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Revision 0

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

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ACRONYMS/ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
C&WDA	Closure and Waste Disposal Authority
CA	Composite Analysis
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
E_h	Oxidation Potential
FEPs	Features, Events, and Processes
FTF	F-Area Tank Farm
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
PA	Performance Assessment
pH	The measure of the acidity or basicity of an aqueous solution
RCRA	Resource Conservation and Recovery Act
QA	Quality Assurance
SDF	Saltstone Disposal Facility
SRS	Savannah River Site

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. 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, over a minimum of 10,000 years, the F-Area Tank Farm (FTF) 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 F-Area Tank Farm (FTF) PA (in either the Base Case or the alternate modeling scenarios), or other supporting documentation.

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 FTF 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 FTF PA is applied as follows:

1. **PA Model Implementation –** Develop the FTF PA (SRS-REG-2007-00002, Rev. 1).
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 FTF PA (SRS-REG-2007-00002, Rev. 0) or other supporting documentation. Finally, Section 4 summarizes the findings of this analysis.

1.2 Quality Assurance

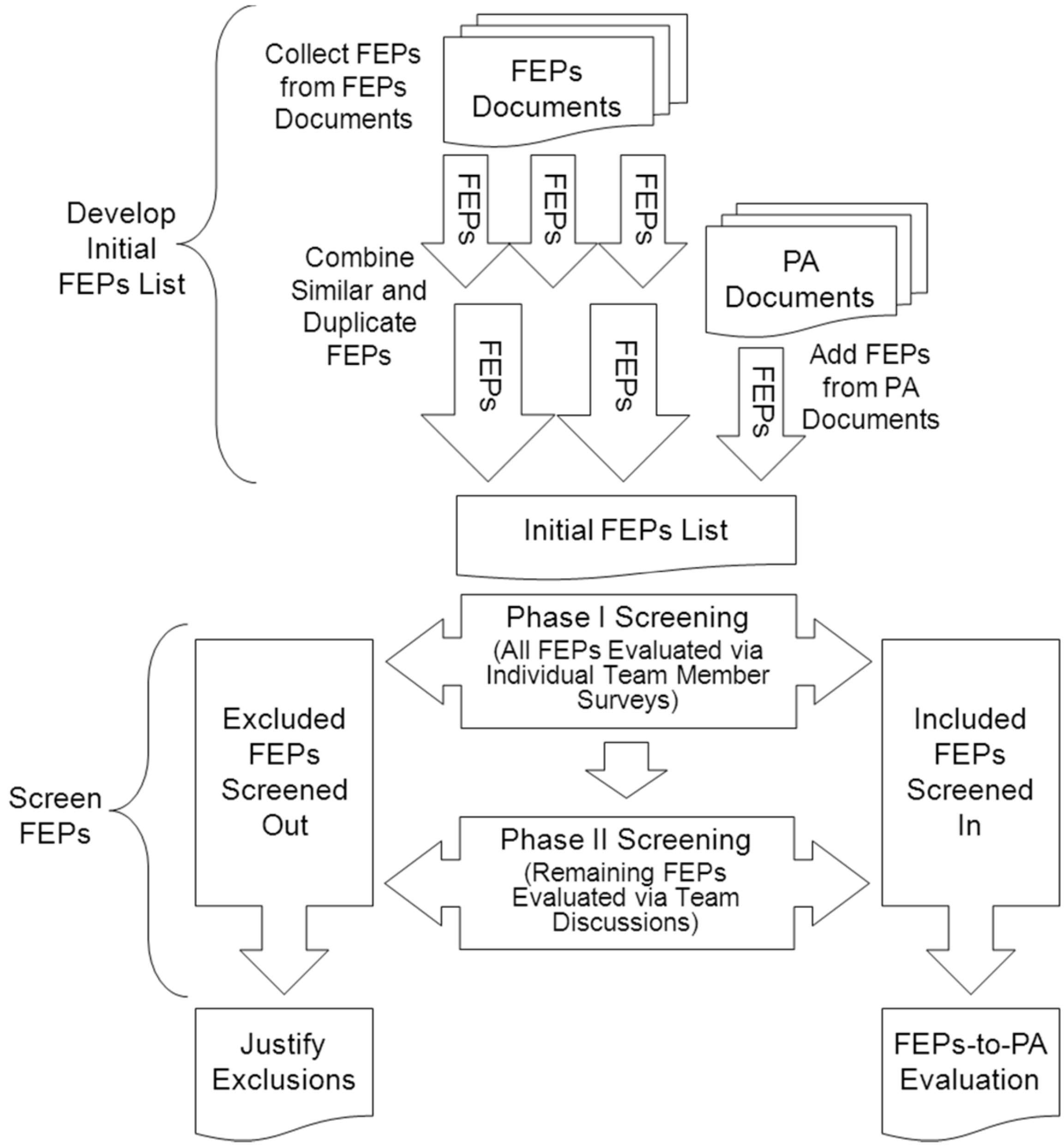
Development of this report and supporting analyses are subject to the quality assurance (QA) program and requirements as defined in Manual 1Q – *Quality Assurance Manual*. Consistent with this QA program, the information provided herein shall undergo technical and management review prior to approval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

2.0 LIQUID WASTES 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; institutional control to 10,000 years; beyond 10,000 years; 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 FTF PA

Table 3.0-1 provides the crosswalk that documents the evaluation of the LW FEPs considered in the FTF PA. In most cases, the document referenced is the FTF PA (SRS-REG-2007-00002, Rev. 1); however, some of the FEPs have been addressed through supporting technical reports or through regulatory-related documents.

