Department of Energy Performance Assessment and Barrier Analyses

Presented to:
Nuclear Waste Technical Review Board

Presented by:

Peter Swift
Subproject Manager
Performance Assessment Strategy and Scope
Sandia National Laboratories
Bechtel SAIC Company, LLC.

September 10, 2002
Las Vegas, Nevada

Overview

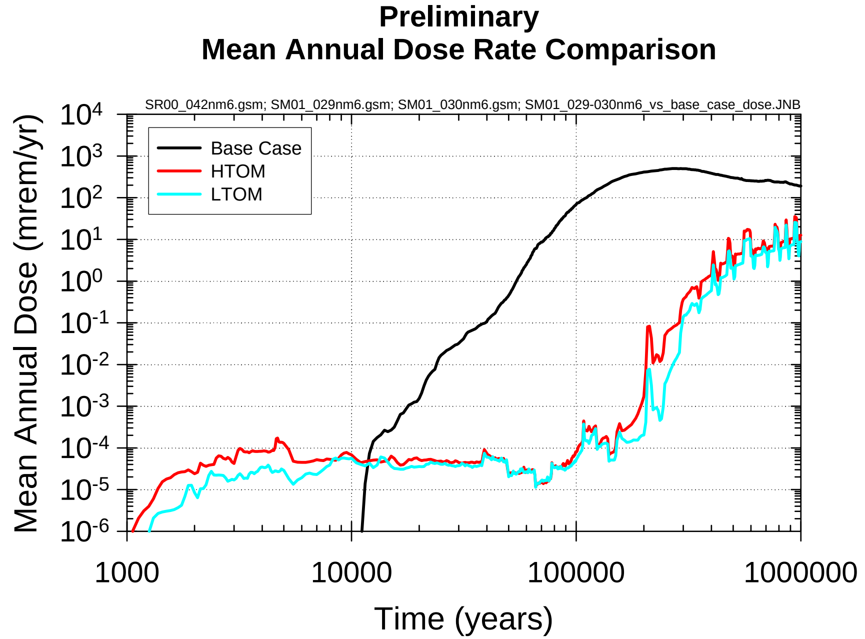
- Current Status of Total System Performance Assessment (TSPA)
- Briefly review overall results of recent DOE TSPAs
  - December 2000: TSPA for the Site Recommendation (TSPA-SR)
  - July 2001: FY01 Supplemental Science and Performance Analyses (SSPA)
  - September 2001: Revised Supplemental TSPA to support the Final Environmental Impact Statement (FEIS) for SR
- Current evaluation of barrier components in sequential addition (“one-on”) analyses

Current Status of TSPA

- **Most recent TSPA results presented to the Board in January, 2002, prepared for the FEIS to support SR**
  - **Similar to, and derived from, the FY01 Supplementary Analyses that incorporated additional uncertainty and new science since the December 2000 TSPA for the Site Recommendation (TSPA-SR)**
- **Next full update of the TSPA, including new models and inputs, will support the License Application (LA) in December 2004**
- **Current work uses minor updates to the FEIS model**
  - **Some models and inputs have not been validated, but are controlled**

TSPA-SR and FY01 SSPA Results Nominal Performance

- Million-year mean annual dose from TSPA-SR (labeled "base case" on figure)
- Mean annual dose from SSPA analyses for high-temperature and low-temperature operating modes (HTOM and LTOM)



- First-order observations from SSPA results
  - Some early waste package (WP) failures cause small doses before 10 kyr
  - Slower WP corrosion delays main rise in dose
  - Lower solubilities reduce peak dose
  - Effects of enhanced long-term climate change model are prominent
  - Thermal effects are small at the system level

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Uncertainty in FY01 SSPA Results Nominal Performance

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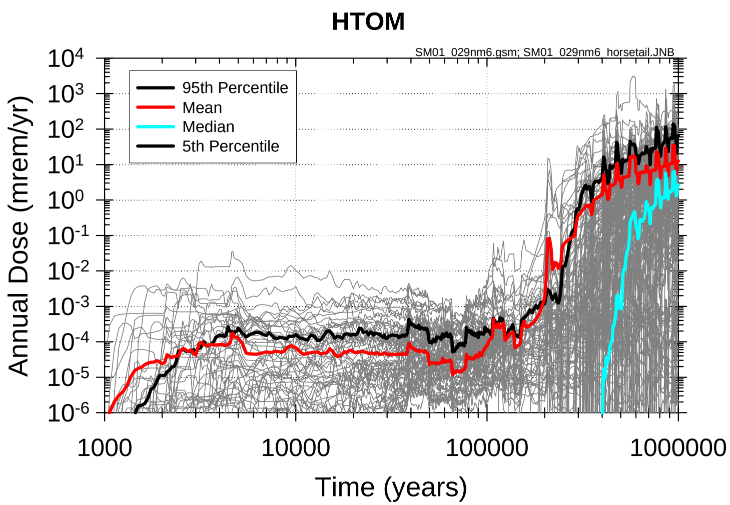
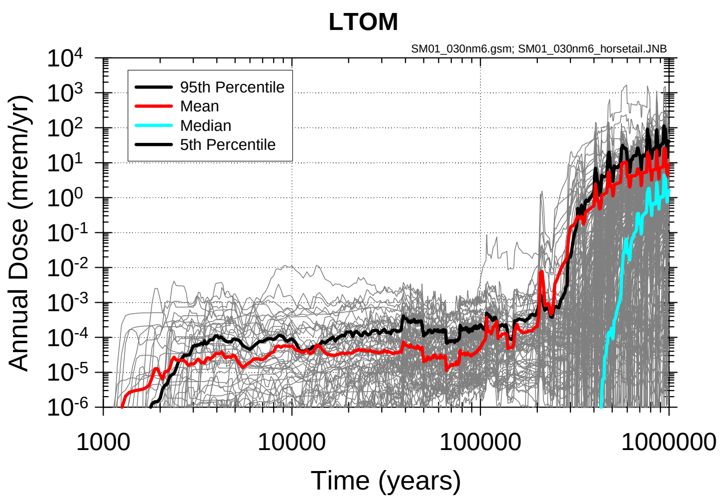
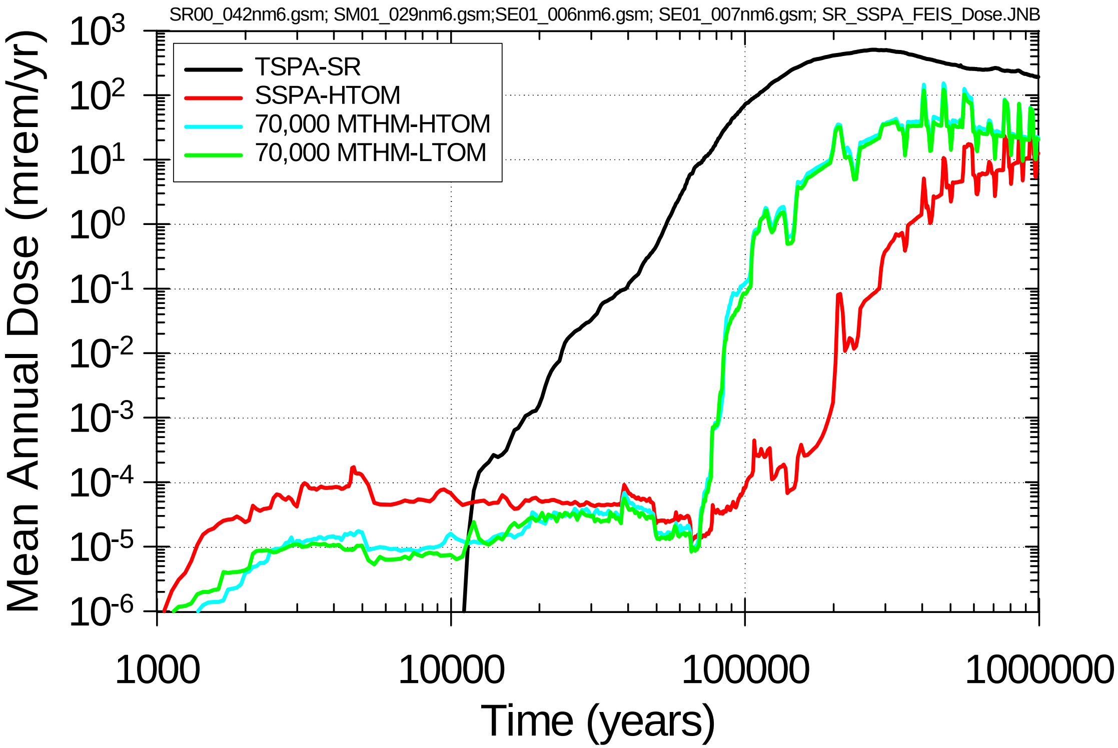




