Exceptional service in the national interest

SAND2013-1428C

Sandia National Laboratories

A Safety Case Approach for Deep Geologic Disposal of DOE HLW and DOE SNF in Bedded Salt

S. David Sevougian,
Bob MacKinnon, Christi Leigh, and Frank Hansen

WM2013 Symposia
Phoenix, AZ, USA
February 25, 2013

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Synopsis

- Using existing technical information, a strong initial safety case can be developed for a geologic repository for DOE HLW and DOE SNF waste, if it were sited in Delaware Basin bedded salt:
  - There is an extensive knowledge base in salt repository sciences based on past investigations in the U.S. and abroad (e.g., WIPP, DOE Salt Repository Project, Gorleben)
  - Performance assessment (PA) methodology for disposal in salt has been developed, matured, and applied successfully in the certification of WIPP
- The conclusions presented here are not intended to preclude siting of a repository for DOE waste elsewhere—but simply meant to capitalize on past investigations in salt host rock

Safety Case – Definition & Roles

- "The safety case is an integration of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in the safety, of the geological disposal facility." (NEA 2004)
  - Quantitative information – calculated values for safety standards and indicators, including uncertainty (e.g., a safety assessment)
  - Qualitative information – supporting evidence and reasoning that builds confidence in the quality of the underlying science and conclusions (e.g., relevant literature, natural analogs)
- Two major roles:
  - Management: a tool to guide the activities of the implementer (e.g., DOE) through the various phases of repository development
  - Communication: transparently explain the current understanding of safety to a broad range of stakeholders, decision makers, and the general public

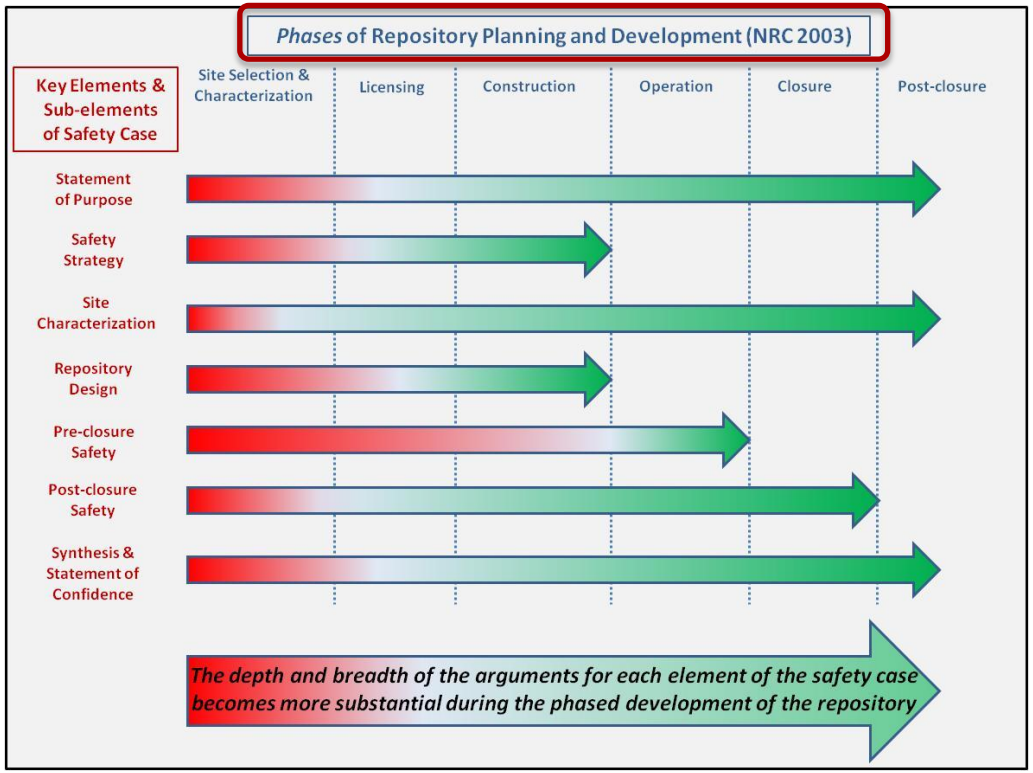
Potential Benefits of Outlining an Initial Safety Case for Bedded Salt Host Rock

