Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
		0.0.00.00	0. ASSESSMENT BASIS									
All	System	0.1.02.01	Timescales of Concern		Yes	The overall timescales of concern will be established by policy and/or regulations. However, generic R&D could potentially be used to address timescale issues. R&D on specific issues will also consider timescales over which they must be applied	Timescale considerations will be included in R&D to address specific topics under Section 2.					
All	System	0.1.03.01	Spatial Domain of Concern		Partial - Site Specific, Design Specific	Depends on specific site and facility design. Generic R&D could be conducted to develop high-level relationships between possible repository geometries, thermal output, and expected waste volumes	Low	High	N/A	Definition of spatial extent (repository design) necessary for safety analysis and design	Fundamental Data Needs	No information existis regarding potential design concepts in different media to determine estimates of size needs for different disposal system design concepts and fuel cycle scenarios.
All	System	0.1.09.01	Regulatory Requirements and Exclusions		No	Policy/Regulatory						
All	System	0.1.10.01	Model Issues	- Conceptual model - Mathematical implementation - Geometry and dimensionality - Process coupling - Boundary and initial conditions	Yes	Applies primarily in the area of method development. Most R&D will be captured in R&D to address specific issues. The integration of models and the degree of hierarchy is a system level consideration. Generic R&D could investigate uncertainty quantification and propagation within both detailed process-level and system level models (both conceptual and mathematical model uncertainty). Generic R&D could also include the development of systematic methodologies and tools to support the evaluation of model adequacy, uncertainty propagation, data, etc.	Model issues will be included in R&D to address specific topics under Section 2.					
All	System	0.1.10.02	Data Issues	- Parameterization and values - Correlations - Uncertainty	Yes	Applies primarily in the area of method development. Most R&D will be captured in R&D for specific issues.	Model issues will be included in R&D to address specific topics under Section 2.					
		1.0.00.00	1. EXTERNAL FACTORS									
		1.1.00.00	1. REPOSITORY ISSUES									
Limited Release - Natural Barriers	Natural System - Geosphere	1.1.01.01	Open Boreholes	- Site investigation boreholes (open, improperly sealed) - Preclosure and postclosure monitoring boreholes - Enhanced flow pathways from EBS	No	Site and media specific. Seals captured in specific issues below.						
Containment, Limited Release Engineered Barriers	Engineered Barriers	1.1.02.01	Chemical Effects from Preclosure Operations	- Water contaminants (explosives residue, diesel, organics, etc.) - Water chemistry different than host rock (e.g., oxiding) - Undesirable materials left - Accidents and unplanned events	Partial - Design Specific, Operations Specific	Generic R&D to identify what is allowable with respect to EBS and EDZ. In generic environments, of most importance is effects on the EDZ. As such, pre-closure operations effects will be considered in EDZ Procecces	Effects of pre-closure operations considered under EDZ issues (2.2.01.01)					
Containment, Limited Release Engineered Barriers	System	1.1.02.02	Chemical 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]	Partial - Design Specific, Operations Specific	Generic R&D could focus on identifng what would be allowable with respect to pre-closure construction/operations for engineered barrier / natural barrier complements within the different media under consideration (for example, construction techniques, emplaced materials, etc). In generic environments, of most importance is effects on the EDZ. As such, pre-closure operations effects will be considered in EDZ Procecces	Effects of pre-closure operations considered under EDZ issues (2.2.01.01)					
Containment, Limited Release Engineered Barriers	System	1.1.02.03	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]	Partial - Design Specific, Operations Specific	Generic R&D could focus on identifng what would be allowable with respect to pre-closure construction/operations for engineered barrier / natural barrier complements within the different media under consideration (for example, construction techniques, emplaced materials, etc). In generic environments, of most importance is effects on the EDZ. As such, pre-closure operations effects will be considered in EDZ Procecces	Effects of pre-closure operations considered under EDZ issues (2.2.01.01)					
Containment, Limited Release Engineered Barriers	System	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	No	Design & Operational Specific						
All	System	1.1.10.01	Control of Repository Site	- Active controls (controlled area) - Retention of records - Passive controls (markers)	No	Policy/Regulatory						

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
		Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Spatial domain of concern is ascribed medium importance at site-screening and site selection points as estimates of facility size are needed to compare with sites. Importance increases at site characterization and suitability points. Current information is deemed inadequate as neither design concpets or specific sites to evaluate concepts within are not known.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
All	System	1.1.13.01	Retrievability		Partial - Site Specific, Design Specific	Also media specific. Policy/Regulatory framework would dictate treatment of retrievability within the safety case. Generic R&D could be conducted on impacts of retrievability for design concepts/media to inform decision making.	Low	High	High	Not expected to important with regard to the safety analysis, however decisions regarding design/operations for retrievability could influence safety analysis - thus, low importance ascribed. Could be of high importance in design/construction - specific to site and media. Retrievability has historically been an important issue for the overall safety case - thus, high importance ascribed.	Improved Confidence	The issue of retrievability has been evaluated for some time. IAEA/NEA effort underway (December 2010 workshop)
		1.2.00.00	2. GEOLOGICAL PROCESSES AND EFFECTS									
		1.2.01.00	2.01. LONG-TERM PROCESSES									
All	System	1.2.01.01	Tectonic Activity – Large Scale	- Uplift - Folding	Partial - Site Specific	Issue is primarily site specific. Process occurs over very long time periods (geologic time). R&D could evaluate potential for larg-scale tectonic activity within potential sites.	N/A	N/A	Low	Large-Scale tectonic processes are very slow and are not expected to be a "credible" process or event that would occur over the very long-term and would not be considered in the safety analysis (FEP expected to be screened out). Would not affect design/construction/operations. Ascribed low importance for supporting overall confidence in the safety case - demonstration that it would not occur	Improved Confidence	Information regarding large scale tectonics exists, improvements may support future site screening activities
All	System	1.2.02.01	Subsidence		No	Site Specific						
All	System	1.2.05.01	Metamorphism	- Structural changes due to natural heating and/or pressure	No	Site Specific						
All	System	1.2.08.01	Diagenesis	- Mineral alteration due to natural processes	Partial - Site Specific	Issue is primarily site specific. Applicable to sedimentary environments (i.e., clay/shale). Process occurs over very long time periods (geologic time). R&D could evaluate potential for diagenesis within potential sites.	N/A	N/A	Low	Diagenesis is a very slow process and is not expected to be a "credible" process or event that would occur over the very long-term and would not be considered in the safety analysis (FEP expected to be screened out). Would not affect design/construction/operations. Ascribed low importance for supporting overall confidence in the safety case - demonstration that it would not occur	Improved Confidence	Information regarding diagenesis exists, improved understanding of potential may support future site screening activities
All	System	1.2.09.01	Diapirism	- Plastic flow of rocks under lithostatic loading - Salt/Evaporites - Clay	Partial - Site Specific	Applicable to salt environments (i.e., clay/shale). Process occurs over very long time periods (geologic time). R&D could evaluate potential for diaperism within potential sites. Repository-scale plastic flow in clay and salts is considered in coupled thermal-mechanical effects below.	N/A	N/A	Low	Diaperism is a very slow process and is not expected to be a "credible" process or event that would occur over the very long-term and would not be considered in the safety analysis (FEP expected to be screened out). Would not affect design/construction/operations. Ascribed low importance for supporting overall confidence in the safety case - demonstration that it would not occur	Improved Confidence	Information regarding diagenesis exists, improved understanding of potential may support future site screening activities
All	System	1.2.09.02	Large-Scale Dissolution		No	Site Specific						
		1.2.03.00	2.03.SEISMIC ACTIVITY									
Containment, Limited Release Engineered Barriers	Engineered Barriers	1.2.03.01	Seismic Activity Impacts EBS and/or EBS Components	- Mechanical damage to EBS (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]	Partial - Site Specific, Design Specific	Specific seismic response depends on the specific site and design of the disposal facility. Generic R&D could focus on improved seismic ground motion response modeling - method development R&D on material response to mechanical impact - captured in specific processes related to mechanical damage below	Medium	Medium	Medium	It must be recognized that seismic response and importance is very media, site, and design specific. Ascribed medium importance to safety analysis - could impact long-term performance - For Granite and Clay Environments. Low Importance for Salt (protection from Backfill) and Deep Borehole (greater depth, small boreholes) Ascribed medium damage for design - could affect design of EBS and overall disposal facility - For Granite and Clay Environments. Low Importance for Salt (protection from Backfill) and Deep Borehole (greater depth, small boreholes) Ascribed medium importance to overall confidence given stakeholder concerns regarding seismic issues	Improved Representation	Seismic ground motion/response models exist and have been used. Potential for improvement. Applicability and need depends on media, site, and design.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	1.2.03.02	Seismic Activity Impacts Geosphere - Host Rock - Other Geologic Units	- Altered flow pathways and properties - Altered stress regimes (faults, fractures) [see also Alterations and Impacts in 2.2.05.01, 2.2.05.02, 2.2.05.03, 2.1.07.01, and 2.1.07.02]	Partial - Site Specific	Specific seismic response depends on specific properties of the geosphere (media and site specific). Such long-term geologic issues could be of importance and understanding impacts in generic media could be useful in site selection and site characterization.	Low	Medium	Medium	It must be recognized that seismic response and importance is very media and site. Ascribed low importance to safety analysis - seismic effects in the far-field are not expected to have a significant impact long-term performance. Ascribed medium damage for design - response of host rock could affect design of EBS and overall disposal facility, primarily for Granite and Clay media. Ascribed medium importance to overall confidence given stakeholder concerns regarding seismic issues	Improved Representation	Seismic ground motion/response models exist and have been used. Potential for improvement. Applicability and need depends on media and site.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	1.2.03.03	Seismic Activity Impacts Biosphere - Surface Environment - Human Behavior	- Altered surface characteristics - Altered surface transport pathways - Altered Recharge	No	Site Specific						
		1.2.04.00	2.04. IGNEOUS ACTIVITY									

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
		Medium: Information supports or improves decisions	N/A	Medium: Information supports or improves decisions	N/A	Medium: Information supports or improves decisions	N/A	Medium: Information supports or improves decisions	N/A	Assigned medium importance to all decision points as retrievability could affect all aspects. Adequacy defined as N/A with respect to R&D program as it will be determined by regulatory/policy framework. Ultimately need to be able to demonstrate waste could be retrieved if policy/regulatory framework requires.
Interface with other organizations/groups conducting R&D on large-scale tectonics		High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	N/A	Completely sufficient (no additional info needed)	N/A	Completely sufficient (no additional info needed)	Understanding large scale tectonics is important to the entire decision process - high importance. Information exists that could be applied, improvements may support future siting efforts. Not applicable for site characterization/design and site suitability decisions - anticipate sites would be selected where process would not occur. Information collected during site screening and selection processes would be sufficient for future decision points
Interface with other organizations/groups conducting R&D on diagenesis	Clay/shale	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	N/A	Completely sufficient (no additional info needed)	N/A	Completely sufficient (no additional info needed)	Understanding diagenesis is important to the site screening and seclection decision process - high importance. Information exists that could be applied, improvements may support future siting efforts. Not applicable for site characterization/design and site suitability decisions - anticipate sites would be selected where process would not occur. Information collected during site screening and selection processes would be sufficient for future decision points
Interface with other organizations/groups conducting R&D on diapirism	Salt	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	N/A	Completely sufficient (no additional info needed)	N/A	Completely sufficient (no additional info needed)	Understanding diagenesis is important to the site screening and seclection decision process - high importance. Information exists that could be applied, improvements may support future siting efforts. Not applicable for site characterization/design and site suitability decisions - anticipate sites would be selected where process would not occur. Information collected during site screening and selection processes would be sufficient for future decision points
		N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Understanding of seismic impacts on EBS not needed for site screening as focus would be primarily on geologic attributes (including seismic, but not response of EBS). Low importance for site-selection - high level models would suffice. Techniques exist to apply, but design concepts have yet to be developed (adequacy insufficient) Medium importance ascribed for site characterization/design and site suitability. Could be of low importance depending on media/site/design. Information deemed inadquate as specific design. While modeling methods exist to quantify impacts, they could potentially be improved.
		Medium: Information supports or improves decisions	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Understanding seismic impacts on geosphere ascribed medium importance for all decision points given importance of seismic response. Techniques exist and can be applied at site screenign and selection points, but improved representation and site-specific information is needed to evaluate at site characterization/site suitability points (adequacy insufficient)

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	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]	No	Site Specific, Design Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	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	No	Site Specific						
		1.3.00.00	3. CLIMATIC PROCESSES AND EFFECTS									
All	System	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, …) [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]	Partial - Site Specific	Local climate impacts long-term processes/performance. Can be affected by large scale climate evolution	Low	N/A	Medium	The long term performance of a robust and well sited geologic disposal system is not expected to be affected by climate change. Climatic features, processes, and parameters could be of importance in site selection and effects would have to be represented in a safety analysis. Would be of no importance to either the safety analysis, design/operations, or overall confidence for a deep borehole due to depth.	Improved Representation	Climate change effects are being investigated extensively. Could leverage on these studies to identify regions/locations that could be most affected by climate change
All	System	1.3.04.01	Periglacial Effects	- Permafrost - Seasonal freeze/thaw	Partial - Site Specific	Local climate impacts long-term processes/performance. Can be affected by large scale climate evolution	Low	N/A	Medium	The long term performance of a robust and well sited geologic disposal system is not expected to be affected by climate change. Climatic features, processes, and paramters could be of importance in site selection and effects would have to be represented in a safety analysis. Would be of no importance to either the safety analysis, design/operations, or overall confidence for a deep borehole due to depth.	Improved Representation	Periglacial effects are well known, but improved understanding could potentially support future siting efforts
All	System	1.3.05.01	Glacial and Ice Sheet Effects	- Glaciation - Isostatic depression - Melt water	Partial - Site Specific	Local climate impacts long-term processes/performance. Can be affected by large scale climate evolution	Low	N/A	Medium	The long term performance of a robust and well sited geologic disposal system is not expected to be affected by climate change. Climatic features, processes, and paramters could be of importance in site selection and effects would have to be represented in a safety analysis. Would be of no importance to either the safety analysis, design/operations, or overall confidence for a deep borehole due to depth.	Improved Representation	Glacial and ice sheet effects are well known, but improved understanding could potentially support future siting efforts
		1.4.00.00	4. FUTURE HUMAN ACTIONS									
All	System	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]	No	Beyond UFD Scope						
All	System	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]	No	Beyond UFD Scope						
All	System	1.4.11.01	Explosions and Crashes from Human Activities	- War - Sabotage - Testing - Resource exploration / exploitation - Aircraft	No	Beyond UFD Scope						
		1.5.00.00	5. OTHER									
All	System	1.5.01.01	Meteorite Impact	- Cratering, host rock removal - Exhumation of waste - Alteration of flow pathways	No	Beyond UFD Scope						
All	System	1.5.01.02	Extraterrestrial Events	- Solar systems (supernova) - Celestial activity (sun - solar flares, gamma-ray bursters, moon - earth tides) - Alien life forms	No	Beyond UFD Scope						
All	System	1.5.03.01	Earth Planetary Changes	- Changes in earth's magnetic field - Changes in earth's gravitational field (tides)	No	Beyond UFD Scope						
		2.0.00.00	2. DISPOSAL SYSTEM FACTORS									
		2.1.00.00	1. WASTES AND ENGINEERED FEATURES									
		2.1.01.00	1.01. INVENTORY									

