Modeling the Performance of Engineered Systems: A Regulatory Perspective

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Background

- Risk (from waste disposal and decommissioning) is commonly affected by the performance of engineered and natural barriers
- Performance assessment (modeling) is used to estimate performance
- Modeling of engineered barriers is generally supported by sparse data and is asserted to be ‘conservative’
- Monitoring has been and continues to be performed

Main Messages

- Performance assessment is a tool to learn about your problem
- Compliance and reality may be different
- Model confidence is essential
- More large-scale controlled observations are needed (over appropriate time frames)

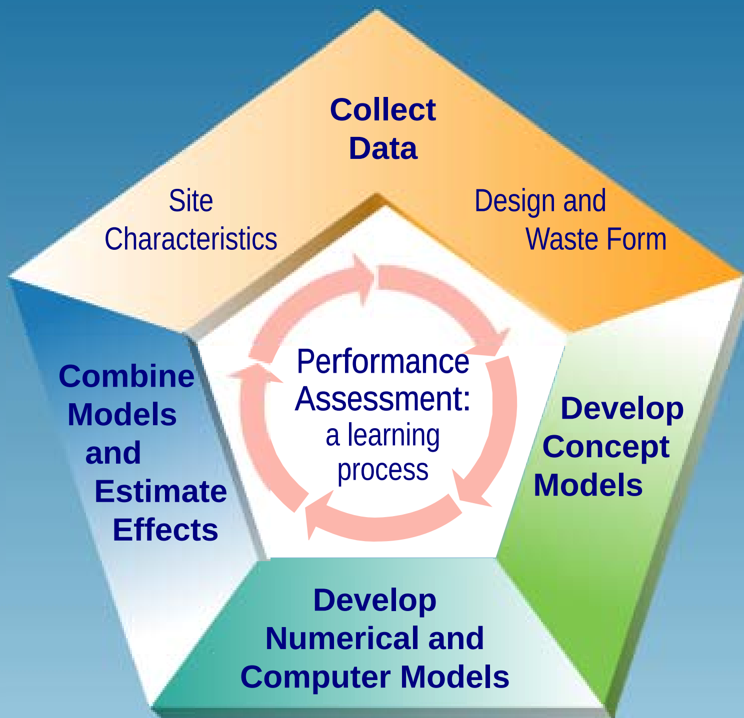
Overview of Performance Assessment

What is Performance Assessment?

- Systematic analysis of what could happen at a site

Why use it?

- Complex system
- Systematic way to evaluate data
- Internationally accepted approach



What is assessed?

- What can happen?
- How likely is it?
- What can result?

How is it conducted?

- Collect data
- Develop scientific models
- Develop computer code
- Analyze results

NRC would require a Performance Assessment to:

- Provide site and design data
- Describe barriers that isolate waste
- Evaluate features, events, and processes that affect safety
- Provide technical basis for models and inputs
- Account for variability and uncertainty
- Evaluate results from alternative models, as needed

Review Elements

- Does the model have a sufficient description?
- Has the barrier functionality and expected performance been described?
- Does the model include sufficient detail of the real system?
- How were degradation mechanisms and related processes determined and represented?
- Are assumed dependencies or interdependencies appropriate?

Review Elements

- How has uncertainty been considered, managed, or incorporated?
- Is integration sufficient?

  barrier performance = f(service environment, other barriers, waste)
- Is the barrier compatible with the service environment? If not, what is the impact on performance?
- How has model support been developed? (e.g., lab tests, field tests, analogs)

For additional description, see for example section 4.3.2 of NUREG-1854 and section 3.5 of Volume 2 of NUREG-1757