- **Monte-Carlo approach used to capture uncertainty in model results based on uncertainty in model inputs**
- **300 TSPA realizations shown for HTOM and LTOM, with 95th, 50th, and the mean annual dose (5th percentiles off-scale)**
- **Regulatory compliance will be based on 10 kyr probability-weighted mean annual dose considering all scenarios (10 CFR 63.114)**

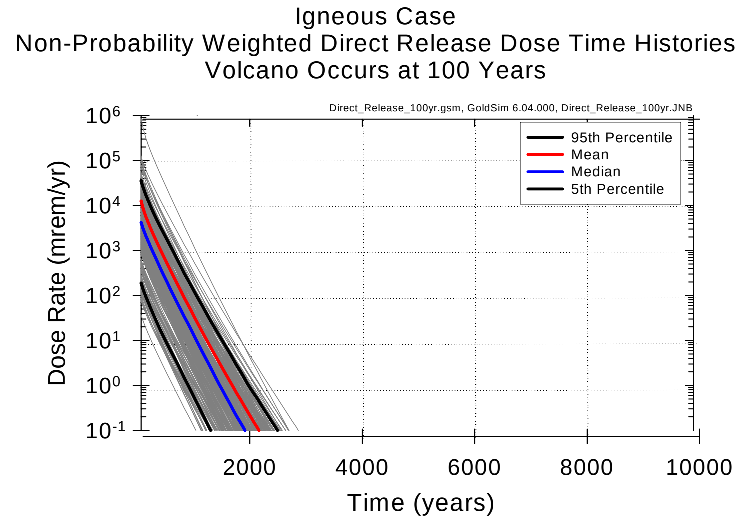
Revised Supplemental TSPA Results used to Support FEIS (Nominal Performance)

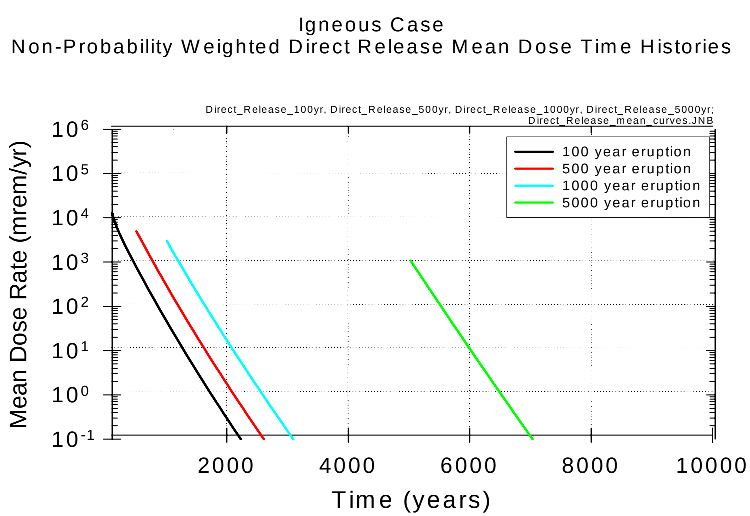
- **Changes since SSPA primarily due to temperature-independent general corrosion model**
- **No significant difference between the 2 operating modes in terms of total system performance**



Analyses for Igneous Activity Scenarios

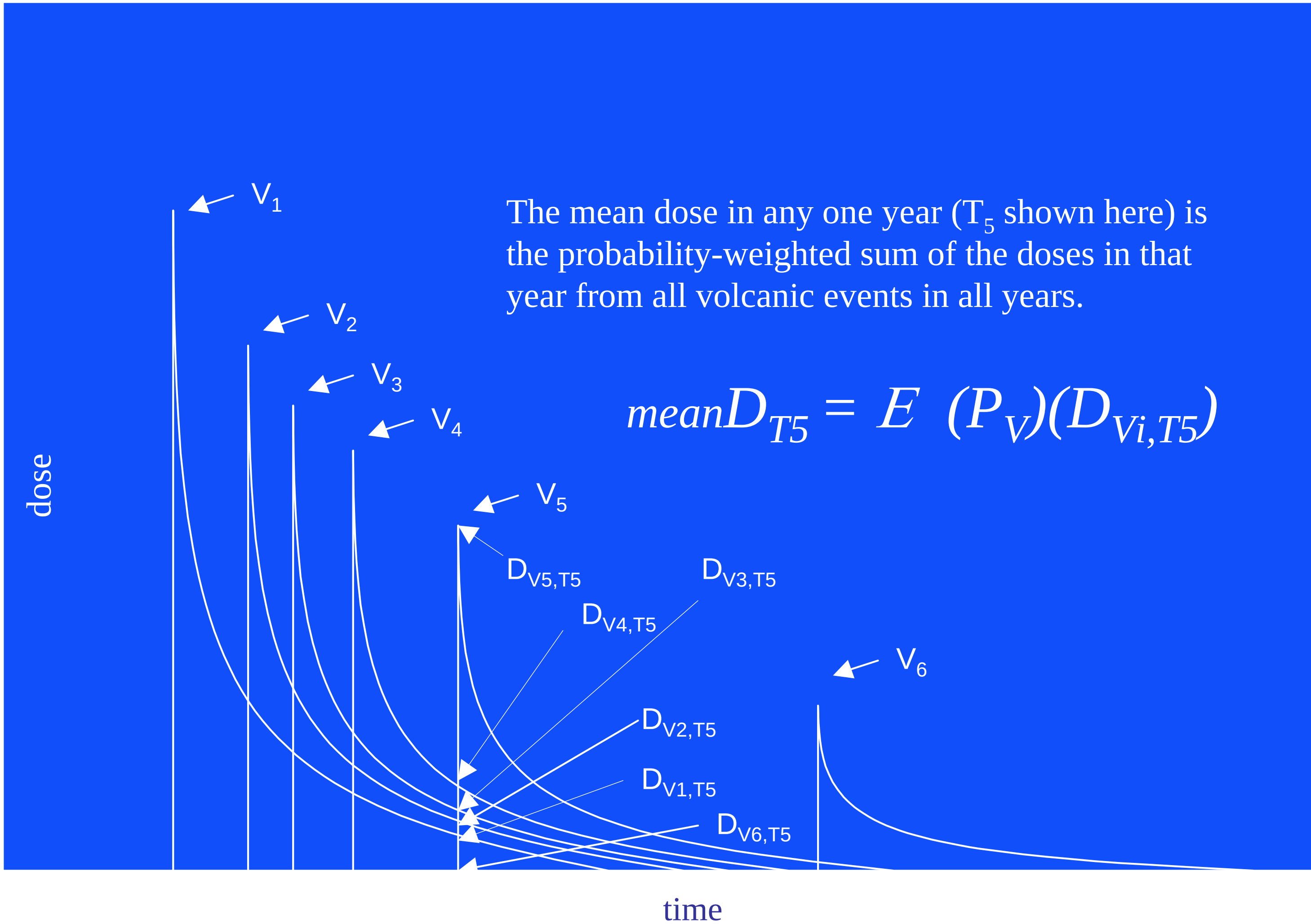
TSPA-SR Eruptive Dose without Probability-Weighting





