EPRI Performance Assessment Program: Approach and Recent Results

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Presented to NWTRB September 20, 2004

Outline

- EPRI's Role
- EPRI's Achievements
- EPRI's Approach
  - Expert team
  - Logic-tree structure/ IMARC Code
  - Examples of past results
- Recent EPRI Results
  - Deliquescence
  - Igneous event/ volcanism
- Future directions for EPRI work

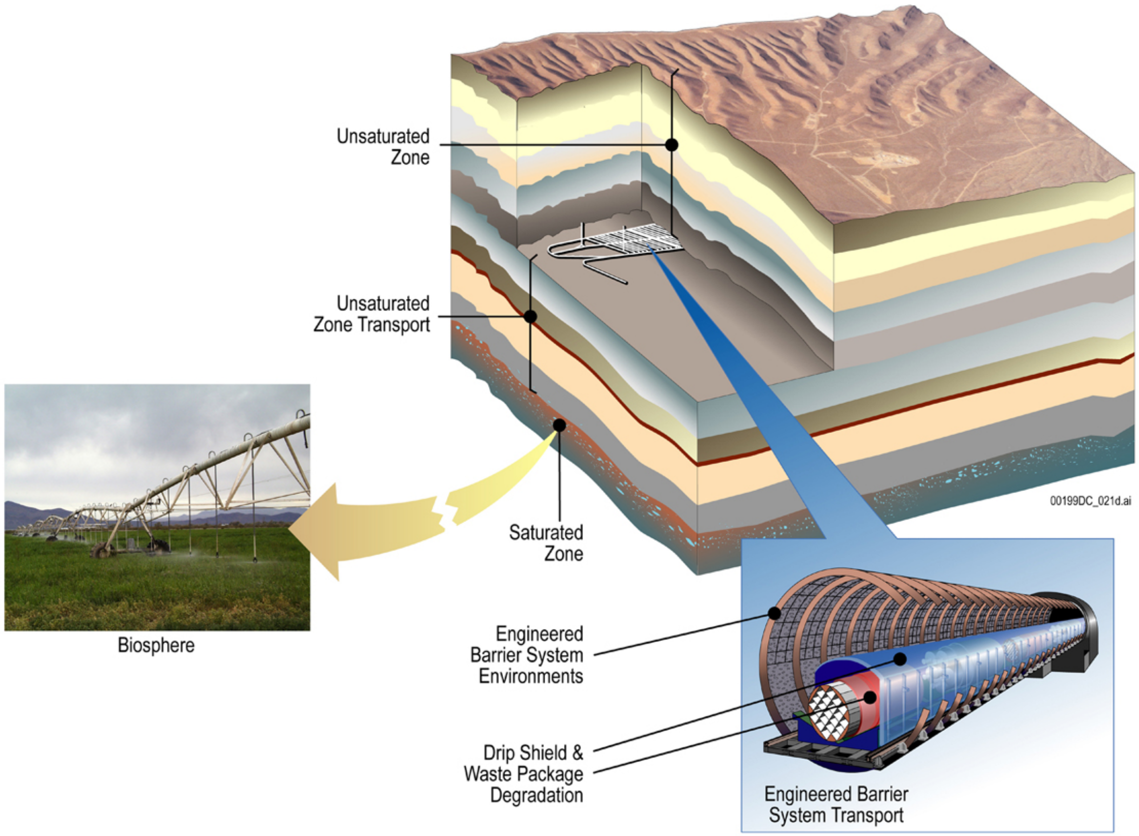
EPRI's Role

- Conduct independent, technically defensible analyses of the long-term isolation of nuclear waste within a repository located at Yucca Mountain (YM).

- Based on these analyses, provide insight to EPRI's members, EPA, NRC, DOE, review organizations such as USNAS, NWTRB and ACNW, and to the public on YM-related issues.

Main Features of the Yucca Mountain Repository System

- Unsaturated Zone (UZ) ~600 meters thick
  - Repository in this zone (unique to Yucca Mountain)
- Engineered Barrier System (EBS)
  - Tunnel, “drip shield”, container, cladding, waste itself
- Saturated Zone (SZ)
  - Groundwater transport 18+km downstream
- Biosphere
  - Where the contaminants come into contact with humans and other biota



EPRI's Achievements Since 1990

- Documented a series of independent safety assessments (Phase 1 to Phase 8).
- In early 1990's, encouraged DOE to begin conducting regular TSPAs.
- Provided industry input to the NAS TYMS Committee on the technical bases for a YM standard (1993-1994).
- Identified several credible alternative conceptual designs, models and data.
- Promoted FEP (features, events and processes) analysis to DOE.
- Helped to initiate early work on Yucca Mountain-specific biosphere.
- Conducted "one-on" (barrier neutralization) analyses to identify the relative barrier contributions to isolation.
- Independent evaluation of the technical bases for "what if?" scenarios:
  - pre-2004: climate change, juvenile/ fabrication defects
  - 2004: igneous eruption event, deliquescence, MIC
  - 2004 (in progress): tunnel stability/ seismicity, colloids, sorption issues.
- Supported and participated in public peer review fora regarding Yucca Mountain (e.g., NAS's TYMS report, NWTRB, NRC's ACNW, Materials Research Society).

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EPRI's Approach

- Assemble and maintain a teams of experts to:
  - review the publicly available information related to the design and performance of the multiple-barrier repository concept for Yucca Mountain,
  - identify, defend and integrate credible, "best-estimate" assumptions, models, data and associated uncertainties into a total system performance assessment model (IMARC) for this repository concept,
  - use IMARC, combined with expert judgement, to evaluate on a risk-informed basis the long-term performance of barriers for waste isolation for the expected evolution of repository conditions, as well as other "what if?" alternative scenarios.

