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Technical Lessons to Learn in Disposal of HLW

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Rob P Rechard
Sandia National Laboratories
Thomas A. Cotton
Complex Systems Group
Mark Nutt
Argonne National Laboratory
Joe T. Carter
Savannah River Nuclear Solutions
Frank V. Perry
Los Alamos National Laboratory
Ruth F. Weiner
Sandia National Laboratories
James A. Blink
Sandia National Laboratories

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US Challenge is to Learn the Important Lessons

- Much has been attempted in last 40 yr in US in siting and licensing a mined, geologic repository
- Two US applications:
  - 1996 Waste Isolation Pilot Plant (WIPP) Compliance Certification Application (CCA)
  - 2008 Yucca Mountain Project (YMP) License Application (LA)
- Both applications confirm that mined, geologic disposal is a technically viable option for long-term isolation of radioactive waste
- What technical lessons of these 2 programs are applicable to future repository programs in US and other countries that help inform a nuclear waste policy?

Participants in Repository Program in US

- Private utilities responsible for storing HLW*
- DOE (cabinet-level government agency) responsible for siting, building, and operating HLW repository
  - Many countries use quasi-private entity
  - Private entity may also be responsible for storage
- EPA sets health standards
- NRC licenses transportation casks and implements EPA health standards for civilian HLW repository

*This talk uses the term HLW as used in this conference where HLW includes spent or used nuclear fuel and reprocessed wastes with high activity

Participants in US Repository Program

- WIPP
  - EPA implements radioactive waste regulation
    - DOE responds to EPA staff questions
    - Public comments on procedural and scientific aspects of application and EPA responds
    - US Appeals Court hears legal contentions
  - State implements EPA's hazardous waste regulation
- YMP
  - NRC implements EPA's health standard for civilian HLW
    - DOE must formally respond to questions raised by NRC staff within 30 days
    - NRC Administrative Judges conduct formal hearing on contentions related to legal and scientific aspects of application; Appealed 1st to NRC commissioners then US courts
  - Sweden abandoned this approach in 2009, and now uses concept more similar to WIPP

EPA Health Standards

- Define reasonable expectation as standard of proof
- Require evaluation of uncertainty in performance measure
- Define performance criteria

  WIPP

  - Cumulative release measure at 5 km boundary
  - 10^4 yr regulatory period

  YMP

  - Dose measure at 18 km boundary (edge of current population)
  - 10^6 yr regulatory period (after 2005 draft)

- Define performance assessment (PA)

Observations for Future Repository Programs

- Use of Reasonable Expectation as Standard of Proof
  - Reasonable expectation as standard of proof successfully applied at WIPP
  - EPA provided useful clarification of concept for YMP
- Inclusion of uncertainties in performance measure
  - Successfully applied at WIPP and YMP

Establish Performance Requirements Prior to Starting Repository Program

- Numerous characterization activities can be used in evaluating a geologic repository (for example, Site Characterization Plan for YMP)
  - Characterization studies eventually culled but use of performance assessment early would have greatly assisted this effort
- Need performance requirements in order for iterations of PA to be effective at guiding characterization, evaluating important features, events, and processes (FEPs), and development of mathematical models
- Although difficult in early 1980s, performance criteria can now be established for future repository programs
  - Both cumulative release and individual dose successfully applied but dose used internationally

PA Process Useful

- PA provides a logical framework for organizing relevant data and information
  - Captures data and information from multiple sources; organizes it in a logical manner and uses it to support decision making, explicitly taking into consideration the uncertainties
- PA framework provides a transparent and traceable means to document the analysis and decisions based on the analysis
  - Poor documentation hinders regulatory communications
- PA provides a means to analyze different components of a complex disposal system behave in isolation and in conjunction with other components

PA Process Useful

- **Multiple iterations of PA used**
  - **WIPP PAs: 1989 (demonstration), 1990 (first full PA), 1991, 1992, 1994 (Systems Prioritization Method, SPM); 1996 (CCA), 2004 (first recertification), 2009 (second recertification)**
  - **YMP PAs: 1991 (demonstration), 1993 (first full PA), 1995; 1998 (Viability Assessment); 2001 (Site Recommendation); 2008 (LA– Authorization to Construct YM repository)**
- **As WIPP and YMP shifted emphasis from characterization for understanding system to compliance analysis, activities need to be evaluated and prioritized in terms of impact on compliance with regulations**
  - **PA Provides a means to prioritize future data, modeling, and monitoring needs**
  - **PA results led to some new technical programs, some programs being cancelled, and some existing programs being refocused**

