U.S. DEPARTMENT OF ENERGY | OFFICE OF ENVIRONMENTAL MANAGEMENT

Use of Performance Assessment to Support Decision-Making

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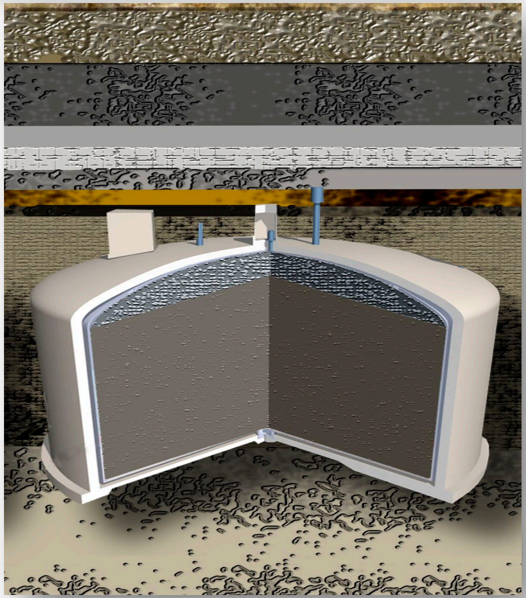
Introduction

- Performance Assessments (PAs), with the supporting body of evidence, provide important input to support decision-making
- Not intended to be a prediction of actual harm in the future, evaluations consider "potential" exposures that may occur
- Use of descriptors like "realistic" or "best estimate" can be misleading and can downplay defense-in-depth considerations
- Need to clearly communicate safety factors and biases that are built into assumptions and standards to illustrate the intent to err on the side of overstating potential consequences



Contents

- Numerical Criteria
- What is PA?
- International Standards and Recommendations
- Key Concepts
- Are we appropriately describing our key assumptions and scenarios?

Numerical Criteria

	DOE Manual 435.1	10 CFR Part 61
Dose Objectives	25 mrem/yr – All Pathways 10 mrem/yr – Air Pathway	25 mrem/yr – All Pathways
Inadvertent Human Intrusion	100 mrem/yr – Chronic 500 mrem – Acute	500 mrem – Acute and Chronic

Note: DOE Manual 435.1-1 also includes groundwater protection and radon flux or concentration limits for releases

"Risk-Informed," Not "Risk-Based"

- DOE/NRC support a "risk-informed" regulatory approach using PA results to support decision-making as opposed to a "risk-based" approach in which such decision-making is solely based on the numerical results of an assessment
- Unknowns, uncertainties and increasingly speculative assumptions over time influence implementation and interpretation of PAs – "reasonable assurance," "reasonable expectation"

"The purpose of computing is insight, not numbers"