- **TSPA-SR models and inputs**
- **Results assume eruption probability = 1 (actual probability ~ 1.6 × 10^{-8}/yr)**
- **Spread in distribution of peak due to uncertainty in**
  - **ASHPLUME inputs: e.g., wind speed, conduit diameter**
  - **Biosphere Dose Conversion Factors (BDCFs)**
- **Drop in “first-year” peak dose at different times due entirely to radioactive decay/ingrowth**
- **Slope of curves determined by soil removal and radioactive decay (dominated by soil removal)**
- **Dose dominated by inhalation pathway, Am, Pu**

Calculating a Probability-Weighted Mean Volcanic Dose



The mean dose in any one year (T_5 shown here) is the probability-weighted sum of the doses in that year from all volcanic events in all years.

$$meanD_{T5} = E \; (P_V)(D_{Vi,T5})$$

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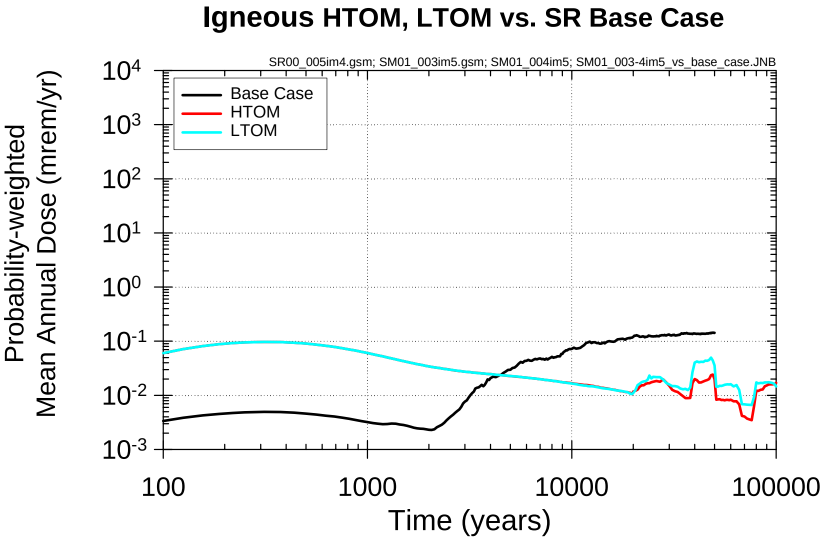
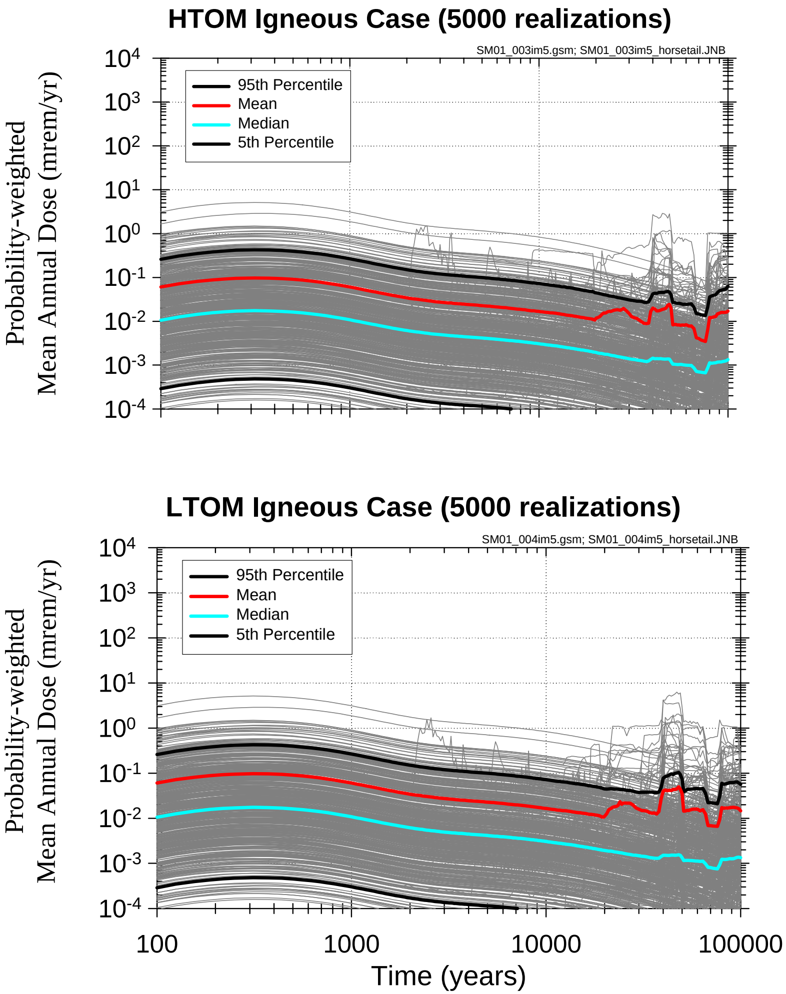
TSPA-SR and FY01 SSPA Results
Igneous Disruption

- **TSPA-SR probability-weighted mean annual dose, 50 kyr (labeled "base case" on figure)**
- **SSPA probability-weighted mean annual dose for high-temperature and low-temperature operating modes (HTOM and LTOM), 100 kyr**
- **First-order observations from SSPA results**



  - **Eruptive doses (left portion of curves) increase by ~25x, dominate for > 10 kyr changes in probability, BDCFs, wind speed, # of packages damaged**
  - **Intrusive groundwater doses (right portion of curves) peak with 38 kyr climate change**
  - **Overall peak probability-weighted dose is similar to TSPA-SR, but dominant pathway shifts from groundwater to eruptive ashfall**