Concepts for Retrievability

- Define retrievability for a mined, geologic repository
  - Does it mean that nothing is done in construction to obstruct retrieval? (current US concept)
  - Does it mean a repository is constructed to facilitate retrieval?
- Define role of retrieval for public health and safety
- Define role of recovery for economic uses
- Retrievability discussed this morning in separate session (Track 11, Session 1)

Public Considers Retrievability

- In Finland, public clear that they wanted their repository to be designed for retrievability
- Retrievablity satisfactorily demonstrated in concept for WIPP and YMP in US
- Yesterday, Jenkins-Smith et al. discussed policy and technical attributes that enhance initial acceptance of HLW management facilities (Track 6, Session 2)
- In US, public considers the possibility of waste retrieval in their preferences for disposal concepts
- When ranking a retrievable option with a non retrievable disposal option, 69% preferred the retrievable option.

Simplicity of Sites to Control Costs of Characterization

- US experience has shown that questions about uncertainty determine extent and thereby cost of site characterization
- Site selection strategies for choosing reasonably simple and predictable sites for characterization may be the best way to reduce uncertainty from the outset and minimize costs in the long run
- Characterize more than one site to mitigate programmatic and technical risk
  - Simple and predictable geology and hydrology advocated by many programs
  - Seismic and volcanic activity can be shown to present small risks for a deep geologic repository but the demonstration can be costly

Site Selection and Characterization

- Social/political issues important issue for initial culling of locations
- Diversity of geologic media is not particularly necessary because of experience gained in US and internationally (and use of multiple barriers)
- Controlling costs of multiple site characterization will be important in US through deliberate use of PA; however this requires establishment of regulatory requirements prior to site selection and characterization
- Site characterization activity discussed further yesterday afternoon by Perry et al. (Track 6, Session 1)

Staged Development

- Staged development provides ability to adapt to changing circumstances.
- The schedule in NWPA, utility contracts, and the blockage of the MRS as buffer storage capacity encouraged a rapid siting, construction, full scale construction, and rapid receipt of HLW
- Annual funding limits for YMP did not jive with rapid full-scale construction
- A slower learn-as-you-go approach is more consistent with annual funding limits
- Stepwise development encourage by Interagency review group (IRG) in 1979 and NAS in
- Caveat: Staged development requires maintaining administrative capacity of regulator and analysis capacity of licensee at high levels

Flexible Repository Development

- Repository development needs to be flexible to adapt to changing circumstances of funding, waste receipt schedule, and waste types
- In US, initial construction authorization and initial receipt of waste are important decision points, however, not necessary to fully construct repository.
- YMP adopted modular surface and subsurface design for flexibility
- Module design concept discussed further tomorrow afternoon by Williams et al. (Track 6, Session 5)

Integration of Waste Management System

- Integrating storage, transportation, and disposal involve significant challenges in US because of scale of operations required to manage large inventory
- Integration becomes more important if long-term storage is a national policy
- Storage decisions made today will impact disposal 100 yr from now
- US has no standardization of storage casks to aid transportation and disposal
- US has waste orphaned at decommissioned reactors with no capability to repackage if necessary
- If integration between storage and disposal not encouraged, waste program will end up with a variety of canister sizes

Integration of Waste Management System

- Development of fuel designs that last a long time in storage after discharge would be useful
- Developing a standardized handling canister that applies to a variety of media with different construction techniques would be helpful (e.g., shafts versus ramps and boreholes versus mined repositories)
- Use of canister materials that last long times in oxic environments over 100 yr would be helpful
- Development of storage cask designs that ensure easy retrievability after 100 yr storage would be helpful

Waste Classification Scheme

- Regardless of overall economics of reprocessing and advanced fuel cycles, the waste classification scheme should not present a disincentive to pursue such advances
- A risk-based approach for defining LLW, lLW, and HLW suggested for US by several professional societies and NAS but not straightforward since the storage/disposal concepts and waste form contribute to the risk not just the radionuclides and activity.