Sandia National Laboratories

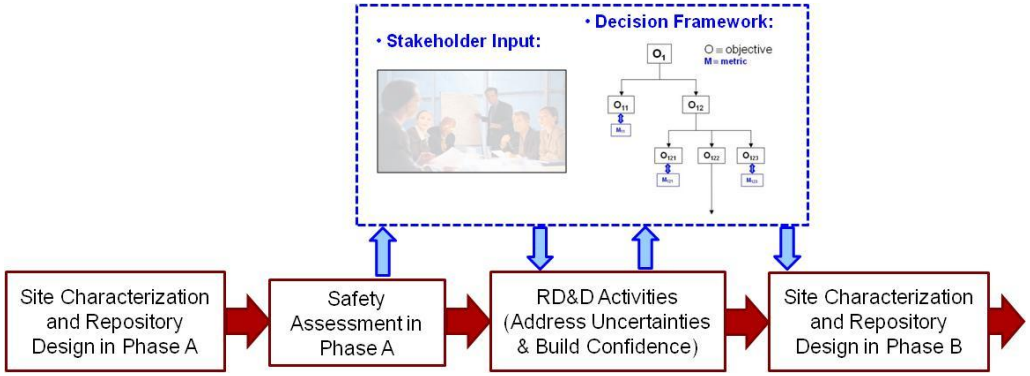
1) Leverage previous R&D in salt science (e.g., WIPP) to reduce future new repository costs and possibly shorten the schedule:
   - Provide a transparent and logical structure for organizing and synthesizing existing salt repository science and identifying any issues or gaps pertaining to safe disposal of DOE HLW and DOE SNF in bedded salt
2) Efficiently plan for all phases of repository development and licensing:
   - Plan future R&D activities for investigating salt disposal using a risk-informed, performance-based approach that prioritizes testing and modeling activities:
     - Limited set of laboratory, field, and underground investigations to address issues related to heat generation
     - Performance assessment modeling to prioritize activities based on risk
     - Confidence-building efforts based on stakeholder and regulator perceptions of uncertainties

Evolution of the Safety Case

- Safety understanding and the associated technical bases evolve with phases of repository development
- Safety case provides a structured framework to assist in prioritizing the technical work in the next phase, to reduce uncertainties and enhance confidence



Iteration of Safety Assessment and Design:



