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Managing Uncertainty and Demonstrating Compliance

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Performance and Risk Assessment Community of Practice Technical Exchange

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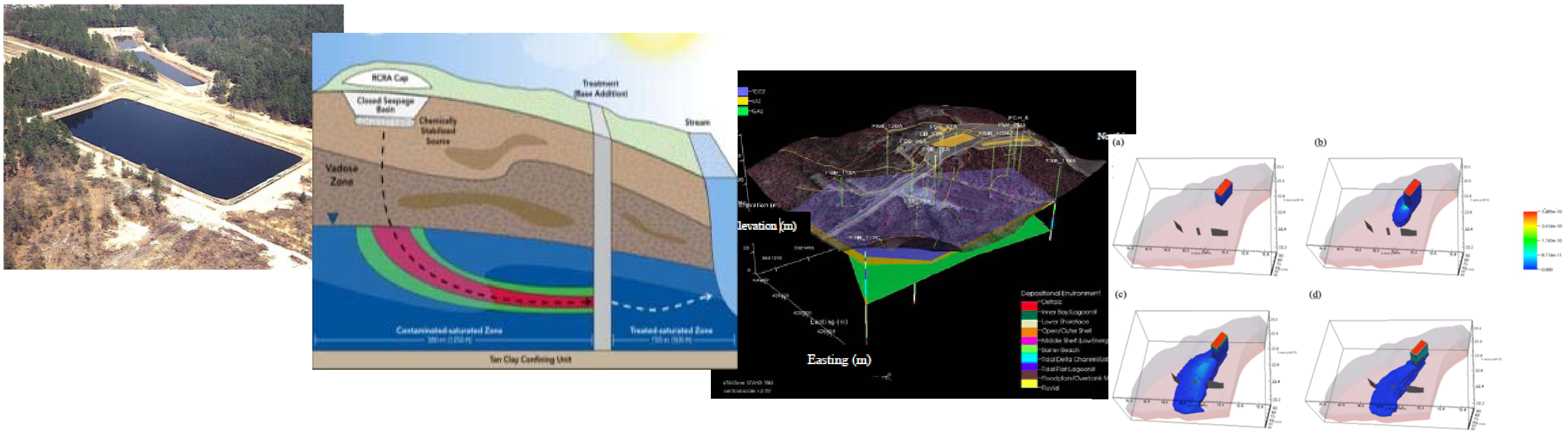
Introduction

- Remediation activities and radioactive waste disposal facilities can go to great lengths to demonstrate safety
- Designs and assessments address potential impacts for very long time frames relative to other human activities
- Uncertainty is inherent in natural systems and long time frames, but it can be effectively managed to make defensible decisions
- Models provide valuable information, but should not be viewed as a "decision-maker"
- An integrated approach with modeling, characterization, monitoring, etc. provides for more effective decision-making

Why Do We Use Models?

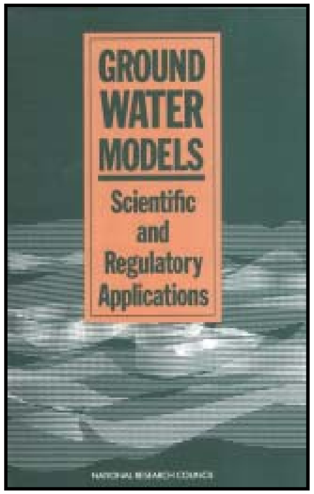
- Improve our understanding of system behavior to support better decisions
  - Project future impacts (10s, 100s, 1,000s of years)
  - Recognize limitations in data/models and prioritize refinements/data collection
  - Evaluate options
  - Optimize designs
- Better communication of the basis for decisions

"The purpose of computing is insight, not numbers"



Managing Uncertainty

- Uncertainty is a fact of life for underground systems, especially when projecting behavior in the far future
- We need to identify approaches to effectively "manage" uncertainties
- Recognize that adding complexity to modeling approach can increase uncertainty depending on data needs (*added detail often provides insights, but maintain proper context*)



"While more complex models increase the range of situations that can be described, increasing complexity… may introduce greater uncertainty in the output if input data are not available or of sufficient quality…"

Components of Managing Uncertainty

- Awareness
  - Need to identify sources of uncertainty
- Importance
  - Identify significant and insignificant uncertainties
- Reduction *(Management)*
  - Identify/implement measures to reduce *(manage)* uncertainties
- Quantification
  - Use safety assessment to illustrate impacts of uncertainty