Uncertainty in FY01 SSPA Results
Igneous Disruption



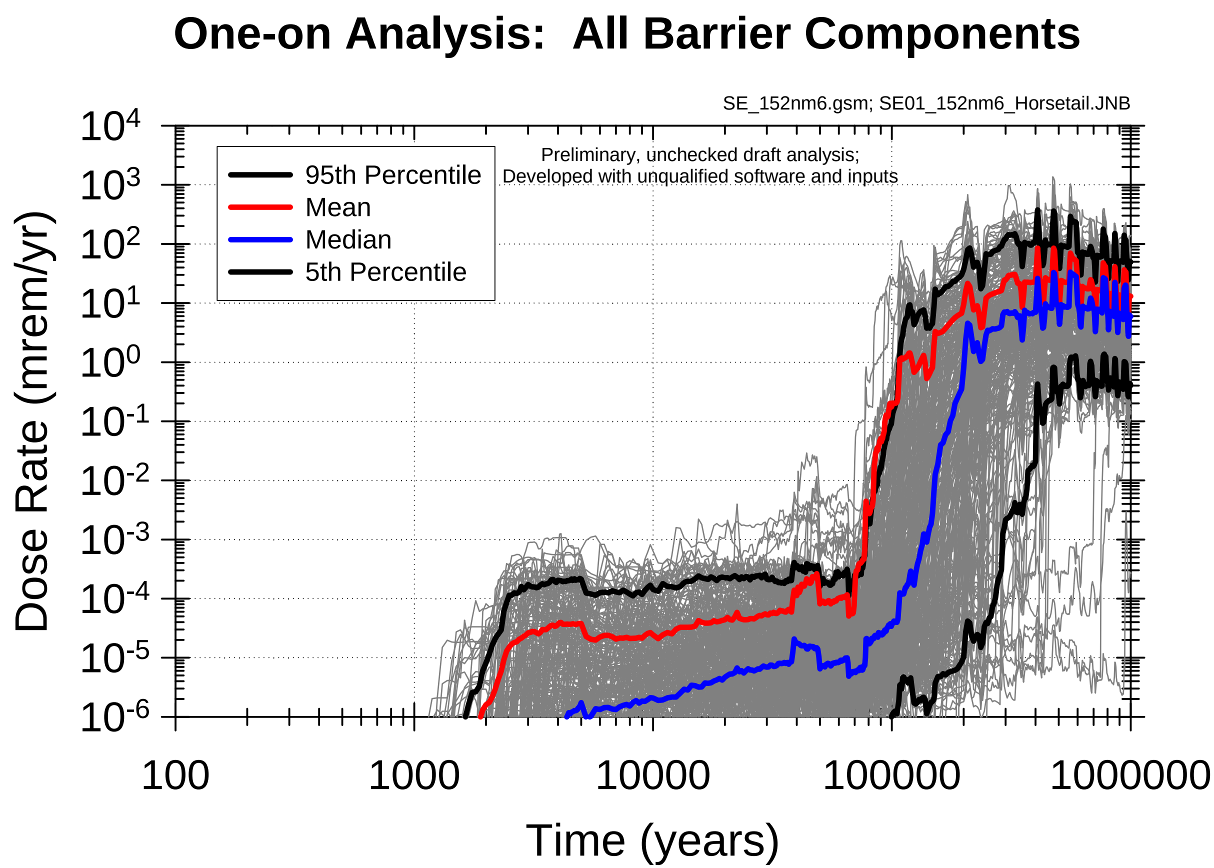
- Monte-Carlo approach used to capture uncertainty in model results based on uncertainty in model inputs
- 500 out of 5000 TSPA realizations shown for HTOM and LTOM, with 95th, 50th, and 5th percentiles and the mean annual dose

Sequential Addition Barrier Analyses

- **Analogous to the Electric Power Research Institute (EPRI) "one-on" analyses**
- **Sequential addition of barrier components shows potential reduction in dose due to addition of each barrier**
  - **Sequence is important: evaluating waste package first, for example, would mask contributions from natural system**
  - **This sequence focuses on the natural system and facilitates comparison with the EPRI results**
- **Caveats:**
  - **Work described here is for insight only**
  - **Analyses apply only to nominal performance**

“One-on” Sequential Analysis Overall Performance

- One million year annual dose
- 300 realizations of HTOM nominal performance
- FEIS model, modified to include Sr-90 and Cs-137 transport, updated long-term climate states, and regulatory specification for 3,000 acre-ft annual groundwater usage



Mean annual dose based on 300 realizations of nominal performance. Models and input values are preliminary. Results are for information only, and are not suitable for comparison to regulatory standards

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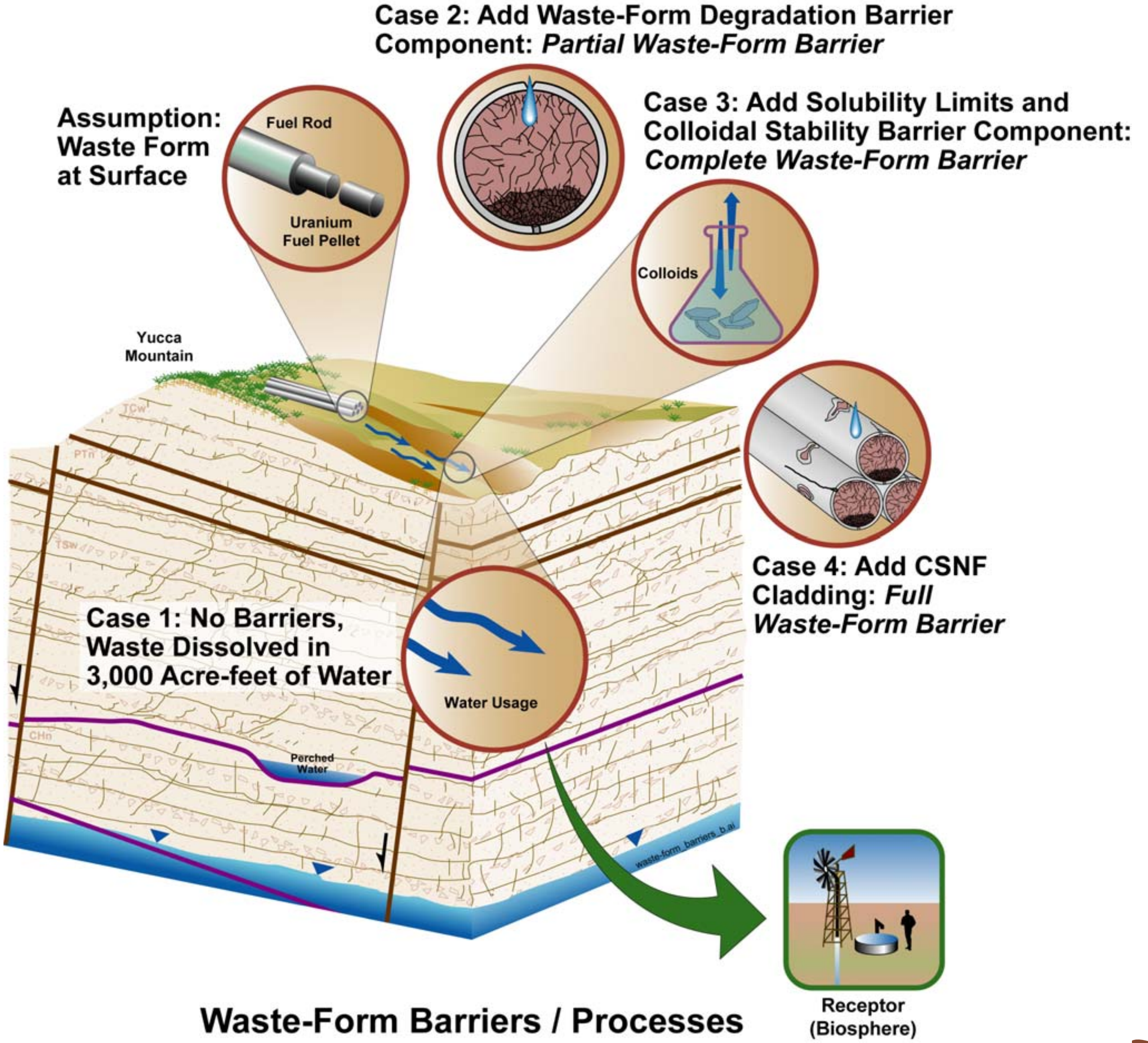
Barrier Component Evaluation