Observations

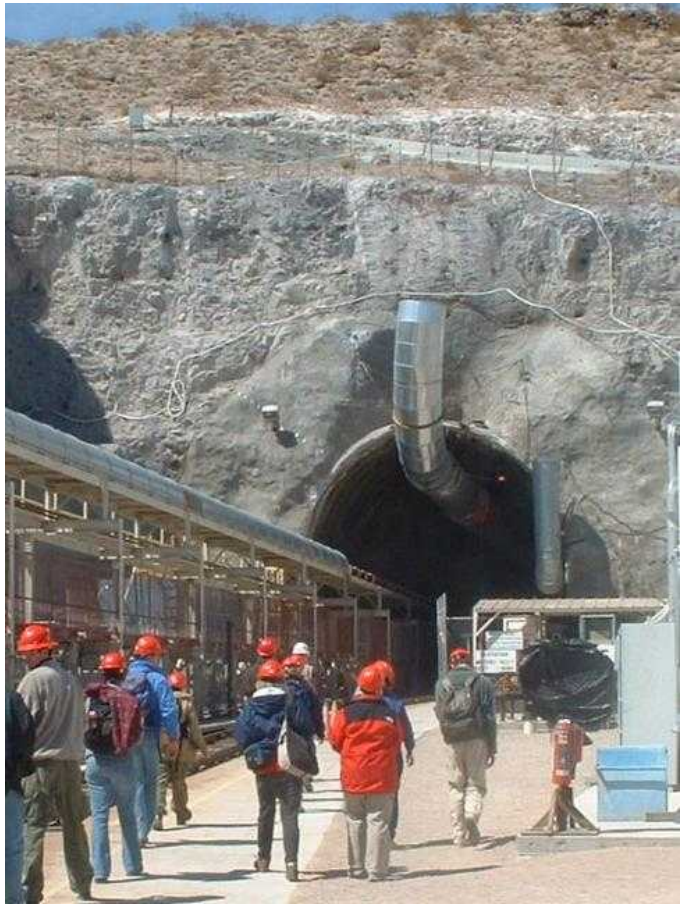
- **Mined, geologic disposal is a viable option for long-term isolation of radioactive waste**
  - **Public preference for retrievability and thus mined disposal**
- **Establish regulations prior to initiating repository program**
  - **Reasonable expectation workable concept**
  - **Uncertainty can be included in measure**
  - **Dose measure workable**
- **Site selection and characterization major challenge**
  - **Many media acceptable**
  - **Site selection based on social/political concerns and simple/predictable geology to reduce uncertainty**
  - **Site characterization costs driven by uncertainty**
- **PA approach helpful**
  - **PA provides a logical framework for organizing information**

Observations

- **Repository development needs to be flexible to adapt to changing circumstances of funding, waste receipt schedule, and waste types**
  - **Modular design of repository provides flexibility**
  - **Staged development provides flexibility, is more consistent with annual funding, and allows a slower learn-as-you-go approach**
- **Storage decisions made today will impact disposal 100 yr from now**
  - **Encourage handling canister designs that are applicable to variety of geologic media**
  - **Encourage storage cask designs with materials that last long time in oxic environments that ensure easy retrieval**
  - **Encourage fuel designs that maintain fuel integrity during long storage period**