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Other organizations/groups investgating climate change.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Understanding large scale climate change is important to the entire decision process - medium importance. Information exists that could be applied, improvements may support future siting efforts.
Other organizations/groups investgating climate change.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Understanding large scale climate change is important to the entire decision process - high importance. Information exists that could be applied, improvements may support future siting efforts.
Other organizations/groups investgating climate change.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Understanding glacial and ice sheet effects is important to the entire decision process - high importance. Information exists that could be applied, improvements may support future siting efforts.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Waste Form	2.1.01.01	Waste Inventory - Radionuclides - Non-Radionuclides	- Composition - Enrichment / Burn-up	Yes	Part of FCT program and fuel cycle scenarios under consideration	High	High	Medium	Importance dependent on geology, but knowledge of inventory is required for both safety analysis and design/construction/operations. Also necessary to evaluate thermal effects (heat generating), waste form degradation (radionuclide release rate), and overall system performance	Fundamental Data Needs	Inventories have been estimated for UNF and HLW generated from different recycling processes. Additional data is needed for other fuel cycle scenarios under consideration by FCT program
Containment, Limited Release Engineered Barriers	Waste Form	2.1.01.03	Heterogeneity of Waste Inventory - Waste Package Scale - Repository Scale	- Composition - Enrichment / Burn-up - Damaged Area	Partial - Design Specific	Dependent on waste streams (driven by FCT fuel cycle scenarios) and design of disposal facility	Medium	High	Medium	Importance dependent on geology, but knowledge of heterogeneity in inventory is required for both safety analysis and design/construction/operations. Also necessary to evaluate thermal effects (heat generating), waste form degradation (radionuclide release rate), and overall system performance	Fundamental Data Needs	Waste forms and repository configuration is not known
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.01.04	Interactions Between Co-Located Waste		Partial - Design Specific	Broad configuration effects	Low	Low	Low	Importance dependent on geology and the design of the engineered system - proximity of waste packages	Fundamental Data Needs	Waste forms and repository configuration is not known
Containment, Limited Release Engineered Barriers	Waste Form	2.1.01.02	Radioactive Decay and Ingrowth	- Amount of decay product - Activities of decay products	Yes	Fundamental Aspect and included in all modeling efforts (not only inventory calculations).	Fundamental issue that will be included in R&D for all topics that must addres radioactive decay and ingrowth					
		2.1.02.00	1.02. WASTE FORM									
Containment, Limited Release Engineered Barriers	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 Fraction - Damaged Area - THC Conditions [see also Mechanical Impact in 2.1.07.06 and Thermal-Mechanical Effects in 2.1.11.06]	Yes	For UOX, MOX and any other UNF from once-through and modified-opened fuel cycles	High	High	Medium	SNF degradation is expected to be of high importance in generic environments under consideration. Strong dependencies on local EBS environment conditions. High importance is added to overall confidence - multiple barriers / defense in depth	Fundamental Gaps in Method, Fundamental Data Needs	U.S. program evaluated the long-term behavior of LWR UOX in oxidizing environments. Other programs have evaluated and are modeling the degradation of UOX and MOX in reducing environments. Little information is available regarding the degradation/alteration of other UNF types.
Containment, Limited Release Engineered Barriers	Waste Form	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	Yes	For UOX, MOX and "cladding" or "outer barrier" for any other UNF from once-through and modified-opened fuel cycles	High	High	Medium	SNF degradation, including the clad, is expected to be of low importance in generic environments under consideration with respect to long-term performance. However, if credit is being taken for cladding in the safety analysis, then importance to the safety analysis would be high. Until a decision is made regarding the amount of credit that would be ascribed to cladding, its importance to the safety analysis is deemed at high. Would be low importance for design and operations - there may be imposed thermal criteria to protect cladding or "outer barrier." Medium importance is added to overall confidence - multiple barriers / defense in depth	Fundamental Gaps in Method, Fundamental Data Needs	U.S. program evaluated the performance attributes of LWR - UOX cladding, but decided not to take credit for cladding in the Yucca Mountain License Application. Other programs directly disposing LWR SNF have taken no credit for cladding. Nothing is known about cladding or other "outer barrier" behavior for other waste forms.
Containment, Limited Release Engineered Barriers	Waste Form	2.1.02.03	Degradation of Organic/Cellulosic Materials in Waste	[see also Complexation in EBS in 2.1.09.54]	Yes	Need to capture effects of organic degradation in EBS environments if materials would be disposed of	Low	Low	Low	Organic/Celluosic waste form materials are not anticipated, but are not precluded. Estimated importance to performance as low, but any effects would need to be captured in EBS environment modeling. Could have impact on sub-surface facility design, but anticipate low importance. Estimated to be of low importance of the overall safety case.	Fundamental Gaps in Method, Fundamental Data Needs	Limited knowledge in effects on EBS in deep geologic disposal systems, but such materials are typically precluded from deep geologic disposal. Some work has been performed in the EU examining the role of isosaccharinic acid complexation from cellulose degradation, primarily focused on the disposal of low-level waste.
Containment, Limited Release Engineered Barriers	Waste Form	2.1.02.05	Pyrophoricity or Flammable Gas from SNF or HLW	[see also Gas Explosions in EBS in 2.1.12.04]	Yes	Operational safety issue. Specific to waste forms (i.e., metallic fuels). Would have to be understood if disposed of.	Low	Low	Low	Pyrophoric or flammable waste forms/materials are not anticipated, but are not precluded (for example, the direct disposal of sodium-bonded fast reactor fuel). Estimated importance to performance as low, but any effects would need to be captured in EBS environment modeling. Could have impact on sub-surface facility design, but anticipate low importance. Estimated to be of low importance of the overall safety case.	Fundamental Gaps in Method, Fundamental Data Needs	Limited knowledge in effects on EBS.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Fuels Campaign, Separations/Waste Form Campaign, Systems Analysis Campaign, and Systems Engineering Effort		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Input condition for design and safety analysis activities - importance increases over time over decision process. Techniques and methods to calculate inventory have been developed and exist. Completely sufficient for legacy wastes (Navy, DOE-EM, existing LWR) - estimates exist. Inventory estimates would need to be further developed and better represent the wastes that would be disposed of in the facility for the fuel cycle scenarios under consideration. The current information is therefore deemed partially sufficient to support this decision. Need to do the calculation once the fuel cycle scenarios are defined (i.e., MOX), but techniques and methods exist and are adequate
Interface with Separations/Waste Form Campaign, Systems Analysis Campaign, and Systems Engineering Effort		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
Interface with Separations/Waste Form Campaign, Systems Analysis Campaign, and Systems Engineering Effort		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
Interface with Fuels Campaign, Systems Analysis Campaign and Systems Engineering effort within FCT. Interface with programs in DOE-NE Office of New Reactor Technologies. Interface with UFD storage/transportation program. These define UNF/SNF types and will quantify input conditions as received for disposal. Interface with FCT Separations/Waste Form Campaign - tools developed for other waste forms can be applied to SNF.		Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Information is completely sufficient for legacy wastes (Navy, DOE-EM, existing LWR) in an oxidizing information. Adequacy of information applies to advanced reactor fuels that would be directly disposed. High-level representations could be developed at site selection decision (partially sufficient). Since models of SNF degradation do not currently exist for mixed oxide and advanced reactor fuels the current information is deemed insufficient to support site characterization/design and site suitability.
Interface with Fuels Campaign, Systems Analysis Campaign and Systems Engineering effort within FCT. Interface with programs in DOE-NE Office of New Reactor Technologies. Interface with UFD storage/transportation program. These define UNF/SNF types and will quantify input conditions as received for disposal. Interface with FCT Separations/Waste Form Campaign - tools developed for other waste forms can be applied to SNF.		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Information is partially sufficient for LWR fuels - R&D could result in improved representation of clad performance Insufficient level in adequacy of information as applied to advanced reactor fuels that would be directly disposed.
Interface with Fuels Campaign, Systems Analysis Campaign, Separations/Waste Form campaign, and Systems Engineering effort within FCT. Interface with programs in DOE-NE Office of New Reactor Technologies. Interface with UFD storage/transportation program. These define UNF/SNF and HLW types and will quantify input conditions as received for disposal.		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Importance and adequacy of information conditional on this type of material not having to be disposed of (not anticipated such material would be disposed). If such material were to be disposed, significant R&D would be required to support their disposal.
Interface with Fuels Campaign, Systems Analysis Campaign, Separations/Waste Form campaign, and Systems Engineering effort within FCT. Interface with programs in DOE-NE Office of New Reactor Technologies. Interface with UFD storage/transportation program. These define UNF/SNF and HLW types and will quantify input conditions as received for disposal.		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Importance and adequacy of information conditional on this type of material not having to be disposed of (not anticipated such material would be disposed). If such material were to be disposed, significant R&D would be required to support their disposal.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Waste Form	2.1.02.02	HLW (Glass, Ceramic, Metal) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Cracking - 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]	Yes	Specific R&D is scope of the Separations/Waste Form Campaign						
Containment, Limited Release Engineered Barriers	Waste Form	2.1.02.04	HLW (Glass, Ceramic, Metal) Recrystallization		Yes	Specific R&D is scope of the Separations/Waste Form Campaign						
		2.1.03.00	1.03. WASTE CONTAINER									
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.01	Early Failure of Waste Packages	- Manufacturing defects - Improper sealing - Constructability and fabrication technology [see also Deviations from Design in 1.1.08.01]	Partial - Design Specific	Also Material Specific. Need design/materials defined to conduct further R&D Generic R&D on closure and NDE methods.	High	High	High	Early waste container failure may be of high importance for performance (magnitude of risk and timing) Manner in which waste containers are closed could be of high importance to design and operations. Early waste package failure of high importance for overall confidence in the safety case	Fundamental Gaps in Method, Fundamental Data Needs	Depends on material/design. Some more advanced than others. U.S. program has evaluated manufacturing defects for the TAD and large waste package concept considered at Yucca Mountain. Other programs have also investigated closure techniques for different materials.
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.02	General Corrosion of Waste Packages	- Dry-air oxidation - Humid-air corrosion - Aqueous phase corrosion - Passive film formation and stability	Partial - Site Specific, Design Specific	Also media specific Specific to EBS materials and concept design Applies to waste container and any other "isolation" barriers that could be included in a design. Focus on material performance under various conditions	High	Medium	High	May be of high importance for performance in certain environments. In addition, the waste container is a key part of a multiple-barrier disposal system concept and must be included in the safety analysis. More Important from a gas generation standpoint in salt and perhaps clay. More Important to granite from a hyrdologic barrier capability standpoint. Not very important to deep borehole for either gas generation or barrier capability. At least Medium importance for design - could effect container / overpack design. Could impact handling / operation (constraints) High importance for overall confidence - primary isolation barrier. Medium importance for for overall confidence in specific EBS design concepts and repository environments	Fundamental Gaps in Method, Fundamental Data Needs	Considerable studies in the corrosion of a variety of metallic materials both in the U.S. and abroad that can be leveraged. Some knowledge gaps exist regarding degradation modes for various alloys under various conditions. Little/no information available regarding new/novel materials Uncertainty in extrapolating short-term laboratory tests to long-time periods and spatially variable conditions. Interest in gas generation resulting from corrosion in some programs (Europe) Potential for novel alloys with increased resistance to corrosion - little information known.
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.03	Stress Corrosion Cracking (SCC) of Waste Packages	- Crack initiation, growth and propagation - Stress distribution around cracks	Partial - Site Specific, Design Specific	Also media specific Specific to EBS materials and concept design Applies to waste container and any other "isolation" barriers that could be included in a design. Focus on material performance under various conditions	High	Medium	High	May be of high importance for performance for certain materials in certain environments. Some safety assessments do not consider SCC important. Stress corrosion cracking (SCC) does not appear to play a big role on copper canister corrosion, even at elevated temperatures. In other repository programs such as Canada and Japan, stress corrosion cracking is not considered on the basis of chemical threshold concentrations and low amounts of SCC agents for this process to occur. Medium importance for design - could affect container / overpack design High importance for overall confidence - primary isolation barrier. Medium importance for for overall confidence in specific EBS design concepts and repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Considerable studies in the corrosion of a variety of metallic materials both in the U.S. and abroad. SCC may not be an issue for some materials in specific environments. Need to identify conditions which SCC can occur (materials and environments).
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.04	Localized Corrosion of Waste Packages	- Pitting - Crevice corrosion - Salt deliquescence [see also 2.1.09.06 Chemical Interaction with Backfill]	Partial - Site Specific, Design Specific	Also media specific Specific to EBS materials and concept design Applies to waste container and any other "isolation" barriers that could be included in a design. Focus on material performance under various conditions	High	Medium	High	May be of high importance for performance in certain environments. Medium importance for design - could effect container/overpack design High importance for overall confidence - primary isolation barrier.	Fundamental Gaps in Method, Fundamental Data Needs	Considerable studies in the corrosion of a variety of metallic materials both in the U.S. and abroad. Improved understanding of localized corrosion effects, in particular stress corrosion cracking, pitting, and crevice corrosion would lead to improved modeling and understanding of waste package performance.
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.05	Hydride Cracking of Waste Packages	- Hydrogen diffusion through metal matrix - Crack initiation and growth in metal hydride phases	Partial - Site Specific, Design Specific	Also media specific Specific to EBS materials and concept design Applies to waste container and any other "isolation" barriers that could be included in a design. Focus on material performance under various conditions	High	Medium	High	May be of high importance for performance in certain environments. Medium importance for design - could effect container/overpack design High importance for overall confidence - primary isolation barrier.	Fundamental Gaps in Method, Fundamental Data Needs	Considerable studies in the corrosion of a variety of metallic materials both in the U.S. and abroad. Long-term effects such as hydrogen embrittlement, de-alloying, creep, segregation, radiation damage, oxide wedging, and the effect of radiolysis on the potential aqueous phase in contact with metallic barrier materials. Identify modeling feasibility of radiolytic effects on corrosion.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Waste Form campaign and NEAMS through GDSE. Tools evaluated in the WF campaign may apply here.										
Interface with Waste Form campaign and NEAMS through GDSE. Tools evaluated in the WF campaign may apply here.										
Interface with industry required - (cask/canister fabrications). Interface with UFD Transportation/Storage program required, depending on "integrated" approach to storage, transporation, and disposal.		N/A	N/A	N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Necessary to understand only at the site suitability phase. Current information is inadequate as materials and design are not defined.
Interface with DOE-NE advanced reactor programs, FCT fuels campaign, and separations/waste form campaign - material development and techniques. Interface with NEAMS for advanced modeling and simulation of waste container materials.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Low importance at site screening - anticipate sites having geochemical conditions that would result in low corrosion rates would be preferred. Existing information is sufficient. Low importance at site selection - high level models needed. Exist for most traditional waste container materials, but not for novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Interface with DOE-NE advanced reactor programs, FCT fuels campaign, and separations/waste form campaign - material development and techniques. Interface with NEAMS for advanced modeling and simulation of waste container materials.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Low importance at site screening - anticipate sites having geochemical conditions that would result in low corrosion rates would be preferred. Existing information is sufficient. Low importance at site selection - high level models needed. Exist for most traditional waste container materials, but not for novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Interface with DOE-NE advanced reactor programs, FCT fuels campaign, and separations/waste form campaign - material development and techniques. Interface with NEAMS for advanced modeling and simulation of waste container materials.		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Low importance at site screening - anticipate sites having geochemical conditions that would result in low corrosion rates would be preferred. Existing information is sufficient. Low importance at site selection - high level models needed. Exist for most traditional waste container materials, but not for novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Interface with reactor, fuels, waste form material development and techniques. NEAMS		Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Low importance at site screening - anticipate sites having geochemical conditions that would result in low corrosion rates would be preferred. Existing information is sufficient. Low importance at site selection - high level models needed. Exist for most traditional waste container materials, but not for novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.06	Microbially Influenced Corrosion (MIC) of Waste Packages	- Potential EBS environments for MIC to develop in repository environments	Yes - and any other "isolation" barriers that could be included in a design. Material focus	Waste container and any other "isolation" barriers that could be included in a design. Material focus.	R&D to address topic covered in R&D regarding corrosion process above (see 2.1.03.02 - 2.1.03.05)					
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.07	Internal Corrosion of Waste Packages Prior to Breach		Partial - Design Specific	Need to know specific waste package design, materials that will be contained, and EBS environment. Cannot do specific R&D on internal corrosion, but can investigate as part of overall material performance R&D	R&D to address topic covered in R&D regarding corrosion process above (see 2.1.03.02 - 2.1.03.05)					
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.03.08	Evolution of Flow Pathways in Waste Packages	- Evolution of physical form of waste package - 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]	Partial - Site Specific, Design Specific	Also material specific. Condition of failed package (characteristics and distribution of potential flow pathways through corrosion penetrations) Methods for modeling/representing flow through breached waste packages	Medium	Low	Medium	Medium Safety Analysis - affects source term from breached waste packages Low for design/construciton/operations - Will result from the materials selected primarily for containment purposes Overall - part of EBS and its performance Highly dependent on EBS design concept	Improved Representation	Typically conservative models applied to flow through perforated waste packages.
		2.1.04.00	1.04. BUFFER / BACKFILL									
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.04.01	Evolution and Degradation of Backfill/buffer	- 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]	Partial - Design Specific	Specific R&D would require establishment of design and selection of material. Generic R&D could be conducted on backfill/buffer materials independent of design.	High	High	High	May be of high importance for performance in certain environments and disposal concepts that utilize backfill/buffer as a engineered barrier - governs "source term" release upon failure of waste packages for certain designs in certain environments. High importance for design/construction - could effect disposal system design that utilize backfill/buffer as an engineered barrier, how it is constructed, and emplacement of waste and backfill/buffer (i.e., size of waste packages and spacing). High importance for overall confidence - secondary isolation barrier and long-term barrier performance	Fundamental Gaps in Method, Fundamental Data Needs	Other countries have performed considerable investigations into different backfill and buffer materials (bentonite and cementitious materials). Additional R&D needed to better understand processes associated with backfill/buffer for these materials. Little/no information available regarding new/novel buffere/backfill materials
		2.1.05.00	1.05. SEALS									
Containment, Limited Release Engineered Barriers	Seals	2.1.05.01	Degradation of Seals	- Alteration / Degradation / Cracking - Erosion / Dissolution / precipitation - Asphalt seals: degradation as a 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]	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of seal design and selection of material - compatible with site/media. Generic R&D could be conducted on seal materials independent of design and site/media.	High	High	High	May be of high importance for performance in certain environments that rely on seals as a key part of the engineered barrier system - Could provide preferential pathways for release. Seal degradation could influence local chemistry Medium importance for design/construction: Since the seals are a key part of the waste isolation system, their importance to design and /construction/ operations is important. However, the design/construction/operation of the overall facility does not depend on the seals themselves. High importance for overall confidence - potential isolation barrier.	Fundamental Gaps in Method, Fundamental Data Needs	Various countries, including USA and international repository programs, have conducted investigations on the stability and degradation of concretes and other sealing materials. WIPP has a certified seal design and the Swedish and Finnish programs are well advanced in granite environments. A collaborative research program has been developed by DOE-EM Office of Waste Processing named the "Cementitious Barriers Partnership". The UFD EBS program will focus mainly on the development of thermodynamic database to be used in the prediction of solubilities of cementitous phases and a computational tool to perform these calculations. It will also evaluate model concepts of cement corrosion and degradation processes. Modeling of solid solution phenomena is key to the accurate representation of cement barrier degradation.
		2.1.06.00	1.06. OTHER EBS MATERIALS									
Containment, Limited Release Engineered Barriers	Other Engineered Features	2.1.06.01	Degradation of Liner / Rock Reinforcement Materials in EBS	- Alteration / Degradation / Cracking - Corrosion - Erosion / Dissolution / Spalling - Dual purpose of liner acting as "structural" feature plus as a barrier component (e.g., getter or isolation purposes). [see also Mechanical Impact in 2.1.07.08, Thermal-Mechanical Effects in 2.1.11.09, Chemical Interaction in 2.1.09.07]	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of sub-surface design and selection of materials - compatible with site/media. Generic R&D could be conducted on materials independent of design and site/media.	Medium	High	Medium	Expected to be of medium at most direct importance to long-term performance. May be of secondary importance by affecting other engineered materials Could be of high importance to repository design and construction. Estimated at medium importance for overall confidence - tunnel stability during operations Degradation within this disposal domain could translate in eventual fast percolation paths in the neighboring bounds of the disposal gallery. However, anticipated 'healing' processes could mitigate the resulting effects deletirous to barrier performance.	Improved Representation	Other countries have investigated a variety of disposal system designs, including other engineered barriers system materials Improved understanding of other EBS material degradation and impacts on other EBS processes (i.e., chemistry) are needed. For example, degradation modes at the cement / rock and cemen / metal barrier interfaces.
		2.1.07.00	1.07. MECHANICAL PROCESSES									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.07.01	Rockfall	- Dynamic loading (block size and velocity) [see also Mechanical Effects on Host Rock in 2.2.07.01]	No	Site Specific, Design Specific Anticipate that site screening and site selection would prefer geologic conditions that would maximize drift/tunnel stability and minimize the potential for rockfall. However, this cannot be assessed with generic R&D.						

