3	"Specific controls exist precluding the introduction of organic constituents to the waste tank systems therefore they were not considered while establishing inventory or for the PA modeling."
4.3.01	Contaminant Concentrations in Water and Other Media	SRR-CWDA-2010-00128, Rev. 0	4.2.2, 5.2, 5.4	Concentrations are modeled as a primary input for the dose calculations.
4.3.02	Dissolution and Precipitation	SRR-CWDA-2010-00128, Rev. 0	4.2.2	Concentrations are determined based on dissolution and precipitation of contaminants.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.3.03	Solubility and Sorption Changes From Chemical and Temperature Interactions	SRR-CWDA-2010-00128, Rev. 0	4.2.2	Concentrations are determined based on solubility and sorption of contaminants.
4.3.04	Dilution of Radionuclides in Groundwater	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.2, 5.2	As concentration is explicitly modeled, dilution is implicitly considered.
4.3.05	Radionuclide Accumulation (Recycling) in Soils	SRR-CWDA-2010-00128, Rev. 0	5.4.1.1.5, 5.6.3.12	A soil buildup factor is included in the PA dose calculation. "A soil buildup factor was applied to account for the buildup of radionuclide concentration in the soil from successive years of irrigation."
4.4.01	Human Exposure Pathways	SRR-CWDA-2010-00128, Rev. 0	4.2, 4.5.4, 4.6.2	Exposure pathways are important parameters for the PA dose calculation. "… [Human] exposure pathways must be defined to calculate receptor doses ... All potential exposure pathways are identified…"
4.4.02	Food Preparation and Water Processing	SRR-CWDA-2010-00128, Rev. 0	4.2.4, 4.6.1, 4.6.2, 5.4, 5.5, 5.6.3.12, 6.3	Development of ingestion parameters (for dose calculations) implicitly considers the effects of food preparation and water processing. EPA-822-R-00-001 "…considers indirect ingestion of water from food with water added at the final phase of food preparation and reports water consumption…"
4.4.03	Radon and Radon Daughter Exposure (Noble Gas Contamination)	SRR-CWDA-2010-00128, Rev. 0	4.5.6, 4.5.7, 5.3, 7.2.9	Radon exposure is explicitly modeled and considered in the PA.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.4.04	Animal, Plant, and Microbe Uptake and Migration of Contaminants	SRR-CWDA-2010-00128, Rev. 0	4.6.1, 4.6.2, 5.4	Dose to plants and animals are considered with respect to their respective roles as pathways to human exposure. "For PA analyses at SRS, soil-to-vegetable …, feed-to-milk, feed-to-beef, water-to-fish, feed-to-poultry, and feed-to-egg transfer factors are the bioaccumulation factors considered."
4.4.05	Radiological Dose Effects/Risks	SRR-CWDA-2010-00128, Rev. 0	4.6.2, 4.7, 4.8.2	Radiological doses are key performance results. "Radiation doses to humans may result from internal inhalation or ingestion of radionuclides by or from external exposure to radionuclides present in the environment. Dose assessment at SRS is carried out by considering radionuclide concentrations in environmental media, factoring in human exposure conditions, and performing the conversion of exposure to dose."
4.4.06	Radiological and Chemical Toxicity/Effects	SRR-CWDA-2010-00128, Rev. 0	2.1.2, 4.8, 5.7	The RCRA/CERCLA Risk Analysis considers the effects of various contaminants. "The data for radiological contaminants were used in combination with the inputs related to receptors … to estimate the potential dose to a hypothetical MOP or an intruder. The data for non-radiological contaminants were used ... to determine the resulting risk to the hypothetical MOP. This risk assessment approach followed the SRS Accelerated Closure Projects (ACP) protocols for human health and ecological risk assessments."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.5.02	Radiation Effects on the Waste Closure System	SRR-CWDA-2010-00128, Rev. 0	3.3, 3.4, 4.2.2.2	Prior to waste removal, the waste tanks contain significantly greater volumes of radioactive material. Despite the larger volumes, the integrity of the system components has not been compromised by radiation effects. It is therefore reasonable to assume that removing waste would significantly reduce any such risk.
4.5.03	Radionuclide Interaction with Corrosion Products	SRR-CWDA-2010-00128, Rev. 0	4.2.1, 4.2.2.2.6	The leaching of degraded materials (both metal and cementitious) into the soil and the effects this material has on the chemistry of the soil, as related to contaminant transport, was considered; however, the effects of corrosion products from the failed steel liner are ignored as a conservative assumption. "After failure, the liner is assumed to not be a hindrance to advection and diffusion (i.e., retardation due to the presence of corrosion products is not included in the model)."
