Review of Uncertainty in the Models Supporting the TSPA-SR: Status Report

Presented to: Nuclear Waste Technical Review Board

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Decision-Making in the Face of Uncertainty

  - "It is appreciated that decision making requires only that the technical arguments, including performance assessment and arguments that give confidence in its findings, are adequate to support the decision at hand, and that an efficient strategy exists to deal at future stages with uncertainties that may compromise feasibility and long-term safety."
Decision-Making in the Face of Uncertainty (Continued)

• DOE is following this logic in the construction of its SR
  – System performance is being estimated
  – Quantified uncertainties are being evaluated

• A Repository Safety Strategy that discusses confidence and steps forward is being updated
Decision-Making in the Face of Uncertainty

Focus of This Presentation is On Technical Analyses

- Manage uncertainties
- Communicate uncertainties

Policy and Technical Assessment

- Assess all uncertainties

Technical Assessment

- Analyze quantified uncertainties

Technical Analyses
Overview of Uncertainty Treatment

- In January 2000, DOE outlined our uncertainty approach
  - Identify sources of uncertainty; and treat quantitatively, qualitatively, or with conservative bounds
  - Manage uncertainties, considering their impact and importance
  - Reduce or mitigate critical uncertainties
  - Assess effects of residual uncertainties
- DOE, MTS, and M&O are examining the implementation and effectiveness of this approach
  - Identify where uncertainties and variability have been included in overall performance assessment (see previous presentations)
  - Identify how all uncertainties have been treated at the process model and abstraction level: September, 2000
  - Evaluate uncertainty treatment and develop recommendations: November, 2000
Overview of Uncertainty Treatment
(Continued)

- A bottoms-up approach is being used to evaluate uncertainty treatment in the process models and abstractions, including:
  - Alternative conceptual models: choice of a preferred model using physical arguments, or through comparisons with test data
  - Parameter distributions using Project data or published data
  - Spatial-extrapolation/time-scale issues (e.g., correlations between measured data and needed data)
  - Partitioning of variability and uncertainty
Overview of Uncertainty Treatment
(Continued)

- Temporal and spatial boundary conditions
- Assumptions/judgments
- Use of data bounds
- Use of conservative estimates
- FEPs (features, events, and processes) screening of low probability/low consequence scenarios

- Current review includes both quantified and unquantified uncertainties
- This presentation is a status report focusing on two detailed examples of the treatment of uncertainties
Example 1: Uncertainties in WP Degradation Processes

- WP Integrity
  - Degradation processes*
    - Corrosion
    - SCC
    - Manufact. defects
  - Selection of specific process models subject to conceptual model uncertainty
  - Features* affecting degradation processes
    - Environments on WP
    - Drift Environment
  - Features considered subject to uncertainty and variability

* Other features, events, and processes were considered but were screened out due to low consequences or probability
Process Model Uncertainty: Stress Corrosion Cracking (SCC)

- SCC is the most significant failure mechanism for the WP
- SCC requires an overlap of three conditions
  - Inputs from NFE model, manufacturing defects model

Demonstrated by laboratory stress corrosion cracking tests

WP weld dimensions, flaws & stress mitigation

Near-field and EBS environment model
Evaluation of Alternative Conceptual Models for Crack Growth

Conceptual models

- **Threshold Stress Intensity**
- **Slip dissolution**

TSPA abstracted model

- Crack tip strain rate
- Environment
- Material properties

Model 1: Threshold stress intensity
- Cracks propagate when stress intensity is above a threshold

Model 2: Slip dissolution
- SCC occurs when passive film on material repetitively slips, ruptures, and reforms due to applied strain in underlying matrix

Slip dissolution model used in abstraction
- Advisors suggest this model is more defensible for 10K year time frame
- Significance of the model is dependent on the degree of stress mitigation
## Uncertainty Treatment in Stress Corrosion Cracking Model: Example Assessments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Topic</th>
<th>Range</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertainty</td>
<td>Initiation stress threshold</td>
<td>Uniform 10-40% of yield strength</td>
<td>Published data on A-22 yield strength; published data on susceptible stainless steels</td>
</tr>
<tr>
<td>Alternative conceptual models</td>
<td>SCC propagation</td>
<td>Threshold stress intensity; Slip dissolution</td>
<td>Judged more defensible for long time periods</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Residual stress range after mitigation</td>
<td>± 5% to ± 30% of yield strength</td>
<td>Published data on carbon steel and Incoloy; judged control of weld stress mitigation process</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Repassivation potential slope</td>
<td>Uniform 0.75-0.84</td>
<td>Published data on resistant SS; Project data on A-22</td>
</tr>
<tr>
<td>Variability</td>
<td>Flaw size</td>
<td>Lognormal</td>
<td>Fit to data from NRC research; checked with published data on piping and vessel welds</td>
</tr>
<tr>
<td>Uncertainty and variability</td>
<td>Probability of non-detect</td>
<td>Lognormal</td>
<td>Published data on inspection reliability for SS</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Fraction of flaws that are surface breaking</td>
<td>Uniform 0.13%-0.49%</td>
<td>Published data</td>
</tr>
</tbody>
</table>
Example of Use of Conservatism: Number of Flaws Considered for SCC