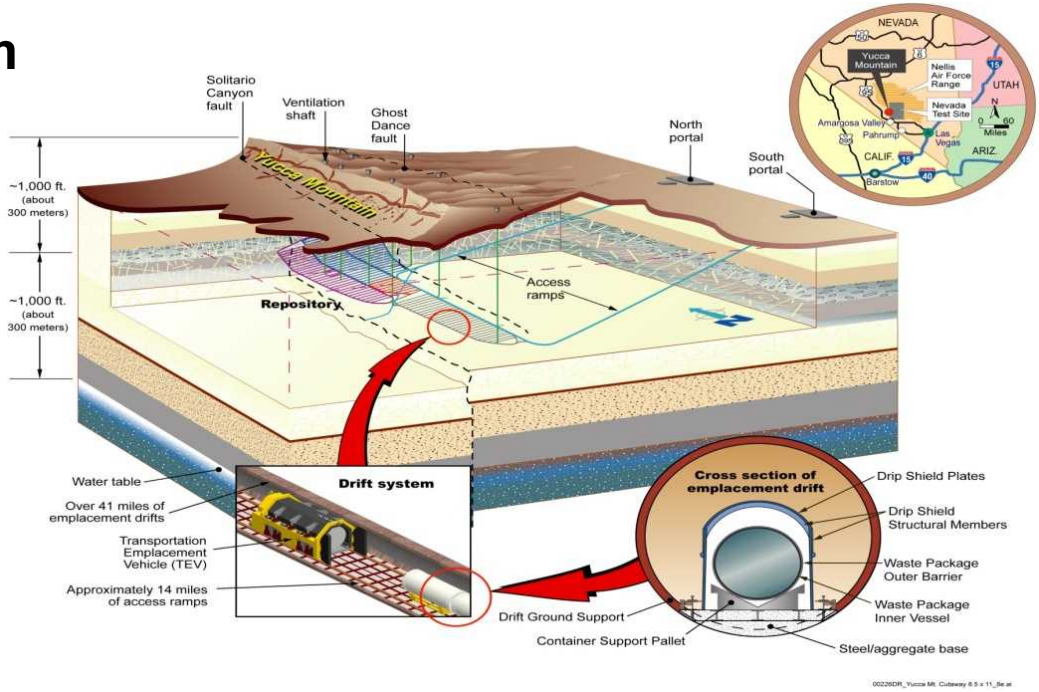
Background on Yucca Mountain

- Approximately 161 kilometers (100 miles) northwest of Las Vegas, Nevada, U.S.A.
- Proposed to be first U.S. repository for disposal of military and civilian spent nuclear fuel (SNF) and high-level waste (HLW)
- License to construct YM repository submitted to U.S. Nuclear Regulatory Commission (NRC) in June 2008
  - License docketed (accepted as complete) by NRC in September 2008
  - Current U.S. Administration has decided YM is not an option and is reevaluating approach to long-term management of nuclear waste



Background on Yucca Mountain

- Proposed repository in unsaturated, fractured volcanic tuff approximately 300 meters (1000 feet) underground and approximately 300 m (1000 ft) above regional water table
- Engineered barrier system
  - Drip shield
  - Waste package
  - Inverts