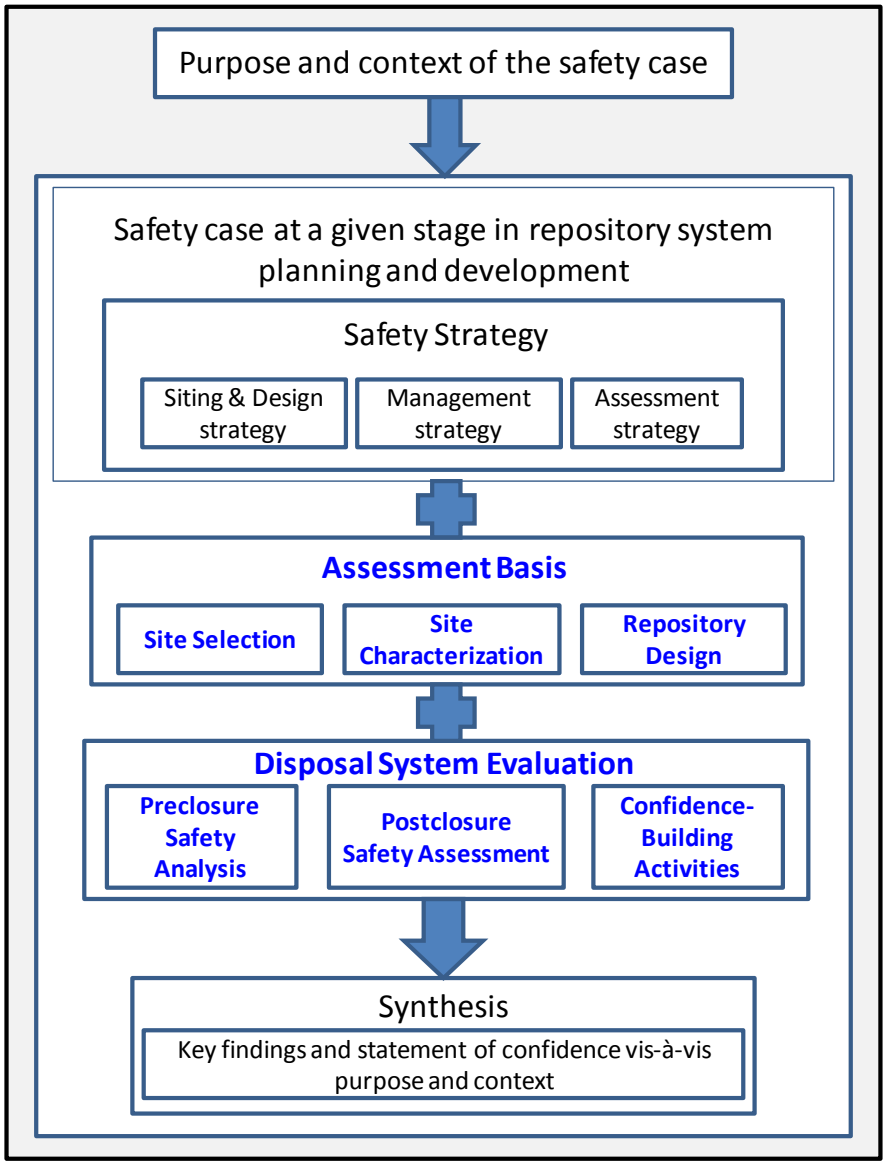
Why DOE Waste?

Sandia National Laboratories

- Not an economic resource
- Much lower heat generation rate simplifies repository design and performance assessment
- The initial safety case could be based on the "non-NWPA" DOE waste inventory:
  - Defined in Sec. 8(c) of the Nuclear Waste Policy Act (NWPA) as waste arising from atomic defense activities or DOE R&D activities
  - Disposition of DOE-owned waste from civilian sources need not be decided upon in order to develop this initial safety case
- The Blue Ribbon Commission (BRC) summarized some of the key issues related to separated or commingled disposal of civilian and defense wastes
- Note: A safety case can be initiated prior to finalization of quantitative safety standards—by initially adopting risk/dose standards used internationally