EPRI Experts

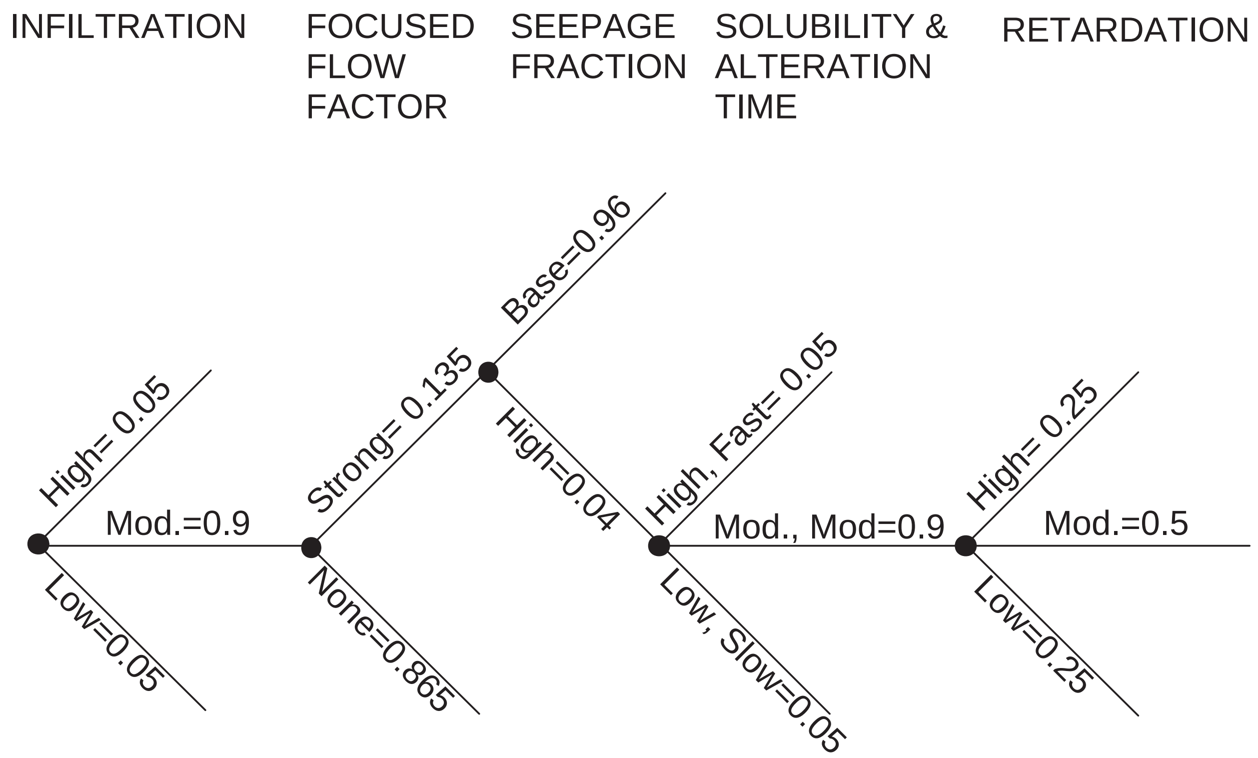
- Marcus BURSIK, SUNY-Buffalo, Igneous events
- Stuart CHILDS, Consultant, Infiltration
- Charles FAIRHUSRT, Univ. Minnesota, Rock engineering
- John KEMENY, Univ. Arizona, Rock mechanics
- Fraser KING, Consultant, Corrosion
- Don LANGMUIR, Consultant, Geochemistry
- Austin LONG, Univ. Arizona, Climate
- Derek MARTIN, Univ. Alberta Tunnel stability
- Tim McEWEN, Consultant, Repository systems
- Meghan MORRISSEY, Colo. School of Mines, Igneous events
- George MUNGOV, Consultant, Coding, QA
- Ben ROSS, Consultant, Thermo-hydrology
- Frank SCHWARTZ,Ohio State Univ., Hydrology
- Mike SHERIDAN,SUNY-Buffalo, Igneous events
- Graham SMITH, Consultant, Biosphere,
- Paul SMITH, Consultant, Safety case
- Ed SUDICKY, Univ. Waterloo,Hydrology
- Trevor SUMMERLING, Consultant, PA
- Japie VAN BLERK, Consultant, Coding

- Monitor Staff

- Mick APTED (Manager), EBS, source-term, compliance analysis
- Randy ARTHUR, Geochemistry
- Matt KOZAK, Colloids, compliance analysis
- Pat SALTER, Radiochemistry
- Mike STENHOUSE, Sorption
- Wei ZHOU, EBS Transport

EPRI Uses a Logic Tree Approach to Probabilistic TSPA (i.e., not Monte Carlo)

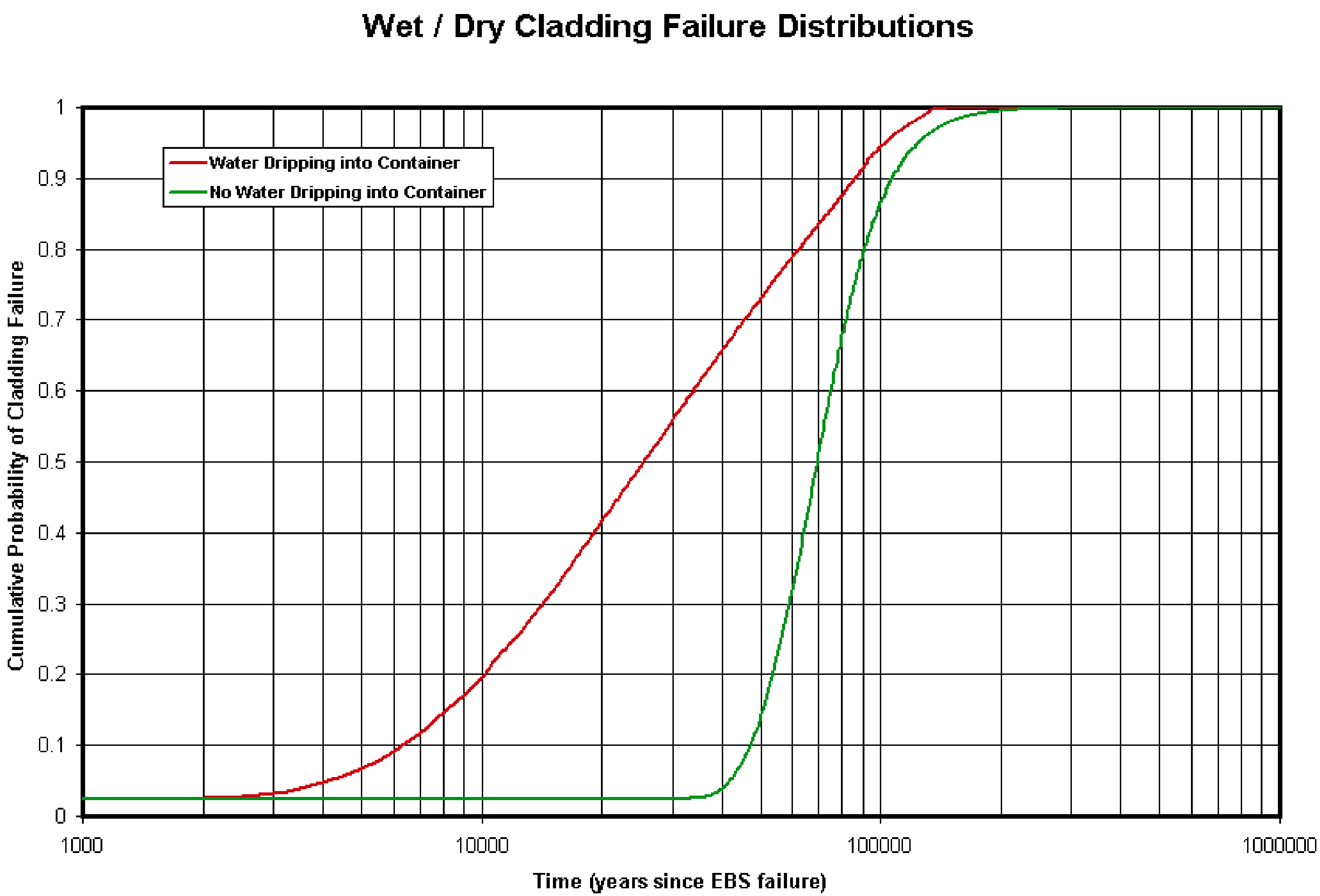
- Limited number of branches with discrete probability and parameter value for each branch.



