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EPRI Review of Geologic Disposal - Lessons Learned

U.S. Nuclear Waste Technical Review Board

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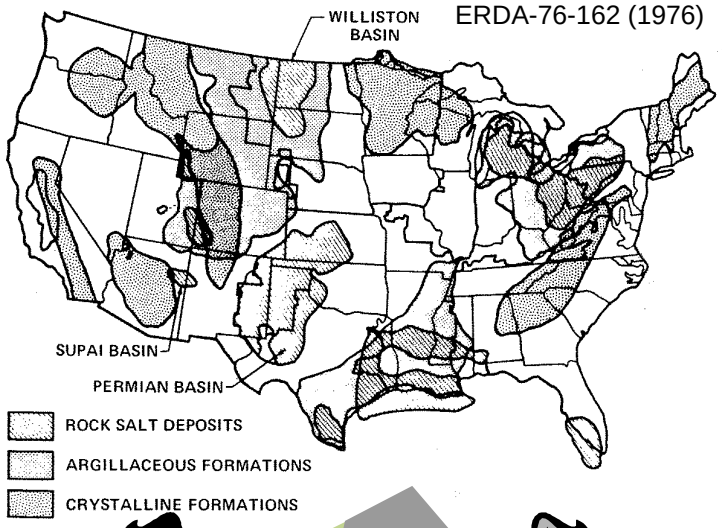
Context for EPRI Geologic Disposal Review

- DOE submission of License Application for Yucca Mountain in 2008
- Effective termination of Yucca Mountain program in 2009 and end of NRC review in 2010
- January 2010 empanelment of Blue Ribbon Commission (BRC)
- EPRI: independent nonprofit conducting research for electricity sector for public benefit

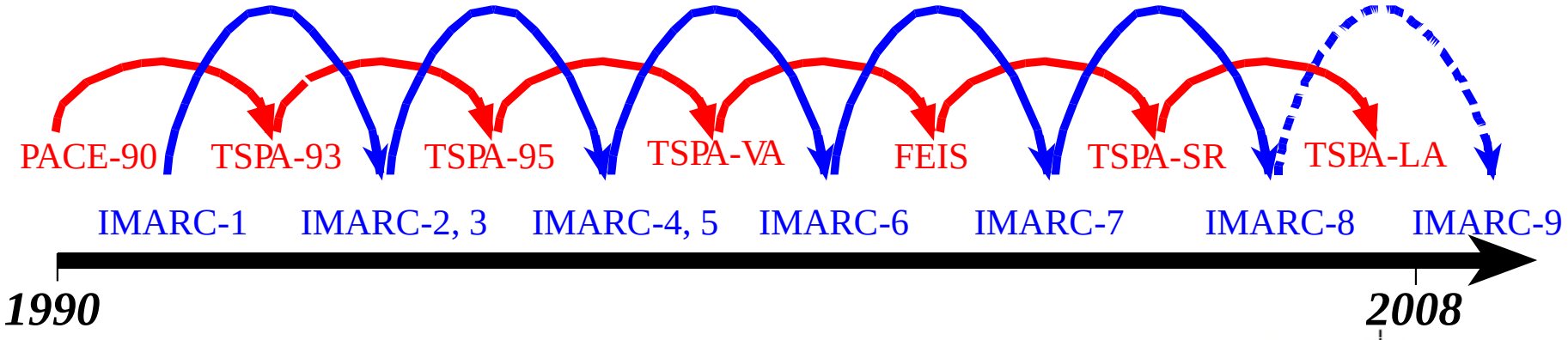
Figure 11-8. POSSIBLE GEOLOGIC FORMATIONS FOR WASTE DISPOSAL IN THE UNITED STATES.
Salt deposits have been the geologic formations given the most attention for waste disposal in the United States. Argillaceous formations include shales in various parts of the country. The crystalline formations include granite, material that is also being seriously investigated as a suitable matrix for waste disposal. (Figure reproduced from ERDA-76-162.)