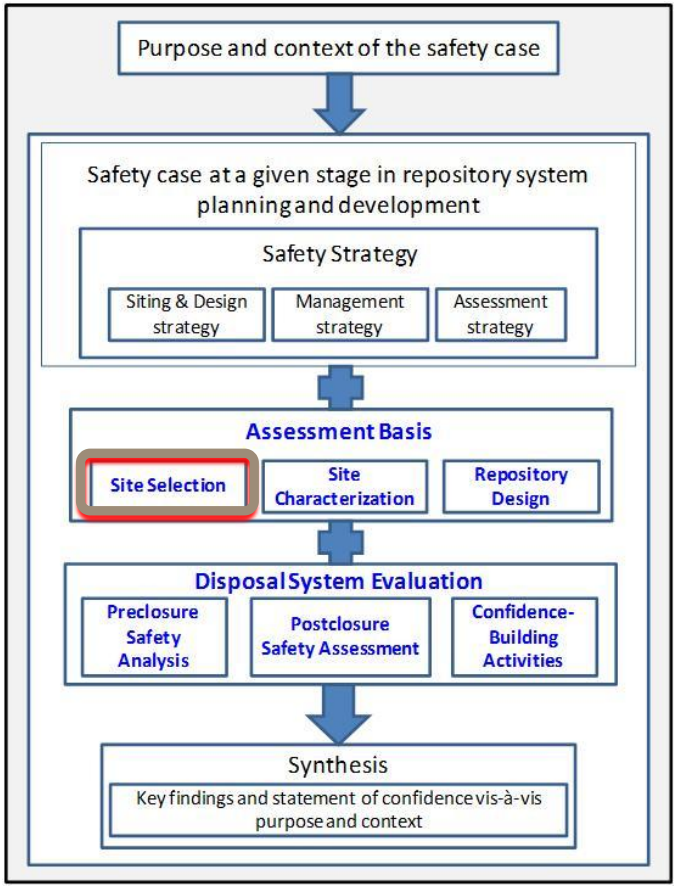
Elements of the Safety Case

- Purpose and Context
- Safety Strategy
- Assessment Basis
  - Site Selection
  - Site Characterization
    - Natural Barriers
  - Repository Design
    - Disposal Concept
    - Waste Inventory
    - Engineered Barriers
- Disposal System Evaluation
  - Preclosure Safety Analysis
  - Postclosure Safety Assessment
  - Confidence-Building Activities
- Synthesis of Findings
  - Statement of Confidence



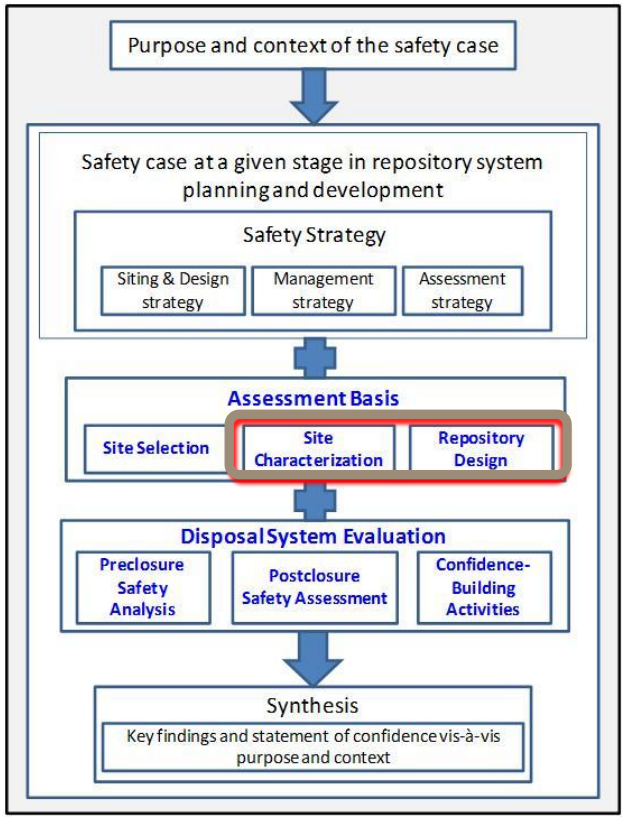
Assessment Basis - Site Selection

- Identification of potential sites
  - Several bedded (and domal) salt deposits in U.S.
  - Potential locations in the Delaware Basin
- Preliminary site characterization information
  - Significant geologic, hydrologic, geochemical, geophysical, thermal-mechanical data exists for sites in the Delaware Basin
- Future siting criteria include
  - Geology – e.g., topography, stratigraphy, depth, lateral extent
  - Hydrology – e.g., subsurface flow and transport, surface waters, climate
  - Tectonic Stability – e.g., no seismic activity, igneous activity, fracturing
  - Socio-economic – e.g., natural resources, population density, public acceptance