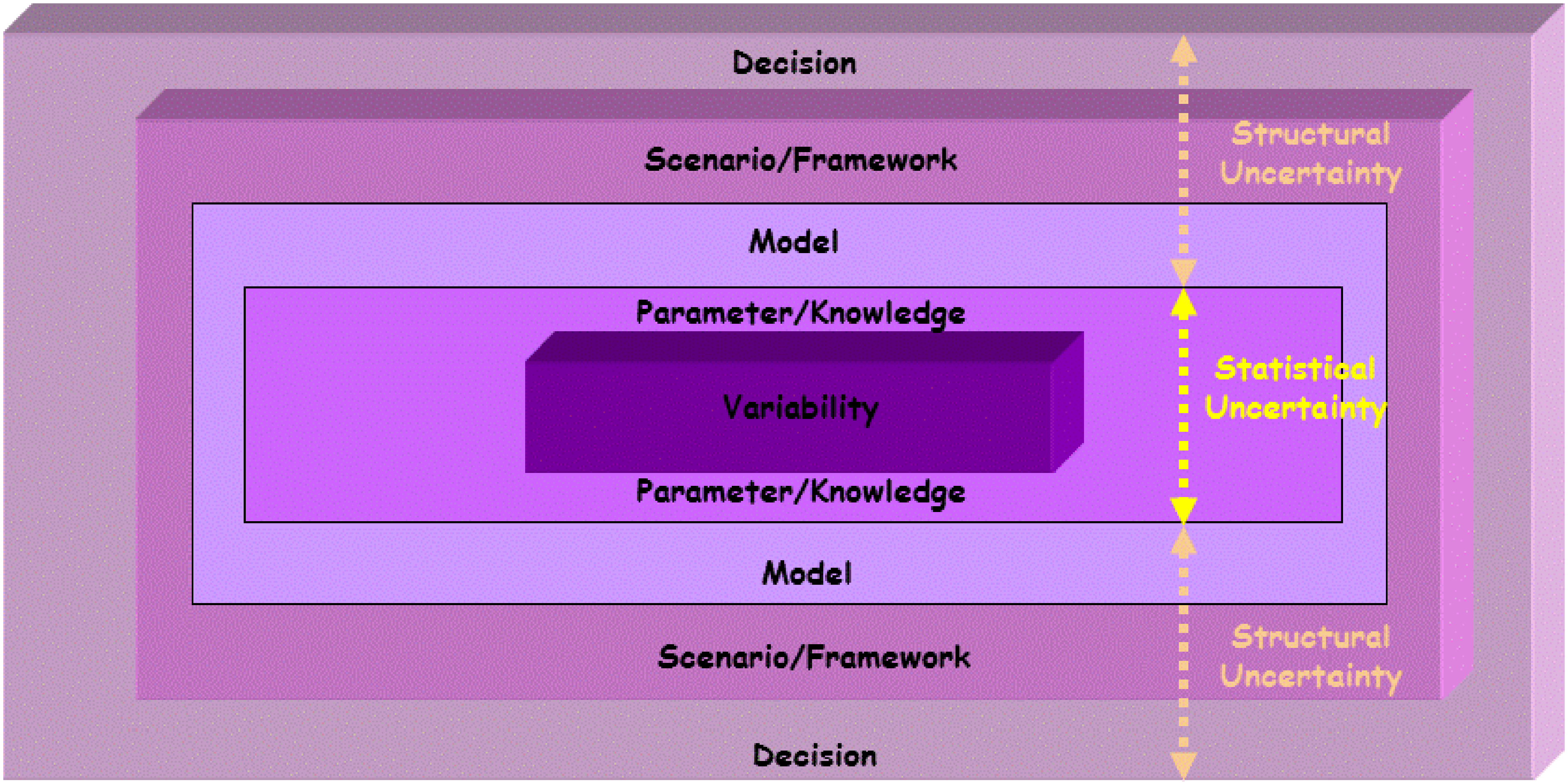
After D. Savage (1995) – The Scientific and Regulatory Basis for the Geologic Disposal of Radioactive Waste

Awareness

Sources of Uncertainty

- Data and Parameters
  - Spatial and temporal variability
- Model
  - Conceptual models, mathematical representation
- Future/Scenario
  - Biosphere, climate, geology, and human behavior
- Other Institutional Uncertainties (International Atomic Energy Agency (IAEA) PRISM Project)
  - Resources, Contextual

Components of Uncertainty

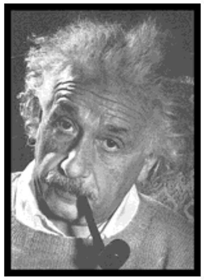


Courtesy: Bruce Crowe

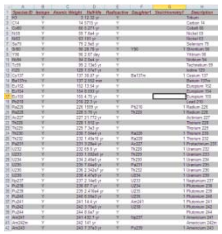
Importance

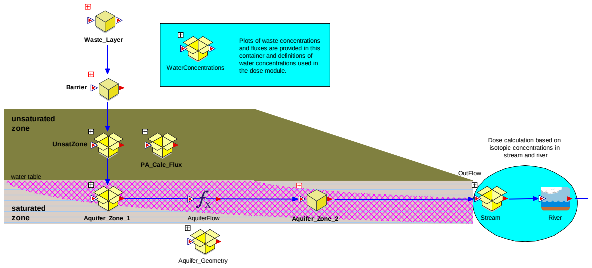
Graded and Iterative Approach

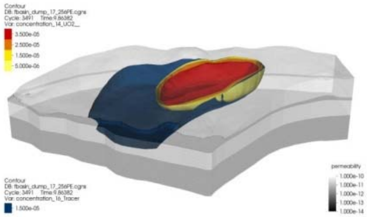
- Stepwise approach to optimize expenditure of resources (start simple, add complexity as needed)
- Some waste streams lead to a need for added refinement (e.g., credit for waste form, containers, engineered facility, etc.)
- Models are used to help identify refinements expected to best contribute to a better decision (and not contribute) – sensitivity/importance analysis

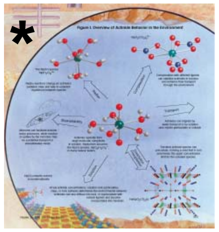


"Everything should be made as simple as possible, but not simpler"









Screening **System-Level** **Process-Level**

Variety of Options for Priorities

Enhanced screening?