4.5.04	Natural or Background Radiation	SRNL-STI-2009-00512, Rev.0	3.1.8	The SRS Composite Analysis assesses contaminants from other site sources.
4.5.05	Medical Radiation	SRNL-STI-2009-00512, Rev.0	3.1.8	The SRS Composite Analysis assesses contaminants from other site sources.
4.5.06	Contaminants from Other Man-Made Sources or Facilities	SRNL-STI-2009-00512, Rev.0	3.1.8	The SRS Composite Analysis assesses contaminants from other site sources.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.5.07	Radiolysis Effects	S-TSR-G-00001, Rev. 26	3.3, 3.4	The report "*Concentration, Storage, and Transfer Facilities, Technical Safety Requirements*" discusses current radiolysis effects in the tank farms. Under current conditions (i.e., prior to waste removal) only a single tank in both FTF and HTF (Tank 48) was identified as having a risk related to radiolysis effects. This impact is prior to waste removal activities. It is therefore reasonable to assume that after cleaning, none of these tanks will see significant impact from radiolysis.
5.1.01	Groundwater Flow and Movement (Near-Field)	SRR-CWDA-2010-00128, Rev. 0	3.1.5.2, 3.1.5.3, 3.2.1, 3.2.2, 4.2.2.1.3, 4.4.3.8, 4.4.4.1.4	Groundwater flow is explicitly discussed throughout the PA.
5.1.02	Groundwater Flow and Movement (Far-Field)	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.3, 4.4.4.1.4	Groundwater flow is explicitly discussed throughout the PA.
5.1.03	Episodic Or Pulse Flow and Release	SRR-CWDA-2010-00128, Rev. 0	3.1.2.3.2, 4.3.1.1, 7.2.2	Due to the extended time frame, episodic rainfall events are expected to have a negligible impact on overall results. Therefore, the PA averages annual rainfall to determine infiltration/flow. "Compilations of rainfall data obtained ... for the site ... [were used to determine] appropriate rainfall assumptions for the performance evaluation of infiltration through the closure cap ..."
5.1.04	Water Influx at the Closure Facility	SRR-CWDA-2010-00128, Rev. 0	4.4.3	Water influx at the closure facility is explicitly modeled in the PA. "The flow leaving the closure cap will travel to the waste tank…"

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.1.05	Focusing of Flow Along Preferred Flow Paths (Fingers, Weeps, Faults, Fractures, etc.)	SRR-CWDA-2010-00128, Rev. 0	4.2.2, 4.4.2, 4.4.3.4	The alternative modeling scenarios consider fast flow paths. "… [For some] scenarios used in the sensitivity analyses … fast flow paths through the grout were modeled."
5.1.07	Flow Diversion and Bypass Flow	SRR-CWDA-2010-00128, Rev. 0	4.2.2, 4.4.2, 4.4.4.1.2, 5.6.3	The alternative modeling scenarios consider alternative flow paths. "… [For some] scenarios used in the sensitivity analyses … fast flow paths through the grout were modeled."
5.1.08	Film/Laminar Flow	SRR-CWDA-2010-00128, Rev. 0	4.4.4.1.2	The PA shows that the waste tanks are assumed to be very saturated (i.e., more than 99%). Therefore, film/laminar flow would not impact results.
5.1.09	External Flow Boundaries	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.2, 4.2.2.1.3, 4.2.2.1.4	The external flow boundaries are defined and described within the PA.
5.1.10	Alteration and Chemical Weathering Along Flow Paths	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.2, 4.2.2.2.3	Degradation of materials implies alteration of the flow paths. In addition, the backfill and soil properties are already relatively unconsolidated – thus the natural system is not likely to undergo any significant change with respect to flow path.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.2.01	Hydrological Response to Geological Changes	SRR-CWDA-2010-00128, Rev. 0	3.1.4.3	Various hydrologic processes were considered during the development of the flow and transport parameters. Studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities. "… the conclusion has been reached that these faults have not had a movement within the past 35,000 years and no movement of a recurring nature within the past 500,000 years. Inclusion in the Atlantic Coastal Fault Province means that the historical precedent established by decades of previous studies on the seismic hazard potential for the Atlantic Coastal Fault Province is relevant to faulting at the SRS."