ERDA-76-162 (1976)



EPRI Role in Geologic Disposal Performance Assessment

- Developed and maintained independent capability to conduct Total System Performance Assessment (TSPA) for Yucca Mountain from 1990 to 2009
  - early demonstration of TSPA for identifying and evaluating important features, events, processes
  - independent, technically defensible assessment of Yucca Mountain performance
- Championed “reasonable expectation” per 40 CFR 197



EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste

- Volumes I – III present technical "observations"
  I. Results from Nuclear Waste Policy Act (NWPA) siting activities prior to the 1987 amendment [1021056]
  II. Review of generic and Yucca Mountain-specific HLW disposal regulations [1021384]
  III. Review of international repository programs: Belgium, Canada, China, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, Taiwan, United Kingdom [1021614]
- **Volume IV - Lessons Learned [1021057]**

Volume IV - Lessons Learned [1021057]

- Need for geologic disposal
- Laws, regulations, and institutional arrangements
- Site screening, selection, and characterization
- Repository design concepts
- Independent peer-review and advisory bodies
- Stakeholder and public involvement

Lessons Learned:
Two Core Principles for Moving Forward

Anticipating and Addressing Uncertainty

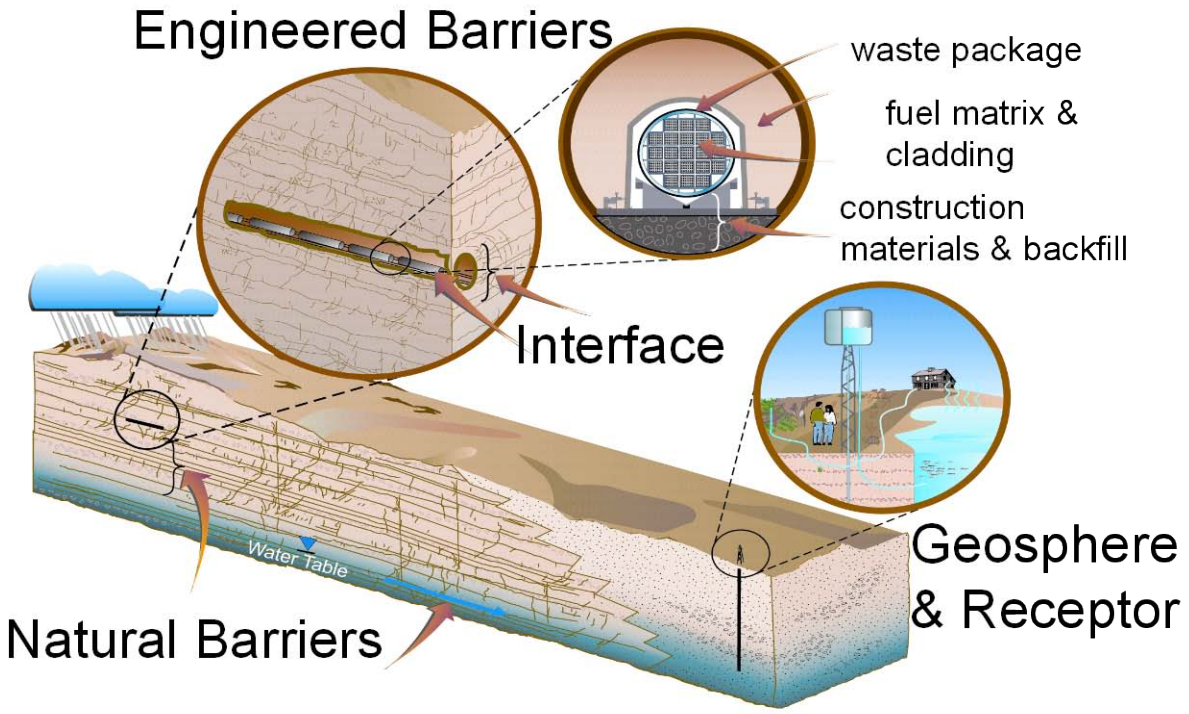
- "Reasonable Expectation" (40 CFR 197.14) provides a sound basis for performance evaluation, compliance
  - absolute proof unattainable
  - many uncertainties increase significantly with time
  - focus should be on risk-significant features, events, processes (FEPs)
  - best estimate rather than worst case
- Flexible, adaptive approach needed to anticipate inevitable "*surprises*" as siting progresses from "*ignorance*" to uncertainty to knowledge (e.g., NAS, 1990)

Course corrections for assumptions and conceptual models are an inherent part of the scientific process – not failures.

NAS, 1990. Rethinking High-Level Radioactive Waste Disposal.