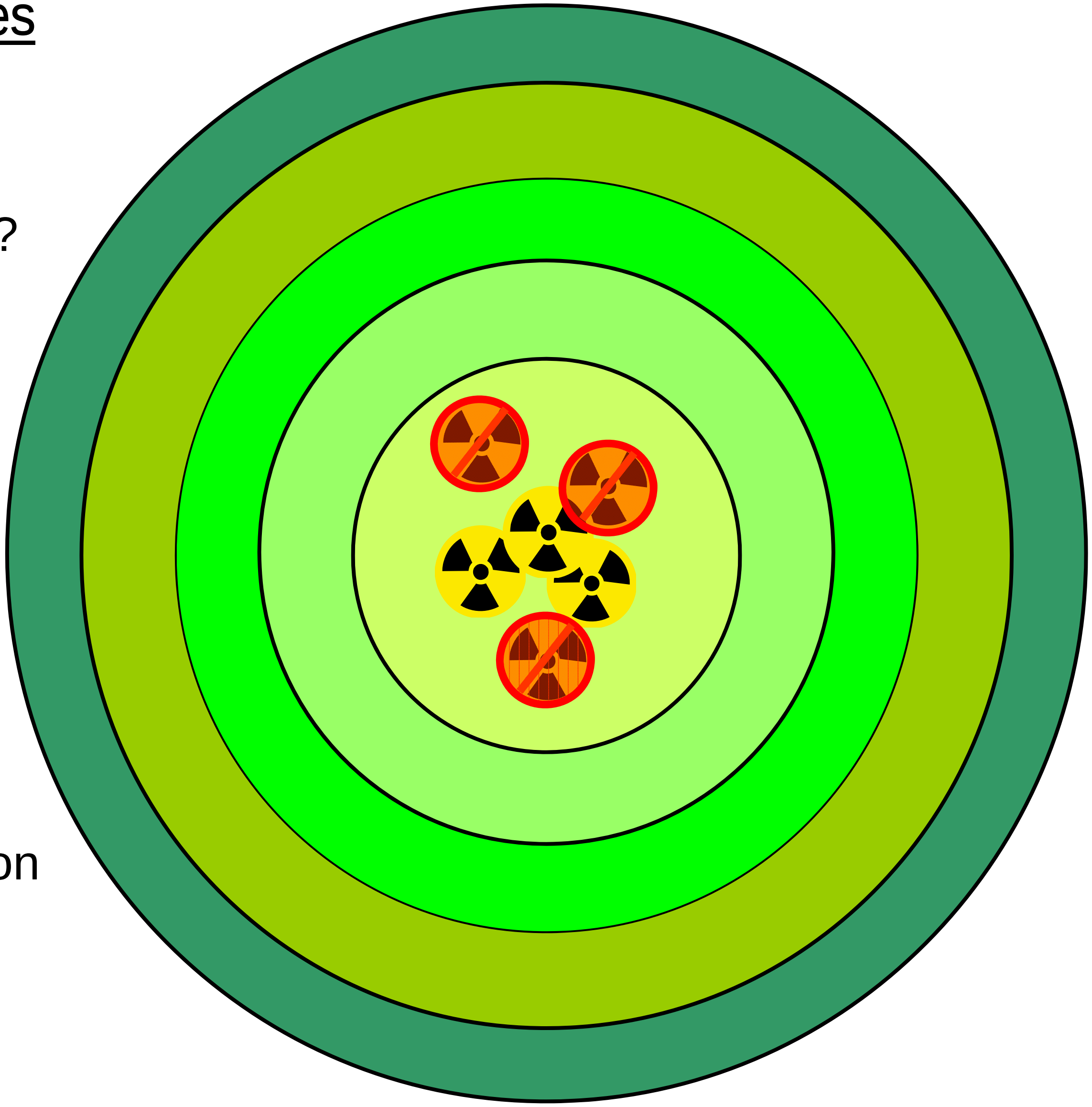
Improved cover representation?

Account for waste form (physical/chemical)?

Account for container (physical/chemical)?

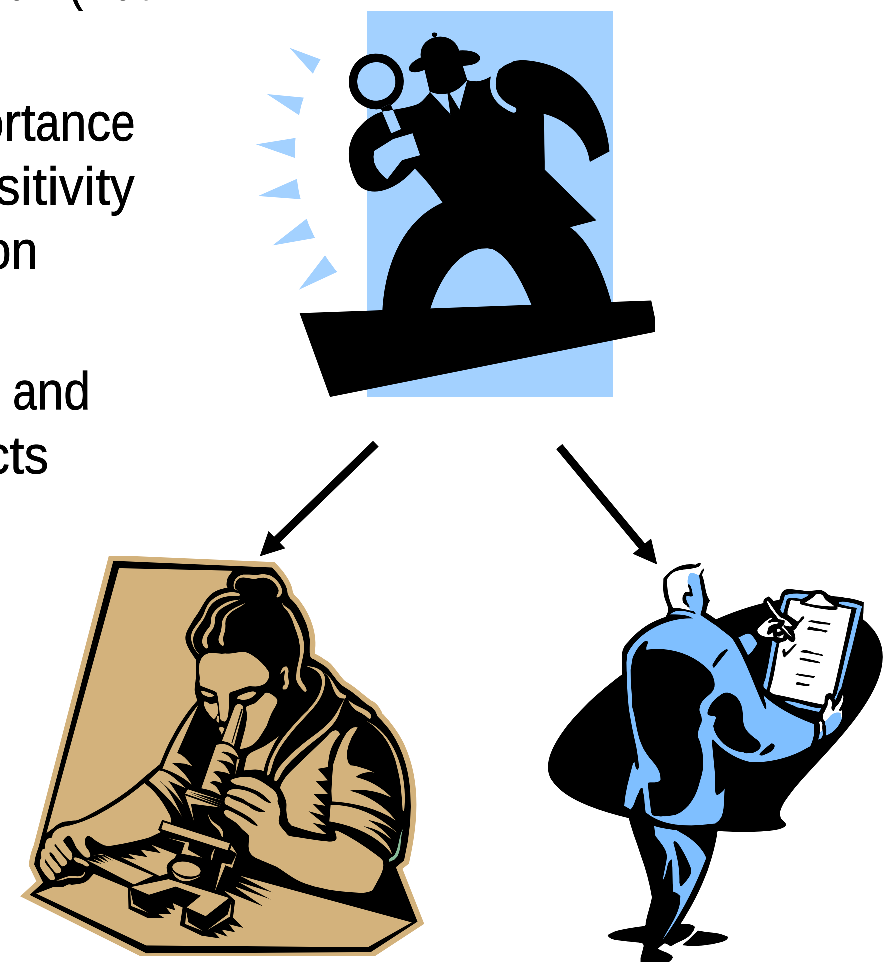
Account for barriers (physical/chemical)?

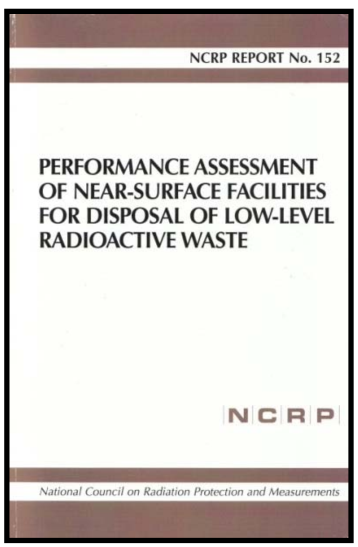
More detailed site representation (physical/chemical)?