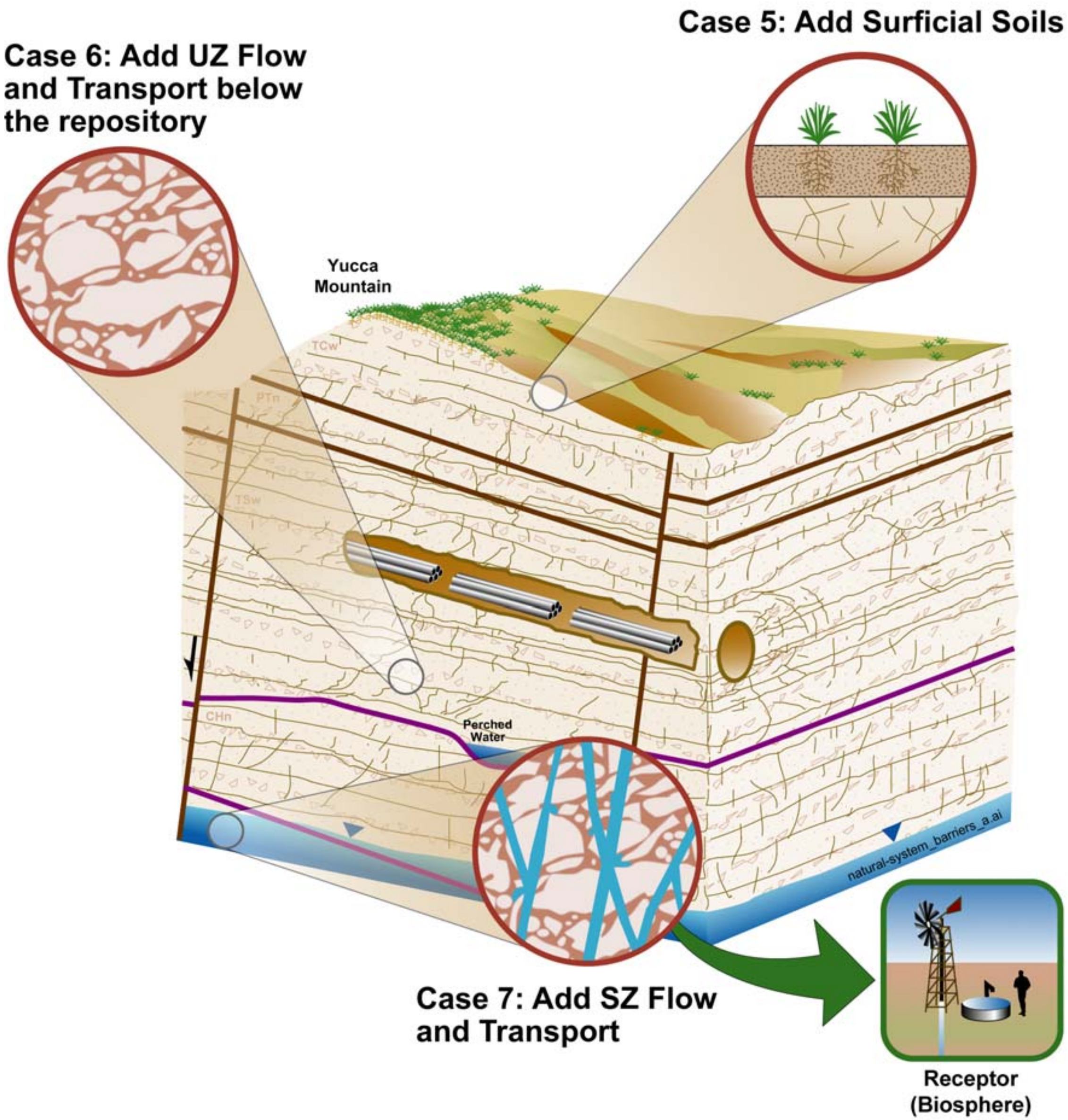
- **12 cases analyzed sequentially and cumulatively**
- **Waste-form components/processes**
  - **Case 1: No barriers**
    - **All waste dissolved directly in 3000 ac-ft/yr of water**
  - **Case 2: Add Waste-form Degradation Barrier Component**
    - **Waste-form degradation rates limit release**
  - **Case 3: Add Solubility Limits and Colloidal Stability**
    - **Combines with degradation rates to give Waste Form Barrier**
  - **Case 4: Add CSNF Cladding**
    - **Cladding degrades by perforation and unzipping**



Waste-Form Barriers / Processes

Barrier Component Evaluation
(Continued)