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with the UFD-NS program		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening phase. Low importance at site selection and site characterization/design - high level models needed (could be conservative). Medium importance at site suitability phases. Improved and defensible models would need to be in place for materials selected and design - also depends on "credit" taken for flow paths through waste containers.
Interface with UFD-NS program (EDZ-NS interface)		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Only applicable to concepts that include backfill/buffer. Strong dependency on EBS design concepts and processes. Not applicable at site screening phase. Low importance at site selection - high level models needed. Exist for most traditional buffer/backfill materials, but not for any novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Interface with UFD-NS program (EDZ-NS interface) Intefrace with DOE-EM -- Cement Barrier Partnership (CBP)		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening phase. Low importance at site selection - high level models needed. Exist for most traditional seal materials and designs, but not for any novel/new materials. High importance at site characterization/design - would need information to begin design of seal system for those media/concepts that rely on seals. High importance at site suitability phases - understanding would need to support defensible representation of seal performance.
Interface with UFD- NS program (EDZ-NS Interface)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design - would need information to begin design of EBS. High importance at site suitability phases - understanding would need to support defensible representation of EBS performance.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.07.02	- Drift Collapse - Drift deformation (EDZ)	- Static loading (rubble volume) - Alteration of seepage - Alteration of EBS flow pathways - Relevant to construction, pre-closure & operational safety - Borehole / tunnel integrity - 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]	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of sub-surface design, selection of materials, and operational techniques - compatible with site/media. Generic R&D could be conducted on performance and impacts independent of design and site/media.	Medium	High	High	Importance to performance estimated at medium. May be N/A for some design concepts and environments. Estimated to be of high importance to design - could limit emplacement "room," tunnel, or borehole size, ground support system, pre-closure safety, etc. Medium importance assumed for overall confidence importance Important for backfilled repository designs in hard or sedimentary rock.	Fundamental Gaps in Method, Fundamental Data Needs	Mechanical effects in emplacement tunnels, rooms, etc. have been investigated in other geologic disposal programs. Being investigated as part of EDZ R&D. Relevant to construction operations, waste emplacement, and the emplacement of backfill material. THM processes could enhance the excavated damage zone thus influencing the hydraulic properties of the EBS backfill/buffer materials.
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.07.03	Mechanical Effects of Backfill	- Degradation of backfill due to mechanical processes - Protection of other EBS components from rockfall / drift collapse	Partial - Design Specific	Specific R&D would require establishment of design and selection of material. Generic R&D could be conducted on backfill/buffer materials independent of design.	Medium	Medium	High	Importance to performance estimated at medium. May be N/A for some design concepts and environments. Could provide mechanical protection to waste container. Medium importance for design/construction - could effect EBS design, how EBS is constructed, and emplacement of waste and backfill/buffer High importance for overall confidence - secondary isolation barrier and long-term barrier performance	Fundamental Gaps in Method, Fundamental Data Needs	Relevant to construction operations, waste emplacement, and the emplacement of backfill material. THM processes could enhance the excavated damage zone thus influencing the hydraulic properties of the EBS backfill/buffer materials.
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.07.04	Mechanical Impact on Backfill	- Rockfall / Drift collapse - Hydrostatic pressure - Internal gas pressure [see also Degradation of Backfill in 2.1.04.01 and Thermal-Mechanical Effects in 2.1.11.08]	Partial - Site Specific, Design Specific	R&D to asses backfill mechanical behavior	Low	High	Low	Importance estimated at high for design construction operations	Fundamental Gaps in Method, Fundamental Data Needs	Relevant to emplacement of backfill material and potential impact on the expected hydraulic properties of the backfill/buffer material. THM processes could enhance the excavated damage zone thus influencing the hydraulic properties of the EBS backfill/buffer materials but long-term 'healing' is expected to mitigate these perturbations.
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.07.05	Mechanical Impact on Waste Packages	- Rockfall / Drift collapse - Waste package movement - Hydrostatic pressure - Internal gas pressure - Swelling corrosion products [see also Thermal-Mechanical Effects in 2.1.11.07]	Partial - Site Specific, Design Specific	Cannot do specific R&D without design and environment. Can perform generic R&D to asses waste package material mechanical behavior	High	Medium	High	Importance dependent on rock type and design of EBS . May be of high importance for performance in certain environments. In addition, the waste container is a key part of a multiple-barrier disposal system concept and must be included in the safety analysis. At least Medium importance for design - could effect container / overpack design and design of surrounding EBS. Could impact handling / operation (constraints) High importance for overall confidence - primary isolation barrier. Low/Medium importance for for overall confidence in specific EBS design concepts and repository environments	Fundamental Gaps in Method, Fundamental Data Needs	Data needs on the effect of loading on waste package surface and corrosion. Evolution and characterization of degradation modes at the waste package interface in the presence of hydrated buffer/backfill materials. Potential emplacement issues
Containment, Limited Release Engineered Barriers	Waste Form	2.1.07.06	Mechanical Impact on SNF Waste Form	- Drift collapse - Swelling corrosion products [see also Thermal-Mechanical Effects in 2.1.11.06]	Partial - Site Specific, Design Specific	R&D to asses SNF material mechanical behavior	Medium	Medium	Medium	Importance dependent on rock type and design of EBS . May be of high importance for performance in certain environments. In addition, the waste form is a key part of a multiple-barrier disposal system concept and must be included in the safety analysis. At least Medium importance for design - could effect container / overpack design and design of surrounding EBS. Could impact handling / operation (constraints) Medium importance for overall confidence - primary isolation barrier. Could be low importance for for overall confidence in specific EBS design concepts and repository environments	Fundamental Gaps in Method, Fundamental Data Needs	Mechanical effects could be associated with waste form degradation (volume changes) but these are expected to minimal.
Containment, Limited Release Engineered Barriers	Waste Form	2.1.07.07	Mechanical Impact on HLW Waste Form	- Drift collapse - Swelling corrosion products - Emplacement - Overall mechanical durability [see also Thermal-Mechanical Effects in 2.1.11.06]	No	Specific R&D is scope of the Separations/Waste Form Campaign						
Containment, Limited Release Engineered Barriers	Other Engineered Features	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 - Swelling corrosion products [see also Thermal-Mechanical Effects in 2.1.11.09]	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of sub-surface design and selection of materials - compatible with site/media. Generic R&D could be conducted to assess materials mechanical behavior independent of design and site/media.	Low	Low	Low	Importance estimated at low for all	Fundamental Gaps in Method, Fundamental Data Needs	Other countries have investigated a variety of disposal system designs, including other engineered barriers system materials Improved understanding of other EBS material degradation and impacts on other EBS processes. Specific to repository environment and design.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with UFD-NS program (NS-EDZ Interface)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design - would need information to begin design of EBS - including tunnel/room/borehole design. High importance at site suitability phases - understanding would need to support defensible representation of EBS performance and EBS design. Strong dependency on EBS design concepts and processes. Important for pre-closure emplacement activities and safety
Interface with UFD-NS program (EDZ-NS interface)		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Only applicable to concepts that include backfill/buffer. Strong dependency on EBS design concepts and processes. Not applicable at site screening phase. Low importance at site selection - high level models needed. Exist for most traditional buffer/backfill materials, but not for any novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design. Strong dependency on EBS design concepts and processes Important for pre-closure emplacement activities and safety
Interface with UFD-NS program (EDZ-NS interface) - EDZ and EBS erosion issues		N/A	N/A	High: Information is essential to decisions	Completely sufficient (no additional info needed)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Only applicable to concepts that include backfill/buffer. Strong dependency on EBS design concepts and processes. Not applicable at site screening phase. Low importance at site selection - high level models needed. Exist for most traditional buffer/backfill materials, but not for any novel/new materials. High importance at site characterization/design and site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Iinterface with UFD storge & transportation program - Initial condition of waste packages in integrated container/waste package system.		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening and site selection phase. Medium importance at site characterization/design - need to understand mechanical impacts an its impacts on design and safety analysis. Medium importance at site suitability phases. Improved and defensible models would need to be in place for materials selected and design.
Interface with Separations/Waste Form Campaign in R&D on mechanical damage to all waste forms (including SNF). Integration with UFD Storage & Transportation R&D - initial condition of SNF		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Information is completely sufficient for legacy wastes (Navy, DOE-EM, existing LWR). Adequacy of information applies to advanced reactor fuels that would be directly disposed. High-level representations could be developed at site selection decision (partially sufficient). Since models of SNF degradation do not currently exist for mixed oxide and advanced reactor fuels the current information is deemed insufficient to support site characterization/design and site suitability. Some dependency on EBS design concepts and processes
SEPARATIONS/WF CAMPAIGN NEEDS TO CONSIDER R&D IN THIS AREA WITHIN THEIR PROGRAM										
Interface with UFD- NS program (EDZ-NS Interface)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design - would need information to begin design of EBS. Medium importance at site suitability phases - understanding would need to support defensible representation of EBS performance.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.07.09	Mechanical Effects at EBS Component Interfaces	- Component-to-component contact (static or dynamic) - Volume changes	Partial - Design Specific	Specific R&D would require establishment of sub-surface design, selection of materials, and operational techniques - compatible with site/media. Methods and parameters for material-material interfaces	High	High	Low	Expected to be of high importance to long-term barrier performance - interactions at waste package/waste form interface may be of more importance. Interface at buffer/backfill and rock interface may also be of importance. Degradation of metallic barriers at the buffer/backfill interface can be very important in the generation of 'redox barriers' that could enhance barrier performance with time. Also, interfacial domains can also served as loci for large transport and chemical gradients where these could strongly influence the overall barrier performance. Exptected to be of low importance to repository design and construction. Estimated at low importance for overall confidence - demonstration of understanding of mechanical interactions	Fundamental Gaps in Method, Fundamental Data Needs	Identification of key interaction at EBS barrier interfaces needs to be established. Clay-metal barrier interfaces can be subjected to metal barrier degradation (e.g., metal corrosion) due to the presence of hydrous phases (clays) that could dehydrate at elevated temperatures. Models and experiments need to be developed to assess these interactions with fluids at barrier interfaces and their effects to barrier performance.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.07.10	Mechanical Degradation of EBS	- Floor buckling - Fault displacement - Initial damage from excavaion / construction - Consolidation of EBS components - Degradation of waste package support structure - 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]	No	"Broad" mechanical degradation of the EBS is media specific and site specific. R&D on generic systems cannot address this topic.						
		2.1.08.00	1.08, HYDROLOGIC PROCESSES									
Limited Release - Enineered Barriers	Engineered Barriers	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 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]	Partial - Site Specific, Design Specific	Generic R&D captured in flow through individual EBS components above and issues below.	"Broad" Flow through the EBS cannot be assessed through generic R&D. EBS flow processes through specific barrier components/materials addressed below.					
Limited Release - Enineered Barriers	Waste Packaging	2.1.08.02	Flow In and Through Waste Packages	- Saturated / Unsaturated flow - Movement as thin films or droplets	Yes	Methods and Properties/Parameters	Medium	Low	Medium	Medium Safety Analysis - affects source term from breached waste packages Low - Design/Construction/Operation - Materials will be selected primarily for containment purposes, however understanding of the flow characteristics through waste package perforations is important and understanding would preclude the use of conservative models (i.e., entire waste package degrades) Overall Confidence medium - part of EBS and its performance	Improved Representation	Typically conservative models applied to flow through perforated waste packages.
Limited Release - Enineered Barriers	Backfill/Buffer	2.1.08.03	Flow in Backfill	- Fracture / Matrix flow	Yes	Methods and Properties/Parameters	High	Medium	High	May be of high importance for performance in certain environments - governs "source term" release upon failure of waste packages for certain designs in certain environments. Would be of no importance to concepts that do not utilize backfill as a key part of the EBS. Medium importance for design - could effect backfill/buffer design and emplacement techniques High importance for overall confidence - secondary isolation barrier.	Fundamental Gaps in Method	Other countries have evaluated flow through buffer/backfill materials. Improved models of flow through breaches could increase understanding of releases from the engineered barriers.
Limited Release - Enineered Barriers	Seals	2.1.08.04	Flow Through Seals	- Fracture / Matrix flow - Gas transport	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of seal design and selection of material - compatible with site/media. Generic R&D could be conducted on seal materials independent of design and site/media - method and parameter development.	High	High	High	May be of high importance for performance in certain environments - Could provide preferential pathways for release. High importance for design/construction - could be key part of isolation system High importance for overall confidence - potential isolation barrier.	Fundamental Gaps in Method, Fundamental Data Needs	Improved models of flow through breaches could increase understanding of releases from the engineered barriers. For cementitious barriers, reactive transport models need to be developed to assess barrier seal performance from processes such as carbonation, sulfate attack, and coupled phenomena influencing gas transport.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with UFD-NS program (NS-EDZ Interface)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design - would need information to begin design of EBS - including tunnel/room/borehole design and material selection. Medium importance at site suitability phases - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Strong dependency on EBS design concepts and processes. Important for pre-closure emplacement activities and safety
SEPARATIONS/WF CAMPAIGN NEEDS TO CONSIDER R&D IN THIS AREA WITHIN THEIR PROGRAM										
Potential interface with NS, depending on design of EBS		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening phase. Low importance at site selection and site characterization/design - high level models needed (could be conservative). Medium importance at site suitability phases an. Could use conservative models, R&D could result in improved representation and defensible models would need to be in place for materials selected and design - also depends on "credit" taken for flow paths through waste containers.
Interface with UFD-NS program (EDZ-NS interface)		N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Only applicable to concepts that include backfill/buffer. Strong dependency on EBS design concepts and processes. Not applicable at site screening phase. Low importance at site selection - high level models needed. Exist for most traditional buffer/backfill materials, but not for any novel/new materials. Medium importance at site characterization/design phase and high at site suitability phase. Improved and defensible models would need to be in place for materials selected and design.
Interface with UFD-NS program		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design - would need information to begin design of seal system. High importance at site suitability phases - understanding would need to support defensible representation of seal performance.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Enineered Barriers	Other Engineered Features	2.1.08.05	Flow Through Liner / Rock Reinforcement Materials in EBS		Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of sub-surface design and selection of materials - compatible with site/media. Generic R&D could be conducted to develop/improve methods and properties/parameters independent of design and site/media. Methods and Properties/Parameters	Low	High	Medium	Expected to be of low direct importance to long-term performance. Could be of high importance to repository design and construction. Estimated at medium importance for overall confidence	Fundamental Gaps in Method, Fundamental Data Needs	Reactive transport models need to be developed to assess barrier seal performance and interactions with fluids at barrier interfaces that could influence gas generation and transport.
Limited Release - Enineered Barriers	Engineered Barriers	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 [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]	Partial - Site Specific, Design Specific	Generic R&D captured in flow through individual EBS components above and issues below.	"Broad" Flow through the EBS cannot be assessed through generic R&D. EBS flow processes through specific barrier components/materials addressed herein.					
Limited Release - Enineered Barriers	Engineered Barriers	2.1.08.07	Condensation Forms in Repository - On Tunnel Roof/Walls - On EBS Components - Moisture transpot	- Heat transfer (spatial and temporal distribution of temperature and relative humidity) - Dripping [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]	Partial - Site Specific, Design Specific	Would not be applicable to those disposal systems in saturated environments with thermal limits below boiling. Specific R&D would require establishment of sub-surface design, selection of materials, and operational techniques - compatible with site/media. Methods for determining impacts and developing representation	Low	Low	Low	Expected to be of low direct importance to long-term performance. Exptected to be of low importance to repository design and construction. Estimated at low importance for overall confidence	Improved Representation	Expected to be of low impact in backfilled repositories. Highly dependent on EBS barrier design and components that would allow flow capture and/or diversion.
Limited Release - Enineered Barriers	Engineered Barriers	2.1.08.08	Capillary Effects in EBS	- Wicking - Richards barrier phenomena	Partial - Site Specific, Design Specific	Would not be applicable to those disposal systems in saturated environments with thermal limits below boiling. Could be applicable to re-wetting in saturated environments that consider above-boiling thermal limits. Specific R&D would require establishment of sub-surface design, selection of materials, and operational techniques - compatible with site/media. Methods for determining impacts and developing representation	High	High	Medium	Expected to be of medium direct importance for salt due to moisture contacting waste package, leading to corrosion and gas generation. Low direct importance to long-term performance for other media (ranking based on salt). Exptected to be of high importance depending on repository design and construction. Estimated at low importance for overall confidence	Improved Representation	Expected to be of low impact in backfilled repositories. For salt importance rises because capillary effects in the backfill are important for determinng how much brione contacts the waste package. Highly dependent on EBS barrier design and components. For example, the presence of a Richards barrier.
Limited Release - Enineered Barriers	Engineered Barriers	2.1.08.09	Influx/Seepage Into the EBS	- 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]	Partial - Site Specific, Design Specific	Would not be applicable to those disposal systems in saturated environments with thermal limits below boiling. Specific R&D would require establishment of sub-surface design, selection of materials, and operational techniques - compatible with site/media. Methods for determining impacts and developing representation	Medium	Low	Medium	Expected to be of medium direct importance to long-term performance - effects release rate from failed engineered barriers. Exptected to be of low importance to repository design and construction. Estimated at medium importance for overall confidence	Fundamental Gaps in Method, Fundamental Data Needs	Expected to be of medium impact in backfilled repositories. Highly dependent on EBS barrier design and components. For example, the presence of a Richards barrier.
		2.1.09.00	1.09. CHEMICAL PROCESSES - CHEMISTRY									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.09.01	Chemistry of Water Flowing into the Repository	- Chemistry of influent water (spatial and temporal distribution) [See also Chemistry in Host Rock 2.2.09.01]	Partial - Site Specific	Also media specific - depends on chemistry of host rock: interface with natural system. In backfilled reporitories, water chemistry will be highly dependent on rock pore water chemistry, local conditions of pressure and temperature, and interactions with site rock types. Cannot do R&D to quantify specific water chemistry (parameters), rather can perform generic R&D to develop methods for quantifying (experimental and analytic) for use in subsequent site-specific R&D.	High	Low	Medium	Expected to be of high direct importance to long-term performance - effects potential degradation processes of engineered barriers and geochemistry inside the EBS, and solubility controls/limits. Exptected to be of low importance to repository design and construction. Estimated at medium importance for overall confidence - demonstration of understanding of geochemical conditions	Fundamental Gaps in Method	Methods to obtain water chemistry exist and have been applied in many different programs. However, obtaining water chemistry information can be difficult in certain situations (i.e., highly charged systems, deep boreholes).

