TSPA Model Development and Sensitivity Analysis of Processes Affecting Performance of a Salt Repository for Disposal of Heat-Generating Nuclear Waste

Fuel Cycle Research & Development

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SUMMARY

This deliverable describes the initial work on designing and developing requirements for a total system performance assessment (TSPA) model that can support preliminary safety assessments for a mined geologic repository for high-level waste (HLW) and spent nuclear fuel (SNF) in salt host rock at a generic site. This work is part of the scope developed for a salt research and development (SRD) study completed on March 23, 2012 and agreed upon by the U.S. Department of Energy Offices of Nuclear Energy and Environmental Management (DOE-NE and DOE-EM). The associated SRD Study Plan was developed in response to the agreement on the technical objectives and science-based scope of work for the study of salt geologic media for potential disposal of commercial and DOE-owned HLW and SNF. There were five primary activities undertaken in FY12 based on the Study Plan, of which this SRD TSPA Model development work falls under Activity 4, “Modeling Studies Related to Salt.”

It should be noted that a preliminary generic salt TSPA model for HLW/SNF disposal has been developed and tested for an isothermal repository in salt, for emplaced waste that is assumed to have no decay heat (Clayton et al. 2011). This model is called the Salt Generic Disposal System Model or Salt GDS Model. However, in order to advance the state-of-the-art of TSPA modeling for salt repositories containing heat-generating HLW/SNF, the present study develops model requirements based on features, events, and processes (FEPs) screening and proposed sensitivity analyses for heat-generating waste. This will lead to a defensible salt repository TSPA model that includes the necessary set of coupled physical-chemical processes required to demonstrate postclosure safety for heat-generating waste.

The FY2012 work on the SRD TSPA Model has focused on several of the key initial steps in the development of a performance assessment (or postclosure safety assessment) model for a generic salt site:

- FEPS identification specific to bedded salt host rock
- Definition of a salt repository “reference case”—descriptions and initial and boundary conditions for the natural and engineered systems for a generic bedded salt site
- Preliminary FEPS screening
- High-level specification of quantitative sensitivity analyses necessary to support FEPs screening, including some based on the Salt GDS Model and some based on advanced process-level models
- Implications of FEPs screening for the construction and requirements of a generic salt TSPA model, based on the physical-chemical processes in the included FEPs

Future work on this TSPA model development activity will present the quantitative results of the FEPs screening sensitivity analyses and possible subsequent changes to the preliminary FEPs screening. It will also further develop the methodology for how the FEPs screening and associated sensitivity analyses guide the construction of a salt TSPA model regarding the appropriate representation of physical-chemical processes and their couplings in each TSPA component or submodel.

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ACRONYMS

ADSM	Advanced Disposal System Model
B	Biological processes
BWR	Boiling Water Reactor
C	Chemical processes
CH	Contact-Handled radioactive waste
CSNF	Commercial Spent Nuclear Fuel
GTCC	Greater-than-Class-C low-level radioactive waste
DOE	Department of Energy
DOE-NE	Department of Energy Office of Nuclear Energy
DOE-EM	Department of Energy Office of Environmental Management
EPA	Environmental Protection Agency
EBS	Engineered Barrier System
EDZ	Excavation Disturbed Zone
FCR&D	Fuel Cycle Research and Development
FEP	Feature, Event, Process
GDS	Generic Disposal System
GWd	Giga-Watt days
GWd/MT	Giga-Watt days per Metric Ton
H	Hydrologic processes
HLW	High-Level Radioactive Waste
HPC	High-Performance Computing (or Computational)
ICRP	International Commission on Radiological Protection
LLW	Low-Level Radioactive Waste
LWR	Light Water Reactor
M	Mechanical processes
MT	Metric Ton
MTHM	Metric Tons of Heavy Metal
NBS	Natural Barrier System
NRC	National Research Council
NWPA	Nuclear Waste Policy Act
PA	Performance Assessment

PWR	Pressurized Water Reactor
R&D	Research and Development
R	Radiological processes
RH	Remote-Handled radioactive waste
SNF	Spent Nuclear Fuel
SRD	Salt R&D Study
T	Thermal processes
TMI	Three-Mile Island
Tr	Radionuclide transport processes
TRU	Transuranic
TSPA	Total System Performance Assessment
UFD	Used Fuel Disposition (Campaign)
UNF	Used Nuclear Fuel
U.S.	United States
U.S. NRC	U.S. Nuclear Regulatory Commission
WIPP	Waste Isolation Pilot Plant
WP	Waste Package

1. INTRODUCTION

The United States (U.S.) currently utilizes a once-through commercial nuclear fuel cycle where used nuclear fuel (UNF)[1] is stored at reactor sites, to be ultimately disposed in a geologic repository. Within the Department of Energy's (DOE) Office of Nuclear Energy (DOE-NE), the Fuel Cycle Research and Development Program (FCR&D) develops options to the current once-through fuel cycle management strategy to enable the safe, secure, economic, and sustainable expansion of nuclear energy, while minimizing proliferation risks, by conducting research and development (R&D) focused on nuclear fuel recycling and waste management to meet U.S. needs.

While significant progress has been made over the last several decades regarding waste disposal technologies, the routine disposal of radioactive waste remains elusive. Experience with the Yucca Mountain Project has illustrated the challenges of siting, characterizing, designing, and licensing a geologic repository for high-level radioactive waste (HLW)[2] and spent nuclear fuel (SNF). To address these challenges, the mission of the Used Fuel Disposition (UFD) Campaign in the FCR&D is to identify alternatives and conduct scientific research and technology development to enable safe storage and disposal of UNF and HLW (DOE 2011). The scope of the Campaign also includes UNF and HLW generated by DOE.

Of primary concern for any geologic repository is the safety objective. In the U.S. the adequacy of the proposed repository is judged against regulations promulgated by the Environmental Protection Agency (EPA) and implemented by the U.S. Nuclear Regulatory Commission (U.S. NRC) in a formal licensing proceeding. With the halting of the Yucca Mountain repository project, the site-specific regulations for judging repository safety are no longer applicable and are subject to revision in the future. In the meantime, an appropriate means for documenting the safety of a proposed repository is the internationally accepted vehicle of the *safety case* (NEA 2004; MacKinnon et al. 2012; Vaughn et al. 2012). Given that the future site of a U.S. geologic repository could be in any number of different locations and geologic settings, the UFD Campaign has pursued the initial development of a safety case for four of the most likely disposal concepts (Vaughn et al. 2012). The first three are mined repositories in three different "generic" host-rock media: salt, shale/clay, and crystalline/granite. The fourth concept is emplacement of radioactive waste in deep vertical boreholes in crystalline basement rock (Brady et al. 2009). The work described in the present study focuses in greater detail on the salt repository concept, and describes a methodology and associated requirements for development of a quantitative safety assessment model for a generic HLW/SNF repository in salt host rock.

The concept of radioactive waste disposal in salt was recognized by the National Academy of Sciences as early as 1957 when they identified salt as the most promising host rock for high-level waste disposal (NRC 1957). Disposal of HLW and spent nuclear fuel (SNF) in a suitable salt formation is attractive because the material is essentially impermeable, self-sealing, thermally

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[1] Used nuclear fuel (UNF) in this document means irradiated fuel from a reactor that is stored pending reprocessing or recycling,

[2] "High-level radioactive waste (HLW)" is defined as in the Nuclear Waste Policy Act, Sec. 2: "highly radioactive material resulting from the reprocessing of spent nuclear fuel..."

conductive, and a significant experience base exists from earlier studies. A mined repository in salt (referred to herein as a salt repository) could potentially achieve complete containment, with no releases to the environment in undisturbed scenarios for as long as the region is geologically stable (Hansen and Leigh 2011). An operational radioactive waste salt repository for defense-generated transuranic (TRU) waste, the Waste Isolation Pilot Plant (WIPP)[3], has since been sited in the Delaware Basin of Southeast New Mexico in the U.S., demonstrating this concept. Lessons learned from siting and operating this facility can be used to support the development of a generic HLW/SNF salt repository. However, it must be noted that phenomena caused by heat from HLW and SNF could add some potentially beneficial and/or detrimental features, events, and processes (FEPs) that are not necessarily important for the significantly cooler TRU waste that is disposed at WIPP. Overall, a FEPs analysis is always required in order to move forward with a safety case, but many of the FEPs screening results performed for WIPP may still be applicable (DOE 1996).

In recent years, the U.S. Department of Energy's Office of Nuclear Energy (DOE-NE) has focused on a generic approach to inform and facilitate decision-making regarding potential disposal pathways for radioactive wastes that currently have no disposal options in the United States (DOE 2011). This includes both HLW and SNF from both commercial nuclear power generation and atomic energy defense activities. Within the scope of this generic approach, DOE-NE has funded an R&D effort in Fiscal Year 2012 (FY12) to design a *safety framework* (i.e., an outline for a more detailed safety case—see Section 2) for geologic disposal of heat-generating waste in a salt formation at a generic site. In parallel with work on the safety framework and safety case, DOE-NE also funded an R&D effort to begin designing a system model that can support preliminary safety assessments for a mined geologic repository in salt at a generic site. This work on safety framework and model development is part of the scope developed for a salt research and development (SRD) study completed on March 23, 2012 and agreed upon by DOE-NE and DOE-EM (McMahon 2012). The associated SRD Study Plan was developed in response to the agreement on the technical objectives and science-based scope of work for the study of salt geologic media for potential disposal of commercial and DOE-owned HLW and SNF. The primary activities undertaken in FY12 based on this plan are as follows:

- Activity 1: Existing Salt Data Compilation and Assessment
- Activity 2: Test Planning for Re-Entry into the North Experimental Area of WIPP
- Activity 3: Thermal, Mechanical, Hydrologic, and Chemical Laboratory Studies Related to Salt
- Activity 4: Modeling Studies Related to Salt
- Activity 5: International Collaboration

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[3] The Waste Isolation Pilot Plant is a DOE waste disposal facility designed to safely isolate defense-related transuranic (TRU) waste from people and the environment. Waste temporarily stored at sites around the country is shipped to WIPP and permanently disposed in rooms mined out of a bedded salt formation 2,150 feet below the surface. WIPP, which began waste disposal operations in 1999, is located 26 miles outside of Carlsbad, NM.

The Total System Performance Assessment (TSPA Model) Development task described in this report is part of the fourth activity. A TSPA model, as used here, refers to a model (or suite of models) that are used to predict the quantitative performance of the repository system, with a typical outcome being a set of dose or risk histories spanning a range of uncertainty associated with the input parameters to the model. The TSPA model is the primary tool for the postclosure safety assessment element of a repository safety case (see Section 2). The specific TSPA model to be developed in the SRD Study is referred to in this report as the SRD TSPA Model.

1.1 Initial Issue (Revision 0)

The initial issue (revision 0) of this TSPA Model Development study focuses on several of the key initial steps in the methodology and development of a performance assessment (or postclosure safety assessment) and associated TSPA model for a generic salt repository (see Section 3):

- FEPS identification
- Reference case definition (descriptions and initial and boundary conditions for the natural and engineered systems)
- FEPS screening and associated sensitivity analyses for justifying screening decisions
- Implications of FEPs screening for the formulation of a generic salt TSPA model

It should be noted that a preliminary generic salt TSPA model for HLW/SNF disposal has been developed and tested for an isothermal repository in salt, for emplaced waste that is assumed to have no decay heat (Clayton et al. 2011). This model is called the Salt Generic Disposal System Model or Salt GDS Model. If, as believed based on previous work, the halite host rock is essentially impermeable after the thermal period (Hansen and Leigh 2011), then this Salt GDS Model should give a reasonable prediction of long-term performance. However, questions remain about the effects of heat on the excavation disturbed zone (EDZ) that surrounds the emplacement drifts (Winterle et al. 2012). Thus, in order to advance the state-of-the-art of TSPA modeling for salt repositories with heat-generating waste, the present study demonstrates a methodology to develop TSPA model requirements based on FEPs screening and sensitivity analyses. This will lead to a salt repository TSPA model that contains the necessary defensible set of physical-chemical processes required to demonstrate postclosure safety for heat-generating waste.

1.2 Future Revisions

Future revisions to this report will contain the quantitative results of FEPs analyses and their implications with respect to the appropriate inclusion of physical-chemical processes and their couplings in each TSPA component or submodel. This will lead to a more detailed set of requirements for the salt TSPA model architecture and computational architecture (Freeze and Vaughn 2012), potentially pointing to the use of a high-performance computational (HPC) framework, if appropriate.

2. SAFETY FRAMEWORK CONTEXT FOR TSPA MODEL DEVELOPMENT

A *safety case* is a formal compilation of evidence, analyses, and arguments that substantiate and demonstrate the safety, and the level of confidence in the safety, of a proposed or conceptual repository (NEA 2004). A safety case also provides the necessary structure for organizing and synthesizing existing knowledge in order to help the repository implementing organization prioritize its future R&D activities. Although the scope of a safety case, and the definitions and terminology used therein, differ somewhat across the various international programs (Schneider et al. 2011; Bailey et al. 2011; NEA 2009; NEA 2004), they all have the same goal of understanding and substantiating the safety of a disposal system.

A *safety framework*, as defined in this SRD effort, is not as detailed and complete as a *safety case* and is primarily intended to organize the activities of this SRD effort according to the elements of a safety case (see below), indicating where there are gaps in the documentation and research. The development of a salt *safety framework* is consistent with DOE-NE's current generic approach to repository research and development, and it provides enough detail to conduct preliminary safety assessments. It follows the outline of the elements of a detailed safety case (MacKinnon et al. 2012), identifies the types of information that will be required to satisfy the elements of the safety case, and anticipates where currently available generic information may exist.

The major elements of the safety case are shown schematically in Figure 2-1. They are patterned after the NEA postclosure safety case (NEA 2004), but include aspects of preclosure safety (MacKinnon et al. 2012):

- *Statement of Purpose*. Describes the current stage or decision point within the program against which the current strength of the safety case is to be judged.
- *Safety Strategy*. This is the high-level approach adopted for achieving safe disposal, and includes the sub-elements of an overall management strategy, a siting and design strategy, and an assessment strategy. Two important principles of the safety strategy are (a) public and stakeholder involvement in key aspects of siting, design, and assessment and (b) alignment of the safety case with the existing legal and regulatory framework.
- *Assessment Basis*. This element comprises the sub-elements of site selection, site characterization, and repository design. It includes a description of (a) the primary characteristics and features of the selected repository site, (b) the location and layout of the repository, (c) a description of the engineered barriers, and (d) a discussion of how the engineered and natural barriers (i.e., the multiple-barrier concept) will function synergistically. In the earliest phases of the repository program it includes the site selection process and associated selection criteria/guidelines.
- *Disposal System Safety Evaluation.* This element of the safety case includes two major sub-elements: a preclosure safety analysis and a postclosure performance assessment. It is primarily a quantitative *safety assessment* of potential radiological consequences associated with a range of possible evolutions of the system over time, i.e., for a range of

scenarios, both before and after repository closure. However, it also includes qualitative arguments related to the intrinsic robustness of the site and design, insights gained from the behavior of natural and anthropogenic analogues, and quantitative sensitivity and uncertainty analyses to quantify key remaining uncertainties, which may be addressed with future R&D, if necessary.

- *Statement of Confidence and Synthesis of Evidence*. The statement of confidence is based on a synthesis of safety arguments and analyses, and includes a discussion of completeness to ensure that no important issues have been overlooked in the safety case. The statement of confidence recognizes the existence of any open issues and residual uncertainties, and perspectives about how they can be addressed in the next phase(s) of repository development, if they are considered to be important to establishing safety.

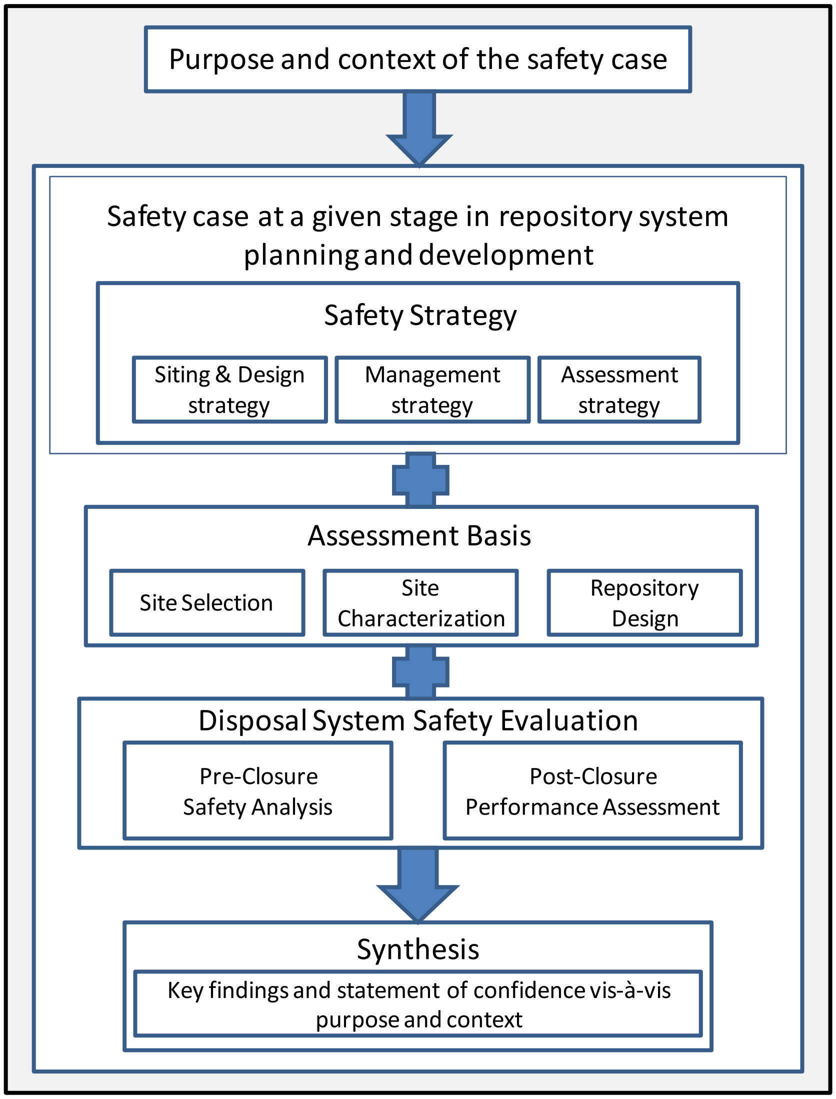

Figure 2-1. Major Elements of the Safety Case (modified from NEA 2004, Fig. 1).

The postclosure *safety assessment*, which in the U.S. program and regulations is generally referred to as the postclosure *performance assessment* (e.g., see 40 CFR 191, the currently applicable standard for all geologic repositories in the U.S. other than Yucca Mountain and the standard under which WIPP is certified), is a key part of the safety case, as indicated above. A complete performance assessment includes quantification of the long-term, postclosure performance of the repository using a computational total system performance assessment (TSPA) model, analysis of the associated uncertainties in this prediction of performance, and comparison with the relevant design requirements and safety standards. Such an assessment requires conceptual and computational models based on the relevant FEPs that are or could be important to safety. The determination of which FEPs should be included in the development of conceptual, mathematical, and numerical TSPA models for a generic repository in salt is the primary focus of this deliverable.

Discussion of the key aspects of a safety case specific to bedded salt, as well as integration of the generic SRD TSPA Model into the salt safety case (framework) will be discussed in more detail in SRD deliverables planned for FY 2013. The crux of salt safety case will be based on the superior performance of the host rock for the undisturbed scenario. Essentially, a salt formation is attractive because the host rock material is effectively impermeable, self-sealing, and thermally conductive. A salt repository could potentially achieve complete containment, with no releases to the environment in undisturbed scenarios for as long as the region is geologically stable (Hansen and Leigh 2011). Thus, long-lasting and complex engineered barriers are unnecessary, which reduces the repository costs and simplifies performance assessment modeling, thereby adding greater confidence to the eventual licensing safety case.

3. TSPA MODEL DEVELOPMENT

As described in Section 1, TSPA model development for a generic salt repository is part of the fourth activity ("Activity 4") of the SRD Study Plan. This activity includes the following three tasks:

- Safety Framework Development
- TSPA Model Development
- Coupled Thermal, Mechanical, and Hydrologic Model (T-H-M) Development

The safety framework document (and, eventually, the more detailed safety case) will put forth arguments to show which various testing and modeling activities are still necessary to build confidence for the safety of a proposed repository. Generally, it does this by using a risk-informed approach. In other words, those activities that are determined to have the greatest potential to reduce performance uncertainty will be given the highest priority. Post-closure safety assessment is a key element of the safety framework approach, and the quantitative analyses that form the basis for establishing post-closure safety risk are provided by the TSPA model. In particular, the TSPA model, in combination with thermal-mechanical-hydrologic-chemical (T-H-M-C) process model results, will provide the analytical basis for planning the activities in Activities 1, 2, and 3, as well as the T-H-M-C process model development efforts that are part of Activity 4.

The TSPA model development effort is intended to design a model(s) to predict subsystem and total system performance of a deep geologic repository in salt for disposal of heat generating nuclear waste. This TSPA model will comprise a model and computational framework comprised of four major model components: inventory and source-term, near-field, far-field, and biosphere, as well as an uncertainty analysis module and a post-processing module. Sensitivity and uncertainty analyses conducted with the evolving SRD TSPA Model and T-H-M-C process models will determine, using a risk-informed approach, the degree of fidelity required within the SRD TSPA Model for representing detailed T-H-M-C processes.

The SRD TSPA Model, developed under this activity, will leverage existing TSPA modeling capability (e.g., from WIPP performance assessment models) and the model development work currently being conducted for UFD's Generic Disposal System Model (GDSM) (Clayton et al. 2011) and Advanced Disposal System Modeling (ADSM) activities (Freeze and Vaughn 2012). As described in Freeze and Vaughn (2012), "the combined objective of these activities [GDSM and ADSM] is to create an advanced disposal system performance assessment (PA) modeling capability that (a) facilitates science-based evaluation of disposal system performance for a range of fuel cycle alternatives in a variety of geologic media and generic disposal system concepts, and (b) takes advantage of HPC technologies." The key point is that these activities will develop an advanced model that is capable of representing repository performance in a wide variety of disposal environments: mined shale/clay, mined crystalline/granite, mined salt, and deep borehole crystalline.

The current SRD TSPA Model Development activity has a shorter time horizon than the ADSM work, and a more focused concentration on one concept and medium: a mined salt repository. However, it will leverage off of the work for the ADSM activity. In fact, the ADSM activity has designated its first test case for a new computational/conceptual framework to be a salt repository (Freeze and Vaughn 2012, Sec. 5). This SRD TSPA Model Development activity will also continue the use of the Salt GDS Model to evaluate potential salt repository performance, during the development period for the more comprehensive SRD TSPA Model (see Section 3.4).

The knowledge base for performance assessments in the U.S. is extensive. Figure 3-1 illustrates the steps in the performance assessment (PA) methodology that was used successfully to certify the WIPP defense TRU waste repository (DOE 1996) and develop the Yucca Mountain License Application (DOE 2008), and has been applied to many other waste disposal projects, dating back to the 1970s (Meacham et al. 2011). The PA methodology shown in Figure 3-1 organizes a variety of types of information that build confidence in postclosure system safety, including (1) the underlying technical bases for the safety assessment models (a component of the *assessment basis* in some safety case concepts, e.g., NEA 2004), (2) the scenario and FEPs analysis that ensure a comprehensive assessment of postclosure performance, (3) the construction and testing of conceptual, mathematical, and numerical PA models, including the total system or TSPA model, (4) the execution of TSPA model and submodel calculations, (5) uncertainty and sensitivity analyses that help quantify where additional information is needed for the next stage of repository development, and (6) a comparison of TSPA model calculations with any applicable safety standards.

The present SRD TSPA Model Development activity for FY 2012 focuses primarily on two of the boxes in Figure 3-1: "Characterize System" (see Section 3.2) and "Identify Scenarios for Analysis" (see Section 3.1.2), but also touching on the boxes "Define Performance Goals" (see Section) and "Build Models and Abstractions" (see Section 3.5). Because the conceptual repository system proposed in this SRD Study is assumed to be located in bedded salt (see Section 3.2), many of the FEPs and associated analyses used for the WIPP PA will be applicable, but subject to some modifications and additions. For example, the phenomena caused by heat from HLW and SNF would add some FEPs, since TRU waste disposed in WIPP is significantly cooler. In addition, the physical and chemical characteristics of HLW are likely to be appreciably different than TRU waste. Therefore, the waste-related and repository FEPs from WIPP would need to be reviewed. Additionally, there will be differences in the disposal concept, container types, and performance period for WIPP as compared to a repository for heat-generating waste, as well as differences in the natural system FEPs, depending on the actual location of the repository. Finally, because FEPs are grouped to construct scenarios for analysis of performance and safety, and because the applicable set of FEPs will be somewhat modified from the set used for WIPP, the appropriate PA scenarios may be different from those included in the WIPP Compliance Certification Application (CCA), as well.

Due to the site-specific nature of many of the WIPP FEPs, the previously compiled UFD FEPs list (Freeze et al. 2011) was used as the starting point for the FEPs screening described here, rather than the WIPP FEPs list (Hansen and Leigh 2011, App. A). However, a cross-walk, i.e., comparison, of the UFD FEPs to the WIPP FEPs is included in this report for completeness and to ensure that no relevant FEPs are overlooked in the development of the SRD TSPA Model for disposal of heat-generating waste (see Appendix A).

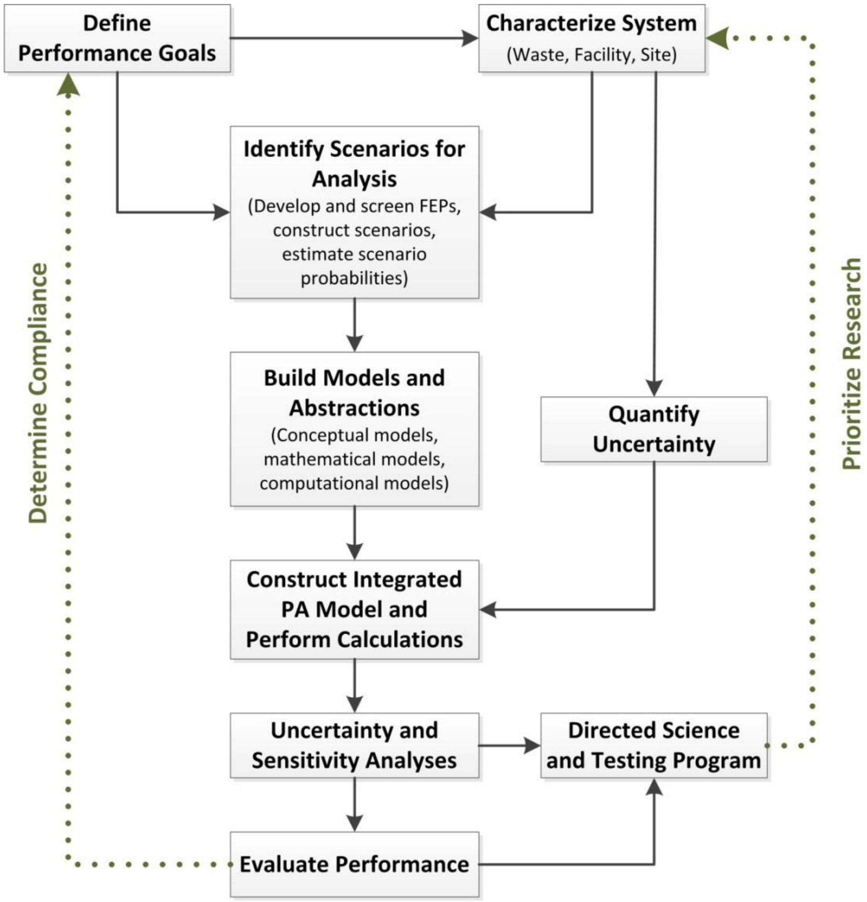

Figure 3-1. Performance Assessment Methodology (from Meacham et al. 2011).

Figure 3-2 is a more detailed flow diagram of the methodology steps taken in FY 2012 to develop a set of TSPA model requirements. These are the steps documented in this report, as indicated by the section numbers in the diagram.

3.1 FEPS Identification and Preliminary Screening

The FEPs process is an identification and evaluation of the features, events, and processes that need to be represented in the safety framework and TSPA model design. A detailed explanation of the process, which includes three major steps, FEPs identification, FEPs classification, and FEPs screening, can be found in Vaughn et al. (2012, Sec. 3.5.4.2) and DOE (2008, Sec. 2.2.1). Ultimately, FEPs are either included or excluded from further consideration using qualitative and/or quantitative justifications. These justifications must generally consider three major criteria: probability of occurrence, consequence to performance, and specific regulatory guidance.

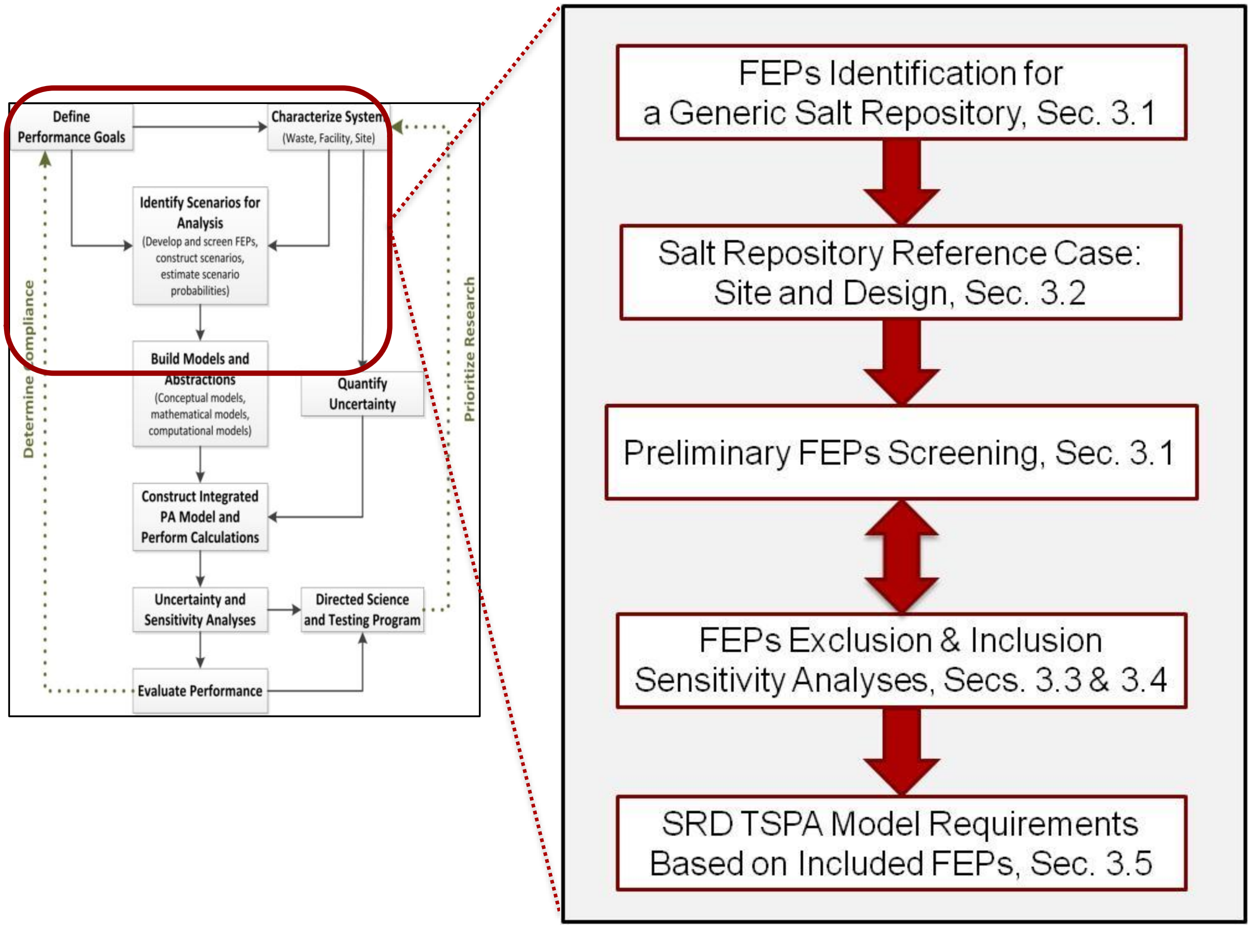

Figure 3-2. Methodology for Development of SRD Salt TSPA Model Requirements—Scope for FY 2012.

For the initial development of the safety framework and TSPA model for a generic bedded salt repository, the FEPs screening will rely primarily on qualitative evaluations of the FEPs, but supplemented with quantitative sensitivity analyses, where necessary (Sections 3.3 and 3.4). The initial qualitative evaluation is based on scientific expert judgments derived from past salt repository experience, and considers all three FEPs screening criteria (probability, consequence, regulation). However, it primarily relies on the first two, since a specific salt site and likely new regulations are not available at this time, i.e., potential site-specific regulatory screening criteria pertaining to the geologic setting, reference biosphere, and/or receptor are not applicable to a generic site. However, this initial qualitative FEPs screening is based on some generic regulatory assumptions, described in Section 3.2.6, related to performance timeframes and possible annual dose standards.

Identification of a set of FEPs for a repository system usually begins with a specification of the major physical features of the system, upon which processes and events act. For a generic salt repository, this is introduced in what follows.

3.1.1 Features of the Generic Salt Disposal System

Figure 3-3 is a visualization of a generic salt disposal system, divided into a set of components and features as introduced in the UFD Generic Safety Case Report (Vaughn et al. 2012, Fig. 3-21). Figure 3-3 presents the major features in a linear fashion from left to right, beginning with the waste form and moving outward towards the Biosphere. In reality, the components are a set of nested regions. For example, the Natural Barrier completely surrounds the Engineered Barriers on all sides, and radionuclides can be transported from the Engineered Barriers to the Natural Barrier along multiple flow pathways, although these details are not shown in Figure 3-3.

The geologic disposal system is subdivided into the components/features that comprise the Engineered Barrier System (EBS) and the Natural Barrier System (NBS), including an interface region between these two major barriers. The EBS consists of the Inventory and Waste Form, the Waste Package, Buffer/Backfill, Tunnels, and Seals/Liner. The Natural Barrier System (NBS) consists of the Excavation Disturbed Zone (EDZ), the (intact) Host Rock, and Other Geologic Units above (including surficial soils) and below the repository, as well as an aquifer, if it exists. The EDZ is the portion of the host rock that may be altered (i.e., structural, mineralogical, and fluid composition changes) as a result of the excavation or the thermal pulse from the emplaced waste forms. The Host Rock also includes the presence of interbeds, including the anhydrite interbeds and clay seams that are usually observed in bedded salt formations.

3.1.2 Initial FEPs Screening and Associated Assumptions

Table A-1 of Appendix A lists 208 disposal system FEPs that are potentially relevant to a repository for permanent disposal of used nuclear fuel (UNF) and high-level waste (HLW) at a generic salt site. The FEPs in Table A-1 are based on the FEP list developed by Freeze et al. (2011, Section 2.2 and Appendix A) for a generic disposal system in any one of four different disposal concepts: mined crystalline/granite, mined shale/clay, mined salt, and deep borehole crystalline. The "UFD FEPs list" in Freeze et al. (2011) was developed from several comprehensive FEP lists and other relevant information (NEA 1999, Appendix D; NEA 2006; SNL 2008). The resulting FEPs in Freeze et al. (2011) have been modified in this report, as necessary, to be more specifically relevant to a generic mined salt repository. These modifications are in the form of additional or different "Associated Processes" for some of the FEPs, as indicated in the third column of Table A-1.

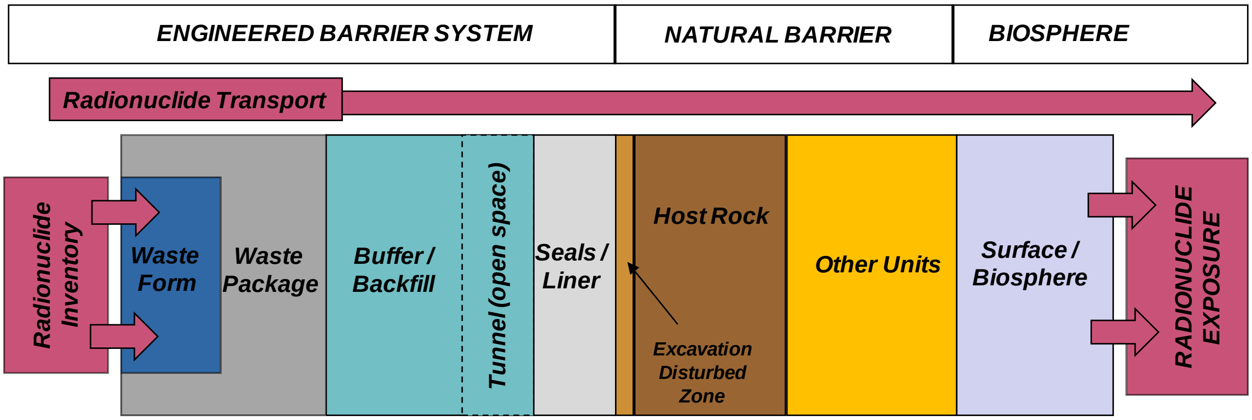

Figure 3-3. Features and Components of the Generic Salt Disposal System.

After modification of the UFD FEPs list to be more salt-specific, the next step is to assign each individual FEP a screening disposition stating whether it should be included or excluded from a salt TSPA model. This preliminary screening disposition is based on scientific judgment, as mentioned above, which will later be supported by documented reasoned arguments or quantitative sensitivity analyses. However, in order to make this preliminary screening judgment, an important step is required, as shown in Figure 3-2: specification of a “reference” site and design. This “reference” site/design for the generic salt repository is discussed in detail in Section 3.2 and includes a detailed set of assumptions that enable the FEPs screening to go forward for a generic salt repository. These assumptions are not intended as requirements for the ultimate site or design and if they are shown to be inappropriate when the final site and design are selected, the FEPs screening will be revisited.

Several of the more important assumptions associated with establishing the reference case are introduced below and are mainly related to the performance of EBS components. The first three of these assumptions are motivated by the unique capability of halite to encapsulate waste in a very low permeability medium. The presence of very low permeability salt surrounding the waste packages and EBS components makes the performance of a salt site relatively independent of the lifetimes of the EBS components, including the waste package. Thus, three important assumptions about the waste package (WP) are as follows:

- The outer corrosion barrier is not a long-term hydrologic barrier.

  This assumption allows many hydrology-related waste package and EBS FEPs to be excluded from the generic salt disposal system models. In other words, details of hydrologic processes in the waste package and EBS do not have to be represented in the long-term performance assessment if the crushed salt backfill reconsolidates within a few hundred years (Clayton et al. 2012). On the other hand, corrosion may remain an important long-term process after the peak temperature because gas generation from anoxic corrosion many generate gas pressure that affects closure rates of the drifts and the flows of brine into and out of the EBS.

- The outer corrosion barrier of the waste package remains structurally intact and acts as a barrier to flow during a period that includes the peak temperature of the decay-heat thermal pulse.

  This assumption ensures that the waste package is recoverable for a period at least 300 years (see Sections 3.2.2.2 and 3.2.6).

- There will be early time failures of the waste package because of manufacturing defects.

  These failures may not require a separate early time failure scenario class for the safety assessment, if they produce negligible differences in long-term dose. Screening sensitivity analyses (see Section 3.3) are required to evaluate the impact of early time failures on dose.

Several other assumptions that facilitate preliminary FEPs screening decisions include:

- Crushed salt backfill will be emplaced around each waste package to provide radiation protection. The crushed salt is considered the “backfill” identified in numerous FEPs in Table A-1.
- Minimal ground support, tunnel liners, or steel sets will be used in the emplacement drifts.

  The presence of these engineered components could delay or prevent the encapsulation of the waste as the emplacement drifts close due to salt creep. Minimal ground support, without liners or steel sets, is consistent with the design and operation of the WIPP repository and allows for the exclusion of many the FEPs related to these EBS components.

- The FEP screening is based on a bedded salt site, although one FEP (1.2.01.05, Diapirism) has been identified where a screening decision changes for bedded versus domal salt.

Using the foregoing assumptions, and the various definitions, assumptions, and specifications associated with the salt disposal reference case described in Section 3.2, the salt-modified FEPs in Table A-1 have been assigned preliminary screening classifications of “Included,” “Excluded” (or “Likely Excluded”), “Site-Specific,” “Design-Specific,” or “Evaluate,” according to the definition of these terms in Appendix A.

3.1.3 Scenario Development

Scenario development organizes the analyses that are to be conducted during the safety assessment based on the included FEPs. Scenarios are organized into scenario classes that are usually based on different types of disruptive events, such as human intrusion, seismicity, volcanism, or other system component failure (i.e., usually, failure of an engineered component). The scenario(s) not associated with disruptive events are combined into a nominal or undisturbed performance scenario class.

For this report, the salt disposal reference case described in Section 3.2 will contain only brief information and/or definitions for disturbed or disruptive scenario classes[4] because the focus of current work is on screening FEPs and developing PA models for the undisturbed scenario class. Primarily this is because the disturbed scenario is usually quite site-specific and the associated regulations for disturbed scenarios are often formulated specifically for the given site (see 40 CFR 194 for the WIPP site or 40 CFR 197 for the Yucca Mountain site). However, even though site and design information related to disruptive FEPs will be minimal in this initial draft of the reference case, human intrusion and component failure FEPs (e.g., early waste package failures) will be screened-in based on the likelihood that they will appear in the applicable regulations, when they are promulgated (e.g., see FEP 1.4.02.01). On the other hand, seismic and volcanic FEPs will be initially screened out, by the assumption that eventual site-selection will avoid such geologic settings.

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[4] See Section 3.2.3.2 regarding the assumed properties of an overpressured region beneath the repository.

3.2 Salt Disposal Reference Case

The current emphasis on analyses for a generic site (Clayton et al. 2011; Vaughn et al. 2012) creates some unique challenges for safety case development and subsequent modeling of a geologic disposal system. Normally, a safety case and the kernel of the safety case, the safety assessment, address a specific site, a well-defined inventory, waste form, and waste package, a specific repository design, and a specific concept of operations. FEPs are then addressed in the context of this information. This level of specificity does not exist for a generic site, so it is important to establish a reference site/design, called a *salt disposal reference case* (or more simply a “reference case”) in this document, to act as a surrogate for site-specific and design-specific information upon which a licensing safety case will eventually be built.

The salt repository reference case described in this section identifies the information needs for initial FEPs screening and the initial design of the SRD TSPA Model for preliminary safety assessments, including the relevant information for the Engineered Barrier System (EBS), the Geosphere and Natural Barrier System (NBS), the Concept of Operations, the Biosphere, and the Regulatory Environment. FEPs screening and TSPA model design is an iterative process for any geologic disposal system, so more detail may be added to this reference case later, as models evolve or as additional information is required for future FEPs screening activities. Figure 3-4 shows the major components of the reference case (inventory, geologic disposal system, concept of operations, biosphere, and regulations) and how the salt reference case fits into a multi-year plan for SRD TSPA Model development and use.

3.2.1 Major Elements of the Salt Disposal Reference Case

As shown in Figure 3-4, a *salt disposal reference case* will have five major elements that support development of the safety framework and design of the SRD TSPA Model. The five major elements of the salt disposal reference case are:

- Waste inventory
- Geologic disposal system (including the engineered and natural barrier systems)
- Concept of operations
- Biosphere
- Regulatory environment

These five elements are summarized here and described in more detail in Sections 3.2.2 through 3.2.6.