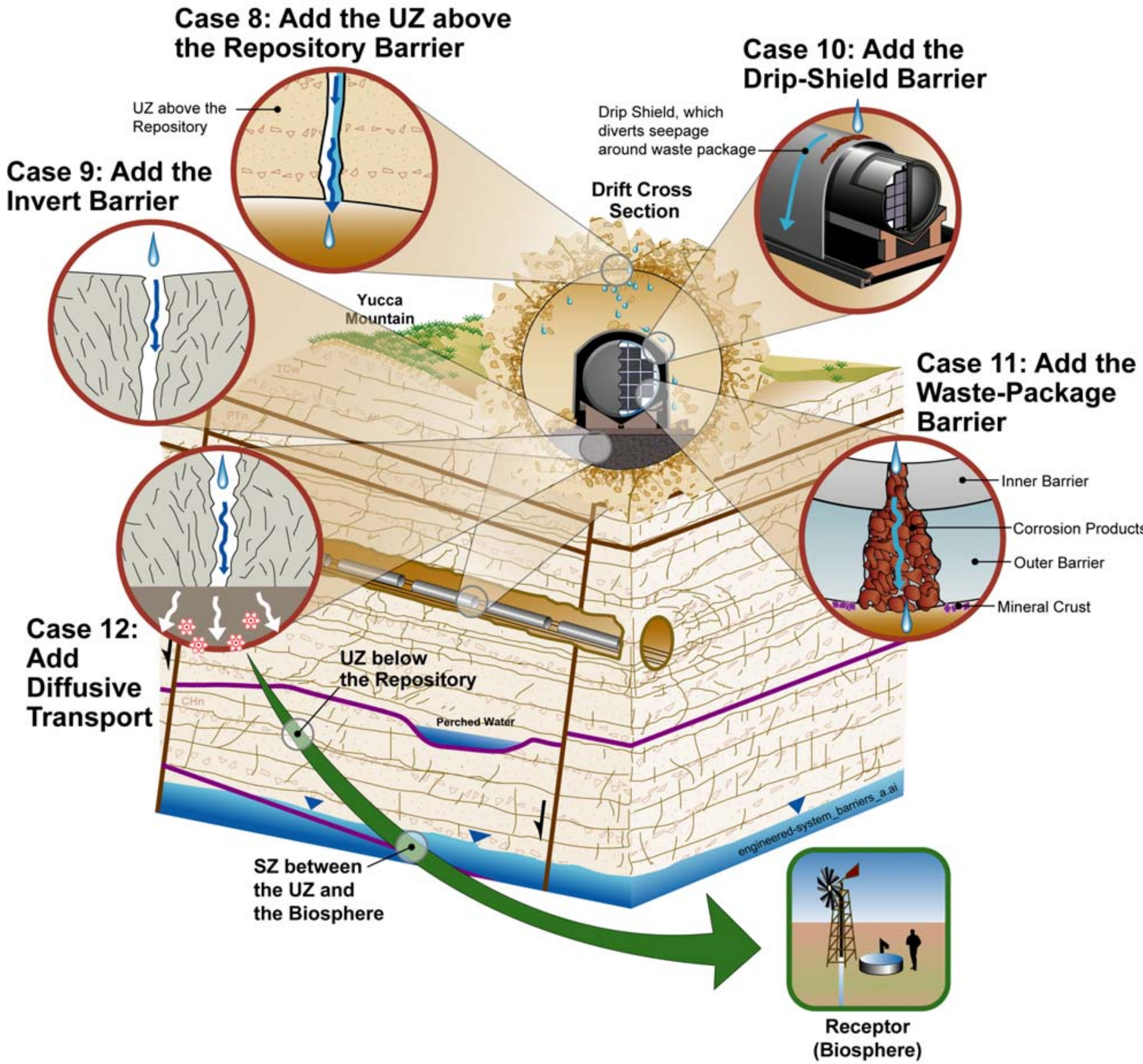
- **Natural System components/processes**
  - Case 5: Add Surficial Soils and Topography
    - Release rate from waste form controlled by infiltration flux
  - Case 6: Add Unsaturated Zone (UZ) Flow and Transport
    - Concentrations reduced by UZ flow and transport processes
  - Case 7: Add Saturated Zone (SZ) Flow and Transport
    - Concentrations reduced by SZ flow and transport processes



Natural-System Barriers / Processes

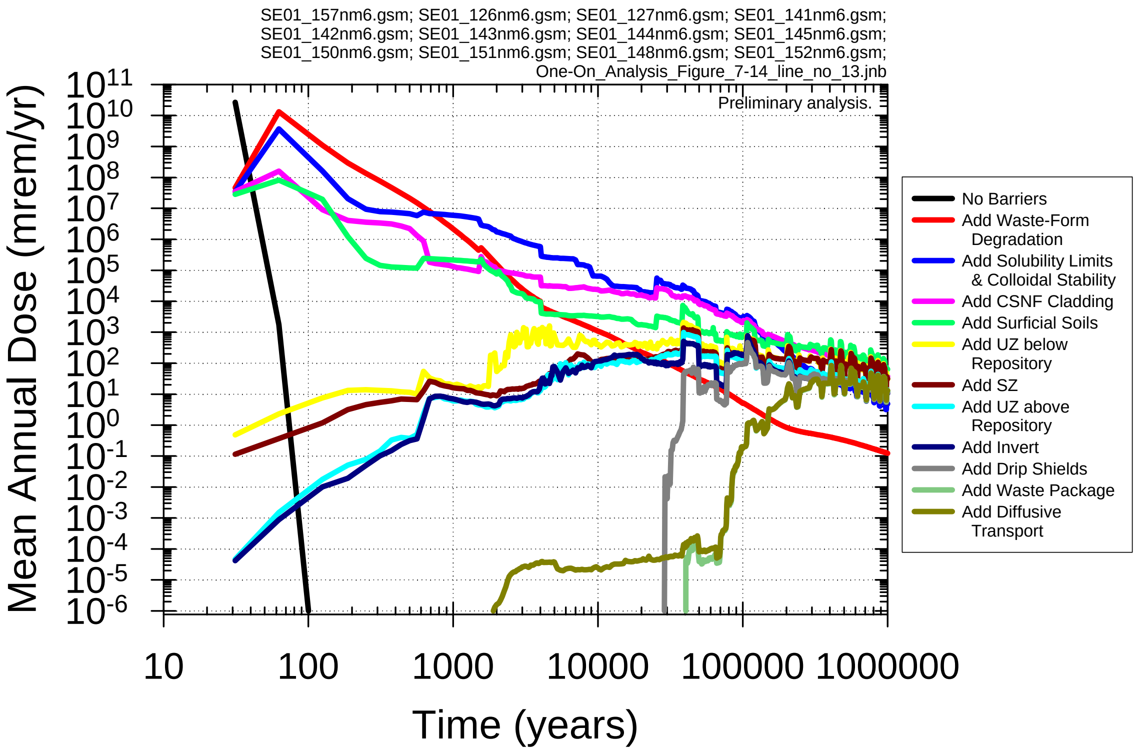
Barrier Component Evaluation
(Continued)

- **Engineered System components/processes**
  - Case 8: Add the UZ above the Repository (Drift Effects)
    - Release controlled by seepage, capillary and thermal effects
  - Case 9: Add the Invert
    - Include sorption on crushed rock and corrosion products
  - Case 10: Add the Drip Shield
    - Include drip shield over all waste, with drip shield degradation
  - Case 11: Add the Waste Package
    - Include waste package degradation model
  - Case 12: Add Diffusive Transport in the EBS
    - Not a “barrier”: allows transport in non-seep environments