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with UFD-NS program		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Low importance at site characterization/design - would need information to begin design of EBS. Medium importance at site suitability phases - understanding would need to support defensible representation of EBS performance.
		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Low importance at site characterization/design and site suitability phases - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Strong dependency on EBS design concepts and processes. Important for pre-closure emplacement activities and safety
Potential interface with NS		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Low importance at site characterization/design and site suitability phases - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Strong dependency on EBS design concepts and processes. Important for pre-closure emplacement activities and safety
Potential interface with NS		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Low importance at site characterization/design and site suitability phases - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Strong dependency on EBS design concepts and processes. Important for pre-closure emplacement activities and safety
Strong interface with natural system - UFD - NS program (in particular EDZ/near field)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design phase - need techniques established to determine incoming water chemistry. High importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Insufficient information regarding other specific media. Strong dependency on host rock

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Waste Packaging	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, …) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or backfill) [see also Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04] - Evolution of water chemistry / interaction with waste packages	Partial - Site Specific, Design Specific	Also media specific - depends on chemistry of water entering the repository and interactions with degraded waste package materials and internals (waste form and packaging structural materials. Generic R&D would focus on methods to quantify evolution (experimental modeling). Parameters could be determined if it can be shown in-package conditions will dominate (independent of in-flux).	High	Medium	High	Expected to be of high direct importance to long-term performance - effects potential degradation processes of waste forms and mobilization of radionuclides. Expteced to be of medium importance to repository design and construction - could potentially affect items like inclusion/selection of buffer/backfill Estimated at high importance for overall confidence - demonstration of understanding of geochemical conditions	Fundamental Gaps in Method, Fundamental Data Needs	Some work has been doine in this respect in terms of modeling (see Wang et al. 2010) and experimental work on miniature waste packages (Ferris et al. 2009). Studies like this can provide important information as to constrain water chemistries inside the waste packages. Still, the information is limited to low temperatures and this might be an important knowledge gap. Limited/no informaiton or methods available for advanced waste forms and alternative spent fuels.
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.09.03	Chemical Characteristics of Water in Backfill	- Water composition (radionuclides, dissolved species, …) - Initial void chemistry (air / gas) - Water chemistry (pH, ionic strength, pCO2, …) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from tunnels and/or backfill) [see also Chemistry in Backfill in 2.1.09.03, Chemistry in Tunnels in 2.1.09.04] - Evolution of water chemistry / interaction with waste packages	Partial - Site Specific, Design Specific	Generic R&D on backfill/buffer interactions. Generic R&D would focus on methods to quantify evolution (modeling). Parameters could be determined if it can be shown backfill/buffer conditions will dominate (independent of in-flux or out of waste package).	High	High	High	Potential high direct importance to long-term performance - could effects potential release rates out of backfill/buffer/getter in certain design concepts in different media, could be key isolation barrier. Could be low in systems where buffer/backfill is not included or not a key isolation barrier Expteced to be of medium importance to repository design and construction - impact inclusion of / choice of buffer/backfill Potentially at high importance for overall confidence - demonstration of understanding of geochemical conditions within backfills/buffers if included as key engineered barrier	Fundamental Gaps in Method, Fundamental Data Needs	In backfilled reporitories, water chemistry will be highly dependent on rock pore water chemistry, local conditions of pressure and temperature, and specific interactions with the barrier/buffer materials. Some modeling work on cation exchange and anion exclusion phenomena in clay has been initalized. Still, there are significant data gaps regarding dependencies on local ionic strength and temperature effects on diffusive transport in clay barriers. There are also knowledge gaps in cementitous backfills. Little/no information available regarding new/novel buffer/backfill materials.
Containment, Limited Release Engineered Barriers	Engineered Barriers	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, …) - Reduction-oxidation potential - Reaction kinetics - Influent chemistry (from construction / emplacement) [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] - Evolution of water chemistry / interaction with waste packages	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in tunnels. Further removed from emplaced waste and coupling to that would be decreased. Accurate accounting of committed materials in the tunnels upon emplacement - site/design specific issues. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Low	Medium	Low	Expected to be of low direct importance to long-term performance - limited influence on EBS chemistry. Expected to be of medium importance to repository design and construction - could impact material selection Estimated at medium importance for overall confidence - demonstration of understanding of geochemical conditions - could influence EBS chemistry depending on materials and proximity to emplaced waste	Fundamental Gaps in Method, Fundamental Data Needs	Expected to be of low impact in backfilled repositories. Could effect interactions with liner, seal, and other EBS barrier components.
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.09.05	Chemical Interaction of Water with Corrosion Products - In Waste Packages - In Backfill - In Tunnels	- Corrosion product formation and composition (waste form, waste package internals, waste package) - Evolution of water chemistry in waste packages, in backfill, and in tunnels [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]	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Generic R&D on this issue would be captured in R&D for 2.1.09.02, .03, .04, .08					
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.09.06	Chemical Interaction of Water with Backfill - On Waste Packages - In Backfill - In Tunnels	- Backfill composition and evolution (bentonite, crushed rock, …) - Evolution of water chemistry in backfill and in tunnels - Enhanced degradation of waste packages (crevice corrosion) [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]	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Generic R&D on this issue would be captured in R&D for 2.1.09.03					
Containment, Limited Release Engineered Barriers	Other Engineered Features	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 (concrete, metal, …) - Rock reinforcement material composition and evolution (grout, rock bolts, mesh, ….) - Other cementitious materials composition and evolution - 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] Closely related to 2.1.05.01 and 2.1.06.01	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	High	High	High	Potentially high direct importance to long-term performance - cementitious materials can have a significant role in geochemical evolution Expteced to be of high importance to repository design and construction - inclusion/selection of materials for use in construction of disposal facility Estimated at high importance for overall confidence - demonstration of understanding of geochemical conditions in cementitious materials	Fundamental Gaps in Method, Fundamental Data Needs	Could potentiall be of high impact in repositories depending on materials chosen and design. Highly dependent on interactions with liner, seal, and other EBS barrier components. Reactive transport models need to be developed to assess barrier seal performance and interactions with fluids at barrier interfaces that could influence fluid transport and chemistry.
Containment, Limited Release Engineered Barriers	Other Engineered Features	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 (concrete, 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]	Partial - Design Specific	Depends on design and materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Generic R&D on this issue would be captured in R&D for 2.1.09.04					