3.2.1.1 Reference Waste Inventory

For the purpose of addressing FEPs generically, a reference inventory is required and should focus on spent nuclear fuel (SNF) and high-level waste (HLW) already in storage or expected from existing reactor operations. This reference inventory will likely include (also see Section 3.2.2.1 for more detail):

a. The current U.S. inventory of spent nuclear fuel from commercial reactors;

b. SNF discharged from the current reactor fleet through final shutdown in about 2055, i.e., the "no replacement nuclear generation" scenario of Carter et al. (2012a, Sec. 3.2.1);

c. HLW and SNF currently owned and managed by DOE, most of which derived from "atomic energy defense activities," as defined in the Nuclear Waste Policy Act (NWPA), Sec. 8(c), as well as a small inventory of HLW derived from commercially related atomic energy uses, such as the West Valley, NY reprocessing plant, the Fort St. Vrain high-temperature gas reactor, and damaged Three Mile Island (TMI) fuel. [Defense-related HLW is essentially the inventory documented in "Case 4" of Carter et al. (2012b)].

d. Naval reactor fuel[5].

The baseline inventory will allow for specification of thermal output and radionuclide masses available for release.

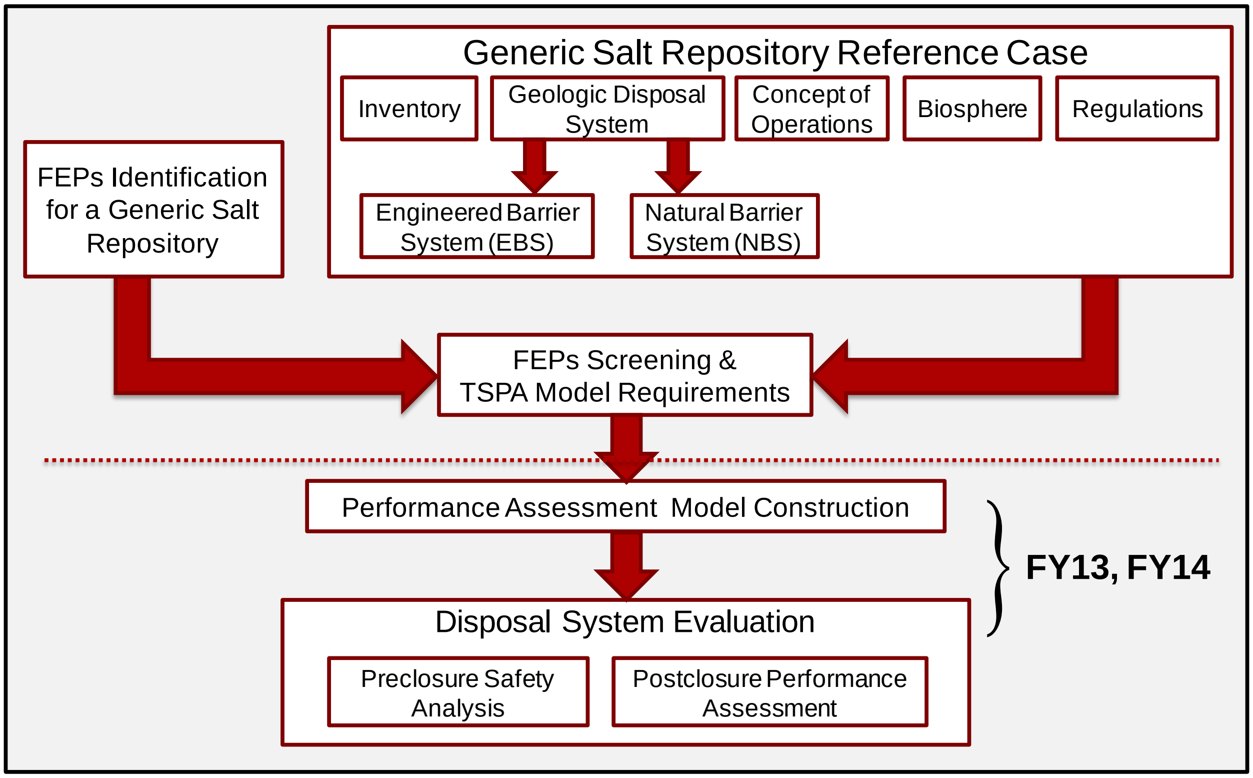

Figure 3-4. Major components of the salt disposal reference case and its place in the SRD TSPA Model development methodology.

3.2.1.2 Reference Geologic Disposal System

Figure 3-3 is a visualization of the geologic disposal system and biosphere, divided into a set of barriers and components as introduced in the UFD Generic Safety Case Report (Vaughn et al 2012). Figure 3-3 presents the major components or features in a linear fashion from left to right, beginning with the waste form and moving outward towards the Biosphere. In reality, the

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[5] As described by Carter et al. (2012b), emplacement of Naval fuel may require re-packaging, since the current 400 MT Naval waste packages exceed the capacity of industry-standard mine hoist equipment.

components are a set of nested regions. For example, the Natural Barrier completely surrounds the Engineered Barriers on all sides, and radionuclides can be transported from the Engineered Barriers to the Natural Barrier along multiple flow pathways, although these details are not shown in Figure 3-3.

The geologic disposal system will consist of the components/features that comprise the Engineered Barriers or Engineered Barrier System (EBS) and the Natural Barrier or Natural Barrier System (NBS), including any interface regions between these two major barriers. The Engineered Barriers consists of the Waste Form, the Waste Package, the Buffer/Backfill, Tunnels, and Seals/Liner. The Natural Barrier System consists of the Excavation Disturbed Zone (EDZ), the (intact) Host Rock, and Other Geologic Units above (including surficial soils) and below the repository, as well as an aquifer, if it exists. The EDZ is the portion of the host rock that may be altered (i.e., structural, mineralogical, and fluid composition changes) as a result of the excavation or the thermal pulse from the emplaced waste forms.

The Surface/Biosphere is evaluated as a receptor, as is done by United Kingdom's Nuclear Decommissioning Authority (NDA) (Bailey et al. 2011, Sec. 10.3.1), rather than a barrier. The reference case will describe the biosphere assumptions at a high level (see Section 3.2.5), in order to facilitate the conversion of radionuclide releases to annual dose. In fact, annual dose from a generic salt repository for undisturbed performance will be negligible because of the low permeabilities of the host rock and anhydrite interbeds (Clayton et al., 2011); however, the assumptions for the Biosphere are included in the reference case for completeness and consistency with previous work (see Section 3.2.5).

Engineered Barriers

The Engineered Barrier System includes everything within the physical excavations for the repository. The EBS includes the source term (represented as Radionuclide Inventory and Waste Form in Figure 1), Waste Package, Buffer and Backfill, Tunnels in the waste disposal area, Tunnel Liners (if used), and Shaft Seals. Some high level definitions and assumptions regarding these components are needed to address FEPs and inform PA models for the preliminary safety assessment:

- *Waste Forms*. The disposed waste forms, such as HLW borosilicate glass or uranium oxide SNF, contain the reference inventory of radionuclides described above in Section 2.2.1. DOE-NE is currently investigating a variety of potential waste forms associated with new fuels and new reactors systems, including recycling. However, the salt repository being considered here will initially be developed for legacy and future wastes (and associated waste forms) from the current commercial nuclear complex and the DOE defense and research complex. As such, the waste forms will mainly be in the form of glass logs, and ceramic or metal fuel rods. The salt reference case will initially only describe the type and general composition of these waste forms. Later, the specific geometry, and the degradation rates in typical salt repository environments, will be added. However, the initial information will be sufficient for a more "inclusive" FEPs screening and initial development of PA models. (See Section 3.2.2.1 for more detail on waste forms.)

- *Other EBS Components*. The salt disposal reference case should identify and describe (at a high level) the other EBS components such as the Waste Package, Buffer, Backfill, and Seal Systems. The information desired should include the component material along with its expected barrier function. For example, it is likely that the primary backfill and seal component will be crushed salt, which reconsolidates under lithostatic pressure to a very low permeability state that will effectively eliminate radionuclide migration. Also, because gas generation is likely to be an important consideration in a salt repository, the potential for EBS components to generate or consume gas should be discussed. (See Sections 3.2.2.2 to 3.2.2.6 for more detail on these components.)

Specific property values (and their associated uncertainty characterization) for parameterization of component performance are not part of the reference case at this time. Instead, the information specified in the reference case will inform subsequent model conceptualization and parameterization. Additional details about the EBS are given in Section 3.2.2.

Geosphere and Natural Barrier System

The geosphere includes the geologic setting and the Natural Barrier System, which are described as follows:

- *Geologic Setting*: The geologic setting includes general information associated with the location of repository within the host rock and the surrounding geology. This information includes the thickness and lateral extent of the host rock, the location of evaporite or clay interbeds within the host rock, and the location of any aquifer(s) above or below the repository. Specific information needs for the geologic setting are as follows:

    1. Type of Salt Formation: The choice of a bedded or domal salt formation should be identified.

    2. Regional Geology: This includes the general location of the repository (e.g., Basin and Range Province; Appalachian Region, etc.), which will define hydrogeologic boundary conditions for the NBS, such as regional groundwater characteristics and flow, regional climatic conditions, and regional disruptive event probabilities (e.g., related to seismicity and volcanism). For the salt disposal reference case, the regional geology may remain undefined in some characteristics, such as event probabilities (with the assumption that these will be screened during a site-selection process), but specified in other characteristics, such as general climatic properties (but only to the level of defining a representative biosphere aquifer—see Section 3.2.5).

    3. Stratigraphy: A generic stratigraphy should be developed including thicknesses, formation mineralogy, and the position of the repository relative to the features of a vertical stratigraphic cross-section, as well as the lateral distance to the biosphere. Representative characteristics such as salt formation thickness, aquifer

location(s) relative to repository, thickness of aquifer(s), aquifer media, and the location and properties of other release paths, such as the location and thicknesses of interbeds and the presence of brine pockets, should be included. Some aquifer characteristics are important to the definition of the biosphere, as discussed in Section 6.

- *Natural Barrier System*: The NBS contains the EDZ, the host rock, and other geologic units, and establishes the boundary conditions for performance of engineered barriers. Characteristics of the repository host rock usually play an important role in limiting the transport of radionuclides from the engineered barriers to other geologic units, and eventually to the accessible environment. Specific information needs for the natural barrier system components are as follows:

    1. Excavation Disturbed Zone. The EDZ is the interface between the EBS and the undisturbed host rock, and should be defined with respect to the spatial extent for mechanically-induced damage from excavation as well as any thermal-chemical alterations to the host rock surrounding excavations during the period of elevated temperatures caused by the decay heat of the emplaced waste. The time required to “heal” any excavation-induced or heat-induced fractures in the salt surrounding the tunnels is required in conceptualizing release paths for the initial PA models. Detailed physical property values for the EDZ are not part of the reference case at this time, but will be assigned during PA model development.

    2. Host Rock and Other Units. The Host Rock and Other Units are the portions of the NBS outside the EDZ. Generic and representative features of the Host Rock and Other Units that influence the Natural Barrier capability in a bedded salt repository include:

        a. Halite interval assumptions including representative thicknesses;
        b. Aquifer assumptions including thickness and location relative to repository (also see Section 3.2.5);
        c. Interbed assumptions, including locations relative to the repository, thicknesses, and materials (such as clay versus anhydrite);
        d. Assumptions concerning the presence of underlying geologic features, such as pressurized brine pockets;
        e. Lateral distance to any water well(s) that are part of the biosphere; and
        f. Assumptions regarding geologic or hydrogeologic features that connect interbeds to aquifers (generally, site-selection would avoid most of these features, such as karst dissolution fronts and breccias pipes—see Section 3.2.3.2).

Further detail about the geosphere and the NBS is given in Section 3.2.3.

3.2.1.3 Reference Concept of Operations

The engineering concept of operations takes into account the characteristics of the EBS and the NBS to define the excavation, emplacement, and closure operations for the repository disposal system. The concept of operations includes repository layout, excavation methods, construction details, emplacement mode for waste packages, segregation of waste types (if needed), emplacement of non-heat generating waste, selection of engineered materials, operational details, design and emplacement of seals and plugs, performance monitoring, and repository closure.

The salt disposal reference case considers concepts of operation at a high level, including emplacement mode, waste package type, major features of the EBS, and repository layout, as appropriate for generic disposal evaluations. The information for repository layout includes the repository footprint, the distance between waste packages, the corresponding thermal areal loading, and the location of seals for the waste emplacement areas. Specifications appropriate for the reference case are described in Section 3.2.4.

3.2.1.4 Biosphere

The reference case should define high-level assumptions to inform the FEPs analysis and the safety assessment modeling for the biosphere. Radiation exposure, typically expressed as annual dose to a receptor in the biosphere, is commonly used as a performance metric in safety assessments (40 CFR 197.20 and 10 CFR 63.311). The salt disposal reference case should include a high level description of the potential biosphere pathways in order to convert radionuclide release concentration to annual dose for a generic site. The approach recommended for the salt disposal reference case is based on a drinking water well bored through the overburden into an aquifer that has been contaminated by radionuclide releases from a repository (see Section 3.2.5 for more details).

3.2.1.5 Reference Regulatory Environment

The site-specific Environmental Protection Agency and U.S. Nuclear Regulatory Commission regulations for Yucca Mountain, 40 CFR 197 and 10 CFR 63, are not applicable to a generic HLW/SNF salt repository, but existing EPA and U.S. NRC regulations for disposal of high-level radioactive wastes in geologic repositories remain in effect, i.e., 40 CFR 191 and 10 CFR 60. However, these existing regulations would likely be superseded for an HLW/SNF salt repository, since they were developed almost 30 years ago and are not consistent with the more recent thinking on regulating geologic repositories that embraces a risk-informed, performance-based approach (U.S. NRC 2004), such as that represented in the site-specific regulations for Yucca Mountain. Thus, the recommended approach for defining a set of regulatory assumptions for the salt safety framework is to combine portions of the existing regulations in 40 CFR 197 and 40 CFR 191, as described in Section 3.2.6.

In the following sections more detailed information is provided about the five major elements of the reference case introduced above.

3.2.2 Reference Salt Disposal System: Engineered Barrier System

The components of the EBS in the reference salt repository are: (1) the Waste Form; (2) the Waste Package; (3) the crushed-salt Backfill; and (4) Tunnels, Panel Closures and Shaft Seals (see Figure 3-3). The salt disposal reference case is initially based on a generic salt repository design concept (Carter et al. 2011), which requires no tunnel liners or buffers. Note that panel closures and shaft seals are not considered part of the engineered barriers for the WIPP by the EPA's 1998 Certification Decision (DOE 2009, Section 44.3). However, the closures and seals are engineered components that are important elements of a geologic disposal system and are therefore considered part of the EBS for this reference case. The following paragraphs describe the functions, configuration, and composition of each component in the EBS.

3.2.2.1 Waste Form and Source Term

Current projections show that, if all operating commercial reactors in the U.S. receive license amendments that extend operating life to 60 years, the total inventory of UNF will reach approximately 140,000 MTHM in the year 2055 (Carter et al. 2012a, Table 3-7). Burnup of the current UNF inventory currently (2010) averages 39.6 GWd/MT for PWRs, and 33.3 GWd/MT for BWRs, and is projected to average 47.3 and 45.3 GWd/MT, respectively, for the total inventory in 2055 (Carter et al. 2012a, Table 3-7). Maximum burnup in 2055 under this "no replacement nuclear generation scenario" is 54.2 and 56.3 GWd/MT for BWRs and PWRs, respectively (Carter et al. 2012a, Table 3-5). For thermal analysis and PA model development, bounding cases at 40 GWd/MT and 60 GWd/MT are considered representative (Hardin et al. 2012, Sec. 1.2), when considering the current inventory burnup and this projected maximum burnup.

The salt disposal reference case must define the radioisotopes that are present in the inventory to support design of PA models. Radioactive decay and ingrowth will also be considered by PA model(s) for the preliminary safety assessments, but half-lives, decay chains, and initial radioisotope masses will be parameterized later, during implementation of PA models. The list of radioisotopes for the salt disposal reference case is based, in part, on the inventory of light water reactor (LWR) SNF tabulated by Carter et al. (2012a, App. C) for a range of burnup values and fuel ages. The defense waste management mission also includes disposition of HLW and DOE spent fuel. Assessment of the types of DOE HLW and DOE SNF and their average radionuclide inventories were provided by BSC (2004a). The number of DOE HLW and DOE SNF canisters and their heat output are summarized by Carter et al. (2012b).

3.2.2.2 Waste Package

SNF or HLW (in glass, ceramic, or metallic form) will be sealed in stainless steel canisters and surrounded by overpacks made of carbon steel with welded closures. Use of stainless canisters for SNF is dictated by the need to load the fuel in pools for shielding, and the requirement to use materials that do not foul the pools (such as carbon steel). A variety of stainless steel grades are used in fuel pools (e.g., 304 and 316). Use of stainless canisters for glass and other HLW forms is dictated by a need for resistance to scale formation when a canister is filled with high temperature waste in molten form, and to limit possible corrosion damage from environmental conditions or radiolysis during storage.

The stainless steel canisters are all thin-walled (e.g., 10 to 20 mm in thickness) with limitations for handling and disposal. Canisters containing 6 MT or more of SNF (12-PWR size or larger) are heavy and typically not designed for horizontal handling or transport. The disposal overpack will be designed to support the canister during transport underground, and has lifting features (trunnions and/or skirts). In addition to providing lifting points for handling, the additional strength and containment imparted by a relatively thick-walled, sealed disposal overpack limits radiological consequences associated with preclosure accident sequences. Once emplaced and covered with backfill, the overpack will be designed to resist package breach from crushing or buckling during a period of approximately 300 years or longer. This period corresponds to the duration assumed for waste recovery, as described in Section 3.2.6.

Because of the extremely low permeability of intact or healed salt (Hansen and Leigh 2011), the geologic disposal concept for salt does not require long-term waste package containment integrity. However, a defense-in-depth philosophy would result in regulations that require the waste package to retain its isolation capability through the thermal period (Hansen and Leigh 2011, Sec. 2.5.1) when brine migration processes are most active around the waste package, prior to reconsolidation of the crushed salt backfill around the waste package. This is likely to be less than 200 years (Clayton et al. 2012), so carbon steel is a reasonable choice for the disposal overpack material. Carbon steel is susceptible to general corrosion of exposed surfaces, but not localized corrosion, which makes its degradation easier to represent in performance assessment models. Penetration rates for general corrosion can approach hundreds of microns per year in warm, humid, high ionic strength brine environment (e.g., for A516 steel, see BSC 2004b), so a wall thickness of 7.5 cm has been initially selected to ensure a 300-year recovery period for the reference case[6] (see Section 3.2.6). A thickness greater than 7.5 cm may be selected later during sensitivity analyses, depending on brine availability and corrosion rates predicted by coupled process models. [Note: Structural calculations have not been conducted yet to support the choice of 7.5 cm, nor the choice of 5 cm in Hardin et al. (2012, Sec. 4.2). A thicker-walled waste package design was selected by the DOE Salt Repository Project during preliminary site selection work that targeted the bedded salt formations in Deaf Smith County, Texas (Westinghouse Electric Corporation 1986). Based on estimated corrosion rates at that time, 2.3 cm of waste package thickness was calculated to be degraded during 1000 years of general corrosion after emplacement (a retrievability period of 1000 years was assumed based on 10 CFR 60). Using this corrosion estimate and estimates of structural strength for A216 carbon steel, waste packages containing 12-PWR intact SNF assemblies were designed with a wall thickness of 12.8 cm, assuming a host rock lithostatic pressure of 18 MPa at the repository horizon (ONWI 1987, Sec. 4.4.4.2 and Appendices C and D). (As a comparison, the lithostatic pressure at the WIPP repository horizon is about 15 MPa.)]

Waste package outer dimensions will be based on Hardin et al. 2012 (Table 1.4-1), which are 1.29 m in diameter and 5 m in length for a 12-PWR waste package. The 12-PWR waste package is chosen for the reference case based on thermal management considerations discussed below in Section 3.2.4.2.

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[6] At a corrosion rate of 100 μm per year, the overpack thickness is reduced by 30 mm in 300 years, or less than one-half of the initial overpack thickness of 75 mm. The corrosion of the overpack may proceed much more slowly than indicated by this estimate because the thermal pulse will initially expel moisture, resulting in a dry environment that inhibits general corrosion. (General corrosion of steel in anoxic environments consumes water, so water availability at the overpack surface is key to understanding package longevity and hydrogen production by anoxic corrosion.)

3.2.2.3 Waste Package Emplacement

Waste packages will be emplaced on the floor of an emplacement drift or in an alcove to one side of a drift, and covered with crushed salt (Carter et al. 2011; Carter et al. 2012b), depending on the power output of the waste package (see Section 3.2.4.1).

Emplacement in vertical or horizontal boreholes is not considered for the salt disposal reference case. Vertical borehole emplacement requires thicker salt beds, so repository development and siting can be more difficult. It also introduces operational limitations and waste containerization restrictions. In addition, it could result in higher pressure gradients around the waste packages that lead to higher brine inflow rates, possibly exacerbating corrosion reactions with waste package materials. Horizontal borehole emplacement is time consuming and therefore expensive compared to placing waste packages directly on the floor of the emplacement drifts, based on the DOE experience with horizontal boreholes at the WIPP. In addition, heat-generating waste packages may cause a rapid loss of structural integrity of the horizontal emplacement boreholes. Thus, for hotter waste packages an alcove emplacement concept is proposed (Carter et al. 2011) in which heat-generating packages are placed in alcoves accessible from a grid of access drifts. A reference generic salt repository disposal concept for SNF from advanced fuel cycles (Hardin et al. 2012; Hardin et al. 2011) implements this arrangement with a 20-meter spacing between waste packages to accommodate relatively hot packages. This is discussed in more detail in Section 3.2.4.2.

3.2.2.4 Backfill

The salt disposal reference case assumes that excavations will be filled with crushed salt backfill after waste packages are emplaced. The crushed salt backfill will initially be only slightly compacted, with porosity of approximately 35% (Rothfuchs et al. 2003). The backfill will begin consolidating as drifts and entries close due to creep of the host salt formation. Salt creep is thermally activated (Callahan 1999) so room closure is expected to proceed fastest in those sections of the repository with the hottest waste packages.

Past field experience (DOE 2012), supplemented by simulations, shows that backfill reconsolidates rather quickly. Simulations using the multi-mechanism model for creep deformation of the intact rock (Munson et al. 1989) and a model for creep behavior of crushed salt (Callahan et al. 1996; Callahan 1999) indicate that the reconsolidation of backfill will be mostly complete in approximately 200 years (Clayton et al. 2012). Consolidation proceeds quickest at first, achieving greatly decreased permeability and increased thermal conductivity of the backfill in the first few decades, and then proceeds more slowly as compressive stress increases in the backfill that resists the inward motion of the host rock. Consolidation of the backfill will eventually progress to a condition of low permeability on the order of 10^{-18} m^2 or less (Hansen and Leigh 2011, Sec. 2.4.1.7) and is expected to eventually restore the backfill to a state approaching the porosity and permeability of intact salt.

3.2.2.5 Liners and Ground Support

The salt disposal reference case assumes that there will be minimal ground support and tunnel liners in the emplacement drifts because extensive ground support or liners could impede or prevent the surrounding salt host rock from encapsulating the waste due to salt creep and drift closure. The design of and operational experience with the WIPP, which has minimal ground support and no tunnel liners in emplacement rooms or in access drifts, is consistent with this assumption.

3.2.2.6 Seal Systems

Plugs, seals, and other closures (collectively referred to here as seals) will be used to isolate emplacement panels and to limit water or radionuclide migration along the shafts. The shaft seal design for the WIPP stands as an example of conservative engineering using redundant elements constructed mostly from natural materials, and has received regulatory acceptance (Hansen and Knowles 2000). The seal design will be specific to local geology and hydrology; for example, a different concept could be appropriate for sealing shaft penetrations through a major aquifer (e.g., Deaf Smith conceptual design; DOE 1986). Plugs are used to “back” sealing materials, i.e., to control settlement and resist pressure from groundwater at interfaces within the seal system.

The primary purpose of the shaft seals is to limit the rates of flow of water or brine into or out of the repository. For the salt reference case, seals are assumed to perform this function with no significant leakage in the vicinity of emplaced waste packages. The shaft seal system is a multi-component barrier: a crushed salt component provides the long term barrier capability and concrete/asphalt components provide the short term (1,000–2,000 years) barrier capability during the time that the crushed salt components consolidate to near-host-rock porosity and permeability. Thus, the primary long-term barrier component of the shaft seal system is crushed salt, which reconsolidates to a state close to that of the surrounding intact rock within approximately 200 years (Clayton et al. 2012).

This design of the shaft seal system is formulated to prevent any significant degree of communication between the waste emplacement areas and any overlying or underlying geologic formations that conduct or store potentially potable water. This design goal is achieved, in part, by the use of seal components made of crushed salt that reconsolidate to a state approaching that of intact salt, and also by assuming that waste emplacement areas are far from the shafts, allowing time for the access tunnels and emplacement drifts to close due to creep of the salt formation. The potential dose effects of shaft seal failures can be analyzed either in a sensitivity study designed to justify a FEPs exclusion for scenarios related to shaft seal failures, or in the performance assessment model itself, if the probability or consequences of a shaft seal failure are above the regulatory limits for FEPs inclusion/exclusion.

3.2.3 Reference Salt Disposal System: Geosphere and Natural Barrier System

The salt disposal reference case requires enabling assumptions or high-level specifications of some aspects of the geologic setting and the Natural Barrier System. This reference information is required for providing a basis for FEPs evaluation and disposal system model conceptualization within the safety framework. Figure 3-3 indicates that the Natural Barrier System includes the Excavation Disturbed Zone (EDZ), the Host Rock, and Other Geologic Units. As defined in Section 3.2.1.2, the EDZ is a region of host rock influenced directly by mechanical stresses caused by excavation and the thermal energy of the emplaced waste.

The reference case considers disposal in bedded salt only. The generic geologic setting includes high-level descriptions of the regional geology, the local stratigraphy, and the location of the repository within that stratigraphy. The geologic setting descriptions provided for this reference case draws on information and characteristics representative of bedded salt formations in the United States.

3.2.3.1 Geologic Setting and Reference Geology

Five major basins which contain significant deposits of bedded salt in the United States were selected to establish a generic basis for the geologic setting of a repository located in bedded salt. No attempt is made to select a "best" site from this list as there are many other considerations for selecting a final site. The five basins are the: (1) Paradox Basin, (2) Permian Salt Basin, (3) Michigan and Appalachian Basins (Salina formation), (4) Williston Basin, and (5) Supai Basin. The domal salt formations found in the Gulf Coast region have not been considered because the focus of this reference case is bedded salt. Table 3-1 presents a summary of salt formation information relevant to the reference case. The information contained in the table is primarily from Pierce and Rich, 1958, Pierce and Rich, 1962, and Johnson and Gonzales, 1978.

Table 3-1. Summary of Salt Formation Information Relevant to the Reference Case.

Basin	**Depth, ft[2] (Min-max to top of salt within basin)**	**Thickness, ft**	**Salt Extent[4] (sq. mi.)**	**Notes**
Paradox[1]	400 – 12,000	0 – <9000 Salt Bearing 100 – 5000 Salt 50 – 530 Individual Beds[3]	12,800	Anticline folds of the beds (Largest thicknesses are associated with the folds). Intrusive igneous mountains, faulted areas. Extent estimate from map: about 160 × 80 mi.
Permian Salt	400–6000	400 – 2200 Salt 0 – 350 Individual Beds	135,000	Extent estimated from map: about 650 × 150-250
Michigan	<1000 – >6000	500 – 1800 Salt 0 – 100 Individual Beds	70,000	Dip 30-40 ft/mile; Extent estimated from map: about 150 mi radius
Appalachian	<1000 – >6000	0 – 8000 Salt 0 – 100 Individual Beds	41,000	Anticlines and synclines of the beds, most beds dip 10 – 20 ft/mile; Basin is 300 × 600 = 180,000 sq mi; Extent estimated from map: about 275 mi × 150 mi
Williston	3000 – >12,000	0 – 400 Salt 0 – 150 Individual Beds	85,700	Extent estimated from map as sum of Prairie, Charles, Opeche Formations and Pine and Dunham Triassic Salt.
Supai	650 – 800	550 Salt 10 – 200 Individual Beds	3000	Extent estimated from map: about 100 mi × 30 mi

1. Specifically, the Paradox member of the Hermosa Formation
2. To top of salt within basin
3. Deposits of salt, no interbeds.
4. Extent: Approximate and based largely on map reading

Paradox Basin

The Paradox Basin is located in southeastern Utah and southwestern Colorado. The thick Hermosa salt formation in this basin was deposited during the Pennsylvanian Age. The Paradox Basin encompasses an area of about 12,800 square miles (3.32×10^6 hectares) with the salt beds beginning at a depth of 400 feet to 12,000 feet, (122 m – 3660 m). Most of the Paradox Basin is characterized by broad open folds trending northwest. Anticlinal folded beds in the southern and southwestern part are widely spaced and of relatively low relief. Two factors control the thickness of salt in the Paradox Basin: (1) the original depositions and (2) subsequent building of folds, where salt can be considerably thicker. Parts of the Paradox Basin are attractive because of the thickness of the bedded salt, the thickness of the shale above and below the bedded salt, and the distance to salt-dissolution features.

Permian Salt Basin

As defined by Bachman and Johnson (1973), "The Permian salt basin in the Western Interior of the United States is defined as that region comprising a series of sedimentary basins in which halite and associated salts accumulated during Permian time. The region includes the western parts of Kansas, Oklahoma, and Texas, and eastern parts of Colorado and New Mexico." The Permian Salt Basin[7] encompasses an area of about 135,000 square miles (3.50×10^7 hectares) with the salt beds beginning at a depth of 400 feet to 6,000 feet, (122 m – 1830 m). The salt deposits are progressively younger from northeast to southwest. In Kansas, Oklahoma, and the northern part of the Texas Panhandle, salts were deposited in the early Permian Age (Leonardian series or epoch). In southeastern New Mexico and southwestern Texas salts were deposited in the late Permian Age (Ochoan series or epoch). The deposits in Texas, New Mexico, and Oklahoma contain gypsum and anhydrite in close association with the salt. In Kansas there is little anhydrite or gypsum. The thickest and most extensive salt beds in the Texas and New Mexico areas of the Permian Salt Basin are in the Castile, Salado and Rustler Formations, which are part of the Ochoan series, which is the last epoch of the Permian Age. The Rustler Formation is the last depositional unit of Permian Age in the Delaware Basin of Southeast New Mexico (a sub-basin of the oil-producing Permian Basin and is considered to be the uppermost part of the Salado lithostratigraphic group of formations. Immediately earlier in depositional time is the Castile group. Together, the Salado and Castile groups comprise the Ochoan epoch in the Delaware Basin. As described by Bachman and Johnson (1973), the Salado Formation exceeds 2,000 feet in thickness in the Delaware basin where it attains its maximum development. The formation is mainly rock salt (halite) with much anhydrite and lesser amounts of interbedded shale, sandstone, and other evaporite minerals. The salt alone is more than 1,600 feet thick. The Salado overlies the Castile Formation in the Delaware basin....The thickness of the Castile Formation may approach 2,000 feet near the center of the Delaware basin. The formation is composed mainly of beds of anhydrite and halite, but also includes a few extensive limestone beds. The salt alone is more than 600 feet thick." The Rustler Formation has a relatively small

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[7] The term "Permian Salt Basin" is apparently used by Bachman and Johnson to distinguish it from the "Permian Basin," which is the term used for the sedimentary (largely carbonate) rocks of West Texas and Southeast New Mexico containing vast petroleum deposits from the Permian Age:

(http://www.netl.doe.gov/technologies/oil-gas/Petroleum/projects/EP/ResChar/15131UofTX.htm amount of salt and is not a representative salt for geologic disposal. Anhydrite is the dominant rock type in the Rustler formation, but dolomite occurs as persistent beds and polyhalite and soluble potassium salts are also present locally (Pierce and Rich, 1962).

Michigan and Appalachian Basins (Salina Formation)

The Salina Formation contains some of the largest deposits of salt in the world, and encompasses major portions of two basins: the Michigan Basin and the Appalachian Basin. The total area underlain by salt is approximately 70,000 square miles (1.81×10^7 hectares) in the Michigan Basin and approximately 41,000 square miles (1.06×10^7 hectares) in the Appalachian Basin. The depth to the top of the Salina Formation varies from less than 1,000 feet, (305 m) to greater than 6,000 feet, (1830 m) in either basin. It underlies portions of New York, Pennsylvania, West Virginia, Ohio, and Michigan. The salt was deposited during the late Silurian, Devonian, and Mississippian Ages. The Michigan Basin is an elliptical structural basin with its center in the Southern Peninsula of Michigan. The Appalachian Basin slopes southeastward in the area of the salt deposits and increases in structural complexity in that direction. The thickest sections of the Salina are in southern New York and in Michigan. Shale is an important constituent near the eastern and northern limits of the Salina Formation. Carbonate, mainly dolomite, increases in abundance to the southwest. The salt, anhydrite, and gypsum occur in several beds, and the salt reaches its maximum thickness in the center of the Michigan Basin.

Williston Basin

The Williston Basin is a large depositional basin located in portions of Montana, western North and South Dakota, and southern Saskatchewan. The Williston Basin encompasses an area of about 86,000 square miles (2.23×10^7 hectares) with the salt beds beginning at a depth of 3,000 feet (914 m) to greater than 12,000 feet (3660 m). It contains large volumes of bedded salt and is well known for its rich deposits of petroleum and potash. The salt was generally deposited during the middle Devonian, Mississippian, Permian, and Triassic Ages. The Williston Basin is a geologic structural basin and is transected by the Missouri River. It lies above an ancient Precambrian geologic basement. The Precambrian basement rocks in the center of the basin beneath the city of Williston, North Dakota lie about 16,000 feet (4,900 m) below the surface.

Supai Basin

The Supai Basin is considerably smaller than the other basins considered as representative of bedded salt. The Supai Basin encompasses an area of 3,000 square miles (7.77×10^5 hectares) with the salt beds beginning at a depth of 650 feet to 800 feet (198 m – 244 m). It is located in east-central Arizona and west-central New Mexico. The salt of the Supai Formation was deposited during the Pennsylvanian and Permian Ages. In general, salt makes up from 5 to 15 percent of the Supai Formation, with interbeds of sandstone, siltstone, limestone, and gypsum.

3.2.3.2 Natural Barrier System

As discussed above in Section 3.2.1.2 and shown in Figure 3-3, the major components of the Natural Barrier System (NBS) are the Excavation Disturbed Zone (EDZ) and the Host Rock and Other Units. Specifications for these two major features/components of the NBS are provided in this section.

Excavation Disturbed Zone for the Reference Case

The *excavation damage zone* (EDZ) is the portion of the near-field host rock that may be altered (i.e., structural, mineralogical, and fluid composition changes) as a result of the excavation or the thermal pulse from the emplaced waste forms. The properties that typically define the EDZ include (1) dilational deformation of the original host rock, (2) strength loss of the host rock, and (3) increased fluid permeability via connected porosity. The EDZ can play an important role in the geomechanical response of salt rooms or openings underground, particularly where structures are placed to retard fluid flow. Physical-chemical processes within the EDZ can influence EBS degradation and radionuclide mobilization, implying that FEPs associated with the EDZ may need to be explicitly included in performance assessment models. However, FEPs sensitivity analyses to investigate these phenomena may allow these FEPs to be screened out, particularly if the crushed-salt backfill around the package dries out rapidly and reconsolidates to very low permeability (Hansen and Leigh 2011).

Salt host rock nearest an excavation opening experiences the greatest damage (induced dilation) and reflects the greatest increase in permeability due to fracturing caused by dilation. Salt farther from the opening undergoes less damage and, as a result, experiences smaller change in permeability. After repository closure, damage in the EDZ is more rapidly reversed in a salt formation than in other repository concepts due to the plasticity of halite. Healing conditions are created as the formation salt compresses materials within the rooms, including engineered barrier systems and/or the waste itself.

Brine is a factor that must be considered in the overall evolution of a salt repository. For example, waste isolation depends closely on the limited availability of brine to mobilize radionuclides. In the performance assessment model, brine is also essential for corrosion of iron and other metals and for sustained microbial activity. In the absence of brine, a salt repository is virtually unaffected by these processes. Three important properties of the EDZ, the extent, porosity, and permeability, as well as the thermal pulse from the waste decay heat, contribute to the volume and rate of brine flow into a potential repository in a bedded salt formation. Stress states that give rise to dilation (voids created by fractures) can be defined in terms of stress invariants, which allow reasonable models of EDZ evolution and devolution. The stress-invariant dilatancy model has been used in structural calculations for many years (Hansen and Leigh 2011, Sec. 2.4.1.1), and based on this experience reasonable estimates of the EDZ can be established for the reference case.

Based on the technical information available, it is expected that the EDZ around rooms of a heat-generating waste repository would heal completely within a 200-year period (Clayton et al. 2012) when administrative controls are assumed to prevent intrusion into the repository. Heat from the waste has been postulated to create a dry halo that could limit corrosion of the waste packages, and rapid healing of the EDZ would limit brine resaturation around a waste package (Hansen and Leigh 2011).

Host Rock and Other Units

Depth to Top of Salt for Reference Case

Using Table 3-1 as a guide, the representative value for the depth to the top of the bedded salt is taken to be 2,000 feet, (610 m) with a range of 1000 feet[8] to 3500 feet (305 m – 1067 m). From the perspective of FEP screening, this range of depths limits the impacts of surface-related phenomena on long-term repository performance. For example, dissolution, glaciation, erosion, and other surface process are slow enough or limited in depth of impact so as not to compromise the integrity of a repository located at these depths. Other external events, such as a meteor impact, are also not expected to be of importance at these depths. Additionally, there are sufficient regions with significant salt deposits located at these depths so that this range of depths does not significantly limit siting options regionally or nationally (although it does rule out the Supai Basin).

Salt Bed Thickness for the Reference Case

The “thickness of salt” is somewhat subjective because it depends on the purity level of the halite and the tolerance for the presence of interbeds and the thickness of these interbeds. The presence of impurities and interbeds are common throughout all of the major salt deposits. For example, while the total thickness of the Salado Formation in the vicinity of the WIPP is 1750 feet, (533 m), it contains numerous interbeds of clay and anhydrite interspersed throughout. The halite content of the Salado is approximately 75-90%, the remaining portion being the interbeds. The horizon for the WIPP repository is located between Anhydrite Marker Beds 138 and 139 in about 13 meters of relatively pure halite. However, even this relatively pure halite has two additional clay seams and two minor Anhydrite layers, called Anhydrite Layers A and B.

Using Table 3-1 as a guide, the reference case will assume that the repository horizon is located in a relatively pure halite stratum that is at least 12 meters thick, with only very thin interbeds and seams of impurities less than 0.25 meters thick. Outside of this “repository zone,” the salt formation will be assumed to be at least 250 feet (76 m) thick with a halite content of at least 50 percent. With the exception of the Supai basin, there are numerous locations throughout the Paradox, Permian, Michigan, Appalachian, and Williston Basins that have salt of this thickness and content.

Lateral Extent for the Reference Case

The lateral extent of the salt deposits in the five major basins (Table 3-1) does not pose any significant limitations for geologic disposal. Two possible approaches could be used to establish the lateral extent of salt: (1) based on existing, site-independent, regulations for the disposal of high-level nuclear waste (40 CFR 191 and 10 CFR 60), or (2) based on the risk-informed, but site-specific, regulations for the disposal of high-level nuclear waste at Yucca Mountain. Current site-specific regulations for high-level waste, 10 CFR 63.302 (at 66 FR 55753), indicate a maximum distance of about 18 km for demonstrating compliance at the boundary of the

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[8] Note that 10 CFR 60.122 lists as a “favorable condition” the siting of a repository at a minimum depth of 300 m from the ground surface.

controlled area in the predominant direction of groundwater flow or 5 km in any other direction. However, these are quite dependent on the groundwater flow regime in the specific vicinity of Yucca Mountain, so they would not be logically applicable to a generic salt site. The preferred approach is to use the controlled area definition in the non-site-specific regulations, 40 CFR 191.12 and 10 CFR 60.2. The former specifies a controlled area ("to be identified with passive institutional controls") of "no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system" and the latter specifies a controlled area ("to be marked by suitable monuments") "extending no more than 10 kilometers in any direction from the outer boundary of the underground facility." It is conservative to choose the minimum of these two, so the lateral extent for the salt repository reference case will be defined as the 5-km distance in 40 CFR 191.12. Both the salt and interbeds of the reference case will be assumed to be uniform over the lateral extent of the repository and the entire underground area encompassed by the 5-km boundary.

Aquifer Definition for the Reference Case

The location and characteristics of an aquifer are important considerations because an aquifer provides a potential pathway to the boundary of the controlled area and thus to the biosphere. *Aquifer* as used here means a water-bearing underground geological formation, group of formations, or part of a formation (excluding perched water bodies) that can yield a significant amount of groundwater to a well or spring at the boundary of the controlled area surrounding the repository. The water quality of the waters in aquifers located in the vicinity of salt deposits is usually too brackish to be potable for direct human consumption, but these waters are often used to support other agricultural or ranching activities. This is particularly true of semi-arid locations. Deeper aquifers are also progressively more saline.

For the purpose of the reference case, an aquifer is assumed to be located above the repository horizon, as is the case in the Permian and Williston Basins. This assumption is not intended to preclude eventual siting in a region where an aquifer beneath a repository could be an important pathway for releases to the biosphere. Thus, during development of the TSPA model, if an aquifer located beneath the repository requires additional submodels or couplings, this will be taken into consideration. For the initial reference case, however, the aquifer is taken to be approximately 750 feet (229 m) above the repository with a range of 500 feet to 1,500 feet (152 m – 457 m). The effective thickness (water producing interval) of the aquifer will be taken as 50 feet (15 m) with a range of 10 feet to 75 feet (3 m – 23 m). The aquifer is assumed to be a saturated, single-porosity sedimentary formation in the regional groundwater basin containing the repository. It is assumed to have a uniform thickness, a constant porosity, and a constant regional Darcy velocity in the portion of the aquifer that might communicate with both the repository horizon and the biosphere location. The stratum beneath the aquifer is assumed to be low permeability rock that acts as an aquitard between the repository and the aquifer. Advection is the dominant radionuclide transport mechanism in the regional aquifer.

Underlying Overpressure Areas for the Reference Case

Regions of over-pressurization (i.e., in excess of hydrostatic pressure at depth) are common in some of the larger bedded salt deposits. The over-pressurization can create a driving force for the potential release of contaminated brine if the region becomes hydrologically connected to the repository (e.g., through a human-intrusion borehole). To account for this possibility, the reference case will assume that an overpressure region is located under the repository footprint at a depth of 750 feet (229 m) below the repository horizon, with a range of 500 feet to 1000 feet (152 m – 305 m). It will contain brine at lithostatic pressure. The thickness of the overpressure region is taken to be 100 m with a range of 25–150 m. Total available brine volume in the unit at pressure is assumed to be 75,000 m^3 with a range of 30,000 to 150,000 m^3. Other properties such a compressibility and transmissivity will be developed later during model conceptualization and parameterization.

Stratigraphic Dip for the Reference case

Some horizontal stratigraphic dip occurs in all bedded salt formations and will influence the flow of brine and gas in and around the repository, particularly when two-phase flow is considered. For example, a regional dip of as little as 1 degree results in an elevation change of 17.5 m over a 1 km distance, which is a horizontal distance less than typical repository dimensions. Because of this elevation change, repository excavation is usually facilitated by reference to a nearby marker bed so that the excavation maintains an equidistance from parallel interbeds. A dip of 1 degree will be assumed for the reference case, ensuring that the effects of two-phase flow must be included in the salt repository PA model.

Interbed Thickness and Location for the Reference Case

A bedded salt formation consists of massive layers of halite mingled with interbeds of anhydrite stringers (called “marker beds” in the WIPP literature), and salt zones enriched with clay or polyhalite—depending on the conditions at the time of deposition. Interbeds between 0.1 and 20 feet (0.03 to 6.1 m) are commonly observed. In their undisturbed condition, the hydraulic conductivity of these interbeds, as well as the massive salt beds, is negligibly small. However, when an opening in salt is made, areas of rock near the free surface experience new, higher stress differences that can produce fractures and enhance permeability. As a result, these interbeds and lateral variations in sedimentary facies provide potential pathways for water seepage through the EDZ into repository workings because they are more transmissive than the halite. In particular, damaged salt in the EDZ will heal when stress differences reduce during reconsolidation following repository closure, whereas fractured anhydrite stringers would not be expected to heal. Thus, damaged anhydrite might have a hydrological connection to a repository room. Measured permeability of native anhydrite is very low ($<10^{-18}$ m^2), but its natural fabric provides a preferred pathway for potential pressurized gas or brine transport.