Sensitivity (Importance) Analysis

- Focus attention on parameters and assumptions of greatest interest for conclusions/decision (not just model)
- NCRP Committee adopted the term “Importance Analysis” to reflect the application of sensitivity analysis to waste management/remediation decision making
- Results guide refinements/data collection and also help guide reviewers to critical aspects




NCRP REPORT No. 152

PERFORMANCE ASSESSMENT OF NEAR-SURFACE FACILITIES FOR DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTE

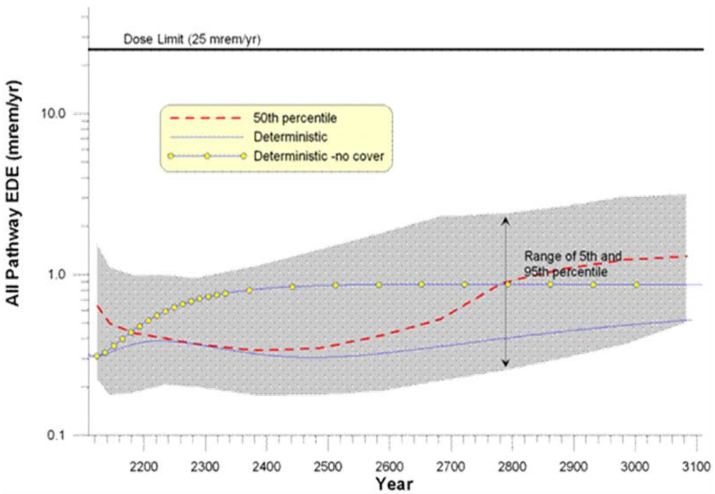
NCRP

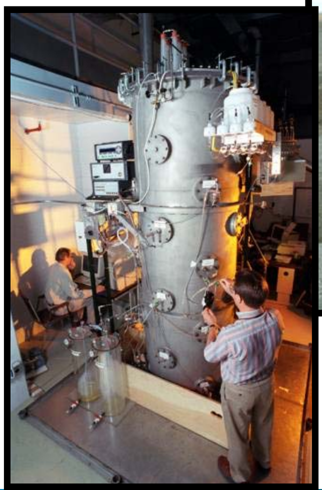
National Council on Radiation Protection and Measurements

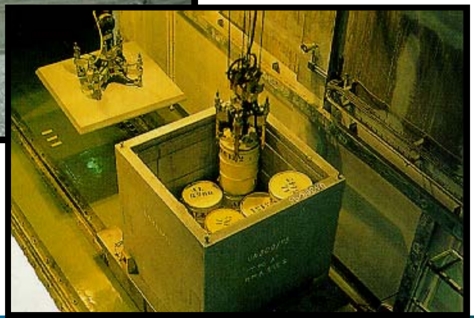
Approaches to Manage Uncertainties

Example Approaches to Manage Uncertainty (after IAEA PRISM project)

- Safety Margins
- Sensitivity/Uncertainty Analysis
- Quality assurance/control
- Stakeholder engagement
- Characterization
- Expert judgment/elicitation
- Verification/Validation of Models
- Plume matching/assimilation
- Decision analysis
- Waste acceptance criteria
- Laboratory experiments
- Reality check – simple calculation
- Demonstration analogues
- Alternative conceptual models
- Alternative design
- Balance realism and conservatism
- Monitoring and surveillance
- Multiple lines of reasoning