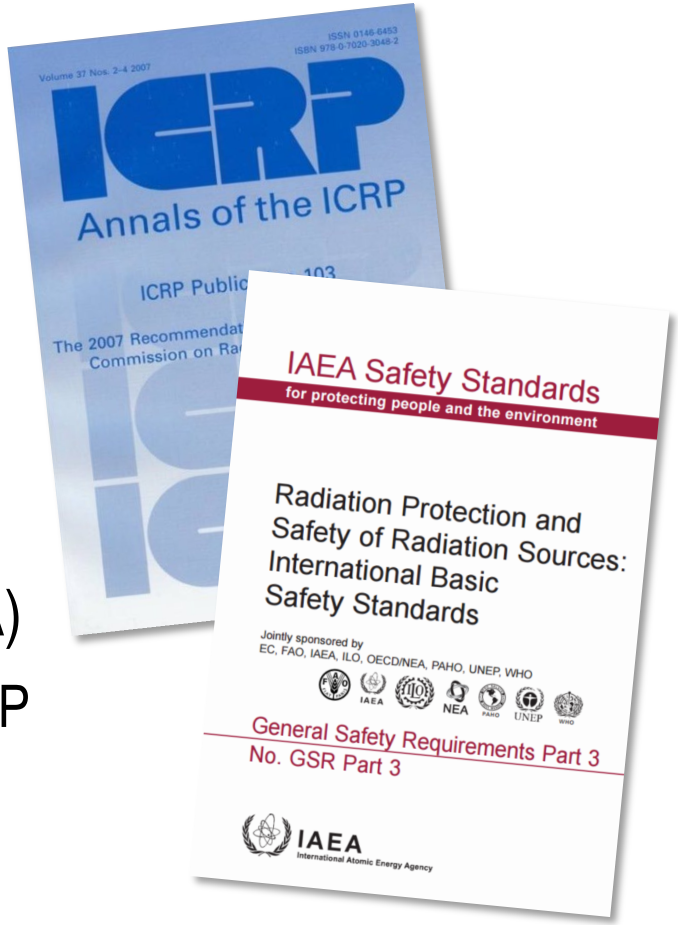
- Richard Hamming

What is Performance Assessment?

- A means to address **post-closure** protection of human health and the environment to support a **decision** process
- A process to **demonstrate confidence** that projected doses are reasonably likely to be **less than** a given standard, not a prediction of actual doses
- A "learning process" to provide perspective on the significance of different site, facility and waste features in the context of the decision (**demonstrate understanding of the full disposal or tank closure system**)

International Standards

- International Commission on Radiological Protection (ICRP) Publications
  - Recognized standards and recommendations
  - Dose limit of 100 mrem/yr for “planned” exposures
  - Concept of potential exposures discussed for waste disposal
- International Atomic Energy Agency (IAEA)
  - Basic Safety Standards largely reflect ICRP

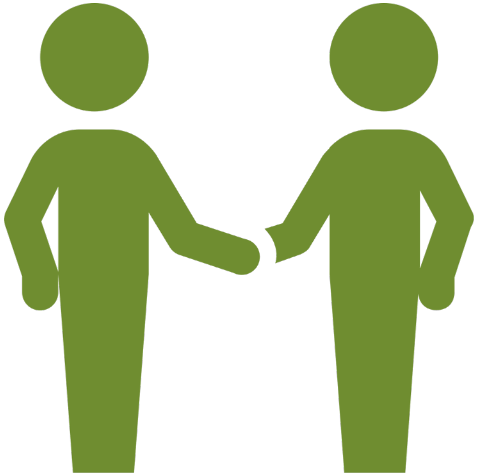


Recommendations/Experience

- IAEA
  - Requirements and Guides
- U.S. Nuclear Regulatory Commission (NRC)
  - Staff Recommendations
- DOE Technical Standards
- National Council on Radiation Protection and Measurements (NCRP)
- Nuclear Energy Agency, European Commission