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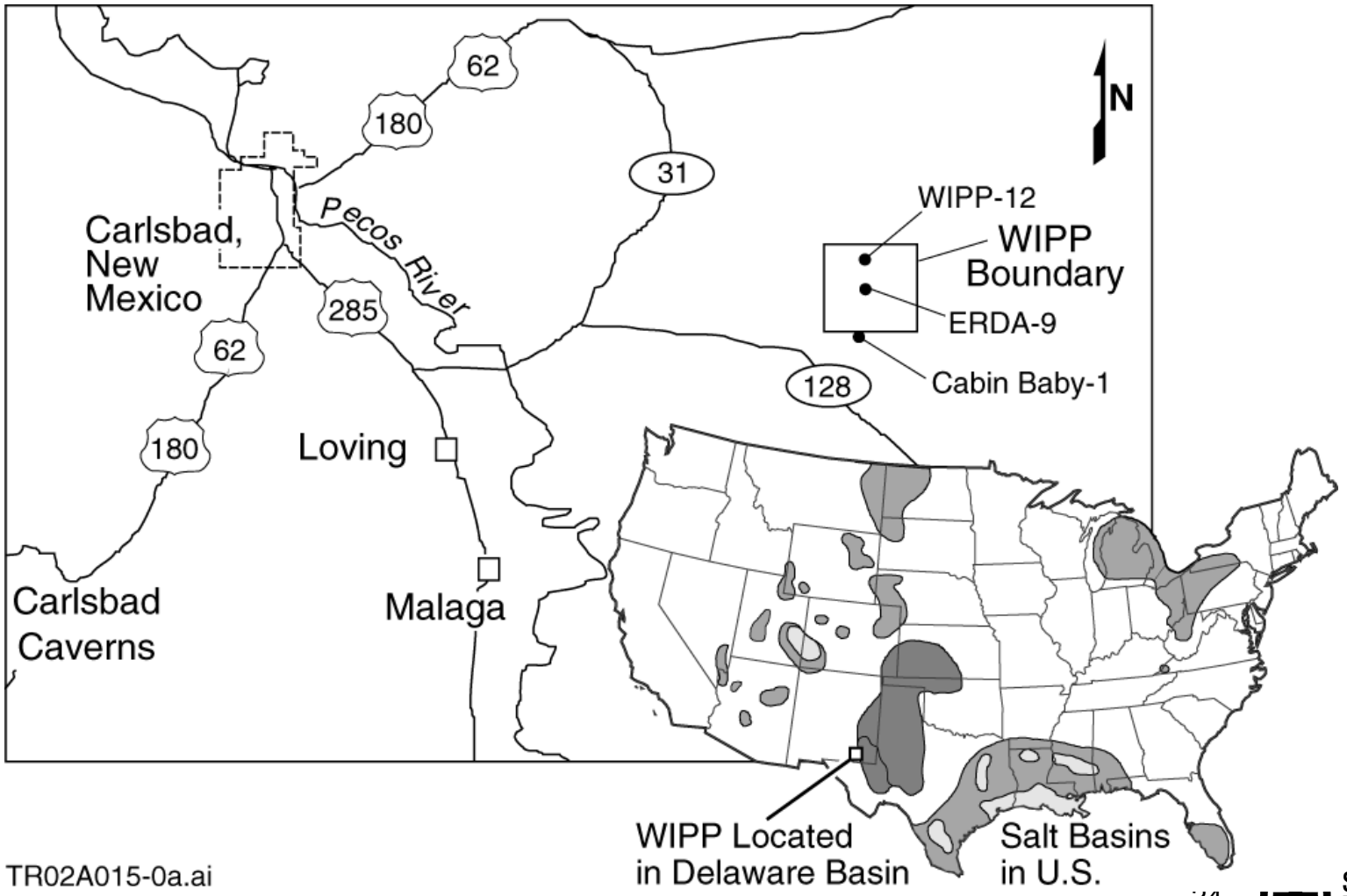
NRC Implementing Regulation

- Prior to 1995
  - Subsystem requirements on natural and engineered barrier performance (as means to require multiple barriers)
  - Reasonable assurance as standard of proof
- After 2001
  - No subsystem requirements
  - Reasonable expectation as standard of proof