Thicker interbeds within one or two room dimensions of the emplacement drifts (e.g., within 4 to 8 meters, depending upon the repository design), would likely be avoided in favor of other underground locations without discernible interbeds. However, to be somewhat conservative for the reference case, the assumed major interbeds above and below the massive salt encompassing the repository horizon will be considered to be 2 feet (0.61 m) thick with a range of 0.5 feet to 4 feet (0.15 m – 1.2 m). Assuming that the maximum extent of the EDZ is about 3 room diameters, or about 12 meters from the floor or ceiling of the emplacement drifts, the closest edge of the assumed interbeds will be taken to be in the range of 12 meters to 15 meters from the repository floor and ceiling, i.e., from 0 to 3 meters beyond the assumed maximum extent of the damaged zone.

Other Geologic Features for the Reference Case

There are a number of other features that may found in some bedded salt deposits (e.g. folds, anticlines, discontinuities such as faults and fractures, breccias chimneys). These are very site-specific and for generic modeling the reference stratigraphy is assumed to be devoid of them. However, the potential for horizontal fracturing within interbeds and at interbed interfaces may be considered in developing PA models, although the permeability and other properties of these fractures will not be defined in this initial definition of the reference case.

Brine Chemistry

The composition of brine in the natural system is important because it establishes the initial chemical conditions from which the chemical environment in the repository evolves. Brine composition is site-specific and varies significantly across the different representative salt formations. There is also considerable variation within a single deposit. This variation is a result of the composition and proximity of various interbeds and impurities within the salt deposits.

Table 3-2 presents a summary of brine compositions from a range of salt deposits and literature sources, highlighting the more important constituents. Based on the information in this table, the representative brine composition will be that of the Michigan Basin Devonian Brine because it generally lies within the ranges of the other formation brines. Information for ionic strength was not available for this brine but will be left to the more detailed selection of parameter values during PA model development.

Table 3-2. Representative Brine Compositions in Various Salt Basins.

Description	**Concentration (mg/l)**							**pH**	**SG**
	Na^+	**Mg^{2+}**	**K^+**	**Ca^{2+}**	**SO_4^{2-}**	**Cl^-**	**C**		
1. ONWI Composite Permian Brine (Molecke 1983)	123000	134	39	1560	3197	191380	30	7.05	NR
2. WIPP Generic Brine A (Molecke 1983)	42000	35000	30000	600	35000	190000	700	6.5	NR
3. WIPP Generic Brine B (Molecke 1983)	115000	10	15	900	3500	175000	700	6.5	NR
4[a]. WIPP GWB Salado (DOE 2009, App. SOTERM)	81150	24790	18260	560	17000	207750	NR	NR	1.2
5[a]. WIPP ERDA-6 Castile (DOE 2009, App. SOTERM)	111960	460	3790	480	16330	170170	980	6.17	1.22
6. MCC Brine (Molecke 1983)	35400	29600	25300	NR	NR	164000	NR	6.5	NR
7. German Quinare Brine Q (Molecke 1983)	6500	85000	29000	NR	13000	270000	NR	NR	NR
8. Michigan Basin Devonian Brine (Wilson and Long 1993)	12400-103000	3540-14600	440-19300	7390-107000	0-1130	120000-251000	NR	3.5-6.2	1.136-1.295
9. Paradox Formation Brine-Moab Region (DOE 2007)	9800-25966	21000-47789	23400-41957	34000-65800	80-1800	29800-259106	NR	4.8-6.0	NR
10[b]. Paradox Basin Mississippian Formation (Garrett 2004; Mayhew and Heylmun 1966)	132000-168000	324-9000	NR	288-14400	2160-8800	183600-264000	NR	4.6-6.7	NR
11[b]. Paradox Basin Paradox Formation (Garrett 2004; Mayhew and Heylmun 1966)	26640-119880	5160-39480	25680-63000	6036-51240	306-5268	145080-260640	NR	4.9-6.2	NR

Notes:

a. Brines 4 and 5 are now considered more representative of WIPP conditions in recent performance assessment calculations than Brines 2 and 3 (DOE 2009, App. SOTERM, Table SOTERM-2, http://www.wipp.energy.gov/library/CRA/2009_CRA/CRA/Appendix_SOTERM/Appendix_SOTERM.htm .

b. Converted from ppm assuming an average brine density of 1.2 g/cc.

3.2.4 Reference Salt Disposal System: Concept of Operations

The salt disposal reference case considers concepts of repository operation at a high level, including emplacement mode, waste package type, major features of the EBS, and repository layout, as appropriate for generic disposal evaluations. Further detail or specification of the engineering concept of operations is likely to require site-specific and design-specific information, which is beyond the scope of the reference case.

Although previous conceptual designs for repositories in salt called for disposal of waste canisters in vertical or horizontal boreholes (ONWI 1987), a simpler disposal scheme has been selected for the generic salt repository, based on Carter et al. (2011), whereby each heat-generating waste package (containing canisterized HLW or SNF) is placed in an alcove on the floor, using rubber-tired equipment. Packages are immediately covered with crushed salt from repository excavations to provide radiation shielding during operations and to facilitate consolidation of salt around the waste. Although waste packages will be used for the salt reference case (see Section 3.2.2.2), the original Carter et al. (2011) design did not use waste packages; it directly disposed of the canisterized HLW from the waste facility.[9] (The unshielded HLW canisters were to be transported to the emplacement alcove in a shielded container but then disposed of as a “bare” canister that is immediately covered with mine-run salt backfill.) This design concept is based on certain other favorable operational and structural conclusions, including: (1) the use of rubber-tire vehicles for construction and disposal operations; (2) avoidance of the use of large diameter, pre-drilled emplacement holes; and (3) the use of narrow disposal room widths to improve mining efficiency and structural stability.

The salt disposal reference case described here includes the disposal of both commercial SNF and DOE-owned HLW (see Section 3.2.2.1). Both types of waste are canisterized and contained in carbon steel overpacks (see Section 3.2.2.2). Thus, the design adopted from Carter et al. (2011) will be modified, if necessary, to accommodate canisters within overpacks (which were not used in the original Carter et al. 2011 design). The use of overpacks allows for a longer period of recovery (extended “retrievability”), since the overpacks retain structural integrity for a longer period of time than canisters, and it provides some shielding during potential recovery operations.

3.2.4.1 Repository Layout and Drift Design

Two repository configurations are defined to accommodate heat-generating waste and waste that produces little or no heat. As mentioned, the original generic salt repository concept (Carter et al. 2011) was developed for glass HLW from reprocessing of commercial SNF (CSNF). Assuming that the recycled UNF is 5 years out-of-the-reactor, and considering transportation and recycling times, the heat load per HLW canister at the time of disposal was taken to have a reasonable bounding value of 8.4 kW per canister (Carter et al. 2011, Sec. 2.1.3). The associated conceptual design for the generic repository layout distributes this hotter HLW on a grid using alcoves and access drifts in a herringbone arrangement (Carter et al. 2011, Figure 14), with about

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[9] The disposal concept of Carter et al. (2011) is for canisterized HLW waste from a single-pass recycle of LWR UNF.

40 feet (12 m) between canisters (Carter et al. 2011, Sec. 5.5 and Figure 14). For the reference case described in the present report, the package (or alcove) spacing is set to 20 meters (Hardin et al. 2012, Figure 1.4-2; Hardin et al. 2011, Figure 4-3), which is somewhat larger than that used in the generic salt repository of Carter et al. (2011). This is done to accommodate larger waste packages containing more HLW (e.g., 15 ft. long instead of 9 ft.) or containing heat-generating SNF (Hardin et al. 2011, Table 4-1).

The alternative concept for cooler wastes is to emplace packages on the floor in a linear drift and immediately backfill with crushed salt (Carter et al. 2012b). Spacing between packages of varying heat load, and the spacing between parallel emplacement drifts can be adjusted to meet thermal criteria; however, packages with lowest heat loads have only about 1 m spacing between them (Carter et al. 2012b, Sec. 4.2).

For the salt disposal reference case the height and width of the access drifts, emplacement drifts, and alcoves are selected to provide clearance for the waste packages, i.e., access drifts and alcoves are approximately 3 m high and 6 m wide (providing clearance for nominally 5-meter-long waste packages). Main access drifts can be higher and wider to accommodate services such as power and ventilation. Drifts and alcoves containing waste packages are to be backfilled with crushed salt either during or just after waste emplacement. Carter et al. (2012b, Sec. 3.3) suggested that additional, non-heat generating waste (remote-handled Greater-Than-Class-C waste or RH GTCC) could also be emplaced in the same alcoves, thus increasing the waste loading of the repository. They also suggested that contact-handled (CH) GTCC, low-level waste (LLW), and mixed waste could be placed in haulage ways and drifts used to access the HLW emplacement alcoves. However, for initial development of the Salt TSPA Model, it has been assumed that no organic matter is present in the emplaced waste, e.g., see FEP 2.1.02.03 in Appendix A.

All waste emplacement and backfilling operations are done remotely. The operation of placing crushed salt over the waste would involve remote controlled, load-haul-dump equipment similar to that in common use in mining. Minimal ground support is required or desirable in a salt repository because more substantial ground support impedes closure of the underground openings and could compromise containment and isolation of the waste.

3.2.4.2 Thermal Management

Previous studies have demonstrated the advantages of salt as a host medium for managing decay heat from SNF and HLW, compared to other geologic media (Hardin et al. 2011). The principal advantages are: (1) greater thermal conductivity, which results in lower near-field temperatures via rapid heat dissipation to the far-field and (2) maximum allowable near-field temperatures higher than in other repository concepts, such as argillaceous formations or granite formations with a clay buffer material (whose barrier functions degrade at temperatures above about 100°C—see Hardin et al. 2012). For the salt repository reference design this near-field temperature constraint is taken to be a peak temperature of 200°C in the host rock at the interface with the waste package outer surface (Hardin et al. 2012, Section 1.4.1), which has implications for waste package size and content, as well as waste package spacing (Hardin et al. 2012, Section 1.4.5.2).

The reference-case salt repository will be configured to accept SNF that varies with respect to initial enrichment, burnup, and age out-of-reactor. A set of thermal calculations investigating sensitivity of peak waste package wall temperature to waste package size (loading), aging time, and repository ventilation rate, showed that a range of waste types including high-burnup CSNF (60 GWd/MT) could readily be emplaced in a generic salt repository (Hardin et al. 2012, Table C-4) without exceeding the host rock thermal limit of 200°C. This study, which was based on the 20-m alcove spacing (40-m drift spacing) mentioned above (Hardin et al. 2012, Figure 1.4-2) showed that smaller waste packages such as the 4-PWR size, allow emplacement in salt as early as 10 years out-of-reactor for 60 GWd/MT fuel without exceeding a temperature of 200°C at the waste package surface (Hardin et al. 2011, Sec. 6.1; Hardin et al. 2012, Table C-4). On the other hand, the current inventory of SNF stored at commercial PWR reactors in the U.S. has average burnup of approximately 40 GWd/MT (Carter et al. 2012a, Table 2-1) and these same numerical simulations demonstrated that this current inventory can be emplaced in 21-PWR size waste packages, at an age of 50 years out-of-reactor, without exceeding a peak salt temperature of 200°C (Clayton et al. 2012; Hardin et al. 2012, Table C-4).

Based on two considerations, the peak host rock temperature constraint (200°C) and the capacity of friction hoisting equipment (Hardin et al. 2012, Sec. 2.3), the salt reference case will initially assume a waste package capacity of 12-PWR assemblies (Hardin et al. 2012, Table 1.4-2), for the initial waste package overpack thickness of 7.5 cm (see Section 3.3). This assumption will maintain the host rock temperature below 200°C, for decay storage times of 50 years or more, even for high burnup fuel (Hardin et al. 2012, Table C-4) and will result in waste package weights of 85 metric tons or less, which is within the payload capacity of the hoist used at the German Gorleben mine (Hardin et al. 2012, Sec. 2.3).

3.2.5 Reference Salt Disposal System: Biosphere

The initial focus of the salt disposal reference case is on the undisturbed performance of a geologic repository at a generic salt site. In the undisturbed case, radionuclide releases from a generic salt site have been shown to be very small, resulting in negligible annual dose with a simple biosphere model (Clayton et al., 2011). In the future, disturbed scenarios may cause more significant releases and doses to the reasonably maximally exposed individual. In order to convert releases of radionuclides to annual dose in either scenario, the high-level assumptions for dose conversion are being included in the salt disposal reference case.

The biosphere model for the salt disposal reference case is based on the approach utilized by the International Atomic Energy Agency's (IAEA) BIOMASS (BIOsphere Modeling and ASSessment) Example Reference Biosphere 1 (ERB1) dose model (IAEA 2003) to convert radionuclide release to an aquifer into estimates of annual dose to a receptor based on consumption of drinking water from a hypothetical water well in the aquifer. For the salt disposal reference case, the shafts provide a potential pathway for radionuclide releases between the repository and the overlying aquifer in an undisturbed scenario, and an intrusion borehole that penetrates the aquifer and the repository is the primary pathway between the repository and the aquifer in a disturbed scenario.

As discussed in Section 3.2.3.2, the aquifer is assumed to be located approximately 750 feet, (229 m) above the repository with a range of 500 feet to 1,500 feet (152 m – 457 m). The effective thickness (water producing interval) of the aquifer is assumed to be 50 feet (15 m), with a range of 10 feet to 75 feet (3 m – 23 m). The aquifer is assumed to be a saturated, single porosity medium with uniform thickness, and advection is the dominant radionuclide transport mechanism.

As a first approximation, the aquifer is assumed to have the properties of clean sand, with a porosity of 0.4 and permeability ranging from 2×10^{-13} m^2 to 10^{-9} m^2 (hydraulic conductivity of 2×10^{-6} m/s to 10^{-2} m/s) (Freeze and Cherry, 1979, Table 2.2 on page 29). For a typical hydraulic gradient of 1 degree (see Section 3.2.3.2), the nominal specific discharge in the aquifer is about 10 m/yr, with a range of 0.2 to 1,000 m/yr. These nominal values may be revised during the parameterization of the safety assessment models.

The transport and fate of radionuclides in the aquifer are a function of the distance from the source to the water well (here assumed to be 5 km), sorptive retardation, and the potential for decay and ingrowth during the transport process, among other factors. The effects of radionuclide decay and of the delay in transport due to sorption can be important factors in determining the potential dose from the water well, especially for radionuclides that travel slowly through the aquifer due to high sorption.

The water well is assumed to be fully penetrating, fully screened, and on the same flow line as the intrusion borehole or shaft releasing the radionuclides into the aquifer. The maximum width of the capture zone of the well, W_{cap} [m], is estimated as:

$$W_{cap} = \frac{Q_{well}}{tv}, \tag{1}$$

where Q_{well} is the discharge rate from the water well [m^3/yr], t is the thickness of the aquifer [m], and v is the specific discharge (Darcy velocity) in the aquifer [m/yr] (Javandel and Tsang, 1986). This estimate is appropriate when W_{cap} is much less than the distance, L [m], from the source to the water well.

Because the release from the source (i.e., the shaft or intrusion borehole) occurs over the entire length of the borehole or shaft intersecting the aquifer, the same formulation can be used to estimate the plume width W_{plume} [m], assuming advection-dominated transport with no dispersion:

$$W_{plume} = \frac{Q_{rel}}{tv}. \tag{2}$$

Q_{rel} [m^3/yr] is the discharge rate of water from the shaft or borehole. Transport in aquifers is generally dominated by advection. Excluding dispersion is a simplifying assumption that is potentially conservative because it reduces the probability that radionuclides released to the aquifer will escape the capture zone of the well.

Dilution occurs when the capture width is greater than the width of the source plume. The dilution factor, D_f [-] is based on the ratio of the capture width and plume width:

$$\begin{aligned} D_f &= \frac{W_{cap}}{W_{plume}} \quad \textit{if } W_{plume} < W_{cap}, \\ &= 1 \qquad \textit{if } W_{plume} \geq W_{cap.} \end{aligned} \tag{3}$$

If Q_{rel} is variable over time, then W_{plume} will be a function of the time of release and so will D_f, What this means conceptually is that, neglecting dispersion and the distortion that occurs near the borehole and well, a pulse of radionuclide *i* released over one time step with a maximum width of W_{plume} (corresponding to Q_{rel} at the time of release) will migrate linearly toward the water well and will not be influenced by the value of Q_{rel} at other time steps. This model requires that Q_{rel} have a negligible effect on the mean Darcy velocity between the borehole and well. If this is true, the values of W_{plume} and D_f for this pulse are determined at the time of release and do not change as the pulse propagates from the source to the water well.

The diluted radionuclide concentration in the water well at time *t*, $C_{well}(t)$ [g/l], is a function of the dilution factor and the radionuclide concentration in the plume near the well over time, $C_{plume\_near\_well}(t)$ [g/l],

$$C_{well}(t) = \frac{C_{plume\_near\_well}(t)}{D_f(t-T)}. \tag{4}$$

$D_f(t-T)$ denotes the dilution factor evaluated at the time of release $t-T$ where T [yr] is the travel time through the aquifer. $C_{plume\_near\_well}(t)$ [g/l] can be estimated from the concentrations released to the aquifer over time, $C_{rel}(t)$, using the equation:

$$C_{plume\_near\_well}(t) = C_{rel}(t-T) \cdot e^{-\lambda T} \tag{5}$$

where λ [yr^{-1}] is the radionuclide decay constant (ingrowth is not included in this equation). The travel time, T, can be estimated from

$$T = \frac{LnR_f}{v} \tag{6}$$

where *n* is the aquifer porosity and R_f is the retardation factor.

The time-dependent individual effective dose rate for the i^{th} radionuclide, $H_{E,i}(t)$ [Sv/yr], is approximated by the following relationship (IAEA 2003, p. 272):

$$H_{E,i}(t) = C_{well,i}(t) * I * dcf_i \tag{7}$$

where I [m^3/yr] is the individual consumption rate and dcf_i [Sv/Bq] is the ingestion dose coefficient. The consumption rate in the reference case is set at 1.2 m^3/yr, which is the 95th percentile for young adults and approximately twice the mean adult consumption rate recommended by ICRP (1975) (IAEA 2003, p. 274-275). Other exposure pathways are assumed to be negligible for the salt disposal reference case. The dose coefficients for the reference case are based on Table C5 of IAEA (2003), which assumes the highest reasonable gut uptake factor for each radionuclide and assumes that short-lived daughter radionuclides are present in secular equilibrium with their parents. Selected values are shown in Table 3-3.

Table 3-3. Selected Dose Coefficients from Table C5 of IAEA (2003).

Radioisotope	Dose Coefficient (Sv/Bq)
I-129	1.10e-7
Sr-90	3.07e-8
Cs-137	1.30e-8
Am-241	2.0e-7
Np-237	1.11e-7
U-233	5.10e-8
Th-229	6.13e-7

3.2.6 Reference Salt Disposal System: Regulatory Environment

As mentioned in Section 3.2.1.5, the site-specific EPA and U.S. NRC regulations for Yucca Mountain, 40 CFR 197 and 10 CFR 63, are not applicable to a generic HLW/SNF salt repository, but existing EPA and U.S. NRC regulations for disposal of high-level radioactive wastes in geologic repositories remain in effect, i.e., 40 CFR 191 and 10 CFR 60. However, these existing regulations would likely be superseded for an HLW/SNF salt repository, since they are not consistent with the more recent thinking on regulating geologic repositories that embraces a risk-informed, performance-based approach (U.S. NRC 2004). Thus, the recommended approach for defining a set of regulatory assumptions for the salt safety framework is to combine portions of the existing regulations in 40 CFR 197 and 40 CFR 191. With these guidelines, the following assumptions are appropriate for the reference case:

1. PA models are based on a screening of FEPs for 10,000 years after repository closure, with the provision that the long-term impacts of seismicity, volcanism, and climate change must be considered for 1,000,000 years (40 CFR 197.20 and 197.35 at 73 FR 61287-61288; 10 CFR 63.311 and 63.342 at 74 FR 10829-10830).
2. SNF and HLW must be recoverable over a period of 300 years after repository closure. In other words, the container should have a low enough corrosion rate and be of sufficient thickness to retain structural integrity for 300 years. The assumption of a 300-year

duration for recovery is consistent with the time scale for salt to encapsulate waste packages by creep closure of drifts and openings in the host rock (Clayton et al. 2012).

3. The distance to the accessible environment is assumed to be 5 km (see the discussion of the lateral extent of the salt host rock in Section 3.2.3.2).
4. The safety assessments for the repository at a generic salt site will be judged on the basis of annual dose, consistent with the approach used in 40 CFR 197.20 and for various international standards (Bailey et al. 2011, Sec. 6.2). The key point here is to use annual dose as a metric for the safety assessments, although the exact numerical limits in the existing regulations will not be the focus of preliminary safety assessments.

A more detailed list of possible regulatory requirements is summarized in Carter et al. (2011, Section 6.1), but the above items are sufficient for building the safety framework for the undisturbed scenario. Additional regulatory assumptions may be identified later during future FEPs analyses and PA sensitivity analyses. Also, additional regulatory assumptions may be required when disturbed scenarios are defined, but they are not needed for the salt disposal reference case at this time.

3.3 Sensitivity Analyses for FEPs Identified as "Evaluate"

In Section 3.1 the appropriate FEPs for a generic salt repository were identified and given a preliminary screening decision, as shown in Appendix A, Table A-1. Those identified as "Evaluate" or "Likely Excluded" require either qualitative arguments or quantitative analyses to justify their inclusion or exclusion for the generic SRD TSPA Model. For each of these "Evaluate" or "Likely Excluded" FEPs, Table B-1 of Appendix B indicates whether a qualitative or quantitative justification is thought to be most appropriate and provides a brief "reasoned argument" for those that only require a qualitative justification, if such an argument can be expressed succinctly. For those FEPs that require a quantitative analysis, Table B-1 identifies a preliminary set of sensitivity analyses that could be performed to make a screening decision. This is a set of eleven sensitivity analyses for EBS-related FEPs and three sensitivity analyses for NBS-related FEPs, based on the major physical-chemical processes represented by the associated FEPs, i.e, either radiological (R), thermal (T), mechanical (M), hydrologic (H), transport (Tr), chemical (C), or biological (B) processes (Vaughn et al. 2012, Sec. 3.5.3.3.1). Many of the identified sensitivity analyses involve multiple physical-chemical processes and may therefore require a coupled process model for the screening calculation.

Although there are more than 75 FEPs that fall into the categories of "Evaluate" or "Likely Excluded," the number of sensitivity analyses identified (14) is much less than this because the authors feel that a reasoned argument can be made for excluding most of these FEPs, based on past experience and R&D related to salt repository science and performance assessment. Of those remaining FEPs that cannot be screening based on a reasoned argument, the total number of sensitivity analyses is also less than the number of "Evaluate" or "Likely Excluded" FEPs because multiple FEPs can sometimes be evaluated with single sensitivity analyses.

Table 3-4 provides additional detail regarding the proposed set of sensitivity analyses, including the type of computational model that might be used for each analysis. There are three general categories of computational models defined for this purpose: (1) a modestly enhanced (six-month timeframe) Salt GDS Model, implemented in GoldSim® (GoldSim Technology Group 2009), (2) a coupled process model (with the relevant physical-chemical processes and appropriate dimensionality), and (3) a bounding analysis. Bounding analyses are envisioned to have conservative values for the key parameters and to be simplified in their representation of the key processes and/or simplified in the number of spatial dimensions. It is expected that all of these analyses could be initiated in FY 2013, with the possible exception of some with new process models that may have a relatively long lead time.

Table 3-4. Proposed Sensitivity Analyses for "Evaluate" and "Likely Excluded" FEPs.

Sensitivity Analysis for "Evaluate" or "Likely Excluded" FEPs	Supported FEPs	Supported Features[1]	Primary Processes Involved (T-H-M-C-Tr-R-B)	Category of Evaluation Model[2]	Brief Description of Sensitivity Analysis
EBS-1: Thermal-Mechanical Analysis of Drift Closure to Define Duration of Creep Closure	1.2.03.01	- Backfill - Tunnel	T-M (more sophisticated models could include gas generation (C) and the presence of brine in the pore spaces, as shown in Figure 3-5)	Enhanced 3-D coupled T-M process model	Conduct coupled 3-D thermal-mechanical process model analysis to evaluate crushed salt backfill consolidation and drift closure and estimate duration of drift closure. Include chemical (gas generation) and hydrologic processes to the extent possible as gas pressure and moisture may have a significant impact on the rate of crushed salt consolidation and drift closure.
EBS-2: Impact of DSNF Degradation	2.1.02.01	- Radionuclide Inventory - Waste Form	H-Tr-C	Enhanced Salt GDS GoldSim Model	Conduct analysis to evaluate effect of some DOE spent nuclear fuel types, such as N reactor fuel, which degrade much more rapidly than commercial SNF. The impact is evaluated for radionuclide releases and transport using available brine flows and gas phase movement analysis results.
EBS-3: Thermal-Chemical Analysis for Long-Term Evolution of HLW Waste Forms	2.1.02.04	- Waste Forms	T-C (Note: The C part is for phase changes of HLW waste forms)	Bounding analysis	Perform bounding analysis for long-term evolution of the HLW waste form phases (glass, ceramic and metallic) for a range of possible thermal conditions, and its potential effect on the waste form degradation. The bounding analysis may consider two approaches: 1) evaluation of potential for phase changes at the calculated waste-package or waste-form peak temperature; and 2) evaluation of potential for long-term phase evolution accounting for the waste package temperature histories.
EBS-4: Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure	2.1.03.01 2.1.09.03 2.1.09.04 2.1.09.07 2.1.09.08 2.1.09.09 2.1.11.13	- Waste Forms - Waste Package - Backfill - Tunnel - Seals (Drift)	T-H-C	Coupled T-C or T-H-C process models	Conduct coupled thermal-chemical analysis to evaluate the effect of various EBS components and their degradation processes on the brine chemistry evolution in waste package, backfill, tunnels and drift seals after waste package failure. The analysis is conducted for a range of possible thermal and

Table 3-4 (continued)

Sensitivity Analysis for "Evaluate" or "Likely Excluded" FEPs	Supported FEPs	Supported Features[1]	Primary Processes Involved (T-H-M-C-Tr-R-B)	Category of Evaluation Model[2]	Brief Description of Sensitivity Analysis
					hydrologic (brine and water vapor) conditions and may use available histories of thermal and hydrologic conditions of EBS components, derived from other process models.
EBS-5: Effect of Early Waste Package Failure on Radionuclide Releases from EBS and NBS.	2.1.03.01	- Waste Package	H-Tr	Enhanced Salt GDS GoldSim Model	Conduct repository response analysis to evaluate impact of early waste package failure on radionuclide releases and transport in the repository. The analysis may use available histories for thermal, chemical and hydrologic conditions in the EBS and NBS, derived from process models.
EBS-6: Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste Form	2.1.07.05 2.1.07.06 2.1.07.07 2.1.11.06 2.1.11.07	- Waste Form - Waste Package	T-C or T-H-C	Coupled T-C or T-H-C process models	Perform thermal-chemical analyses to evaluate the effect of mechanical damage to the waste form and mechanical failure of the waste package on the evolution of brine chemistry in these EBS components. The analysis evaluates the potential impact on brine water chemistry from failed waste packages and waste forms with greatly increased surface area caused by severe mechanical damage. The analysis is conducted for a range of possible thermal and hydrologic (brine and water vapor) conditions and/or may use available histories of thermal and hydrologic conditions in the emplacement drift, derived from other process models.
EBS-7: Thermal-Hydrologic-Chemical Analysis for Brine and Water Vapor Movement in Emplacement Drifts	2.1.08.07 2.1.11.10	- Waste Package - Backfill - Tunnels - Drift Seals	T-H-C	Coupled T-H-C process model	Conduct coupled thermal-hydrologic-chemical analysis to evaluate evolution and movement of brine and water vapor in the emplacement drifts for a range of possible thermal and hydrologic conditions. The analysis is conducted for varying degrees of closure of the emplacement drift, including complete closure. The analysis may consider a range of possible thermal and hydrologic (brine and water vapor) conditions and/or may use available histories of

Table 3-4 (continued)

Sensitivity Analysis for “Evaluate” or “Likely Excluded” FEPs	Supported FEPs	Supported Features[1]	Primary Processes Involved (T-H-M-C-Tr-R-B)	Category of Evaluation Model[2]	Brief Description of Sensitivity Analysis
					thermal-hydrologic conditions in the emplacement drift, derived from other process models.
EBS-8: Analysis for Radionuclide Sorption on Corrosion Products and Salt in Emplacement Drift	2.1.09.53	- Waste Form - Waste Package - Backfill - Tunnels - Drift Seals	T-H-Tr-C	Bounding Analysis	Conduct a bounding analysis to evaluate sorption of radionuclides on degradation products of the waste package and other EBS components and on consolidated salt backfill for a range of possible thermal, chemical and hydrologic conditions in the emplacement drift. The analysis may use available thermal-chemical-hydrologic condition histories in the emplacement drift. The analysis may involve critical review and analysis of available literature data that are applicable to the conditions expected in the salt EBS (i.e., high ionic strength, elevated temperature, and anoxic chemically reducing environments).
EBS-9: Analysis for Colloid Stability in EBS	2.1.09.56	- Waste Form - Waste Package - Backfill - Tunnels - Drift Seals	C	Bounding analysis	Conduct analysis to evaluate stability of colloids in EBS for a range of possible chemical, thermal and hydrologic conditions in EBS. The analysis may use available histories of thermal-chemical-hydrologic conditions in EBS, derived from other process models. It evaluates types of colloids that could exist and form in EBS. The analysis may involve critical review and analysis of available literature data that are applicable to the conditions expected in the salt EBS (i.e., high ionic strength, elevated temperature, and anoxic chemically reducing environments).
EBS-10: Analysis for Diffusivity of Colloids in EBS	2.1.09.58	- Waste Form - Waste Package - Backfill - Tunnels - Drift Seals	H-Tr	Bounding analysis	Conduct analysis to evaluate diffusivity of colloids in EBS for a range of possible chemical, thermal and hydrologic conditions in the EBS. The analysis may use available histories for thermal-chemical-hydrologic conditions in the EBS, derived from other process models. It also considers types of colloids that could exist and form in EBS. The analysis may

Table 3-4 (continued)

Sensitivity Analysis for "Evaluate" or "Likely Excluded" FEPs	Supported FEPs	Supported Features[1]	Primary Processes Involved (T-H-M-C-Tr-R-B)	Category of Evaluation Model[2]	Brief Description of Sensitivity Analysis
					involve bounding calculations to estimate mass transport rates of colloids by diffusion and compare to diffusive and advective mass transport rates of dissolved radionuclides.
EBS-11: Thermal-Hydrologic Analysis of Brine Flow in EBS	2.1.11.11 2.1.11.12	- Waste Package - Backfill - Tunnels - Drift Seals	T-H	Coupled T-H process model	Conduct coupled thermal-hydrologic analysis to evaluate effect of thermally driven brine flows in EBS, including convective and buoyant flows. The analysis is conducted for the condition of complete closure of emplacement drift, which is representative of the emplacement drift condition following the creep closure. The analysis may consider a range of possible thermal conditions and/or may use available histories for thermal conditions in the emplacement drift, derived from other process models.
GEO-1: Thermal-Hydrologic-Chemical Analysis for Brine Flow and Water Vapor Movement in Host Rock and Geosphere	2.2.08.05 2.2.11.04 2.2.11.07	- Host Rock - Other Units	T-H-C	Coupled T-H-C process model	Conduct coupled thermal-hydrologic-chemical analysis to evaluate evolution and movement of brine and water vapor, and evolution of brine chemistry in the host rock and geosphere, for a range of possible thermal and hydrologic conditions in NBS. The analysis may use available histories for thermal conditions in the host rock and geosphere, derived from other process models.
GEO-2: Gas Phase Transport of Radionuclides in Geosphere	2.2.12.03	- Host Rock - Other Units	H-Tr	Coupled H-Tr process model	Conduct coupled hydrologic-transport process model analysis to evaluate gas-phase transport of radionuclides in the geosphere for a range of possible hydrologic conditions in natural barrier system. The analysis may use available histories for hydrologic conditions in the host rock and geosphere, derived from other process models.

Table 3-4 (continued)

Sensitivity Analysis for "Evaluate" or "Likely Excluded" FEPs	Supported FEPs	Supported Features[1]	Primary Processes Involved (T-H-M-C-Tr-R-B)	Category of Evaluation Model[2]	Brief Description of Sensitivity Analysis
GEO-3: Chemical-Hydrologic Analysis for RN Transport in Surface and Biosphere	2.3.09.03	- Surface/ Biosphere	H-Tr-C	Coupled H-Tr-C process model	Conduct coupled hydrologic-chemical transport process model analysis to evaluate radionuclide transport and redistribution in the surface environments encompassing the biosphere. Because the FEPs are site specific, the sensitivity analysis must be tailored for a specific candidate site or well-defined surface/biosphere environments.

[1] These features correspond to the EBS-NBS features/components in Figure 3-3.

[2] There are three general categories of models: (1) a modestly enhanced (6 month timeframe) Salt GDS GoldSim® model, (2) a coupled process model (with the relevant physical-chemical processes and appropriate dimensionality), and (3) a bounding analysis. Bounding analyses are envisioned to have conservative values for the key parameters and to be simplified in their representation of the key processes and/or simplified in the number of spatial dimensions.

3.4 Potential Sensitivity Analyses with the Salt GDS Model for FEPs Identified as "Included"

Section 3.3 described a set of sensitivity analyses felt to be important for the set of FEPs labeled as "Evaluate" or "Likely Excluded" in order to make an initial judgment for inclusion or exclusion of the FEP in a salt TSPA model. These analyses are considered the most important for the initial construction of the SRD TSPA Model. However, another set of sensitivity analyses may be useful even for those FEPs that have already been given a preliminary classification of "Include." In particular, as described in Section 3.1, the FEPs screening documented in Appendix A is based on the expert judgment of the authors but is considered preliminary pending further analysis. In order to further substantiate and justify a FEPs inclusion decision, and also how the FEP should be represented in a TSPA model, a quantitative sensitivity analysis can be useful. For example, analyses with the current Salt GDS Model (Clayton et al. 2011), mentioned in Section 1.1, can be appropriate for judging whether a given FEP may be represented with a simple bounding model in a TSPA or whether it needs to be represented with a detailed coupled process model, or whether it needs to be included at all. If preliminary analyses with a conservative, but simple, representation indicate no effect on overall system performance, then a detailed coupled process representation is not likely to be warranted (DOE 2008, Sec. 2.4; U.S. NRC 2003, Sec. 2.2.1).

3.4.1 Summary of Salt GDS Model

The Salt GDS Model developed under the Generic Disposal System Model (GDSM) activity (Clayton et al. 2011) is intended to evaluate and improve the understanding of the generic disposal system response and processes relevant to long-term disposal of UNF and HLW in a salt formation. The current salt GDS model consists of four major model components: source-term, near-field, far-field, and biosphere. The source-term and near-field model include the following components: (1) waste package configurations, (2) inventory for different waste types (commercial UNF, existing DOE HLW (DHLW), and hypothetical commercial reprocessing HLW (CHLW)), (3) repository layout, (4) waste form degradation, (5) solubility of key radionuclides, (6) near-field volume, (7) repository waste inventory scenarios, and (8) repository radionuclide release scenarios. Details of the far-field and biosphere models are provided in Clayton et al. (2011, Sec. 3.1.2). Development of the model and resulting performance assessment analyses have been documented in various project reports (Wang and Lee 2010; Clayton et al. 2011) and in recent publications (Lee et al. 2011; Lee et al. 2012).

Some limiting assumptions are made in the Salt GDS Model, which will be eliminated during development of the SRD TSPA Salt Model discussed in this report. The most important of these assumptions include the following:

- an isothermal condition at 25°C
- the waste package overpack and the waste form canisters are conservatively assumed to fail immediately at the time of repository closure (i.e., at time zero), and waste form degradation occurs from the beginning of the analysis.

The Salt GDS Model considers two scenarios for the potential pathways for radionuclide release and transport from a generic salt repository: the undisturbed (or reference) case, and the disturbed case. In the reference case, radionuclides are released from the repository by a sequence of processes that could occur in a salt repository, and the case assumes that the repository drift and shaft seals and the underlying interbed could provide the primary pathways for radionuclide release and transport from the repository. Although the movement of brines in the above release pathways is likely very small, the pathway conceptual models are supported by previous analyses for salt repository sites: the interbed release pathway conceptual model is supported by the performance analyses of certain scenarios for the WIPP site (Helton et al. 1998), and the drift and shaft seals release pathway conceptual model is consistent with the analyses for certain scenarios of the WIPP (Helton et al. 1998) and Gorleben domal salt sites (Buhmann et al. 2009, Rübel 2009). Figure 3-7 shows a conceptual representation of the release pathways assumed for the Salt GDS Model.

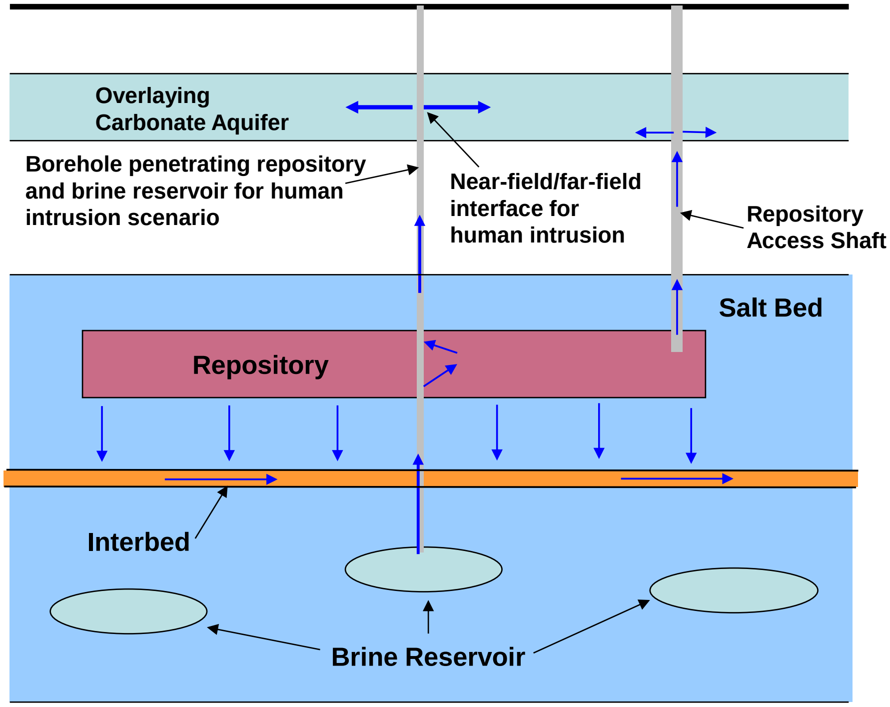

Figure 3-7. A Schematic Showing the Conceptual Model for Radionuclide Release and Transport in the Salt GDS Model (after Clayton et al. 2011, Fig. 3.1-1).

3.4.2 Salt GDS Model Sensitivity Analyses

This section describes the set of sensitivity analyses to be undertaken with the Salt GDS Model for included FEPs that will help to indicate the relative importance of the underlying FEPs to total system performance. Those that are quite important to repository performance are candidates for additional R&D and a higher fidelity representation in the SRD TSPA Model compared to those that have little effect. [Note that green highlighting indicates an "Included" FEP and blue highlighting indicates an "Evaluate" FEP.]

3.4.2.1 Sensitivity Analyses to Address FEPs Related to EBS

- Effect of UNF instantaneous release RNs (i.e., gap and grain boundary RNs). This is not considered in the current model. The impact of the related FEP(s) can be evaluated using the YMP data.

  (Related FEP: 2.1.02.01).

- Effect of enhanced UNF and HLW degradation rate caused by mechanical disintegration under mechanical loads up to the lithostatic pressure at the repository depth, following waste package structural collapse from salt creep deformation and closure. Mechanical disintegration of WF will increase the exposed surface area of the WF and result in increased degradation rates. The current model does not consider this process. Impact of the related FEPs can be evaluated using a range of time periods when this could occur.

  (Related FEPs: 2.1.02.01, 2.1.07.06, 2.1.07.07, 2.1.11.06).

- Effect of waste package performance. The current model does not consider waste package performance (i.e., WF degradation at the beginning of simulation). Impact of the related FEPs can be evaluated considering a range of waste package failure times. Brine flows out of failed waste packages are delayed by the amount of time corresponding to the waste package failure time. The brine flow rate history profiles from the near-field and underlying interbed of the current model may be used, assuming the near-field temperature has cooled down significantly by the time of waste package failure.

  (Related FEPs: 2.1.03.01, 2.1.03.02, 2.1.03.03, 2.1.03.04, 2.1.03.05, 2.1.03.07).

- Effect of sorption of dissolved RNs on EBS materials. The current model does not consider RN sorption on geologic and degraded EBS materials in the EBS and near-field. Impact of the related FEPs can be captured and analyzed with the RN sorption models for the EBS and near-field.

  (Related FEPs: 2.1.09.53).

3.4.2.2 Sensitivity Analyses to Address FEPs Related to Near-Field, Including Crushed Salt Backfill

The current Salt GDS Model assumes the waste packages and waste emplacement area are backfilled with crushed salt.

- Effect of prolonged dry-out period around the waste emplacement area on waste package degradation and failure and RN release from failed waste packages. Impact of the related FEPs can be evaluated by delaying the brine flows out of failed waste packages by a range of time periods corresponding to the dry-out period plus waste package failure time. Note that the brine flow rate history profiles in the near-field and underlying interbed for this case could be different from those of the current model for the isothermal ambient temperature condition.

(Related FEPs: 2.1.04.01, 2.1.08.06, 2.1.11.08).

- Effect of incomplete consolidation of crushed salt backfill. The current model assumes complete consolidation of salt backfill to the condition of intact salt. Existing data indicates that crushed salt of larger grains (or particle size) takes longer for consolidation than that of finer grains, and crushed salt grains larger than certain particle sizes may not consolidate to the condition of intact salt. The resulting permeability and porosity can be higher than those of intact salt. Impact of the related FEPs can be evaluated using higher brine flow rates out of waste emplacement area, which may be captured using a range of multipliers to those of the current model. Note that the brine flow rate history profiles from the near-field and underlying interbed could be different from those of the current model.

  (Related FEPs: 2.1.04.01, 2.1.08.03, 2.1.08.06, 2.1.11.08).

- Effect of degraded and/or compromised shaft seals. The sealing properties of shaft seals, especially at the interface between the non-salt components (e.g., concrete, asphalt, clay, etc.) and host salt rock may degrade over time from interaction with concentrated brines. If this could occur, pressurization of the repository from combined actions of corrosion gas production and decreasing confined space from salt creep closure could push contaminated brines upward, potentially releasing dissolved RNs in the overlying aquifer. Impact of the related FEPs can be evaluated with a separate pathway from repository directly to the overlying aquifer. Information is needed on the features of the flow pathway at the interface and potential brine flow rate ranges.

  (Related FEPs: 2.1.05.01, 2.1.08.04).

3.4.2.3 Sensitivity Analyses to Address FEPs Related to Far-Field Flow and Transport

- Effect of mixing and dilution in the far-field interbed. The current model assumes no mixing and dilution in the far-field interbed. A major interbed in a bedded salt formation is typically characterized as a continuous layer with a significant thickness and greatly extended widths and lengths. The effect of the related FEPs can be captured and evaluated by successively increasing the width of the GoldSim® cells representing the far-field interbed in the direction of brine flow and RN transport.

  (Related FEPs: 2.2.09.62).

- Mechanism to release dissolved RNs from far-field interbed to regional aquifer. The current model assumes a hypothetical mechanism exists to connect the far-field interbed to regional aquifer. Impact of the related FEPs can be evaluated using alternative pathways that are consistent with the common features of regional geology of bedded salt formation.