Example: Climate Effects on Infiltration Rates [mm/yr]

Climate	Low	Mod.	High
Greenhouse (0-1000 years)	1.1	11.3	19.2
Interglacial (1000-2000 years)	1.1	7.2	9.6
Full Glacial Maximum (beyond 2000 years)	6.8	19.6	35.4

"Wet"/"Dry"Cladding Failure Rates



EBS Diffusive Release Model in IMARC

- Allows release from
  - Waste packages in “dry” areas
  - Waste packages with “pin-hole”/ localized failures
- Conceptual model for diffusive release
  - Excellent contact between all EBS components and surfaces i.e.,spent fuel, cladding, container interior walls, invert, surrounding rock (initial bounding assumption)
  - Multiple continuous water pathways through EBS (initial bounding assumption)
  - Diffusion through partially saturated porous corrosion products (extremely slow release from EBS, possible colloid attenuation)

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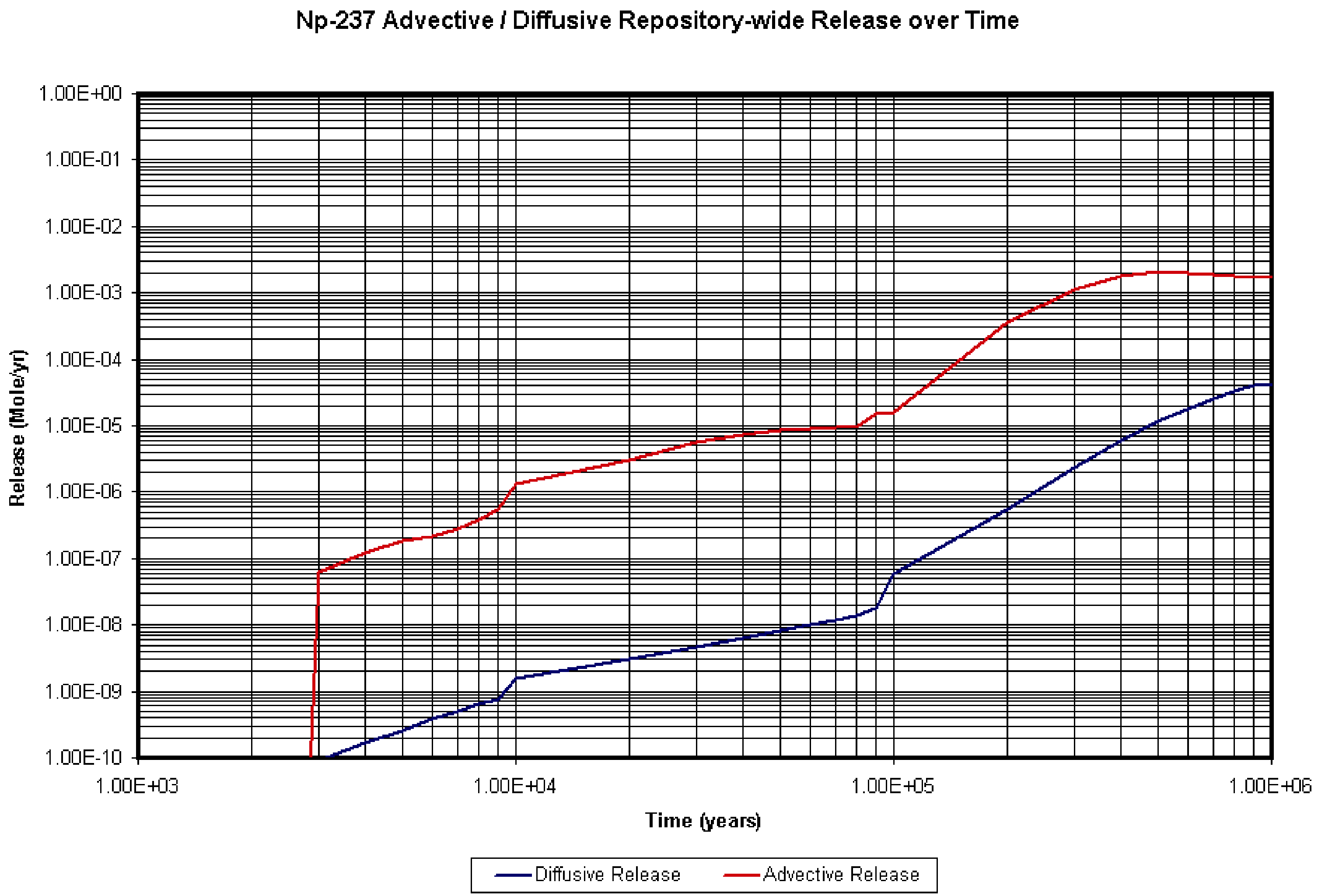
Repository-Wide Np-237 Advective and Diffusive Release from the EBS