Assessment Basis – Site Characterization and Repository Design

- Identify characteristics and features of the site and the conceptual disposal system
  - DOE waste inventory and waste forms
  - Natural barrier properties and their uncertainty and spatial variability—robust existing database
  - Engineered barriers, including waste packages, backfill, and seal system
- Design the repository layout/location and engineered features to maximize safety functions and barrier capability
  - Maximize emplacement density while observing design thermal constraints and safe operations
  - Consider beginning with Carter et al. 2012 (on-floor disposal for low-heat HLW)
  - Use process models and PA models to evaluate repository evolution for both undisturbed and disturbed scenarios for the proposed design

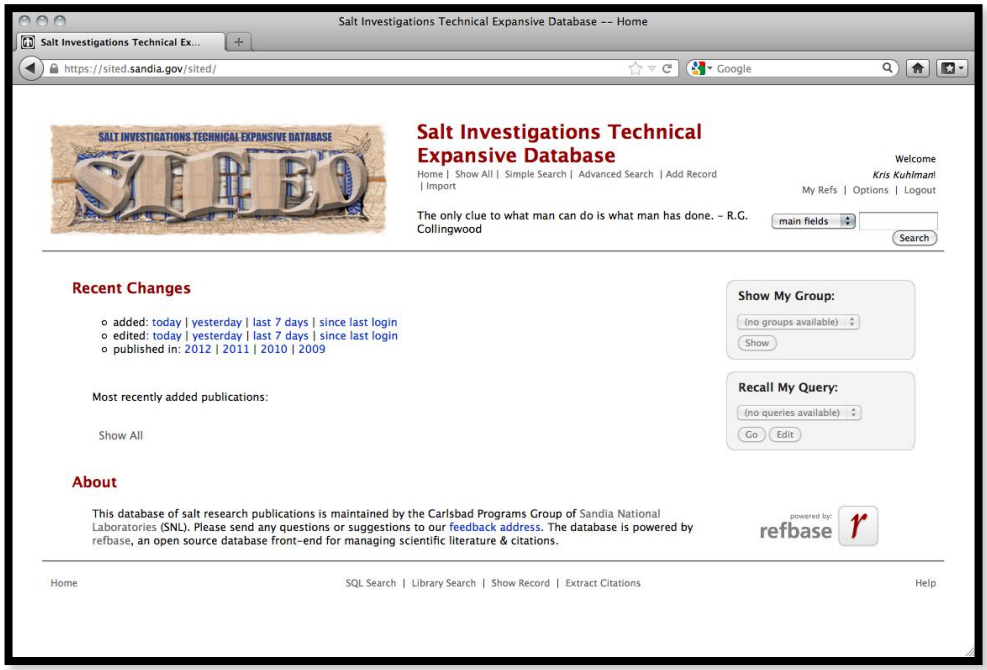


Existing Salt Technical Bases

- Reviewed WIPP, Avery Island, DOE Salt Repository Project, and German salt research, including
  - History of US regulations relevant to salt repositories
  - History of repository siting process in salt
  - History of relevant (laboratory/in situ) testing
    - Thermal/mechanical tests (i.e., heater tests)
    - Thermal/hydrologic/mechanical tests (i.e., brine migration tests)
    - Geomechanical tests (i.e., room closure and creep)
- Created a digital archive/database with various capabilities, including
  - Create “reading list” of top reports/tests for a given test type
  - Acquire, index, and assess WIPP reports and data, including some that are not readily available
  - Create summary report