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface needed with Separations/Waste Form campaign and NEAMS - need understanding of degradation products and interaction with local environment. Interface with outher aspects of UFD-ES and UFD-NS programs - coupled processes.		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design phase - need techniques established to determine in-package water chemistry. High importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Insufficient information regarding other specific media.
Potential interactions with DOE-EM: Cement Barrier Partnership (CBP) Interface with UFD-ES and UFD-NS programs - coupled processes		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Medium importance at site characterization/design phase - need techniques established to determine in-package water chemistry. High importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Partially sufficient at site characterization/design phase for "traditional" backfills/buffers - insufficient for new/novel materials. Insufficient information at site suitability phase.
Interface with UFD-ES and UFD-NS programs - coupled processes		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Highly dependent on design concept Low importance at site characterization/design phase - need techniques established to determine in-package water chemistry. Low importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Insufficient information regarding other specific media.
Potential interactions with DOE-EM: Cement Barrier Partnership (CBP) Interface with UFD-ES and UFD-NS programs - coupled processes		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Highly dependent on design concept Medium importance at site characterization/design phase - need techniques established to determine in-package water chemistry. High importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Insufficient information regarding other specific media.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.09.09	Chemical Effects at EBS Component Interfaces	- Component-to-component contact (chemical reactions) - Consolidation of EBS components - Barrier degradation at EBS component interfaces	Partial - Design Specific	Depends on design and materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution at candidate EBS maerial interfaces (modeling).	High	Medium	Low	Expected to be of high importance to long-term barrier performance - interactions at waste package/waste form interface may be of more importance. Interface at buffer/backfill and rock interface may also be of importance. Degradation of metallic barriers at the buffer/backfill interface can be very important in the generation of 'redox barriers' that could enhance barrier performance with time. Also, interfacial domains can also served as loci for large transport and chemical gradients where these could strongly influence the overall barrier performance. Exptected to be of medium importance to repository design and construction - could affect selection of materials Estimated at medium importance for overall confidence - demonstration of understanding of geochemical conditions at interfaces - could affect transport properties	Fundamental Gaps in Method, Fundamental Data Needs	Identification of key interaction at EBS barrier interfaces needs to be established. Clay-metal barrier interfaces can be subjected to metal barrier degradation (e.g., metal corrosion) due to the presence of hydrous phases (clays) that could dehydrate at elevated temperatures. Models and experiments need to be developed to assess these interactions with fluids at barrier interfaces and their effects to barrier performance.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.09.10	Chemical Effects of Waste Rock Contact (ASSUMING AS EBS - ROCK CONTACT)	- Waste-to-host rock contact (chemical reactions) - Component-to-host rock contact (chemical reactions)	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in EBS and host-rock. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Generic R&D on this issue would be captured in R&D for 2.1.09.04					
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.09.11	Electrochemical Effects in EBS	- Enhanced metal corrosion	Partial - Design Specific	Depends on design and metallic materials that would be included in EBS. Generic R&D would focus primarily on methods to quantify effects (modeling).	Included with R&D on all corrosion processes for metallic materials (2.1.03 and 2.1.06)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	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]	Partial - Site Specific, Design Specific	Depends on design and materials that would be included in EBS and host-rock. Generic R&D would focus primarily on methods to quantify chemistry and represent evolution (modeling).	Included with R&D on all corrosion processes for metallic materials (2.1.09.03 and 2.1.09.04)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	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 [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]	Yes	Strong link to geochemistry, material selection, design, and emplaced waste forms. Generic R&D would focus on method development (experimental and analytic) and quantification of parameters where independence with specific media can be shown.	High	Medium	High	Expected to be of high direct importance to long-term performance - solubility controls effect radionuclide release from the EBS. Exptected to be of medium importance to repository design and construction - could affect EBS material selection and design Estimated at high importance for overall confidence - key part of safety case	Improved Representation	Considerable work has been done in the U.S. and in other countries regarding radionuclide speciation and dissolved concentration limits. Improved understanding of solubility controls and dissolved concentration limits would lead to improved radionuclide transport models and better understanding of disposal system performance. Large knowledge gaps on radionuclide solubilities at elevated temperatures and in concetrated electrolyte solutions. Accurate redox speciation chemistry of important radionuclides such as Pu and Np are still a matter of investigation. Improved understanding of potential solubility-controlling phases for radionuclides with mixed compositions (i.e., not necessarily pure end-members). Complex water chemistry / solid solutions in EBS Methods - Experimental and representation (model) Phases / controls for advanced fuel compositions - data and methods needs
		2.1.09.50	1.09. CHEMICAL PROCESSES - TRANSPORT									
Limited Release - Enineered Barriers	Engineered Barriers	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 -Saturation [see also Gas Phase Transport in 2.1.12.03]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	High	Medium	High	Expected to be of high direct importance to long-term performance in certain environments - EBS transport affects release rate into the natural system. Exptected to be of medium importance to repository design and construction. Estimated at high importance for overall confidence - key part of safety case	Fundamental Gaps in Method, Fundamental Data Needs	Considerable work has been done in the U.S. and in other countries regarding EBS transport. Improved understanding of EBS transport processes would lead to improved radionuclide transport models and better understanding of disposal system performance. For backfilled repositories, focus should be given to diffusive transport through barriers and waste package. Thermal loading from WF is important

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Potential interactions with DOE-EM: Cement Barrier Partnership (CBP) Interface with UFD-ES and UFD-NS programs - coupled processes		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Not applicable at site screening or site selection phases. Highly dependent on design concept Medium importance at site characterization/design phase - need techniques established to determine in-package water chemistry. High importance at site suitability phase - understanding would need to support defensible representation of EBS performance and EBS design, including interactions. Insufficient information regarding other specific media.
Interface with Separations/Waste Form campaign and NEAMS - need understanding of speciation and solubility constraints within waste forms.		Medium: Information supports or improves decisions	Completely sufficient (no additional info needed)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	Medium importance at site screening phase - would prefer sites with geochemical conditions that would favor low solubility limits for key radionuclides. Current information base is deemed sufficient. Medium importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process High importance at site characterization/design phase - need techniques established to determine solubility controls. High importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls.
Interface with Separations/Waste Form Campaign regarding radionuclide transport representation within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches.		N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Medium importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. High importance at site characterization/design phase - need techniques established to determine solubility controls. High importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Enineered Barriers	Engineered Barriers	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 - Saturation	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate diffusive transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	High	Medium	High	Expected to be of high direct importance to long-term performance in certain environments - EBS transport affects release rate into the natural system. Expteted to be of medium importance to repository design and construction. Estimated at high importance for overall confidence - key part of safety case	Fundamental Gaps in Method, Fundamental Data Needs	Considerable work has been done in the U.S. and in other countries regarding EBS transport. Improved understanding of EBS transport processes would lead to improved radionuclide transport models and better understanding of disposal system performance. For backfilled repositories, focus should be given to diffusive transport through barriers and waste package. Thermal loading from WF is important
Limited Release - Enineered Barriers	Engineered Barriers	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 - Saturation [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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate sorption processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	High	Medium	High	Could be of high direct importance to long-term performance in certain environments - EBS transport affects release rate into the natural system. Expteted to be of medium importance to repository design and construction. Estimated at high importance for overall confidence - could be key part of safety case	Fundamental Gaps in Method, Fundamental Data Needs	Considerable work has been done in the U.S. and in other countries regarding EBS transport and sorption processes relevant to radionuclides. Improved understanding of EBS transport processes, in particular sorption, would lead to improved radionuclide transport models and better understanding of disposal system performance. Current modeling work on reactive-transport through barriers is being considered and will be expanded to include radionuclides.
Limited Release - Enineered Barriers	Engineered Barriers	2.1.09.54	Complexation in EBS	- Formation of organic complexants (humates, fulvates, organic waste) - Enhanced transport of radionuclides associated with organic complexants - Inorganic complexation (alkali, metal) captured in chemical equilibrium models [see also Degradation of Organics in Waste in 2.1.02.03]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate complexation processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Medium	Low	Low	Do not anticipate the presence organic comlexants in deep geologic disposal environments due to Waste Acceptance Criteria and site environment. However, this can be site specific, for example, the Boom clay formation whose pore waters contain a fair amount of dissolved organics.	Fundamental Gaps in Method, Fundamental Data Needs	Carbon- and sulphate-bearing phases will be likely present at the repository environment. Seal material made of asphalt have bitumen that can degrade into CO2 and organic phases. Interactions between sulphate- and iron-beraing phases in the present or absence of organics needs to be accurately represented in models given the importance of potential redox buffers in the EBS environment.
Limited Release - Enineered Barriers	Engineered Barriers	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) - Formation of co-precipitated colloids - Sorption/attachment of radionuclides to colloids (clay, silica, waste form, FeOx, microbes)	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate colloid formation processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Medium	Medium	Medium	Advanced waste forms may generated colloids that could potentially be important with respect to radionuclide transport. There is potential for colloid formation in clay barriers as a result barrier erosion and mechanical degradation. Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research. The role of humics, fulvics and other organic materials has been widely studied in the EU.

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Separations/Waste Form Campaign regarding radionuclide transport representation within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches.		N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Medium importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. High importance at site characterization/design phase - need techniques established to determine solubility controls. High importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding radionuclide transport representation within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches.		N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Medium importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. High importance at site characterization/design phase - need techniques established to determine solubility controls. High importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding radionuclide transport representation within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches.		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Enineered Barriers	Engineered Barriers	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 setting)	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate colloid formation processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Medium	Medium	Medium	Advanced waste forms may generated colloids that could potentially be important with respect to radionuclide transport. There is potential for colloid formation in clay barriers as a result barrier erosion and mechanical degradation. Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research. The role of humics, fulvics and other organic materials has been widely studied in the EU.
Limited Release - Enineered Barriers	Engineered Barriers	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	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Also dependence on importance of colloid formation and stability within the EBS (if they don't form or are unstable, then transport is not applicable) Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Low	Low	Low	Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research. The role of humics, fulvics and other organic materials has been widely studied in the EU.
Limited Release - Enineered Barriers	Engineered Barriers	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	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Also dependence on importance of colloid formation and stability within the EBS (if they don't form or are unstable, then transport is not applicable) Generic R&D would investigate diffusive transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Low	Low	Low	Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research.
Limited Release - Enineered Barriers	Engineered Barriers	2.1.09.59	Sorption of Colloids in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel	- 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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Also dependence on importance of colloid formation and stability within the EBS (if they don't form or are unstable, then transport is not applicable) Generic R&D would investigate colloid sorption processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Low	Low	Low	Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research. The role of humics, fulvics and other organic materials has been widely studied in the EU.
Limited Release - Enineered Barriers	Engineered Barriers	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]	No	Site Specific, Design Specific						

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Enineered Barriers	Engineered Barriers	2.1.09.61	Filtration of Colloids in EBS	- Physical filtration (dependent on flow pathways, colloid size) - Electrostatic filtration - Colloid trapping at the air-water interface [see Sorption of Colloids at Air-Water Interface in EBS 2.1.09.60]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Also dependence on importance of colloid formation and stability within the EBS (if they don't form or are unstable, then transport is not applicable) Generic R&D would investigate colloid sorption processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Low	Low	Low	Colloid transport requires certain conditions for the hosting media which are not expected in buffer/backfill repository environments.	Fundamental Gaps in Method, Fundamental Data Needs	Although colloids might form, their role in transport will be highly dependent on other parameters of the EBS. Colloidal phases may have an important effect of radionuclide solubility but their stability under various conditions and their role as soilubility-controlling phases is still a matter of research. The role of humics, fulvics and other organic materials has been widely studied in the EU.
Limited Release - Enineered Barriers	Seals	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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate diffusive/advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Included with R&D on EBS radionuclide transport (2.1.09.51 through 2.1.09.54)					
Limited Release - Enineered Barriers	Engineered Barriers	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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate diffusive/advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes. Parameters could be determined for EBS materials if independent from site/media and specific design.	Included with R&D on EBS radionuclide transport (2.1.09.51 through 2.1.09.54)					
		2.1.10.00	1.10. BIOLOGICAL PROCESSES									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.10.01	Microbial Activity in EBS - Natural - Anthropogenic	- Effects on corrosion - Formation of complexants - Formation of microbial colloids - Formation of biofilms - Biodegradation - Biomass production - Bioaccumulation [see also Microbialllly Influenced Corrosion in 2.1.03.06, Complexation in EBS in 2.1.09.54, Radiological Mutation of Microbes in 2.1.13.03]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media . Generic R&D would investigate these issues for individual barrier materials as part of material degradation and radionuclide transport R&D	Included with R&D on EBS degradation and radionuclide transport processes/issues above					
		2.1.11.00	1.11. THERMAL PROCESSES									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.01	Heat Generation in EBS	- 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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept, wastes emplaced, site/media . Generic R&D would investigate improved methods for representing heat transfer in geologic environments and different design concepts Simpleer approaches and methods to support system-level analyses. Improved coupled THMC representation for future application in safety analyses.	High	High	High	Heat distribution in the EBS is important to repository design and EBS material performance.	Fundamental Data Needs	Work has been done in the U.S. and in other countries regarding to the effect of heat on EBS performance. Strong influence to THCM coupled processes in the EBS. Thermal management criteria is strongly tied to barrier concept and performance. THCM models and data needs are essential to the assessment of barrier performance.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Separations/Waste Form Campaign regarding colloid formation/stability within waste forms. Interface with NEAMS and DOE-EM ASCEM program in the development of advanced radionuclide transport models. Interface with UFD-NS program in development of radionuclide transport modeling approaches (as applicable to colloids).		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - potential for coupled processes Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance. Current information base is deemed partially sufficient. Medium importance at site characterization/design phase - need techniques established to determine solubility controls. Medium importance at site suitability phase - understanding would need to support defensible representation of radionuclide transport controls. At each level, information is available to represent EBS transport, but would have to be applied to specific environments/media/designs. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.
Interface with Separations/Waste Form Campaign, Systems Analysis campaign, and FCT Systems Engineering efforts. Thermal load assessment from inventories, and dependencies on EBS design concepts. Interface with UFD-NS program on coupled THMC modeling		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance and determining potential 'footprint' of disposal facility within candidate sites. Current information base is deemed partially sufficient. High importance at site characterization/design phase - supports development of design and initial assessments of disposal system performance (safety analysis). High importance at site suitability state - need understanding of heat generation and THMC processes, defensible representations. R&D would lead to improved methods. Thus, adequacy of information is deemed partially sufficient at all decision points.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.02	Exothermic Reactions in EBS	- Oxidation of SNF - Hydration of concrete	Partial - Site Specific, Design Specific	Dependent on materials emplaced as part of EBS. Anticipate that exothermal reactions would not have significant impact on disposal system. Generic R&D could focus on determining potential for different EBS materials	N/A	N/A	N/A	Expected to be of low impact in backfilled repository environments	Fundamental Gaps in Method, Fundamental Data Needs	Assessment of the effects from exothermic reactions could be approached from the thermochemical properties of EBS materials. Information needed for advanced fuels that could potentially be direct disposed and waste forms.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.03	Effects of Backfill on EBS Thermal Environment	- Thermal blanket - Condensation	Partial - Site Specific, Design Specific	Dependent on EBS design concept backfill/buffer materials, and site/media . Generic R&D would investigate thermal properties and evolution of backfill/buffer materials in thermal environments. This would be coupled with R&D on the evolution and effects in EBS backfill materials.	High	Medium	High	Applicable to design concepts that include buffer/backfill materials. Lower importance to deep borehole concepts because primary backfill/seal is above the waste and not expected to be affected by the thermal pulse. Heat distribution in the EBS is important to repository design and EBS material performance.	Fundamental Gaps in Method, Fundamental Data Needs	Work has been done in the U.S. and in other countries regarding to the effect of heat transport on EBS performance. Strong influence to THCM coupled processes in the EBS. Thermal management criteria is strongly tied to barrier concept and performance. THCM models and data needs are essential to the assessment of barrier performance. Little/no information regarding new/novel backfill/buffer materials
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.04	Effects of Drift Collapse on EBS Thermal Environment	- Thermal blanket - Condensation	Partial - Site Specific, Design Specific	Dependent on EBS design concept backfill/buffer materials, and site/media . R&D to asses generic impacts, but detailed R&D would require identification of site(s) and design concept(s).	Medium	Medium	Low	Importance to performance estimated at medium. May be N/A for some design concepts and environments. Estimated to be of medium importance to design - could limit emplacement "room" or tunnel size. Low importance assumed for overall confidence importance Low importance for backfilled repository designs in hard or sedimentary rock.	Fundamental Gaps in Method, Fundamental Data Needs	Relevant to construction operations, waste emplacement, and the emplacement of backfill material. THM processes could enhance the excavated damage zone thus influencing the hydraulic properties of the EBS backfill/buffer materials.
Containment, Limited Release Engineered Barriers	Engineered Barriers	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]	Partial - Site Specific, Design Specific	Dependent on EBS design concept backfill/buffer materials, and site/media. Would be considered in overall R&D on EBS thermal environment. May not be applicable to some sites and design concepts (i.e., low-heat or thermally constrained)	Included with R&D on Heat Generation in EBS processes/issues above (2.1.11.01)					
Containment, Limited Release Engineered Barriers	Waste Form	2.1.11.06	Thermal-Mechanical Effects on Waste Form and In-Package EBS Components	- Alteration - Cracking - Thermal expansion / stress	Partial - Site Specific, Design Specific	R&D to asses SNF material mechanical behavior	Included with R&D on mechanical properties of and effects on backfill processes/issues above (2.1.07.06 and 2.1.07.07)					
Containment, Limited Release Engineered Barriers	Waste Packaging	2.1.11.07	Thermal-Mechanical Effects on Waste Packages	- Thermal sensitization / phase changes - Cracking - Thermal expansion / stress/ creep	Partial - Site Specific, Design Specific	Cannot do specific R&D without design and environment. Can perform generic R&D to asses waste package material mechanical behavior	Included with R&D on mechanical properties of and effects on waste package processes/issues above (2.1.07.05)					
Containment, Limited Release Engineered Barriers	Backfill/Buffer	2.1.11.08	Thermal-Mechanical Effects on Backfill	- Alteration - Cracking - Thermal expansion / stress	Partial - Site Specific, Design Specific	Specific R&D would require establishment of design and selection of material. Generic R&D could be conducted on backfill/buffer materials independent of design.	Included with R&D on mechanical properties of and effects on backfill processes/issues above (2.1.07.03 and 2.1.07.04)					
Containment, Limited Release Engineered Barriers	Other Engineered Features	2.1.11.09	Thermal-Mechanical Effects on Other EBS Components - Seals - Liner / Rock Reinforcement Materials - Waste Package Support Structure	- Alteration - Cracking - Thermal expansion / stress	Partial - Site Specific, Design Specific	Also media specific. Specific R&D would require establishment of sub-surface design and selection of materials - compatible with site/media. Generic R&D could be conducted to assess materials mechanical behavior independent of design and site/media.	Included with R&D on mechanical properties of and effects on waste package processes/issues above (2.1.07.08)					