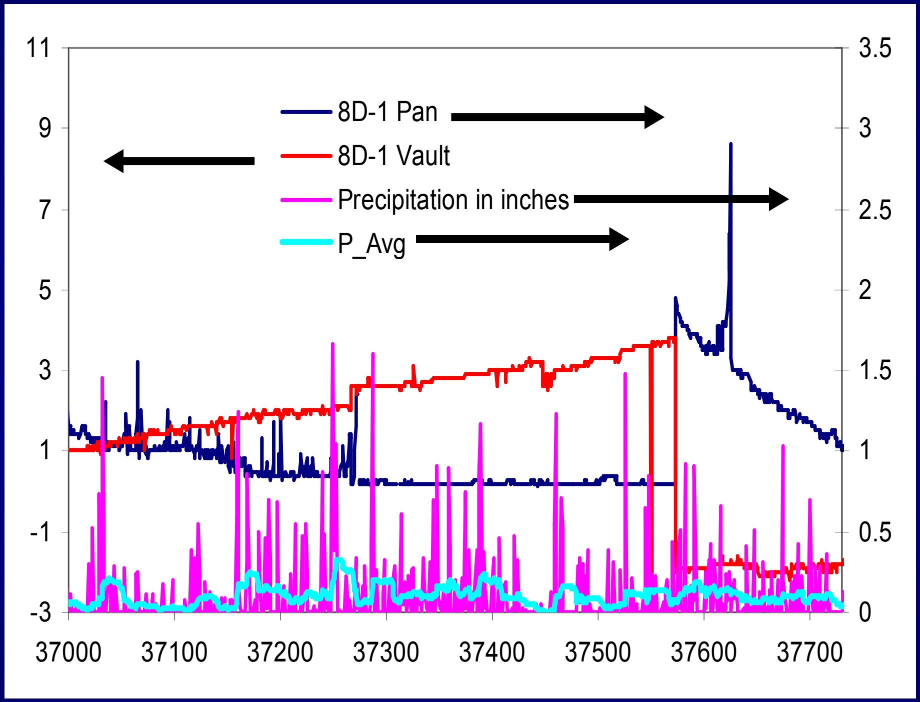
Sufficient detail of the real system

Example: Waste Tanks (Idaho, West Valley)

Original Conceptual Model:

-Buried concrete vaults would limit water entering the system

-Thick unsaturated zone would limit transport (Idaho)



Observations:

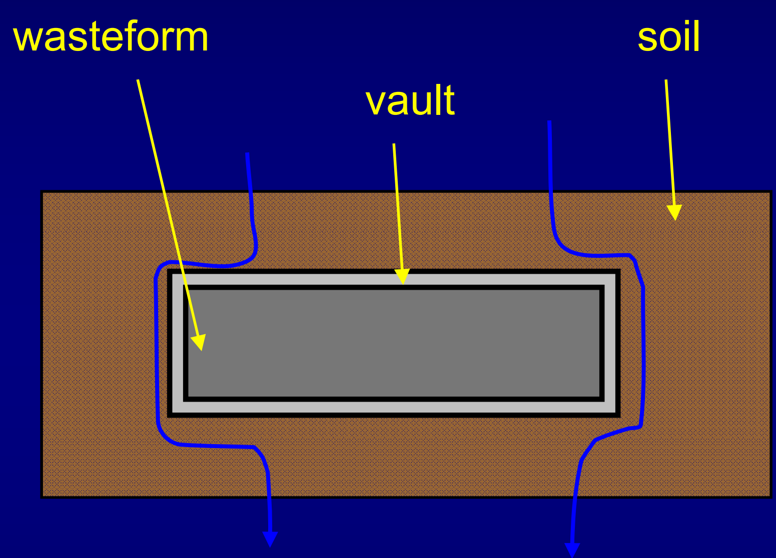
-Dynamic snowmelt and precipitation events results in infiltration through cracks and joints in the vaults

-Transport to saturated zone through discrete features much more rapid than anticipated (observed from spills)