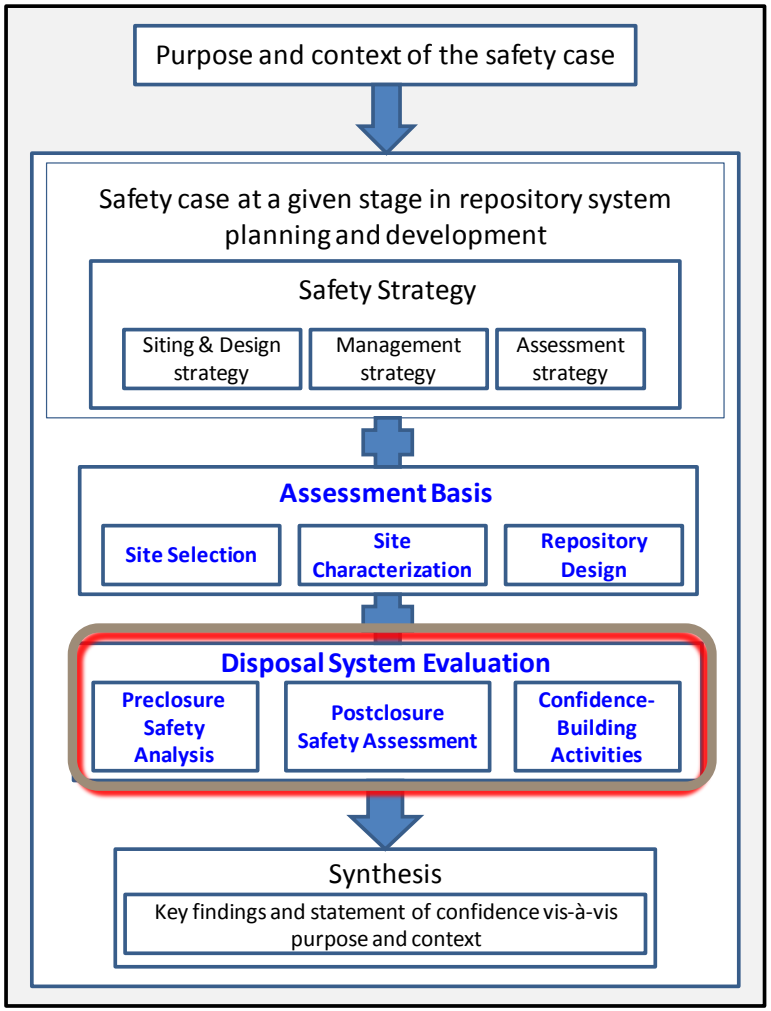
Salt Investigations Technical Expansive Database (SITED)

- Based on open-source bibliographic database (Refbase)
- Browser-based database interface
- Interface allows:
  - Adding bibliographic info
  - Uploading pdf/text/data files
  - Searching existing records
- PDF versions of most relevant reports now exist in SITED
  - >10,000 reports from all sources (SNL/DOE/EU)
  - Thousands checked for relevance
  - Hundreds reviewed in detail
- Bibliographic data (author, title, # pages) imported from:
  - SNL Technical Library
  - DOE Office of Science Information Bridge (http://osti.gov/bridge)
  - European Scientific Library (http://bookshop.europa.eu/en/)