  (Related FEPs: 2.2.08.08, 2.2.08.09, 2.2.09.64, 2.2.09.65).

- Brine flow rate from the far-field interbed to regional aquifer. The current model assumes all of the brines in the far-field interbed flows into a hypothetical regional aquifer. Impact of the related FEPs can be evaluated using alternative measures or assumptions that are consistent with the common features of regional geology of bedded salt formation.

(Related FEPs: 2.2.09.62, 2.2.09.64, 2.2.09.65).

- Mixing/dilution rate in regional aquifer. The current model uses the aquifer dilution rate of 10^4 m^3/yr, which is a suggested value in the IAEA BIOMASS ERB 1B dose model but without providing a basis. Impact of the related FEPs can be evaluated using alternative measures or assumed values that are consistent with the common features of regional hydrogeology of bedded salt formation.

  (Related FEPs: 2.2.09.62, 2.2.09.64, 2.2.09.65).

3.4.2.4 Sensitivity Analyses to Address FEPs Related to Biosphere

- Effect of location of biosphere. The current model assumes a hypothetical biosphere is located 5 km down gradient from the boundary of repository footprint. The parameter was chosen arbitrarily. Impact of the related FEP can be evaluated using alternative measures that are consistent with the common generic features for expected lifestyle of future populations in the area of such a geologic formation that is suitable for a salt repository.

  (Related FEPs: 2.2.08.08, 2.2.08.09, 2.2.09.64, 2.2.09.65).

- Effect of groundwater consumption. The current model uses the IAEA BIOMASS ERB 1B dose model, for which a water consumption rate of 1.2 m^3/yr is assumed for the exposed individual. Impact of the related FEP can be captured and evaluated using alternative measures that are consistent with the common generic features for the aquifer and expected lifestyle of future populations in the area of such a geologic formation that is suitable for a salt repository.

  (Related FEPs: 2.2.08.09).

3.5 Requirements for SRD TSPA Model Based on Included FEPs

Conceptual and mathematical models are a qualitative and analytical accounting, respectively, for the FEPs that are to be included in the TSPA. Conceptual models are broadly qualitative and reflect how physical-chemical processes (e.g., thermal, mechanical, chemical, etc.) should be included in the overall suite of performance assessment models. They describe how fundamental physical and chemical processes are represented and coupled spatially and temporally. The total system (or TSPA) conceptual model describes how these FEPs and associated process models are represented in a probabilistic performance assessment. The conceptual models must have sufficient information to construct and implement mathematical and numerical models for the safety assessment. Once the conceptual model(s) is decided upon, an exact mathematical representation or model is provided to allow for the approximate numerical estimation (see numerical models below) of the spatial-temporal evolution of the repository system for multiple realizations of the inherent uncertainty.

The TSPA numerical model will provide an approximation for the solution of the conceptual and mathematical models based on a variety of solution algorithms that generally discretize the continuous spatial and temporal domains of the mathematical equations (Freeze and Vaughn 2012). The numerical model includes the specification of the level of resolution of the discrete spatial grid in the various model domains, including both the near-field and far-field domains (see Figure 3-3). Parameterization is the characterization and specification of values for the physical parameters in the numerical model, such as permeability, thermal conductivity, and degradation rates, as well as a representation of the epistemic uncertainty in their values based on the current state of knowledge. The salt disposal reference case defined in Section 3.2 is meant to contain sufficient information to help focus and guide the direction of the numerical model development and parameterization.

The existing and new knowledge base arising from the other SRD Study activities (Activities 1, 2, 3, and 5—see Section 1), including data mining, laboratory testing, and international collaborations will be used to inform the initial development of the SRD TSPA Model. An important step in the development of the SRD TSPA Model is the identification and evaluation of coupled processes important to overall system performance, and how the important coupled processes will be included in the SRD TSPA Model in a defensible way. An important aspect of this evaluation will be to conduct sensitivity and uncertainty analyses with the SRD TSPA Model, based on analyses from the underlying THMC process model(s), to determine those parameters and processes most important to the safety of a salt repository. These assessments will lead to specification of the methods and approach to be used for SRD TSPA Model development. It is envisioned that coupled processes near the heat-generating waste and in the disturbed rock zone will likely be included as boundary conditions to the SRD TSPA Model or incorporated as part of the source term. Information from the TSPA sensitivity and uncertainty analyses, as well as from studies with the THMC process model(s), will be integrated into the safety framework at various key decision points to inform, prioritize, and focus test design and data gathering activities.

Table C-1 in Appendix C provides a categorization of “Included” and “Likely Included” FEPs for the TSPA Model based on their primary classification by physical-chemical process(es): radiological, thermal, mechanical, hydrologic, transport, chemical, and biological, or R-T-M-H-Tr-C-B. This classification in terms of major processes allows a grouping of the FEPs into primary submodels or “process kernels” (Freeze and Vaughn 2012, Sec. 4.1.1) that will form the building blocks of the various domain or component submodels (e.g., the waste package domain—see Figure 3-3) that comprise the SRD TSPA Model.

As a first step in illustrating how each TSPA submodel can be either derived from the included FEPs or built to ensure that all relevant included FEPs are part of the submodel, the waste package feature/domain is used as an example. Based on previous repository modeling experience (e.g., DOE 2008, Sections 2.3 and 2.4), it is assumed that the primary submodels needed for the waste package domain are (1) a waste package structural model (for mechanical deformations), (2) a fluid-phase flow and radionuclide transport model in the waste package domain, and (3) a waste package degradation (corrosion) model. The relationship of the first two of these submodels to the included FEPs is demonstrated here as a way of showing: (1) requirements for the SRD TSPA Model construction based on which FEPs (mainly, processes) must be part of the TSPA, and (2) how primary TSPA submodels may be formulated in a hierarchical fashion according to the major physical-chemical processes in the included FEPs. It should be emphasized that this is an illustration that may change depending of the sensitivity of materials and flows to the individual processes and to the time scale of the calculations.

Figure 3-5 presents a three-tiered hierarchy of process models for structural response of the waste package. The “core” of the waste package structural response submodel is a coupled thermal-mechanical (T-M) model to predict the loads on the waste package overpack, based on creep closure of emplacement drifts and reconsolidation of crushed salt backfill surrounding the waste package. Slow viscoplastic flow (creep) of rock salt in the crushed salt backfill is quite temperature dependent, so a T-M coupling is required for these calculations. In effect, the T-M processes are the central “core” of the waste package structural submodel.

A more complete model of the closure process must also consider stresses generated by the presence of fluid phases in the pore spaces of the backfill. Thus, as a second tier in the hierarchical construction of the waste package structural submodel, the effects of hydrologic inflow could be considered. This is important for two reasons. First, H_2 gas generation from anoxic corrosion of the steel overpack will not occur without the presence of liquid water; and, second, once liquid brine fills the void space in the crushed salt backfill, it will provide a backpressure that resists further consolidation of backfill. The presence of liquid brine could be represented as a fixed or predefined parameter in the core T-M submodel, or could be represented as a coupled thermal-mechanical-hydrologic (T-M-H) model that is illustrated as the second tier in Figure 3-5.

Anoxic corrosion is important because it can reduce the thickness of the outer corrosion barrier and it can generate hydrogen gas that provides a backpressure resisting closure of the emplacement drifts. The presence of gas could initially be represented as a fixed parameter or time history in the core T-M submodel or in the T-M-H second-tier model, or subsequently coupled to a dynamic chemical (C) model of gas generation that is part of a coupled thermal-mechanical-hydrologic-chemical (T-M-H-C) process submodel. This T-M-H-C model is shown as a third tier in Figure 3-5. The second and third tiers in Figure 3-5 could be combined if corrosion and hydrologic inflows are both sensitive to the thermal pulse and therefore highly transient. Alternately, the fully coupled T-M-C-H model may not be necessary if gas generation or hydrologic inflows can be approximated or bounded in an appropriate manner.

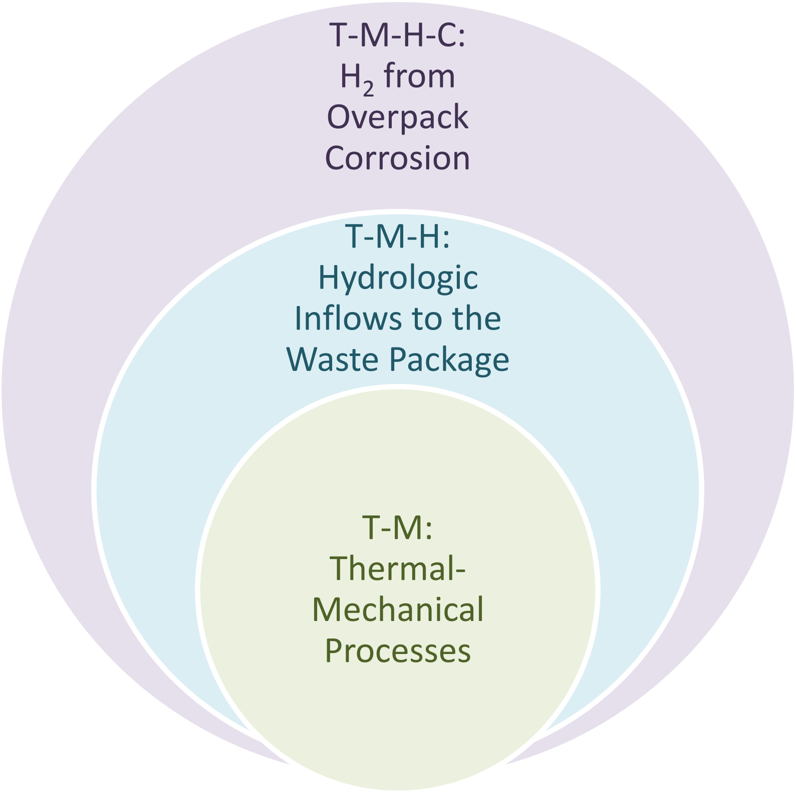

Figure 3-5. Hierarchy of coupled process models for structural response of the waste package.

The coupled process submodels in Figure 3-5 are directly relevant to a subset of the FEPs identified as “Included” and “Likely Included” in Appendix C, Table C-1. Table 3-5 identifies these included and likely included FEPs that are relevant to structural response of the waste package. The FEPs in Table 3-5 have been sorted into a “core” submodel for T-M behavior in the waste package domain, with additional FEPs identified for the T-M-H and T-M-H-C submodels in the second and third tiers, respectively, of Figure 3-5.

Figure 3-6 presents a three-tiered hierarchy of process models for fluid-phase flow and radionuclide transport in the waste package. The “core” process model is a coupled hydrologic-transport (H-Tr) model to predict the rate of radionuclide release from the waste-package domain to the EDZ (see Figure 3-3). Radionuclide decay and ingrowth is part of the transport model and sorption is represented by partition coefficients in the core H-Tr submodel. A more complete H-Tr-C model for flow and transport processes could consider the effects of chemical reactions on transport, including surface complexation on iron corrosion products generated by corrosion, or mineral precipitation/dissolution as a result of reaching a solubility limit(s) for one or more radioelements (second tier in Figure 3-6). Finally, temperature will influence radionuclide solubilities and chemical reactions during reactive transport, particularly during the thermal pulse arising from the waste decay heat. The additional of thermal response to create a coupled T-H-Tr-C model is illustrated as the third tier in Figure 3-6.

The coupled process models in Figure 3-6 are again relevant to a subset of the FEPs identified as "Included" and "Likely Included" in Appendix C, Table C-1. Table 3-6 identifies the included and likely included FEPs that are relevant to fluid-phase flow and radionuclide transport in the waste package. The FEPs in Table 3-6 have been sorted into a "core" submodel for H-Tr behavior in the waste package domain, with additional FEPs identified for the H-Tr-C and the T-H-Tr-C submodels in the second and third tiers, respectively, of Figure 3-6.

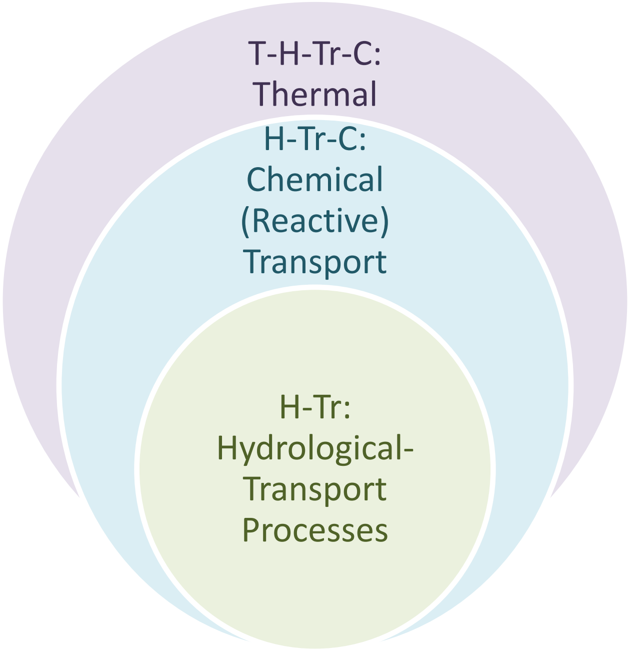

Figure 3-6. Hierarchy of coupled process models for flow and transport in the waste package

The foregoing descriptions are illustrative of how other repository domains and components can be related to the included FEPs, and are helpful in describing requirements as to which processes must be included in the TSPA. This set of requirements/processes is eventually contingent on the results of the sensitivity analyses discussed previously in Sections 3.3 and 3.4.

Table 3-5. Included and Likely Included FEPs Related to Submodels for Structural Response of the Waste Package

(R = Radiological; T = Thermal; M = Mechanical; H = Hydrologic; Tr = Transport; C = Chemical)

UFD FEP Number	FEP Description	Notes	R	T	M	H	Tr	C
INCLUDED FEPS FOR “CORE” PROCESS SUBMODEL (T-M) FOR STRUCTURAL RESPONSE OF THE WASTE PACKAGE:								
2.1.04.01	Evolution and Degradation of Backfill	Reconsolidation of backfill during room closure affects fluid flow and the presence of brine affects the ability of backfill to consolidate		✓	✓			
2.1.07.01	Rockfall			✓	✓			
2.1.07.02	Drift Collapse			✓	✓			
2.1.07.03	Mechanical Effects of Backfill	Backfill consolidation around waste package		✓	✓			
2.1.07.04	Mechanical Response of Backfill				✓			
2.1.07.05	Mechanical Response of Waste Packages				✓			
2.1.07.06	Mechanical Response of SNF Waste Form				✓			
2.1.07.07	Mechanical Response of HLW Waste Form				✓			
2.1.07.08	Mechanical Response of Other EBS Components	Waste package support materials only			✓			
2.1.07.09	Mechanical Effects at EBS Component Interfaces				✓			
2.1.11.01	Heat Generation in EBS			✓				
2.1.11.03	Effects of Backfill on EBS Thermal Environment			✓	✓			
2.1.11.04	Effects of Room Closure on EBS Thermal Environment			✓	✓			
2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components			✓	✓			

Table 3-5. (continued).

UFD FEP Number	FEP Description	Notes	R	T	M	H	Tr	C
2.1.11.07	Thermal-Mechanical Effects on Waste Packages			✓	✓			
2.1.11.08	Thermal-Mechanical Effects on Backfill			✓	✓			
ADDITIONAL INCLUDED FEPS FOR WASTE PACKAGE STRUCTURAL RESPONSE SUBMODEL WITH FLOW (T-M-H):								
2.1.08.01	Flow Through the EBS	Determines brine availability during consolidation				✓		
2.1.08.02	Flow in and Through the Waste Package	Determines presence of water in the waste package				✓		
2.1.08.03	Flow in Backfill	Determines brine availability during consolidation				✓		
2.1.08.08	Capillary Effects in EBS	Determines brine availability during consolidation				✓		
ADDITIONAL INCLUDED FEPS FOR WASTE PACKAGE STRUCTURAL RESPONSE SUBMODEL WITH FLOW AND CORROSION (T-M-H-C):								
2.1.03.02	General Corrosion of Waste Packages	Thickness of waste package overpack		✓		✓		✓
2.1.03.05	Hydride Cracking of Waste Packages	Integrity of overpack when pits/cracks form		✓				✓

Table 3-6. Included and Likely Included FEPs Related to Submodels for Fluid-Phase Flow and Radionuclide Transport in the Waste Package
(R = Radiological; T = Thermal; M = Mechanical; H = Hydrologic; Tr = Transport; C = Chemical)

UFD FEP Number	Description	Notes	R	T	M	H	Tr	C
INCLUDED FEPS FOR “CORE” PROCESS SUBMODEL (H-Tr) FOR FLOW AND TRANSPORT IN THE WASTE PACKAGE:								
2.1.08.01	Flow Through the EBS					✓		
2.1.08.02	Flow in and Through the Waste Package					✓		
2.1.08.03	Flow in Backfill					✓		
2.1.08.04	Flow Through Seals					✓		
2.1.08.06	Alteration and Evolution of EBS Flow Pathways					✓		
2.1.08.08	Capillary Effects in EBS					✓		
2.1.08.09	Influx/Seepage Into the EBS					✓		
2.1.01.01	Waste Inventory	Characteristic of the waste form						
2.1.01.02	Radioactive Decay and Ingrowth						✓	
2.1.09.51	Advection of Dissolved Radionuclides in EBS	In the waste form and waste package				✓	✓	
2.1.09.52	Diffusion of Dissolved Radionuclides in EBS	In the waste form and waste package				✓	✓	
2.1.09.57	Advection of Colloids in EBS	In the waste form and waste package				✓	✓	
2.1.09.59	Sorption onto Colloids in EBS	In the waste form and waste package					✓	
ADDITIONAL INCLUDED FEPS FOR WASTE PACKAGE FLOW AND TRANSPORT SUBMODEL COUPLED WITH CHEMICAL REACTIONS (H-Tr-C):								
2.1.09.02	Chemical Characteristics of Water in Waste Packages							✓
2.1.09.05	Chemical Interaction of Water with Corrosion Products	In the waste package						✓
2.1.09.06	Chemical Interaction of Water with Backfill	In the backfill surrounding the waste package						✓

Table 3-6. (continued).

UFD FEP Number	Description	Notes	R	T	M	H	Tr	C
2.1.09.10	Chemical Effects of Waste-Rock Contact							✓
2.1.09.13	Radionuclide Speciation and Solubility in EBS	In the waste form and waste package						✓
2.1.09.55	Formation of Colloids in EBS	In the waste form and waste package					✓	✓
ADDITIONAL INCLUDED FEPS FOR WASTE PACKAGE FLOW AND TRANSPORT SUBMODEL COUPLED WITH CHEMICAL REACTIONS AND THERMAL RESPONSE (T-H-Tr-C)								
2.1.11.01	Heat Generation in EBS			✓				
2.1.11.03	Effects of Backfill on EBS Thermal Environment*			✓				
2.1.11.04	Effects of Room Closure on EBS Thermal Environment*			✓				
2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components**			✓		✓	✓	✓
2.1.11.07	Thermal-Mechanical Effects on Waste Packages**			✓		✓	✓	✓
2.1.11.10	Thermal Effects on Flow in EBS			✓		✓		

*The potential for room closure to alter thermal conductivity of the backfill is likely to be approximated in this model, so a checkmark has not been included in the “M” category because it is unlikely that the mechanical process would be fully coupled to the T-H-Tr-C model.

**The focus of FEPs 2.1.11.06 and 2.1.11.07 is on the potential for mechanical loading to cause severe damage to the waste form and/or waste package, thereby resulting in chemical changes to the brine flowing into and through the waste package. This chemical effect may be important, even though the overall FEP analysis assumes that the waste package is not a significant hydrological barrier to long-term performance. It is unlikely that the mechanical processes would be fully coupled to the T-H-Tr-C model, so a checkmark has not been included in the “M” category.

4. RECOMMENDATIONS AND FUTURE WORK

It is recommended that future revisions to this report describe the quantitative results of FEPs sensitivity analyses proposed in Sections 3.3 and 3.4, and their implications with respect to the appropriate inclusion of physical-chemical processes and their couplings in each TSPA component or submodel (as well as between submodels). These results should be combined with the methodology suggested in Section 3.5 for the hierarchical construction of TSPA submodels. The result will be a determination of the degree of coupling of R-T-M-H-Tr-C-B processes within the various TSPA Model realizations, as well as the fidelity required for each of these processes in the TSPA Model, such as the dimensionality of the processes and their mathematical representation. As described by Hardin (2012), these processes may be represented with a “lumped” model or with a high fidelity model. Another possibility is the use of multidimensional response surface (DOE 2008, Sections 2.3 and 2.4). The foregoing considerations will result in a more detailed set of requirements for the generic salt TSPA model architecture and computational architecture (Freeze and Vaughn 2012), potentially pointing to the use of a high-performance computational (HPC) framework, if appropriate.

In addition, as the FEPs sensitivity analyses are completed and the TSPA model requirements are set more specifically, more definition can be given to many of the reference case definitions in Section 3.2, including parameter values and associated uncertainty ranges for the processes that are included in the SRD TSPA Model. Also, as the repository siting process evolves, and if the siting leans towards a particular salt host rock location, more details regarding the reference engineered systems can be formulated, as well as more details about the geosphere, such as the aquifer properties.

The preparation of the initial FEPs list and associated screening recommendations in Appendix A has identified a number of specific future activities (in FY 2013) that may be necessary for a salt repository FEPs list:

- A number of FEPs should be split into two or more FEPs because they are too broad in scope. As indicated in Appendix A, such broad FEPs definitions has led to different Include or Exclude recommendations for the individual parts of many of the FEP, which complicates the use of FEPs for TSPA model formulation. An example is FEP 2.1.07.10, Mechanical Degradation of EBS.
- FEPs sometimes seem to duplicate the same scope. For example, FEP 1.3.01.01, Climate Change, includes both natural and anthropogenic changes. FEP 1.4.01.01, Human Influences on Climate, seems to duplicate the anthropogenic portion of FEP 1.1.03.01. Another example is FEP 2.1.09.08, Chemical Interactions of Water with Other EBS Components, which appears to be redundant with FEPs 2.1.09.05 through 2.1.09.07.

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Appendix A: FEPs IDENTIFICATION FOR GENERIC SALT TSPA MODEL

Table A-1 is the list of generic UFD FEPs documented in Freeze et al. (2011) but with some changes to the FEPs that make them more appropriate for a generic salt repository. In particular, the FEP "Associated Processes" in the third column of Table A-1 has salt-specific changes that are identified in a **reddish brown** typeface. The FEP Descriptions in the second column also include an overall R&D priority ranking for each FEP, based on the UFD Campaign Roadmap (DOE 2011, Appendix B).

The preliminary screening recommendations for the individual FEPs are documented in the fourth column of Table A-1. Screening recommendations are also considered in light of the salt disposal reference case described in Section 3.2, where appropriate. The preliminary screening identifies the following categories for the 208 FEPs in Table A-1:

- Included. A FEP that is almost certain to be screened in to the SRD TSPA Model, independent of the type of salt site or specific site characteristics. An example of an included FEP is FEP 2.2.08.02, Advective Flow, or FEP 2.2.09.52, Advective Transport, in the geosphere.
- Excluded – A FEP that is almost certain to be screened out of the SRD TSPA Model, independent of the specific salt site. An example of an excluded FEP is FEP 1.5.01.01, Meteorite Impact.
- Site-Specific – A FEP that requires a substantial amount of detailed information for a specific site. An example is FEP 1.4.02.01, Human Intrusion, which requires knowledge of the potential for mining and resource extraction activities at a specific site in order to develop a detailed screening argument.
- Design-Specific – A FEP that requires detailed information for a specific repository design. Examples would be galvanic effects between dissimilar metals in a waste package, such as FEPs 2.1.09.09, Chemical Effects at EBS Component Interfaces, and FEP 2.1.09.11, Electrochemical Effects in EBS, which require knowledge of waste package design and EBS materials to formulate a detailed screening argument.
- Evaluate – All other FEPs are candidates for screening sensitivity analyses to determine their disposition with respect to the SRD TSPA Model. Some of these analyses will involve coupled processes, with the results providing guidance on which phenomena must be included in the SRD TSPA Model. For example, the hydrologic state at and near the waste package during the initial thermal pulse is likely to result from a coupled mechanical-hydrologic-thermal-chemical process because: (1) creep closure of drifts will reconsolidate crushed salt backfill surrounding the waste package, thereby changing the permeability of the backfill and the amount of brine that can contact the waste package, (2) the thermal conductivity of crushed salt and its creep rate are temperature dependent,

(3) the thermal pulse causes brine to evaporate more quickly near the waste package, and (4) corrosion of the waste package outer barrier will generate gas pressure that may resist creep closure of drifts and reduce inward flow of brine toward the waste package.

The foregoing FEP categories are not mutually exclusive, and multiple categories have sometimes been identified for an individual FEP. As an example, the magnitude and timing of seismic events is very site-specific. On the other hand, seismic ground motion is very unlikely to produce significant mechanical damage to a waste package because room closure due to salt creep will restrict the motion of a waste package and other EBS components during a seismic event. In this situation, the seismic-related FEPs have been identified as both “Site-Specific” and “Likely Excluded”. The modifier “Likely” has been added because a specific site could have a severe seismic hazard that would require inclusion in performance assessment, although it is expected that the site-selection process would eliminate such sites from consideration.

A.1 Cross-Walk to Other FEP Lists

The fifth and sixth columns in Table A-1 provide a cross-walk to the FEP list for the WIPP defense TRU waste repository (Hansen and Leigh 2011, Appendix A), a bedded salt site, and to the FEPs included in the Salt GDS Model (Clayton et al. 2011, Appendix B). The Include/Exclude status of the WIPP FEPs and Salt GDS FEPs is indicated.

A.2 Comparison to Included FEPs in a Generic Engineered Barrier System (EBS) Model

Lists of included FEPs for the “far-field” EBS subdomain, for the “near-field” EBS subdomain, and for the waste package subdomain have been developed for a generic EBS model (Hardin 2012, Tables 3-1, 3-2, and 3-3) that is applicable to a variety of repository concepts, including those emplaced in shale or granite. Most of the included FEPs in Hardin (2012, Tables 3-1 through 3-3) are consistent with the screening recommendations in Table A-1 of this report, in the sense that the corresponding FEPs in Table A-1 are similarly identified as “Included,” or “Evaluate.” The notable exceptions are based on salt-specific issues, and are as follows:

- FEP 1.2.03.01, Seismic Activity Impacts EBS and/or EBS Components, has been identified as a “Likely Excluded” in Table A-1 because creep closure of emplacement drifts in halite will encapsulate waste packages within the EBS, thereby preventing significant damage from ground motion and fault displacement.
- FEP 2.1.07.01, Rockfall, FEP 2.1.07.02, Drift Collapse, FEP 2.1.07.05, Mechanical Impact on Waste Packages, FEP 2.1.07.08, Mechanical Impact on Other EBS Components, and FEP 2.1.07.10, Mechanical Degradation of EBS, have been identified in Table A-1 as Included because of creep closure but Excluded for seismic effects from ground motion and fault displacement. The rationale for excluding seismic effects is explained in the previous bullet.
- FEP 2.1.08.05, Flow Through Liner/Rock Reinforcement Materials in EBS, has been identified as “Excluded” in Table A-1 for long-term performance because ground support will be minimized in a salt formation and, if present, is likely to be encapsulated when salt creep closes the emplacement drifts of the repository.

- FEP 2.1.09.03, Chemical Characteristics of Water in Backfill and FEP 2.1.09.12, Chemical Effects of Drift Collapse, have been identified as Excluded in Table A-1 because the backfill is assumed to be crushed salt, and the presence of additional salt in the emplacement drifts should not alter the chemical characteristics of the groundwater in the emplacement drifts.

A.3 Comparison to Excluded FEPs in a Generic Natural System Conceptual Model

A list of sixteen excluded FEPs has been developed for a conceptual model of the generic natural system of a high-level waste repository (Arnold et al., 2012, Table 2-1). Five of the Excluded FEPs in the generic natural system model are also identified as Excluded in Table A-1. Eight of the Excluded FEPs in the generic natural system model are identified as Evaluate in Table A-1, primarily because of uncertainty related to site-specific properties. Three of the excluded FEPs in the generic natural system model are identified as Included or Likely Included in Table A-1: FEP 2.2.09.04, Chemical Interactions and Evolution of Groundwater in Other Geologic Units, FEP 2.2.09.05, Radionuclide Speciation and Solubility in Host Rock, and FEP 2.2.09.05, Radionuclide Speciation and Solubility in Other Geologic Units. Analysis may demonstrate that these three FEPs should be excluded, as suggested by Arnold et al. (2012), but they are maintained as Included in Table A-1 until the analysis has been performed.

Table A-1. Features, Events, and Processes (FEPs) Potentially Relevant to Disposal of SNF and HLW at a Generic Salt Site, based on Freeze et al. (2011). [Changes for a generic salt site are identified by a **reddish brown typeface**.]