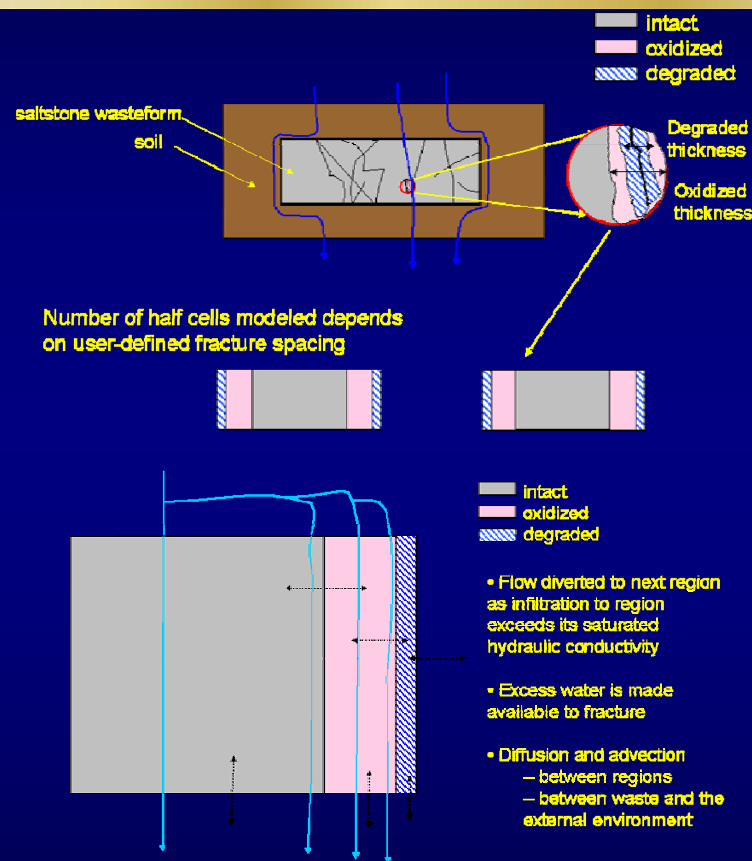
- Sufficient detail in temporal and spatial data needs to be included.

Sufficient detail of the real system

Example – Grouted Wasteform in Vault



3D, unsaturated flow, temporally invariant physical and chemical parameters



- A highly-abstracted model with strongly integrated processes can have high complexity.

Development of Model Support

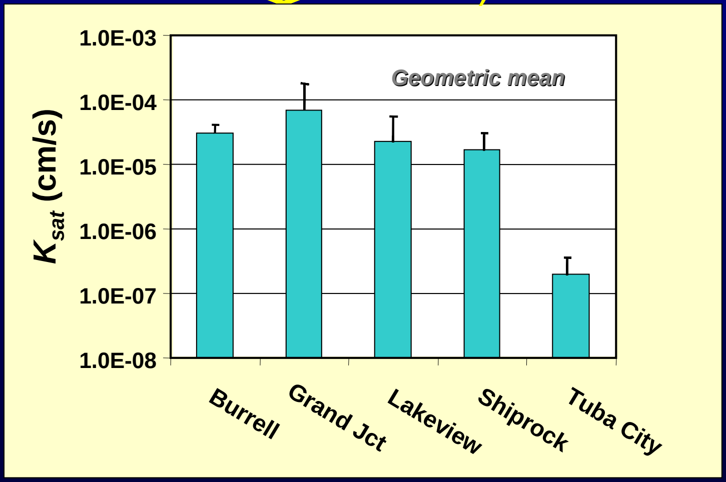
Example: Uranium Mill Tailings

Original Conceptual Model:

- -Use Resistive Covers to limit infiltration and waste release
- -Low hydraulic conductivity soil layers will limit water contact with the waste
- -Covers will slowly change over time

A)

B)



Observations:

- A) –Plant encroachment occurred more rapidly
- B) -Resistive properties difficult to achieve at the field-scale
- -Pedogenesis and other processes can alter hydraulic properties

Model Support for Engineered Barriers

- Model support for engineered barriers should be commensurate with the barriers impact on risk
- More field-scale observations are needed:
  - Good examples: (Benson – engineered covers, Waugh – engineered covers, Langton – cement lysimeters, Tauxe [Neptune] – ant nest depths)
- Return on investment (ROI) is high from field-scale observations for mitigating decision risk
- Opportunity for data mining of observations from analogous facilities
- Smart vs. dumb monitoring

Modeling Implications

- Performance assessment modeling should consider the potential impact of discrete pathways on infiltration, engineered barrier performance, and contaminant transport
- Modeling must carefully consider the degree of coupling of features, events, and processes
- Smoothing of temporal responses to facilitate modeling should be carefully evaluated

Conclusions

- Performance assessment is a tool to learn about your problem
- Model confidence is essential
- Supporting data needs to ‘catch up’ with numerical simulations
- More large-scale controlled observations are needed