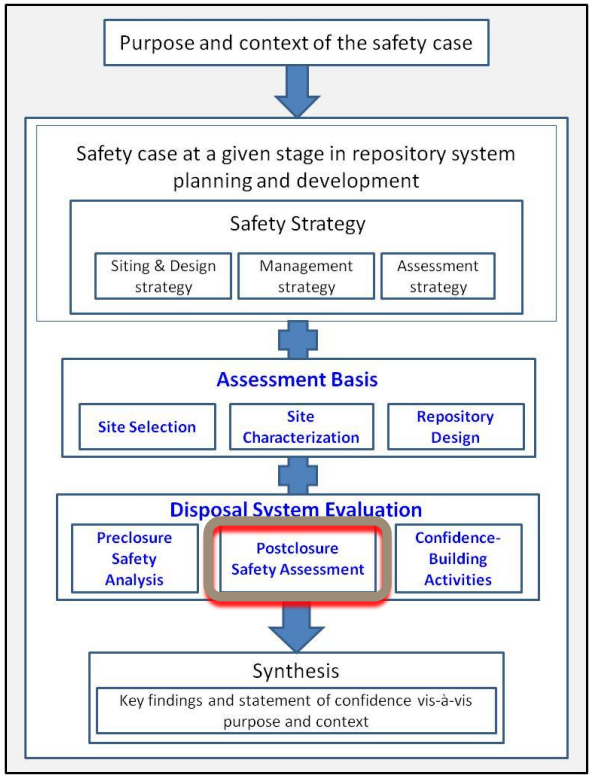
Disposal System Evaluation

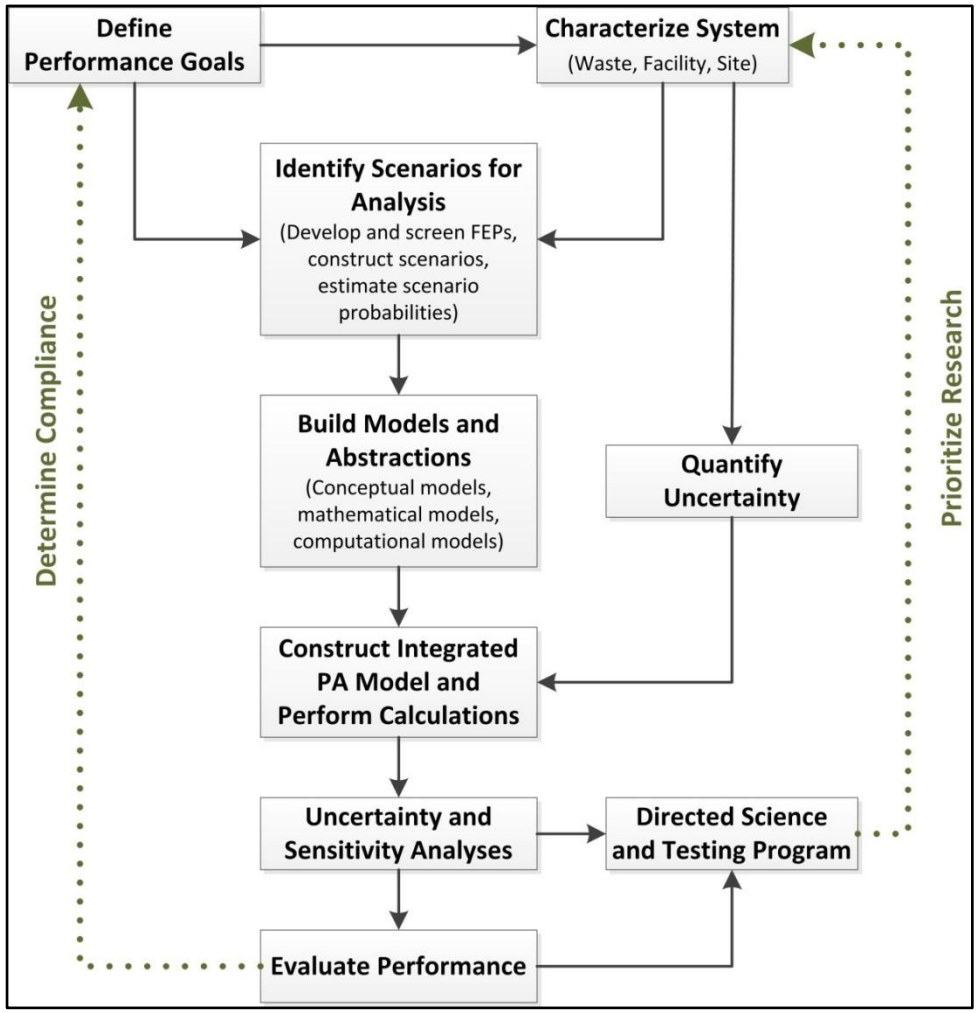
- Preclosure Safety Analysis
  - Worker/public exposure from repository operations accidents
  - Include transportation and packaging/ handling safety analyses
  - Current knowledge base includes U.S. experience with WIPP and German experience with Asse and Morsleben
- Postclosure Safety Assessment
  - Quantitative comparison to system safety standards (dose or risk)
  - Quantitative/qualitative analysis of barrier capability or subsystem safety functions
  - Uncertainty/sensitivity analyses
- Confidence-Building Activities