Engineered-System Barriers / Processes

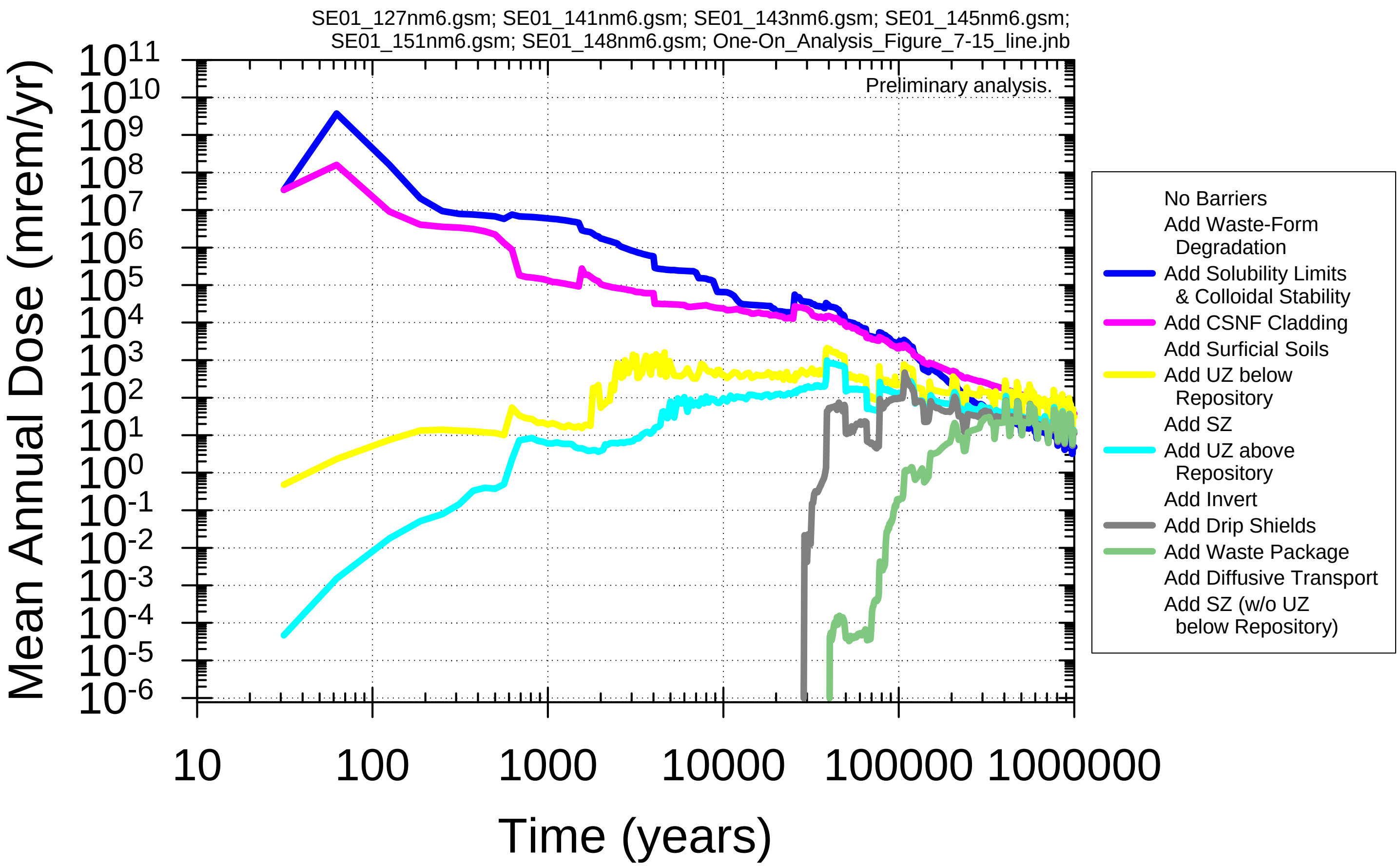
Sequential Analysis Results



Mean annual dose based on 300 realizations of nominal performance. Models and input values are preliminary. Results are for information only, and are not suitable for comparison to regulatory standards

- **The "no barrier" case shows a hypothetical peak mean dose of ~ 2.8 x 10^{10} mrem/yr**
- **The full system shows a peak mean annual dose for nominal performance during the first 10,000 years of < 10^{-4} mrem/yr**
- **For this sequence, UZ below the repository provides the largest incremental impact on the time of overall peak dose, shifting from < 100 yr to ~ 40 kyr, and lowering the peak > 4 orders of magnitude**

Sequential Analysis Results
Selected Components



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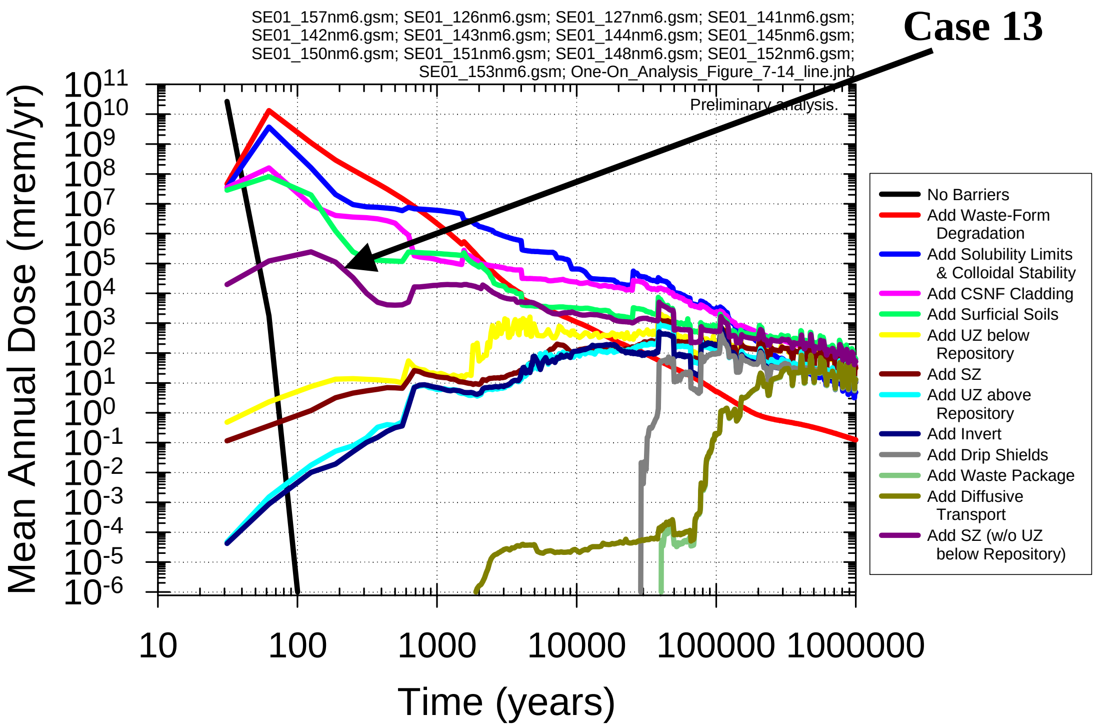
Sequential Analysis Results: Case 13



Mean annual dose based on 300 realizations of nominal performance. Models and input values are preliminary. Results are for information only, and are not suitable for comparison to regulatory standards