Table 3.0-1: LW FEPs to FTF PA Evaluation

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.1.01	Assessment Context Factors	SRS-REG-2007-00002, Rev.1	1.0, 2.1	The PA approach and process state the performance objectives to be addressed.
1.1.02	Assessment Purpose	SRS-REG-2007-00002, Rev.1	2.1	"Performance Assessments are used to provide the DOE with a reasonable expectation that … closure of facilities will meet defined performance objectives for the protection of the public and the environment into the future."
1.1.03	Assessment Conditions	SRS-REG-2007-00002, Rev.1	2.1	The PA approach and process state the assessment conditions to be addressed.
1.1.04	Documentation and Presentation of Results	SRS-REG-2007-00002, Rev.1	1.0, 2.1, 2.4	The PA results and related documents are available for review by stakeholders.
1.1.05	Transparency of Assessment Approach	SRS-REG-2007-00002, Rev.1	1.0, 2.1	The inputs and basis for assumptions used are available for review by stakeholders.
1.1.06	Assessment Timeframe (Phases of Disposal)	SRS-REG-2007-00002, Rev.1	2.6.1, 2.6.5	"… no federal protection is assumed beyond the 100-year period of institutional control. The period of compliance will be 10,000 years following closure. A 100-year period of institutional control will begin in year 2020."
1.1.07	Safety Effects Beyond Periods of Control	SRS-REG-2007-00002, Rev.1	2.6.1, 2.6.5	The PA evaluates safety effects to 10,000 years, which is well beyond the 100-year period of control.
1.1.08	Spatial Domain of Concern	SRS-REG-2007-00002, Rev.1	4.2.3.1, 4.4.4.1	The referenced section provides a detailed description of the modeled area. Near-field and far-field (seepline) domains are described.
1.1.09	Assessment Endpoints	SRS-REG-2007-00002, Rev.1	2.5.1, 2.5.2	LLW disposal performance assessment endpoints to be addressed are identified and defined.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.2.01	Regulatory Compliance	SRS-REG-2007-00002, Rev.1	2.5.1, 2.5.2, 8.1	PA results with respect to regulatory compliance are discussed.
1.2.02	Protection of Human Health and the Environment	SRS-REG-2007-00002, Rev.1	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.
1.2.03	Performance Requirements and Criteria	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	2.4.4, 2.5, 3.1, 3.2	Various requirements are discussed and considered throughout the PA.
1.2.05	ALARA	SRS-REG-2007-00002, Rev.1	5.8	This section provides a detailed ALARA analysis.
1.2.06	Administrative Control of the Waste Closure Facility	SRS-REG-2007-00002, Rev.1	2.4.2, 2.4.3, 3.1.7	PA identifies the mission, vision, and responsibilities for monitoring.
1.2.07	Waste Acceptance Requirements and Criteria	SRS-REG-2007-00002, Rev.1	3.3.2	Process history and waste transfer data collected and used to determine residual volume and concentration.
1.3.01	Model and Data Issues	SRS-REG-2007-00002, Rev.1	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.
1.3.02	Software Codes	SRS-REG-2007-00002, Rev.1	4.3	Software is thoroughly discussed in this section.
1.3.03	Model Approaches	SRS-REG-2007-00002, Rev.1	4.2, 4.3	ISCM, PORFLOW, and GoldSim approaches and processes are discussed.
1.3.04	Systematic Assessment Approach	SRS-REG-2007-00002, Rev.1	2.1, 4.3, 5.6.2	Integration of PORFLOW and GoldSim models are discussed and benchmarked.
1.3.05	Iterative Assessment Approach	SRS-REG-2007-00002, Rev.1	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.3.06	Realistic Assessment Approach	SRR-CWDA-2011-00054, Rev. 1	2.6	The response to RAI-PA-1 provides a discussion of how "realistic" versus "conservative" approaches have been considered for the PA.
1.3.07	Conservative Assessment Approach	SRR-CWDA-2011-00054, Rev. 1	2.6	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	5.6	This combination of deterministic and probabilistic modeling provides confidence in the Base Case and alternative configurations.
1.3.10	Uncertainties	SRS-REG-2007-00002, Rev.1	5.6, 5.6.4	Section 5.6.4 provides a description of the uncertainty analyses.
1.3.11	Sensitivity Analyses	SRS-REG-2007-00002, Rev.1	5.6, 5.6.6	Section 5.6.6 provides a description of the sensitivity analyses.
1.3.12	Model Confidence	SRS-REG-2007-00002, Rev.1	5.6, 5.6.2	The benchmarking analysis developed in GoldSim provides an alternative model to provide greater confidence in the modeled results.
1.3.13	Alternative Simplified Modeling Approach	SRS-REG-2007-00002, Rev.1	5.6, 5.6.2	The benchmarking analysis developed in GoldSim uses simplified assumptions to implement flow data.
1.3.14	Evaluate Multiple Endpoints	SRS-REG-2007-00002, Rev.1	5.2, 5.5	Using the PORFLOW model for the Base Case, "the FTF PA provides groundwater radionuclide concentrations at 1m, 100m and exposure points at the two seeplines approximately 1,600m from FTF."
1.3.15	Processing Limitations to Modeling	SRS-REG-2007-00002, Rev.1	4.3	Modeling limitations were handled during model development and implementation.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
1.4.01	Development of Expertise	SRS-REG-2007-00002, Rev.1	9.0	PA preparers have numerous years of experience developing, revising, and analyzing, the PA.
1.4.02	Monitoring and Surveillance	SRS-REG-2007-00002, Rev.1	2.3, 2.4.1, 2.4.2, 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.
1.4.03	Retrievability	SRS-REG-2007-00002, Rev.1	2.4.4	FTF waste is residual after tank cleaning. The fill with grout option chosen prevents waste retrievability.
1.4.04	Regulatory and Peer Reviews	SRS-REG-2007-00002, Rev.1	Revision History	The Revision History indicates that Revision B of the PA was submitted to the DOE Low Level Waste (LLW) Federal Review Group (LFRG), followed by an initial issue (Rev 0) of the PA being released approximately four months later. Rev 0 incorporated review comments from the technical/peer review from the LFRG. Rev 1 incorporated additional review comments from regulators.
1.4.05	Confidence Building (External to Modeling)	SRS-REG-2007-00002, Rev.1	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.
1.4.06	Target Audience (Stakeholders Involvement)	SRR-CWDA-2009-00059, Rev. 0	2.1, 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).