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Separations/Waste Form and Fuels campaigns and FCT System Engineering - identify if any materials have potential for exothermic reactions.		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Highly dependent on materials that would be emplaced Not applicable at site screening or site selection phase. Low importance at site characterization/design phase and medium at site suitibality phases - need to understand materials that would be emplaced and liklihood of exothermic reactions. If it needs to be included, defensible representations would have to be developed to support safety analysis. Adequacy of information is deemed insufficient as no information is known regarding potential of advanced fuels and waste forms for exothermic reactions.
Interface with NEAMS		N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening phase. Low importance at site selection phase - need high level representation for evaluating performance and determining potential 'footprint' of disposal facility within candidate sites. Current information base is deemed partially sufficient. High importance at site characterization/design phase - supports development of design and initial assessments of disposal system performance (safety analysis). Improved understanding for "traditional" backfill/buffer materials, no information available for new/novel backfill materials - current information is partially adequate. High importance at site suitability state - need understanding of backfill/buffer thermal behavior. R&D would lead to improved methods and information for traditional and new/novel backfill/buffer materials. Thus, adequacy of information is deemed insufficient at this decision point.
Interface with UFD-NS program		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Highly dependent on design concept, meaterials selected, waste emplaced, and thermal environment - strongly coupled process Not applicable at site screening and site selection phases. Medium importance at site characterization/design and site suitability phases - supports development of design and initial assessments of disposal system performance (safety analysis). Need understanding of impacts on thermal behavior (and other processes). Adequacy of information is deemed insufficient at these decision points.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.10	Thermal Effects on Flow in EBS	- Altered influx/seepage - Altered saturation / relative humidity (dry-out, resaturation) - Condensation - Relevant to deep-borehole and salt repository concepts	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	Included with R&D on Heat Generation in EBS processes/issues above (2.1.11.01)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.11	Thermally-Driven Flow (Convection) in EBS	- Convection	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	Included with R&D on Heat Generation in EBS processes/issues above (2.1.11.01)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.12	Thermally-Driven Buoyant Flow / Heat Pipes in EBS	- Vapor flow	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	Included with R&D on Heat Generation in EBS processes/issues above (2.1.11.01) and EBS hydrologic processes/issues above (2.1.08)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.13	Thermal Effects on Chemistry and Microbial Activity in EBS		Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	Included with R&D on Heat Generation in EBS processes/issues above (2.1.11.01) and EBS hydrologic processes/issues above (2.1.08)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.11.14	Thermal Effects on Transport in EBS	- Thermal diffusion (Soret effect) - Thermal osmosis	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate advective transport processes in materials for individual barriers and components of the EBS. Focus would be on methods development and controlling processes.	Included with R&D on EBS transport processes/issues above (2.1.09.51 through 2.1.09.61)					
		2.1.12.00	1.12 GAS SOURCES AND EFFECTS									
Containment, Limited Release Engineered Barriers	Engineered Barriers	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 waste package corrosion - CO_2, CH_4, and H_2S generation from microbial degradation	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate potential for gas generation from emplacement of wastes and EBS materials.	High	Low	Low	Gas transport could be very important in controlling EBS chemistry in backfilled and low-permeability repository concepts.	Fundamental Gaps in Method, Fundamental Data Needs	There are needs for modeling approaches and experimental data to accurately assess the importance of gas transport through EBS.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.12.02	Effects of Gas on Flow Through the EBS	- Two-phase flow - Gas bubbles [see also Buoyant Flow/Heat Pipes in 2.1.11.12]	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate impacts of gas on groundwater flow through EBS materials.	High	Low	Low	Gas transport could be very important in controlling EBS chemistry in backfilled repository concepts.	Fundamental Gaps in Method, Fundamental Data Needs	There are needs for modeling approaches and experimental data to accurately assess the importance of gas transport through EBS.
Limited Release - Enineered Barriers	Engineered Barriers	2.1.12.03	Gas Transport in EBS	- Gas phase transport - Gas phase release from EBS	Partial - Site Specific, Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Generic R&D would investigate impacts of gas on radionuclide transport through EBS materials.	High	Medium	Low	Gas transport could be very important in controlling EBS chemistry in backfilled repository concepts.	Fundamental Gaps in Method, Fundamental Data Needs	There are needs for modeling approaches and experimental data to accurately assess the importance of gas transport through EBS.

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with WF and potentially NEAMS		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, and waste emplaced. Not applicable at site screening and site selection phases. Medium importance at site characterization/design and site suitability phases - potential for gas generation could affect design and safety analysis. Need understanding of potential for gas generation from emplaced materials. Since materials are not known, adequacy of information is deemed insufficient at this decision point.
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, and waste emplaced. Not applicable at site screening and site selection phases. Medium importance at site characterization/design and site suitability phases - potential for gas "enhanced" flow and transport could affect design and safety analysis. Need understanding of potential for gas generation from emplaced materials. Since materials are not known, adequacy of information is deemed insufficient at this decision point.
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Highly dependent on design concept, meaterials selected, and waste emplaced. Not applicable at site screening and site selection phases. Medium importance at site characterization/design and site suitability phases - potential for gas "enhanced" flow and transport could affect design and safety analysis. Need understanding of potential for gas generation from emplaced materials. Since materials are not known, adequacy of information is deemed insufficient at this decision point.

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.12.04	Gas Explosions in EBS	[see also Flammable Gas from Waste in 2.1.02.05]	No	Likely to be precluded by waste acceptance and facility design criteria						
		2.1.13.00	1.13. RADIATION EFFECTS									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.13.01	Radiolysis - In Waste Package - In Backfill - In Tunnel	- Gas generation - Altered water chemistry	Partial - Design Specific	Dependent on EBS design concept (disposal facility geometry and materials) and site/media (advection/diffusion dominated system). Included in generic R&D regarding EBS geochemistry	Included with R&D on EBS geochemical processes/issues above (2.1.09.06 through 2.1.09.09)					
Containment, Limited Release Engineered Barriers	Engineered Barriers	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)	Yes	Applicable to directly disposed SNF waste forms only. Could have effect on waste packaging and buffer/backfill for very "hot" HLW.	Low	Low	Low	Effects of radiation are likely to be more important at gap and grain boundary or other domains where defects are more likely to be found. Enhancement of waste form degradation requires the presence of liquid water for this process to be highly effective. The effects of radiation on EBS is likely to be minimal given the shielding of waste package components, however it could occur for very "hot" waste forms.	Fundamental Gaps in Method, Fundamental Data Needs	Anticipated to be of low impact to the overall repository performance.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.13.03	Radiological Mutation of Microbes		No	Site Specific Also very likely to be screened out. It is highly unlikely that microbes could mutate into something that somehow utilizes a different metabolic pathway than one that is currently in existence.						
		2.1.14.00	1.14. NUCLEAR CRITICALITY									
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.14.01	Criticality In-Package	- Formation of critical configuration	Partial - Design Specific	Site and design specific	Low	Medium	High	Burnup credit, poison inserts Medium for "Design, Construction, Operations" if burnup credit strongly influence amount of waste to be emplaced - could influence design criteria	Fundamental Data Needs	Data for burnup credit assessment Fuels from advanced fuel cycles that would be directly disposed and/or advanced waste forms may have different concentrations of fissile isotopes and poisons, necessitating the need to assess the potential for nuclear criticality.
Containment, Limited Release Engineered Barriers	Engineered Barriers	2.1.14.02	Criticality in EBS or Near-Field	- Formation of critical configuration	Partial - Design Specific	Methods development, demonstration in potential plausible configurations Design specific Lack of validation data for critical configuration	Low	Medium	High	Burnup credit, poison inserts Medium for "Design, Construction, Operations" if burnup credit strongly influence amount of waste to be emplaced - could influence design criteria	Fundamental Data Needs	Data for burnup credit assessment Fuels from advanced fuel cycles that would be directly disposed and/or advanced waste forms may have different concentrations of fissile isotopes and poisons, necessitating the need to assess the potential for nuclear criticality.
		2.2.00.00	2. GEOLOGICAL ENVIRONMENT									
		2.2.01.00	2.01. EXCAVATION DISTURBED ZONE (EDZ)									
Limited Release - Natural Barriers	Natural System - Geosphere	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 - Thermal-chemical alteration [see also Mechanical Effects of Excavation in 1.1.02.02]	Partial - Site Specific, Design Specific	And Operational Specific Generic studies to evaluate potential in generic systems, identify key processes, potential impacts, importance	High	High	High	Radionuclide mobility and transport pathways directly impacts long-term repository performance. Short term room closure directly impacts repository desgin , constrcution, and operations for salt or clay disposal environments.	Fundamental Data Needs	Need to know the evolution of the characteristics of the EDZ under the thermal-mechanical and wetting changes (clay and salt). Need to understand the coupled evolution of near-field host rock (EDZ) and backfill. Considerable work has been done for WIPP and European programs. European programs starting multi-year projects investigating thermal-mechanical and moisture effects in the EDZ. This issue includes other disturbances (e.g., ventilation) beyond just excavation effects.
		2.2.02.00	2.02. HOST ROCK									
All	Natural System - Geosphere	2.2.02.01	Stratigraphy and Properties of Host Rock	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts - Physical properties - Flow pathways [see also Fractures in 2.2.05.01 and Faults in 2.2.05.02]	Partial - Site Specific	Characterization methods	High	Medium	High	Rock heterogeneities and extetns directly impact far-field performance in waste isolation.	Fundamental Gaps in Method	Many site characterization methods have been developed for repository and other related programs (EM, carbon sequestration). More refined methods can be developed to define flow paths (discontinuities, heterogenities, fracture connectivity, and uncertainty quantification).
		2.2.03.00	2.03. OTHER GEOLOGIC UNITS									