5.2.03	Hydraulic Potentials and Gradients	SRR-CWDA-2010-00128, Rev. 0	3.1.5.2, 3.1.5.3, 4.2.2.1.3	Hydrostratigraphy is explicitly considered in the development of the PA flow models. "The GSAD [General Separations Area Database] is a subset of site-wide data sets of soil lithology and groundwater information. Figure 3.1-18 shows the location of all hydrostratigraphic picks used in the GSAD. Picks were made based on a combination of geophysical logs, Cone Penetration Test (CPT) logs, and core descriptions."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.2.04	Interfaces Between Different Waters	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.5	Transport model interfaces are specifically considered in the development of the PA flow models. For example: "Groundwater flow in the much larger scale saturated zone, or aquifer model, is controlled by net infiltration or recharge over a broad area surrounding the HTF. Rather than using the flow exiting the vadose zone at the water table as a direct input to the aquifer model, an average recharge value is applied to the aquifer flow model based on field studies."
5.2.05	Effects Related to Air and Vapor Flow and Evaporation within the System	SRR-CWDA-2010-00128, Rev. 0	4.5, 5.3	The PA provides an airborne pathway transport analysis and summary of dose to MOP.
5.2.06	Perched Water Develops	SRR-CWDA-2010-00128, Rev. 0	3.2.4.5.2	Site preparation indicates that prior to closure consideration shall be given to breaking up surfaces to prevent features from acting as perched water zones. "…surfaces … may need to be broken up or removed in order to prevent the asphalt from acting as a perched water zone within the closure cap and to promote downward infiltration …"
5.3.01	Contaminant Release and Migration Factors	SRR-CWDA-2010-00128, Rev. 0	4.2.2	The PA explicitly examines and models contaminant release and migration. "Over the course of time, the mobile contaminants in the closed waste tanks and ancillary equipment are likely to release and gradually migrate downward through unsaturated soil to the hydrogeologic units comprising the shallow aquifers underlying the HTF."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.02	Contaminant Release Pathways	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.2, 4.2.2.1.3, 4.2.3.1	The PA explicitly examines and models contaminant release and migration pathways. “Exposure to contaminants could occur through various pathways associated with groundwater, surface water uses, and air exposure.”
5.3.03	Multiphase Transport Processes	SRR-CWDA-2010-00128, Rev. 0	4.2	Various transport phases, pathways, and mechanisms have been considered in the development of the PA.
5.3.04	Contaminant Release from the Waste Form and Engineered Barrier System	SRR-CWDA-2010-00128, Rev. 0	4.2.1	The PA explicitly examines and models contaminant release and migration. “In the waste release model, there are three phase types considered, 1) an aqueous pore fluid phase, 2) a matrix phase composed primarily of non-radionuclide elements, and 3) discrete radionuclide phases embedded in the matrix.”
5.3.05	Solid-Mediated Migration of Contaminants	SRNL-STI-2011-00498, Rev. 0	4.2.2	The recent report "Mobilization and Characterization of Colloids Generated from Cement Leachates Moving Through a SRS Sandy Sediment" examines the potential for colloid generation within the native environment. The conclusion of the report indicated "that very little colloidal materials were generated ... " and “What little that was precipitated, was too large to move through porous media."
5.3.06	Gas-Mediated Migration of Contaminants	SRR-CWDA-2010-00128, Rev. 0	4.5, 5.3	The PA provides an airborne pathway transport analysis and summary of dose to MOP.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.07	Water-Mediated Migration of Contaminants	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.2, 4.2.2.1.3	The PA explicitly examines and models water-mediated contaminant migration. "The primary mechanism for transport of radionuclides from the HTF is expected to be leaching to the groundwater, groundwater transport to the well and the stream, and subsequent human consumption or exposure."
5.3.08	Diffusion (Molecular Diffusion and Matric)	SRR-CWDA-2010-00128, Rev. 0	4.2.2	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. For example: "The cementitious materials … will influence the HTF contaminant transport processes in cementitious materials and soils including advection, diffusion, dispersion, and sorption."
5.3.09	Dispersion and Imbibition	SRR-CWDA-2010-00128, Rev. 0	4.2.2	This FEP represents important parameters in the groundwater flow and transport model that is explicitly included within the PA. For example: "The cementitious materials … will influence the HTF contaminant transport processes in cementitious materials and soils including advection, diffusion, dispersion, and sorption."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.10	Advection	SRR-CWDA-2010-00128, Rev. 0	4.2.2	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. For example: "The cementitious materials … will influence the HTF contaminant transport processes in cementitious materials and soils including advection, diffusion, dispersion, and sorption."
5.3.11	Sorption and Desorption of Dissolved Contaminants (Kd Retardation)	SRR-CWDA-2010-00128, Rev. 0	4.2.2	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. For example: "The cementitious materials … will influence the HTF contaminant transport processes in cementitious materials and soils including advection, diffusion, dispersion, and sorption."