2.1.01	Definition of the Exposed Member of the Public	SRS-REG-2007-00002, Rev.1	4.2.4.1, 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)	SRS-REG-2007-00002, Rev.1	4.6.2, 5.6.3.11	Diet and ingestion properties are used to define various dose factors.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.1.03	Human Behavior and Habits (Non-Diet Related)	SRS-REG-2007-00002, Rev.1	4.2.4.1	Although the PA does not explicitly define the MOP, consideration for the MOP characteristics and exposure pathways was given during the PA development.
2.1.04	Human Dwellings	SRS-REG-2007-00002, Rev.1	4.2.4.2.6	Although the PA does not explicitly define the features of MOP dwellings, consideration for such was given during the development of Section 4.2.4.2.6.
2.1.05	Demographics and Community	SRS-REG-2007-00002, Rev.1	3.1.1.1, 3.1.1.3, 4.2.4.2, 5.6.3.11	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	SRS-REG-2007-00002, Rev.1	3.1.7, 4.2.4.2, 5.6.3.11	Factors related to land and water use was considered during the development of the human health exposure parameters.
2.2.02	Water Management	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	4.6.2, 5.6.3.11	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	SRS-REG-2007-00002, Rev.1	4.2.4, 4.6.2, 5.6.3.11	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	SRS-REG-2007-00002, Rev.1	4.6.2, 5.6.3.11	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	SRS-REG-2007-00002, Rev.1	4.2.4, 4.6.2, 5.6.3.11	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)	SRS-REG-2007-00002, Rev.1	6.0	The PA makes conservative assumption about future human actions via the IHI analysis.
2.3.02	Future Knowledge of the Facility	SRS-REG-2007-00002, Rev.1	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.3.03	Social and Institutional Developments	SRS-REG-2007-00002, Rev.1	6.0	The human intruder scenario conservatively addresses the impact of future changes to social patterns.
2.3.04	Technological Developments	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	3.1.3, 4.2.4, 4.6	Factors related to biome impacts were considered during the development of the human health exposure parameters.
2.4.02	Microbial Activity	SRS-REG-2007-00002, Rev.1	3.2.3.3, 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 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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.5.01	Geological Environment and Processes	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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)	SRS-REG-2007-00002, Rev.1	3.1.4.3, 3.1.5, 3.1.5.1, 3.2.4.7	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.06	Near-Surface Aquifers and Water-Bearing Features	SRS-REG-2007-00002, Rev.1	3.1.5.1, 4.2.3, 4.2.3.1.4	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	SRS-REG-2007-00002, Rev.1, SRR-CWDA-2011-00054, Rev. 1	4.2.3, 4.4.4.1.2	Calibrations of the GSA/PORFLOW transport model implicitly reflect consideration for "soft-zone" effects. The response to RAI-FF-1 also addresses this FEP.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.5.08	Undetected Geologic Features	SRNL-STI-2010-00734	3.1.5.2, 4.2.3.2	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	SRS-REG-2007-00002, Rev.1	3.1.4.2, 4.2.3.2	Various geologic and environmental processes were considered during the development of the flow and transport parameters.
2.5.11	Hydraulic Properties	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.3.1.3, 4.2.3.2.2	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.
2.6.01	Mechanical Effects on Geologic Features	WSRC-STI-2007-00184, Rev. 2 and K-CLC-F-00073, Rev. 2	3.2.1.5, 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.
2.6.02	Tectonic Activity and Processes	SRS-REG-2007-00002, Rev.1, 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 Configuration D was not explicitly linked to seismic events, the types of cracks caused by credible seismic events at the FTF are assumed to be bounded by Configuration D.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.6.04	Deformation and Metamorphism	SRS-REG-2007-00002, Rev.1	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 FTF wastes will be buried in shallow conditions that are not conducive to these processes.
2.6.07	Deposition	SRS-REG-2007-00002, Rev.1	3.1.4.2	The SRS is located in the Upper Coastal Plain depositional environment. Soil and environmental properties inherently incorporate such depositional characteristics.
2.6.08	Erosion and Weathering	WSRC-STI-2007-00184, Rev. 2	3.4.2	The report "FTF Closure Cap and Infiltration Estimates" discusses stability considerations for the closure cap, including the effects of erosion and weathering.
2.6.09	Mass Wasting	WSRC-STI-2007-00184, Rev. 2	3.4.2	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.
2.6.12	Hydrogeological Processes and Conditions	SRS-REG-2007-00002, Rev.1	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
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.
2.7.03	Precipitation	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 (including precipitation) when developing the infiltration estimates.
2.7.05	Warm Weather Effects	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 (including weather) when developing the infiltration estimates.
2.7.06	Cold Weather Effects	SRS-REG-2007-00002, Rev.1 and SRR-CWDA-2011-00044, Rev. 1	3.1.2.3, 3.2.4, 3.2.4.7	Table 3.2-9 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 FTF PA.
2.7.07	Climate Change	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.
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.
2.8.01	Water	SRS-REG-2007-00002, Rev.1	3.1.7.1, 4.2.3.1	Water is a primary transport mechanism considered throughout the PA.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.8.02	Surface-Water Bodies	SRS-REG-2007-00002, Rev.1	3.1.1.1, 3.1.1.2, 3.1.3, 3.1.5, 3.1.7.1.1, 4.2.3.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	3.1.3, 3.1.5.1, 3.1.5.4, 3.1.7.1, 3.2.4.5.3, 4.2.3.1	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.
2.8.05	Capillary Rise	SRS-REG-2007-00002, Rev.1	4.2.3.2, 7.2.2	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	SRS-REG-2007-00002, Rev.1	3.2.4, 4.2.3.1.3, 4.2.3.1.4	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)).