Presented NWTRB September 20,2004

EPRI Approach to “Normal” Release Case

- Climatic changes affecting infiltration included
- Thermal dry-out and re-flux (evaporation/ condensation cycle) modeled
- Container and cladding must fail for diffusive release to begin (juvenile failures included)
- Drip shield failure allows advective release (where local flow is high enough)
- Advection/diffusion through UZ and SZ to 18km “fencepost”
- Perturbations to Normal Release Mode
  - Igneous events (2004; see later)
  - Deliquescence (2004; see May 2004 NWTRB meeting)
  - Colloids, seismicity (in progress, see later)

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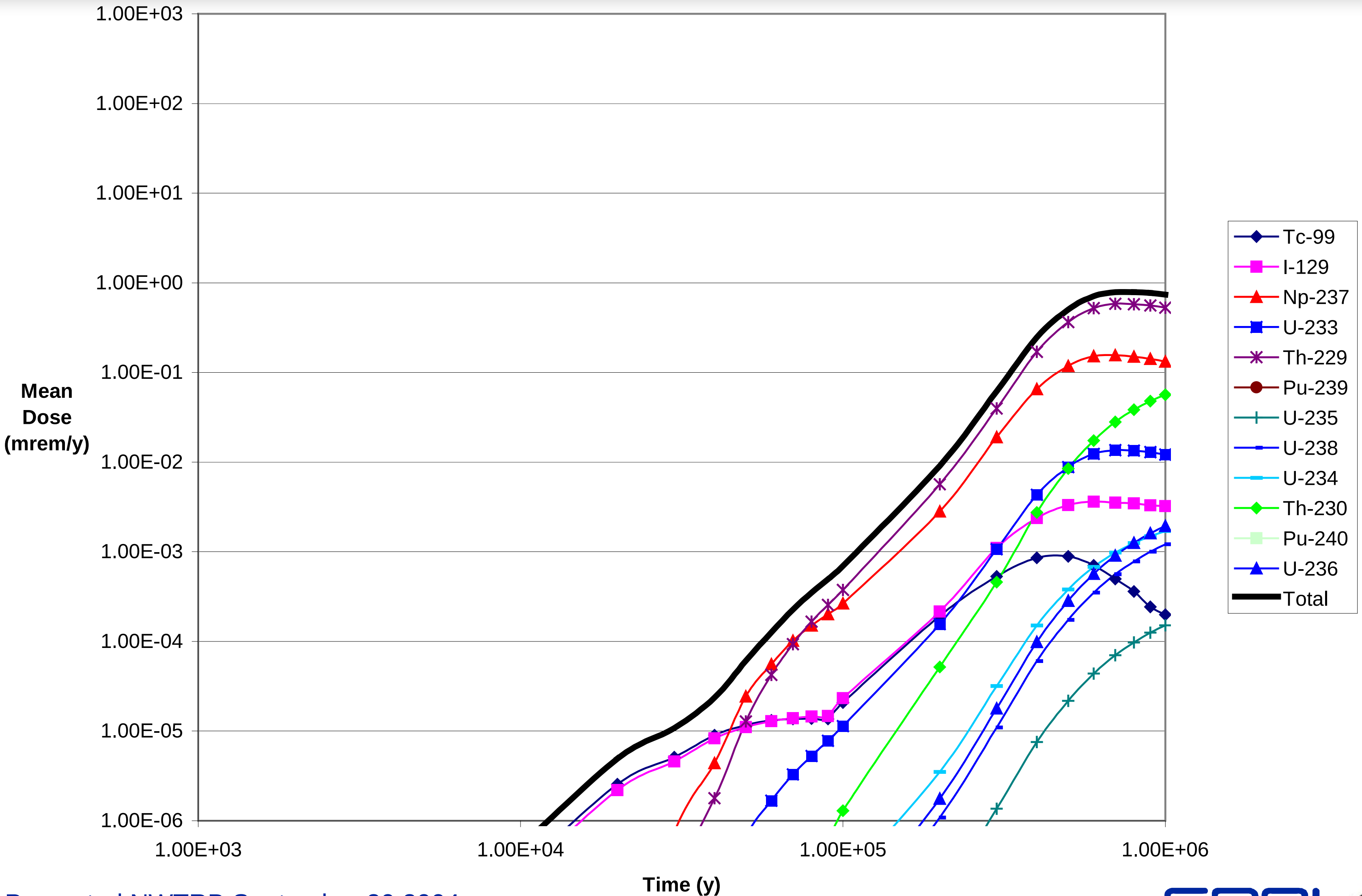
Past Results: Normal Release Case



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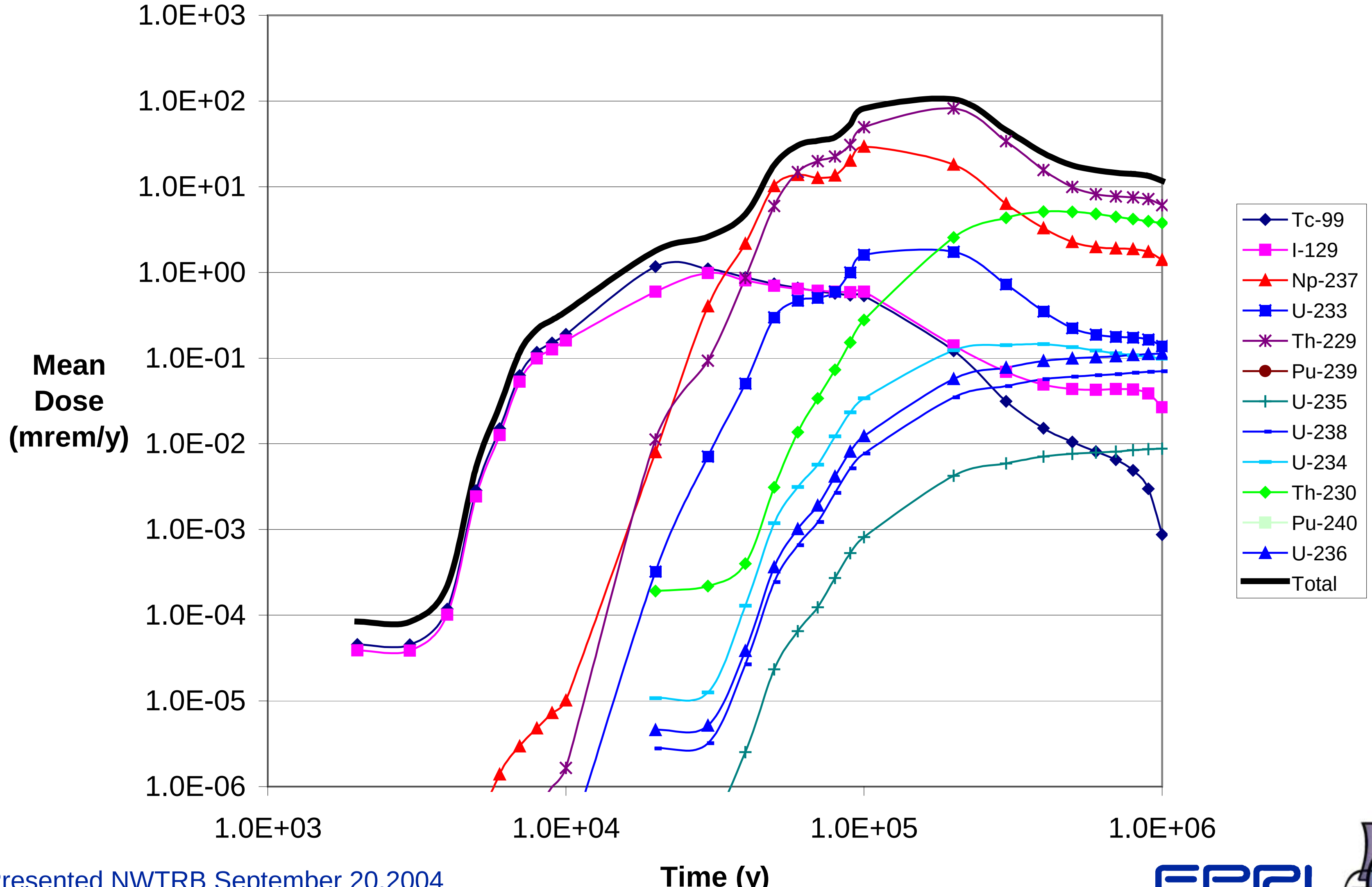
Past Result: Normal Release Case with No Contribution from Waste Package



