Approaches for Uncertainty Quantification and Sensitivity Analysis

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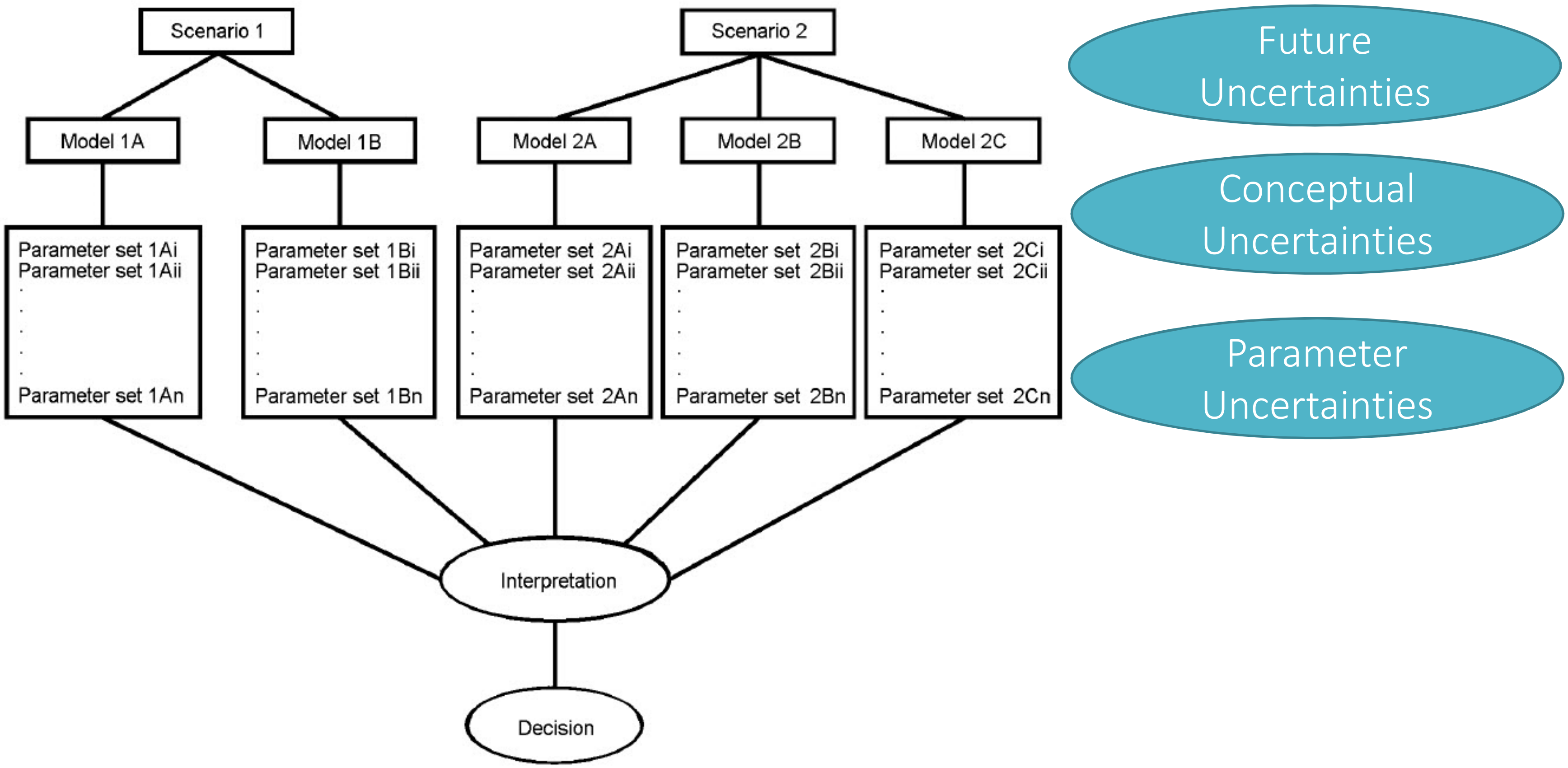
Scope of the Presentation

- General structure of uncertainty analysis
  - Characterization of uncertainties
  - Propagation of uncertainties
- Use of Features, Events, and Processes
- Introduction to Safety Functions
- Use of safety functions in structuring a performance assessment