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
0.0.00.00	0. ASSESSMENT BASIS				
0.1.02.01	Timescales of Concern		Include		Included
0.1.03.01	Spatial Domain of Concern **Priority 2.14 out of 8 (generic)** **(*Research priorities from Appendix B of UFD R&D Roadmap (DOE 2011)*)**		Include	W1 Disposal Geometry Incl. W6 Shaft Seal Geometry Incl. W109 Panel Closure Geometry Incl.	Included
0.1.09.01	Regulatory Requirements and Exclusions		Include	H57 Loss of Records Excl. (WIPP does not take credit for Passive Institutional Controls)	Partially
0.1.10.01	Model Issues	- Conceptual model - Mathematical implementation - Geometry and dimensionality - Process coupling - Boundary and initial conditions	Include		Partially
0.1.10.02	Data Issues	- Parameterization and values - Correlations - Uncertainty	Include		Partially
1.0.00.00	1. EXTERNAL FACTORS				
1.1.00.00	1. REPOSITORY ISSUES				
1.1.01.01	Open Boreholes	- Site investigation boreholes (open, improperly sealed) - Preclosure and postclosure monitoring boreholes	Evaluate Likely Exclude because salt creep encapsulates and seals	W11 Post-Closure Monitoring Excl. W39 Underground Boreholes Incl. (Improperly Sealed)	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Enhanced flow pathways from EBS Borehole intrusions into aquifers, brine pockets, and the repository are represented by FEP 1.4.02.01, Human Intrusion	openings and EBS components.	H31 Natural Borehole Fluid Flow Excl. H32 Waste-Induced Borehole Flow Excl.	
1.1.02.01	Chemical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock	- Water contaminants (explosives residue, diesel, organics, etc.) - Water chemistry different than host rock (e.g., oxidizing) - Undesirable materials left - Accidents and unplanned events	Design-Specific		No
1.1.02.02	Mechanical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock	- Creation of excavation-disturbed zone (EDZ) - Stress relief - Boring and blasting effects - Rock reinforcement effects (drillholes) - Accidents and unplanned events - Enhanced flow pathways [see also Evolution of EDZ in 2.2.01.01]	Include the EDZ and Disturbed Rock Zone Inclusion of the EDZ and local ground support may be important to flow pathways for long-term performance		No
1.1.02.03	Thermal-Hydrologic Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock	- Site flooding - Preclosure ventilation - Accidents and unplanned events	Evaluate Likely Exclude because ventilation removes waste heat and moisture, and because site flooding and improper operations should be prevented by repository operations.		No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
1.1.08.01	Deviations from Design and Inadequate Quality Control	- Error in waste emplacement (waste forms, waste packages, waste package support materials) - Error in EBS component emplacement (backfill, seals, liner) - Inadequate excavation / construction (planning, schedule, implementation) - Aborted / incomplete closure of repository - Material and/or component defects - Undetected manufacturing defects in waste packages and other EBS components	Evaluate impact of early waste package failures on chemistry of brine in backfill/tunnels and on early radionuclide releases from EBS (see FEP 2.1.03.01, Early Failure of the Waste Package) Excluded for the waste package as a long-term hydrologic barrier because we do not need to take credit for the package as a flow barrier once salt encapsulates the waste. Excluded for other components, assuming the QA Program will install EBS components to design specifications.		No
1.1.10.01	Control of Repository Site	- Active controls (controlled area) - Retention of records - Passive controls (markers)	Include impact of active and passive controls on the drilling rate for exploratory boreholes for long-term performance	H57 – Loss of Records	No
1.1.13.01	Retrievability		Included for preclosure design Excluded for postclosure period if regulations exclude retrievability from consideration.		No
1.2.00.00	2. GEOLOGICAL PROCESSES AND EFFECTS				
1.2.01.00	2.01. LONG-TERM PROCESSES				
1.2.01.01	Tectonic Activity – Large Scale	- Uplift - Folding	Site Specific Likely Excluded if site selection	N4 Regional Tectonics Excl. N5 Regional Uplift & Subsidence Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Priority 1.44 out of 8 (generic)		identifies sites in relatively stable tectonic settings and salt backfill is used.		
1.2.01.02	Subsidence		Evaluate based on generic depth to top of salt and geologic information in the salt disposal reference case. Likely Excluded – significant subsidence may be excluded by the site selection process	N5 Regional Uplift & Subsidence Excl.	No
1.2.01.03	Metamorphism	- Structural changes due to natural heating and/or pressure	Site Specific Likely Excluded – significant metamorphism should be excluded by the site selection process, consistent with other international programs	N15 Metamorphic Activity Excl.	No
1.2.01.04	Diagenesis	- Mineral alteration due to natural processes	Site Specific Likely Excluded, consistent with other international programs		No
1.2.01.05	Diapirism **Priority 1.44 out of 8 (salt)**	- Plastic flow of rocks under lithostatic loading - Salt / evaporates	Excluded for bedded salt (salt creep is included in many EBS-related FEPs) Included for domal salt.	N6 Salt Deformation Excl. N7 Diapirism Excl.	No
1.2.01.06	Large-Scale Dissolution		Site Specific Shallow dissolution from (say) potash extraction may be Included if mining affects a local aquifer. Dissolution at or near the repository depth should be	N16 Shallow Dissolution Incl. N18 Deep Dissolution Excl. N20 Breccia Pipes Excl. N21 Collapse Breccias Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			excluded by the site selection process		
1.2.03.00	2.03.SEISMIC ACTIVITY				
1.2.03.01	Seismic Activity Impacts EBS and/or EBS Components **Priority 4.94 out of 8 (generic)**	- Mechanical damage to EBS (liners, rock bolts and wire mesh, drift reinforcements materials, and EDZ) from ground motion, rockfall, drift collapse, fault displacement [see also Mechanical Impacts in 2.1.07.04, 2.1.07.05, 2.1.07.06, 2.1.07.07, 2.1.07.08, and 2.1.07.10]	Site Specific – highly dependent on repository depth, site stratigraphy, EBS design, and seismic hazard at a site. Likely Excluded by room closure encapsulating EBS components, thereby preventing damage from ground motion and fault displacement, and by the use of minimal ground support in a salt repository.	N8 Formation of Fractures Incl. in near-field Excl. in far-field N9 Changes in Fracture Properties Incl. in near-field Excl. in far-field N11 Fault Movement Excl. N12 Seismic Activity Incl.	No
1.2.03.02	Seismic Activity Impacts Geosphere - Host Rock - Other Geologic Units **Priority 2.34 out of 8 (generic)**	- Altered flow pathways and properties - Altered stress regimes (faults, fractures) - Regional tectonics, regional uplift, and regional subsidence - Changes in fault/fracture properties [see also Alterations and Impacts in 1.2.01.01, 1.2.01.02, 2.2.05.01, 2.2.05.02, 2.2.05.03, 2.1.07.01, and 2.1.07.02]	Evaluate based on generic depth to top of salt and reference case info. Likely Excluded – geosphere has withstood seismic events over geologic time periods.	N3 Changes in Regional Stress Excl. N4 Regional Tectonics Excl. N5 Regional Uplift & Subsidence Excl. N8 Formation of Fractures Incl. in near-field Excl. in far-field N9 Changes in Fracture Properties Incl. in near-field Excl. in far-field N10 Formation of New Faults Excl. N11 Fault Movement Excl. N12 Seismic Activity Incl. N31 Hydrologic Response to Earthquakes Excl.	No
1.2.03.03	Seismic Activity Impacts Biosphere - Surface Environment - Human Behavior	- Altered surface characteristics - Altered surface transport pathways - Altered recharge - Regional uplift or	Site Specific – highly dependent on site location relative to faults. Likely Excluded	N5 Regional Uplift & Subsidence Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		subsidence			
1.2.04.00	2.04. IGNEOUS ACTIVITY				
1.2.04.01	Igneous Activity Impacts EBS and/or EBS Components	- Mechanical damage to EBS (from igneous intrusion) - Chemical interaction with magmatic volatiles - Transport of radionuclides (in magma, pyroclasts, vents) [see also Mechanical Impacts in 2.1.07.04, 2.1.07.05, 2.1.07.06, 2.1.07.07, and 2.1.07.08]	Site Specific – highly dependent on repository depth, site stratigraphy, volcanic hazard, and site location relative to active vents and previous volcanic activity. Likely Excluded – volcanism will likely be excluded by the site selection process; drift closure is expected to restore the underground facility to *in situ* condition in a few hundred years, eliminating the excavations as preferential pathways for magma to reach the waste packages.	N13 Volcanic Activity Excl. N14 Magmatic Activity Excl.	No
1.2.04.02	Igneous Activity Impacts Geosphere - Host Rock - Other Geologic Units	- Altered flow pathways and properties - Altered stress regimes (faults, fractures) - Igneous intrusions - Altered thermal and chemical conditions [see also Alterations and Impacts in 2.2.05.01, 2.2.05.02, 2.2.05.03, 2.1.07.01, 2.1.07.02, 2.2.09.03, 2.2.11.06 and 2.2.11.07]	Site Specific – highly dependent on repository depth, site stratigraphy, and site location relative to active vents and previous volcanic activity. Likely Excluded – volcanism will likely be excluded by the site selection process	N13 Volcanic Activity Excl. N14 Magmatic Activity Excl.	No
1.2.04.03	Igneous Activity Impacts Biosphere - Surface	- Altered surface characteristics - Altered surface transport	Site Specific – highly dependent on site location relative to active vents, previous	N13 Volcanic Activity Excl. N14 Magmatic Activity Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Environment - Human Behavior	pathways - Altered recharge - Ashfall and ash redistribution	volcanic activity, and local wind patterns (for ash redistribution) Likely Excluded – volcanism will likely be excluded by the site selection process		
1.3.00.00	3. CLIMATIC PROCESSES AND EFFECTS				
1.3.01.01	Climate Change - Natural - Anthropogenic **Priority 1.85 out of 8 (generic)**	- Variations in precipitation and temperature - Long-term global (sea level, …) - Short-term regional and local - Seasonal local (flooding, storms, …) [see also Human Influences on Climate in 1.4.01.01] [contributes to Precipitation in 2.3.08.01, Surface Runoff and Evapotranspiration in 2.3.08.02]	Site Specific – highly dependent on site location and local weather conditions. Included – impact of climate change on recharge of groundwater system is likely to be important for transport in the geosphere. Excluded – Anthropogenic sources	N61 Climate Change Incl. N64 Seas and Oceans Excl. N68 Sea Level Changes Excl. H47 Greenhouse Gas Effects Excl. H48 Acid Rain Excl. H49 Damage to the Ozone Layer Excl.	No
1.3.04.01	Periglacial Effects **Priority 1.85 out of 8 (generic)**	- Permafrost - Seasonal freeze/thaw	Site Specific – highly dependent on site location. Evaluate based on generic depth to top of salt and geologic information in salt disposal reference case.	N63 Permafrost Excl.	No
1.3.05.01	Glacial and Ice Sheet Effects **Priority 1.85 out of 8 (generic)**	- Glaciation - Isostatic depression - Melt water	Site Specific – highly dependent on site location. Evaluate based on generic depth to top of salt and reference case info.	N62 Glaciation Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
1.4.00.00	4. FUTURE HUMAN ACTIONS				
1.4.01.01	Human Influences on Climate - Intentional - Accidental	- Variations in precipitation and temperature - Global, regional, and/or local - Greenhouse gases, ozone layer failure [contributes to Climate Change in 1.3.01.01]	Included through FEP 1.3.01.01, Climate Change Exclude. Yucca Mountain arguments can be used (DOE 2008).	H47 Greenhouse Gas Effects Excl. H48 Acid Rain Excl. H49 Damage to the Ozone Layer Excl.	No
1.4.02.01	Human Intrusion - Deliberate - Inadvertent	- Drilling (resource exploration, …) - Mining / tunneling - Unintrusive site investigation (airborne, surface-based, …) [see also Control of Repository Site in 1.1.10.01]	Included – inadvertent borehole intrusions for resource exploration are the main release pathway for the WIPP site; Likely Included for solution mining if potash deposits exist close to the repository.	W84 Cuttings Incl. W85 Cavings Incl. W86 Spallings Incl. H13 Conventional Underground Potash Mining Incl. H14 Mining for Other Resources Excl. H18 Deliberate Mining Intrusion Excl. H21 Drilling Fluid Flow Excl. H22 Drilling Fluid Loss Excl. H23 Blowouts Excl. H24 Drilling Induced Geochemical ChangesInc H25 Oil and Gas Extraction Excl. H26 Groundwater Extraction Excl. H27 Liquid Waste Disposal – Outside Boundary Excl. H28 Enhanced Oil and Gas Production Outside Boundary of Site Excl. H29 Hydrocarbon Storage Outside Boundary of Site Excl. H30 Fluid-Injection-Induced Geochemical Changes Excl. H31 Natural Borehole Fluid Flow Excl. H32 Waste-Induced Borehole Flow Excl. H34 Borehole-Induced Solution and Subsidence Excl. H35 Borehole-Induced Mineralization Excl. H36 Borehole-Induced Geochemical Changes Incl. H37 Changes in Groundwater Flow Due To	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
				Mining Incl. H38 Changes in Geochemistry Due To Mining Excl. H39 Changes in Groundwater Flow Due To Explosions Excl. H58 Solution Mining for Potash Excl. H59 Solution Mining for Other Resources Excl.	
1.4.11.01	Explosions and Crashes from Human Activities	- War - Sabotage - Testing - Resource exploration / exploitation - Aircraft	Excluded Excluded on low consequence or low probability	H19 Explosions for Resource Recovery Excl. H20 Underground Nuclear Device Testing Excl. H39 Changes in Groundwater Flow Due To Explosions Excl.	No
1.5.00.00	5. OTHER				
1.5.01.01	Meteorite Impact	- Cratering, host rock removal - Exhumation of waste - Alteration of flow pathways	Excluded Excluded on low probability	N40 Impact of a Large Meteorite Excl.	No
1.5.01.02	Extraterrestrial Events	- Solar systems (supernova) - Celestial activity (sun - solar flares, gamma-ray bursters; moon – earth tides) - Alien life forms	Excluded Excluded on low probability		No
1.5.03.01	Earth Planetary Changes	- Changes in earth's magnetic field - Changes in earth's gravitational field (tides) - Changes in ocean currents	Excluded Excluded on low consequence		No
2.0.00.00	2. DISPOSAL SYSTEM FACTORS				
2.1.00.00	1. WASTES AND ENGINEERED FEATURES				
2.1.01.00	1.01. INVENTORY				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.01.01	Waste Inventory - Radionuclides - Non-Radionuclides **Priority 2.05 out of 8 (generic)**	- Composition - Enrichment / Burn-up	Included – characteristic of the waste form	W2 Waste Inventory Incl.	Included
2.1.01.02	Radioactive Decay and Ingrowth	- Decay chains - Decay products - Neutron activation	Included	W12 Radionuclide Decay and In-Growth Incl.	Included
2.1.01.03	Heterogeneity of Waste Inventory - Waste Package Scale - Repository Scale **Priority 1.92 out of 8 (generic)**	- Composition - Enrichment / Burn-up - Damaged Area	Included	W3 Heterogeneity of Waste Forms Incl.	Partially
2.1.01.04	Interactions Between Co-Located Waste **Priority 1.47 out of 8 (generic)**		Evaluate based on generic inventory and reference case information.		No
2.1.02.00	1.02. WASTE FORM				
2.1.02.01	SNF (Commercial, DOE) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release **Priority 4.01 out of 8 (generic)**	Degradation is dependent on: - Composition - Geometry / Structure - Enrichment / Burn-up - Surface Area - Gap and Grain Boundary Fraction - Damaged Area - THC Conditions [see also Mechanical Impact in 2.1.07.06 and Thermal-Mechanical Effects in 2.1.11.06]	Included for most fuel types Included for fuel types that degrade slowly, so that radionuclide dissolution and mass transport control releases from the waste package. May be Excluded for fuel types such as N reactor fuel which degrade much more rapidly than radionuclide dissolution and mass transport.	W4 Container Form Excl. W5 Container Material Inventory Incl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.02.02	HLW (Glass, Ceramic, Metal) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release	Degradation is dependent on: - Composition - Geometry / Structure - Surface Area - Damaged / Cracked Area - Mechanical Impact - THC Conditions [see also Mechanical Impact in 2.1.07.07 and Thermal-Mechanical Effects in 2.1.11.06]	Included	W4 Container Form Excl. W5 Container Material Inventory Incl.	Partially
2.1.02.03	Degradation of Organic/Cellulosic Materials in Waste **Priority 4.47 out of 8 (generic)**	- Nitrification - Sulfidization - Methanogenesis [see also Complexation in EBS in 2.1.09.54]	Excluded – current inventory has no organic materials.	W44 Degradation of Organic MaterialIncl.	No
2.1.02.04	HLW (Glass, Ceramic, Metal) Recrystallization		Likely Excluded for borosilicate glass waste. If peak temperature is less than glass transition temperature, the degradation rate of borosilicate glass is insensitive to the presence of a crystalline phase. Evaluate for other HLW forms.		No
2.1.02.05	Pyrophoricity or Flammable Gas from SNF or HLW **Priority 4.47 out of 8 (generic)**	[see also Gas Explosions in EBS in 2.1.12.04]	Evaluate for DSNF and spent uranium fuels; Likely Excluded for other spent fuels and waste forms.		No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.02.06	SNF Cladding Degradation and Failure **Priority 5.33 out of 8 (generic)**	- Initial damage - General Corrosion - Microbially Influenced Corrosion - Localized Corrosion - Enhanced Corrosion (silica, fluoride) - Stress Corrosion Cracking - Hydride Cracking - Unzipping - Creep - Internal Pressure - Mechanical Impact	Likely Excluded because we do not need to take credit for the cladding as a long-term hydrologic barrier in salt once the salt encapsulates the waste packages and because it will require an extensive effort to define the probability and magnitude of clad failures.		No
2.1.03.00	1.03. WASTE CONTAINER				
2.1.03.01	Early Failure of Waste Packages **Priority 0.38 out of 8 (generic)**	- Manufacturing defects - Improper sealing - Constructability and fabrication technology [see also Deviations from Design in 1.1.08.01]	Evaluate impact of early waste package failures on chemistry of brine in backfill/tunnels and on early radionuclide releases from EBS; Excluded for the waste package as a long-term hydrologic barrier because we do not need to take credit for the waste package as a flow barrier once salt encapsulates the waste.		No
2.1.03.02	General Corrosion of Waste Packages **Priority 4.34 out of 8 (generic)**	- Dry-air oxidation in anoxic condition - Humid-air corrosion in anoxic condition - Aqueous phase corrosion in anoxic condition - Passive film formation and stability - Chemistry of brine	Included for presence of corrosion products and for gas generation by anaerobic corrosion. Evaluate for impact on water chemistry using corrosion rates and failure rates and gas generation rates for		No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		contacting WP - Salt deliquescence - Hydrogen gas buildup - Effect of close contact with salt undergoing creep deformation	carbon steel overpack. Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste.		
2.1.03.03	Stress Corrosion Cracking (SCC) of Waste Packages **Priority 4.34 out of 8 (generic)**	- Residual stress distribution in WP from fabrication - Stress development and distribution in contact with salt undergoing creep deformation - Crack initiation, growth and propagation - Stress distribution and evolution around advancing cracks	Evaluate for impact on water chemistry using corrosion rates and failure rates and gas generation for carbon steel overpack. Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste.		No
2.1.03.04	Localized Corrosion of Waste Packages **Priority 4.34 out of 8 (generic)**	- Pitting - Crevice corrosion - Salt deliquescence - Effect of close contact with salt undergoing creep deformation [see also 2.1.09.06 Chemical Interaction with Backfill]	Evaluate for impact on water chemistry using corrosion rates and failure rates and gas generation rates for carbon steel overpack. Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste.		No
2.1.03.05	Hydride Cracking of Waste Packages **Priority 4.34 out of 8 (generic)**	- Hydrogen diffusion through metal matrix - Crack initiation and growth in metal hydride phases	Likely Included as waste package is exposed to buildup of H_2 gas pressure from corrosion. Evaluate for impact on water chemistry using corrosion		No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			rates and failure rates and gas generation rates for carbon steel overpack. Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste.		
2.1.03.06	Microbially Influenced Corrosion (MIC) of Waste Packages	- Viable colonies of halophilic bacteria - EBS environments promoting and sustaining microbial colonies	Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Likely Excluded for gas generation because the inventory does not include any organics to support the indigenous microbes in salt. Evaluate for impact on water chemistry using failure rates and gas generation rates for a carbon steel overpack.		No
2.1.03.07	Internal Corrosion of Waste Packages Prior to Breach		Excluded as a long-term hydrologic effect because we do not need to take credit for the internals once salt encapsulates the waste. Evaluate for long-term gas generation by anoxic corrosion and for structural response of partly degraded internal components; Design Specific – dependent on		No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			materials for the internal supports for fuel rod bundles. Evaluate for impact on water chemistry using failure rates and gas generation		
2.1.03.08	Evolution of Flow Pathways in Waste Packages **Priority 1.96 out of 8 (generic)**	- Evolution of physical form of waste package degradation - Plugging of cracks in waste packages [see also Evolution of Flow Pathways in EBS in 2.1.08.06, Mechanical Impacts in 2.1.07.05, 2.1.07.06, and 2.1.07.07, Thermal-Mechanical Effects in 2.1.11.06 and 2.1.11.07]	Excluded because we do not need to take credit for the detailed flow pathways once salt encapsulates the waste		No
2.1.04.00	1.04. BUFFER / BACKFILL				
2.1.04.01	Evolution and Degradation of Backfill **Priority 3.50 out of 8 (generic)**	- Alteration - Thermal expansion / Degradation - Swelling / Compaction - Erosion / Dissolution - Evolution of backfill flow pathways [see also Evolution of Flow Pathways in EBS in 2.1.08.06, Mechanical Impact in 2.1.07.04, Thermal-Mechanical Effects in 2.1.11.08, Chemical Interaction in 2.1.09.06]	Included for crushed salt	W9 Backfill Physical Properties Excl. W31 Differing Thermal Expansion of Repository Components Excl. W75 Chemical Degradation of Backfill Excl.	No
2.1.05.00	1.05. SEALS				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.05.01	Degradation of Seals **Priority 2.76 out of 8 (generic)** **This is better stated as "Evolution of Seal Components"**	- Alteration / Degradation / Cracking - Erosion / Dissolution - Asphalt seals: degradation as function of temperature and degassing [see also Mechanical Impact in 2.1.07.08, Thermal-Mechanical Effects in 2.1.11.09, Chemical Interaction in 2.1.09.08]	Included. The presence of asphalt, concrete, and crushed salt seal components in the shafts should reduce flow through the shafts to negligible volumes, but the shafts remain a pathway for releases in the undisturbed scenario and therefore are retained in the generic salt disposal system model.	W36 Consolidation of Shaft Seals Incl. W37 Mechanical Degradation of Shaft Seals Incl. W74 Chemical Degradation of Shaft Seals Incl. W76 Microbial Growth on Concrete Incl. W113 Consolidation of Panel ClosuresInc W114 Mechanical Degradation of Panel Closures Incl. W115 Chemical Degradation of Panel Closures Incl.	No
2.1.06.00	1.06. OTHER EBS MATERIALS				
2.1.06.01	Degradation of Liner / Rock Reinforcement Materials in EBS **Priority 2.62 out of 8 (generic)**	- Alteration / Degradation / Cracking - Corrosion - Erosion / Dissolution / Spalling [see also Mechanical Impact in 2.1.07.08, Thermal-Mechanical Effects in 2.1.11.09, Chemical Interaction in 2.1.09.07]	Excluded by the use of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case. Likely excluded for gas generation due to anaerobic corrosion because of minimal mass of iron-based alloys in the ground support system and liners.		No
2.1.07.00	1.07. MECHANICAL PROCESSES				
2.1.07.01	Rockfall **There may be roof failure during room closure, but it will not be like the rockfall during a seismic event in a hard, fractured rock. This FEP and**	- Dynamic loading (block size and velocity) [see also Mechanical Effects on Host Rock in 2.2.07.01]	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific. Excluded on low probability for the effects of seismic ground motion or a volcanic event.	W20 Salt Creep Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	the next FEP could be combined into a "Room Closure" FEP for a salt repository.		The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion or volcanic events to cause rockfall.		
2.1.07.02	Drift Collapse **Priority 2.70 – generic**	- Alteration of seepage - Alteration of EBS flow pathways - Alteration of EBS thermal environment [see also Evolution of Flow Pathways in EBS in 2.1.08.06, Chemical Effects of Drift Collapse in 2.1.09.12, and Effects of Drift Collapse on TH in 2.1.11.04, Mechanical Effects on Host Rock in 2.2.07.01]	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific Excluded on low probability for the effects of seismic ground motion or a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion or volcanic events to cause drift collapse.	W20 Salt Creep Incl.	No
2.1.07.03	Mechanical Effects of Backfill **Priority 3.29 out of 8 (generic)**	- Crushed salt backfill should consolidate during room closure process - Static and dynamic loading on EBS structures - Restricts displacement of EBS components during ground motion and fault displacement - Protection of ~~other~~ EBS components from rockfall /	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific Excluded on low probability for seismic ground motion. The encapsulation process for a backfilled room should be	W9 Backfill Physical Properties Excl. W35 Mechanical Effects of Backfill Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		drift collapse caused by ground motion and fault displacement	completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to modify backfill. Excluded on low probability/low consequence from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill looks like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.		
2.1.07.04	Mechanical Impact on Backfill **Priority 2.94 out of 8 (generic)**	- Rockfall / Drift collapse - Hydrostatic/lithostatic pressure of drift walls on any backfill present - Internal gas pressure - H2 gas buildup from anoxic corrosion of WP and other EBS components [see also Degradation of Backfill in 2.1.04.01 and Thermal-Mechanical Effects in 2.1.11.08]	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground	W20 Salt Creep Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			motion to modify backfill. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill looks like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.		
2.1.07.05	Mechanical Impact on Waste Packages Could be generalized to **Mechanical Response of Waste Package.** Internal gas pressure and swelling of corrosion products affect the mechanical response, but are not related to "impact". **Priority 2.76 out of 8 (generic)**	- Rockfall / Drift collapse - Waste package movement - Lithostatic pressure from salt creep - Hydrostatic pressure as repository is fully saturated - Internal gas pressure from anoxic corrosion of internal components - Swelling corrosion products [see also Thermal-Mechanical Effects in 2.1.11.07]	Included for quasi-static creep closure and corrosion of overpack; Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Evaluate impact of waste package failures on water chemistry and radionuclide mobilization. Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic events to affect the	W20 Salt Creep Incl. W33 Movement of Containers Excl. W64 Effects of Metal Corrosion Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			waste package. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill behaves like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.		
2.1.07.06	Mechanical Impact on SNF Waste Form **Priority 3.27 out of 8 (generic)**	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep [see also Thermal-Mechanical Effects in 2.1.11.06]	Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Evaluate for impact on water chemistry and radionuclide mobilization; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to affect the waste form. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository,	W20 Salt Creep Incl. W32 Consolidation of Waste Incl. W64 Effects of Metal Corrosion Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
			providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill behaves like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.		
2.1.07.07	Mechanical Impact on HLW Waste Form	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep [see also Thermal-Mechanical Effects in 2.1.11.06]	Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Evaluate for impact on water chemistry and radionuclide mobilization; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to affect the waste form. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill behaves like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.	W20 Salt Creep Incl. W32 Consolidation of Waste Incl. W64 Effects of Metal Corrosion Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.07.08	Mechanical Impact on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Materials **Could be generalized to: Mechanical Response of Other EBS Components** **Priority 2.16 out of 8 (generic)**	- Rockfall / Drift collapse - Movement - Hydrostatic pressure as repository is fully saturated - Lithostatic pressure from salt creep - Swelling corrosion products [see also Thermal-Mechanical Effects in 2.1.11.09]	Included for quasi-static creep closure and corrosion of components; Excluded for EBS components as long-term hydrologic barriers because we do not need to take credit for the EBS components once salt encapsulates the waste; Excluded by the use of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to affect the other EBS components. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill looks like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.	W20 Salt Creep Incl. W36 Consolidation of Shaft Seals Incl. W113 Consolidation of Panel Closures Incl. W64 Effects of Metal Corrosion Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.07.09	Mechanical Effects at EBS Component Interfaces **Priority 2.56 out of 8 (generic)**	- Component-to-component contact (static or dynamic) - Volume changes - Thermal expansion	Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is site specific. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to affect the interfaces. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill looks like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.	W31 Differing Thermal Expansion of Repository Components Excl. W64 Effects of Metal Corrosion Excl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.07.10	Mechanical Degradation of EBS	- Roof buckling and floor heave - Fault displacement - Initial damage from excavation / construction - Consolidation of EBS components - Degradation of waste package support structure and drift support structures - Alteration of EBS flow pathways [see also Mechanical Effects from Preclosure in 1.1.02.02, Evolution of Flow Pathways in EBS in 2.1.08.06, Drift Collapse in 2.1.07.02, Degradation in 2.1.04.01, 2.1.05.01, and 2.1.06.01, and Mechanical Effects on Host Rock in 2.2.07.01]	Included for quasi-static creep closure & corrosion of EBS components; Excluded for EBS components as long-term hydrologic barriers because we do not need to take credit for the EBS components once salt encapsulates the waste; Excluded for ground support because it is expected to be minimal and will be removed before closure; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) seismic ground motion to cause mechanical degradation. Excluded on low probability/low consequence for the effects from a volcanic event. The encapsulation process for a backfilled room should be completed by 200 years after closure of the repository, providing little time for major (low frequency) volcanic events to modify backfill. After 200 years, salt backfill looks like intact halite, and does not provide a preferential pathway relative to the host rock for magma flows.		Partially
2.1.08.00	1.08. HYDROLOGIC PROCESSES				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.08.01	Flow Through the EBS	- Saturated / Unsaturated flow - Preferential flow pathways - Density effects on flow - Initial hydrologic conditions - Flow pathways out of and into EBS [see also Open Boreholes in 1.1.01.01, Thermal-Hydrologic Effects from Preclosure in 1.1.02.03, Flow in Waste Packages in 2.1.08.02, Flow in Backfill in 2.1.08.03, Flow through Seals 2.1.08.04, Flow through Liner in 2.1.08.05, Thermal Effects on Flow in 2.1.11.10, Effects of Gas on Flow in 2.1.12.02]	Included	W9 Backfill Physical Properties Excl. N27 Effects of Preferential Pathways Incl. W7 Shaft Seal Physical Properties Incl. W90 Advection Incl. W110 Panel Closure Physical Properties Incl.	Partially
2.1.08.02	Flow In and Through Waste Packages **Priority 0.86 out of 8 (generic)**	- Saturated / Unsaturated flow - Movement as thin films or droplets	Included	N27 Effects of Preferential Pathways Incl. W90 Advection Incl.	Partially
2.1.08.03	Flow in Backfill **Priority 2.76 out of 8 (generic)**	- Saturated / Unsaturated flow - Fracture / Matrix flow – fracture flow does not occur in crushed salt - Preferential flow pathway as crushed salt backfill undergoes consolidation	Included	N27 Effects of Preferential Pathways Incl. W90 Advection Incl.	Partially
2.1.08.04	Flow Through Seals **Priority 2.80 out of 8 (generic)**	- Saturated / Unsaturated flow - Fracture / Matrix flow - Gas transport (in UFD, Appendix A list)	Included. The presence of asphalt, concrete, and crushed salt seal components in the shafts, per the salt disposal	N25 Fracture Flow Incl. N27 Effects of Preferential Pathways Incl. W6 Shaft Seal Geometry Incl. W7 Shaft Seal Physical Properties Incl. W90 Advection Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Preferential flows in non-salt portion - Brine formation by salt deliquescence	reference case, should reduce flow through the shafts to negligible amounts, but the shafts remain a pathway for releases in the undisturbed scenario and therefore are retained in the generic salt disposal system model.	W109 Panel Closure Geometry Incl. W110 Panel Closure Physical Properties Incl.	
2.1.08.05	Flow Through Liner / Rock Reinforcement Materials in EBS **Priority 0.85 out of 8 (generic)**	- Saturated / Unsaturated flow - Flow pathways along rock bolts - Fracture / Matrix flow	Likely Excluded for the long-term effects on flow through the liner/rock reinforcement because of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case, and because salt will encapsulate any ground support that is used.	N27 Effects of Preferential Pathways Incl. W90 Advection Incl.	No
2.1.08.06	Alteration and Evolution of EBS Flow Pathways	- Drift collapse - Degradation/consolidation of EBS components - Plugging of flow pathways - Formation of corrosion products - Water ponding - Brine formation by salt deliquescence [see also Evolution of Flow Pathways in WPs in 2.1.03.08, Evolution of Backfill in 2.1.04.01, Drift Collapse in 2.1.07.02, and Mechanical Degradation of EBS in 2.1.07.10]	Included for the effects of quasi-static creep closure, degradation and consolidation of EBS components, plugging of flow pathways, formation of corrosion products, and water ponding. Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event; Site Specific – direct fault displacement from a seismic event.	W64 Effects of Metal Corrosion Excl. H35 Borehole-Induced Mineralization Excl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.08.07	Condensation Forms in Repository - On Tunnel Roof / Walls - On EBS Components **Priority 1.73 out of 8 (generic)**	- Heat transfer (spatial and temporal distribution of temperature and relative humidity) - Dripping - Moisture movement - Brine formation by salt deliquescence - Release and migration of inclusion brine [see also Heat Generation in EBS in 2.1.11.01, Effects on EBS Thermal Environment in 2.1.11.03 and 2.1.11.04]	Evaluate Complex coupled thermal-mechanical-hydrologic process determines presence and mobility of brine in consolidated salt backfill.		No
2.1.08.08	Capillary Effects in EBS **Priority 1.87 (generic)**	- Wicking - Capillary barrier - Osmotic binding	Included for the impact of wicking on the availability of brine to support corrosion of iron-based alloys in the overpack.	W41 Wicking Incl.	No
2.1.08.09	Influx/Seepage Into the EBS **Priority 1.89 out of 8 (generic)**	- Water influx rate (spatial and temporal distribution) [see also Open Boreholes in 1.1.01.01, Thermal Effects on Flow in EBS in 2.1.11.10, Flow Through Host Rock in 2.2.08.01, Effects of Excavation on Flow in 2.2.08.04]	Included. This FEP has High importance to radionuclide transport, EBS component corrosion, and waste form degradation, per (Freeze et al., 2011, Appendix B, page B-125)	W40 Brine Inflow Incl. W42 Fluid Flow Due to Gas Production Incl. H31 Natural Borehole Fluid Flow Excl. H32 Waste-Induced Borehole Flow Excl. H34 Borehole-Induced Solution and Subsidence Excl. H37 Changes in Groundwater Flow Due To Mining Incl. H39 Changes in Groundwater Flow Due To Explosions Excl.	Partially
2.1.09.00	1.09. CHEMICAL PROCESSES - CHEMISTRY				
2.1.09.01	Chemistry of Water Flowing into the Repository	- Chemistry of influent water (spatial and temporal distribution)	Included	H24 Drilling-Induced Geochemical Changes Incl. H30 Fluid-Injection-Induced	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Priority 2.64 out of 8 (generic)	- Thermal effect - Chemistry of brine originated from inclusion brine - Chemistry of brine originated from intrusion groundwater - Chemistry of brine formed from salt deliquescence - Effect of anoxic condition [See also Chemistry in Host Rock 2.2.09.01]		Geochemical Changes Incl.	
2.1.09.02	Chemical Characteristics of Water in Waste Packages **Priority 2.76 out of 8 (generic)**	- Water composition (radionuclides, dissolved species, …) - Initial void chemistry (air / gas) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or backfill) - Effect of corrosion of waste canister and internal components - Effect of waste form corrosion - Evolution of water chemistry / interaction with waste packages [see also Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Included after breach of waste package; Evaluate for a high ionic strength brine solution with a mild steel or stainless steel container.	W51 Chemical Effects of Corrosion Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W58 Dissolution of Waste Incl. W59 Precipitation of Secondary Minerals Excl. Excl. W60 Kinetics of Precipitation and Dissolution Excl. W64 Effects of Metal Corrosion Incl. W65 Reduction-Oxidation Fronts Excl. W66 Reduction-Oxidation Kinetics Incl. W67 Localized Reducing Zones Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.09.03	Chemical Characteristics of Water in Backfill **Priority 1.47 out of 8 (generic)**	- Water composition (radionuclides, dissolved species, …) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or waste package) - Brine originated from inclusion brine - Brine originated from intrusion groundwater - Brine formed from salt deliquescence - Effect of gas formed from WP anoxic corrosion - Effect of anoxic condition - Evolution of water chemistry / interaction with backfill [see also Chemistry in Waste Packages in 2.1.09.02, Chemistry in Tunnels in 2.1.09.04]	Evaluate – determine if water chemistry in backfill is affected by H_2 gas generated by the anoxic corrosion process or by the presence of corrosion products.	W10 Backfill Chemical Composition Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl.	No
2.1.09.04	Chemical Characteristics of Water in Tunnels **Priority 1.77 out of 8 (generic)**	- Water composition (radionuclides, dissolved species, …) - Initial void chemistry (air/gas) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from near-field host rock)	Evaluate – determine if water chemistry in backfill is affected by H_2 gas generated by the anoxic corrosion process. Chemical interactions with corrosion products included in FEP 2.1.09.05.	W10 Backfill Chemical Composition Incl. W51 Chemical Effects of Corrosion Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl. W64 Effects of Metal Corrosion Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Initial chemistry (from construction / emplacement) - Evolution of water chemistry / interaction with seals, liner/rock reinforcement materials, waste package support materials [see also Chemical Effects from Preclosure in 1.1.02.01, Chemistry of Water Flowing in 2.1.09.01, Chemistry in Waste Packages in 2.1.09.02, Chemistry in Backfill in 2.1.09.03]			
2.1.09.05	Chemical Interaction of Water with Corrosion Products - In Waste Packages - In Backfill - In Tunnels Possibly included in 2.1.09.02, 2.1.09.03, and 2.1.09.04	- Corrosion product formation and composition (waste form, waste package internals, waste package) - Evolution of water chemistry in waste packages, in backfill, and in tunnels - Effect of water chemistry on corrosion products characteristics [contributes to Chemistry in Waste Packages in 2.1.09.02, Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Included, particularly for the potential for gas generation and contact with corrosion products to change chemistry of groundwater.	W51 Chemical Effects of Corrosion Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W58 Dissolution of Waste Incl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl. W64 Effects of Metal Corrosion Incl. W65 Reduction-Oxidation Fronts Excl. W66 Reduction-Oxidation Kinetics Incl. W67 Localized Reducing Zones Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.09.06	Chemical Interaction of Water with Backfill - On Waste Packages - In Backfill - In Tunnels Possibly included in 2.1.09.02, 2.1.09.03, and 2.1.09.04	- Backfill composition and evolution (bentonite, crushed rock, ...) - Evolution of water chemistry in backfill, and in tunnels - Enhanced degradation of waste packages (crevice formation) - Brine originated from inclusion brine - Brine originated from intrusion groundwater - Brine formed from salt deliquescence - Effect of gas formed from EBS anoxic corrosion - Effect of anoxic condition [contributes to Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04, Localized Corrosion of WPs in 2.1.03.04]	Included Chemical interactions with corrosion products are included in FEP 2.1.09.05.	W10 Backfill Chemical Composition Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl.	No
2.1.09.07	Chemical Interaction of Water with Liner / Rock Reinforcement and Cementitious Materials in EBS - In Backfill - In Tunnels **Priority 2.80 out of 8 (generic)**	- Liner composition and evolution (Portland cement, special concrete formulations for salt, metal, ...) - Rock reinforcement material composition and evolution (grout, rock bolts, mesh, ...) - Composition and evolution of other cementitious materials, including any special formulations for salt - Evolution of water	Likely Excluded because there will be minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case, and because the presence of salt and salt backfill in the tunnels will not change the chemical interactions with the waste packages and backfill.	W51 Chemical Effects of Corrosion Incl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W58 Dissolution of Waste Incl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl. W64 Effects of Metal Corrosion Incl. W65 Reduction-Oxidation Fronts Excl. W66 Reduction-Oxidation Kinetics Incl. W67 Localized Reducing Zones Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		chemistry in backfill, and in tunnels [contributes to Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]			
2.1.09.08	Chemical Interaction of Water with Other EBS Components - In Waste Packages - In Tunnels	- Seals composition and evolution - Waste Package Support composition and evolution (Portland cement, special concrete formulations for salt, metal, ...) - Other EBS components (other metals (copper), ...) - Evolution of water chemistry in backfill, and in tunnels [contributes to Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Evaluate Design Specific	W8 Shaft Seal Chemical CompositionExc W111 Panel Closure Chemical Composition Excl. W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl.	No
2.1.09.09	Chemical Effects at EBS Component Interfaces **Priority 2.61 out of 8 (generic)**	- Component-to-component contact (chemical reactions) - Consolidation of EBS components - Barrier degradation at interfaces	Evaluate Design Specific	W50 Galvanic Coupling (within The repository) Excl.	No
2.1.09.10	Chemical Effects of Waste-Rock Contact	- Waste-to-host rock contact (chemical reactions) - Component-to-host rock contact (chemical reactions)	Included	W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.09.11	Electrochemical Effects in EBS	- Enhanced metal corrosion	Likely Excluded, but reevaluate once a more detailed design is available.	W94 Electrochemical Effects Excl. W95 Galvanic Coupling (outside the Repository) Excl. W96 Electrophoresis Excl.	No
2.1.09.12	Chemical Effects of Drift Collapse	- Evolution of water chemistry in backfill and in tunnels (from altered seepage, from altered thermal-hydrology) [contributes to Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Excluded Salt will encapsulate the EBS, so the presence of salt and salt backfill in the tunnels after drift collapse will not change the chemistry of the groundwater.		No
2.1.09.13	Radionuclide Speciation and Solubility in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 4.86 out of 8 (generic)**	- Dissolved concentration limits - Limited dissolution due to inclusion in secondary phase - Enhanced dissolution due to alpha recoil - Complexation with organic ligands - Formation of various types of colloids [controlled by Chemistry in Waste Packages in 2.1.09.02, Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Included	W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W58 Dissolution of Waste Incl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl. W99 Alpha Recoil Excl.	Partially
2.1.09.50	1.09. CHEMICAL PROCESSES - TRANSPORT				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2 .1.09.51	Advection of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 3.06 out of 8 (generic)**	- Flow pathways and velocity - Advective properties (porosity, tortuosity) - Dispersion - Level of Saturation [see also Gas Phase Transport in 2.1.12.03]	Included	W77 Solute Transport Incl. W83 Rinse Excl. W90 Advection Incl.	Partially
2.1.09.52	Diffusion of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 3.06 out of 8 (generic)**	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Brine Saturation	Included	W91 Diffusion Incl. W92 Matrix Diffusion Incl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl. W100 Enhanced Diffusion Excl.	No
2.1.09.53	Sorption of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 3.06 out of 8 (generic)**	- Surface complexation properties - Flow pathways and velocity - Brine Saturation - Sorption on EBS degradation products - Sorption in anoxic condition - Effect of brine ionic strength [see also Chemistry in Waste Packages in 2.1.09.02, Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Evaluate for sorption onto corrosion products – difficult to prove that contaminated water comes into contact with the mass of corrosion products; Excluded for other EBS elements – conservative to ignore sorption.	W61 Actinide Sorption Incl. in Culebra and Dewey Lake Excl. elsewhere W62 Kinetics of Sorption Excl. W63 Changes in Sorptive SurfacesExcl.	No
2.1.09.54	Complexation in EBS **Priority 1.62 out of 8 (generic)**	- Formation of organic complexants (humates, fulvates, organic waste) - Enhanced transport of radionuclides associated	Excluded because there are no organic materials in the inventory	W68 Organic Complexation Incl. W69 Organic Ligands Incl. W70 Humic & Fulvic Acids Incl. W71 Kinetics of Organic Complexation Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		with organic complexants - Formation of inorganic complexes is covered in FEP 2.1.09.13. [see also Degradation of Organics in Waste in 2.1.02.03, see Radionuclide Speciation in 2.1.09.13 for inorganic complexation]			
2.1.09.55	Formation of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 1.79 out of 8 (generic)**	- Formation of intrinsic colloids - Formation of pseudo colloids (host rock fragments, waste form fragments, corrosion products, microbes, and humics) - Formation of co-precipitated colloids - Sorption/attachment of radionuclides to colloids (clay, silica, waste form, FeOx, microbes)	Included	W64 Effects of Metal Corrosion Incl. W79 Colloid Formation and Stability Incl. W82 Suspension of Particles Incl.	No
2.1.09.56	Stability of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 1.79 out of 8 (generic)**	- Chemical stability of attachment (dependent on water chemistry) - Mechanical stability of colloid (dependent on colloid size, gravitational settling)	Evaluate stability of different types of colloids in high ionic strength brines.	W79 Colloid Formation and Stability Incl. W82 Suspension of Particles Incl.	No
2.1.09.57	Advection of Colloids in EBS - In Waste Form - In Waste Package - In Backfill	- Flow pathways and velocity - Advective properties (porosity, tortuosity) - Dispersion - Saturation	Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56	W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W87 Microbial Transport Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	- In Tunnel **Priority 1.42 out of 8 (generic)**	- Colloid concentration			
2.1.09.58	Diffusion of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 1.42 out of 8 (generic)**	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Saturation - Colloid concentration	Evaluate Likely Excluded - diffusion of colloids is likely to be a slow process relative to diffusion of dissolved species.	W78 Colloid Transport Incl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl.	No
2.1.09.59	Sorption onto Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel **Priority 1.42 out of 8 (generic)**	- Surface complexation properties - Flow pathways and velocity - Saturation - Colloid concentration [see also Chemistry in Waste Packages in 2.1.09.02, Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04]	Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56	W81 Colloid Sorption Incl. W88 Biofilms Excl.	No
2.1.09.60	Sorption of Colloids at Air-Water Interface in EBS	- Colloid trapping at the air-water interface in unsaturated porous media [see also Filtration of Colloids in EBS in 2.1.09.61]	Excluded within the repository excavations – conservative to ignore sorption	W81 Colloid Sorption Incl. W88 Biofilms Excl.	No
2.1.09.61	Filtration of Colloids in EBS **Priority 1.42 out of 8 (generic)**	- Physical filtration or trapping (dependent on flow pathways, colloid size) - Electrostatic filtration	Excluded within the repository excavations – conservative to ignore filtration.	W80 Colloid Filtration Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.09.62	Radionuclide Transport Through Liners and Seals	- Advection - Dispersion - Diffusion - Sorption [contributes to Radionuclide release from EBS in 2.1.09.63]	Included for Seals. The shafts remain a viable pathway for releases in the undisturbed scenario and therefore are retained in the generic salt disposal system model. Excluded for Liners because liners will not be installed in emplacement drifts, per the salt disposal reference case.	W6 Shaft Seal Geometry Incl. W109 Panel Closure Geometry Incl. W61 Actinide Sorption Excl. W62 Kinetics of Sorption Excl. W63 Changes in Sorptive Surfaces Excl. W77 Solute Transport Incl. W78 Colloid Transport Incl. W87 Microbial Transport Incl.	No
2.1.09.63	Radionuclide Release from the EBS - Dissolved - Colloidal - Gas Phase	- Spatial and temporal distribution of releases to the host rock (due to varying flow pathways and velocities, varying component degradation rates, varying transport properties) [contributions from Dissolved in 2.1.09.51/52/53, Colloidal in 2.1.09.57/58/59, Gas Phase in 2.1.12.03, Liners and Seals in 2.1.09.62]	Included	W34 Container Integrity Excl. W61 Actinide Sorption Excl. W77 Solute Transport Incl. W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W81 Colloid Sorption Incl. W87 Microbial Transport Incl.	No
2.1.10.00	1.10. BIOLOGICAL PROCESSES				
2.1.10.01	Microbial Activity in EBS - Natural - Anthropogenic	- Effects on corrosion - Formation of complexants - Formation of microbial colloids - Formation of biofilms - Gas generation by biodegradation - Biomass production - Bioaccumulation [see also Microbially	Likely Excluded based on no organic material in the inventory. .	N71 Microbes Incl./Excl. Incl. for colloids & gas generation; other impacts Excl. W44 Degradation of Organic Material Incl. W45 Effects of Temperature on Microbial Gas Generation Incl. W46 Effects of Pressure on Microbial Gas Generation Excl. W47 Effects of Radioactivity on Microbial Gas Generation Excl. W48 Effects of Biofilms on Microbial	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		Influenced Corrosion in 2.1.03.06, Complexation in EBS in 2.1.09.54, Radiological Mutation of Microbes in 2.1.13.03]		Gas Generation Incl. W76 Microbial Growth on Concrete Excl.	
2.1.11.00	1.11. THERMAL PROCESSES				
2.1.11.01	Heat Generation in EBS **Priority 2.59 out of 8 (generic)**	- Radionuclide decay - Heat transfer (spatial and temporal distribution of temperature and relative humidity) [see also Thermal-Hydrologic Effects from Preclosure in 1.1.02.03, Waste Inventory in 2.1.01.01]	Included - heat generation from radioactive decay is a major thermal source in the system.	W13 Heat from Radioactive Decay Excl. W14 Nuclear Criticality Heat Excl.	No
2.1.11.02	Exothermic Reactions in EBS **Priority 0.99 out of 8 (generic)**	- Oxidation of SNF - Hydration of concrete	Evaluate – may be Excluded if these reactions are minor heat sources compared to radioactive decay in the waste	W72 Exothermic Reactions Excl. W73 Concrete Hydration Excl.	No
2.1.11.03	Effects of Backfill on EBS Thermal Environment **Priority 2.22 out of 8 (generic)**	- Thermal conductivity of backfill - Thermal blanket - Condensation	Included – thermal conductivity of backfill is important for heat transfer from the waste to the host rock.	W9 Backfill Physical Properties Excl. W29 Thermal Effects on Material Properties Excl.	No
2.1.11.04	Effects of Drift Collapse on EBS Thermal Environment **Priority 2.39 out of 8**	- Thermal conductivity of rubble - Thermal blanket - Condensation	Included – room closure and consolidation of crushed salt backfill are important for heat transfer to the host rock.	W20 Salt Creep Incl. W29 Thermal Effects on Material Properties Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	(generic)				
2.1.11.05	Effects of Influx (Seepage) on Thermal Environment	- Temperature and relative humidity (spatial and temporal distribution) [see also Influx/Seepage into EBS in 2.1.08.09]	Evaluate – may be Excluded if low influx rates may have minor impact on thermal environment.	N28 Thermal Effects on Groundwater Flow Excl.	No
2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components	- Mechanical loads from room closure due to salt creep - Alteration - Cracking - Thermal expansion / stress	Included for quasi-static creep closure and corrosion of overpack; Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Evaluate impact of waste package failures on water chemistry and radionuclide mobilization.	W20 Salt Creep Incl. W31 Differing Thermal Expansion of Repository Components Excl.	No
2.1.11.07	Thermal-Mechanical Effects on Waste Packages	- Mechanical loads from room closure due to salt creep - Thermal sensitization / phase changes - Cracking - Thermal expansion / stress / creep	Included for quasi-static creep closure and corrosion of overpack; Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Evaluate impact of waste package failures on water chemistry and radionuclide mobilization.	W20 Salt Creep Incl. W31 Differing Thermal Expansion of Repository Components Excl.	No
2.1.11.08	Thermal-Mechanical Effects on Backfill	- Mechanical loads from room closure due to salt creep - Consolidation of backfill	Included for the effects of quasi-static creep closure of the host rock and the resulting	W20 Salt Creep Incl. W31 Differing Thermal Expansion of Repository Components Excl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Alteration - Cracking - Thermal expansion / stress - Movement of WP due to the negative buoyance	mechanical loading on and consolidation of crushed salt backfill.	W35 Mechanical Effects of Backfill Excl.	
2.1.11.09	Thermal-Mechanical Effects on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Structure	- Mechanical loads from room closure due to salt creep - Alteration - Cracking - Thermal expansion / stress	Excluded for Liners and Rock Reinforcement because ground support will be minimized in the design of a salt repository, per the salt disposal reference case, and because salt will encapsulate any ground support that is used; Excluded for waste package support structure because the packages are placed directly on the floor of the emplacement drift, with no support structure, per the salt disposal reference case; Included for Seals	W20 Salt Creep Incl. W31 Differing Thermal Expansion of Repository Components Excl.	No
2.1.11.10	Thermal Effects on Flow in EBS	- Altered influx/seepage - Altered saturation / relative humidity (dry-out, resaturation) - Condensation	Evaluate Likely Included to capture dryout and rewetting of the EBS	N28 Thermal Effects on Groundwater Flow Excl. W29 Thermal Effects on Material Properties Excl.	No
2.1.11.11	Thermally-Driven Flow (Convection) in EBS	- Convection	Evaluate Likely Excluded after consolidation of crushed salt	N28 Thermal Effects on Groundwater Flow Excl. W43 Convection Excl.	No
2.1.11.12	Thermally-Driven Buoyant Flow / Heat Pipes in EBS	- Vapor flow	Evaluate Likely Excluded after consolidation of crushed salt	N28 Thermal Effects on Groundwater Flow Excl. W43 Convection Excl. W89 Transport of Radioactive GasesExcl	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.11.13	Thermal Effects on Chemistry and Microbial Activity in EBS		Evaluate temperature dependence of solubility limits; Excluded for thermal effects on microbial activity because there is no organic material in the inventory.	W45 Effects of Temperature on Microbial Gas Generation Incl.	No
2.1.11.14	Thermal Effects on Transport in EBS	- Thermal diffusion (Soret effect) - Thermal osmosis	Evaluate	W93 Soret Effect Excl. W98 Osmotic Processes Excl.	No
2.1.12.00	1.12. GAS SOURCES AND EFFECTS				
2.1.12.01	Gas Generation in EBS **Priority 0.98 out of 8 (generic)**	- Repository Pressurization - Mechanical Damage to EBS Components - He generation from waste from alpha decay - H_2 generation from anoxic corrosion of waste package and other EBS components - H_2 generation from radiolysis - CO_2, CH_4, and H_2S generation from microbial activity - Vaporization of water - Influence of gas pressure on room closure by salt creep - Influence of gas pressure on advective flows toward and away from the repository	Included for gas generation from anoxic corrosion; Excluded for gas generation from microbial degradation of organic materials.	W26 Pressurization Incl. W44 Degradation of Organic Material Incl. W45 Effects of Temperature on Microbial Gas Generation Incl. W46 Effects of Pressure on Microbial Gas Generation Excl. W47 Effects of Radioactivity on Microbial Gas Generation Excl. W48 Effects of Biofilms on Microbial Gas Generation Incl. W49 Gases from Metal Corrosion Incl. W54 Helium Gas Production Excl. W55 Radioactive Gases Excl. W99 Alpha Recoil Excl.	Partially
2.1.12.02	Effects of Gas on Flow Through the EBS	- Two-phase flow - Gas bubbles - Corrosion gas buildup	Included.	W42 Fluid Flow Due To Gas Production Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Priority 0.98 out of 8 (generic)	[see also Buoyant Flow/Heat Pipes in 2.1.11.12]			
2.1.12.03	Gas Transport in EBS **Priority 1.02 out of 8 (generic)**	- Gas phase transport - Gas phase release from EBS - Corrosion gas buildup	Evaluate Likely Excluded	W89 Transport of Radioactive Gases Excl. W90 Advection Incl.	Partially
2.1.12.04	Gas Explosions in EBS	[see also Flammable Gas from Waste in 2.1.02.05]	Evaluate Likely Excluded	W27 Gas Explosions Excl.	No
2.1.13.00	1.13. RADIATION EFFECTS				
2.1.13.01	Radiolysis - In Waste Package - In Backfill - In Tunnel	- Gas generation - Altered water chemistry	Evaluate	W52 Radiolysis of Brine Excl. W53 Radiolysis of Cellulose Excl.	No
2.1.13.02	Radiation Damage to EBS Components - Waste Form - Waste Package - Backfill - Other EBS Components **Priority 1.73 out of 8 (generic)**	- Enhanced waste form degradation - Enhanced waste package degradation - Enhanced backfill degradation - Enhanced degradation of other EBS components (liner/rock reinforcement materials, seals, waste support structure)	Evaluate – we are unaware of any journal articles on radiation damage to crushed salt backfill	W15 Radiological Effects on Waste Excl. W16 Radiological Effects on Containers Excl. W17 Radiological Effects on Shaft Seals Excl. W112 Radiological Effects on Panel Closures Excl.	No
2.1.13.03	Radiological Mutation of Microbes		Likely Excluded		No
2.1.14.00	1.14. NUCLEAR CRITICALITY				
2.1.14.01	Criticality In-Package **Priority 0.96 out of 8 (generic)**	- Formation of critical configuration - Accumulation of fissile materials to a critical mass	Evaluate Likely Excluded per other international programs	W14 Nuclear Criticality Heat Excl. W28 Nuclear Explosions Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.1.14.02	Criticality in EBS or Near-Field **Priority 0.96 out of 8 (generic)**	- Formation of critical configuration - Accumulation of fissile materials to a critical mass	Evaluate Likely Excluded per other international programs	W14 Nuclear Criticality Heat Excl. W28 Nuclear Explosions Excl.	No
2.2.00.00	2. GEOLOGICAL ENVIRONMENT				
2.2.01.00	2.01. EXCAVATION DISTURBED ZONE				
2.2.01.01	Evolution of EDZ **Priority 2.58 out of 8 (salt)**	- Lateral extent, heterogeneities - Physical properties - Flow pathways - Chemical characteristics of groundwater in EDZ - Radionuclide speciation and solubility in EDZ - Thermal-mechanical effects, particularly healing of fractures in the EDZ - Thermal-chemical alteration, particularly diffusion of sulfates from the host rock into the disposal rooms (affects gas generation) [see also Mechanical Effects of Excavation in 1.1.02.02, Seismic Activity Impacts EBS and/or EBS Components in 1.2.03.01]	Included Evaluate: potential evolution of EDZ and DRZ from a high permeability to a low permeability state is important for releases from the EBS to the geosphere.	W18 Disturbed Rock Zone Incl.	No
2.2.02.00	2.02. HOST ROCK				
2.2.02.01	Stratigraphy and Properties of Host Rock	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts	Included	N1 Stratigraphy Incl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Priority 3.74 out of 8 (salt)	- Physical properties - Flow pathways [see also Fractures in 2.2.05.01 and Faults in 2.2.05.02]			
2.2.03.00	2.03. OTHER GEOLOGIC UNITS				
2.2.03.01	Stratigraphy and Properties of Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts - Physical properties - Flow pathways - Pressurized brine reservoirs - Interbeds - [see also Fractures in 2.2.05.01 and Faults in 2.2.05.02]	Included.	N1 Stratigraphy Incl. N2 Brine Reservoirs Incl.	Partially
2.2.05.00	2.05. FLOW AND TRANSPORT PATHWAYS				
2.2.05.01	Fractures - Host Rock - Other Geologic Units **Priority 3.65 out of 8 (salt)**	- Rock properties - Hydrologic properties [see also Stratigraphy and Properties in 2.2.02.01 and 2.2.03.01]	Included for the clay seams and anhydrite interbeds in the host rock; Excluded for intact halite because creep closure will heal fractures	N25 Fracture Flow Incl. N27 Effects of Preferential Pathways Incl. N31 Hydrological Response to Earthquakes Excl.	No
2.2.05.02	Faults - Host Rock - Other Geologic Units	- Rock properties - Hydrologic properties [see also Stratigraphy and Properties in 2.2.02.01 and 2.2.03.01]	Site Specific – presence of faults in the geosphere is highly site specific Excluded for host rock salt	N25 Fracture Flow Incl. N27 Effects of Preferential Pathways Incl. N31 Hydrological Response to Earthquakes Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.2.05.03	Alteration and Evolution of Geosphere Flow Pathways - Host Rock - Other Geologic Units **Priority 2.46 out of 8 (salt)**	- Changes In rock properties - Changes in faults - Changes in fractures - Changes in flow pathways, aquifers, and aquitards, including potential for plugging and dissolution - Changes in saturation - Evolution of properties (porosity, permeability, etc.) in interbeds [see also Stratigraphy and Properties in 2.2.02.01 and 2.2.03.01, Fractures in 2.2.05.01, and Faults in 2.2.05.02] [see also Thermal-Mechanical Effects in 2.2.11.06 and Thermal-Chemical Alteration in 2.2.11.07]	Included because gas generation from corrosion can alter flow pathways by fracturing Anhydrite interbeds or clay seals; Included because potash mining beneath an aquifer can alter the transmissivity of the aquifer; Excluded for the halite beds of the host rock because creep of halite is expected to eliminate discontinuities in the halite and return it to an intact state.	N8 Formation of Fractures Incl. in near-field; Excl. in far-field N9 Changes in Fracture Properties Incl. in near-field; Excl. in far-field N10 Formation of New Faults Excl. N11 Fault Movement Excl. N16 Shallow Dissolution Incl. N18 Deep Dissolution Excl. N22 Fracture Infills Excl. N31 Hydrological Response to Earthquakes Excl. N32 Natural Gas Intrusion Excl. W23 Subsidence Excl. W24 Large-Scale Rock Fracturing Excl. W25 Disruption Due to Gas Effects Incl. H25 Oil and Gas Extraction Excl. H26 Groundwater Extraction Excl. H27 Liquid Waste Disposal Outside Boundary of Site Excl. H28 Enhanced Oil and Gas Production Outside Boundary of Site Excl. H29 Hydrocarbon Storage Outside Boundary of Site Excl. H34 Borehole-Induced Solution and Subsidence Excl. H35 Borehole-Induced Mineralization Excl. H37 Changes in Groundwater Flow Due To Mining Incl. H39 Changes in Groundwater Flow Due To Explosions Excl. H58 Solution Mining for Potash Excl. H59 Solution Mining for Other ResourcesExcl. H60 Liquid Waste Disposal Inside Boundary of Site Excl. H61 Enhanced Oil and Gas Production Inside Boundary of Site Excl. H62 Hydrocarbon Storage Inside Boundary of Site Excl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.2.07.00	2.07. MECHANICAL PROCESSES				
2.2.07.01	Mechanical Effects on Host Rock **Priority 3.83 out of 8 (salt)**	- From subsidence due to repository-related excavations - From salt creep - From healing of the EDZ - From dissolution of halite - From solution mining of other strata - From fracturing caused by gas pressurization - Chemical precipitation / dissolution [see also Subsidence in 1.2.02.01, Thermal-Mechanical Effects in 2.2.11.06 and Thermal-Chemical Alteration in 2.2.11.07]	Included for healing of the EDZ and DRZ Site Specific for other processes, but likely excluded for other geologic units	W18 Disturbed Rock Zone Incl. W19 Excavation-Induced Changes in Stress Incl. W20 Salt Creep Incl. W21 Changes in the Stress Field Incl. W22 Roof Falls Incl. W23 Subsidence Excl. W24 Large-Scale Rock Fracturing Excl. W25 Disruption Due To Gas Effects Incl. W26 Pressurization Incl. W27 Gas Explosions Excl. W28 Nuclear Explosions Excl. W30 Thermally Induced Stress Changes Excl.	No
2.2.07.02	Mechanical Effects on Other Geologic Units **Priority 3.10 out of 8 (salt)**	- From subsidence due to repository-related excavations - From solution mining of other strata - Chemical precipitation / dissolution - Stress regimes [see also Subsidence in 1.2.02.01, Thermal-Mechanical Effects in 2.2.11.06 and Thermal-Chemical Alteration in 2.2.11.07]	Included because potash mining beneath an aquifer can alter the transmissivity of the aquifer.	W19 Excavation-Induced Changes in Stress Incl. . W21 Changes in the Stress Field Incl. W23 Subsidence Excl. W24 Large-Scale Rock Fracturing Excl. W26 Pressurization Incl. W27 Gas Explosions Excl. W28 Nuclear Explosions Excl. W30 Thermally Induced Stress Excl. Changes Excl. H58 Solution Mining for Potash Incl. H59 Solution Mining for Other Resources Excl.	No
2.2.08.00	2.08. HYDROLOGIC PROCESSES				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.2.08.01	Flow Through the Host Rock **Priority 7.73 out of 8 (salt)**	- Saturated flow - Fracture flow / matrix imbibition (probably not applicable to salt) - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways (including flow in interbed) - Density and thermal effects on flow - Flow pathways out of Host Rock [see also Influx/Seepage into EBS in 2.1.08.09, Alteration of Flow Pathways in 2.2.05.03, Thermal Effects on Flow in 2.2.11.01, Effects of Gas on Flow in 2.2.12.02]	Included	N23 Saturated Groundwater Flow Incl. N24 Unsaturated Groundwater Flow Incl. N25 Fracture Flow Incl. N26 Density Effects on Groundwater Flow Excl. N27 Effects of Preferential Pathways Incl. N28 Thermal Effects on Groundwater Flow Excl. W40 Brine Inflow Incl. W90 Advection Incl.	Partially
2.2.08.02	Flow Through the Other Geologic Units - Confining units - Aquifers - Salt - **Priority 7.73 out of 8 (salt)**	- Saturated flow - Fracture flow / matrix imbibition - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways (including flow in interbed) - Density and thermal effects on flow - Saline or freshwater intrusions - Flow pathways out of Other Geologic Units [see also Alteration of Flow Pathways in 2.2.05.03, Thermal Effects on Flow in 2.2.11.01, Effects of Gas on	Included	N23 Saturated Groundwater Flow Incl. N24 Unsaturated Groundwater Flow Incl. N25 Fracture Flow Incl. N26 Density Effects on Groundwater Flow Excl. N27 Effects of Preferential Pathways Incl. N28 Thermal Effects on Groundwater Flow Excl. N29* Saline Intrusion Excl. N30* Freshwater Intrusion Excl. W90 Advection Incl. *Hydrogeological Effects	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		Flow in 2.2.12.02]			
2.2.08.03	Effects of Recharge on Geosphere Flow - Host Rock - Other Geologic Units	- Infiltration rate - Water table rise/decline - Effect of climate change including glaciation [see also Infiltration in 2.3.08.03]	Included	N55 Infiltration Incl. N58 River Flooding Excl. N59 Precipitation Incl. N61 Climate Change Incl. N62 Glaciation Excl. N62 Permafrost Excl.	No
2.2.08.04	Effects of Repository Excavation on Flow Through the Host Rock **Priority 7.10 out of 8 (salt)**	- Saturated flow (flow sink) - Unsaturated flow (capillary diversion, drift shadow) - Influx/Seepage into EBS (film flow, enhanced seepage) [see also Influx/Seepage into EBS in 2.1.08.09]	Included	H37 Changes in Groundwater Flow Due To Mining Incl.	No
2.2.08.05	Condensation Forms in Host Rock	- Condensation cap - Shedding - Deliquescence of mixed salts [see also Thermal Effects on Flow in Geosphere in 2.2.11.01]	Evaluate		No
2.2.08.06	Flow Through EDZ **Priority 7.73 out of 8 (salt)**	- Saturated / Unsaturated flow - Fracture / Matrix flow	Included	W18 Disturbed Rock Zone Incl. W90 Advection Incl.	No
2.2.08.07	Mineralogic Dehydration **Priority 6.49 out of 8 (salt)**	- Dehydration reactions release water and may lead to volume changes	Evaluate	H35 Borehole-Induced Mineralization Excl.	No
2.2.08.08	Groundwater Discharge to Biosphere Boundary	- Surface discharge (water table, capillary rise, surface water)	Included	N53 Groundwater Discharge Incl. N56 Changes in Groundwater Recharge & Discharge Incl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Flow across regulatory boundary - Brine flow from repository preferential pathway (i.e., interbeds) to regional aquifer			
2.2.08.09	Groundwater Discharge to Well	- Human use (drinking water, bathing water, industrial) - Agricultural use (irrigation, animal watering) - Mixing, dispersion and dilution in aquifer - Aquifer characteristics and flow pattern - Well pumping rate - Well location relative to contaminant plume location	Included Likely included per international programs		Partially
2.2.09.00	2.09.CHEMICAL PROCESSES - CHEMISTRY				
2.2.09.01	Chemical Characteristics of Groundwater in Host Rock **Priority 2.40 out of 8 (salt)**	- Water composition (radionuclides, dissolved species, …) - Water chemistry (temperature, pH, Eh, ionic strength, pO2 …) - Reduction-oxidation potential - Reaction kinetics - Interaction with EBS - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Effect of gas formed from EBS anoxic corrosion - Effect of anoxic condition	Included	N33 Groundwater Geochemistry Incl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		[see also Chemistry in Tunnels in 2.1.09.04, Chemical Interactions and Evolution in 2.2.09.03] [contributes to Chemistry of Water Flowing into Repository in 2.1.09.01]			
2.2.09.02	Chemical Characteristics of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Water composition (radionuclides, dissolved species, …) - Water chemistry (temperature, pH, Eh, ionic strength, pO2 …) - Reduction-oxidation potential - Reaction kinetics - Saline or freshwater intrusion - Interaction with other geologic units - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Effect of gas formed from EBS anoxic corrosion - Effect of anoxic condition [see also Chemical Interactions and Evolution in 2.2.09.04]	Included	N33 Groundwater Geochemistry Incl.	No
2.2.09.03	Chemical Interactions and Evolution of Groundwater in Host Rock **Priority 2.10 out of 8 (salt)**	- Host rock composition and evolution - Evolution of water chemistry in host rock - Chemical effects on density - Interaction with EBS - Reaction kinetics	Included Evaluate for reaction kinetics	N35* Freshwater Intrusion Excl. N36 Changes in Groundwater Eh Excl. N37 Changes in Groundwater pH Excl. N38 Effects of Dissolution Excl. H24 Drilling-Induced Geochemical Changes Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		- Mineral dissolution/precipitation - Redissolution of precipitates after dry-out - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Evolution of gas generation from EBS anoxic corrosion - Effect of anoxic condition [contributes to Chemistry in Host Rock in 2.2.09.01]		H30 Fluid-Injection-Induced Geochemical Changes Excl. H35 Borehole-Induced Mineralization Excl. H36 Borehole-Induced Geochemical Changes Incl. H38 Changes in Geochemistry Due To Mining Excl. *Geochemical Effects	
2.2.09.04	Chemical Interactions and Evolution of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.10 out of 8 (salt)**	- Host rock composition and evolution - Evolution of water chemistry in host rock - Chemical effects on density - Reaction kinetics - Mineral dissolution/precipitation - Recharge chemistry - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Evolution of gas generation from EBS anoxic corrosion - Effect of anoxic condition [contributes to Chemistry in Other Geologic Units in 2.2.09.02]	Included	N34* Saline Intrusion Excl. N35* Freshwater Intrusion Excl. N36 Changes in Groundwater Eh Excl. N37 Changes in Groundwater pH Excl. N38 Effects of Dissolution Excl. H24 Drilling-Induced Geochemical Changes Excl. H30 Fluid-Injection-Induced Geochemical Changes Excl. H35 Borehole-Induced Mineralization Excl. H36 Borehole-Induced Geochemical Changes Incl. H38 Changes in Geochemistry Due To Mining Excl. *Geochemical Effects	No
2.2.09.05	Radionuclide Speciation and Solubility in Host Rock	- Dissolved concentration limits - Water composition - Water chemistry (temperature, pH, Eh, ionic	Included	W56 Speciation Incl. W57 Kinetics of Speciation Excl	Included