WIPP located in Delaware Basin near Carlsbad, NM



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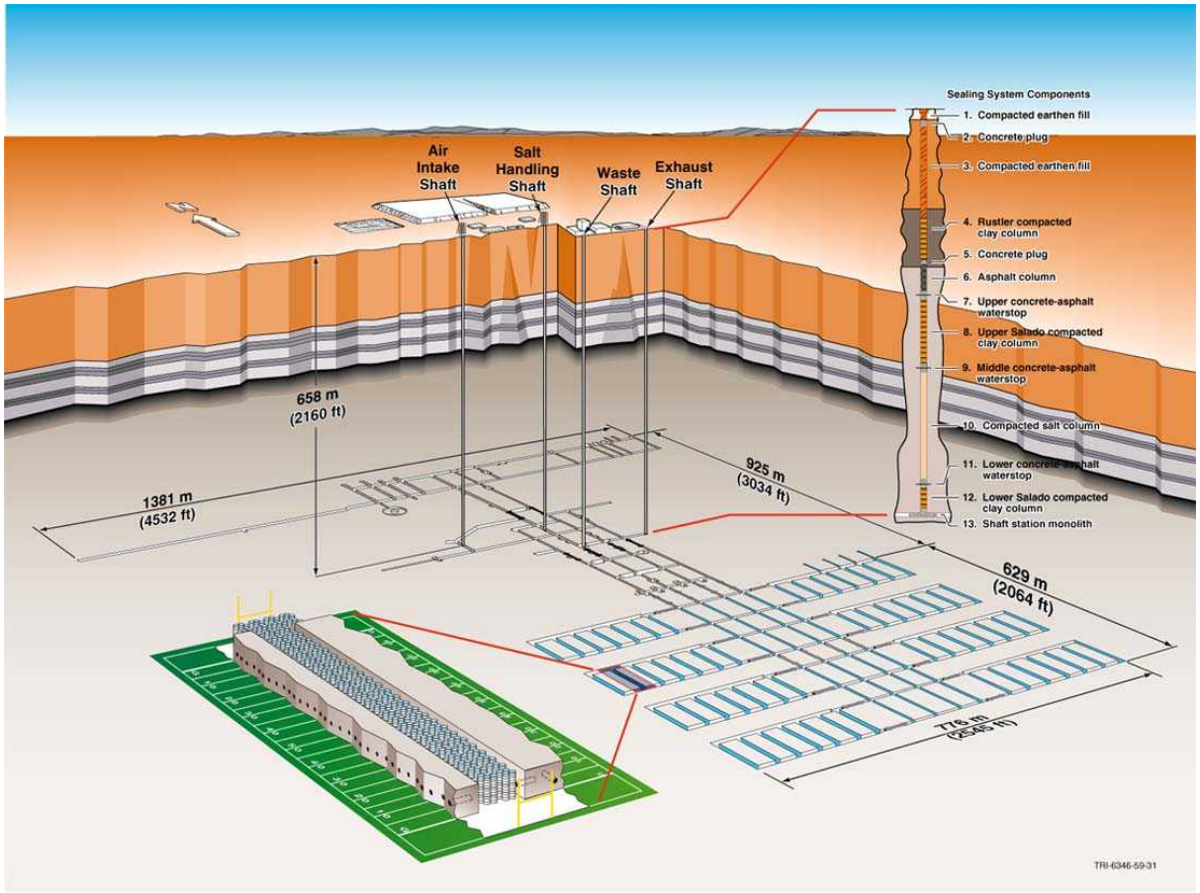
Background on Waste Isolation Pilot Plant (WIPP)

- First mined geologic repository in US for disposal of defense-related transuranic (TRU) waste, European-equivalent of intermediate-level waste
- ~42 km (26 mi) east of Carlsbad, New Mexico, USA
- Compliance Certification Application (CCA) submitted to Environmental Protection Agency (EPA) in October 1996; Received approval in 1999; Recertified in 2004; 2009

Background on WIPP

- **Disposal rooms 655 m (2,150 ft) underground in geologically-stable bedded salt formation (Salado); heavy reliance on natural barrier**



WIPP Repository

- **Successfully operating for over 11 years (first waste shipment on March 26, 1999)**

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Background on Retrievability in US

- Waste isolation options in early 1970s in US categorized mined, geologic repositories as a storage option
- Also, “repository” termed a “terminal storage” facility
- Closure after backfilling and sealing a terminal storage facility was permanent storage
- Storage referred to waste isolation with planned ability to readily retrieve, especially during pilot phase, but with retrievability still possible after closure
- Disposal referred to waste isolation with no initial provision or intention for retrieval
- These distinctions disappeared with NWPA definitions

Background on EPA and NRC Statements on Retrievability

- 1985 EPA health standard stated “any current concept for a mined geologic repository meets this [retrievability] requirement without any additional procedures or design features”
- NRC stated “the geologic repository operations area must be designed to preserve the option of waste retrieval…To satisfy this objective, the geologic repository operations area must be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after the waste emplacement..”
- “a reasonable schedule is one that would permit retrieval in about the same time as that required to construct the geologic repository operations area and emplace waste.”
- NRC also stated “Waste retrieval is intended to be an unusual event only to be undertake to protect public health and safety”

Background on PA Process

- In early stages, characterization focuses on gaining understanding of the system and identifying greatest sources of uncertainty
- As knowledge of the system improves, features, events and processes (FEPs) can be developed and scenarios analyzed
- Conceptual and mathematical models are developed based on relevant FEPs
- Probabilistic modeling is conducted that considers both parameter and scenario uncertainties

Background on PA Process

- Sensitivity analysis conducted to determine which models, scenario, and parameters have greatest impact on performance measures
- R&D activities influencing performance measures are funded that produce reductions in uncertainty while other activities are scaled back
- Iterative– new information used to refine requirements, performance measures, alternatives, and models

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