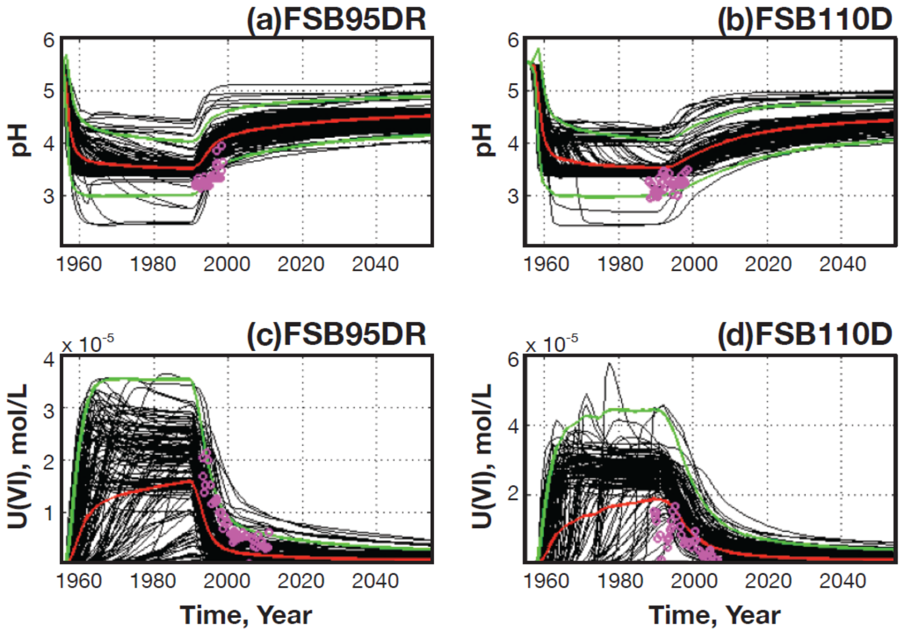






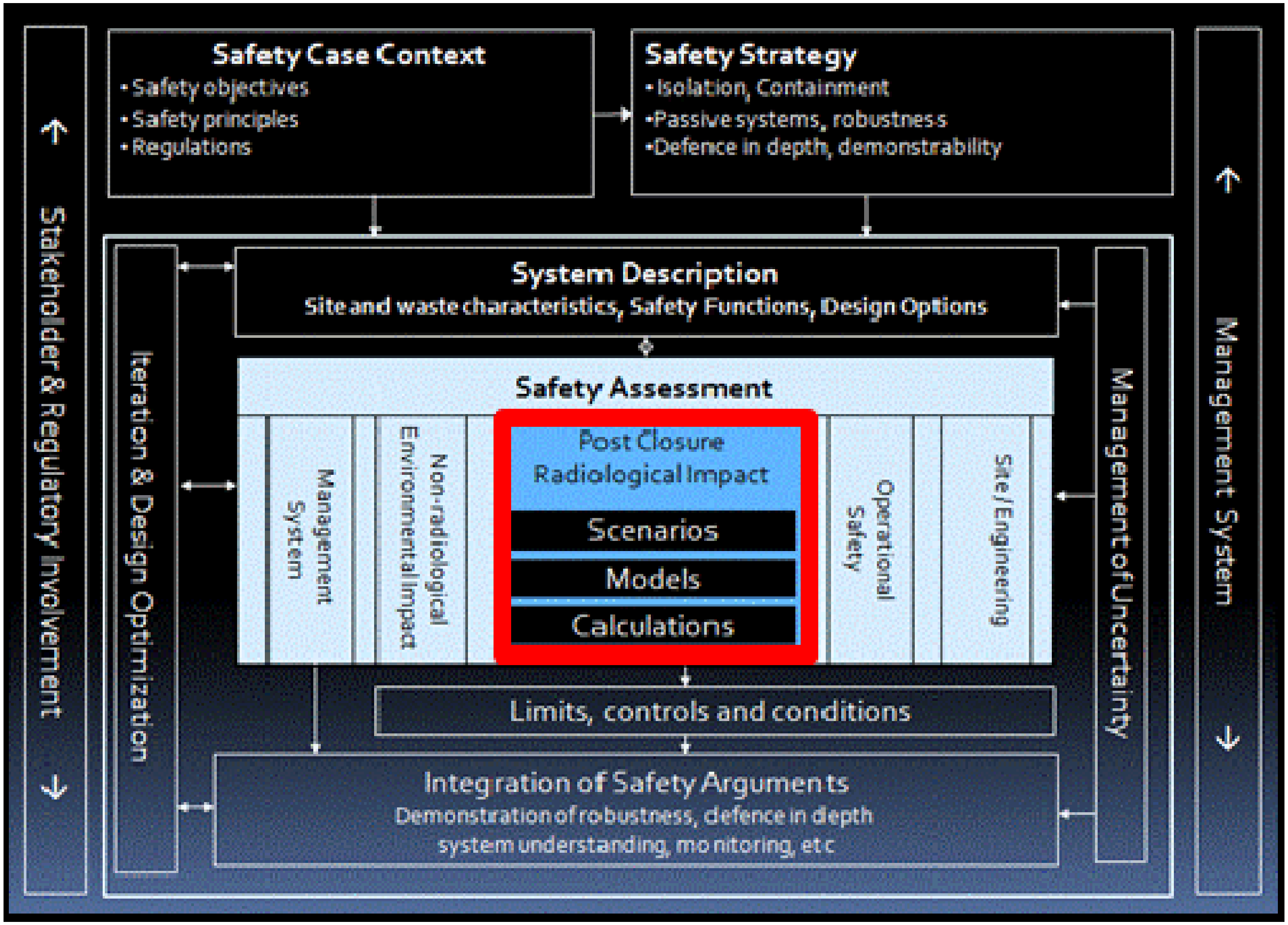
Integration of Modeling, Monitoring, Characterization, etc.

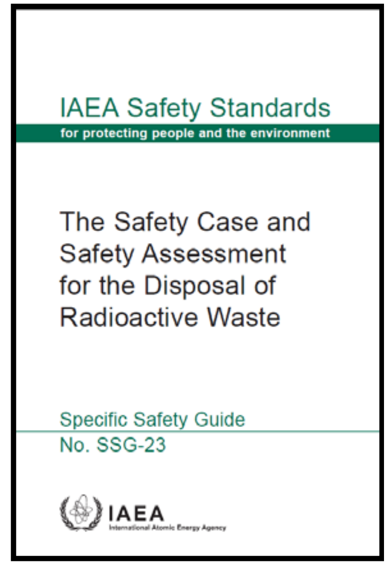
- Decisions are based on the body of evidence, including recognition of stakeholder interests
- Characterization and monitoring information tie the modeling to observed behavior (effective communication) and support better informed decision-making
- Optimally, modeling informs characterization and monitoring needs and characterization/monitoring help to identify modeling refinements
- Important during assessment and as part of maintenance after decision



Integrated Approach - International Concept of Safety Case for Decision-Making

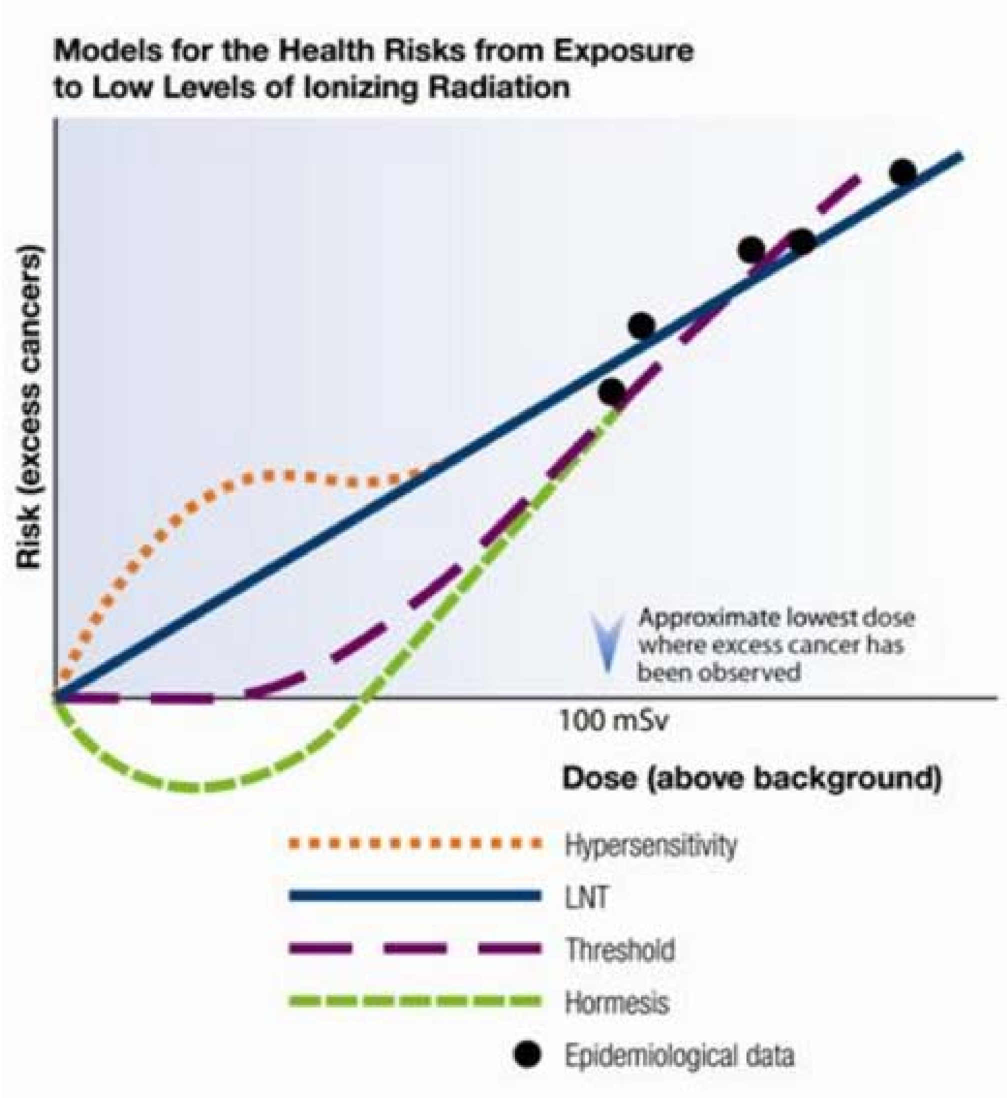
Effective means to document body of evidence used to support a decision