The Geologic Repository as a System

- Focus on appropriate endpoints
  - human health risk
  - NOT performance of individual components
- Identification of risk-significant FEPs
- Optimization for safety, robustness



Modified from DOE/OCRWM image

Multiple natural AND engineered barriers contribute to ultimate performance of a geologic repository for defense in depth.

Key Attributes for New Program

These Follow from the Two Principles

- Regulation – risk/dose based, all-pathways approach
- Performance and compliance – total system performance assessment methods
- Site screening, selection and characterization – FEPs evaluated in context of system performance
- Repository design – tailored to site, adaptable

Regulations for Geologic Disposal

- Trend internationally is toward risk-based regulation
- Containment requirements, subsystem performance requirements, separate groundwater pathway are redundant *and could be detrimental to optimization*
- Most evolved US regulations, 40 CFR 197 and 10 CFR 63, strictly apply only to Yucca Mountain, Nevada
- Licensing of any other geologic repository reverts to the generic (*and obsolete*) 40 CFR 191 and 10 CFR 60
- EPA certification of WIPP may provide model for utility and application of generic standards/regulations

Existing standards and regulations provide a basis for a simpler, risk-based, all pathways approach – evolution NOT revolution needed.

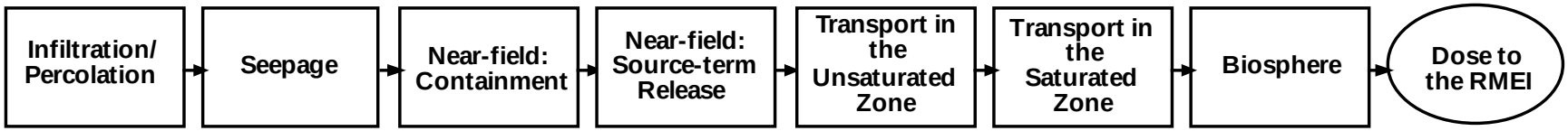
Regulatory Compliance Period

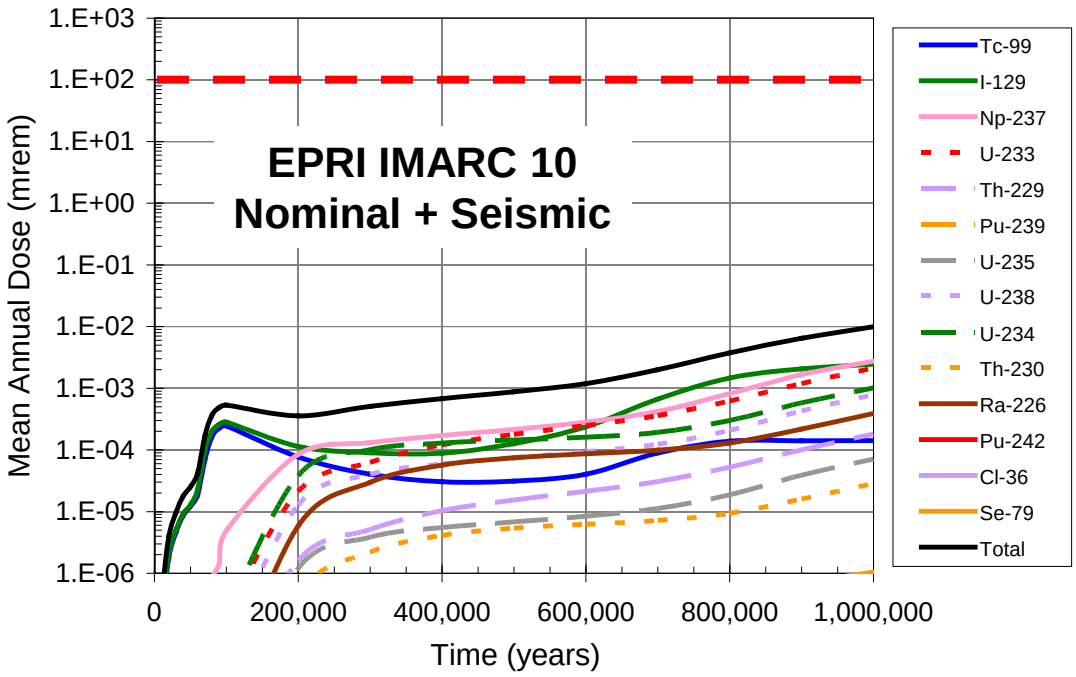
- Extension of Yucca Mountain compliance period to 10^6 yrs resulted from EPA response to narrow court ruling:
  - tied to legal finding on consistency with National Academy of Sciences recommendations (1995) per Energy Policy Act of 1992
  - NOT driven by finding of inadequate protection
- International examples encompass range: 10^4 – 10^6 yrs
- Growing consensus on need for increasingly qualitative treatment for far distant time periods (10^5 – 10^6 yrs)
  - EPRI (2005) recommended fixed assumptions, stylized analyses, higher dose limit for compliance demonstration after 10,000 yrs
  - final revised 40 CFR 197 consistent with EPRI (2005)
  - phased regulatory approaches common to other national programs