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Priority 2.40 out of 8 (salt)	strength, pO2,pH2 …) - Reduction-oxidation potential [controlled by Chemistry in Host Rock in 2.2.09.01]			
2.2.09.06	Radionuclide Speciation and Solubility in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Dissolved concentration limits - Water composition - Water chemistry (temperature, pH, Eh, ionic strength, pO2,pH2 …) - Reduction-oxidation potential [controlled by Chemistry in Other Geologic Units in 2.2.09.02]	Included	W56 Speciation Incl. W57 Kinetics of Speciation Excl	Included
2.2.09.50	2.09. CHEMICAL PROCESSES - TRANSPORT				
2.2.09.51	Advection of Dissolved Radionuclides in Host Rock **Priority 2.53 out of 8 (generic)**	- Flow pathways and velocity - Advective properties (porosity, permeability, tortuosity) - Dispersion - Matrix diffusion - Saturation - Brine flow driven by brine density difference [see also Gas Phase Transport in 2.2.12.03]	Included	W77 Solute Transport Incl. W90 Advection Incl.	Included
2.2.09.52	Advection of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock)	- Flow pathways and velocity - Advective properties (porosity, permeability, tortuosity) - Dispersion	Included.	W77 Solute Transport Incl. W90 Advection Incl.	Included

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	- Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Matrix diffusion - Saturation - Brine flow driven by brine density difference [see also Gas Phase Transport in 2.2.12.03]			
2.2.09.53	Diffusion/Dispersion of Dissolved Radionuclides in Host Rock **Priority 2.40 out of 8 (salt)**	- Gradients (concentration, chemical potential) - Diffusive properties (porosity, tortuosity, diffusion coefficients) - Flow pathways and velocity - Saturation	Included	W91 Diffusion Incl. W92 Matrix Diffusion Incl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl. W100 Enhanced Diffusion Excl.	Included
2.2.09.54	Diffusion/Dispersion of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Gradients (concentration, chemical potential) - Diffusive properties (porosity, tortuosity, diffusion coefficients) - Flow pathways and velocity - Saturation	Included	W91 Diffusion Incl. W92 Matrix Diffusion Incl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl. W100 Enhanced Diffusion Excl.	Included
2.2.09.55	Sorption of Dissolved Radionuclides in Host Rock **Priority 2.40 out of 8 (salt)**	- Surface complexation properties - Flow pathways and velocity - Saturation - Mineralogical composition of host rock - Brine ionic strength - Brine redox condition - Effect of H2 gas buildup [see also Chemistry in Host Rock in 2.2.09.01]	Included	W61 Actinide Sorption Incl. in Culebra, Dewey Lake Excl. elsewhere W62 Kinetics of Sorption Excl. W63 Changes in Sorptive SurfacesExcl.	Partially
2.2.09.56	Sorption of Dissolved Radionuclides in	- Surface complexation properties	Included	W61 Actinide Sorption Incl. in Culebra, Dewey Lake	Included

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Flow pathways and velocity - Saturation - Mineralogical composition of host rock - Brine ionic strength - Brine redox condition - Effect of H2 gas buildup [see also Chemistry in Host Rock in 2.2.09.01]		Excl. elsewhere W62 Kinetics of Sorption Excl. W63 Changes in Sorptive Surfaces Excl.	
2.2.09.57	Complexation in Host Rock **Priority 2.40 out of 8 (salt)**	- Presence of organic complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants [see Radionuclide Speciation in 2.2.09.05 for inorganic complexation]	Likely Excluded. There are no organics in the inventory but the presence of carbonate and/or sulfate in the anhydrite interbeds may promote complexation with actinides.	W68 Organic Complexation Incl. W69 Organic Ligands Incl. W70 Humic & Fulvic Acids Incl. W71 Kinetics of Organic Complexation Excl.	No
2.2.09.58	Complexation in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.40 out of 8 (salt)**	- Presence of organic complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants [see Radionuclide Speciation in 2.2.09.06 for inorganic complexation]	Evaluate Site Specific, but likely excluded for deep aquifers	W68 Organic Complexation Incl. W69 Organic Ligands Incl. W70 Humic & Fulvic Acids Incl. W71 Kinetics of Organic Complexation Excl.	No
2.2.09.59	Colloidal Transport in Host Rock **Priority 2.22 out of 8 (salt)**	- Flow pathways and velocity - Saturation - Advection - Dispersion - Diffusion - Sorption - Colloid concentration - Colloid stability	Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56	W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W81 Colloid Sorption Incl. W87 Microbial Transport Incl. W88 Biofilms Excl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.2.09.60	Colloidal Transport in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 2.22 out of 8 (salt)**	- Flow pathways and velocity - Saturation - Advection - Dispersion - Diffusion - Sorption - Colloid concentration - Colloid stability	Likely Included if colloids are formed within the repository and/or host rock.	W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W81 Colloid Sorption Incl. W87 Microbial Transport Incl. W88 Biofilms Excl. W97 Chemical Gradients Excl. W98 Osmotic Processes Excl.	No
2.2.09.61	Radionuclide Transport Through EDZ	- Advection - Dispersion - Diffusion - Sorption	Included	W77 Solute Transport Incl. W78 Colloid Transport Incl. W87 Microbial Transport Incl.	No
2.2.09.62	Dilution of Radionuclides in Groundwater - Host Rock - Other Geologic Units **Priority 2.10 out of 8 (salt)**	- Mixing with uncontaminated groundwater - Mixing at withdrawal well [see also Groundwater Discharge to Well in 2.2.08.09]	Included		Partially
2.2.09.63	Dilution of Radionuclides with Stable Isotopes - Host Rock - Other Geologic Units **Priority 2.10 out of 8 (salt)**	- Mixing with stable and/or naturally occurring isotopes of the same element	Site Specific and dependent on “stylized” scenario used to define dose Evaluate		No
2.2.09.64	Radionuclide Release from Host Rock - Dissolved - Colloidal - Gas Phase **Priority 2.40 out of 8**	- Spatial and temporal distribution of releases to the Other Geologic Units or to the Biosphere (due to varying flow pathways and velocities, varying transport properties)	Included	W34 Container Integrity Excl. W61 Actinide Sorption Excl. W77 Solute Transport Incl. W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W81 Colloid Sorption Incl. W87 Microbial Transport Incl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	(salt)	[contributions from Dissolved in 2.2.09.51/53/55, Colloidal in 2.2.09.59, Gas Phase in 2.2.12.03, EDZ in 2.2.09.61]			
2.2.09.65	Radionuclide Release from Other Geologic Units - Dissolved - Colloidal - Gas Phase **Priority 2.40 out of 8 (salt)**	- Spatial and temporal distribution of releases to the Biosphere (due to varying flow pathways and velocities, varying transport properties) [see also Groundwater Discharge to Biosphere Boundary in 2.2.08.08, Groundwater Discharge to Well in 2.2.08.09, Recycling of Accumulated Radionuclides in 2.3.09.55] [contributions from Dissolved in 2.2.09.52/54/56, Colloidal in 2.2.09.60, Gas Phase in 2.2.12.03]	Included	W61 Actinide Sorption Excl. W77 Solute Transport Incl. W78 Colloid Transport Incl. W80 Colloid Filtration Incl. W81 Colloid Sorption Incl. W87 Microbial Transport Incl.	Partially
2.2.10.00	2.10. BIOLOGICAL PROCESSES				
2.2.10.01	Microbial Activity in Host Rock **Priority 1.32 out of 8 (generic)**	- Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation - - Nutrients availability and replenishment [see also Complexation in Host Rock in 2.2.09.57]	Site Specific – viability of microbial colonies is site specific Likely excluded	N71 Microbes Incl./Excl. Incl. for colloids & gas generation; Other impacts Excl. W44 Degradation of Organic Material Incl. W45 Effects of Temperature on Microbial Gas Generation Incl. W46 Effects of Pressure on Microbial Gas Generation Excl. W47 Effects of Radioactivity on Microbial Gas Generation Excl. W48 Effects of Biofilms on Microbial Gas Generation Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
				W79 Colloid Formation and StabilityIncl. W88 Biofilms Excl.	
2.2.10.02	Microbial Activity in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers **Priority 1.32 out of 8 (generic)**	- Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation - Nutrients availability and replenishment [see also Complexation in Other Geologic Units in 2.2.09.58]	Site Specific – viability of microbial colonies is site specific Likely excluded	N71 Microbes Incl./Excl. Incl. for colloids and gas generation; other impacts Excl. W44 Degradation of Organic MaterialIncl. W48 Effects of Biofilms on Microbial Gas Generation Incl. W76 Microbial Growth on ConcreteExcl.	No
2.2.11.00	2.11. THERMAL PROCESSES				
2.2.11.01	Thermal Effects on Flow in Geosphere - Repository-Induced - Natural Geothermal **Priority 2.10 out of 8 (salt)**	- Altered saturation / relative humidity (dry-out, resaturation) - Altered gradients, density, and/or flow pathways, including dryout of clay seams in the host rock - Vapor flow - Condensation	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.	N28 Thermal Effects on Groundwater Flow Excl. W29 Thermal Effects on Material Properties Excl. H7 Geothermal Excl.	No
2.2.11.02	Thermally-Driven Flow (Convection) in Geosphere **Priority 2.10 out of 8 (salt)**	- Convection	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.	N28 Thermal Effects on Groundwater Flow Excl. W43 Convection Excl.	No
2.2.11.03	Thermally-Driven Buoyant Flow / Heat Pipes in Geosphere **Priority 1.66 out of 8 (salt)**	- Vapor flow	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.	N28 Thermal Effects on Groundwater Flow Excl. W43 Convection Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.2.11.04	Thermal Effects on Chemistry and Microbial Activity in Geosphere **Priority 2.40 out of 8 (salt)**	- Mineral precipitation / dissolution - Altered solubility [contributes to Chemistry in 2.2.09.01 and 2.2.09.02]	Evaluate	W45 Effects of Temperature on Microbial Gas Generation Incl.	No
2.2.11.05	Thermal Effects on Transport in Geosphere	- Thermal diffusion (Soret effect) - Thermal osmosis	Evaluate	W93 Soret Effect Excl. W98 Osmotic Processes Excl.	No
2.2.11.06	Thermal-Mechanical Effects on Geosphere **Priority 2.30 out of 8 (salt)**	- Thermal expansion / compression - Altered properties of fractures, faults, rock matrix	Evaluate	W29 Thermal Effects on Material Properties Excl. W30 Thermally Induced Stress Changes Excl.	No
2.2.11.07	Thermal-Chemical Alteration of Geosphere **Priority 2.30 out of 8 (salt)**	- Mineral precipitation / dissolution - Altered properties of fractures, faults, rock matrix - Alteration of minerals / volume changes -	Evaluate	W56 Speciation Incl./Excl. W57 Kinetics of Speciation Excl. W59 Precipitation of Secondary Minerals Excl. W60 Kinetics of Precipitation and Dissolution Excl. N42 Chemical Weathering Excl.	No
2.2.12.00	2.12. GAS SOURCES AND EFFECTS				
2.2.12.01	Gas Generation in Geosphere	- Degassing (clathrates, deep gases) - Microbial degradation of organics - Vaporization of water	Likely Excluded during site screening and characterization	N71 Microbes Incl./Excl. Incl. for colloids and gas generation; other impacts Excl. W44 Degradation of Organic Material Incl.	No
2.2.12.02	Effects of Gas on Flow Through the Geosphere **Priority 0.95 out of 8 (generic)**	- Altered gradients and/or flow pathways - Vapor/air flow - Two-phase flow - Gas bubbles - Natural Gas Intrusion from formations beneath repository (N32)	Included	N32 Natural Gas Intrusion Excl. W25 Disruption Due to Gas Effects Incl. W42 Fluid Flow Due To Gas Production Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		[see also Buoyant Flow/Heat Pipes in 2.2.11.03]			
2.2.12.03	Gas Transport in Geosphere **Priority 0.73 out of 8 (salt)**	- Gas phase transport - Gas phase release from Geosphere	Likely excluded	W89 Transport of Radioactive Gases Excl. W90 Advection Incl.	No
2.2.14.00	2.14. NUCLEAR CRITICALITY				
2.2.14.01	Criticality in Far-Field	- Formation of critical configuration - Accumulation of critical mass of fissile materials	Site Specific Likely Excluded per other international programs and has low importance for salt, per (Freeze et al., 2010, page B-346)	W28 Nuclear Explosions Excl.	No
2.3.00.00	3. SURFACE ENVIRONMENT				
2.3.01.00	3.01. SURFACE CHARACTERISTICS				
2.3.01.01	Topography and Surface Morphology	- Recharge and discharge areas	Site Specific	N39 Physiography Incl.	No
2.3.02.01	Surficial Soil Type	- Physical and chemical attributes	Included	N50 Soil Development Excl.	No
2.3.04.01	Surface Water	- Lakes, rivers, springs - Dams, reservoirs, canals, pipelines - Coastal and marine features - Water management activities	Included	N51 Stream and River Flow Excl. N52 Surface Water Bodies Excl. N53 Groundwater Discharge Incl. N54 Groundwater Recharge Incl. N55 Infiltration Incl. N56 Changes in Groundwater Recharge & Discharge Incl. N57 Lake Formation Excl. N58 River Flooding Excl. N59 Precipitation (Rainfall) Incl. N65 Estuaries Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
				N66 Coastal Erosion Excl. N67 Marine Sediment Transport and Deposition Excl. N68 Sea Level Changes Excl.	
2.3.05.01	Biosphere Characteristics	- Climate - Soils - Flora and fauna - Microbes - Evolution of biosphere (natural, anthropogenic – e.g., acid rain) [see also Climate Change in 1.3.01.01, Surficial Soil Type in 2.3.02.01, Microbial Activity in 2.3.10.01]	Included - Climate, Soils, Flora, Fauna, and Microbes impact on surface characteristics that may affect dose in the biosphere.	N50 Soil Development Excl. N56 Changes in Groundwater Recharge & Discharge Incl. N57 Lake Formation Excl. N58 River Flooding Excl. N59 Precipitation (Rainfall) Incl. N60 Temperature Incl. N61 Climate Change Incl. N62 Glaciation Excl. N63 Permafrost Excl. N69 Plants Excl. N70 Animals Excl. N71 Microbes Incl./Excl. Incl. for colloids and gas generation Other impacts Excl. N72 Natural Ecological Development Excl.	No
2.3.07.00	3.07. MECHANICAL PROCESSES				
2.3.07.01	Erosion	- Mechanical weathering (N41) - Denudation - Subsidence - Aeolian or fluvial erosion (N43, N44) - Mass wasting (erosion)(N45) [see also Subsidence in 1.2.02.01, Periglacial Effects in 1.3.04.01, Glacial Effects in 1.3.05.01, Surface Runoff in 2.3.08.02, and Soil and	Site Specific	N41 Mechanical Weathering Excl. N43 Aeolian Erosion Excl. N44 Fluvial Erosion Excl. N45 Mass Wasting(Erosion) Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		Sediment Transport in 2.3.09.53]			
2.3.07.02	Deposition	- Mechanical or chemical weathering - Aeolian or fluvial deposition (N46, N47) - Lacustrine deposition (N48) - Mass wasting (i.e., landslides)(N49)	Site Specific	N41 Mechanical Weathering Excl. N42 Chemical Weathering Excl. N46 Aeolian Deposition Excl. N47 Fluvial Deposition Excl. N48 Lacustrine Deposition Excl. N49 Mass Wasting (Deposition) Excl.	No
2.3.07.03	Animal Intrusion into Repository	- Burrowing animals can affect structure of surface sediments (N70)	Site Specific	N70 Animals Excl. Refers to impact on surface sediments rather than burrowing into the repository itself	No
2.3.08.00	3.08. HYDROLOGIC PROCESSES				
2.3.08.01	Precipitation	- Spatial and temporal distribution [see also Climate Change in 1.3.01.01] [contributes to Infiltration in 2.3.08.03]	Included for impact on recharge of the groundwater system	N59 Precipitation Incl.	No
2.3.08.02	Surface Runoff and Evapotranspiration **Priority 1.58 out of 8 (generic)**	- Runoff, impoundments, flooding, increased recharge - Evaporation - Condensation - Transpiration (root uptake) [see also Climate Change in 1.3.01.01, Erosion in 2.3.07.01] [contributes to Infiltration in 2.3.08.03]	Included for impact on recharge of the groundwater system	N51 Stream and River Flow Excl. N52 Surface Water Bodies Excl. N55 Infiltration Incl. N56 Changes in Groundwater Recharge & Discharge Incl. N57 Lake Formation Excl. N58 River Flooding Excl. N59 Precipitation (Rainfall) Incl. N60 Temperature Incl. N66 Coastal Erosion Excl. N67 Marine Sediment Transport and Deposition Excl.	No
2.3.08.03	Infiltration and Recharge **Priority 1.58 out of 8**	- Spatial and temporal distribution - Effect on hydraulic gradient - Effect on water table	Included for impact on recharge of the groundwater system	N53 Groundwater Discharge Incl. N54 Groundwater Recharge Incl. N55 Infiltration Incl. N56 Changes in Groundwater	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
	(generic)	changes [see also Topography in 2.3.01.01, Surficial Soil Type in 2.3.02.01] [contributes to Effects of Recharge in 2.2.08.03]		Recharge & Discharge Incl. N57 Lake Formation Excl. N58 River Flooding Excl. N59 Precipitation (Rainfall) Incl.	
2.3.09.00	3.09. CHEMICAL PROCESSES - CHEMISTRY				
2.3.09.01	Chemical Characteristics of Soil and Surface Water	- Altered recharge chemistry (natural) - Altered recharge chemistry (anthropogenic – e.g., acid rain) - Chemical weathering (N42) [contributes to Chemical Evolution of Groundwater in 2.2.09.04]	Evaluate	N42 Chemical Weathering Excl. N54 Groundwater Recharge Incl. N55 Infiltration Incl. N56 Changes in Groundwater Recharge & Discharge Incl. N59 Precipitation (Rainfall) Incl. N60 Temperature Incl. H46 Altered Soil or Surface Water Chemistry by Human Activities Incl.	No
2.3.09.02	Radionuclide Speciation and Solubility in Biosphere	- Dissolved concentration limits	Included		No
2.3.09.03	Radionuclide Alteration in Biosphere	- Altered physical and chemical properties - Isotopic dilution	Evaluate with reference biosphere parameters, if possible		Partially
2.3.09.50	3.09. CHEMICAL PROCESSES - TRANSPORT				
2.3.09.51	Atmospheric Transport Through Biosphere **Priority 0.73 out of 8 (generic)**	- Radionuclide transport in air, gas, vapor, particulates, aerosols - Processes include: wind, plowing, degassing, precipitation	Excluded by biosphere reference case	W89 Transport of Radioactive Gases Excl. W90 Advection Incl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.3.09.52	Surface Water Transport Through Biosphere **Priority 0.85 out of 8 (generic)**	- Radionuclide transport and mixing in surface water - Processes include: lake mixing, river flow, spring discharge, overland flow, irrigation, aeration, sedimentation, dilution [see also Surface Water in 2.3.04.01]	Excluded by biosphere reference case	N51 Stream and River Flow Excl. N52 Surface Water Bodies Excl. N57 Lake Formation Excl. N58 River Flooding Excl. N59 Precipitation (Rainfall) Incl. N66 Coastal Erosion Excl. N67 Marine Sediment Transport and Deposition Excl.	No
2.3.09.53	Soil and Sediment Transport Through Biosphere **Priority 0.85 out of 8 (generic)**	- Radionuclide transport in or on soil and sediments - Processes include: fluvial (runoff, river flow), aeolian (wind), saltation, glaciation, bioturbation (animals) [see also Erosion in 2.3.07.01, Deposition in 2.3.07.02]	Excluded by biosphere reference case	N43 Aeolian Erosion Excl. N44 Fluvial Erosion Excl. N45 Mass Wasting(Erosion) Excl. N51 Stream and River Flow Excl. N52 Surface Water Bodies Excl. N46 Aeolian Deposition Excl. N47 Fluvial Deposition Excl. N48 Lacustrine Deposition Excl. N49 Mass Wasting (Deposition) Excl. N70 Animals Excl. Refers to impact on surface sediment rather than burrowing into the repository itself	No
2.3.09.54	Radionuclide Accumulation in Soils **Priority 0.85 out of 8 (generic)**	- Leaching/evaporation from discharge (well, groundwater upwelling) - Deposition from atmosphere or water (irrigation, runoff)	Excluded by biosphere reference case	N46 Aeolian Deposition Excl. N47 Fluvial Deposition Excl. N48 Lacustrine Deposition Excl. N49 Mass Wasting (Deposition) Excl.	No
2.3.09.55	Recycling of Accumulated Radionuclides from Soils to Groundwater **Priority 0.73 out of 8 (generic)**	[see also Radionuclide Release in 2.2.09.65]	Excluded by biosphere reference case		No
2.3.10.00	3.10. BIOLOGICAL PROCESSES				

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
2.3.10.01	Microbial Activity in Biosphere	- Effect on biosphere characteristics - Effect on transport through biosphere	Excluded by biosphere reference case	N71 Microbes Incl./Excl. Incl. for colloids and gas generation other impacts Excl. W87 Microbial Transport Incl. for geosphere	No
2.3.11.00	3.11. THERMAL PROCESSES				
2.3.11.01	Effects of Repository Heat on Biosphere		Excluded	N28 Thermal Effects on Groundwater Flow Excl. W29 Thermal Effects on Material Properties Excl. W30 Thermally Induced Stress Changes Excl.	No
2.4.00.00	4. HUMAN BEHAVIOR				
2.4.01.00	4.01. HUMAN CHARACTERISTICS				
2.4.01.01	Human Characteristics	- Physiology - Metabolism - Adults, children [contributes to Radiological Toxicity in 3.3.06.02]	Included by biosphere reference case		No
2.4.01.02	Human Evolution	- Changing human characteristics - Sensitization to radiation - Changing lifestyle	Likely Excluded by regulation		No
2.4.04.00	4.04. LIFESTYLE				
2.4.04.01	Human Lifestyle	- Diet and fluid intake (food, water, tobacco/drugs, etc.) - Dwellings - Household activities - Leisure activities [see also Land and Water	Included by biosphere reference case		Partially

Table A-1. (continued).

UFD FEP Number	**Description**	**Associated Processes**	**Screening Recommendation for a Generic Salt Site**	**Status & Crosswalk for WIPP**	**Status GDS Model**
		Use in 2.4.08.01] [contributes to Ingestion in 3.3.04.01, Inhalation in 3.3.04.02, External Exposure in 3.3.04.03]			
2.4.08.00	4.08. LAND AND WATER USE				
2.4.08.01	Land and Water Use	- Agricultural (irrigation, plowing, fertilization, crop storage, greenhouses, hydroponics) - Farms and Fisheries (feed, water, soil) - Urban / Industrial (development, energy production, earthworks, population density) - Natural / Wild (grasslands, forests, bush, surface water)	Site Specific	H43 Reservoirs Excl. H44 Irrigation Excl. H45 Lake Usage Excl. H50 Coastal Water Use Excl. H51 Sea Water Use Excl. H52 Estuarine Water Use Excl. H53 Arable Farming Excl. H54 Ranching Excl. H55 Fish Farming Excl.	No
2.4.08.02	Evolution of Land and Water Use	- New practices (agricultural, farming, fisheries) - Technological developments - Social developments (new/expanded communities)	Site Specific	H1 Oil and Gas Exploration Incl. H2 Potash Exploration Incl. H3 Water Resources Exploration Excl. H4 Oil and Gas Exploration Incl. H5 Groundwater Exploitation Excl. H6 Archaeological Investigations Excl. H7 Geothermal Excl. H8 Other Resources Incl. H9 Enhanced Oil and Gas RecoveryIncl. H10 Liquid Waste Disposal Excl. H11 Hydrocarbon Storage Excl. H12 Deliberate Drilling Intrusion Excl. H13 Conventional Underground Potash Mining Incl. H14 Mining for Other Resources Excl. H15 Tunneling Excl. H16 Construction of Underground Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
				Facilities H17 Archaeological Excavations Excl. H18 Deliberate Mining Intrusion Excl. H40 Land Use Changes Excl. H41 Surface Disruptions Incl. H42 Damming of Streams or Rivers Excl. H56 Demographic Change and Urban Development Excl.	
3.0.00.00	3. RADIONUCLIDE / CONTAMINANT FACTORS (BIOSPHERE)				
3.1.00.00	1. CONTAMINANT CHARACTERISTICS				
3.2.00.00	2. RELEASE / MIGRATION FACTORS				
3.3.00.00	3. EXPOSURE FACTORS				
3.3.01.00	3.01. RADIONUCLIDE / CONTAMINANT CONCENTRATIONS				
3.3.01.01	Radionuclides in Biosphere Media	- Soil - Surface Water - Air - Plant Uptake - Animal (Livestock, Fish) Uptake - Bioaccumulation [contributions from Radionuclide Release from Geologic Units in 2.2.09.65, Transport Through Biosphere in 2.3.09.51/52/53/54/55]	Included using the biosphere model for the salt disposal reference case.	W101 Plant Uptake Excl. W102 Animal Uptake Excl. W103 Accumulation in Soils Excl. H50 Coastal Water Use Excl. H51 Sea Water Use Excl. H52 Estuarine Water Use Excl.	No
3.3.01.02	Radionuclides in Food Products	- Diet and fluid sources (location, degree of	Excluded by biosphere reference case	W101 Plant Uptake Excl. W102 Animal Uptake Excl.	Partially

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
		contamination, dilution with uncontaminated sources) - Foodstuff and fluid processing and preparation (water filtration, cooking techniques) [see also Land and Water Use in 2.4.08.01, Radionuclides in Biosphere Media in 3.3.01.01]			
3.3.01.03	Radionuclides in Non-Food Products	- Dwellings (location, building materials and sources, fuel sources) - Household products (clothing and sources, furniture and sources, tobacco, pets) - Biosphere media [see also Land and Water Use in 2.4.08.01, Radionuclides in Biosphere Media in 3.3.01.01]	Excluded by biosphere reference case	W103 Accumulation in Soils Excl.	No
3.3.04.00	3.04. EXPOSURE MODES				
3.3.04.01	Ingestion **Priority 0.54 out of 8 (generic)**	- Food products - Soil, surface water	Included	W104 Ingestion Excl. W108 Injection Excl.	Partially
3.3.04.02	Inhalation **Priority 0.54 out of 8 (generic)**	- Gases and vapors - Suspended particulates (dust, smoke, pollen)	Excluded by biosphere reference case	W105 Inhalation Excl.	No
3.3.04.03	External Exposure **Priority 0.54 out of 8 (generic)**	- Non-Food products - Soil, surface water	Excluded by biosphere reference case	W106 Irradiation Excl. W107 Dermal Sorption Excl.	No

Table A-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Status & Crosswalk for WIPP	Status GDS Model
3.3.06.00	3.06. TOXICITY / EFFECTS				
3.3.06.01	Radiation Doses	- Exposure rates (ingestion, inhalation, external exposure) - Dose conversion factors - Gases and vapors - Suspended particulates (dust, smoke, pollen)	Included		Partially
3.3.06.02	Radiological Toxicity and Effects	- Human health effects from radiation doses	Included		No
3.3.06.03	Non-Radiological Toxicity and Effects	- Human health effects from non-radiological toxicity	Likely excluded by regulation		No

Appendix B:
RECOMMENDED APPROACHES TO SCREENING FEPs IDENTIFIED AS “EVALUATE” OR “LIKELY EXCLUDED”

The FEPs identified in Table A-1 as “Evaluate” or “Likely Excluded” require a screening argument to justify their inclusion or exclusion for a TSPA model for a generic salt site. Table B-1 provides a recommended approach to screen these FEPs, based on either a quantitative analysis or a qualitative reasoned argument. Table B-1 does not consider the FEPs identified as “Included” or “Excluded,” since these screening decisions are felt to be more justifiable based on the expert judgment of the authors. However, reasoned arguments that justify the “Included” or “Excluded” categorization will need to be provided at some stage in the development of the safety framework/case prior to licensing. Also, some quantitative analyses may be appropriate to justify the “Included” and “Excluded” categorizations, as discussed in Section 3.4.

For those FEPs that have been identified as requiring a quantitative analysis, Table B-1 identifies a preliminary set of sensitivity analyses that could be performed to make a screening decision. There are a total of eleven screening analyses for the EBS domain and three analyses for the geosphere, based on the major physical-chemical processes represented by the associated FEPs, i.e, either radiological (R), thermal (T), mechanical (M), hydrologic (H), transport (Tr), chemical (C), or biological (B) processes. Many of the identified sensitivity analyses involve multiple physical-chemical processes and may therefore require a coupled process model for the screening calculation. More detail about the identified sensitivity analyses is provided in Section 3.3, Table 3-4, of this report.

For those FEPs that have been identified as requiring a reasoned argument, Table B-1 provides a preliminary outline of such an argument, if it can be expressed succinctly.

Table B-1. Physical-Chemical Processes and Recommended Sensitivity Analyses for Screening FEPs Identified as “Evaluate” and “Likely Excluded.”