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Some of the Differences between *Past* DOE and EPRI TSPA Models

- EPRI assumes one early container failure
  - DOE plots shown assume <1 early failure
- EPRI assumes better cladding and container performance
- EPRI includes detailed EBS diffusive transport model
  - New DOE model may more closely match EPRI approach
- EPRI handles time-stepping differently
- EPRI fixes long-term climate to full glacial maximum
- EPRI BDCFs higher in some cases
  - EPRI assumes additional non-drinking water pathways
- EPRI bases doses on plume size with a groundwater flux of ~750 acre-ft/yr
  - Probably an underestimate due to limitations in vertical extent of EPRI SZ model; sensitivity analyses in progress.

Past Results: "Hazard Index"

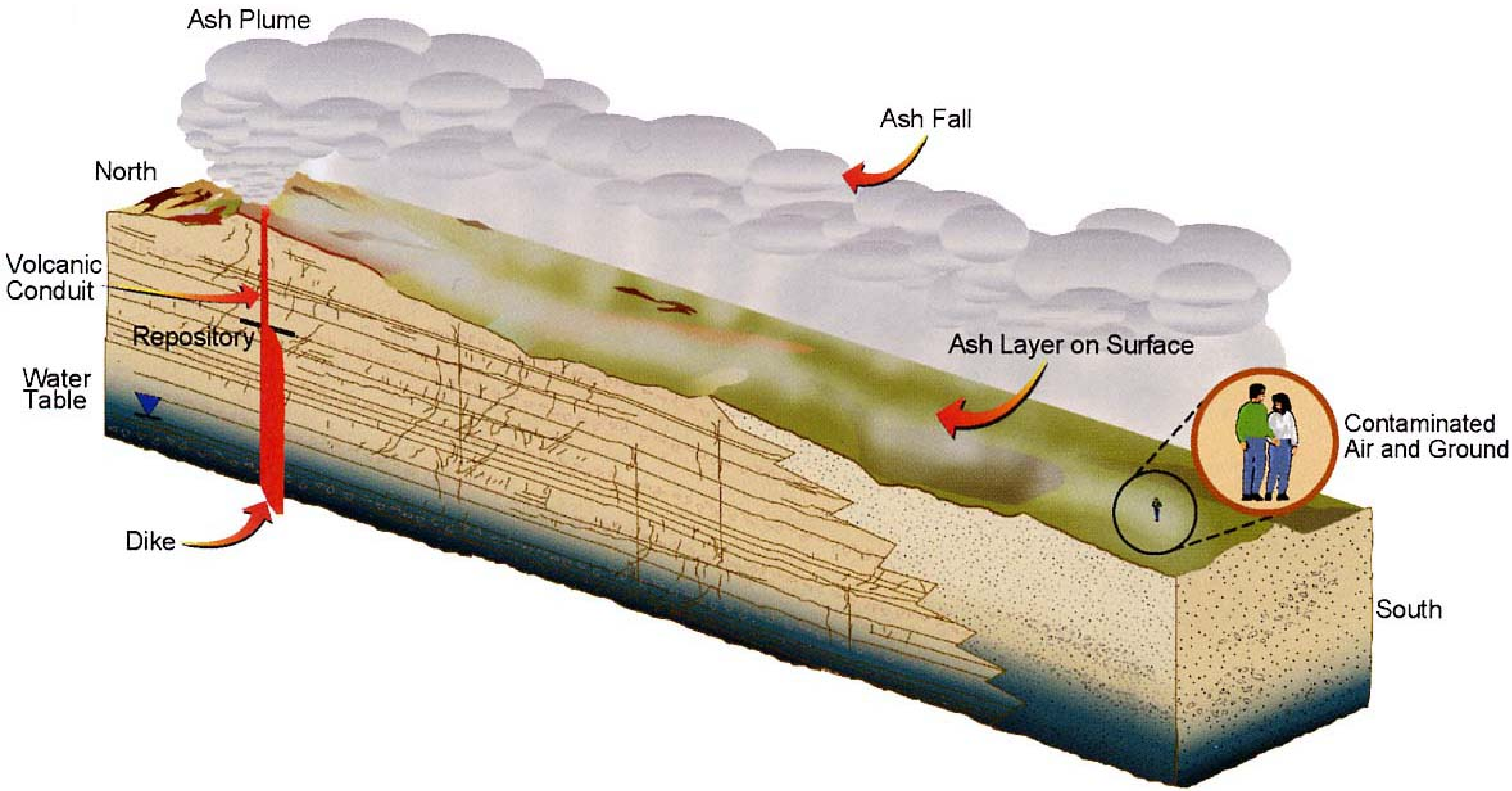
Essentially a "one-on" (rather than "one-on") series of analyses