Regulation of a HLW repository other than Yucca Mountain could revert to a 10,000-year quantitative compliance period.

NAS, 1995. Technical Bases for Yucca Mountain Standards.

Demonstrating Compliance





- TSPA as primary tool for:
  - demonstrating repository safety over long timeframes
  - identification and emphasis on most risk-significant FEPs
- TSPA applied in context of *reasonable expectation*

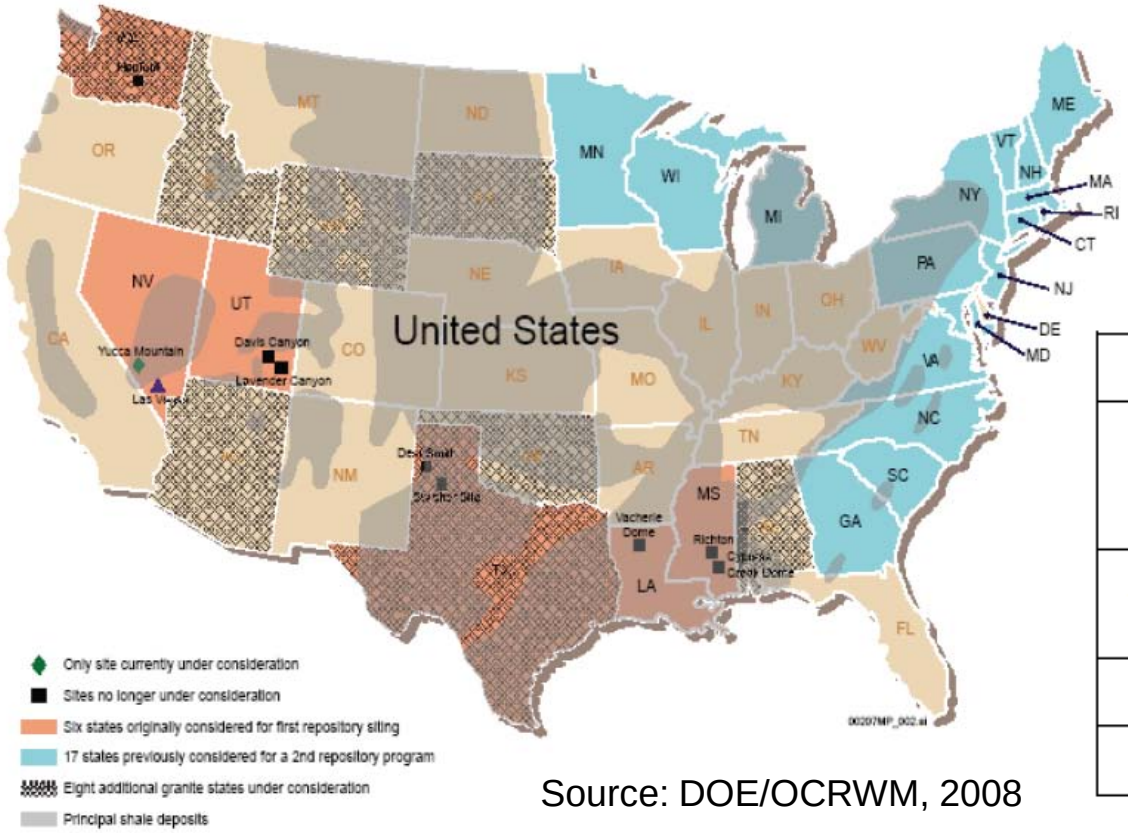
Site Screening, Selection, and Characterization

- No single “best” approach for site selection process: mixed results for nominative, volunteer approaches internationally
  - highly dependent on country-specific factors
  - important, unique role of State governments in the U.S.
- Overly restrictive siting criteria risk elimination of suitable candidates, distraction from more risk-significant aspects
  - favorable hydrologic conditions
  - groundwater travel times
  - cumulative and fractional release limits
- Objective is an “adequately safe” site

A “best” site neither exists nor is necessary.
Successful siting experiences do not necessarily translate to other nations.