Structure of Uncertainty or Importance Analysis



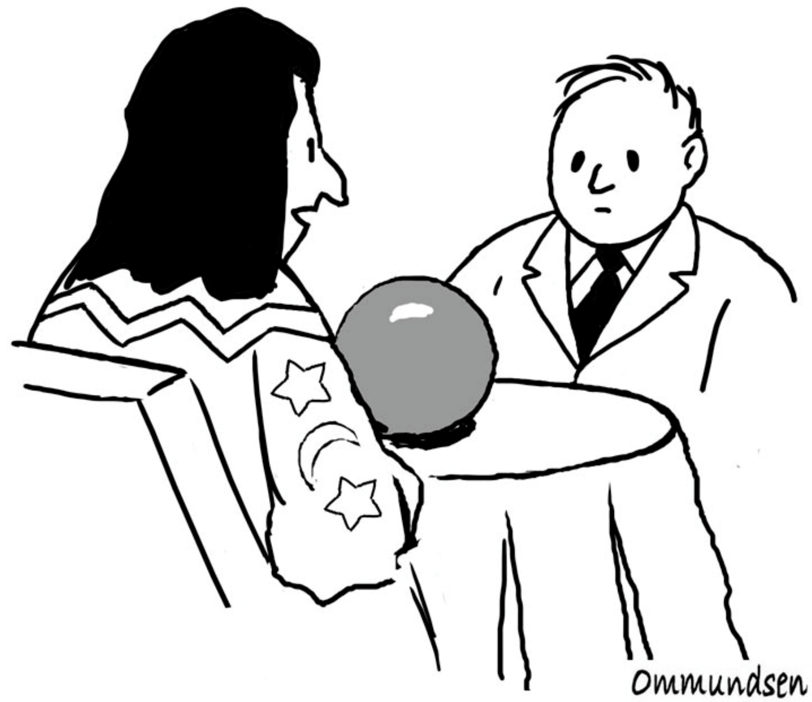
Source: NCRP 152

A General Approach for Treating Uncertainty

Evaluate Multiple Lines of Reasoning for Each Type of Uncertainty

- Consideration of alternative scenarios for future uncertainty
- Consideration of alternative models for conceptual uncertainty
- Consideration of alternative parameter sets for parameter uncertainty

The result is a potentially large number of calculations that represents the uncertainty



"Is this needed for a Bayesian analysis?"

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Interpretation

Each set of scenario, model, and parameter set is assigned a weighting factor

- May be implicit (disregarding a model = weighting factor of zero)
- May be qualitative (Model 1a is better than Model 1b)
- May be quantitative (probabilistic)

The filter defines how the information is used in making a decision

The choice of filter depends on

- Assessment context
- Philosophy of analyst

A few comments about probabilistic approaches

- Subjective probabilities and ranges are easy to assign: we are not representing variability
- Technically superior way to span the range of the input space
- That superiority comes at a cost

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Characterization of uncertainties 1

Aleatory vs. epistemic

- Performance assessment uncertainties are dominated by epistemic uncertainties (Type B)
- Even when large amounts of data exist, uncertainty about application to future field conditions is more important
  - Transition to different constitutive behavior under different boundary conditions (e.g. hydraulic conductivity)
  - Transition to different constitutive behavior in time
- Aleatory uncertainties (Type A) are generally unimportant
  - This situation differs from power plant risk assessments
  - Also differs from other types of risk assessment activities

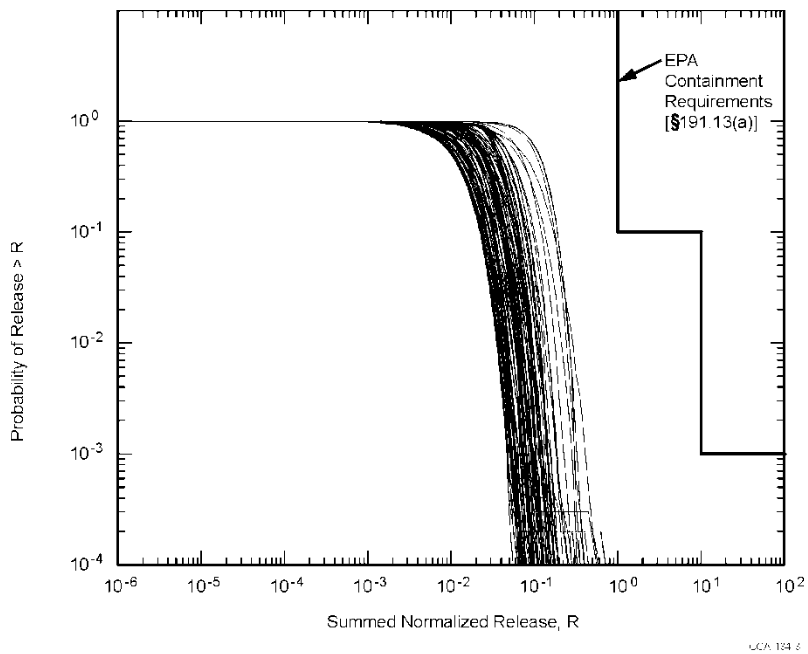

Figure 6-35. Distribution of CCDFs for Normalized Radionuclide Releases to the Accessible Environment from the WIPP, Replicate 1