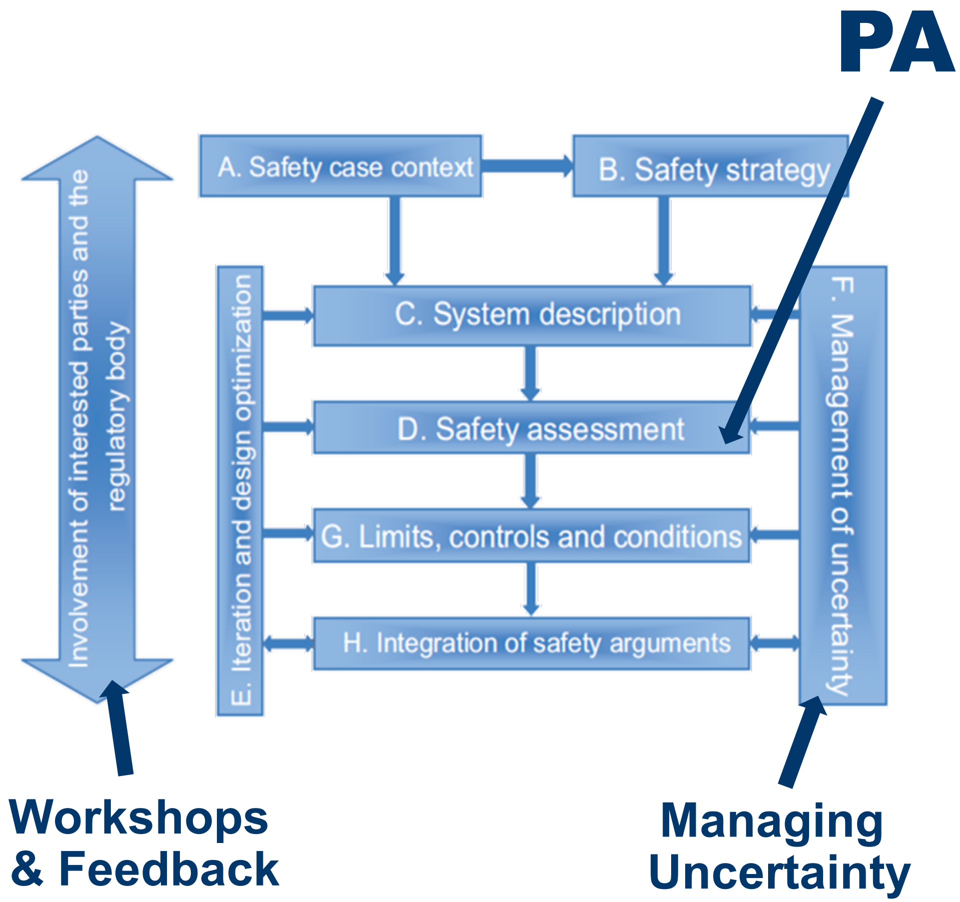
Key Concepts

- General agreement on some basic principles:
  - Safety Case and Managing Uncertainty
  - Defense-in-Depth
  - Safety Margins
  - Complexity – Graded and Iterative Approach, Multiple Modeling Approaches
  - Safety Functions
  - PA Maintenance – Integration of Modeling, Monitoring and Model Support Activities



Safety Case

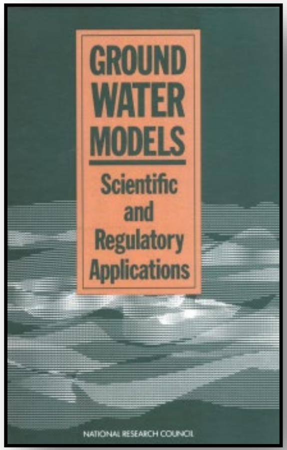
- Captures the integrated approach to safety, similar to Integrated Safety Management System
- Much of the PA context and approach is focused on managing uncertainty
- Integration of multiple safety arguments to support a decision