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
2.8.07	Discharge Zones Within the Assessment Domain	SRS-REG-2007-00002, Rev.1	4.2.3.1.3, 4.2.3.1.4	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, 4.2.3.1	The SRS Composite Analysis shall assess contaminant discharge outside the FTF boundary.
2.8.09	Hydrological Regime and Water Balance (Near-Surface)	SRS-REG-2007-00002, Rev.1	3.2.4.1.3, 4.2.3.1.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	3.2	The PA discusses the construction and functions of the various FTF facilities.
3.1.03	Facility Factors	SRS-REG-2007-00002, Rev.1	3.2	The PA discusses the construction and functions of the various FTF facilities.
3.1.04	Multi-Barrier Safety Function	SRS-REG-2007-00002, Rev.1	3.2.1, 3.2.3, 3.2.4, 5.6.7.3	The PA discusses the construction and functions of the various FTF 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	SRS-REG-2007-00002, Rev.1	3.2, 3.2.1, 3.2.2, 3.2.3, 3.2.4	The PA discusses the construction and functions of the various FTF facilities. The PA also describes and analyzes multiple barriers to demonstrate the robustness of the closure system.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.2.02	Schedule and Planning	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	3.2	The PA describes the construction of closure tanks and facilities in significant detail.
3.2.06	Operation	SRS-REG-2007-00002, Rev.1	2.3	This section describes the Facility Life Cycle that includes facility operation.
3.2.07	Removal or Stabilization of Waste	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	2.3	This section describes the Facility Life Cycle that includes closure.
3.3.01	Closure System Features and Materials	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	3.2.1	These characteristics are important parameters considered during the development of the waste release model.
3.3.05	Closure System Buffer (Closure Cap, Backfill, and Near-Field Soil) Properties	WSRC-STI-2007-00184, Rev. 2	3.2.4, 4.2.3.2	The report "FTF Closure Cap and Infiltration Estimates" provides significant consideration of closure cap and soil properties to determine infiltration estimates.
3.3.06	Bentonite and Vermiculite Effects	WSRC-STI-2007-00184, Rev. 2	3.2.4, 4.2.3.2	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.3.07	Closure Cap Thickness and Material Properties	SRS-REG-2007-00002, Rev.1	4.2.3.2.1, 4.2.3.2.2	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	SRS-REG-2007-00002, Rev.1	3.2.1	The material properties of the closure cap parameters are explicitly considered in the PA.
3.3.09	Disposal Unit or Facility Floor Thickness	SRS-REG-2007-00002, Rev.1	3.2.1	The material properties of this parameter is explicitly considered in the PA.
3.3.10	Ancillary Equipment and Piping/Transfer Lines	SRS-REG-2007-00002, Rev.1	3.2.2	Ancillary equipment and transfer lines are modeled as contaminant sources in the PA.
3.4.01	Hydrological Processes and Conditions	SRS-REG-2007-00002, Rev.1	3.1.5, 3.2.3.3, 4.2.3.1.3, 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	SRS-REG-2007-00002, Rev.1	4.2.3.2.2	The moisture characteristic curves indirectly account for hydrostatic pressure in the system.
3.4.03	Condensation on Closure System Surfaces	SRS-REG-2007-00002, Rev.1	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.
3.5.01	Chemical/ Geochemical Processes and Conditions	SRS-REG-2007-00002, Rev.1	3.1.6, 4.2.2.1, 4.2.2.6, 4.2.3, 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	SRS-REG-2007-00002, Rev.1	3.1.6, 4.2, 4.2.2, 4.2.3	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 FTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.5.03	Evolving Water Chemistry in the Near-Field	SRS-REG-2007-00002, Rev.1	4.2.3, 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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	4.2, 4.2.2, 4.2.3	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.06	Eh Conditions	SRS-REG-2007-00002, Rev.1	4.2, 4.2.2, 4.2.3	Water chemistry evolution (such as Eh and pH transitioning) is a primary driver in changes to contaminant transport properties.
3.5.07	Colloid Generation	SRNL-STI-2011-00498, Rev. 0	4.2.3, 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	SRS-REG-2007-00002, Rev.1	3.1.6, 4.2.2.1, 4.2.2.6, 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	SRS-REG-2007-00002, Rev.1	4.2.2	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	SRS-REG-2007-00002, Rev.1	4.2.2.5	The effects of carbonation and calcite are discussed.
3.5.11	Reaction Kinetics	SRS-REG-2007-00002, Rev.1	4.2.2	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.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.5.14	Leaching	SRS-REG-2007-00002, Rev.1	4.2.2	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, 4.2.3.2	The report "FTF Closure Cap Concept and Infiltration Estimates" discusses considerations for temperature and thermal effect on the near-field.
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.
3.7.01	Chemical Degradation of Engineered System Metals	SRS-REG-2007-00002, Rev.1	4.2.3.2.5	Waste tank liner failure is a significant modeling parameter included in the PA.
3.7.02	Corrosion	SRS-REG-2007-00002, Rev.1	4.2.3.2.5, 4.4.2, 4.4.3	Waste tank liner failure is a significant modeling parameter included in the PA.
3.7.03	Stress-Corrosion Cracking and Hydride Cracking of Engineered System Metals	SRS-REG-2007-00002, Rev.1	4.2.3.2.5, 4.4.2, 4.4.3	Waste tank liner failure is a significant modeling parameter included in the PA.
3.7.06	Waste Container, Package, or Over-Pack Failure	SRS-REG-2007-00002, Rev.1	4.2, 4.4, 4.2.3.2.5	Tank liner failure is explicitly modeled and discussed throughout the PA.
3.7.07	Degradation of Non-Metal Solids: Backfill, Rock, Grout, Cement, etc.	SRS-REG-2007-00002, Rev.1	3.2.3.3, 3.2.4.7, 4.2.2.6, 4.2.3.2.3	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.