(R = Radiological; T = Thermal; M = Mechanical; H = Hydrologic; Tr = Transport; C = Chemical; B = Biological)

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
0.0.00.00	0. ASSESSMENT BASIS										
0.1.02.01	Timescales of Concern		Included								
0.1.03.01	Spatial Domain of Concern		Included								
0.1.09.01	Regulatory Requirements and Exclusions		Included								
0.1.10.01	Model Issues		Included								
0.1.10.02	Data Issues		Included								
1.0.00.00	1. EXTERNAL FACTORS										
1.1.00.00	1. REPOSITORY ISSUES										
1.1.01.01	Open Boreholes		**Evaluate** **Likely Excluded** because salt creep encapsulates and seals openings and EBS components.					✓			
1.1.02.01	Chemical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock		Design-Specific								
1.1.02.02	Mechanical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock		Included for the EDZ								
1.1.02.03	Thermal-Hydrologic Effects from Preclosure Operations - In EBS	- Site flooding - Preclosure ventilation - Accidents and unplanned events	**Evaluate** **Likely Excluded** because ventilation removes waste	Provide a **Reasoned Argument**							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
	- In EDZ - In Host Rock		heat and moisture, and because site flooding and improper operations should be prevented by repository operations.								
1.1.08.01	Deviations from Design and Inadequate Quality Control	- Error in waste emplacement (waste forms, waste packages, waste package support materials) - Error in EBS component emplacement (backfill, seals, liner) - Inadequate excavation / construction (planning, schedule, implementation) - Aborted / incomplete closure of repository - Material and/or component defects - Undetected manufacturing defects in waste packages and other EBS components	**Evaluate** impact of early waste package failures on chemistry of brine in backfill/tunnels and on early radionuclide releases from EBS (see FEP 2.1.03.01, Early Failure of the Waste Package) Excluded for the waste package as a long-term hydrologic barrier because we do not need to take credit for the package as a flow barrier once salt encapsulates the waste. Excluded for other components, assuming the QA Program will install EBS components to design specifications.	See FEP 2.1.03.01, Early Failure of the Waste Package, for details		✓				✓	
1.1.10.01	Control of Repository Site		Included for impact of active and passive controls on the drilling rate for exploratory boreholes for long-term performance								
1.1.13.01	Retrievability		Included for preclosure design Excluded for postclosure period if regulations exclude retrievability from consideration.								
1.2.00.00	2. GEOLOGICAL PROCESSES AND EFFECTS										
1.2.01.00	2.01. LONG-TERM PROCESSES										

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
1.2.01.01	Tectonic Activity – Large Scale	- Uplift - Folding	**Likely Excluded** if site selection identifies sites in relatively stable tectonic settings and salt backfill is used.	Provide a **Reasoned Argument** based on tectonic activity in regions of the US with large salt basins.							
1.2.01.02	Subsidence		**Evaluate** based on generic depth to top of salt and geologic information in the salt disposal reference case. **Likely Excluded** – significant subsidence may be excluded by the site selection process	Provide a **Reasoned Argument** based on geologic information in salt disposal reference case.							
1.2.01.03	Metamorphism	- Structural changes due to natural heating and/or pressure	**Likely Excluded** – significant metamorphism should be excluded by the site selection process, consistent with other international programs	Provide a **Reasoned Argument**							
1.2.01.04	Diagenesis	- Mineral alteration due to natural processes	**Likely Excluded**, consistent with other international programs	Provide a **Reasoned Argument**							
1.2.01.05	Diapirism		Excluded for bedded salt								
1.2.01.06	Large-Scale Dissolution		Shallow dissolution from (say) potash extraction may be Included if mining affects a local aquifer; Dissolution at or near the repository depth should be excluded by the site selection process.								
1.2.03.00	2.03.SEISMIC ACTIVITY										
1.2.03.01	Seismic Activity Impacts EBS and/or EBS Components	- Mechanical damage to EBS (liners, rock bolts and wire mesh, drift reinforcements materials, and EDZ) from ground	**Likely Excluded** by room closure encapsulating EBS components, thereby preventing damage from ground motion and fault	**EBS-1**: Thermal-mechanical Thermal-Mechanical Analysis of Drift Closure to Define Duration of Creep		✓	✓				

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
		motion, rockfall, drift collapse, fault displacement	displacement, and by the use of minimal ground support in a salt repository. Site Specific – highly dependent on repository depth, site stratigraphy, EBS design, and seismic hazard at a site.	Closure; Then add a **reasoned argument** based on EBS-1 analysis results and generic hazard curve(s) for the probability of a major earthquake during the drift closure period.							
1.2.03.02	Seismic Activity Impacts Geosphere - Host Rock - Other Geologic Units	- Altered flow pathways and properties - Altered stress regimes (faults, fractures) - Regional tectonics, regional uplift, and regional subsidence - Changes in fault/fracture properties	**Evaluate** based on generic depth to top of salt and reference case info. **Likely Excluded** – geosphere has withstood seismic events over geologic time periods.	Provide a **reasoned argument** based on the ages of candidate salt basins and their integrity under seismic loading over geologic time scales.							
1.2.03.03	Seismic Activity Impacts Biosphere - Surface Environment - Human Behavior	- Altered surface characteristics - Altered surface transport pathways - Altered recharge - Regional uplift or subsidence	**Likely Excluded** Site Specific – highly dependent on site location relative to faults.	Provide a **reasoned argument** based on the ages of candidate salt basins and their integrity under seismic loading over geologic time scales.							
1.2.04.00	2.04. IGNEOUS ACTIVITY										
1.2.04.01	Igneous Activity Impacts EBS and/or EBS Components	- Mechanical damage to EBS (from igneous intrusion) - Chemical interaction with magmatic volatiles - Transport of radionuclides (in magma, pyroclasts, vents)	**Likely Excluded** – volcanism will likely be excluded by the site selection process; drift closure is expected to restore the underground facility to *in situ* condition in a few hundred years, eliminating the excavations as preferential pathways for magma to reach the waste packages. Site Specific – highly dependent on repository depth, site stratigraphy, volcanic	Provide a **reasoned argument** if information on the frequency and magnitude of igneous activity is available for major salt basins.							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			hazard, and site location relative to active vents and previous volcanic activity.								
1.2.04.02	Igneous Activity Impacts Geosphere - Host Rock - Other Geologic Units	- Altered flow pathways and properties - Altered stress regimes (faults, fractures) - Igneous intrusions - Altered thermal and chemical conditions	**Likely Excluded** – volcanism will likely be excluded by the site selection process	Provide a **reasoned argument** if information on the frequency and magnitude of igneous activity is available for major salt basins.							
1.2.04.03	Igneous Activity Impacts Biosphere - Surface Environment - Human Behavior	- Altered surface characteristics - Altered surface transport pathways - Altered recharge - Ashfall and ash redistribution	**Likely Excluded** – volcanism will likely be excluded by the site selection process Site Specific – highly dependent on site location relative to active vents, previous volcanic activity, and local wind patterns (for ash redistribution)	Provide a **reasoned argument** if information on the frequency and magnitude of igneous activity is available for major salt basins.							
1.3.00.00	3. CLIMATIC PROCESSES AND EFFECTS										
1.3.01.01	Climate Change - Natural - Anthropogenic		Included – impact of climate change on recharge of groundwater system is likely to be important for transport in the geosphere. Excluded – Anthropogenic sources								
1.3.04.01	Periglacial Effects	- Permafrost - Seasonal freeze/thaw	**Evaluate** based on generic depth to top of salt and geologic information in salt disposal reference case. Site Specific – highly dependent on site location.	Provide a **reasoned argument**							
1.3.05.01	Glacial and Ice Sheet Effects	- Glaciation - Isostatic depression - Melt water	**Evaluate** based on generic depth to top of salt and reference case info. Site Specific – highly dependent on site location.	Provide a **reasoned argument**							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
1.4.00.00	4. FUTURE HUMAN ACTIONS										
1.4.01.01	Human Influences on Climate - Intentional - Accidental		Included through FEP 1.3.01.01, Climate Change								
1.4.02.01	Human Intrusion - Deliberate - Inadvertent		Included – inadvertent borehole intrusions for resource exploration are the main release pathway for the WIPP site; Likely Included for solution mining if potash deposits exist close to the repository.								
1.4.11.01	Explosions and Crashes from Human Activities		Excluded								
1.5.00.00	5. OTHER										
1.5.01.01	Meteorite Impact		Excluded								
1.5.01.02	Extraterrestrial Events		Excluded								
1.5.03.01	Earth Planetary Changes		Excluded								
2.0.00.00	2. DISPOSAL SYSTEM FACTORS										
2.1.00.00	1. WASTES AND ENGINEERED FEATURES										
2.1.01.00	1.01. INVENTORY										
2.1.01.01	Waste Inventory - Radionuclides - Non-Radionuclides		Included – characteristic of the waste form								
2.1.01.02	Radioactive Decay and Ingrowth		Included								
2.1.01.03	Heterogeneity of Waste Inventory - Waste Package Scale - Repository Scale		Included								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.01.04	Interactions Between Co-Located Waste		**Evaluate** based on generic inventory and reference case information	Not clear if **calculations** or a **reasoned argument** is needed here.							
2.1.02.00	1.02. WASTE FORM										
2.1.02.01	SNF (Commercial, DOE) Degradation - Alteration / Phase Separation - Dissolution / Leaching Radionuclide Release	Degradation is dependent on: - Composition - Geometry / Structure - Enrichment / Burn-up - Surface Area - Gap and Grain Boundary Fraction - Damaged Area - THC Conditions	**Likely Excluded** for fuel types such as N reactor fuel which degrade much more rapidly than radionuclide dissolution and mass transport.	**EBS-2:** Impact of DSNF Degradation				✓	✓	✓	
				Provide **reasoned argument** to include or exclude DSNF based on EBS-2 analysis results.							
2.1.02.02	HLW (Glass, Ceramic, Metal) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release		Included								
2.1.02.03	Degradation of Organic/Cellulosic Materials in Waste		Excluded – current inventory has no organic materials.								
2.1.02.04	HLW (Glass, Ceramic, Metal) Recrystallization		**Likely Excluded** for borosilicate glass waste. If peak temperature is less than glass transition temperature, the degradation rate of boro-silicate glass is insensitive to the presence of a crystalline phase. **Evaluate** for other HLW forms.	**EBS-3:** Thermal-Chemical Analysis for Long-Term Evolution of HLW Waste Forms		✓				✓	

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.02.05	Pyrophoricity or Flammable Gas from SNF or HLW	[see also Gas Explosions in EBS in 2.1.12.04]	**Evaluate** for DSNF and spent uranium fuels; **Likely Excluded** for other spent fuels and waste forms.	Provide a **reasoned argument** based on spent fuel composition for pyrophoricity and the potential generation of flammable gases.							
2.1.02.06	SNF Cladding Degradation and Failure	- Initial damage - General Corrosion - Microbially Influenced Corrosion - Localized Corrosion - Enhanced Corrosion (silica, fluoride) - Stress Corrosion Cracking - Hydride Cracking - Unzipping - Creep - Internal Pressure - Mechanical Impact	**Likely Excluded** because we do not need to take credit for the cladding as a long-term hydrologic barrier in salt once the salt encapsulates the waste packages and because it will require an extensive effort to define the probability and magnitude of clad failures.	Provide a **reasoned argument** based on data for clad degradation and failure from the current generation of used fuel rods; or Provide **Reasoned Argument** to **Exclude** cladding as a long-term hydrologic barrier (it is conservative to ignore cladding as a hydrologic barrier)							
2.1.03.00	1.03. WASTE CONTAINER										
2.1.03.01	Early Failure of Waste Packages	- Manufacturing defects - Improper sealing - Constructability and fabrication technology	**Evaluate** impact of early waste package failures on chemistry of brine in backfill/tunnels and on early radionuclide releases from EBS; Excluded for the waste package as a long-term hydrologic barrier because we do not need to take credit for the waste package as a flow barrier once salt encapsulates the waste.	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
				EBS-5: Effect of Early Waste Package Failure on RN Releases from EBS and NBS.				✓	✓		

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.03.02	General Corrosion of Waste Packages		Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Included for the presence of corrosion products and for gas generation by anaerobic corrosion. **Evaluate** for impact on water chemistry using corrosion rates and failure rates and gas generation rates for carbon steel overpack.	Prepare a **Reasoned Argument**							
2.1.03.03	Stress Corrosion Cracking (SCC) of Waste Packages		Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. **Evaluate** for impact on water chemistry using corrosion rates and failure rates and gas generation for carbon steel overpack.	Prepare a **Reasoned Argument**							
2.1.03.04	Localized Corrosion of Waste Packages		Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. **Evaluate** for impact on water chemistry using corrosion rates and failure rates and gas generation rates for carbon steel overpack.	Prepare a **Reasoned Argument**							
2.1.03.05	Hydride Cracking of Waste Packages		Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			package once salt encapsulates the waste. Likely Included as waste package is exposed to buildup of H_2 gas pressure from corrosion. Evaluate for impact on water chemistry using corrosion rates and failure rates and gas generation rates for carbon steel overpack.								
2.1.03.06	Microbially Influenced Corrosion (MIC) of Waste Packages	- Viable colonies of halophilic bacteria - EBS environments promoting and sustaining microbial colonies	**Likely Excluded** for gas generation because the inventory does not include any organics to support the indigenous microbes in salt. Evaluate for impact on water chemistry using failure rates and gas generation rates for a carbon steel overpack. Excluded for waste package as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste.	Provide **Reasoned Argument** to **Exclude** WP/overpack as a long-term hydrologic barrier in salt (it is conservative for releases to ignore the waste package as a hydrologic barrier)							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.03.07	Internal Corrosion of Waste Packages Prior to Breach		**Evaluate** for gas generation by anoxic corrosion and for structural response of partly degraded internal components; Excluded as a long-term hydrologic effect because we do not need to take credit for the internals once salt encapsulates the waste. Design Specific – dependent on materials for the internal supports for fuel assemblies and HLW canisters.	Provide **Reasoned Argument** to **Exclude** WP internal corrosion prior to WP breach based on available water amount and water consumption by anoxic corrosion inside WP.							
2.1.03.08	Evolution of Flow Pathways in Waste Packages		Excluded because we do not need to take credit for the detailed flow pathways once salt encapsulates the waste								
2.1.04.00	1.04. BUFFER / BACKFILL										
2.1.04.01	Evolution and Degradation of Backfill		Included for crushed salt								
2.1.05.00	1.05. SEALS										
2.1.05.01	Degradation of Seals		Included. The presence of asphalt, concrete, and crushed salt seal components in the shafts should reduce flow through the shafts to negligible volumes, but the shafts remain a pathway for releases in the undisturbed scenario and therefore are retained in the generic salt								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			disposal system model.								
2.1.06.00	1.06. OTHER EBS MATERIALS										
2.1.06.01	Degradation of Liner / Rock Reinforcement Materials in EBS	- Alteration / Degradation / Cracking - Corrosion - Erosion / Dissolution / Spalling [see also Mechanical Impact in 2.1.07.08, Thermal-Mechanical Effects in 2.1.11.09, Chemical Interaction in 2.1.09.07]	**Likely excluded** for gas generation due to anaerobic corrosion because of minimal mass of iron-based alloys in the ground support system and liners. Excluded by the use of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case.	Provide a **reasoned argument**, based on the use of minimal ground support, without a liner, in the emplacement drifts, per the salt disposal reference case.							
2.1.07.00	1.07. MECHANICAL PROCESSES										
2.1.07.01	Rockfall		Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific. Excluded on low probability for the effects from seismic ground motion or from a volcanic event.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.07.02	Drift Collapse		Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific Excluded on low probability for the effects from seismic ground motion or from a volcanic event.								
2.1.07.03	Mechanical Effects of Backfill		Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is highly site specific Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.								
2.1.07.04	Mechanical Impact on Backfill		Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.07.05	Mechanical Impact on Waste Packages	- Rockfall / Drift collapse - Waste package movement - Lithostatic pressure from salt creep - Hydrostatic pressure as repository is fully saturated - Internal gas pressure from anoxic corrosion of internal components - Swelling corrosion products	**Evaluate** for impact of waste package failures on water chemistry and radionuclide mobilization Included for quasi-static creep closure and corrosion of overpack; Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.	**EBS-6:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste Form Provide **Reasoned Argument** to **Exclude** WP/overpack as a long-term hydrologic barrier in salt (it is conservative for releases to ignore the flow pathways in the waste package as a hydrologic barrier)		✓		✓	✓	✓	
2.1.07.06	Mechanical Impact on SNF Waste Form	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep	**Evaluate** for impact on water chemistry and radionuclide mobilization; Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion.	**EBS-6:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste Form Provide **Reasoned Argument** to **Exclude** WP/overpack as a long-term hydrologic barrier in salt (it is		✓		✓	✓	✓	

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			Excluded on low probability/low consequence for the effects from a volcanic event.	conservative for releases to ignore the flow pathways in the waste package as a hydrologic barrier)							
2.1.07.07	Mechanical Impact on HLW Waste Form	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep	**Evaluate** for impact on water chemistry and radionuclide mobilization; Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Site Specific – direct fault displacement from a seismic event. Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.	**EBS-6:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste Form Provide **Reasoned Argument** to **Exclude** WP/overpack as a long-term hydrologic barrier in salt (it is conservative for releases to ignore the flow pathways in the waste package as a hydrologic barrier)		✓		✓	✓	✓	
2.1.07.08	Mechanical Impact on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Materials		Included for quasi-static creep closure and corrosion of components; Excluded for EBS components as long-term hydrologic barriers because we do not need to take credit for the EBS components once salt encapsulates the waste; Excluded by the use of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case; Excluded ground motion from a seismic event; Site Specific – direct fault								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			displacement from a seismic event. Excluded on low probability for the effects of seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.								
2.1.07.09	Mechanical Effects at EBS Component Interfaces		Included for quasi-static creep closure; Site Specific – direct fault displacement from a seismic event is site specific. Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence for the effects from a volcanic event.								
2.1.07.10	Mechanical Degradation of EBS		Included for quasi-static creep closure & corrosion of EBS components; Excluded for EBS components as long-term hydrologic barriers because we do not need to take credit for the EBS components once salt encapsulates the waste; Excluded for ground support because it is expected to be minimal and will be removed before closure; Site Specific – direct fault displacement from a seismic event.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			Excluded on low probability for the effects from seismic ground motion. Excluded on low probability/low consequence the the effects from a volcanic event.								
2.1.08.00	1.08. HYDROLOGIC PROCESSES										
2.1.08.01	Flow Through the EBS		Included								
2.1.08.02	Flow In and Through Waste Packages		Included								
2.1.08.03	Flow in Backfill		Included								
2.1.08.04	Flow Through Seals		Included. The presence of asphalt, concrete, and crushed salt seal components in the shafts, per the salt disposal reference case, should reduce flow through the shafts to negligible amounts, but the shafts remain a pathway for releases in the undisturbed scenario and therefore are retained in the generic salt disposal system model.								
2.1.08.05	Flow Through Liner / Rock Reinforcement Materials in EBS	- Saturated / Unsaturated flow - Flow pathways along rock bolts - Fracture / Matrix flow	**Likely Excluded** for the long-term effects on flow through the liner/rock reinforcement because of minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case, and because salt will encapsulate any ground support that is used.	Provide a **reasoned argument** that flow through these EBS components are not important, based on the use of minimal ground support in the emplacement drifts, per the salt disposal reference case.							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.08.06	Alteration and Evolution of EBS Flow Pathways		Included for the effects of quasi-static creep closure, degradation and consolidation of EBS components, plugging of flow pathways, formation of corrosion products, and water ponding. Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event; Site Specific – direct fault displacement from a seismic event.								
2.1.08.07	Condensation Forms in Repository - On Tunnel Roof / Walls - On EBS Components	- Heat transfer (spatial and temporal distribution of temperature and relative humidity) - Dripping - Moisture movement - Brine formation by salt deliquescence - Release and migration of inclusion brine	**Evaluate**	**EBS-7:** Thermal-Hydrologic-Chemical Analysis for Brine and Water Vapor Movement in Emplacement Drifts		✓		✓		✓	
2.1.08.08	Capillary Effects in EBS		Included for the impact of wicking on the availability of brine to support corrosion of iron-based alloys in the overpack.								
2.1.08.09	Influx/Seepage Into the EBS		Included. This FEP has High importance to radionuclide transport, EBS component corrosion, and waste form degradation, per (Freeze et al., 2011, Appendix B, page B-125)								
2.1.09.00	1.09. CHEMICAL PROCESSES -										

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
	CHEMISTRY										
2.1.09.01	Chemistry of Water Flowing into the Repository		Included								
2.1.09.02	Chemical Characteristics of Water in Waste Packages		Included after breach of waste package								
2.1.09.03	Chemical Characteristics of Water in Backfill	- Water composition (radionuclides, dissolved species, …) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or waste package) - Brine originated from inclusion brine - Brine originated from intrusion groundwater - Brine formed from salt deliquescence - Effect of gas formed from WP anoxic corrosion - Effect of anoxic condition - Evolution of water chemistry / interaction with backfill	**Evaluate** – determine if water chemistry in backfill is affected by H_2 gas generated by the anoxic corrosion process or by the presence of corrosion products.	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.09.04	Chemical Characteristics of Water in Tunnels	- Water composition (radionuclides, dissolved species, …) - Initial void chemistry (air/gas) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from near-field host rock) - Initial chemistry (from construction / emplacement) - Evolution of water chemistry / interaction with seals, liner/rock reinforcement materials, waste package support materials	**Evaluate** – determine if water chemistry in backfill is affected by H_2 gas generated by the anoxic corrosion process. Chemical interactions with corrosion products included in FEP 2.1.09.05.	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
2.1.09.05	Chemical Interaction of Water with Corrosion Products - In Waste Packages - In Backfill - In Tunnels		Included, particularly for the potential for gas generation and contact with corrosion products to change chemistry of groundwater.								
2.1.09.06	Chemical Interaction of Water with Backfill - On Waste Packages - In Backfill - In Tunnels Possibly included in 2.1.09.02, 2.1.09.03, and 2.1.09.04		Included Chemical interactions with corrosion products are included in FEP 2.1.09.05.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.09.07	Chemical Interaction of Water with Liner / Rock Reinforcement and Cementitious Materials in EBS - In Backfill - In Tunnels	- Liner composition and evolution (Portland cement, special concrete formulations for salt, metal, ...) - Rock reinforcement material composition and evolution (grout, rock bolts, mesh, ...) - Composition and evolution of other cementitious materials, including any special formulations for salt - Evolution of water chemistry in backfill, and in tunnels	**Likely Excluded** because there will be minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case, and because the presence of salt and salt backfill in the tunnels will not change the chemical interactions with the waste packages and backfill.	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
2.1.09.08	Chemical Interaction of Water with Other EBS Components - In Waste Packages - In Tunnels	- Seals composition and evolution - Waste Package Support composition and evolution (Portland cement, special concrete formulations for salt, metal, ...) - Other EBS components (other metals (copper), ...) - Evolution of water chemistry in backfill, and in tunnels	**Evaluate**	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
2.1.09.09	Chemical Effects at EBS Component Interfaces	- Component-to-component contact (chemical reactions) - Consolidation of EBS components - Barrier degradation at interfaces	**Evaluate**	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
2.1.09.10	Chemical Effects of Waste-Rock Contact		Included								
2.1.09.11	Electrochemical Effects in EBS	- Enhanced metal corrosion	**Likely Excluded**, but reevaluate once a more detailed design is available.	Prepare a **Reasoned Argument** based on the EBS materials							

Table B-1. (continued).

UFD FEP Number	**Description**	**Associated Processes**	**Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A**	**Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”**	**Relevant Process Calculations**						
					R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.1.09.12	Chemical Effects of Drift Collapse		Excluded Salt will encapsulate the EBS, so the presence of salt and salt backfill in the tunnels after drift collapse will not change the chemistry of the groundwater.								
2.1.09.13	Radionuclide Speciation and Solubility in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Included								
2.1.09.50	1.09. CHEMICAL PROCESSES - TRANSPORT										
2.1.09.51	Advection of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Included								
2.1.09.52	Diffusion of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Included								
2.1.09.53	Sorption of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Surface complexation properties - Flow pathways and velocity - Brine Saturation - Sorption on EBS degradation products - Sorption in anoxic condition - Effect of brine ionic strength	**Evaluate** for sorption onto corrosion products – difficult to prove that contaminated water comes into contact with the mass of corrosion products; Excluded for other EBS elements – conservative to ignore sorption.	**EBS-8:** Analysis for RN Sorption on Corrosion Products and Salt in Emplacement Drift		✓		✓		✓	

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.1.09.54	Complexation in EBS		Excluded because there are no organic materials in the inventory								
2.1.09.55	Formation of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Included								
2.1.09.56	Stability of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Chemical stability of attachment (dependent on water chemistry) - Mechanical stability of colloid (dependent on colloid size, gravitational settling)	**Evaluate** stability of different types of colloids in high ionic strength brines.	**EBS-9:** Chemical Analysis for Colloid Stability in EBS				✓		✓	
2.1.09.57	Advection of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56								
2.1.09.58	Diffusion of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Saturation - Colloid concentration	**Evaluate** **Likely Excluded** - diffusion of colloids is likely to be a slow process relative to diffusion of dissolved species.	**EBS-10:** Analysis for Diffusivity of Colloids in EBS				✓	✓		
2.1.09.59	Sorption onto Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56								
2.1.09.60	Sorption of Colloids at Air-Water Interface in EBS		Excluded within the repository excavations because it is conservative to ignore sorption.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.09.61	Filtration of Colloids in EBS		Excluded within the repository excavations because it is conservative to ignore filtration.								
2.1.09.62	Radionuclide Transport Through Liners and Seals		Included for Seals. The shafts remain a viable pathway for releases in the undisturbed scenario and therefore are retained in the generic salt disposal system model. Excluded for Liners because liners will not be installed in emplacement drifts, per the salt disposal reference case.								
2.1.09.63	Radionuclide Release from the EBS - Dissolved - Colloidal - Gas Phase		Included								
2.1.10.00	1.10. BIOLOGICAL PROCESSES										
2.1.10.01	Microbial Activity in EBS - Natural - Anthropogenic	- Effects on corrosion - Formation of complexants - Formation of microbial colloids - Formation of biofilms - Gas generation by biodegradation - Biomass production - Bioaccumulation	**Likely Excluded** based on no organic material in the inventory. .	Provide a **Reasoned Argument** that microbial colonies will be limited to extreme halophiles by the lack of organic matter in the waste							
2.1.11.00	1.11. THERMAL PROCESSES										
2.1.11.01	Heat Generation in EBS		Included - heat generation from radioactive decay is a major thermal source in the system.								
2.1.11.02	Exothermic Reactions in EBS	- Oxidation of SNF - Hydration of concrete	**Evaluate** – may be Excluded if these reactions are minor heat sources compared to	Provide a **Reasoned Argument** that exothermic reactions							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			radioactive decay in the waste	will not produce significant heat output compared to radionuclide decay.							
2.1.11.03	Effects of Backfill on EBS Thermal Environment		Included – thermal conductivity of backfill is important for heat transfer from the waste to the host rock.								
2.1.11.04	Effects of Drift Collapse on EBS Thermal Environment		Included – room closure and consolidation of crushed salt backfill are important for heat transfer to the host rock.								
2.1.11.05	Effects of Influx (Seepage) on Thermal Environment	- Temperature and relative humidity (spatial and temporal distribution)	**Evaluate** – may be Excluded if low influx rates may have minor impact on thermal environment.	Provide a **Reasoned Argument**, supported by EBS-12: Hydrologic Inflow Rates if necessary.							
2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components		Included for the effects of quasi-static creep closure of the host rock and heat generated by the waste. Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. **Evaluate** impact of waste form degradation on water chemistry and radionuclide mobilization.	**EBS-6:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste Form		✓	✓	✓		✓	
2.1.11.07	Thermal-Mechanical Effects on Waste Packages	- Mechanical loads from room closure due to salt creep - Thermal sensitization / phase changes - Cracking - Thermal expansion / stress / creep	Included for the effects of quasi-static creep closure of the host rock and heat generated by the waste. Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take	**EBS-6:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package After Waste Package Failure and Severe Mechanical Damage of Waste Package and Waste		✓	✓	✓		✓	

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			credit for the package once salt encapsulates the waste. **Evaluate** impact of waste package failure on water chemistry and radionuclide mobilization.	Form							
2.1.11.08	Thermal-Mechanical Effects on Backfill		Included for the effects of quasi-static creep closure of the host rock and the resulting mechanical loading on and consolidation of crushed salt backfill.								
2.1.11.09	Thermal-Mechanical Effects on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Structure		Excluded for Liners and Rock Reinforcement because ground support will be minimized in the design of a salt repository, per the salt disposal reference case, and because salt will encapsulate any ground support that is used;. Excluded for waste package support structure because the packages are placed directly on the floor of the emplacement drift, with no support structure, per the salt disposal reference case; Included for Seals								
2.1.11.10	Thermal Effects on Flow in EBS	- Altered influx/seepage - Altered saturation / relative humidity (dry-out, resaturation) - Condensation	**Evaluate**	**EBS-7:** Thermal-Hydrologic-Chemical Analysis for Brine and Water Vapor Movement in Emplacement Drifts		✓		✓		✓	
2.1.11.11	Thermally-Driven Flow (Convection) in EBS	- Convection	**Evaluate** **Likely Excluded** after consolidation of crushed salt	**EBS-12:** Thermal-Hydrologic Analysis of Brine Flow in EBS		✓		✓			

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.1.11.12	Thermally-Driven Buoyant Flow / Heat Pipes in EBS	- Vapor flow	**Evaluate** **Likely Excluded** after consolidation of crushed salt	**EBS-11:** Thermal-Hydrologic Analysis of Brine Flow in EBS		✓		✓			
2.1.11.13	Thermal Effects on Chemistry and Microbial Activity in EBS		**Evaluate** **Evaluate** temperature dependence of solubility limits; Excluded for thermal effects on microbial activity because there is no organic material in the inventory.	**EBS-4:** Thermal-Chemical Analysis for Brine Chemistry in Waste Package, Backfill, and Tunnels Including Waste Package Failure		✓		✓		✓	
2.1.11.14	Thermal Effects on Transport in EBS	- Thermal diffusion (Soret effect) - Thermal osmosis	**Evaluate**	Provide a **Reasoned Argument**							
2.1.12.00	1.12. GAS SOURCES AND EFFECTS										
2.1.12.01	Gas Generation in EBS		Included for gas generation from anoxic corrosion; Excluded for gas generation from microbial degradation of organic materials.								
2.1.12.02	Effects of Gas on Flow Through the EBS		Included.								
2.1.12.03	Gas Transport in EBS	- Gas phase transport - Gas phase release from EBS - Corrosion gas buildup	**Evaluate** **Likely Excluded**	Provide a **Reasoned Argument**							
2.1.12.04	Gas Explosions in EBS	[see also Flammable Gas from Waste in 2.1.02.05]	**Evaluate** **Likely Excluded**	Provide a **Reasoned Argument**							
2.1.13.00	1.13. RADIATION EFFECTS										
2.1.13.01	Radiolysis - In Waste Package - In Backfill - In Tunnel	- Gas generation - Altered water chemistry	**Evaluate**	Provide a **Reasoned Argument**							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.1.13.02	Radiation Damage to EBS Components - Waste Form - Waste Package - Backfill - Other EBS Components	- Enhanced waste form degradation - Enhanced waste package degradation - Enhanced backfill degradation - Enhanced degradation of other EBS components (liner/rock reinforcement materials, seals, waste support structure)	**Evaluate** – we are unaware of any journal articles on radiation damage to crushed salt backfill	Provide a **Reasoned Argument**							
2.1.13.03	Radiological Mutation of Microbes		**Likely Excluded**	Provide a **Reasoned Argument**							
2.1.14.00	1.14. NUCLEAR CRITICALITY										
2.1.14.01	Criticality In-Package	- Formation of critical configuration - Accumulation of fissile materials to a critical mass	**Evaluate** **Likely Excluded** per other international programs	Provide a **Reasoned Argument**							
2.1.14.02	Criticality in EBS or Near-Field	- Formation of critical configuration - Accumulation of fissile materials to a critical mass	**Evaluate** **Likely Excluded** per other international programs	Provide a **Reasoned Argument**							
2.2.00.00	2. GEOLOGICAL ENVIRONMENT										
2.2.01.00	2.01. EXCAVATION DISTURBED ZONE										
2.2.01.01	Evolution of EDZ		Included								
2.2.02.00	2.02. HOST ROCK										
2.2.02.01	Stratigraphy and Properties of Host Rock		Included								
2.2.03.00	2.03. OTHER GEOLOGIC UNITS										
2.2.03.01	Stratigraphy and Properties of Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.2.05.00	2.05. FLOW AND TRANSPORT PATHWAYS										
2.2.05.01	Fractures - Host Rock - Other Geologic Units		Excluded for intact halite because creep closure will heal fractures								
2.2.05.02	Faults - Host Rock - Other Geologic Units		Excluded for intact halite because creep closure will heal fractures								
2.2.05.03	Alteration and Evolution of Geosphere Flow Pathways - Host Rock - Other Geologic Units		Included because gas generation from corrosion can alter flow pathways by fracturing Anhydrite interbeds or clay seals; Included because potash mining beneath an aquifer can alter the transmissivity of the aquifer; Excluded for the halite beds of the host rock because creep of halite is expected to eliminate discontinuities in the halite and return it to an intact state.								
2.2.07.00	2.07. MECHANICAL PROCESSES										
2.2.07.01	Mechanical Effects on Host Rock	- From subsidence due to repository-related excavations - From salt creep - From healing of the EDZ - From dissolution of halite - From solution mining of other strata - From fracturing caused by gas pressurization - Chemical precipitation / dissolution	Included for healing of the EDZ Site Specific for other processes, but likely excluded for other geologic units								
2.2.07.02	Mechanical Effects on Other Geologic Units	- From subsidence due to repository-related excavations	Included because potash mining beneath an aquifer can alter the transmissivity of								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
		- From solution mining of other strata - Chemical precipitation / dissolution - Stress regimes	the aquifer.								
2.2.08.00	2.08. HYDROLOGIC PROCESSES										
2.2.08.01	Flow Through the Host Rock		Included								
2.2.08.02	Flow Through the Other Geologic Units - Confining units - Aquifers - Salt		Included								
2.2.08.03	Effects of Recharge on Geosphere Flow - Host Rock - Other Geologic Units		Included								
2.2.08.04	Effects of Repository Excavation on Flow Through the Host Rock		Included								
2.2.08.05	Condensation Forms in Host Rock	- Condensation cap - Shedding - Deliquescence of mixed salts	**Evaluate**	**GEO-1:** Thermal-Hydrologic-Chemical Analysis for Brine Flow and Water Vapor Movement in Host Rock and Geosphere.		✓		✓		✓	
2.2.08.06	Flow Through EDZ		Included								
2.2.08.07	Mineralogic Dehydration	- Dehydration reactions release water and may lead to volume changes	**Evaluate**	Prepare a **Reasoned Argument,** based on the considerations of potential quantity of dehydrated water, relative to brine flows in the host rock, for a range of thermal conditions in the host rock. Salt creep should be considered to evaluate effect of							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
				volume changes associated with mineral dehydration.							
2.2.08.08	Groundwater Discharge to Biosphere Boundary		Included								
2.2.08.09	Groundwater Discharge to Well		Included Likely included per international programs								
2.2.09.00	2.09.CHEMICAL PROCESSES - CHEMISTRY										
2.2.09.01	Chemical Characteristics of Groundwater in Host Rock		Included								
2.2.09.02	Chemical Characteristics of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included								
2.2.09.03	Chemical Interactions and Evolution of Groundwater in Host Rock		Included **Evaluate** for reaction kinetics	Prepare a **Reasoned Argument,** based on the effect of related reaction kinetics on the groundwater chemistry in the host rock with respect to the time step scales used in the repository performance assessment.		✓		✓	✓	✓	
2.2.09.04	Chemical Interactions and Evolution of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.2.09.05	Radionuclide Speciation and Solubility in Host Rock		Included								
2.2.09.06	Radionuclide Speciation and Solubility in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included								
2.2.09.50	2.09. CHEMICAL PROCESSES - TRANSPORT										
2.2.09.51	Advection of Dissolved Radionuclides in Host Rock		Included								
2.2.09.52	Advection of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included.								
2.2.09.53	Diffusion/Dispersion of Dissolved Radionuclides in Host Rock		Included								
2.2.09.54	Diffusion/Dispersion of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included								
2.2.09.55	Sorption of Dissolved Radionuclides in Host Rock		Included								
2.2.09.56	Sorption of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Included								
2.2.09.57	Complexation in Host	- Presence of organic	**Likely Excluded.** There are no	Prepare a **Reasoned**							

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
	Rock	complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants	organics in the inventory but the presence of carbonate and/or sulfate in the anhydrite interbeds may promote complexation with actinides.	**Argument,** based on the lack of organic matter in the inventory.							
2.2.09.58	Complexation in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Presence of organic complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants	**Evaluate** Site Specific, but likely excluded for deep aquifers	Prepare a **Reasoned Argument**, based on the lack of organic matter in the inventory.							
2.2.09.59	Colloidal Transport in Host Rock		Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56								
2.2.09.60	Colloidal Transport in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Likely Included if colloids are formed within the repository and/or host rock.								
2.2.09.61	Radionuclide Transport Through EDZ		Included								
2.2.09.62	Dilution of Radionuclides in Groundwater - Host Rock - Other Geologic Units		Included								
2.2.09.63	Dilution of Radionuclides with Stable Isotopes - Host Rock - Other Geologic Units	- Mixing with stable and/or naturally occurring isotopes of the same element	**Evaluate** Site Specific and dependent on "stylized" scenario used to define dose	Prepare a **Reasoned Argument**							
2.2.09.64	Radionuclide Release from Host Rock - Dissolved - Colloidal - Gas Phase		Included								
2.2.09.65	Radionuclide Release from Other Geologic Units - Dissolved	- Spatial and temporal distribution of releases to the Biosphere (due to varying flow pathways and	Included								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	**T**	**M**	**H**	**Tr**	**C**	**B**
	- Colloidal - Gas Phase	velocities, varying transport properties)									
2.2.10.00	2.10. BIOLOGICAL PROCESSES										
2.2.10.01	Microbial Activity in Host Rock	- Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation - - Nutrients availability and replenishment	**Likely excluded**	Prepare a **Reasoned Argument**							
2.2.10.02	Microbial Activity in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation - Nutrients availability and replenishment	**Likely excluded**	Prepare a **Reasoned Argument**							
2.2.11.00	2.11. THERMAL PROCESSES										
2.2.11.01	Thermal Effects on Flow in Geosphere - Repository-Induced - Natural Geothermal	-	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.								
2.2.11.02	Thermally-Driven Flow (Convection) in Geosphere	-	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.								
2.2.11.03	Thermally-Driven Buoyant Flow / Heat Pipes in Geosphere	-	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.2.11.04	Thermal Effects on Chemistry and Microbial Activity in Geosphere	- Mineral precipitation / dissolution - Altered solubility	**Evaluate**	**GEO-1:** Thermal-Hydrologic-Chemical Analysis for Brine Flow and Water Vapor Movement in Host Rock and Geosphere And provide a **Reasoned Argument** to exclude thermal effects on microbial activity in geosphere		✓		✓		✓	
2.2.11.05	Thermal Effects on Transport in Geosphere	- Thermal diffusion (Soret effect) - Thermal osmosis	**Evaluate**	Provide a **Reasoned Argument**							
2.2.11.06	Thermal-Mechanical Effects on Geosphere	- Thermal expansion / compression - Altered properties of fractures, faults, rock matrix	**Evaluate**	Provide a **Reasoned Argument**							
2.2.11.07	Thermal-Chemical Alteration of Geosphere	- Mineral precipitation / dissolution - Altered properties of fractures, faults, rock matrix - Alteration of minerals / volume changes	**Evaluate**	**GEO-1:** Thermal-Hydrologic-Chemical Analysis for Brine Flow and Water Vapor Movement in Host Rock and Geosphere		✓		✓		✓	
2.2.12.00	2.12. GAS SOURCES AND EFFECTS										
2.2.12.01	Gas Generation in Geosphere	- Degassing (clathrates, deep gases) - Microbial degradation of organics - Vaporization of water	**Likely Excluded** during site screening and characterization	Provide a **Reasoned Argument**							
2.2.12.02	Effects of Gas on Flow Through the Geosphere		Included								
2.2.12.03	Gas Transport in Geosphere	- Gas phase transport - Gas phase release from Geosphere	**Likely excluded**	**GEO-2:** Gas Phase Transport of Radionuclides in the Geosphere				✓	✓		
2.2.14.00	2.14. NUCLEAR										

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
	CRITICALITY										
2.2.14.01	Criticality in Far-Field	- Formation of critical configuration - Accumulation of critical mass of fissile materials	**Likely Excluded** per other international programs and has low importance for salt, per (Freeze et al., 2010, page B-346)	Provide a **Reasoned Argument**							
2.3.00.00	3. SURFACE ENVIRONMENT										
2.3.01.00	3.01. SURFACE CHARACTERISTICS										
2.3.01.01	Topography and Surface Morphology		Site Specific								
2.3.02.01	Surficial Soil Type		Included								
2.3.04.01	Surface Water		Included								
2.3.05.01	Biosphere Characteristics		Included - Climate, Soils, Flora, Fauna, and Microbes impact on surface characteristics that may affect dose in the biosphere.								
2.3.07.00	3.07. MECHANICAL PROCESSES										
2.3.07.01	Erosion		Site Specific								
2.3.07.02	Deposition		Site Specific								
2.3.07.03	Animal Intrusion into Repository		Site Specific								
2.3.08.00	3.08. HYDROLOGIC PROCESSES										
2.3.08.01	Precipitation		Included for impact on recharge of the groundwater system								
2.3.08.02	Surface Runoff and Evapotranspiration		Included for impact on recharge of the groundwater system								
2.3.08.03	Infiltration and Recharge		Included for impact on recharge of the groundwater system								
2.3.09.00	3.09. CHEMICAL										

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as “Evaluate” or “Likely Excluded” in Appendix A	Recommended Approach for Screening FEPs Identified as “Evaluate” or “Likely Excluded”	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
	PROCESSES - CHEMISTRY										
2.3.09.01	Chemical Characteristics of Soil and Surface Water	- Altered recharge chemistry (natural) - Altered recharge chemistry (anthropogenic – e.g., acid rain) - Chemical weathering (N42)	**Evaluate**	Provide a **Reasoned Argument**							
2.3.09.02	Radionuclide Speciation and Solubility in Biosphere		Included								
2.3.09.03	Radionuclide Alteration in Biosphere	- Altered physical and chemical properties - Isotopic dilution	**Evaluate** with reference biosphere parameters, if possible	**GEO-3**: Chemical-Hydrologic Analysis for Radionuclide Transport in Surface and Biosphere				✓	✓	✓	
2.3.09.50	3.09. CHEMICAL PROCESSES - TRANSPORT										
2.3.09.51	Atmospheric Transport Through Biosphere		Excluded by biosphere reference case								
2.3.09.52	Surface Water Transport Through Biosphere		Excluded by biosphere reference case								
2.3.09.53	Soil and Sediment Transport Through Biosphere		Excluded by biosphere reference case								
2.3.09.54	Radionuclide Accumulation in Soils		Excluded by biosphere reference case								
2.3.09.55	Recycling of Accumulated Radionuclides from Soils to Groundwater		Excluded by biosphere reference case								
2.3.10.00	3.10. BIOLOGICAL PROCESSES										
2.3.10.01	Microbial Activity in Biosphere		Excluded by biosphere reference case								
2.3.11.00	3.11. THERMAL PROCESSES										
2.3.11.01	Effects of Repository Heat on Biosphere		Excluded								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
2.4.00.00	4. HUMAN BEHAVIOR										
2.4.01.00	4.01. HUMAN CHARACTERISTICS										
2.4.04.01	Human Lifestyle	- Physiology - Metabolism - Adults, children	Included by biosphere reference case								
2.4.01.02	Human Evolution	- Changing human characteristics - Sensitization to radiation - Changing lifestyle	**Likely Excluded** by regulation	**Reasoned Argument,** possibly excluded by regulation							
2.4.04.00	4.04. LIFESTYLE										
2.4.04.01	Human Lifestyle	- Diet and fluid intake (food, water, tobacco/drugs, etc.) - Dwellings - Household activities - Leisure activities	Included by biosphere reference case								
2.4.08.00	4.08. LAND AND WATER USE										
2.4.08.01	Land and Water Use		Site Specific								
2.4.08.02	Evolution of Land and Water Use		Site Specific								
3.0.00.00	3. RADIONUCLIDE / CONTAMINANT FACTORS (BIOSPHERE)										
3.1.00.00	1. CONTAMINANT CHARACTERISTICS										
3.2.00.00	2. RELEASE / MIGRATION FACTORS										
3.3.00.00	3. EXPOSURE FACTORS										
3.3.01.00	3.01. RADIONUCLIDE / CONTAMINANT CONCENTRATIONS										
3.3.01.01	Radionuclides in Biosphere Media		Included using the biosphere model for the salt disposal								

Table B-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site, Emphasizing FEPs Identified as "Evaluate" or "Likely Excluded" in Appendix A	Recommended Approach for Screening FEPs Identified as "Evaluate" or "Likely Excluded"	Relevant Process Calculations						
					R	T	M	H	Tr	C	B
			reference case.								
3.3.01.02	Radionuclides in Food Products		Excluded by biosphere reference case								
3.3.01.03	Radionuclides in Non-Food Products		Excluded by biosphere reference case								
3.3.04.00	3.04. EXPOSURE MODES										
3.3.04.01	Ingestion		Included								
3.3.04.02	Inhalation		Excluded by biosphere reference case								
3.3.04.03	External Exposure		Excluded by biosphere reference case								
3.3.06.00	3.06. TOXICITY / EFFECTS										
3.3.06.01	Radiation Doses		Included								
3.3.06.02	Radiological Toxicity and Effects		Included								
3.3.06.03	Non-Radiological Toxicity and Effects	- Human health effects from non-radiological toxicity	**Likely excluded** by regulation	**Reasoned Argument,** possibly excluded by regulation							

Appendix C:
CLASSIFICATION OF INCLUDED OR LIKELY INCLUDED FEPs BY MAJOR PHYSICAL-CHEMICAL PROCESS

The FEPs identified in Table A-1 as “Included” or “Likely Included” encompass a range of physical-chemical processes that are expected to be included in the SRD TSPA Model. Table C-1 identifies the key physical processes that are relevant to each of the “Likely Included” or “Included” FEPS, subdivided according to radiological (R), thermal (T), mechanical (M), hydrologic (H), transport (Tr), chemical (C), and/or biological (B) processes. This classification by process can be augmented by an additional FEPs classification by physical domain or repository component (see Figure 3.3) to further guide the development of the SRD TSPA Model. This is the approach outlined in Section 3.5 of this report.