IAEA Figure

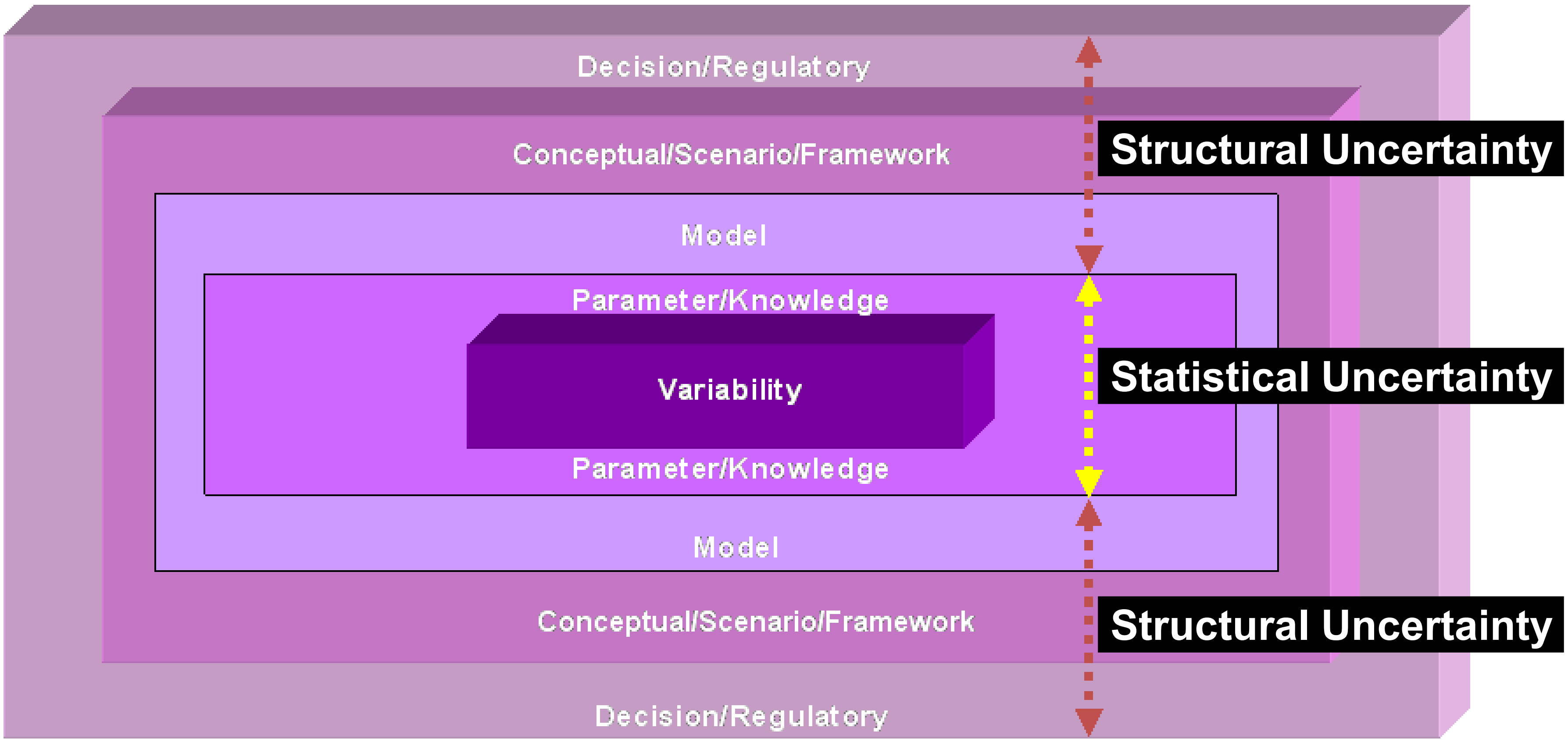
Managing Uncertainty

- Uncertainty in human habits, data and models is unavoidable for PAs
- Typically, we strive to effectively "manage" uncertainties
  1. Identify and acknowledge
  2. Prioritize importance
     (Does uncertainty impact decision?)
  3. Select approaches to manage
     (research, characterization, design features, pessimistic-bias…)
  4. Quantify, as appropriate



"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…"

Uncertainty



Courtesy: Bruce Crowe, Nevada National Security Site

Defense-in-Depth

- Extraordinary efforts to consider potential consequences in the far future
- PAs are one part of a robust defense-in-depth approach for safety
- Multiple levels of added safety factors (e.g., dose constraints, conservative bias)
- Integrated total system approach (site, facility, admin/ technical controls)