Attempted differentiation between Type A and Type B uncertainties in WIPP performance assessments

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Characterization of Uncertainties 2:
Features, Events, and Processes (FEPs)

- Features
  - Aspects of the disposal system associated with performance
  - Generally thought of as physical components
- Events
  - Discrete occurrences
  - Relatively short duration
- Processes
  - Longer term evolutionary aspects of the system
  - Generally represent relationships between features

In practice, little differentiation between these three, and one simply discusses "FEPs"

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FEPs Background

Scenario approaches developed in the 1980s

- Sandia methodology
- Developed for U.S. HLW waste program
- Legal requirement to represent all events and processes
- Requirement to combine them probabilistically
- Intended to identify all potential scenarios

Scenario approaches developed in the 1990s

- SKB methodology
- A move away from probabilistic approaches
- Inclusion of FEPs representing the model

Scenario approaches developed in the 2000s

- Multiple methodologies with common features
- Extension to FEPs for near surface disposal

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Application of FEP Approaches (in principle)

Comprehensive FEP list

Screening

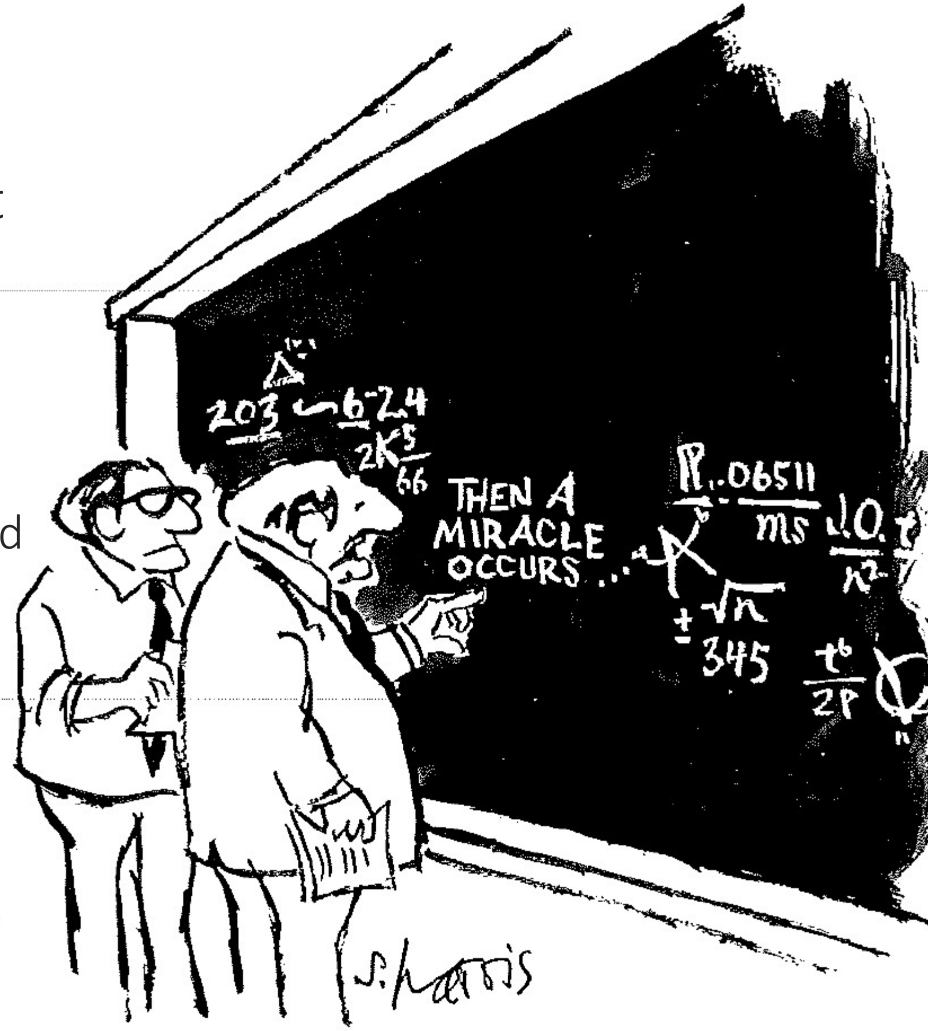
Describing relationships between FEPs

Arranging them into calculational cases, or scenarios

Differences between published approaches represent differences in ordering of these basic steps