Site Screening, Selection, and Characterization

- All nations expect to site a geologic repository regardless of size, geologic diversity, population
- Geologic diversity in U.S. = no shortage of candidate sites



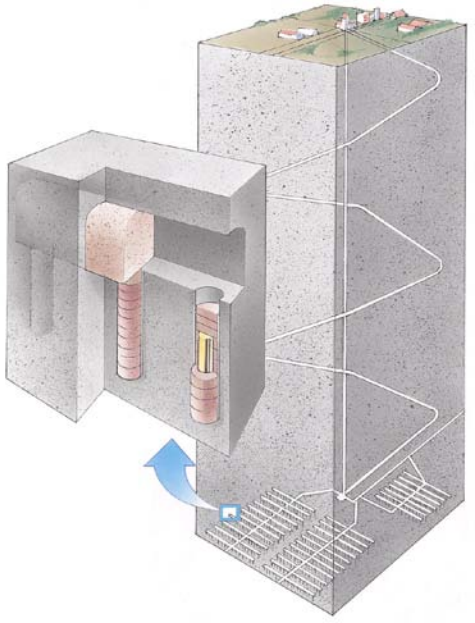
Source: DOE/OCRWM, 2008

Geology	Countries
Crystalline rock (*e.g.*, granite, gneiss)	Sweden, Finland, Japan, Canada
Argillaceous rock (*e.g.*, clay)	France, Switzerland, Belgium
Salt	USA (WIPP), Germany
Volcanic tuff	USA (Yucca Mountain)

Repository Design Concepts

- Repository performance determined by both natural and engineered barriers working in concert (as a system)
- Multiple barriers provide defense in depth
- Collective international experience offers repository design concepts suited for a range of environments and requirements
- New alternative repository design concepts offer greater flexibility in storage and disposal and fuel cycle integration

KBS-3 Design Concept
(Sweden, Finland)