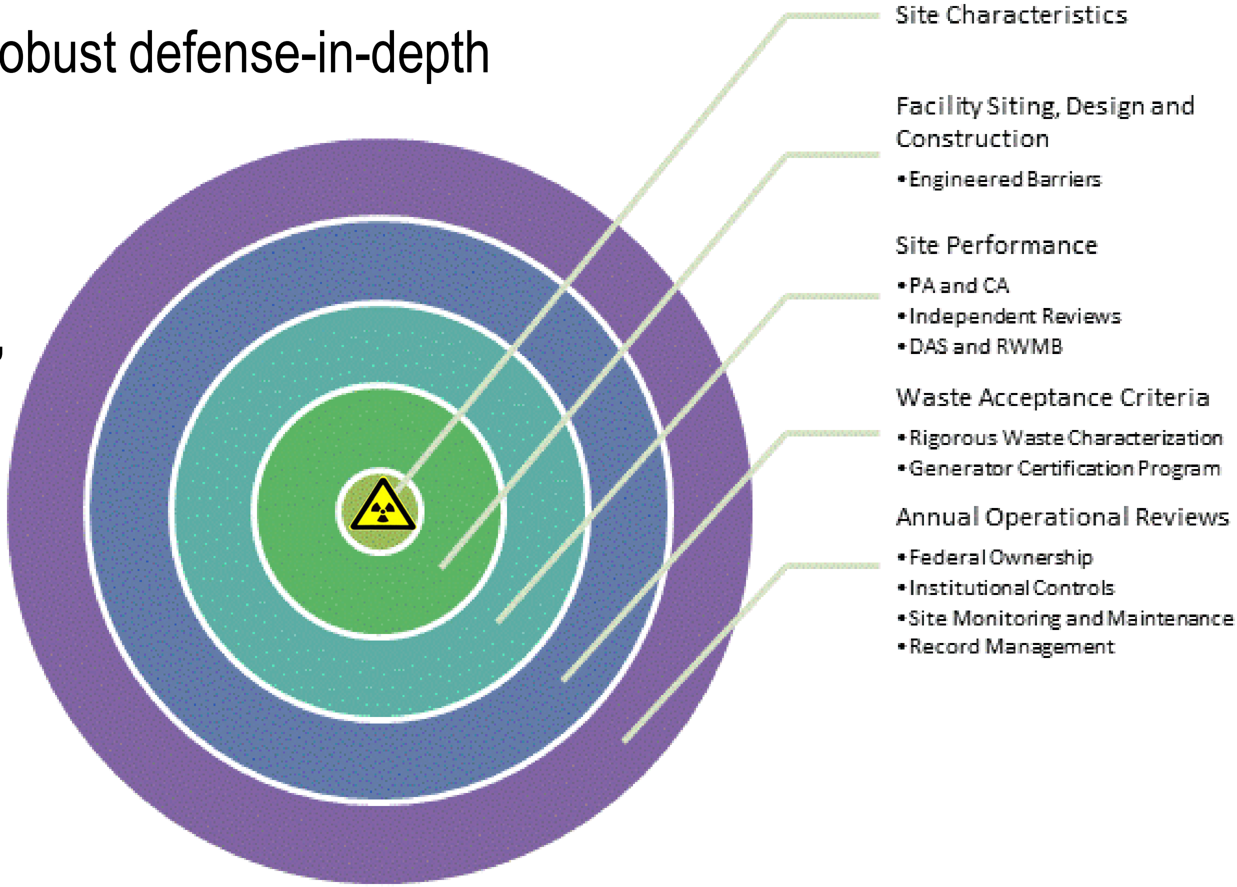


Figure: DOE Presentation to NRC ACRS – October 2013

Built-in Safety Margin for Dose Limits

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

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

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

EPA Recommended Radon Action Level of 4 pCi/L in Basements (~576 mrem/yr**)

25 mrem/yr – NRC and DOE LLW All Pathways Limit for Disposal Facilities

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

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

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

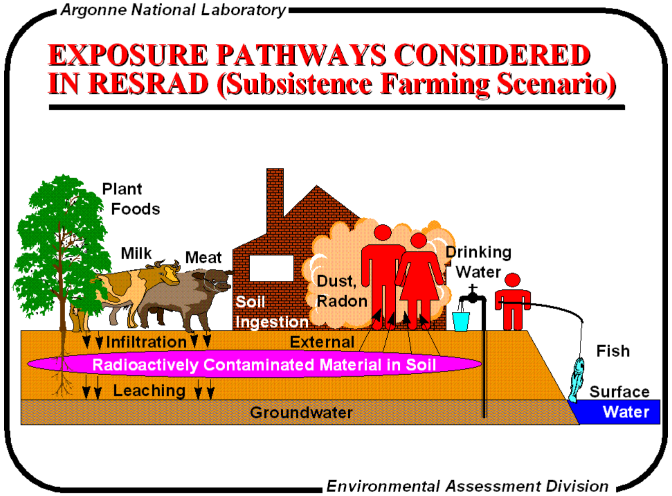
One Transcontinental round trip flight - 5 mRem

*EPA 540-R-012-13 (2014) has identified 12 mrem/yr as the new level for protectiveness criteria
**EPA Dose Calculator- accessed April 25, 2022 (https://www.epa.gov/radiation/calculate-your-radiation-dose)

Note: Air crew average (300 mrem/yr), from United Nations Scientific Committee on the Effects of Atomic Radiation (2000)

Safety Margin – More Highly Exposed Individuals

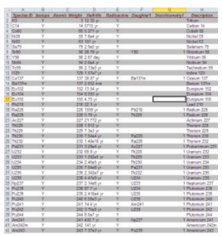
- Assume loss of memory and failure of controls
- Assume exposure occurs at time and location of peak concentration
- Assume there will be a residential, subsistence farmer
- Inadvertent intrusion assumed to occur