Courtesy: IAEA (draft)

Safety Margins – Linear-Non-Threshold Dose Model for Standards



- Dose limits for compliance based on a model that assumes that effects observed at high doses extrapolate linearly to effects at low doses
- Generally considered to provide added margin of safety
- "There is little scientific evidence of any measurable adverse health effects at radiation doses below about 100 mSv" *(10 rem)*

Canadian Nuclear Safety Commission
http://nuclearsafety.gc.ca/eng/resources/health/linear-non-threshold-model/index.cfm

Built-in Safety Margin for Dose Limits

100,000 mrem – Dose leading to ~5% chance of Fatal Cancer (UNSCEAR)

10,000 mrem/yr – IAEA mandatory intervention

5,000 mrem/yr – Worker dose standard (DOE)

2,000 mrem/yr – IAEA upper end of range for decisions in existing exposure situations (also intrusion)

620 mrem/yr – US Average dose all sources (NCRP)

100 mrem/yr – All sources limit (IAEA practices, DOE)

25 mrem/yr – NRC and DOE LLW

15 mrem/yr – EPA Radiation (40 CFR 191)*

10 mrem/yr – Air (atmospheric) (40 CFR 61)

4 mrem/yr – Drinking Water (40 CFR 141)

1 mrem/yr – IAEA Exemption/Clearance

In 2009, NCRP updated US Annual Average Dose from 360 to 620 mrem/yr

EPA Recommended Radon Action Level of 4 pCi/L in Basements ~7 x 10^{-3} Risk of lung cancer for non-smoker

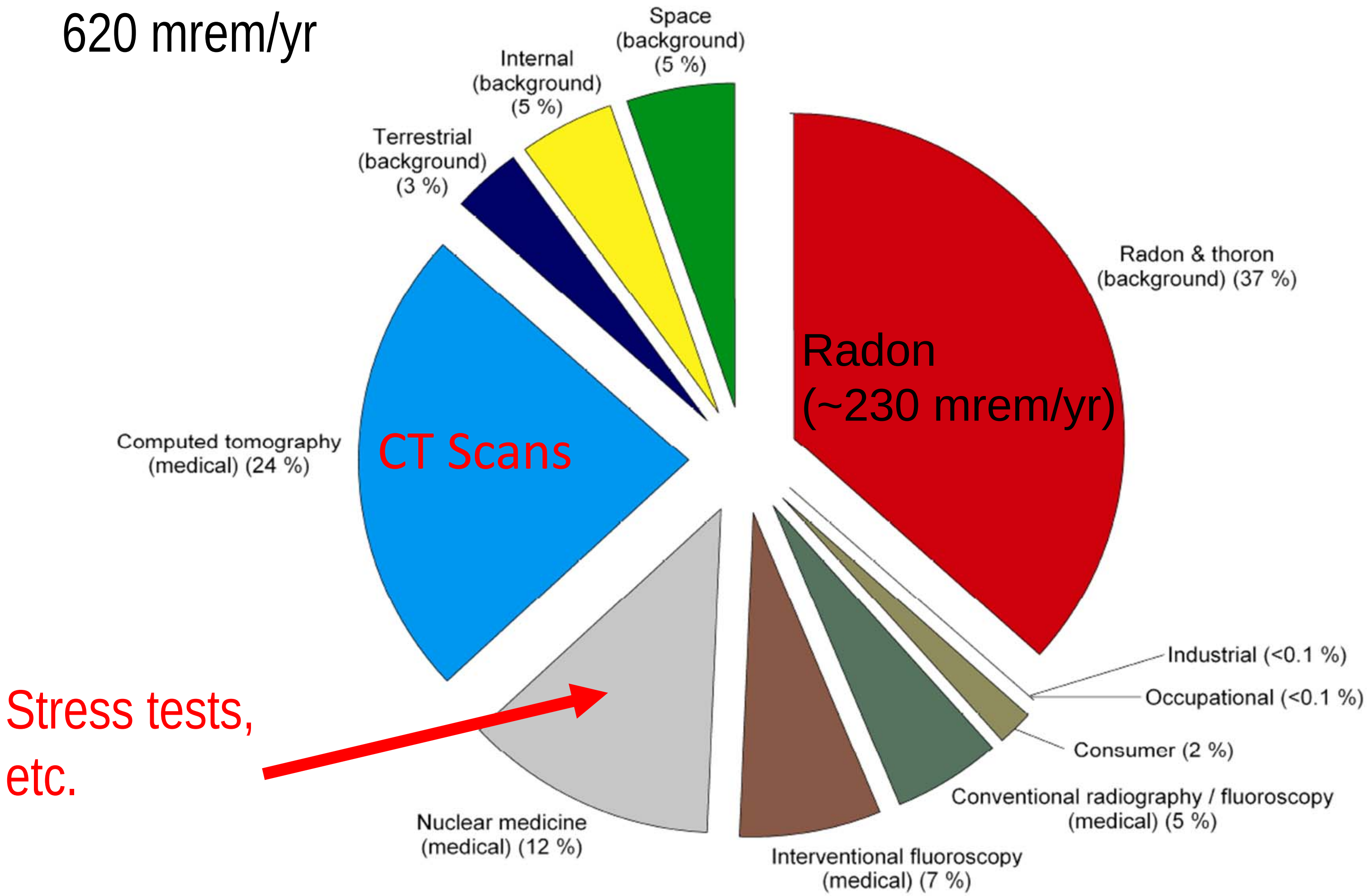
One Transcontinental round trip flight - 5 mRem