5.3.12	Radionuclide Fluxes to the Biosphere	SRR-CWDA-2010-00128, Rev. 0	4.2.3, 5.2	Radionuclide fluxes into the biosphere are explicitly modeled in the PA. "The primary water source for the MOP exposure pathways is a well drilled into the groundwater aquifers. A GSA stream is the secondary water source for recreational use pathways and the fish ingestion pathway."
5.3.13	Fast Transport Pathways	SRR-CWDA-2010-00128, Rev. 0	4.4.1, 4.4.2, 5.6	The alternative modeling scenarios consider fast flow paths. "… [For some] scenarios used in the sensitivity analyses … fast flow paths through the grout were modeled."
5.3.14	Long-Term Release of Radionuclides	SRR-CWDA-2010-00128, Rev. 0	4.4.2, 4.4.3, 5.5.1	The PA modeling simulates effects to 100,000 years after closure.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.15	Radionuclide Release Outside The Reference Biosphere	SRNL-STI-2009-00512, Rev. 0	4.4.4.1	The SRS Composite Analysis shall assess contaminant discharge outside the HTF boundary.
5.3.16	Vadose Zone Depth	SRR-CWDA-2010-00128, Rev. 0	4.2.2.2.2, 5.6.3.9	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. "The thicknesses of the vadose zone below the different waste tanks range from approximately -35.5 to 18.2 feet with negative values indicating the base of the tank is below the water table."
5.3.17	Saturated Zone Depth	SRR-CWDA-2010-00128, Rev. 0	4.2.2.1.3, 5.6.3.10	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. "The aquifer thickness is therefore important to the receptor dose calculation, because it defines the cell volume, which directly affects the concentration."
5.3.18	Depth of Assessment Well	SRR-CWDA-2010-00128, Rev. 0	5.6.3.11	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. "To simulate the probability that the well source might be drilled into a lower aquifer … well depth probabilities … [were] used."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.19	Horizontal Distance to Points of Assessment	SRR-CWDA-2010-00128, Rev. 0	5.2.1	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA. "Since contaminant transport is not via a straight line, but by the applicable aquifers, the actual travel distance to reach 100 meters from the HTF boundary is greater than 100 meters for some sources."
6.1.01	Inadvertent Human Intrusion	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2, 6.2, 6.3, 6.4,	The IHI analysis is explicitly modeled in the PA. "…[The] HTF PA provides inadvertent intruder doses consistent with the requirements for 10 CFR 61.42, as well as analyses for the air pathways and radon ground surface flux consistent with the requirements for DOE O 435.1 Chg 1."
6.1.02	Deliberate Human Intrusion	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2, 6.2, 6.3, 6.4,	A deliberate intrusion would have similar impacts to an inadvertent intrusion.
6.1.03	Drilling Activities	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2, 4.2.3.2.5, 5.6.3.11, 6.2, 6.3, 6.4,	Drilling activities are explicitly considered in the IHI analysis. "It is assumed, in this scenario, that an intruder lives in a building near the well drilled as part of the intruder-drilling scenario and engages in agricultural and recreational activities on the contaminated site and stream."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.1.04	Excavating and Mining Activities	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2.3	Excavation is discussed in the PA and identified as not an applicable dose pathway due to the disposal depth of the stabilized contaminants. "In this scenario, it is assumed that after the end of active institutional controls, a construction project begins at the site with associated earthmoving [i.e., excavating] activities ... Due to the disposal depth of the stabilized contaminants in the waste tanks and in ancillary equipment … [this] scenario is not considered applicable."
6.1.05	Animal/Plant Intrusion	SRR-CWDA-2010-00128, Rev. 0	4.2.3.2.8	This Scenario is considered bounded by the results of the human intrusion scenarios. "The amount of contamination excavated from animal burrows or vegetative intrusion is far less than that involved in the agricultural (intruder-drilling) scenarios for drilling a domestic well into the underlying aquifers. Therefore, this scenario is bounded by the Chronic Intruder-Agricultural (Post-Drilling) Scenario and … does not require further analysis."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.1.06	Igneous or Seismic Event Precedes Human Intrusion	SRR-CWDA-2010-00128, Rev. 0	3.1.4	Although this FEP is not explicitly addressed, studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities. Uncertainty and sensitivity analyses, as well as conservatisms built into the intruder scenario and alternative modeling scenarios, are assumed to capture the impact of this FEP. "… the conclusion has been reached that these faults have not had a movement within the past 35,000 years and no movement of a recurring nature within the past 500,000 years. Inclusion in the Atlantic Coastal Fault Province means that the historical precedent established by decades of previous studies on the seismic hazard potential for the Atlantic Coastal Fault Province is relevant to faulting at the SRS."