Application of FEPs (in practice)

- Modern usage includes both identification of scenarios and construction of models
- The path from FEPs to models is not clear
  - Typically a leap occurs between FEPs and models
  - Current assessments often receive criticism for this leap
  - The reality is that models are developed using professional judgment, informed by FEPs
- FEPs are best viewed as a communication tool, not a fundamental feature of scenarios and models
- Strong use as an auditing tool to ensure conceptual completeness



"I think you should be more explicit here in step two."

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Issues in applying FEP Approaches

- Lack of clear path from FEPs to models
- Time consuming
- Inconsistent with the way people build models
  - Bottom-up approach
  - Immediate focus on details at a level that may be excessive
  - Lack of focus on risk-relevant (safety relevant) information

These issues influenced the development of the "Safety Function" Approach

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Safety Functions

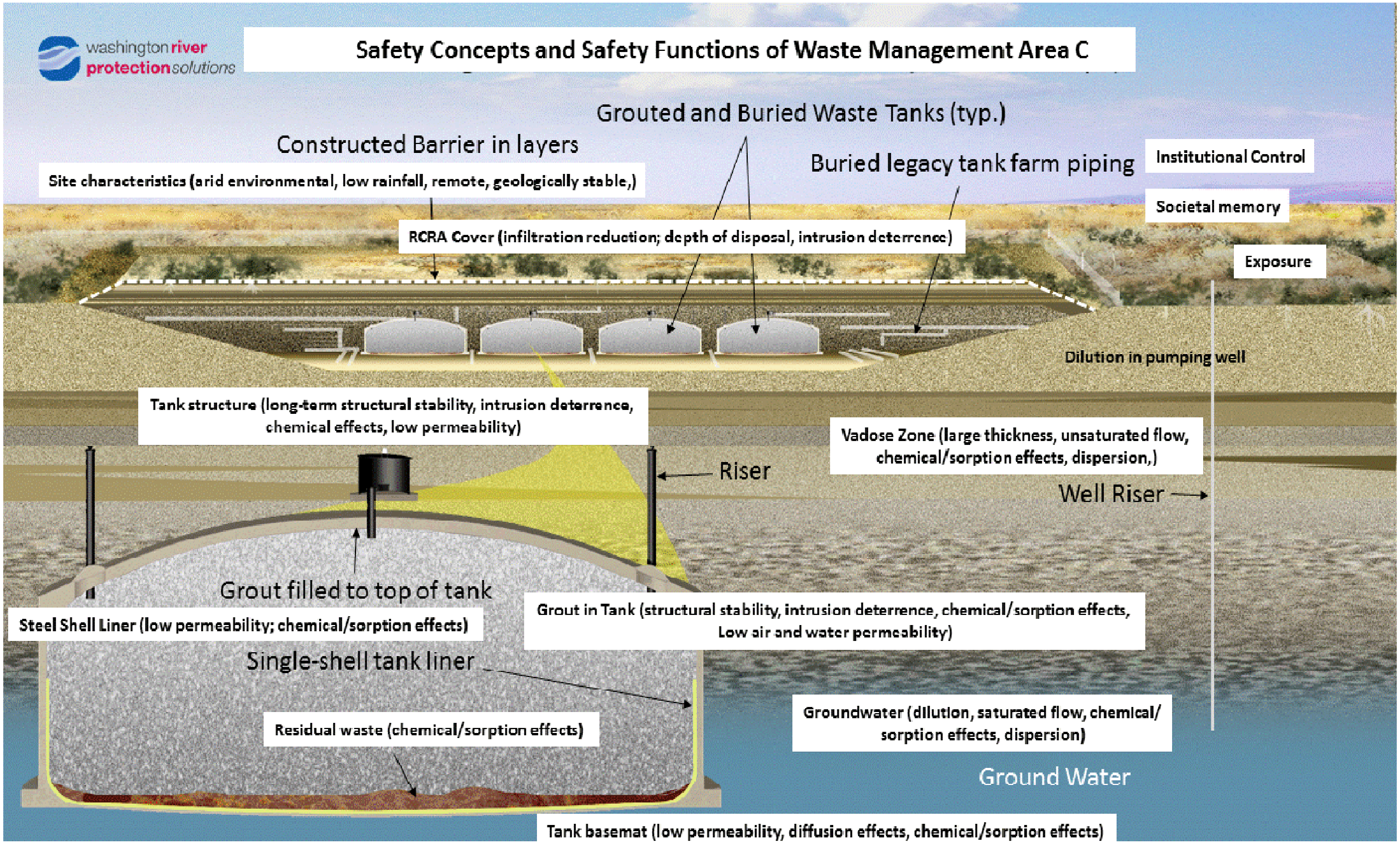
Specific features of the system that provide safety