3.7.09	Concrete Shrinkage/Expansion	SRS-REG-2007-00002, Rev.1	4.2.3.2.3	The PA Model assumes concrete shrinkage will have a negligible effect on the grout and does not model this process.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.7.10	Sulfate and Chloride Attack	SRS-REG-2007-00002, Rev.1	3.2.3.3, 4.2.3.2.5	Various chemical degradation mechanisms (such as sulfate attack and carbonation) have been considered during the development of degradation modeling.
3.7.11	Carbonation	SRS-REG-2007-00002, Rev.1	3.2.3.3, 4.2.3.2.3, 4.2.3.2.5	Various chemical degradation mechanisms (such as sulfate attack and carbonation) have been considered during the development of degradation modeling.
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.
3.8.01	Alternatives to Pre-Closure Activities	DOE/EIS-0303	2.4.4, 3.2.1.5, 3.2.3, 4.3.2	The “High-Level Waste Tank Closure Final Environmental Impact Statement” discusses alternatives for waste tank cleaning and stabilization.
3.8.02	Incomplete Closure	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	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 FTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
3.8.06	Void Space Formation	SRS-REG-2007-00002, Rev.1	3.2.3, 4.2.3.2, 4.4.2	The alternative modeling scenarios implicitly consider the effects of incomplete tank closures or potential mistakes in waste removal and stabilization activities.
3.8.07	Material Volume Changes	SRS-REG-2007-00002, Rev.1	3.2.3.3	This section discusses the effects of volumetric expansion of degraded materials.
3.8.08	Electrochemical Effects in the Closure System (Including Anion Exclusion)	SRS-REG-2007-00002, Rev.1	4.2	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	3.2.1.5, 3.2.4	The report "Static Settlement of F-Area Waste Storage Tanks 18 and 19" examined waste tank stability and other mechanical effects.
4.1.01	Waste Type Classification	SRS-REG-2007-00002, Rev.1	2.5, 3.3.1	Waste properties and features are explicitly modeled in the PA.
4.1.02	Waste Form Characteristics	SRS-REG-2007-00002, Rev.1	3.3.1, 4.2.2, 4.5.2.2	Waste properties and features are explicitly modeled in the PA.
4.1.03	Waste Inventory	SRS-REG-2007-00002, Rev.1	3.3.2, 3.3.3	Waste properties and features are explicitly modeled in the PA.
4.1.04	Waste Allocation and Emplacement	SRS-REG-2007-00002, Rev.1	3.3.2, 3.3.3	Waste properties and features are explicitly modeled in the PA.
4.1.05	Waste Homogeneity	SRS-REG-2007-00002, Rev.1	3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.3	Waste properties and features are explicitly modeled in the PA.
4.1.06	Highly Radioactive Radionuclides (HRRs)	SRS-REG-2007-00002, Rev.1	3.3.2, 5.8	Results discussed in the PA focus on the impacts from the HRRs.
4.1.07	Metallic Wastes	SRS-REG-2007-00002, Rev.1	3.3	Implicit in the description of the waste inventory is consideration of the properties of metallic wastes.
4.1.08	Non-Metallic, Inorganic Wastes	SRS-REG-2007-00002, Rev.1	3.3	Implicit in the description of the waste inventory is consideration of the properties of non-metallic, inorganic wastes.
4.1.09	Organic Wastes	SRS-REG-2007-00002, Rev.1	3.3	Implicit in the description of the waste inventory is consideration of the properties of organic wastes.
4.1.10	Volatiles and Potential for Volatility	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.4.1, 7.2.4	Volatiles and potential volatility are explicitly modeled in the PA.
4.2.01	Radioactive Decay and In-Growth	SRS-REG-2007-00002, Rev.1	3.3.2, 4.2.1	Waste properties and features are explicitly modeled in the PA.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
4.2.02	Activity Limits in Disposed Waste	SRS-REG-2007-00002, Rev.1	3.3.2, 4.2.1	Waste properties and features are explicitly modeled in the PA.
4.2.03	Contaminant Solubility, Solubility Limits, and Speciation	SRS-REG-2007-00002, Rev.1	4.2.2	Waste properties and features are explicitly modeled in the PA.
4.2.04	Reduction-Oxidation Potential (Redox Fronts)	SRS-REG-2007-00002, Rev.1	4.2.2, 4.2.3.2.2	Redox fronts are an important modeling parameter for contaminant transport in the PA.
4.2.06	Degradation of the Inorganic Waste	SRS-REG-2007-00002, Rev.1	3.2.3.3, 4.2.2.6	Waste properties and features are explicitly modeled in the PA.
4.2.07	Degradation of the Organic Waste	SRS-REG-2007-00002, Rev.1	3.3	The characteristics of the waste were considered in the development of the model. However, as there were no organic wastes in the contaminant inventory, this FEP has no impact.
4.3.01	Contaminant Concentrations in Water and Other Media	SRS-REG-2007-00002, Rev.1	3.1.5.4, 3.3.2.3, 3.3.3, 4.2.2, 5.2, 5.4	Concentrations are modeled as a primary input for the dose calculations.
4.3.02	Dissolution and Precipitation	SRS-REG-2007-00002, Rev.1	4.2.2	Concentrations are determined based on dissolution and precipitation of contaminants.
4.3.03	Solubility and Sorption Changes From Chemical and Temperature Interactions	SRS-REG-2007-00002, Rev.1	4.2.2	Concentrations are determined based on solubility and sorption of contaminants.
4.3.04	Dilution of Radionuclides in Groundwater	SRS-REG-2007-00002, Rev.1	4.4.4.2.1	As concentration is explicitly modeled, dilution is implicitly considered.
4.3.05	Radionuclide Accumulation (Recycling) in Soils	SRS-REG-2007-00002, Rev.1	4.2.2, 4.2.4, 4.6.2, 5.6.3.11	A soil buildup factor is included in the PA dose calculation.
4.4.01	Human Exposure Pathways	SRS-REG-2007-00002, Rev.1	4.2.4, 4.5.4, 4.6.2	Exposure pathways are important parameters for the PA dose calculation.
4.4.02	Food Preparation and Water Processing	SRS-REG-2007-00002, Rev.1	4.2.4, 4.6.2, 5.4.1, 5.4.2, 5.5.2, 5.6.3.11, 6.3.1	Development of ingestion parameters (for dose calculations) implicitly considers the effects of food preparation and water processing.
4.4.03	Radon and Radon Daughter Exposure (Noble Gas Contamination)	SRS-REG-2007-00002, Rev.1	4.5.6, 4.5.7, 5.3, 7.2.4	Radon exposure is explicitly modeled and considered in the PA.