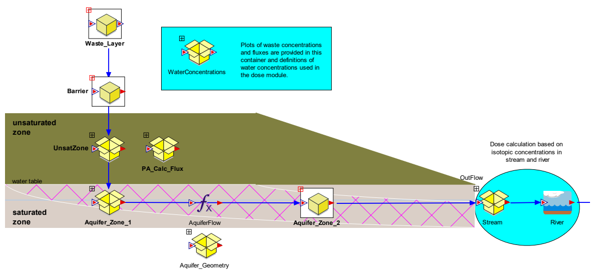


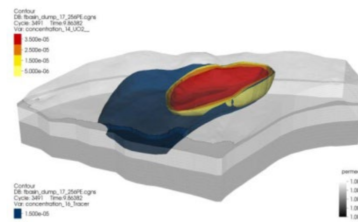
Range of Complexity

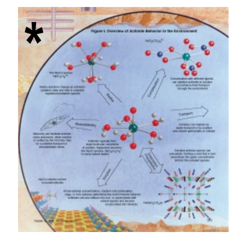
Graded and Iterative Approach

- Level of detail based on "importance" for a decision
- Multiple levels of detail typically used, barrier assumptions source of bias









Screening → System-Level ← Process-Level

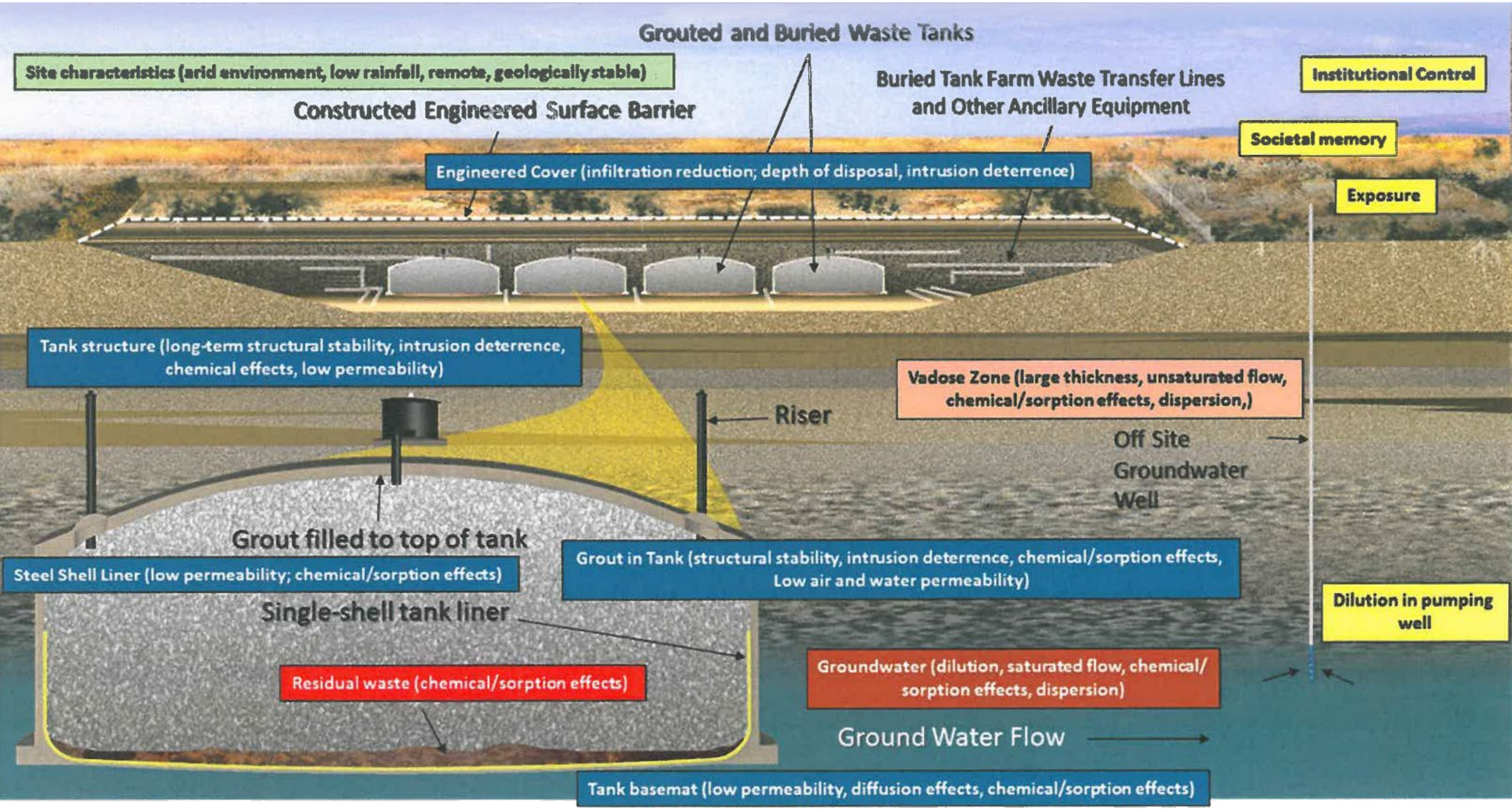
Combination of Modeling Approaches

- Probabilistic modeling using system-level models and deterministic modeling using more detailed models (multiple lines of reasoning)
- Use of multiple modeling approaches helps to improve understanding and provides additional checks and balance

Challenges

- High complexity for processes and dimensionality can provide insights on role of details, but long simulation run times
  - Challenge to effectively conduct sensitivity and uncertainty analysis, which are valuable tools to improve understanding and identify unexpected behavior
  - Are you missing important uncertainties or interactions?
- Less detail, but probabilistic complexity can provide insights on range of potential results and importance of different assumptions and combinations of assumptions
  - Can be challenging to represent details in a system and also conduct numerous realizations for uncertainty analysis
  - Does your simplified model adequately capture the behavior of the system? Are you ignoring or simplifying key features that could be lost in the complexity of a probabilistic model?

Safety Functions – What function does each feature provide?



Sensitivity (Importance) Analysis

- Focus attention on parameters and assumptions of greatest interest for conclusions/decision
- NCRP Committee adopted the term "Importance Analysis" to reflect the application of sensitivity analysis to waste management/remediation decision making
- Individual "what-if" type cases can be run with detailed models (including barrier analyses)