- Eliminating ALL barriers then add 13 potential "barriers" one-by-one (including)
  - **3,000 year waste-form alteration time**
  - **Moderate solubility**
  - **Cladding, container and drip shield time-dependent failures**
  - **EBS sorption and diffusive transport constraints**
  - **Accessible Environment (AE) at 5 km**
  - **UZ/SZ with moderate retardation**
  - **AE in front of alluvium or at 18 km**
  - **Dose from all pathways**
- Amount that the 'Hazard Index' (dose rate) is reduced indicates potential barrier importance

Conclusions from Hazard Index Analyses

- Many barriers can contribute substantially to "performance" (Hazard Index reduction)
  - Not all "eggs are in one basket"
- The amount of performance depends on what other barriers are assumed. Examples:
  - Engineered barriers added first: 9 orders of magnitude reduction
  - Engineered barriers added after natural: 0-5 orders of magnitude reduction (depending on time)
  - Natural barriers alone reduce dose to below natural background levels

Recent Results: Igneous Event/ Volcanism

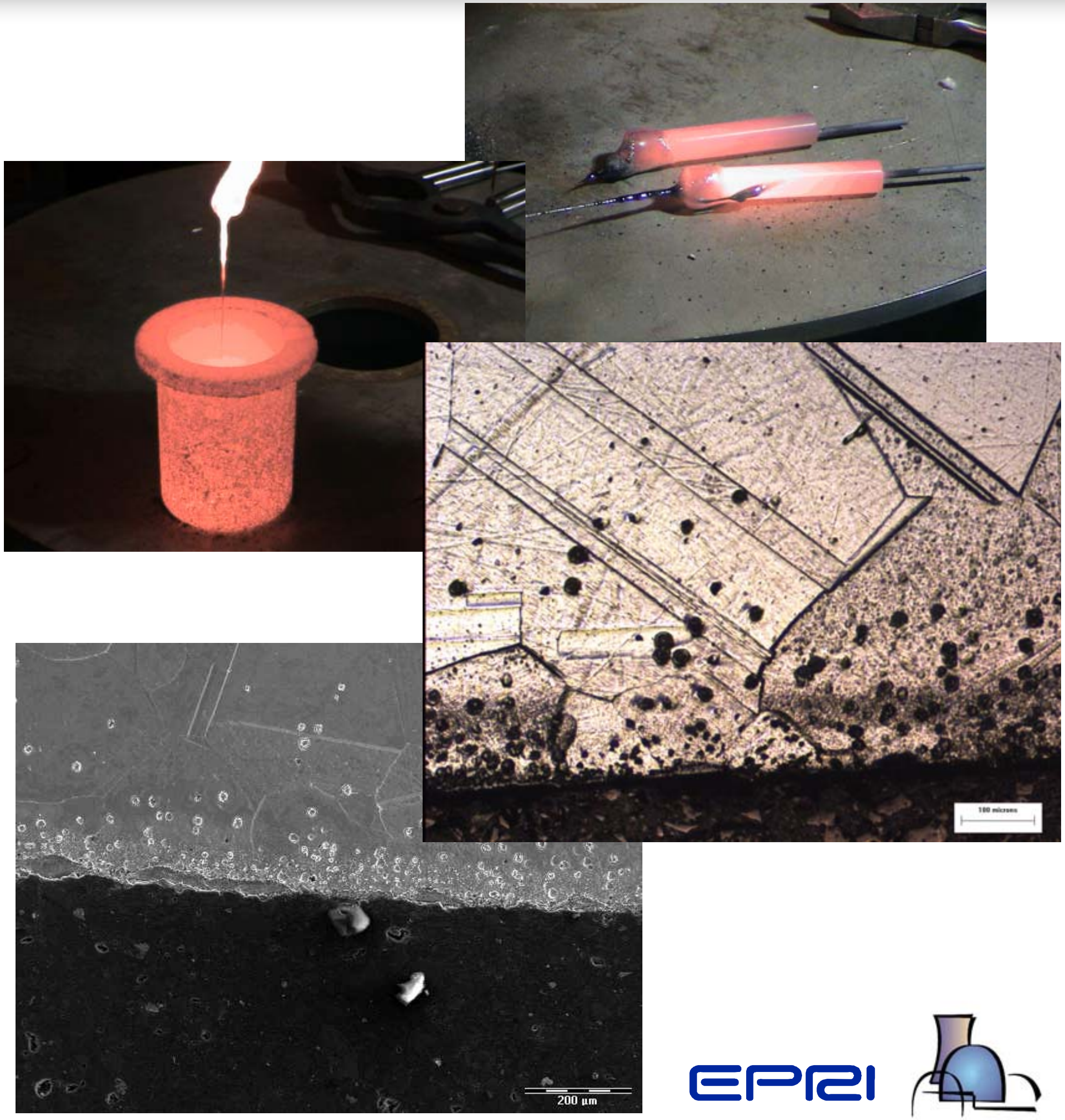


SAGE Simulation of Hydrous Dike-Drift Interaction

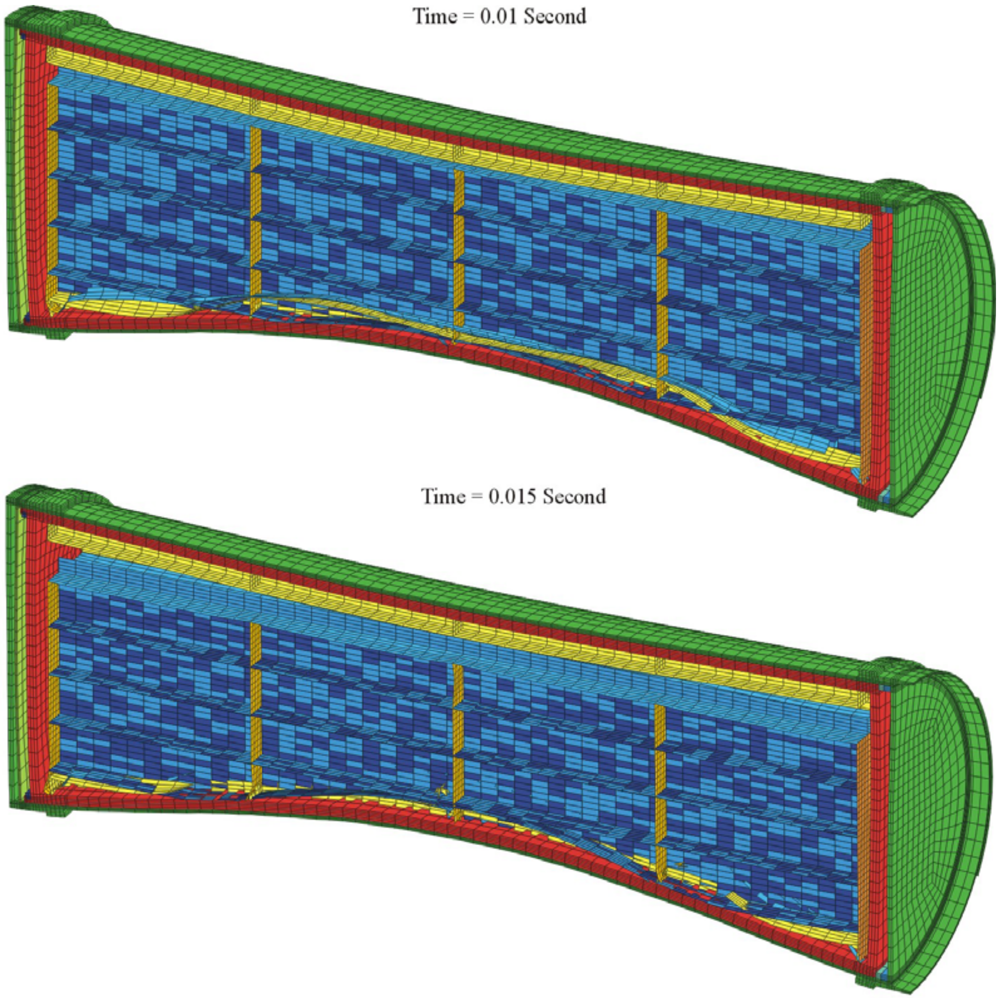
QuickTime™ and a
Graphics decompressor
are needed to see this picture.

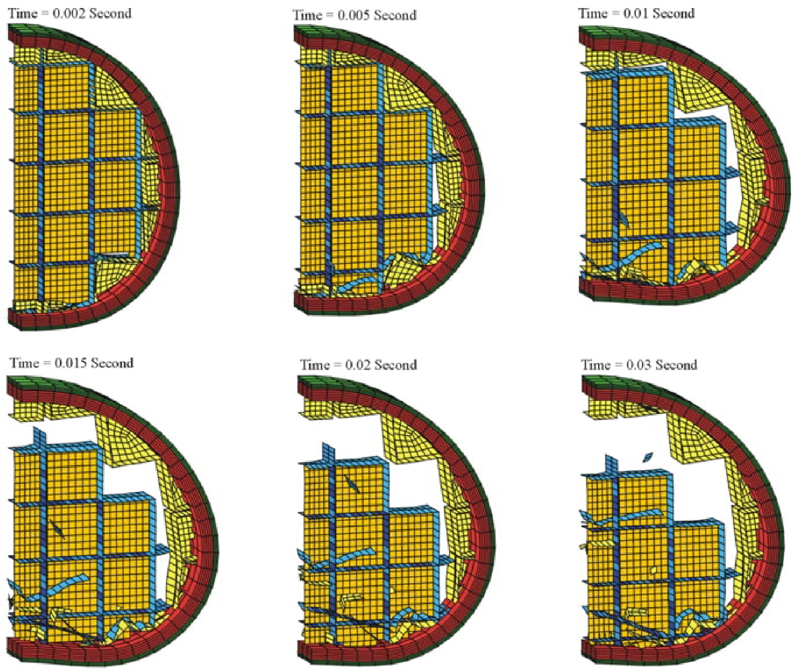
Magma – C22 Interaction Tests

- C22 contacted by 1200˚C basalt magma from 1 hr to 1 month (3-5 days is expected time for magma to solidify).
- C22 material still intact after 1 month.
- Surface voiding up to 600 microns after 1 month.
- No evidence of IGA or other degradation.