Note: Air crew average (300 mrem/yr) From UNSCEAR (2000)

*EPA 540-R-012-13 (2014) has identified 12 mrem/yr as the new level for protectiveness criteria

NCRP 2009 Report - Annual Average Dose

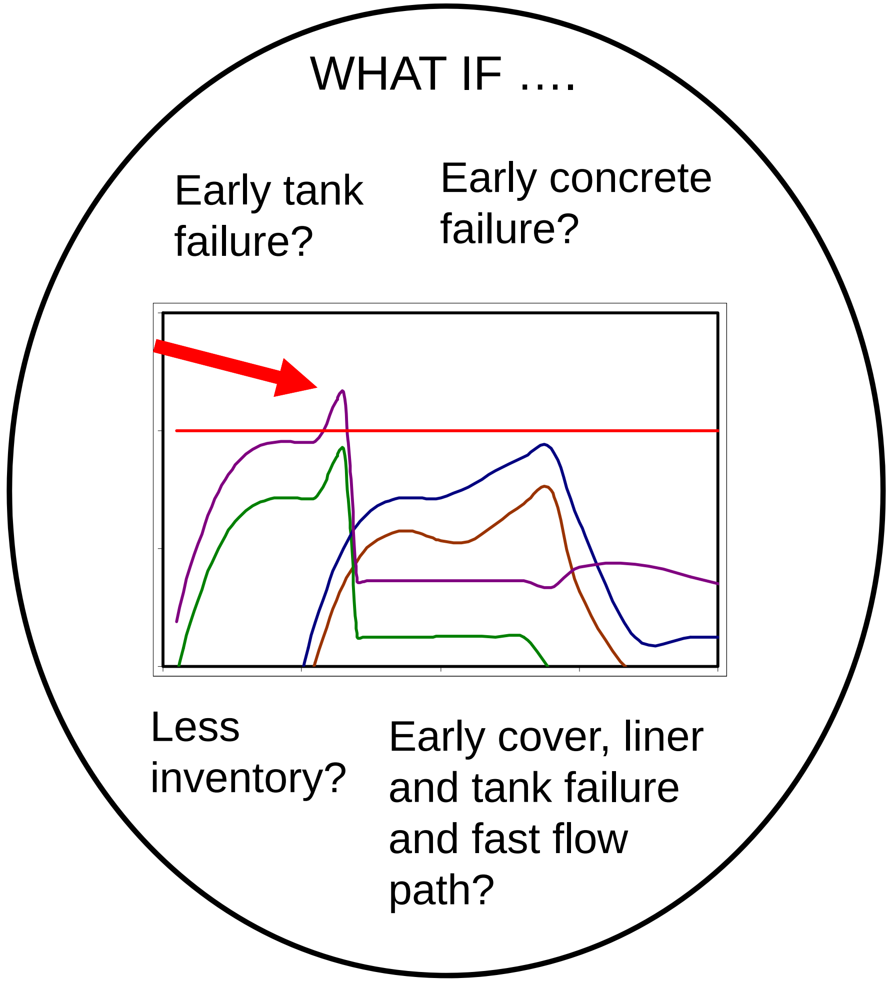
620 mrem/yr



Compliance and Decision-Making

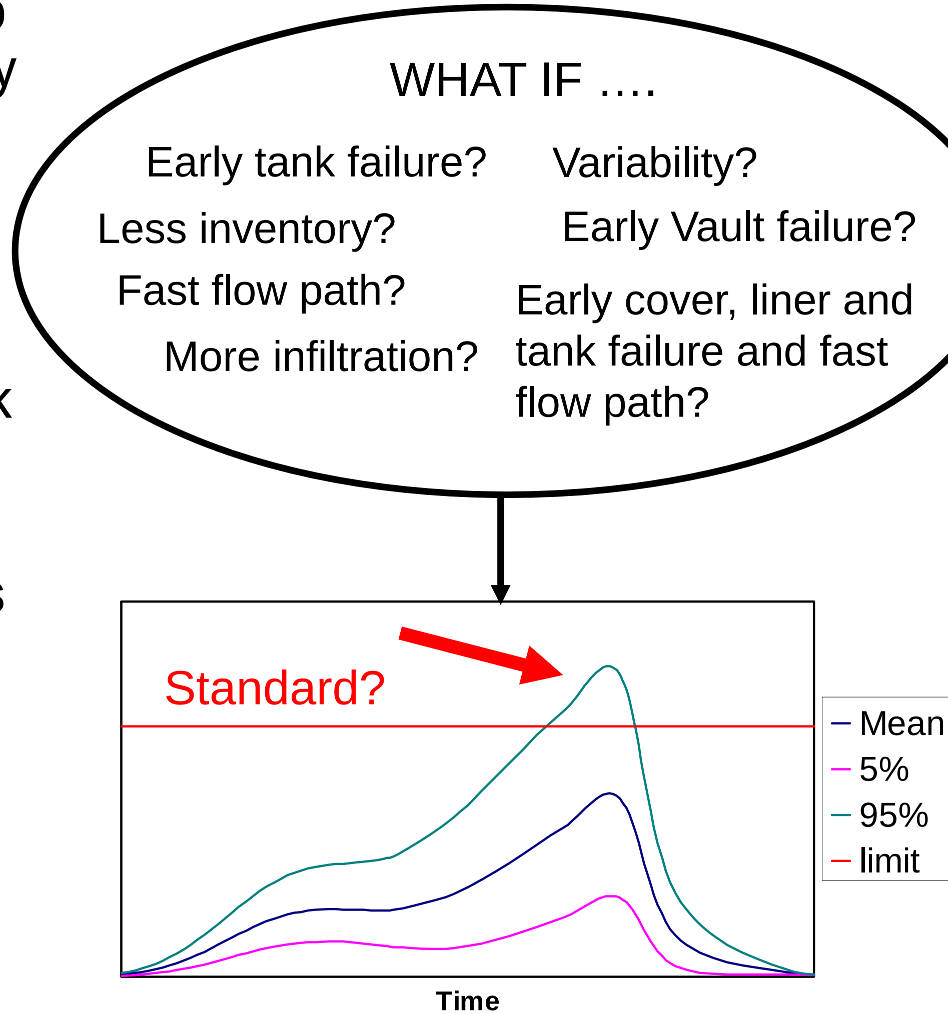
Deterministic Approaches

- Traditional, deterministic standards for disposal and remediation
- Effort focused on developing & negotiating compliance case, including scenarios & parameters
- Demonstrate dose is less than standard
- Add sensitivity cases to address "what-if" type questions, different conceptual models, etc.