Table C-1. Classification of Included or Likely Included FEPs for a Generic Salt Repository TSPA Model Based on Physical-Chemical Processes.
(R = Radiological; T = Thermal; M = Mechanical; H = Hydrologic; Tr = Transport; C = Chemical; B = Biological)

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
0.0.00.00	0. ASSESSMENT BASIS									
0.1.02.01	Timescales of Concern		Included							
0.1.03.01	Spatial Domain of Concern		Included							
0.1.09.01	Regulatory Requirements and Exclusions		Included							
0.1.10.01	Model Issues	- Conceptual model - Mathematical implementation - Geometry and dimensionality - Process coupling - Boundary and initial conditions	Included							
0.1.10.02	Data Issues	- Parameterization and values - Correlations - Uncertainty	Included							
1.0.00.00	1. EXTERNAL FACTORS									
1.1.00.00	1. REPOSITORY ISSUES									
1.1.01.01	Open Boreholes		Evaluate Likely Excluded because salt creep encapsulates and seals openings and EBS components.							
1.1.02.01	Chemical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock		Design-Specific							
1.1.02.02	Mechanical Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock	- Creation of excavation-disturbed zone (EDZ) - Stress relief - Boring and blasting effects - Rock reinforcement effects (drillholes) - Accidents and unplanned events - Enhanced flow pathways	Included for the EDZ Inclusion of the EDZ and local ground support may be important to flow pathways for long-term performance			✓				

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
1.1.02.03	Thermal-Hydrologic Effects from Preclosure Operations - In EBS - In EDZ - In Host Rock		Evaluate Likely Excluded because ventilation removes waste heat and moisture, and because site flooding and improper operations should be prevented by repository operations.							
1.1.08.01	Deviations from Design and Inadequate Quality Control		Evaluate impact of early waste package failures on chemistry of brine Excluded for the waste package as a long-term hydrologic barrier Excluded for other components, assuming the QA Program will install EBS components to design specifications.							
1.1.10.01	Control of Repository Site	- Active controls (controlled area) - Retention of records - Passive controls (markers)	Included for impact of active and passive controls on the drilling rate for exploratory boreholes for long-term performance							
1.1.13.01	Retrievability		Included for preclosure design Excluded for postclosure period if regulations exclude retrievability from consideration.							
1.2.00.00	2. GEOLOGICAL PROCESSES AND EFFECTS									
1.2.01.00	2.01. LONG-TERM PROCESSES									
1.2.01.01	Tectonic Activity – Large Scale		Likely Excluded if site selection identifies sites in relatively stable tectonic settings and salt backfill is used.							
1.2.01.02	Subsidence		Likely Excluded – significant subsidence may be excluded by the site selection process.							
1.2.01.03	Metamorphism		Likely Excluded – significant							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
			metamorphism should be excluded by the site selection process.							
1.2.01.04	Diagenesis		Likely Excluded, consistent with other international programs							
1.2.01.05	Diapirism		Excluded for bedded salt (salt creep is included in many EBS-related FEPs)							
1.2.01.06	Large-Scale Dissolution		Dissolution at or near the repository depth should be excluded by the site selection process.							
1.2.03.00	2.03.SEISMIC ACTIVITY									
1.2.03.01	Seismic Activity Impacts EBS and/or EBS Components		Likely Excluded by room closure encapsulating EBS components							
1.2.03.02	Seismic Activity Impacts Geosphere - Host Rock - Other Geologic Units		Likely Excluded – geosphere has withstood seismic events over geologic time periods.							
1.2.03.03	Seismic Activity Impacts Biosphere - Surface Environment - Human Behavior		Likely Excluded							
1.2.04.00	2.04. IGNEOUS ACTIVITY									
1.2.04.01	Igneous Activity Impacts EBS and/or EBS Components		Likely Excluded –drift closure is expected to restore the underground facility to *in situ* condition, eliminating the excavations as preferential pathways for magma to reach the waste packages.							
1.2.04.02	Igneous Activity Impacts Geosphere - Host Rock - Other Geologic Units		Likely Excluded – volcanism will likely be excluded by the site selection process							
1.2.04.03	Igneous Activity Impacts Biosphere - Surface Environment		Likely Excluded – volcanism will likely be excluded by the site selection process							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
	- Human Behavior									
1.3.00.00	3. CLIMATIC PROCESSES AND EFFECTS									
1.3.01.01	Climate Change - Natural - Anthropogenic	- Variations in precipitation and temperature - Long-term global (sea level, …) - Short-term regional and local - Seasonal local (flooding, storms, …)	Included – impact of climate change on recharge of groundwater system is likely to be important for transport in the geosphere. Excluded - Anthropogenic sources				✓			
1.3.04.01	Periglacial Effects **Priority 1.85 out of 8 (generic)**		Evaluate based on generic depth to top of salt and geologic information in salt disposal reference case.							
1.3.05.01	Glacial and Ice Sheet Effects **Priority 1.85 out of 8 (generic)**		Evaluate based on generic depth to top of salt and reference case info.							
1.4.00.00	4. FUTURE HUMAN ACTIONS									
1.4.01.01	Human Influences on Climate - Intentional - Accidental		Excluded. YMP arguments can be used.							
1.4.02.01	Human Intrusion - Deliberate - Inadvertent	- Drilling (resource exploration, …) - Mining / tunneling - Unintrusive site investigation (airborne, surface-based, …)	Included – inadvertent borehole intrusions for resource exploration are the main release pathway for the WIPP site; Likely Included for solution mining			✓	✓			
1.4.11.01	Explosions and Crashes from Human Activities		Excluded on low consequence or low probability							
1.5.00.00	5. OTHER									
1.5.01.01	Meteorite Impact		Excluded on low probability							
1.5.01.02	Extraterrestrial Events		Excluded on low probability							
1.5.03.01	Earth Planetary Changes		Excluded on low consequence							
2.0.00.00	2. DISPOSAL SYSTEM FACTORS									
2.1.00.00	1. WASTES AND ENGINEERED									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
	FEATURES									
2.1.01.00	1.01. INVENTORY									
2.1.01.01	Waste Inventory - Radionuclides - Non-Radionuclides	- Composition - Enrichment / Burn-up	Included – characteristic of the waste form							
2.1.01.02	Radioactive Decay and Ingrowth	- Decay chains - Decay products - Neutron activation	Included					✓		
2.1.01.03	Heterogeneity of Waste Inventory - Waste Package Scale - Repository Scale	- Composition - Enrichment / Burn-up - Damaged Area	Included							
2.1.01.04	Interactions Between Co-Located Waste		Evaluate based on generic inventory and reference case information							
2.1.02.00	1.02. WASTE FORM									
2.1.02.01	SNF (Commercial, DOE) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release	Degradation is dependent on: - Composition - Geometry / Structure - Enrichment / Burn-up - Surface Area - Gap and Grain Boundary Fraction - Damaged Area - THC Conditions	Included for most fuel types		✓				✓	
2.1.02.02	HLW (Glass, Ceramic, Metal) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release	Degradation is dependent on: - Composition - Geometry / Structure - Surface Area - Damaged / Cracked Area - Mechanical Impact - THC Conditions	Included		✓				✓	
2.1.02.03	Degradation of Organic/Cellulosic Materials in Waste		Excluded – current inventory has no organic materials.							
2.1.02.04	HLW (Glass, Ceramic, Metal) Recrystallization		Likely Excluded for borosilicate glass waste. Evaluate for other HLW forms.							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.1.02.05	Pyrophoricity or Flammable Gas from SNF or HLW		Likely Excluded for other spent fuels and waste forms; Evaluate for DSNF and spent uranium fuels;							
2.1.02.06	SNF Cladding Degradation and Failure		Likely Excluded because we do not need to take credit for the cladding as a long-term hydrologic barrier in salt.							
2.1.03.00	1.03. WASTE CONTAINER									
2.1.03.01	Early Failure of Waste Packages	- Manufacturing defects - Improper sealing - Constructability and fabrication technology	Excluded for the waste package as a long-term hydrologic barrier.							
2.1.03.02	General Corrosion of Waste Packages	- Dry-air oxidation in anoxic condition - Humid-air corrosion in anoxic condition - Aqueous phase corrosion in anoxic condition - Passive film formation and stability - Chemistry of brine contacting WP - Salt deliquescence - Hydrogen gas buildup - Effect of close contact with salt undergoing creep deformation	Included for the presence of corrosion products and for gas generation by anoxic corrosion; Excluded for waste package as a long-term hydrologic barrier.		✓		✓		✓	
2.1.03.03	Stress Corrosion Cracking (SCC) of Waste Packages	- Residual stress distribution in WP from fabrication - Stress development and distribution in contact with salt undergoing creep deformation - Crack initiation, growth and propagation - Stress distribution and evolution around advancing cracks	Excluded for waste package as a long-term hydrologic barrier. Evaluate for impact on water chemistry using corrosion rates and failure rates and gas generation rates for carbon steel overpack.							
2.1.03.04	Localized Corrosion of Waste Packages	- Pitting - Crevice corrosion - Salt deliquescence - Effect of close contact with salt undergoing creep deformation	Excluded for waste package as a long-term hydrologic barrier. Evaluate for impact on water chemistry using corrosion							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
			rates and failure rates and gas generation rates for carbon steel overpack.							
2.1.03.05	Hydride Cracking of Waste Packages	- Hydrogen diffusion through metal matrix - Crack initiation and growth in metal hydride phases	Likely Included as waste package is exposed to buildup of H_2 gas pressure from corrosion; Excluded for waste package as a long-term hydrologic barrier.		✓				✓	
2.1.03.06	Microbially Influenced Corrosion (MIC) of Waste Packages		Excluded for waste package as a long-term hydrologic barrier. Likely Excluded for gas generation because the inventory does not include any organics.							
2.1.03.07	Internal Corrosion of Waste Packages Prior to Breach		Excluded as a long-term hydrologic effect. Evaluate for long-term gas generation by anoxic corrosion; Evaluate for impact on water chemistry using failure rates and gas generation							
2.1.03.08	Evolution of Flow Pathways in Waste Packages **Priority 1.96 out of 8 (generic)**		Excluded because we do not need to take credit for the detailed flow pathways once salt encapsulates the waste							
2.1.04.00	1.04. BUFFER / BACKFILL									
2.1.04.01	Evolution and Degradation of Backfill	- Alteration - Thermal expansion / Degradation - Swelling / Compaction - Erosion / Dissolution - Evolution of backfill flow pathways	Included for crushed salt		✓	✓				
2.1.05.00	1.05. SEALS									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.05.01	Degradation of Seals **This is better stated as "Evolution of Seal Components"**	- Alteration / Degradation / Cracking - Erosion / Dissolution - Asphalt seals: degradation as function of temperature and degassing	Included.		✓	✓			✓	
2.1.06.00	1.06. OTHER EBS MATERIALS									
2.1.06.01	Degradation of Liner / Rock Reinforcement Materials in EBS		Excluded by the use of minimal ground support and no liner in the emplacement drifts.							
2.1.07.00	1.07. MECHANICAL PROCESSES									
2.1.07.01	Rockfall	- Dynamic loading (block size and velocity)	Included for quasi-static creep closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects of a volcanic event.		✓	✓				
2.1.07.02	Drift Collapse	- Alteration of seepage - Alteration of EBS flow pathways - Alteration of EBS thermal environment	Included for quasi-static creep closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects of a volcanic event.		✓	✓				
2.1.07.03	Mechanical Effects of Backfill	- Crushed salt backfill should consolidate during room closure process - Static and dynamic loading on EBS structures - Restricts displacement of EBS components during ground motion and fault displacement - Protection of ~~other~~ EBS components from rockfall / drift collapse caused by ground motion and fault displacement	Included for quasi-static creep closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects of a volcanic event.		✓	✓				

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.07.04	Mechanical Impact on Backfill	- Rockfall / Drift collapse - Hydrostatic/lithostatic pressure of drift walls on any backfill present - Internal gas pressure - H2 gas buildup from anoxic corrosion of WP and other EBS components	Included for quasi-static creep closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.			✓				
2.1.07.05	Mechanical Impact on Waste Packages	- Rockfall / Drift collapse - Waste package movement - Lithostatic pressure from salt creep - Hydrostatic pressure as repository is fully saturated - Internal gas pressure from anoxic corrosion of internal components - Swelling corrosion products	Included for quasi-static creep closure and corrosion of overpack; Evaluate for impact of waste package failures on water chemistry and radionuclide mobilization; Excluded for waste package integrity as a long-term hydrologic barrier; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.			✓				
2.1.07.06	Mechanical Impact on SNF Waste Form	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep	Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Evaluate for impact on water chemistry and radionuclide mobilization; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.			✓				
2.1.07.07	Mechanical Impact on HLW Waste Form	- Drift collapse - Swelling corrosion products - Breakage following WP structural collapse under lithostatic pressure from salt creep	Included for quasi-static creep closure, and corrosion of overpack and corrosion products; Evaluate for impact on water chemistry and radionuclide mobilization; Excluded for the effects of ground motion from a			✓				

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
			seismic event; Excluded for the effects from a volcanic event.							
2.1.07.08	Mechanical Impact on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Materials	- Rockfall / Drift collapse - Movement - Hydrostatic pressure as repository is fully saturated - Lithostatic pressure from salt creep - Swelling corrosion products	Included for quasi-static creep closure and corrosion of components; Excluded for EBS components as long-term hydrologic barriers; Excluded by the use of minimal ground support and no liner in the emplacement drifts; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event;			✓				
2.1.07.09	Mechanical Effects at EBS Component Interfaces	- Component-to-component contact (static or dynamic) - Volume changes - Thermal expansion	Included for quasi-static creep closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.			✓				
2.1.07.10	Mechanical Degradation of EBS	- Roof buckling and floor heave - Fault displacement - *Initial damage from excavation / construction* - *Consolidation of EBS components* - *Degradation* of waste package support structure and drift support structures - Alteration of EBS flow pathways	Included for quasi-static creep closure & corrosion of EBS components; Excluded for EBS components as long-term hydrologic barriers; Excluded for ground support because it is expected to be minimal and will be removed before closure; Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.		✓	✓	✓			
2.1.08.00	1.08. HYDROLOGIC PROCESSES									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.08.01	Flow Through the EBS	- Saturated / Unsaturated flow - Preferential flow pathways - Density effects on flow - Initial hydrologic conditions - Flow pathways out of and into EBS	Included				✓			
	Flow In and Through Waste Packages		Included				✓			
2.1.08.03	Flow in Backfill	- Saturated / Unsaturated flow - Fracture / Matrix flow – fracture flow does not occur in crushed salt - Preferential flow pathway as crushed salt backfill undergoes consolidation	Included				✓			
2.1.08.04	Flow Through Seals	- Saturated / Unsaturated flow - Fracture / Matrix flow - Gas transport (in UFD, Appendix A list) - Preferential flows in non-salt portion - Brine formation by salt deliquescence	Included				✓			
2.1.08.05	Flow Through Liner / Rock Reinforcement Materials in EBS	- Saturated / Unsaturated flow - Flow pathways along rock bolts - Fracture / Matrix flow	Likely Excluded for the long-term effects on flow through the liner/rock reinforcement because of minimal ground support and no liner in the emplacement drifts.							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.08.06	Alteration and Evolution of EBS Flow Pathways	- Drift collapse - Degradation/consolidation of EBS components - Plugging of flow pathways - Formation of corrosion products - Water ponding - Brine formation by salt deliquescence	Included for the effects of quasi-static creep closure, degradation and consolidation of EBS components, plugging of flow pathways, formation of corrosion products, and water ponding. Excluded for the effects of ground motion from a seismic event; Excluded for the effects from a volcanic event.			✓	✓		✓	
2.1.08.07	Condensation Forms in Repository - On Tunnel Roof / Walls - On EBS Components	- Heat transfer (spatial and temporal distribution of temperature and relative humidity) - Dripping - Moisture movement - Brine formation by salt deliquescence - Release and migration of inclusion brine	Likely Included because these processes may be important for dryout and rewetting during the thermal pulse.		✓		✓		✓	
2.1.08.08	Capillary Effects in EBS	- Wicking - Capillary barrier - Osmotic binding	Included				✓			
2.1.08.09	Influx/Seepage Into the EBS	- Water influx rate (spatial and temporal distribution)	Included				✓			
2.1.09.00	1.09. CHEMICAL PROCESSES - CHEMISTRY									
2.1.09.01	Chemistry of Water Flowing into the Repository	- Chemistry of influent water (spatial and temporal distribution) - Thermal effect - Chemistry of brine originated from inclusion brine - Chemistry of brine originated from intrusion groundwater - Chemistry of brine formed from salt deliquescence - Effect of anoxic condition	Included		✓		✓		✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.09.02	Chemical Characteristics of Water in Waste Packages	- Water composition (radionuclides, dissolved species, …) - Initial void chemistry (air / gas) - Water chemistry (pH, ionic strength, pCO2, pO2.pH2.) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or backfill) - Effect of corrosion of waste canister and internal components - Effect of waste form corrosion - Evolution of water chemistry / interaction with waste packages	Included after breach of waste package		✓				✓	
2.1.09.03	Chemical Characteristics of Water in Backfill		Evaluate – determine if water chemistry in backfill is affected by H$_2$ gas generated by the anoxic corrosion process or by the presence of corrosion products.							
2.1.09.04	Chemical Characteristics of Water in Tunnels		Evaluate – determine if water chemistry in backfill is affected by H$_2$ gas generated by the anoxic corrosion process.							
2.1.09.05	Chemical Interaction of Water with Corrosion Products - In Waste Packages - In Backfill - In Tunnels Possibly included in 2.1.09.02, 2.1.09.03, and 2.1.09.04	- Corrosion product formation and composition (waste form, waste package internals, waste package) - Evolution of water chemistry in waste packages, in backfill, and in tunnels - Effect of water chemistry on corrosion products characteristics	Included		✓				✓	
2.1.09.06	Chemical Interaction of Water with Backfill - On Waste Packages - In Backfill - In Tunnels		Included Chemical interactions with corrosion products are included in FEP 2.1.09.05.		✓				✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
	Possibly included in 2.1.09.02, 2.1.09.03, and 2.1.09.04									
2.1.09.07	Chemical Interaction of Water with Liner / Rock Reinforcement and Cementitious Materials in EBS - In Backfill - In Tunnels		Likely Excluded because there will be minimal ground support and no liner in the emplacement drifts, per the salt disposal reference case, and because the presence of salt and salt backfill in the tunnels will not change the chemical interactions with the waste packages and backfill.							
2.1.09.08	Chemical Interaction of Water with Other EBS Components - In Waste Packages - In Tunnels		Evaluate							
2.1.09.09	Chemical Effects at EBS Component Interfaces		Evaluate							
2.1.09.10	Chemical Effects of Waste-Rock Contact	- Waste-to-host rock contact (chemical reactions) - Component-to-host rock contact (chemical reactions)	Included		✓				✓	
2.1.09.11	Electrochemical Effects in EBS	-	Likely Excluded, but reevaluate once a more detailed design is available.							
2.1.09.12	Chemical Effects of Drift Collapse		Excluded because salt will encapsulate the EBS.							
2.1.09.13	Radionuclide Speciation and Solubility in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Dissolved concentration limits - Limited dissolution due to inclusion in secondary phase - Enhanced dissolution due to alpha recoil - Complexation with organic ligands - Formation of various types of colloids	Included	✓	✓				✓	
2.1.09.50	1.09. CHEMICAL PROCESSES - TRANSPORT									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.09.51	Advection of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Flow pathways and velocity - Advective properties (porosity, tortuosity) - Dispersion - Level of Saturation	Included				✓	✓		
2.1.09.52	Diffusion of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Brine Saturation	Included				✓	✓		
2.1.09.53	Sorption of Dissolved Radionuclides in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Evaluate for sorption onto corrosion products; Excluded for other EBS elements – conservative to ignore sorption.							
2.1.09.54	Complexation in EBS		Excluded because there are no organic materials in the inventory							
2.1.09.55	Formation of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Formation of intrinsic colloids - Formation of pseudo colloids (host rock fragments, waste form fragments, corrosion products, microbes, and humics) - Formation of co-precipitated colloids - Sorption/attachment of radionuclides to colloids (clay, silica, waste form, FeOx, microbes)	Included		✓				✓	✓
2.1.09.56	Stability of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Evaluate stability of different types of colloids in high ionic strength brines.							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.1.09.57	Advection of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Flow pathways and velocity - Advective properties (porosity, tortuosity) - Dispersion - Saturation - Colloid concentration	Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56				✓	✓		
2.1.09.58	Diffusion of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel		Likely Excluded - diffusion of colloids is likely to be a slow process relative to diffusion of dissolved species.							
2.1.09.59	Sorption onto Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- Surface complexation properties - Flow pathways and velocity - Saturation - Colloid concentration	Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56		✓			✓		✓
2.1.09.60	Sorption of Colloids at Air-Water Interface in EBS		Excluded within the repository excavations – conservative to ignore sorption							
2.1.09.61	Filtration of Colloids in EBS		Excluded within the repository excavations because conservative to ignore filtration.							
2.1.09.62	Radionuclide Transport Through Liners and Seals	- Advection - Dispersion - Diffusion - Sorption	Included for Seals; Excluded for Liners.				✓	✓		
2.1.09.63	Radionuclide Release from the EBS - Dissolved - Colloidal - Gas Phase	- Spatial and temporal distribution of releases to the host rock (due to varying flow pathways and velocities, varying component degradation rates, varying transport properties)	Included				✓	✓		
2.1.10.00	1.10. BIOLOGICAL PROCESSES									
2.1.10.01	Microbial Activity in EBS - Natural - Anthropogenic		Likely Excluded based on no organic material in the inventory.							
2.1.11.00	1.11. THERMAL PROCESSES									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.11.01	Heat Generation in EBS	- Radionuclide decay - Heat transfer (spatial and temporal distribution of temperature and relative humidity)	Included		✓					
2.1.11.02	Exothermic Reactions in EBS **Priority 0.99 out of 8 (generic)**		Evaluate – may be Excluded if these reactions are minor heat sources compared to radioactive decay in the waste							
2.1.11.03	Effects of Backfill on EBS Thermal Environment	- Thermal conductivity of backfill - Thermal blanket - Condensation	Included – thermal conductivity of backfill is important for heat transfer from the waste to the host rock.		✓	✓				
2.1.11.04	Effects of Drift Collapse on EBS Thermal Environment	- Thermal conductivity of rubble - Thermal blanket - Condensation	Included – room closure and consolidation of crushed salt backfill are important for heat transfer to the host rock.		✓	✓				
2.1.11.05	Effects of Influx (Seepage) on Thermal Environment		Evaluate – may be Excluded if low influx rates may have minor impact on thermal environment.							
2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components	- Mechanical loads from room closure due to salt creep - Alteration - Cracking - Thermal expansion / stress	Included for the effects of quasi-static creep closure of the host rock and heat generated by the waste. Excluded for waste package integrity as a long-term hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Evaluate impact of waste form degradation on water chemistry and radionuclide mobilization.		✓	✓				
2.1.11.07	Thermal-Mechanical Effects on Waste Packages	- Mechanical loads from room closure due to salt creep - Thermal sensitization / phase changes - Cracking - Thermal expansion / stress /	Included for the effects of quasi-static creep closure of the host rock and heat generated by the waste. Excluded for waste package integrity as a long-term		✓	✓				

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		creep	hydrologic barrier because we do not need to take credit for the package once salt encapsulates the waste. Evaluate impact of waste package failure on water chemistry and radionuclide mobilization.							
2.1.11.08	Thermal-Mechanical Effects on Backfill	- Mechanical loads from room closure due to salt creep - Consolidation of backfill - Alteration - Cracking - Thermal expansion / stress - Movement of WP due to the negative buoyance	Included for the effects of quasi-static creep closure of the host rock		✓	✓				
2.1.11.09	Thermal-Mechanical Effects on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Structure	- Mechanical loads from room closure due to salt creep - Alteration - Cracking - Thermal expansion / stress	Included for Seals; Excluded for Liners and Rock Reinforcement; Excluded for waste package support structure because the packages are placed directly on the floor.		✓	✓				
2.1.11.10	Thermal Effects on Flow in EBS	- Altered influx/seepage - Altered saturation / relative humidity (dry-out, resaturation) - Condensation	Likely Included to capture dryout and rewetting of the EBS		✓		✓			
2.1.11.11	Thermally-Driven Flow (Convection) in EBS		Likely Excluded after consolidation of crushed salt							
2.1.11.12	Thermally-Driven Buoyant Flow / Heat Pipes in EBS		Likely Excluded after consolidation of crushed salt							
2.1.11.13	Thermal Effects on Chemistry and Microbial Activity in EBS		Evaluate temperature dependence of solubility limits; Excluded for thermal effects on microbial activity because there is no organic material in the inventory.							
2.1.11.14	Thermal Effects on Transport in EBS		Evaluate							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.12.00	1.12. GAS SOURCES AND EFFECTS									
2.1.12.01	Gas Generation in EBS	- Repository Pressurization - Mechanical Damage to EBS Components - He generation from waste from alpha decay - H_2 generation from anoxic corrosion of waste package and other EBS components - H_2 generation from radiolysis - CO_2, CH_4, and H_2S generation from microbial activity - Vaporization of water - Influence of gas pressure on room closure by salt creep - Influence of gas pressure on advective flows toward and away from the repository	Included for gas generation from anoxic corrosion; Excluded for gas generation from microbial degradation of organic materials.	✓	✓		✓		✓	
2.1.12.02	Effects of Gas on Flow Through the EBS	- Two-phase flow - Gas bubbles - Corrosion gas buildup	Included.				✓			
2.1.12.03	Gas Transport in EBS		Likely Excluded							
2.1.12.04	Gas Explosions in EBS		Likely Excluded							
2.1.13.00	1.13. RADIATION EFFECTS									
2.1.13.01	Radiolysis - In Waste Package - In Backfill - In Tunnel		Evaluate							
2.1.13.02	Radiation Damage to EBS Components - Waste Form - Waste Package - Backfill - Other EBS Components		Evaluate – we are unaware of any journal articles on radiation damage to crushed salt backfill							
2.1.13.03	Radiological Mutation of Microbes		Likely Excluded							
2.1.14.00	1.14. NUCLEAR CRITICALITY									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.1.14.01	Criticality In-Package		Likely Excluded per other international programs							
2.1.14.02	Criticality in EBS or Near-Field		Likely Excluded per other international programs							
2.2.00.00	2. GEOLOGICAL ENVIRONMENT									
2.2.01.00	2.01. EXCAVATION DISTURBED ZONE									
2.2.01.01	Evolution of EDZ	- Lateral extent, heterogeneities - Physical properties - Flow pathways - Chemical characteristics of groundwater in EDZ - Radionuclide speciation and solubility in EDZ - Thermal-mechanical effects, particularly healing of fractures in the EDZ - Thermal-chemical alteration, particularly diffusion of sulfates from the host rock into the disposal rooms (affects gas generation)	Included		✓	✓	✓			
2.2.02.00	2.02. HOST ROCK									
2.2.02.01	Stratigraphy and Properties of Host Rock	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts - Physical properties - Flow pathways	Included							
2.2.03.00	2.03. OTHER GEOLOGIC UNITS									
2.2.03.01	Stratigraphy and Properties of Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts - Physical properties - Flow pathways - Pressurized brine reservoirs - Interbeds	Included							
2.2.05.00	2.05. FLOW AND TRANSPORT PATHWAYS									

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.2.05.01	Fractures - Host Rock - Other Geologic Units	- Rock properties - Hydrologic properties	Included for clay seams and anhydrite interbeds in the host rock; Excluded for intact halite because creep closure will heal fractures							
2.2.05.02	Faults - Host Rock - Other Geologic Units		Excluded for host rock salt							
2.2.05.03	Alteration and Evolution of Geosphere Flow Pathways - Host Rock - Other Geologic Units	- Changes In rock properties - Changes in faults - Changes in fractures - Changes in flow pathways, aquifers, and aquitards, including potential for plugging and dissolution - Changes in saturation - Evolution of properties (porosity, permeability, etc.) in interbeds	Included because gas generation from corrosion can alter flow pathways by fracturing Anhydrite interbeds or clay seals; Included because potash mining beneath an aquifer can alter the transmissivity of the aquifer; Excluded for the halite beds of the host rock because creep of halite is expected to eliminate discontinuities in the halite and return it to an intact state.		✓		✓		✓	
2.2.07.00	2.07. MECHANICAL PROCESSES									
2.2.07.01	Mechanical Effects on Host Rock	- From subsidence due to repository-related excavations - From salt creep - From healing of the EDZ - From dissolution of halite - From solution mining of other strata - From fracturing caused by gas pressurization - Chemical precipitation / dissolution	Included for healing of the EDZ			✓				
2.2.07.02	Mechanical Effects on Other Geologic Units	- From subsidence due to repository-related excavations - From solution mining of other strata - Chemical precipitation / dissolution - Stress regimes	Included because potash mining beneath an aquifer can alter the transmissivity of the aquifer.			✓				

Table C-1. (continued).

UFD FEP Number	**Description**	**Associated Processes**	**Screening Recommendation for a Generic Salt Site**	**Relevant Physical Processes**						
				R	**T**	**M**	**H**	**Tr**	**C**	**B**
2.2.08.00	2.08. HYDROLOGIC PROCESSES									
2.2.08.01	Flow Through the Host Rock	- Saturated flow - Fracture flow / matrix imbibition (probably not applicable to salt) - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways (including flow in interbed) - Density and thermal effects on flow - Flow pathways out of Host Rock	Included				✓			
2.2.08.02	Flow Through the Other Geologic Units - Confining units - Aquifers - Salt	- Saturated flow - Fracture flow / matrix imbibition - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways (including flow in interbed) - Density and thermal effects on flow - Saline or freshwater intrusions - Flow pathways out of Other Geologic Units	Included				✓			
2.2.08.03	Effects of Recharge on Geosphere Flow - Host Rock - Other Geologic Units	- Infiltration rate - Water table rise/decline - Effect of climate change including glaciation	Included				✓			
2.2.08.04	Effects of Repository Excavation on Flow Through the Host Rock	- Saturated flow (flow sink) - Unsaturated flow (capillary diversion, drift shadow) - Influx/Seepage into EBS (film flow, enhanced seepage)	Included			✓	✓			
2.2.08.05	Condensation Forms in Host Rock		Evaluate							
2.2.08.06	Flow Through EDZ	- Saturated / Unsaturated flow - Fracture / Matrix flow	Included			✓	✓			
2.2.08.07	Mineralogic Dehydration **Priority 6.49 out of 8 (salt)**		Evaluate							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.2.08.08	Groundwater Discharge to Biosphere Boundary	- Surface discharge (water table, capillary rise, surface water) - Flow across regulatory boundary - Brine flow from repository preferential pathway (i.e., interbeds) to regional aquifer	Included				✓			
2.2.08.09	Groundwater Discharge to Well	- Human use (drinking water, bathing water, industrial) - Agricultural use (irrigation, animal watering) - Mixing, dispersion and dilution in aquifer - Aquifer characteristics and flow pattern - Well pumping rate - Well location relative to contaminant plume location	Included Likely included per international programs				✓			
2.2.09.00	2.09.CHEMICAL PROCESSES - CHEMISTRY									
2.2.09.01	Chemical Characteristics of Groundwater in Host Rock	- Water composition (radionuclides, dissolved species, …) - Water chemistry (temperature, pH, Eh, ionic strength, pO2 …) - Reduction-oxidation potential - Reaction kinetics - Interaction with EBS - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Effect of gas formed from EBS anoxic corrosion - Effect of anoxic condition	Included		✓				✓	
2.2.09.02	Chemical Characteristics of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Water composition (radionuclides, dissolved species, …) - Water chemistry (temperature, pH, Eh, ionic strength, pO2 …) - Reduction-oxidation potential - Reaction kinetics - Saline or freshwater intrusion - Interaction with other geologic	Included		✓				✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		units - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Effect of gas formed from EBS anoxic corrosion - Effect of anoxic condition								
2.2.09.03	Chemical Interactions and Evolution of Groundwater in Host Rock	- Host rock composition and evolution - Evolution of water chemistry in host rock - Chemical effects on density - Interaction with EBS - Reaction kinetics - Mineral dissolution/precipitation - Redissolution of precipitates after dry-out - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Evolution of gas generation from EBS anoxic corrosion - Effect of anoxic condition	Included for equilibrium chemistry Evaluate reaction kinetics		✓		✓	✓	✓	
2.2.09.04	Chemical Interactions and Evolution of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Host rock composition and evolution - Evolution of water chemistry in host rock - Chemical effects on density - Reaction kinetics - Mineral dissolution/precipitation - Recharge chemistry - Origin of brine (inclusion brine, intrusion groundwater brine, brine formed from salt deliquescence, etc.) - Evolution of gas generation from EBS anoxic corrosion - Effect of anoxic condition	Included		✓		✓	✓	✓	
2.2.09.05	Radionuclide Speciation and Solubility in Host Rock	- Dissolved concentration limits - Water composition - Water chemistry (temperature, pH, Eh, ionic strength,	Included		✓				✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		pO2,pH2 …) - Reduction-oxidation potential								
2.2.09.06	Radionuclide Speciation and Solubility in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Dissolved concentration limits - Water composition - Water chemistry (temperature, pH, Eh, ionic strength, pO2,pH2 …) - Reduction-oxidation potential	Included		✓				✓	
2.2.09.50	2.09. CHEMICAL PROCESSES - TRANSPORT									
2.2.09.51	Advection of Dissolved Radionuclides in Host Rock	- Flow pathways and velocity - Advective properties (porosity, permeability, tortuosity) - Dispersion - Matrix diffusion - Saturation - Brine flow driven by brine density difference	Included				✓	✓		
2.2.09.52	Advection of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Flow pathways and velocity - Advective properties (porosity, permeability, tortuosity) - Dispersion - Matrix diffusion - Saturation - Brine flow driven by brine density difference	Included				✓	✓		
2.2.09.53	Diffusion/Dispersion of Dissolved Radionuclides in Host Rock	- Gradients (concentration, chemical potential) - Diffusive properties (porosity, tortuosity, diffusion coefficients) - Flow pathways and velocity - Saturation	Included				✓	✓		
2.2.09.54	Diffusion/Dispersion of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Gradients (concentration, chemical potential) - Diffusive properties (porosity, tortuosity, diffusion coefficients) - Flow pathways and velocity - Saturation	Included				✓	✓		
2.2.09.55	Sorption of Dissolved Radionuclides in Host Rock	- Surface complexation properties - Flow pathways and velocity - Saturation - Mineralogical composition of	Included				✓		✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		host rock - Brine ionic strength - Brine redox condition - Effect of H2 gas buildup								
2.2.09.56	Sorption of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Surface complexation properties - Flow pathways and velocity - Saturation - Mineralogical composition of host rock - Brine ionic strength - Brine redox condition - Effect of H2 gas buildup	Included				✓		✓	
2.2.09.57	Complexation in Host Rock		Likely Excluded. There are no organics in the inventory.							
2.2.09.58	Complexation in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Evaluate							
2.2.09.59	Colloidal Transport in Host Rock	- Flow pathways and velocity - Saturation - Advection - Dispersion - Diffusion - Sorption - Colloid concentration - Colloid stability	Likely Included if colloids are formed and stable, per FEPs 2.1.09.55 and 2.1.09.56				✓	✓		
2.2.09.60	Colloidal Transport in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Flow pathways and velocity - Saturation - Advection - Dispersion - Diffusion - Sorption - Colloid concentration - Colloid stability	Likely Included if colloids are formed within the repository and/or host rock.				✓	✓		
2.2.09.61	Radionuclide Transport Through EDZ	- Advection - Dispersion - Diffusion	Included				✓	✓	✓	

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		- Sorption								
2.2.09.62	Dilution of Radionuclides in Groundwater - Host Rock - Other Geologic Units	- Mixing with uncontaminated groundwater - Mixing at withdrawal well	Included				✓			
2.2.09.63	Dilution of Radionuclides with Stable Isotopes - Host Rock - Other Geologic Units		Evaluate							
2.2.09.64	Radionuclide Release from Host Rock - Dissolved - Colloidal - Gas Phase	- Spatial and temporal distribution of releases to the Other Geologic Units or to the Biosphere (due to varying flow pathways and velocities, varying transport properties)	Included				✓	✓		
2.2.09.65	Radionuclide Release from Other Geologic Units - Dissolved - Colloidal - Gas Phase	- Spatial and temporal distribution of releases to the Biosphere (due to varying flow pathways and velocities, varying transport properties)	Included				✓	✓		
2.2.10.00	2.10. BIOLOGICAL PROCESSES									
2.2.10.01	Microbial Activity in Host Rock		Likely excluded							
2.2.10.02	Microbial Activity in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers		Likely excluded							
2.2.11.00	2.11. THERMAL PROCESSES									
2.2.11.01	Thermal Effects on Flow in Geosphere - Repository-Induced - Natural Geothermal	- Altered saturation / relative humidity (dry-out, resaturation) - Altered gradients, density, and/or flow pathways, including dryout of clay seams in the host rock - Vapor flow - Condensation	Likely Included. Thermal effects in geosphere may be small but it will be difficult to exclude thermal considerations from the generic salt disposal system model.		✓		✓			
2.2.11.02	Thermally-Driven Flow (Convection) in Geosphere	- Convection	Likely Included.		✓		✓			
2.2.11.03	Thermally-Driven Buoyant Flow / Heat Pipes in Geosphere	- Vapor flow	Likely Included.		✓		✓			

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.2.11.04	Thermal Effects on Chemistry and Microbial Activity in Geosphere		Evaluate							
2.2.11.05	Thermal Effects on Transport in Geosphere		Evaluate							
2.2.11.06	Thermal-Mechanical Effects on Geosphere		Evaluate							
2.2.11.07	Thermal-Chemical Alteration of Geosphere		Evaluate							
2.2.12.00	2.12. GAS SOURCES AND EFFECTS									
2.2.12.01	Gas Generation in Geosphere		Likely Excluded during site screening and characterization							
2.2.12.02	Effects of Gas on Flow Through the Geosphere	- Altered gradients and/or flow pathways - Vapor/air flow - Two-phase flow - Gas bubbles - Natural Gas Intrusion from formations beneath repository (N32)	Included				✓			
2.2.12.03	Gas Transport in the Geosphere		Likely excluded							
2.2.14.00	2.14. NUCLEAR CRITICALITY									
2.2.14.01	Criticality in Far-Field		Likely Excluded per other international programs and has low importance for salt, per (Freeze et al., 2010, page B-346)							
2.3.00.00	3. SURFACE ENVIRONMENT									
2.3.01.00	3.01. SURFACE CHARACTERISTICS									
2.3.01.01	Topography and Surface Morphology	- Recharge and discharge areas	Site Specific							
2.3.02.01	Surficial Soil Type	- Physical and chemical attributes	Included							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.3.04.01	Surface Water	- Lakes, rivers, springs - Dams, reservoirs, canals, pipelines - Coastal and marine features - Water management activities	Included							
2.3.05.01	Biosphere Characteristics	- Climate - Soils - Flora and fauna - Microbes - Evolution of biosphere (natural, anthropogenic – e.g., acid rain)	Included - Climate, Soils, Flora, Fauna, and Microbes impact on surface characteristics that may affect dose in the biosphere.							
2.3.07.00	3.07. MECHANICAL PROCESSES									
2.3.07.01	Erosion		Site Specific							
2.3.07.02	Deposition		Site Specific							
2.3.07.03	Animal Intrusion into Repository		Site Specific							
2.3.08.00	3.08. HYDROLOGIC PROCESSES									
2.3.08.01	Precipitation	- Spatial and temporal distribution	Included for impact on recharge of the groundwater system				✓			
2.3.08.02	Surface Runoff and Evapotranspiration	- Runoff, impoundments, flooding, increased recharge - Evaporation - Condensation - Transpiration (root uptake)	Included for impact on recharge of the groundwater system				✓			
2.3.08.03	Infiltration and Recharge	- Spatial and temporal distribution - Effect on hydraulic gradient - Effect on water table changes	Included for impact on recharge of the groundwater system				✓			
2.3.09.00	3.09. CHEMICAL PROCESSES - CHEMISTRY									
2.3.09.01	Chemical Characteristics of Soil and Surface Water		Evaluate							
2.3.09.02	Radionuclide Speciation and Solubility in Biosphere		Included							
2.3.09.03	Radionuclide Alteration in Biosphere		Evaluate with reference biosphere parameters, if possible							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
2.3.09.50	3.09. CHEMICAL PROCESSES - TRANSPORT									
2.3.09.51	Atmospheric Transport Through Biosphere		Excluded by biosphere reference case							
2.3.09.52	Surface Water Transport Through Biosphere		Excluded by biosphere reference case							
2.3.09.53	Soil and Sediment Transport Through Biosphere		Excluded by biosphere reference case							
2.3.09.54	Radionuclide Accumulation in Soils		Excluded by biosphere reference case							
2.3.09.55	Recycling of Accumulated Radionuclides from Soils to Groundwater		Excluded by biosphere reference case							
2.3.10.00	3.10. BIOLOGICAL PROCESSES									
2.3.10.01	Microbial Activity in Biosphere		Excluded by biosphere reference case							
2.3.11.00	3.11. THERMAL PROCESSES									
2.3.11.01	Effects of Repository Heat on Biosphere		Excluded							
2.4.00.00	4. HUMAN BEHAVIOR									
2.4.01.00	4.01. HUMAN CHARACTERISTICS									
2.4.01.01	Human Characteristics	- Physiology - Metabolism - Adults, children	Included by biosphere reference case							
2.4.01.02	Human Evolution	- Changing human characteristics - Sensitization to radiation - Changing lifestyle	Likely Excluded by regulation							
2.4.04.00	4.04. LIFESTYLE									
2.4.04.01	Human Lifestyle	- Diet and fluid intake (food, water, tobacco/drugs, etc.) - Dwellings - Household activities - Leisure activities	Included by biosphere reference case							
2.4.08.00	4.08. LAND AND WATER USE									
2.4.08.01	Land and Water Use	- Agricultural (irrigation, plowing, fertilization, crop storage,	Site Specific							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		greenhouses, hydroponics) - Farms and Fisheries (feed, water, soil) - Urban / Industrial (development, energy production, earthworks, population density) - Natural / Wild (grasslands, forests, bush, surface water)								
2.4.08.02	Evolution of Land and Water Use	- New practices (agricultural, farming, fisheries) - Technological developments - Social developments (new/expanded communities)	Site Specific							
3.0.00.00	3. RADIONUCLIDE / CONTAMINANT FACTORS (BIOSPHERE)									
3.1.00.00	1. CONTAMINANT CHARACTERISTICS									
3.2.00.00	2. RELEASE / MIGRATION FACTORS									
3.3.00.00	3. EXPOSURE FACTORS									
3.3.01.00	3.01. RADIONUCLIDE / CONTAMINANT CONCENTRATIONS									
3.3.01.01	Radionuclides in Biosphere Media	- Soil - Surface Water - Air - Plant Uptake - Animal (Livestock, Fish) Uptake - Bioaccumulation	Included using the biosphere model for the salt disposal reference case.							✓
3.3.01.02	Radionuclides in Food Products		Excluded by biosphere reference case							
3.3.01.03	Radionuclides in Non-Food Products		Excluded by biosphere reference case							
3.3.04.00	3.04. EXPOSURE MODES									
3.3.04.01	Ingestion	- Food products - Soil, surface water	Included							✓
3.3.04.02	Inhalation	- Gases and vapors - Suspended particulates (dust,	Excluded by biosphere reference case							

Table C-1. (continued).

UFD FEP Number	Description	Associated Processes	Screening Recommendation for a Generic Salt Site	Relevant Physical Processes						
				R	T	M	H	Tr	C	B
		smoke, pollen)								
3.3.04.03	External Exposure	- Non-Food products - Soil, surface water	Excluded by biosphere reference case							
3.3.06.00	3.06. TOXICITY / EFFECTS									
3.3.06.01	Radiation Doses	- Exposure rates (ingestion, inhalation, external exposure) - Dose conversion factors - Gases and vapors - Suspended particulates (dust, smoke, pollen)	Included	✓						✓
3.3.06.02	Radiological Toxicity and Effects	- Human health effects from radiation doses	Included	✓						✓
3.3.06.03	Non-Radiological Toxicity and Effects		Likely excluded by regulation							