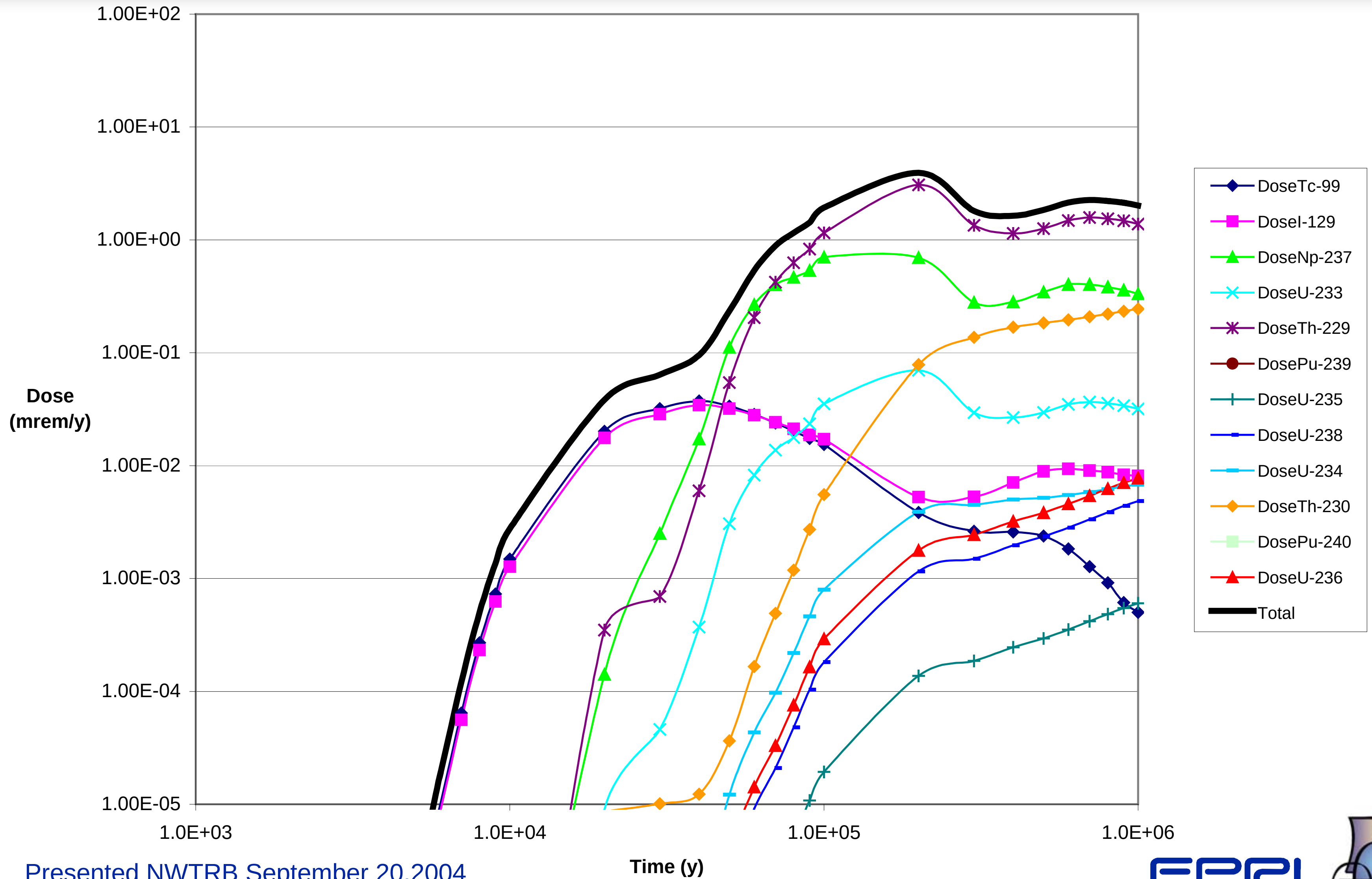


ANSYS Analysis of Dike-impacted Package: No rupture for 10 m/s ascent rate (100x)





Recent Results: Igneous Intrusive Case Conditional Dose
(assumes event probability = 1)



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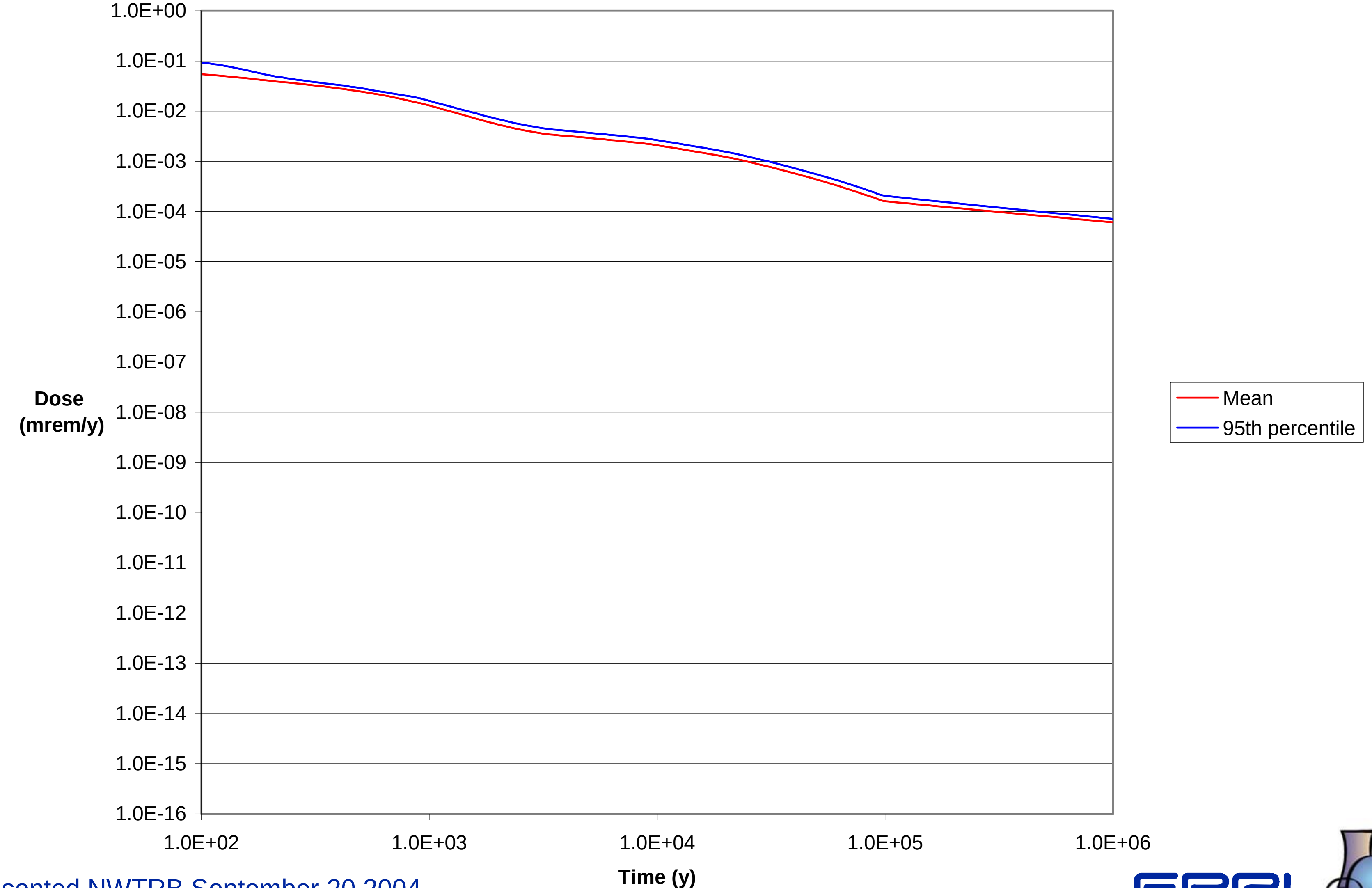
Recent Results: Igneous Intrusive Case Conditional Dose
(assumes event probability = 1 *and* that releases occur)



Future Directions for EPRI Work

- Continue to address any new "what if?" scenarios – both probabilities and consequences
  - Compare and contrast to DOE and NRC approaches
  - Develop independent model(s) as necessary to include in IMARC
- Evaluate Pre-Closure issues
  - Surface facility design and risks
  - Subsurface facility design
- Evaluation transportation risks
  - Co-funding NAS panel
  - Actively following NRC Package Performance Study work
  - Evaluate existing and develop new transportation risk assessments, if appropriate
  - Is transportation system adequately developed?

EPRI Work after DOE License Application Submittal

- Evaluate LA and supporting documents
  - Are they adequate? (will involve entire nuclear industry to answer)
  - Use IMARC and related analyses to develop independent assessments, as necessary
- Develop publications and expert witnesses for potential involvement in licensing proceedings