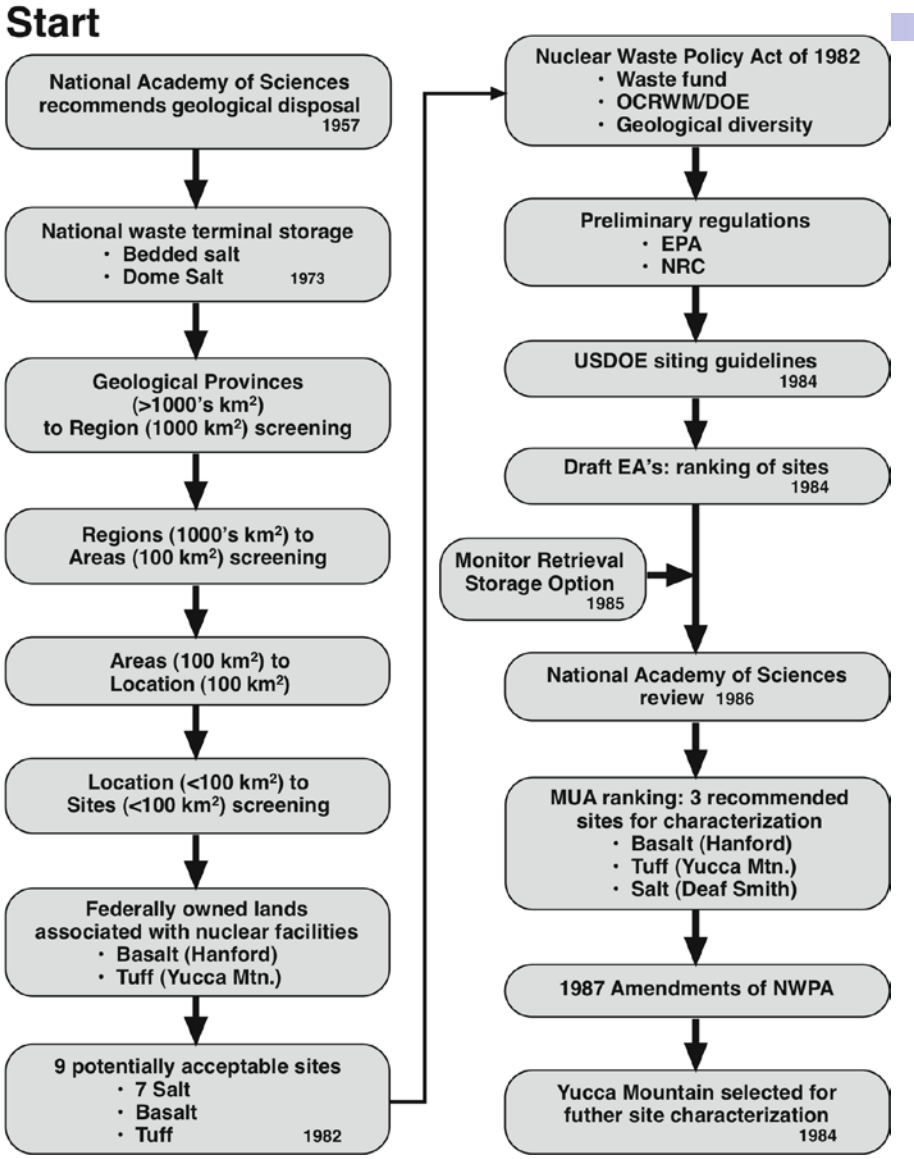


Source: SKB

Flexible repository designs allow for some degree of course correction.

Additional Observations and Lessons Learned

Common Mischaracterization: "No technical basis for Yucca Mountain selection"



- Selection of Yucca Mountain resulted from an abridged NWPA process – ***but there was a process***
- Yucca Mountain was top site for composite ranking in technically-based multiattribute utility analysis (MUA)

DOE, 1986. A Multattribute Utility Analysis of Sites Nominated for Characterizations for the First Radioactive Waste Repository – A Decision Aiding Methodology

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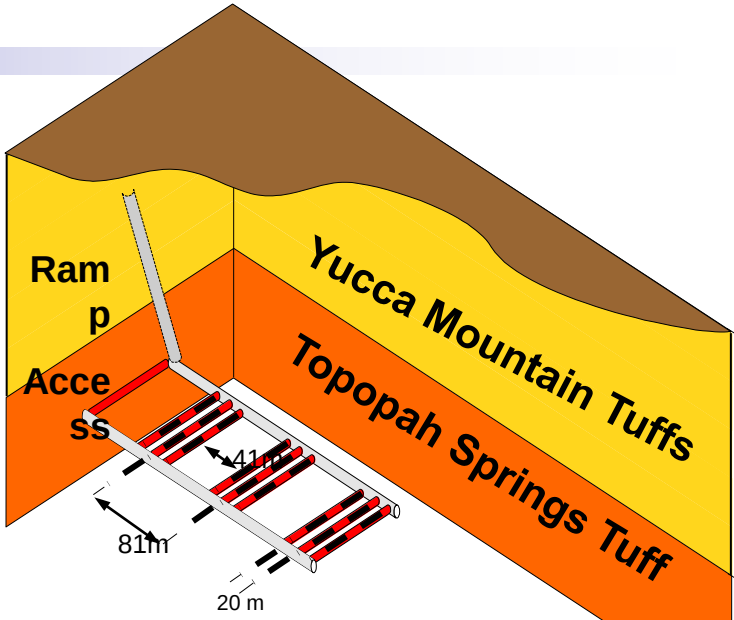
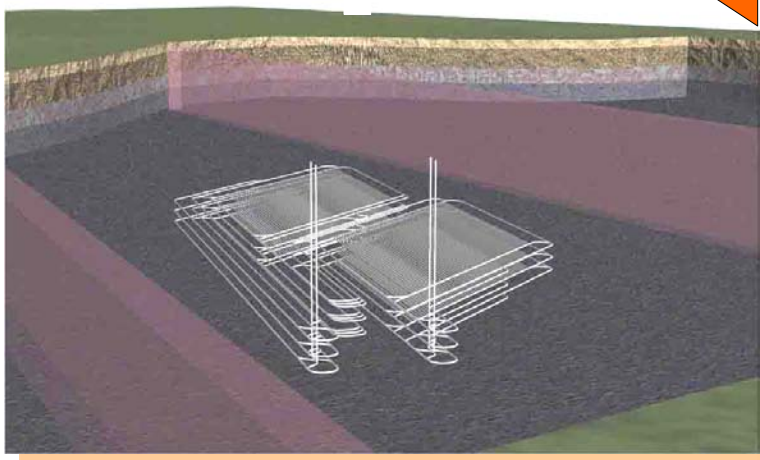
Technical vs. Legal Repository Capacity