- Probabilistic calculations can also be used to provide statistical representations of importance
- Results guide refinements/data collection and also help guide reviewers to critical aspects

PA Maintenance

Integrating Modeling, Monitoring and Model Support

- PA is a living document
- On-going monitoring and characterization work
- As new information is obtained, significance of any changes will be evaluated
- Special analyses can be conducted to address potentially significant changes

Are We Appropriately Describing Our Assumptions and Scenarios?

- Terms like "Realistic," "Expected," "Best Estimate," etc. can be misused to describe a PA compliance case (better applied to individual assumptions)
- Realism vs. conservatism - continually improving, but implying "*realistic*" assessments is unrealistic and misleading
- Conservatism (pessimistic or cautious bias) is deliberately included in all assessments
- Clearly communicate intentional bias, and especially, don't imply biases are not present
- Key point: A challenge for PA is communication of individual "what if" simulations that may exceed a constraint (if base model implied to be "realistic", it may be more difficult to explain)

Safety Functions - Examples

Example features that contribute to safety for LLW disposal include:

- Contextual
  - Public knowledge (societal memory, visitor centers, records)
  - Institutional controls (active: fences, guards - passive: deed restrictions, public records)
  - Annual public dose limit – 1 mSv (less than background and maximum reference level)
  - Assumed receptors and habits (current habits)
- Engineered Barriers
  - Cover system, containers, waste forms, vaults, liner system
  - Physical and chemical barriers (water flow, transport)
- Natural Features of the Site
  - Precipitation and infiltration rates (influence releases)
  - Vadose zone and aquifer (delay and disperse)