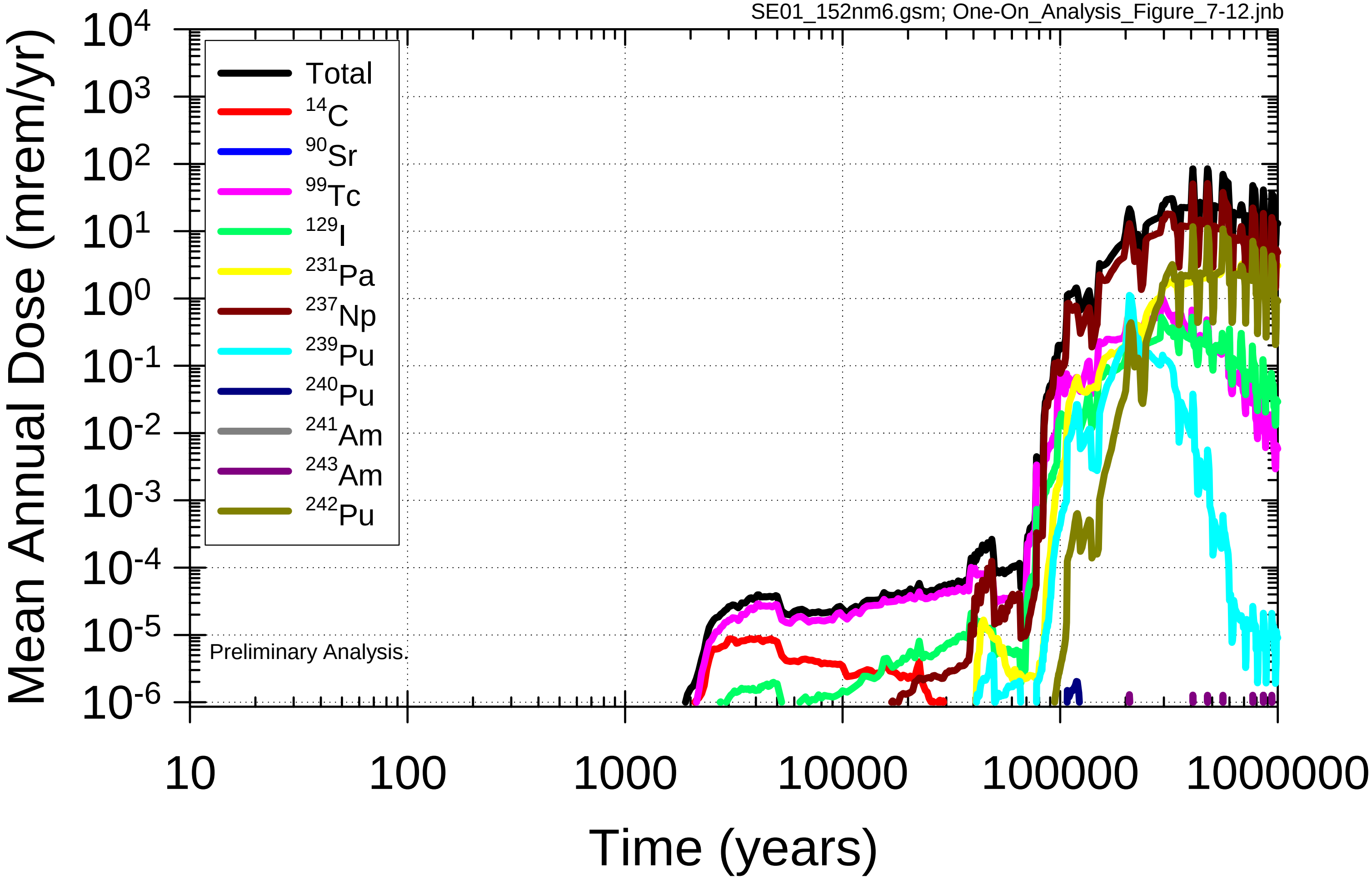
- **Saturated zone barrier component added before the unsaturated zone below the repository, at same place in sequence as Case 6**
- **Radionuclide transport bypasses the UZ, without any contribution from engineered components**
- **Removes possible masking effect of UZ on SZ**

Conclusions

- **Changes in TSPA results from TSPA-SR to present are consistent with purposes of the analyses**
  - **Increasing emphasis on realistic treatment of uncertainty, less reliance on bounding assumptions**
  - **New information incorporated as available (e.g., igneous disruption scenario)**
  - **Uncertainty in relatively few processes drives changes in results**
    - **e.g., waste package performance (early failure, general corrosion rate); solubility limits; igneous activity**
- **"One-on" barrier component analyses provide additional insight into nominal performance**
  - **Order matters in a sequential analysis**

Backup

One-On Sequential Analysis Total Dose
Selected Contributors to Nominal Performance



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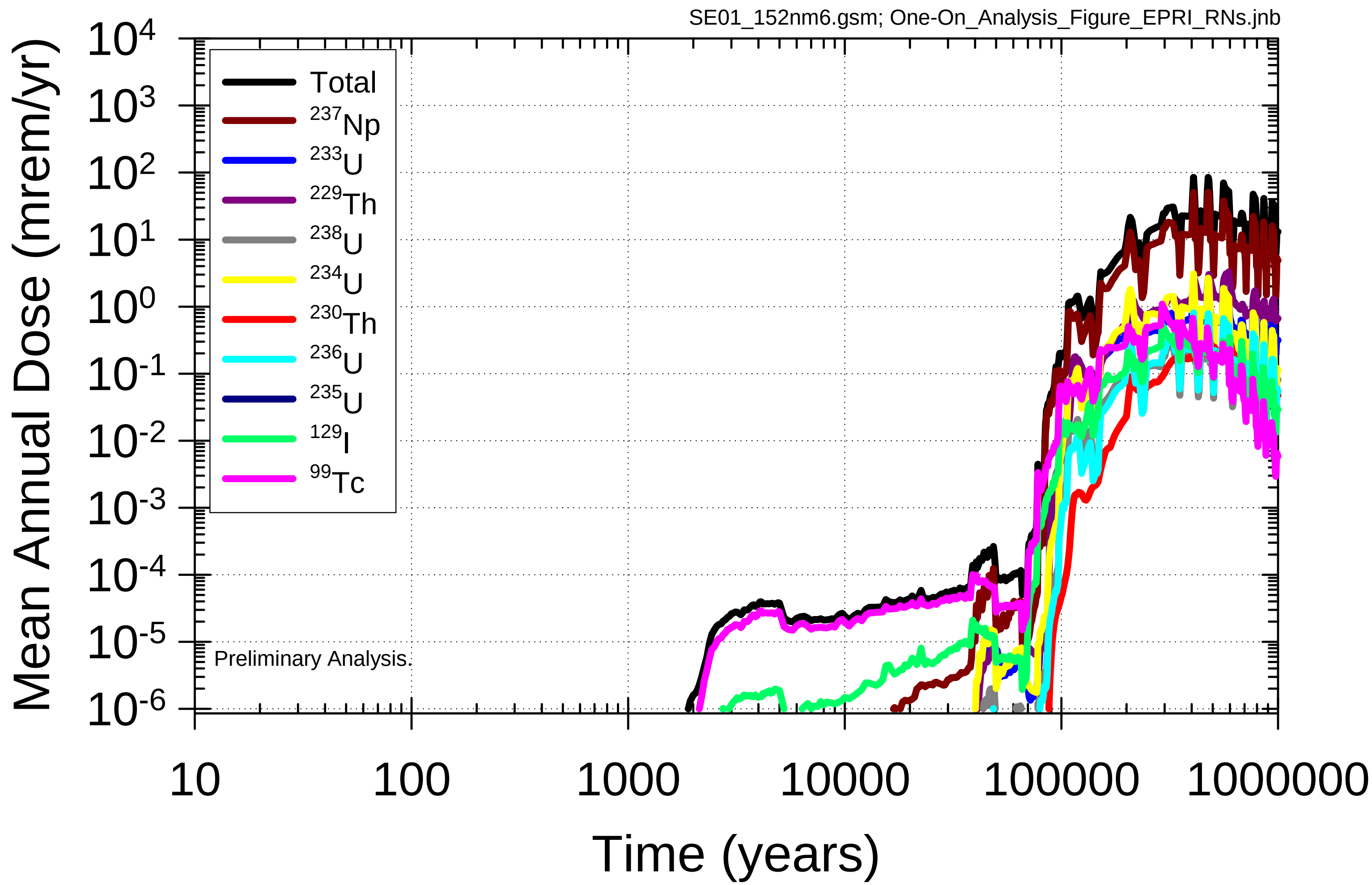
One-On Sequential Analysis Total Dose
Additional Contributors to Nominal Performance



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