Table 3.0-1: LW FEPs to FTF 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	SRS-REG-2007-00002, Rev.1	4.2.4.2.8, 5.4.1, 5.4.2, 6.3.1.2, 6.3.1.3	Dose to plants and animals are only considered with respect to their respective roles as pathways to human exposure.
4.4.05	Radiological Dose Effects/Risks	SRS-REG-2007-00002, Rev.1	4.6.2, 4.7.1, 4.8.2	Radiological doses are key performance results.
4.4.06	Radiological and Chemical Toxicity/Effects	SRS-REG-2007-00002, Rev.1	4.8.2, 5.7	The RCRA/CERCLA Risk Analysis considers the effects of various contaminants.
4.5.02	Radiation Effects on the Waste Closure System	SRS-REG-2007-00002, Rev.1	3.3.2, 3.3.3, 4.2.3.2.3	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	SRS-REG-2007-00002, Rev.1	4.2.2	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.
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 FTF 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	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)	SRS-REG-2007-00002, Rev.1	3.1.5.2, 3.1.5.3, 3.2.1, 3.2.2, 4.2.3.1.3, 4.4.2, 4.4.4.1.2	Groundwater flow is explicitly discussed throughout the PA.
5.1.02	Groundwater Flow and Movement (Far-Field)	SRS-REG-2007-00002, Rev.1	4.2.3.1.4, 4.4.4.1.4	Groundwater flow is explicitly discussed throughout the PA.
5.1.03	Episodic Or Pulse Flow and Release	SRS-REG-2007-00002, Rev.1	3.2.4.1.3, 4.4.2.5	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.
5.1.04	Water Influx at the Closure Facility	SRS-REG-2007-00002, Rev.1	3.2.4.1.3	Water influx at the closure facility is explicitly modeled in the PA.
5.1.05	Focusing of Flow Along Preferred Flow Paths (Fingers, Weeps, Faults, Fractures, etc.)	SRS-REG-2007-00002, Rev.1	4.2.2, 4.4.2, 4.4.4.1.2	The alternative modeling scenarios consider fast flow paths.
5.1.07	Flow Diversion and Bypass Flow	SRS-REG-2007-00002, Rev.1	3.2.4.5, 3.2.4.5.1, 3.2.4.7, 4.4.2, 4.4.4.1.2, 5.6.3.6	The alternative modeling scenarios consider alternative flow paths.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.1.08	Film/Laminar Flow	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.3.1.3, 4.2.3.1.4	The external flow boundaries are defined and described within the PA.
5.1.10	Alteration and Chemical Weathering Along Flow Paths	SRS-REG-2007-00002, Rev.1	4.2.3.2.2, 4.2.3.2.3	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.
5.2.01	Hydrological Response to Geological Changes	SRS-REG-2007-00002, Rev.1	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.
5.2.03	Hydraulic Potentials and Gradients	SRS-REG-2007-00002, Rev.1	3.1.5.2, 3.1.5.3, 4.2.3.1.3	Hydrostratigraphy is explicitly considered in the development of the PA flow models.
5.2.04	Interfaces Between Different Waters	SRS-REG-2007-00002, Rev.1	4.2.3.1.4	Transport model interfaces are specifically considered in the development of the PA flow models.
5.2.05	Effects related to air and vapor flow and evaporation within the system	SRS-REG-2007-00002, Rev.1	4.5, 5.3	The PA provides an airborne pathway transport analysis and summary of dose to MOP.
5.2.06	Perched Water Develops	SRS-REG-2007-00002, Rev.1	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.
5.3.01	Contaminant Release and Migration Factors	SRS-REG-2007-00002, Rev.1	4.2.3	The PA explicitly examines and models contaminant release and migration.
5.3.02	Contaminant Release Pathways	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.3.1.3, 4.2.4.1	The PA explicitly examines and models contaminant release and migration pathways.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.03	Multiphase Transport Processes	SRS-REG-2007-00002, Rev.1	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	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.3.1.3, 4.2.3.1.4, 4.2.3.2	The PA explicitly examines and models contaminant release and migration.