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.2.01	Seismicity	SRR-CWDA-2010-00128, Rev. 0, SRR-CWDA-2011-00054, Rev. 1	3.1.4.3, 4.4.2	As discussed within the PA, tectonic and seismic activity are considered; however studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities. The response to RAI-SS-2 provides additional detail to how this FEP was considered. Although alternate tank configurations are not explicitly linked to seismic events, the types of cracks caused by credible seismic events at the HTF are assumed to be bounded by these alternate tank configurations. “. The presence of the channel in the model is not ascribed to a particular cause, but is used to reflect the fact that various mechanisms have been postulated that could result in a significantly increased hydraulic conductivity (e.g., grout shrinkage, seismic induced fractures).”
6.2.02	Seismic-Induced Damage or Changes to System Components	SRR-CWDA-2010-00128, Rev. 0	3.1.4.3, 3.2.3.2, 4.4.2	As discussed within the PA, tectonic and seismic activity are considered; however studies have shown that the geologic area is tectonically stable and the events that would impact performance have been characterized as having low probabilities.
6.2.03	Effects of Subsidence	K-CLC-F-00073, Rev. 2	3.2.1.6, 3.2.3.2	The report "Static Settlement of F-Area Waste Storage Tanks 18 and 19" examined the potential for waste tank movement due to static loading (which is perceived to be the most likely mechanism for tank movement). This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.4.02	Flooding or Drainage System Failure	SRR-CWDA-2010-00128, Rev. 0	3.1.5.4	The PA indicates that flood hazard analyses showed that no impact is expected from flooding due to low likelihood. "Flood hazard recurrence frequencies have been calculated ... [and determined that] flooding will not affect the HTF and is therefore not considered in this PA."
6.4.03	Movement of the Waste Form	K-CLC-F-00073, Rev. 2	3.2.1.6, 3.2.3.2	The report "Static Settlement of F-Area Waste Storage Tanks 18 and 19" examined the potential for waste tank movement due to static loading (which is perceived to be the most likely mechanism for tank movement). This report applies to the HTF PA, as the tank configurations and site-specific environments are similar or identical.
6.4.04	Cave-In, Collapse, or Rockfall	SRR-CWDA-2010-00128, Rev. 0	3.2.4.4	The stability of the engineered system is predicated on the stability of the closure cap. "Calculations to evaluate the physical stability of the closure cap design … have been made … While the methodology … specifically addresses a 1,000-year timeframe, the use of site-specific PMP event data … provides assurance of physical stability of the closure cap design…." Therefore, this FEP has been considered and determined to be inconsequential.
6.4.05	Accidents and Unplanned Events	SRR-CWDA-2010-00128, Rev. 0	4.4.2, 5.6.3, 5.6.4, 5.6.5, 5.6.7, 5.6.8	Although this FEP is not explicitly addressed by the PA, uncertainty and sensitivity analyses, as well as conservatisms built into the intruder scenario and alternative modeling scenarios, are assumed to capture the impact of this FEP.

Table 3.0-1: LW FEPs to HTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.4.06	Explosions and Crashes	SRR-CWDA-2010-00128, Rev. 0	4.4.2, 5.6.3, 5.6.4, 5.6.5, 5.6.7, 5.6.8	Although this FEP is not explicitly addressed by the PA, uncertainty and sensitivity analyses, as well as conservatisms built into the intruder scenario and alternative modeling scenarios, are assumed to capture the impact of this FEP.

4.0 CONCLUSIONS

This *ex post facto* FEPs analysis confirms that the existing (Revision 0) HTF PA appropriately considered the relevant FEPs within the tank configurations, the waste release modeling, the cementitious material and liner failure analyses, the air pathway and groundwater transport pathway scenarios, and the barrier analysis and uncertainty/sensitivity alternate modeling scenarios.

However, it should be noted that many of the findings in this evaluation draw conclusions based on implicit relationships between PA implementation and FEPs descriptions. In general, more explicit discussions of how specific FEPs have been addressed within the PA would have provided greater confidence that these FEPs have been adequately considered, yet this would have required FEPs screening prior to PA development. Regardless, this analysis has determined that the HTF PA appropriately applied the best available or best estimate values, and includes reasonably conservative assumptions that bound the impacts of the relevant FEPs. Additional modeling is not required in the HTF PA to evaluate the effects of the FEPs on the calculated doses to the MOP or IHI for Revision 0, or to further demonstrate compliance with performance objectives as defined in DOE Manual 435.1-1 and 10 CFR 61. Furthermore, future revisions of the HTF PA will not require additional modeling cases, configurations, or scenarios (beyond those identified within this document) to ensure adequate consideration of the relevant FEPs.

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