Focus on the key elements of particular value or interest with respect to safety: a “top down” approach

Safety functions represent the way that multiple and redundant barriers provide system performance

- Institutional
- Retention (delay)
- Flow-limiting
- Dispersive
- Chemical

WMA C Safety Functions



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Categories of WMA C safety functions in the draft performance assessment

Institutional (3 safety functions)

Engineered Barriers (10 safety functions)

Waste Form (1 safety function)

Vadose Zone (4 safety functions)

Saturated Zone (4 safety functions)

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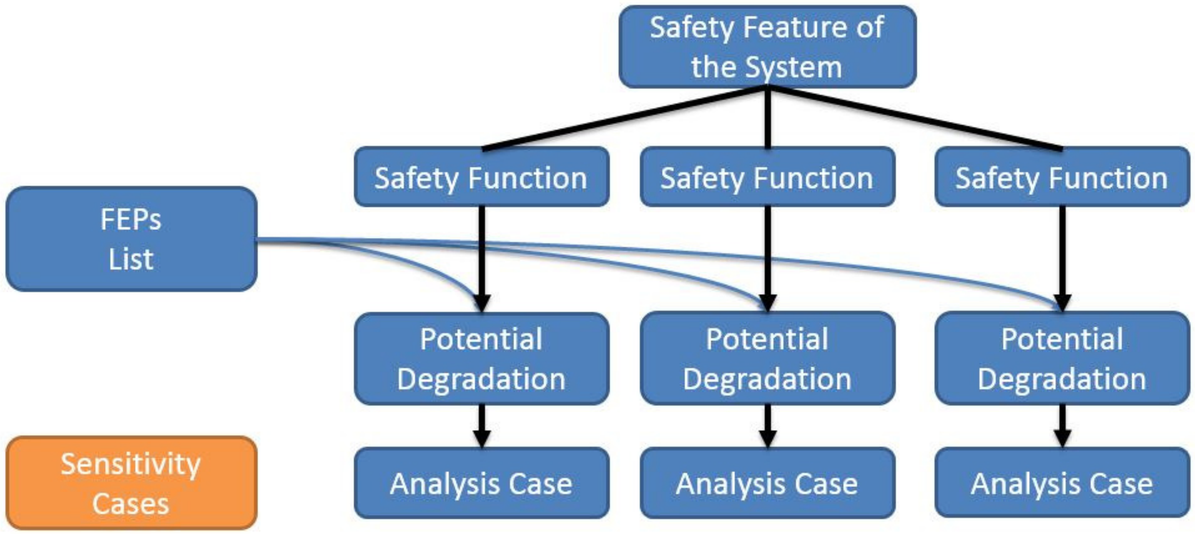
Use of Safety Functions

Use of safety functions allows coherent structure for the performance assessment

- What happens if all the safety functions behave as expected? -- Base Case
- What happens if a safety function fails? – Sensitivity cases
- What can cause the safety function to fail?
- FEP analysis is to identify FEPs that can potentially disrupt the safety function

Complementary Use of Safety Functions and FEPs



Identify safety functions

Identify which FEPs can degrade a safety function

For potential degradation FEPs, identify a sensitivity case to evaluate degraded safety function

The analysis cases may represent classes of similar FEPs that potentially affect the same safety function
--for example

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Potentially disruptive FEPs acting on a surface barrier flow safety function

Root growth

Erosion

Soil changes

Intrusion

Water management

Etc

These FEPs all may lead to an increase in flow rate, which can be evaluated in a single analysis case

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Barrier Analyses

Assume that a safety function fails even when there is no FEP that would cause the failure

- Or -

Assume the safety function failure exceeds the type of failure expected from a FEP

Undertaken to evaluate the robustness of the system

NOT intended as compliance analyses

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Summary

The use of safety functions is an emerging approach to structuring performance assessments

Takes a top –down focused look at parts of the system that are key factors for safety

Complementary use of safety functions with FEP approaches provides structure to the analysis

- Analysis cases that focus on key issues related to performance, linked back to potentially disruptive FEPs
- Provides an efficient way to look at the robustness of the performance assessment

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