- Technical disposal capacity ≠ legal or regulatory limit established for non-technical reasons
  - Yucca Mountain legal limit tied to second repository
  - Limit also used to support fuel cycle alternatives
- EPRI (2007) modeling indicated at least 4 times the legal limit of CSNF could be emplaced at Yucca Mountain, possibly expandable up to 9 times the limit
- DOE *Second Repository Report* (2008) presents similar conclusion





EPRI, 2007. Room at the Mountain. 1015046

Independent Peer-Review and Stakeholder Involvement

- Independent advisory bodies and peer-review are vital for a credible disposal program
  - EPRI
  - Nuclear Waste Technical Review Board
  - National Academy of Sciences
  - International peers
- Non-technical issues (social, political, economic) can overshadow technical merits of a repository program

Summary

DOE/OCRWM

- Objective is “adequately safe” ***NOT*** “best” site
- Nature of siting process calls for a flexible, adaptable process – “surprises happen”
- Consider repository as a system; other key attributes of repository program follow:
  - all pathways, risk-based regulatory approach
  - TSPA approach for demonstrating compliance
  - risk-informed FEP evaluation in site screening, selection, characterization
  - tailored repository design to complement site
- Value, importance of independent technical peer-review
- Technical credibility necessary but not sufficient

EPRI Geologic Disposal Review Series (2010)

- EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste: Volume I - The U.S. Site Selection Process Prior to the Nuclear Waste Policy Amendments Act. [1021056] http://my.epri.com/portal/server.pt?Abstract_id=000000000001021056
- EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste: Volume II - U.S. Regulations for Geologic Disposal. [1021384] http://my.epri.com/portal/server.pt?Abstract_id=000000000001021384
- EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste: Volume III - Review of National Repository Programs. [1021614] http://my.epri.com/portal/server.pt?Abstract_id=000000000001021614
- EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste: Volume IV - Lessons Learned. [1021057] http://my.epri.com/portal/server.pt?Abstract_id=000000000001021057

Other Recent, Relevant EPRI Reports

- *Occupational Risk Consequences of the Department of Energy's Approach to Repository Design, Performance Assessment and Operation in the Yucca Mountain License Application.* EPRI, Palo Alto, CA: 2008. 1018058. http://my.epri.com/portal/server.pt?Abstract_id=000000000001018058
- *EPRI Yucca Mountain Total System Performance Assessment Code (IMARC) Version 10: Model Description and Analyses.* EPRI, Palo Alto, CA: 2009. 1018712. http://my.epri.com/portal/server.pt?Abstract_id=000000000001018712
- *International Review Team Report: A Peer Review of the Yucca Mountain IMARC Total System Performance Assessment EPRI Model.* EPRI, Palo Alto, CA: 2009. 1018711. http://my.epri.com/portal/server.pt?Abstract_id=000000000001018711
- *Evaluation of a Spent Fuel Repository at Yucca Mountain, Nevada: 2008 Progress Report.* EPRI, Palo Alto, CA: 2008. 1016631. http://my.epri.com/portal/server.pt?Abstract_id=000000000001016631
- *Program on Technology Innovation: Room at the Mountain: Analysis of the Maximum Disposal Capacity for Commercial Spent Nuclear Fuel in a Yucca Mountain Repository.* EPRI, Palo Alto, CA: 2007. 1015046. http://my.epri.com/portal/server.pt?Abstract_id=000000000001015046
- *Yucca Mountain Licensing Standard Options for Very Long Time Frames: Technical Bases for the Standard and Compliance Assessments.* EPRI, Palo Alto, CA: 2005. 1011754. http://my.epri.com/portal/server.pt?Abstract_id=000000000001011754

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