5.3.05	Solid-Mediated Migration of Contaminants	SRNL-STI-2011-00498, Rev. 0	4.2.3	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	SRS-REG-2007-00002, Rev.1	4.5, 5.3	The PA provides an airborne pathway transport analysis and summary of dose to MOP.
5.3.07	Water-Mediated Migration of Contaminants	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.2.3.1.3	The PA explicitly examines and models water-mediated contaminant migration.
5.3.08	Diffusion (Molecular Diffusion and Matric)	SRS-REG-2007-00002, Rev.1	4.2.3.2.2, 5.6.2.1.4	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
5.3.09	Dispersion and Imbibition	SRS-REG-2007-00002, Rev.1	4.4.4.1	This FEP represents important parameters in the groundwater flow and transport model that is explicitly included within the PA.
5.3.10	Advection	SRS-REG-2007-00002, Rev.1	4.4.2	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
5.3.11	Sorption and Desorption of Dissolved Contaminants (Kd Retardation)	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.4.2	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
5.3.12	Radionuclide Fluxes to the Biosphere	SRS-REG-2007-00002, Rev.1	4.2.3.1.2, 4.5.5.1, 4.5.7, 5.1, 5.3, 5.6.2.2.1, 5.6.7.3	Radionuclide fluxes into the biosphere are explicitly modeled in the PA.
5.3.13	Fast Transport Pathways	SRS-REG-2007-00002, Rev.1	4.4.2, 4.4.3, 5.6.3.1, 5.6.4.2.3, 5.6.7.3	The alternative modeling scenarios consider fast flow paths.
5.3.14	Long-Term Release of Radionuclides	SRS-REG-2007-00002, Rev.1	3.2.3.1, 4.4.2, 4.4.3, 5.5.1, 5.6.3.7, 5.6.5	Although the compliance period extends to 10,000 years after closure, PA modeling simulates effects to 20,000 years (and in Figure 5.5-9 to 100,000 years) after closure.
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 FTF boundary.
5.3.16	Vadose Zone Depth	SRS-REG-2007-00002, Rev.1	4.2.3.2.2, 5.6.3.9	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
5.3.17	Saturated Zone Depth	SRS-REG-2007-00002, Rev.1	4.2.3.2.2, 5.6.3.12	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
5.3.18	Depth of Assessment Well	SRS-REG-2007-00002, Rev.1	5.6.3.10	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
5.3.19	Horizontal Distance to Points of Assessment	SRS-REG-2007-00002, Rev.1	5.2.1	This FEP represents an important parameter in the groundwater flow and transport model that is explicitly included within the PA.
6.1.01	Inadvertent Human Intrusion	SRS-REG-2007-00002, Rev.1	4.2.4, 5.6.3.10, 5.6.3.11, 6.2, 6.4,	The IHI analysis is explicitly modeled in the PA.
6.1.02	Deliberate Human Intrusion	SRS-REG-2007-00002, Rev.1	4.2.4, 5.6.3.10, 5.6.3.11, 6.3, 6.4,	A deliberate intrusion would have similar impacts to an inadvertent intrusion.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.1.03	Drilling Activities	SRS-REG-2007-00002, Rev.1	4.2.4, 5.6.3.10, 6.3, 6.4,	Drilling activities are explicitly considered in the IHI analysis.
6.1.04	Excavating and Mining Activities	SRS-REG-2007-00002, Rev.1	3.1.7, 4.2.4.2.3	Excavation is discussed in the PA and identified as not an applicable dose pathway due to the disposal depth of the stabilized contaminants.
6.1.05	Animal/Plant Intrusion	SRS-REG-2007-00002, Rev.1	4.2.4.2.8	The amount of material displaced by biotic intrusion is much less than a human intruder; therefore the human intruder scenario provides a conservative impact of a biotic intrusion.
6.1.06	Igneous or Seismic Event Precedes Human Intrusion	SRS-REG-2007-00002, Rev.1	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.
6.2.01	Seismicity	SRS-REG-2007-00002, Rev.1, SRR-CWDA-2011-00054, Rev. 1	3.1.4.3, 4.4.2.4	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 Configuration D was not explicitly linked to seismic events, the types of cracks caused by credible seismic events at the FTF are assumed to be bounded by Configuration D.