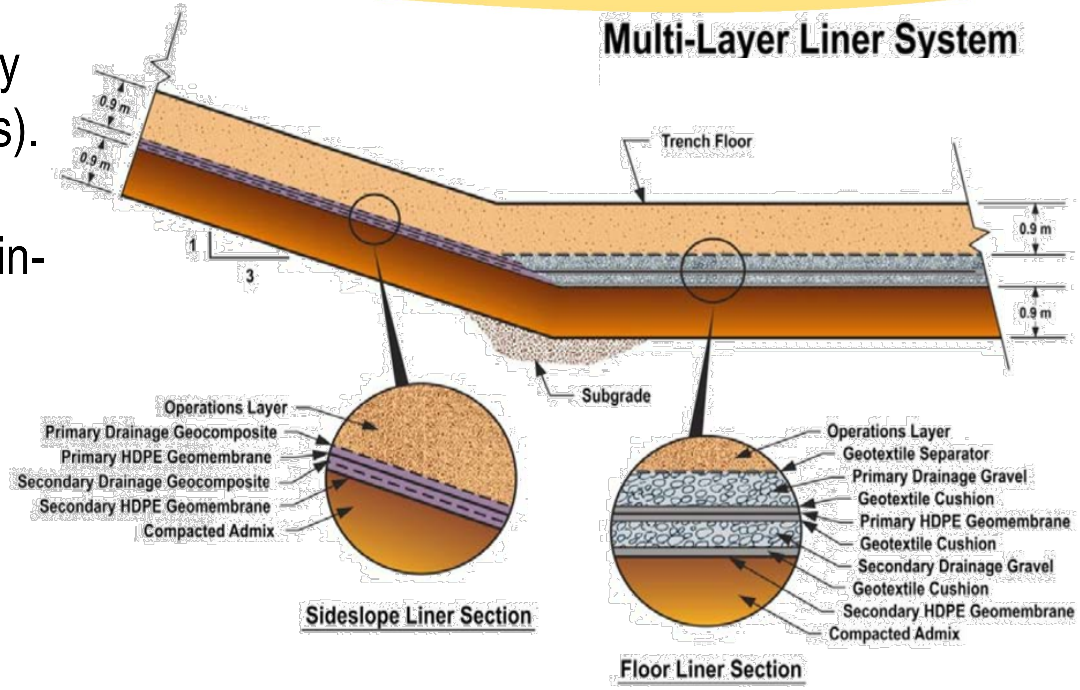
Safety Functions – Actual Implementation (Defense-in-Depth)

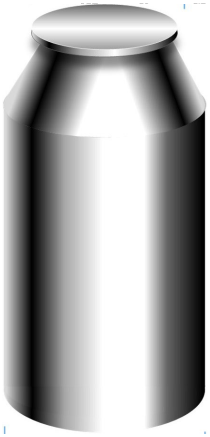
Typical assumptions for safety functions:

- Contextual
  - Public knowledge (memory and passive controls assumed to fail in future)
  - Annual average public dose constraint (LLW disposal - 0.25 mSv or less)
  - Assumed receptors and habits (time and location of peak, subsistence habits, inadvertent intruder)
- Engineered Barriers
  - Early failure of barriers
  - Less than expected performance physically and chemically
- Natural Features of the Site
  - Higher than expected precipitation/infiltration
  - Pessimistic assumptions for natural features

Barriers – Defense-in-Depth

- Barriers expected to perform for very long times (up to thousands of years). PA considers varied degrees of degraded performance for defense-in-depth and to manage uncertainty
- Pessimistic bias
  - Effective life of barriers
  - Performance of barriers
  - Effect of barriers on other input parameters
- Multiplied through the PA
  - Waste Form
  - Containers
  - Cover System
  - Vaults
  - Liner System





Stainless Steel Container

Key Points

- Assessment should not be portrayed as a prediction of the level of harm, it is an analysis intended to provide quantitative evidence that doses are reasonably expected to be *less than* regulatory limits
- Emphasize concepts of "potential" exposures, "reasonable assurance/expectation," "managing uncertainty with pessimistic/cautious bias" to provide perspective when discussing results (especially for extreme cases)
- Avoid the use of terms like "realistic," "best estimate," "expected," etc. to explain approach used for a PA (all PAs include some cautious or pessimistic bias, such terms may be more appropriate for individual assumptions)
- Multiple lines of reasoning (e.g., different model complexity) can help to better understand system and serve as a check and balance to identify potential problems with models
- Explain cautious/pessimistic bias in the contextual basis, key assumptions and role of "what if" cases in a PA to better communicate defense-in-depth