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with Separations/Waste Form Campaign. Impacts and effects of radiation damage on waste forms should be considered in their R&D on degradation processes.		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Low: Information useful but not necessary	Insufficient (cannot adequately represent issue)	Not applicable at site screening and site selction phases. Low importance at site characterization / design and site suitability phases. Information for advanced fuels and waste forms not know, thus information is deemed insufficient to support these decision points.
Interface with Fuels and Separations/Waste Form campaign and UFD - storage / transportation program (potentially degraded conditions)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Not applicable at site screening and site selction phases. Medium importance at site characterization / design and site suitability phases. Information for waste package configurations, advanced fuels, and waste forms not know, thus information is deemed insufficient to support these decision points.
Interface with Fuels and Separations/Waste Form campaign and UFD - storage / transportation program (potentially degraded conditions)		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Not applicable at site screening and site selction phases. Medium importance at site characterization / design and site suitability phases. Information for waste package configurations, advanced fuels, and waste forms not know, thus information is deemed insufficient to support these decision points.
Interface with UFD-ES program - coupled processes	Granite/Crystalline	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Progress has been made in the UFD program in the development of constitutive relationships and thermal-hydrologic-mechanical and chemical models for simulating EDZ evolution in both clay and salt repositories.
	Deep Boreholes	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	
	Salt	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	
	Granite/Crystalline	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	Progress has been made in the UFD program in collecting regional geological data and archiving the data using a GIS system.
	Deep Boreholes	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
All	Natural System - Geosphere	2.2.03.01	Stratigraphy and Properties of Other Geologic Units (Non-Host-Rock)	- Rock units - Thickness, lateral extent, heterogeneities, discontinuities, contacts - Physical properties - Flow pathways [see also Fractures in 2.2.05.01 and Faults in 2.2.05.02]	Partial - Site Specific	Characterization methods	High	Low	High	Other geologic units may define far field release pathways. Judged to be high for performance (safety analysis), low for design, construction and operations, (Information about other geologic units above the repository horizon is necessary for the development of ramps, shafts, and seals) and high for overall confidence.	Improved Representation	Many site characterization methods have been developed for repository and other related programs. Can be grouped with issues in 2.2.02.01. Different investigation methods (e.g., from surface rather than from underground excavation) may be used.
		2.2.05.00	2.05. FLOW AND TRANSPORT PATHWAYS									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.05.01	Fractures - Host Rock - Other Geologic Units	- Rock properties [see also Stratigraphy and Properties in 2.2.02.01 and 2.2.03.01]	Partial - Site Specific	Characterization methods	High	Low	High	Fractures are an important release pathway for crystalline repositories.	Fundamental Gaps in Method	Modeling sparsely fractured media is challenging. Need to develop improved modeling tools to represent fractures/fracture sets as discrete features. Need information to characterize/model connectivity, channelization (e.g., tracer tests).
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 - Plugging of flow pathways - Changes in saturation [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]	Partial - Site Specific	Characterization methods and methods for modeling evolution	Low	N/A	Low	Rock property changes in flow pathways can generally be screened out. Alkaline plume from the near field may need to be considered. Importance to the safety analysis may be higher for salt - Interbed fracturing resulting from gas generation.	Improved Confidence	Data for validation is lacking. Some gaps may exist in modeling the interaction of chemical (alkaline) plume with the surrounding rocks. Column experiments and natural analogues could be used for understanding the alkaline plume.
		2.2.07.00	2.07. MECHANICAL PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.07.01	Mechanical Effects on Host Rock	- From subsidence - From salt creep - From clay deformation - From granite deformation (rockfall / drift collapse into tunnels - Chemical precipitaiton/ 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]	Partial - Site Specific, Design Specific	Can be addressed generically for different rock types	High	High	High	Mechanical effects are more important in near-field than far-field. Importance is dependent of rock type	Fundamental Gaps in Method, Fundamental Data Needs	European programs starting multi-year projects investigating thermal-mechanical and moisture effects. Note that there are also international collaborations in EM Need to interface with EBS.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.07.02	Mechanical Effects on Other Geologic Units	- From subsidence - 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]	Partial - Site Specific	Can be addressed generically for different rock types	Medium	N/A	Medium	Less important than host rock except for glaciation	Fundamental Gaps in Method, Fundamental Data Needs	Need to refine geomechanical modeling techniques. Need to validate models for glacial loading/unloading. Need natural analogue data.
		2.2.08.00	2.08. HYDROLOGIC PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.01	Flow Through the Host Rock	- Saturated flow - Fracture flow / matrix imbibition - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways - Density effects on flow - Flow pathways in 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]	Partial - Site Specific	Characterization and modeling methods	High	Low	High	Flow regimes and pathways are important factors for long-term performance assessments. See also discussion in FEP 2.2..05.01	Fundamental Gaps in Method, Fundamental Data Needs	Need to develop improved modeling tools to represent fractures/fracture sets as discrete features in crystalline. Need information to characterize/model connectivity, channelization (e.g., tracer tests). Need to understand fracturation and healing in clays and salt. Water migration in salt is a unique process that needs to be better understtod. Need to understand thermal and pressure gradients and gas generation and migration. Need to capture and validate uncertainty.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.02	Flow Through the Other Geologic Units - Confining units - Aquifers	- Saturated flow - Fracture flow / matrix imbibition - Unsaturated flow (fingering, capillarity, episodicity, perched water) - Preferential flow pathways - Density effects on flow - 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 Flow in 2.2.12.02]	Partial - Site Specific	Characterization and modeling methods	High	Low	High	Flow regimes and pathways are important factors for long-term performance assessments.	Fundamental Gaps in Method, Fundamental Data Needs	Need to develop improved modeling tools to represent fractures/fracture sets as discrete features in crystalline. Need information to characterize/model connectivity, channelization (e.g., tracer tests). Need to capture and validate uncertainty.

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
	Granite/Crystalline	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Deep Boreholes	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.** Current UFD activities focus on the development of discrete fracture network (DFN) model for fracture media and the collection of field data for model validation. A prototype DFN was developed.
	Deep Boreholes	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.** The UFD program has initiated international collaborations on DECOVALEX and Mont Terri tests on mechanical properties of clay materials.
	Deep Boreholes	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.03	Effects of Recharge on Geosphere Flow - Host Rock - Other Geologic Units	- Infiltration rate - Water table rise/decline [see also Infiltration 2.3.08.03]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 [see also Influx/Seepage into EBS in 2.1.08.09]	Partial - Site Specific, Design Specific	Modeling methods	Medium	Low	Medium	Alteration to flow field around excavation may be important. Need to consider effects on flow with and without backifll/sealing. More important in lower permeability media.	Fundamental Gaps in Method	Requires same R&D as FEP 2.2.08.01.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.05	Condensation Forms in Host Rock	- Condensation cap - Shedding [see also Thermal Effects on Flow in Geosphere in 2.2.11.01]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.06	Flow Through EDZ	- Saturated / Unsaturated flow - Fracture / Matrix flow	Partial - Site Specific, Design Specific	Modeling methods	High	Low	High	Flow regimes and pathways are important factors for long-term performance assessments.	Fundamental Gaps in Method, Fundamental Data Needs	Flow in the EDZ is closely tied to the evolution of the EDZ. R&D related to FEP 2.2.01.01
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.07	Mineralogic Dehydration	- Dehydration reactions release water and may lead to volume changes	Partial - Site Specific, Design Specific	Important for a clay repository	Low	Medium	Low	Dehydration may change the hydrologic properties of the near field and may also impact the repository excavation and operation. Need to understand dessication behavior of clay.	Fundamental Gaps in Method, Fundamental Data Needs	Significant work has been done. But signicant gaps exist in modeling the coupled THMC processes. This is most important in clay. R&D related to FEP 2.2.01.01
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.08	Groundwater Discharge to Biosphere Boundary	- Surface discharge (water table, capillary rise, surface water) - Flow across regulatory boundary	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.08.09	Groundwater Discharge to Well	- Human use (drinking water, bathing water, industrial) - Agricultural use (irrigation, animal watering)	No	Site Specific						
		2.2.09.00	2.09 CHEMICAL PROCESSES - CHEMISTRY									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.01	Chemical Characteristics of Groundwater in Host Rock	- Water composition (radionuclides, dissolved species, …) - Water chemistry (temperature, pH, Eh, ionic strength …) - Reduction-oxidation potential - Reaction kinetics - Interaction with EBS - Interaction with host rock [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]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	N/A	High	Water chemistry directly impact radionuclide transport in both the near field and far field.	Fundamental Gaps in Method, Fundamental Data Needs	Methods for characterizing groundwater chemistry and models to predict water chemistry evolution in the near field need to be futher improved. Need to define a generic chemistry for each geologic environment. Need to identify interactions with EBS materials (e.g., introduced fluids, alkaline plume from the near field). R&D to determine potential for identifcation of favorable and/or unfavorable groundwater chemistries. Need to characterize effect of microbial activity on water chemistry. Need to identify chemical sampling methods to characterize initial fluid composition (e.g., clay, unsaturated rock). Evaluate interactions of various waste forms/waste streams with various chemical environments. Identify method to characterize groundwater composition - spatial and temporal variability, scale dependence Salt - Need to understand brine chemistry, interaction of high ionic strength brine with EBS components Need better characterization of deep crystalline water chemistry (deep boreholes).
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 …) - Reduction-oxidation potential - Reaction kinetics - Interaction with other geologic units [see also Chemical Interactions and Evolution in 2.2.09.04]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	N/A	High	See FEP 2.2.09.01	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.01

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
										Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.
	Deep Boreholes	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	The current UFD activities focus on modeling flows in fractured media (e.g. granitic rocks) as well as in low-permeability media (e.g., shale or salt). A prototype of discrete fracture network model was developed. A conceptual model for Non-Darcian flow fine-grain sediments was developed.
	Salt	N/A	N/A	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	High: Information is essential to decisions	Insufficient (cannot adequately represent issue)	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
Interface with UFD-ES program - coupled processes	Granite/Crystalline	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
Interface with UFD-ES program - coupled processes	Deep Boreholes	N/A	N/A	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	Medium: Information supports or improves decisions	Insufficient (cannot adequately represent issue)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues**

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.03	Chemical Interactions and Evolution of Groundwater in Host Rock	- Host rock composition and evolution (granite, clay, salt ...) - 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 [contributes to Chemistry in Host Rock in 2.2.09.01]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Medium	See FEP 2.2.09.01	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.01
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 (granite, clay, salt ...) - Evolution of water chemistry in host rock - Chemical effects on density - Reaction kinetics - Mineral dissolution/precipitation - Recharge chemistry [contributes to Chemistry in Other Geologic Units in 2.2.09.02]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Medium	See FEP 2.2.09.01	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.01
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.05	Radionuclide Speciation and Solubility in Host Rock	- Dissolved concentration limits [controlled by Chemistry in Host Rock in 2.2.09.01]	Partial - Site Specific	Characterization and modeling methods. Includes complexation	High	N/A	High	Radionucldie speciation impacts radionuclide sorption in transport port pathways. Complexation may enhance radionuclide mobility.	Fundamental Gaps in Method, Fundamental Data Needs	Accurate prediction radionuclide of speciation in a natural system under various conditions remains challenging. Thermodynamic data for modeling speciation/solubility for high ionic strength and high temeprature environments is needed. Need methods to fill in thermodynamic data gaps. Need methods to measure insitu redox conditions, characterize actinide/radionuclide speciation, and model radionuclide speciation for a range of redox conditions. Signicant work has been done on simple systems. Better characterization of complexants is needed.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.06	Radionuclide Speciation and Solubility in Other Geologic Units (Non-Host-Rock)	- Dissolved concentration limits [controlled by Chemistry in Other Geologic Units in 2.2.09.02]	Partial - Site Specific	See FEP 2.2.09.05	High	N/A	High	See FEP2.2.09.05	Fundamental Gaps in Method, Fundamental Data Needs	See FEP2.2.09.05
		2.2.09.50	2.09. CHEMICAL PROCESSES - TRANSPORT									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.51	Advection of Dissolved Radionuclides in Host Rock	- Flow pathways and velocity - Advective properties (porosity, tortuosity) - Dispersion - Matrix diffusion - Saturation [see also Gas Phase Transport in 2.2.12.03]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	Medium	High	One of the key factors controlling repository performance. Includes all physical transport processes: advection, dispersion, diffusion, dilution Design - Need to avoid major fractures intersecting reposiotry footprint.	Fundamental Gaps in Method, Fundamental Data Needs	The effects of geologic formation heterogeneity and their scale dependence is not fully understood. Need to consider/characterize scale dependence of properties for all physical transport processes. Effect of saturation on physical transport properties has additional uncertainty that could be reduced. Need to better understand bentonite/host rock interface (bentonite saturation) Advection follows flow, see FEP 2.2.08.01. Need to better understand the effect of channeling and advective flow-wetted surfaces on diffusion and sorption. Dispersion - Evaluate alternative advection/dispersion conceptual models. Diffusion - Need better characteriziation / conceptualization of diffusion in small pores (e.g., clays) - membrane effect (EDL overlap). Need generic experimental work (e.g., engiineered materials). Dilution - Well understood.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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, tortuosity) - Dispersion - Matrix diffusion - Saturation [see also Gas Phase Transport in 2.2.12.03]	Partial - Site Specific	See FEP 2.2.09.51	High	N/A	High	See FEP 2.2.09.51	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.51
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.53	Diffusion of Dissolved Radionuclides in Host Rock	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Saturation	Partial - Site Specific	See FEP 2.2.09.51	High	N/A	High	See FEP 2.2.09.51	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.51

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with UFD-ES program - coupled processes	Salt	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	to sub-processes/sub-issues. For the UFD program, chemical charactristics of generic groundwater are being collected and analyzed to support model development.
Interface with UFD-ES program - coupled processes										
International collaborations, DOE-EM and DOE-Science activities	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.54	Diffusion of Dissolved Radionuclides in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers	- Gradients (concentration, chemical potential) - Diffusive properties (diffusion coefficients) - Flow pathways and velocity - Saturation	Partial - Site Specific	See FEP 2.2.09.51	High	N/A	High	See FEP 2.2.09.51	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.51
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.55	Sorption of Dissolved Radionuclides in Host Rock	- Surface complexation properties - Flow pathways and velocity - Saturation [see also Chemistry in Host Rock in 2.2.09.01]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	N/A	High	One of the key paraemters controlling radionuclide retention and migration. High for both the safety analysis and overall confidence in the safety case.	Fundamental Gaps in Method, Fundamental Data Needs	Need to develop improved sorption models (beyond kd) - consider kinetics (irreversibility) Need to develop surface complexation models that account for forces that are non-electrostatic in nature. Need improved models of sorption changes along flow paths (speciation) - also need data (leverage work from EM and Office of Science and International). Need to separate spatial variability from uncertainty in kd values. Improve measurement of multiple samples. Need to be able to extrapolate models/data from simple systems to actual systems. Need to quantify reactive surface area. Field demo sites exist for validation. Data gaps for kds for elevated temperature and high ionic strength media. Need to incorporate these processes in reactive transport models.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 [see also Chemistry in Host Rock in 2.2.09.01]	Partial - Site Specific	See FEP2.2.09.55	High	N/A	High	See FEP 2.2.09.55	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.09.55
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.57	Complexation in Host Rock	- Presence of organic complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants	Partial - Site Specific	See FEP2.2.09.05	High	N/A	High	Complexation may enhance radionuclide mobility. See FEP2.2.09.05	Well Understood	Signicant work has been done on simple systems. Better characrerization of complexants is needed. See FEP2.2.09.05
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.58	Complexation in Other Geologic Units (Non-Host-Rock)	- Presence of organic complexants (humates, fulvates, carbonates, …) - Enhanced transport of radionuclides associated with organic complexants	Partial - Site Specific	See FEP2.2.09.05	High	N/A	High	See FEP2.2.09.05	Well Understood	See FEP2.2.09.05
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.59	Colloidal Transport in Host Rock	- Flow pathways and velocity - Saturation - Advection - Dispersion - Diffusion - Sorption - Colloid concentration	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	High	Colloid-facilitated radionuclide transport may influence total dose release. Colloids are likely to be unstable in salt repositories.	Fundamental Gaps in Method, Fundamental Data Needs	Signicant work has been done. But the puzzle is yet to be put together. Evidence suggests that Pu travels further than kd models would predict. Need improved models that can reproduce this observed behavior. Need improved techniques for insitu characterization and quantification of colloids. Leverage info from NAGRA working group on colloids. Colloid formation - Better understand formation from clay materials, sorption/desorption (attachment/detachment). Colloid instability in high ionic strength environments. Colloid transport - Need to reduce uncertainty in infiltration. Need to better represent heterogeneous behavior of colloids. Need better understanding of colloid transport behavior in unsaturated environments to reduce conservatisms in current models. Muliple rate kinetics and irreversibility of radionuclide sorption onto colloids - better understand size dependence.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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	Partial - Site Specific	See FEP 2.2.09.59	Medium	N/A	High	See FEP 2.2.09.59	Fundamental Gaps in Method, Fundamental Data Needs	Signicant work has been done. But the puzzle is yet to be put together.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.61	Radionuclide Transport Through EDZ	- Advection - Dispersion - Diffusion - Sorption	Partial - Site Specific, Design Specific	Modeling methods	High	N/A	High	One of the key paraemters controlling radionuclide release from the near field. In addition to physical processes, need to look at time-dependent changes in flow path due to mechanical processes. R&D issues are captured in FEP 2.2.01.01.	Fundamental Gaps in Method, Fundamental Data Needs	More thermodynamic data are needed for elevated temperatures.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.62	Dilution of Radionuclides in Groundwater - Host Rock - Other Geologic Units	- Mixing with uncontaminated groundwater - Mixing at withdrawal well [see also Groundwater Discharge to Well in 2.2.08.09]	Partial - Site Specific	See FEP 2.2.09.51	Medium	N/A	Medium	Dilution impacts total dose release	Well Understood	Its effect depends on actual hydrologic conditions.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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	Partial - Site Specific	See FEP 2.2.09.51	Medium	N/A	Medium	The same as above	Well Understood	See FEP 2.2.09.51