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

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.2.02	Seismic-Induced Damage or Changes to System Components	SRS-REG-2007-00002, Rev.1	3.1.4.3, 3.2.3.3, 4.4.2.4	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	3.2.1.5, 3.2.4	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).
6.4.02	Flooding or Drainage System Failure	SRS-REG-2007-00002, Rev.1	3.1.5.4	The PA indicates that "The 100-year, 1,000-year and 10,000-year flood water levels for UTR Basin near F-Area is approximately 138, 140 and 143 feet above MSL." These values are all below the bottom of the waste tanks; therefore, no impact is expected.
6.4.03	Movement of the Waste Form	K-CLC-F-00073, Rev. 2	3.2.1.5, 3.2.4	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).
6.4.04	Cave-In, Collapse, or Rockfall	SRS-REG-2007-00002, Rev.1	3.2.4.4	The stability of the engineered system is predicated on the stability of the closure cap.
6.4.05	Accidents and Unplanned Events	SRS-REG-2007-00002, Rev.1	5.6.4, 5.6.6	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 FTF PA Evaluation (Continued)

FEP ID	FEP Name	Referenced Document	PA Section(s)	Technical Basis
6.4.06	Explosions and Crashes	SRS-REG-2007-00002, Rev.1	5.6.4, 5.6.6	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 FTF 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 FTF 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 FTF PA to evaluate the effects of the FEPs on the calculated doses to the MOP or IHI, or to further demonstrate compliance with performance objectives as defined in DOE Manual 435.1-1 and 10 CFR 61.

5.0 REFERENCES

10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*, U.S. Nuclear Regulatory Commission, Washington DC, January 5, 2010, http://www.nrc.gov/reading-rm/doc-collections/cfr/part061/, Accessed January 20, 2011.

DOE M 435.1-1, Chg. 1, *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington DC, June 19, 2001.

DOE/EIS-0303, *Savannah River Site High-Level Waste Tank Closure Final Environmental Impact Statement*, U.S. Department of Energy – Savannah River, Savannah River Site, Aiken SC, May 2002.

K-CLC-F-00073, William, T. L., *Static Settlement of F-Area Waste Storage Tanks 18 and 19*, Savannah River Site, Aiken, SC, Rev. 2, June 20, 2006.

Manual 1Q, *Quality Assurance Manual*, Savannah River Site, Aiken, SC, Rev. 11, March 8, 2011.

S-TSR-G-00001, *Concentration, Storage, and Transfer Facilities*, Technical Safety Requirements, Savannah River Site, Aiken, SC, Rev. 26, March 1, 2010.

SAND2010-3348 P, Freeze, G., *Features*, *Events*, *and Processes (FEPs) for Nuclear Waste Repository Systems*. Sandia National Laboratories, Albuquerque, New Mexico, June 21, 2010.

SRNL-STI-2009-00512, *Savannah River Site DOE 435.1 Composite Analysis (Volumes 1 and 2)*, Savannah River Site, Aiken, SC, Rev. 0, June 10, 2010.

SRNL-STI-2010-00734, Flach, G. P., Kaplan, D. I., Phifer, M. A., McDowell-Boyer, L. and Cook, J. R., *Mineralogical, Hydrogeochemical, and Environmental Isotope Data Supporting the E-Area Low-Level Waste Facility Performance Assessment*, Savannah River Site, Aiken, SC, Rev. 0, October 2011.

SRNL-STI-2011-00498, Li, D., Roberts, K. A., Kaplan, D. I., and Seaman, J.C., *Mobilization and Characterization of Colloids Generated From Cement Leachates Moving Through a SRS Sandy Sediment*, Savannah River Site, Aiken, SC, Rev. 0, September 20, 2011.

SRR-CWDA-2009-00059, *Comment Response Matrix for Citizens Advisory Board (CAB) Comments on Revision 0 of SRS-REG-2007-00002, Performance Assessment for F-Tank Farm*, Savannah River Site, Aiken, SC, Rev. 0, February 16, 2009.

SRR-CWDA-2011-00044, *Comment Response Matrix for Nuclear Regulatory Commission RAI-2009-02 Second Request for Additional Information (RAI) on the Saltstone Disposal Facility Performance Assessment (SRR-CWDA-2009-00017, Revision 0, dated October 29, 2009)*, Savannah River Site, Aiken, SC, Rev. 1, August 25, 2011.

SRR-CWDA-2011-00054, *Comment Response Matrix for United States Nuclear Regulatory Commission Staff Comments on the Draft Basis for Section 3116 Determination and Associated Performance Assessment for the F-Tank Farm at the Savannah River Site*, Savannah River Site, Aiken, SC, Rev. 1, October 25, 2011.

SRR-CWDA-2012-00011, Hommel, S., *Features, Events, and Processes for Liquid Waste Performance Assessments*, Savannah River Site, Aiken, SC, Rev. 0, February 14, 2012.

SRS-REG-2007-00002, *Performance Assessment for the F-Tank Farm at the Savannah River Site*, Savannah River Site, Aiken, SC, Rev. 1, March 31, 2010.

WSRC-STI-2007-00184, Phifer, M. A., *FTF Closure Cap Concept and Infiltration Estimates*, Savannah River Site, Aiken, SC, Rev. 2, October 15, 2007.