Probabilistic Approaches

- Now generally expected for PAs to support sensitivity and uncertainty analysis
- Effort focused on quantifying scenarios and developing distributions for inputs
- For compliance, demonstrate peak of mean or median is less than deterministic standard
- “What-if” and uncertainty analysis implicitly included
- Relative likelihood of extreme cases

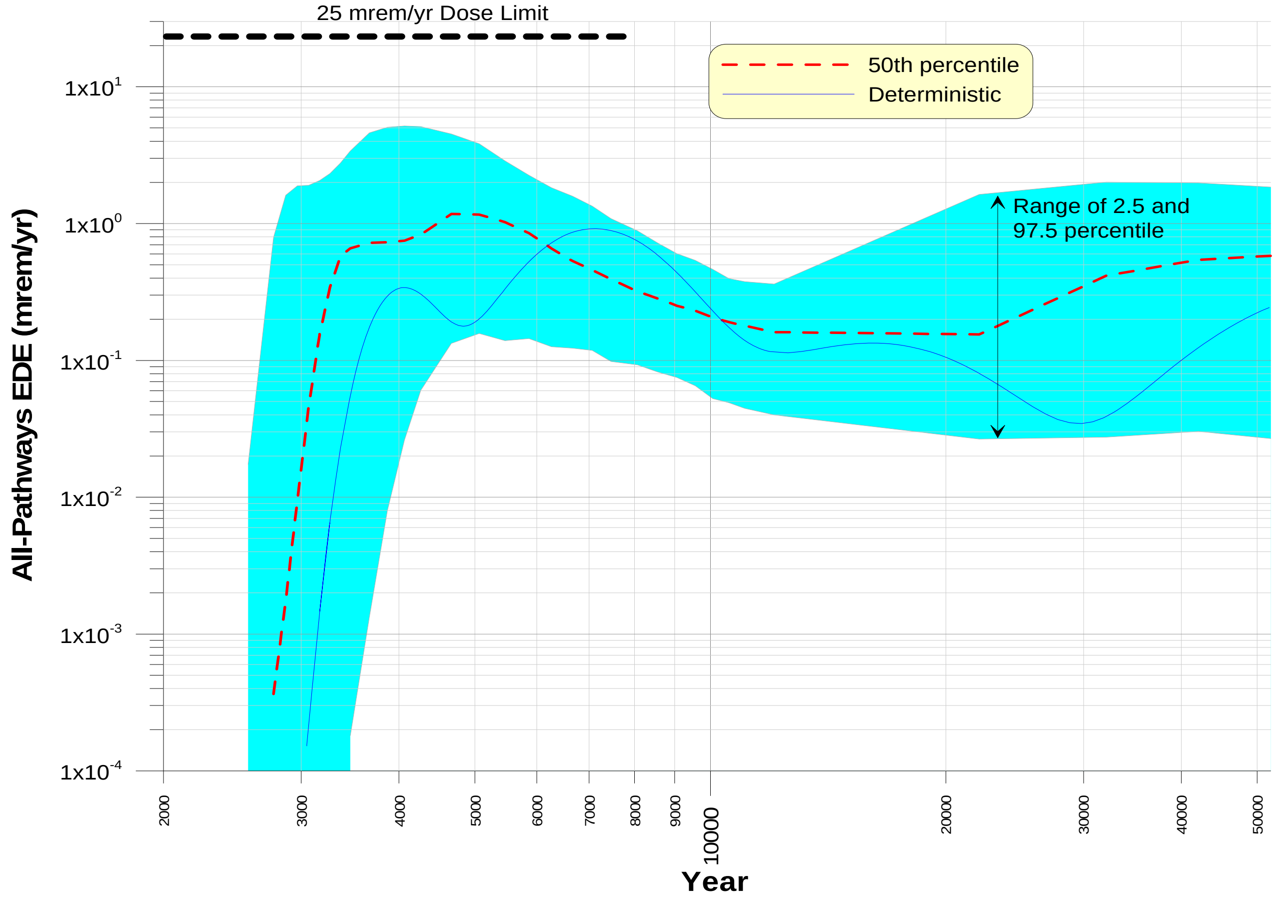


Why Peak of the Mean or Median?

- NRC and EPA place emphasis on using central tendencies (i.e., mean or median) as the basis for decision-making when considering probabilistic distributions of results, for example:
  - NRC acceptance guidelines and consensus standards for use in risk-informed regulation (SECY-97-221)
  - NRC consolidated decommissioning guidance (NUREG-1757)
  - NRC staff guidance for waste determinations (NUREG-1854)
  - EPA Environmental protection standards for spent fuel, HLW, TRU (40 CFR Part 191)
- Important to convince reviewers that sensitivities and uncertainties are understood, ALARA considerations must still be addressed
- Recognize role of assessments as decision tools, not decision makers

Hybrid Approach

- Agree on deterministic compliance case(s) to compare with deterministic standard (add sensitivity cases)
- Use probabilistic approach to capture "what-if" questions and uncertainty analysis (using benchmarked model)
- Multiple lines of reasoning using different levels of modeling detail
- Continuous improvement of both approaches in iterative process



Conclusions

- Models serve an important role to support decision-making, but should not be viewed as a "decision-maker" on their own
- Key roles for models include improving understanding of system and enhanced communication of basis for decision
- Uncertainties are a fact of life and must be acknowledged and managed, there are many potential approaches to manage uncertainty
- Graded and iterative approach places emphasis on identifying important contributors to decision-making
- Effective management of uncertainty involves integration of modeling, characterization, monitoring and other activities to provide ties to the real system
- Decision-making needs to acknowledge safety factors that are built-in to standards
- Probabilistic and/or deterministic approaches can be used to manage uncertainties and demonstrate compliance for DOE PAs

Questions?

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