- Abstraction introduces additional conservatisms:
  - Orientation of flaws not included:
    - Only radial flaws have sufficient stress intensity to propagate to through-wall cracks
    - Process model results and literature indicate that less than 1% of flaws have radial orientation
    - Conservative assumption is that all flaws are subject to SCC
  - Considered surface-breaking flaws and all embedded flaws in outer 25% of depth of weld
Quantified Uncertainties in Model Outputs: Time to First Crack Failure Distribution

Waste Package 1st Crack Failure
(100 Realizations; 20-mm WPOB; 15-mm DS; 400 WP/DS Pairs; Backfill)

Fraction of Waste Packages Failed

Time (years)
Example 2: Thermal-hydrologic Models for TSPA-SR

**Inputs**
- Infiltration
- Hydrologic data
- Thermal data
- In-situ data

**Models**
- UZ Property Model
  - UZ Flow and Transport
  - Seepage
  - TH
    - Heater test TH
    - TH Multi-scale
    - TH Abstractions
  - THC
    - Mountain-scale TH

**Outputs**
- UZ Transport
- Seepage
- Seepage during thermal period
- Temp & humidity within drift
- Chem of water, gas comp. entering drift
- Porosity/perm changes
- TH effect on UZ F&T
Use of UZ Properties Model to Define Parameter Uncertainties

- Purpose is to develop a best-estimate hydrologic property set that is most consistent with measurements and their uncertainties
- Matrix and fracture parameters for use in UZ flow and transport, drift seepage, drift-scale and mountain-scale coupled process models
- Calibration process uses data inversion to compare and adjust the modeled parameters and the data
- ITOUGH2 computer code considers uncertainties in input data, analysis, and output parameters and their sensitivities
Property Set Calibration

- Data inverted:
  - Matrix saturation
  - Matric potential
  - Pneumatic pressure in fractures

- Parameters estimated (for the high, mean, low infiltration cases):
  - Fracture and matrix permeability
  - Fracture and matrix van Genuchten parameters: $\alpha$ and $m$
  - Fracture activity parameter

- Parameter uncertainties for 31 model layers, assumed to have uniform properties within each layer

- Spatial variability in infiltration incorporated using a 200m radius average around boreholes
Evaluation of Ambient Property Sets for Use as TH Property Sets

- Predictions made for single heater test using properties from
  - TSPA-VA
  - Drift Scale Property Set (TSPA-SR base case)
  - Single Heater Test Property Set (median bulk permeability)
- Considered two forms of the dual permeability model (DKM)
  - Constant value reduction factor between matrix/fracture
  - Active fracture model
- Predicted temperatures using property sets and conceptual flow models are compared to measured temperature data
- Evaluated statistically, but not a calibration (no adjustment of parameter values)
- Concluded that ambient drift scale property set and active fracture DKM are suitable for use in TH models for SR
## Uncertainty Treatment Multi-Scale Thermal Hydrologic Model: Example Assessments

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<td>Infiltration</td>
<td>High, mean, low rates</td>
<td>Project data and interpretation</td>
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<tr>
<td>Spatial variability</td>
<td>Infiltration</td>
<td>Estimates at over 600 points across repository</td>
<td>Project data and interpretation</td>
</tr>
<tr>
<td>Temporal variability</td>
<td>Infiltration</td>
<td>Present day, monsoon, glacial transition climate states</td>
<td>Project data and interpretation</td>
</tr>
<tr>
<td>Variability</td>
<td>Thermal hydrologic properties</td>
<td>Mean properties for each hydrologic unit, infiltration flux, climate state</td>
<td>Property set calibration, lab measurements, and property correlations</td>
</tr>
<tr>
<td>Variability</td>
<td>Heated repository footprint</td>
<td>Center/ edge effects, rep host unit, topography</td>
<td>Thermal modeling</td>
</tr>
<tr>
<td>Spatial and temporal variability</td>
<td>WP heat-generation histories for different waste package types</td>
<td>Eight WP types fixed y % representation in repository</td>
<td>Modeling of heat generation for waste inventory</td>
</tr>
<tr>
<td>Spatial variability</td>
<td>Boundary temperatures and pressures at surface and water table</td>
<td>Vary based on elevation</td>
<td>Project data and modeling</td>
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Uncertainty and Variability in MSTHM Output

Influence of three possible infiltration states evaluated
Summary

- DOE’s approach to uncertainties recognizes the need to assess, quantify, manage and communicate uncertainties

- Uncertainties, variability, and conservatisms are being identified in all process models providing input to the TSPA

- We are in the process of examining the current implementation -- focus to date has been on understanding the details of what has been done and how adequately it is documented
Next steps

- Complete the detailed review of uncertainty treatment and how uncertainties are reflected in the TSPA-SR
- Assess where we need to improve the characterization and/or documentation of uncertainty
- Develop recommendations to be used in future uncertainty treatment, including:
  - Assuring consistent definitions and methods for treating quantified uncertainties
  - Improving importance analyses of quantified uncertainties
  - Suggesting approaches for evaluating key unquantified uncertainties in terms of their implications to TSPA dose uncertainties