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
	Deep Boreholes	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.** Progress has been made in understanding radionuclide interactions with various mineral phases, especially, iodine interations with clay materials and Pu_i with iron oxides and clays. Numerical simulations show that chemcial and structural heterogeneities of geologic media have a signicant effect on radionuclide transport. Inlternational collaobration with Grimsel site on colloidal transport was initiated.
	Salt	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.09.64	Radionuclide Release from Host Rock - Dissolved - Colloidal - Gas Phase	- Spatial and temporal distribution of releases to the Other Geologic Units (due to varying flow pathways and velocities, varying transport properties) [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]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	N/A	High	Directly impact total system performance	Fundamental Gaps in Method, Fundamental Data Needs	The effect of geologic formation heterogeneity is not well understood.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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) [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]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	High	N/A	High	The same as above	Fundamental Gaps in Method, Fundamental Data Needs	The same as above
		2.2.10.00	2.10. BIOLOGICAL PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.10.01	Microbial Activity in Host Rock	Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation [see also Complexation in Host Rock in 2.2.09.57]	Partial - Site Specific	Characterization methods	Medium	N/A	Medium	Microbial actvity may impact radionuclide mobility through modifying water chemsitry and bioaccumulation.	Fundamental Gaps in Method, Fundamental Data Needs	Better methods for quanitify mircobial actvity in a subsurface enviroments and its impact on water chemistry (see FEP 2.2.09.01). Try to leverage work from EM, Office of Science, and WIPP. Better understand how microbes may be limited by environment
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.10.02	Microbial Activity in Other Geologic Units (Non-Host-Rock)	Formation of complexants - Formation and stability of microbial colloids - Biodegradation - Bioaccumulation [see also Complexation in Other Geologic Units in 2.2.09.58]	Partial - Site Specific	Characterization methods	Medium	N/A	Medium	See FEP 2.2.10.01	Fundamental Gaps in Method, Fundamental Data Needs	See FEP 2.2.10.01
		2.2.11.00	2.11. THERMAL PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 - Vapor flow - Condensation	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Medium	Thermal effects in the near-field are more important. Need coupled THCM R&D. See discussion in EDZ FEPs. Releavnt for deep borehole disposal and repository near field. Need to better understand thermal effects on salt and moisture movement in salt Need to better understand thermal effects (dryout) on flow through clay. Need to develop method to support thermal limits (prediction of far field and surface temperatures) Effect on design is medium due to importnace of thermal loading.	Improved Representation	Much can be learned from geothermal studies. Improved representation would be needed for unsaturated sites. Current approach relies on multi-scale model implementation. HPC may provide for more transparent model implementation. Need to collaborate with EBS
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.02	Thermally-Driven Flow (Convection) in Geosphere	- Convection	Partial - Site Specific	See FEP 2.2.11.01	Medium	N/A	Medium	The same as above	Improved Representation	The same as above
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.03	Thermally-Driven Buoyant Flow / Heat Pipes in Geosphere	- Vapor flow	Partial - Site Specific	See FEP 2.2.11.01	Low	N/A	Low	The same as above	Improved Representation	The same as above
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.04	Thermal Effects on Chemistry and Microbial Activity in Geosphere	- Mineral precipitation / dissolution - Altered solubility [contributes to Chemistry in 2.2.09.01 and 2.2.09.02]	Partial - Site Specific	See FEP 2.2.09.01 and 2.2.09.05	High	N/A	High	Highly impact near-field chemistry	Fundamental Gaps in Method, Fundamental Data Needs	Likely to be screened out in far field, but is important in near field/EDZ. Large gap in thermodynamic data at elevated temperatures. Specification of thermodynamic approach for modeling clay dehydration and alteration.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.05	Thermal Effects on Transport in Geosphere	- Thermal diffusion (Soret effect) - Thermal osmosis	Partial - Site Specific	See FEP 2.2.09.51	N/A	N/A	N/A	Likely to be screened out	Improved Representation	no addition data needed
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.06	Thermal-Mechanical Effects on Geosphere	- Thermal expansion / compression - Altered properties of fractures, faults, rock matrix	Partial - Site Specific	See FEP 2.2.07.01	Medium	Low	High	Likely to be screened out in far field. Could be important to EDZ and near field. See FEPs 2.2.07.01 and 2.2.01.01 for importance discussion	Fundamental Data Needs	No additional data needed for far field. See FEPs 2.2.07.01 and 2.2.01.01 for state of the art discussion

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.**
	Deep Boreholes	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Deep Boreholes	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.** Current UFD activites focus on the thermal effects on water flows in the near field of a repository, especially on the moisture evolution in a clay repository.
	Salt	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
Interface with UFD-ES program - coupled processes										

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.11.07	Thermal-Chemical Alteration of Geosphere	- Mineral precipitation / dissolution - Altered properties of fractures, faults, rock matrix - Alteration of minerals / volume changes - Formation of near-field chemically altered zone (rind)	Partial - Site Specific	See FEP 2.2.09.01 and 2.2.09.05.	Medium	Low	High	Likely to be screened out in far field. R&D necessary to support screenining decision. Could be important to EDZ and near field. See FEPs 2.2.09.01 and 2.2.09.05 and 2.2.01.01 for importance discussions.	Fundamental Data Needs	No additional data needed for far field. See FEPs 2.2.09.01 and 2.2.09.05 and 2.2.01.01 for state of the art discussions. R&D necessary to support screenining decision (potential for irreversible changes in clay properties due to thermal chemical reactions, dewatering of salt as thermal fields cause migration of water and vapor, development of a chemically altered zone).
		2.2.12.00	2.12. GAS SOURCES AND EFFECTS									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.12.01	Gas Generation in Geosphere	- Degassing (clathrates, deep gases) - Microbial degradation of organics	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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 [see also Buoyant Flow/Heat Pipes in 2.2.11.03]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific. Likely to be screened out	Medium	Low	Medium	Gas flow may be improtant in clay and salt Need to dissipate geenrated gas from EBS materials. May impact selection of materials. Interface with EBS	Fundamental Gaps in Method, Fundamental Data Needs	Relevant research in European programs (GAST - NAGRA, FORGE - small scale modeling) and in Japan.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.12.03	Gas Transport in Geosphere	- Gas phase transport - Gas phase release from Geosphere	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Low	N/A	Low	Transport of gaseous radionuclides (e.g. C-14)	Well Understood	Transport of gaseous radionuclides in a saturated enviroment may need to be better understood.
		2.2.14.00	2.14. NUCLEAR CRITICALITY									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.2.14.01	Criticality in Geosphere	- Formation of critical configuration	Partial - Site Specific, Design Specific	Likely to be screened out. Modeling methods to support screening arguments	Low	Low	Medium	Likely to be screened out in geosphere, may be of consideration in near-field. May impact design. If not screened on probability will need to be integrated with THMC as a consequence of criticality is heat generation.	Gaps in Method and Data	Modeling tools need to be in place for screening calcualtions and consequence evaluations..
		2.3.00.00	3. SURFACE ENVIRONMENT									
		2.3.01.00	3.01. SURFACE CHARACTERISTICS									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.01.01	Topography and Surface Morphology	- Recharge and discharge areas	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.02.01	Surficial Soil Type	- Physical and chemical attributes	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.04.01	Surface Water	- Lakes, rivers, springs - Dams, reservoirs, canals, pipelines - Coastal and marine features - Water management activities	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.05.01	Biosphere Characteristics	- Climate - Soils - Flora and fauna - Microbes - Evolution of biosphere (natural, anthropogenic – e.g., acid rain) [see also Climate in 1.3.01.01, Surficial Soil Type in 2.3.02.01, Microbial Activity in 2.3.10.01]	No	Site Specific						
		2.3.07.00	3.07. MECHANICAL PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.07.01	Erosion	- Weathering - Denudation - Subsidence [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 Sediment Transport in 2.3.09.53]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.07.02	Deposition	- Weathering	No	Site Specific						
Containment, Limited Release Engineered Barriers	Natural System - Geosphere	2.3.07.03	Animal Intrusion into Repository		No	Site Specific						
		2.3.08.00	3.08. HYDROLOGIC PROCESSES									

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
Interface with UFD-ES program - coupled processes	Clay/Shale	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	**Importance and adquacy determined for overall process/issue and is applicable to sub-processes/sub-issues.** Gas generation and migration are currently captured in the thermal-hydrologic-mechanical-chemical (THMC) modeling. UFD is planning to initiate international collaboration in this area.
	Deep Boreholes	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
	Salt	N/A	N/A	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	High: Information is essential to decisions	Partially sufficient (issue can be represented but needs improvement)	
	Clay/Shale	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
	Granite/Crystalline Deep Boreholes Salt Clay/Shale	N/A	N/A	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	Low: Information useful but not necessary	Completely sufficient (no additional info needed)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	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]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.08.02	Surface Runoff and Evapotranspiration	- Runoff, impoundments, flooding, increased recharge - Evaporation - 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]	Partial - Site Specific	Effects would be included in geosphere flow and transport	Low	N/A	Low	Local infiltration likely to be important only for unsaturated sites. Could be considered in regional flow modeling for saturated environments	Improved Representation	Regional ground water flow modeling is well understood. Could be opportunity for model improvement, including surface recharge component.
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.08.03	Infiltration and Recharge	- Runoff, impoundments, flooding, increased recharge - Evaporation - 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]	Partial - Site Specific	Effects would be included in geosphere flow and transport	Low	N/A	Low	Local infiltration likely to be important only for unsaturated sites. Could be considered in regional flow modeling for saturated environments	Improved Representation	Regional ground water flow modeling is well understood. Could be opportunity for model improvement, including surface recharge component.
		2.3.09.00	3.09. CHEMICAL PROCESSES - CHEMISTRY									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Geosphere	2.3.09.01	Chemical Characteristics of Soil and Surface Water	- Altered recharge chemistry (natural) - Altered recharge chemistry (anthropogenic – e.g., acid rain) [contributes to Chemical Evolution of Groundwater in 2.2.09.04]	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.02	Radionuclide Speciation and Solubility in Biosphere	- Dissolved concentration limits	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.03	Radionuclide Alteration in Biosphere	- Altered physical and chemical properties - Isotopic dilution	No	Site Specific						
		2.3.09.50	3.09. CHEMICAL PROCESSES - TRANSPORT									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.51	Atmospheric Transport Through Biosphere	- Radionuclide transport in air, gas, vapor, particulates, aerosols - Processes include: wind, plowing, irrigation, degassing, saltation, precipitation	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Low	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.52	Surface Water Transport Through Biosphere	- Radionuclide transport and mixing in surface water - Processes include: lake mixing, river flow, spring discharge, aeration, sedimentation, dilution [see also Surface Water in 2.3.04.01]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.53	Soil and Sediment Transport Through Biosphere	- Radionuclide transport in on soil and sediments - Processes include: fluvial (runoff, river flow), eolian (wind), glaciation, bioturbation (animals) [see also Erosion in 2.3.07.01, Deposition in 2.3.07.02	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.54	Radionuclide Accumulation in Soils	- Leaching/evaporation from discharge (well, groundwater upwelling) - Deposition from atmosphere or water (irrigation, runoff)	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.09.55	Recycling of Accumulated Radionuclides from Soils to Groundwater	[see also Radionuclide Release in 2.2.09.65]	Partial - Site Specific	Characterization and modeling methods. Parameters are site specific	Low	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
		2.3.10.00	3.10. BIOLOGICAL PROCESSES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.10.01	Microbial Activity in Biosphere	- Effect on biosphere characteristics - Effect on transport through biosphere	No	Site Specific						
		2.3.11.00	3.11. THERMAL PROCESSES									

FCT PROGRAM INTERFACE	Media	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points								DISCUSSION
		Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
		Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	Medium: Information supports or improves decisions	Partially sufficient (issue can be represented but needs improvement)	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.3.11.01	Effects of Repository Heat on Biosphere		No	Site Specific						
		2.4.00.00	4. HUMAN BEHAVIOR									
		2.4.01.00	4.01. HUMAN CHARACTERISTICS									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.4.01.01	Human Characteristics	- Physiology - Metabolism - Adults, children [contributes to Radiological Toxicity in 3.3.06.02]	No	Beyond UFD Scope						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.4.01.02	Human Evolution	- Changing human characteristics - Sensitization to radiation - Changing lifestyle	No	Beyond UFD Scope						
		2.4.04.00	4.04. LIFESTYLE									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	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 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]	No	Beyond UFD Scope						
		2.4.08.00	4.08. LAND AND WATER USE									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	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)	No	Site Specific						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	2.4.08.02	Evolution of Land and Water Use	- New practices (agricultural, farming, fisheries) - Technological developments - Social developments (new/expanded communities)	No	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									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.01.01	Radionuclides in Biosphere Media	- Soil - Surface Water - Air - Plant Uptake - Animal (Livestock, Fish) Uptake [contributions from Radionuclide Release from Geologic Units in 2.2.09.65, Transport Through Biosphere in 2.3.09.51/52/53/54/55]	No	Site Specific Beyond UFD Scope						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.01.02	Radionuclides in Food Products	- Diet and fluid sources (location, degree of 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]	No	Site Specific Beyond UFD Scope						

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	

Objective	Feature	Process (Issue)			Ability to Address through Generic R&D		Importance of Issue/Process to Safety Case				State of the Art Relative to Issue/Process	
		UFD FEP ID	UFD FEP Title	Process/Issue Description	Yes/No/Partial	Discussion	Performance (Safety Analysis)	Design, Construction, Operations	Overall Confidence	Discussion	Status	Discussion
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	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]	No	Site Specific Beyond UFD Scope						
		3.3.04.00	3.04. EXPOSURE MODES									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.04.01	Ingestion	- Food products - Soil, surface water	Yes	Methods	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.04.02	Inhalation	- Gases and vapors - Suspended particulates (dust, smoke, pollen)	Yes	Methods	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.04.03	External Exposure	- Non-Food products - Soil, surface water	Yes	Methods	Medium	N/A	Low	Radionuclide transport processes in the biosphere, while needed in evaluating disposal system performance, are expected to be very site specific. Their overall importance to performance is expected to be low.	Well Understood	Radionuclide transport processes in the biosphere are well understood and used in many different application. Improved models for representing process could potentially build confidence in the safety case
		3.3.06.00	3.06. TOXICITY / EFFECTS									
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.06.01	Radiation Doses	- Exposure rates (ingestion, inhalation, external exposure) - Dose conversion factors - Gases and vapors Suspended particulates (dust, smoke, pollen)	No	Beyond UFD Scope						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.06.02	Radiological Toxicity and Effects	- Human health effects from radiation doses	No	Beyond UFD Scope						
Limited Release - Natural Barriers, Dispersion and Dilution	Natural System - Biosphere	3.3.06.03	Non-Radiological Toxicity and Effects	- Human health effects from non-radiological toxicity	No	Beyond UFD Scope						

FCT PROGRAM INTERFACE	Importance of Issue/Process and Adequacy of the Current State of the Art Relative to Decision Points									
	Media	Site Screening		Site Selection		Site Characterization and Disposal System Design		Site Suitability		DISCUSSION
		Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	Importance	Adequacy	
		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	
		N/A	N/A	N/A	N/A	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	Low: Information useful but not necessary	Partially sufficient (issue can be represented but needs improvement)	