Role of Postclosure Safety or Performance Assessment (PA)

- "Performance assessment is arguably the most important part of the safety case..." (NWTRB 2011)
- Guides RD&D and informs site characterization and design during phased repository development

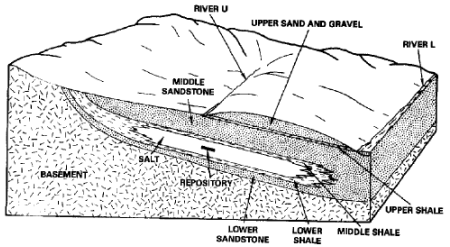




Iterative PA Methodology

Some Past U.S. Salt PA and R&D Efforts

1) "Risk Methodology for Geologic Disposal of Radioactive Waste," Campbell et al. 1978—developed for a "reference" bedded salt repository for HLW, ILW, and LLW:



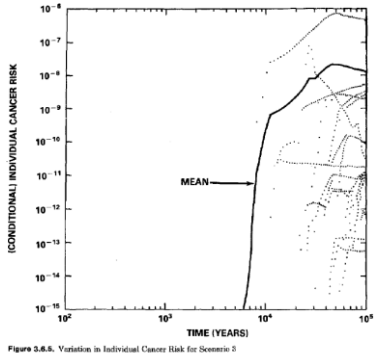
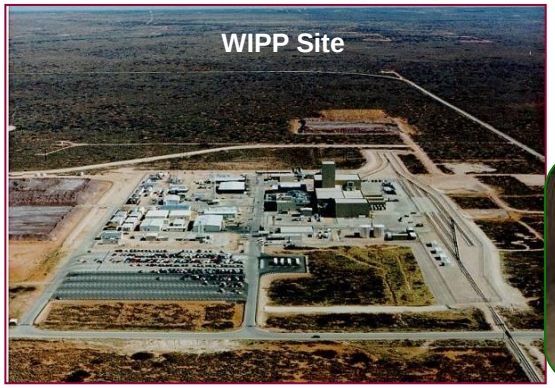


Figure 3.6.5. Variation in Individual Cancer Risk for Scenario 3

2) Salt Repository Project (SRP), Deaf Smith County, TX: "Postclosure performance assessment of the SCP (Site Characterization Plan) conceptual design for horizontal emplacement: Revision 1," ONWI (Office of Nuclear Waste Isolation) 1987b

3) Waste Isolation Pilot Plant (WIPP) for defense TRU waste, Compliance Certification Application (CCA) Performance Assessment, DOE 1996



- Initially sited – 1975
- Certified by the EPA – 1998
- First Waste Receipt – March 26, 1999
- First Recertification – March 2006
- Second Recertification – November 2010
- More than 10,000 shipments to date

Long-term Performance of the WIPP

- Geologic barriers provide long-term isolation
  - Dry climate
  - Very low permeability of salt
- No releases of radionuclides to the accessible environment occur during the 10,000-year performance period without human intrusion
- Hypothetical borehole intrusions as a result of future oil and gas exploration are evaluated as part of the long-term performance assessment
  - Releases due to multiple human intrusions are well below regulatory limits

International PA and R&D— Gorleben Preliminary Safety Assessment*

Sandia National Laboratories

1. Assessment Basis

site characterisation and long-term predicition
waste characterization and waste quantity
safety concept and safety demonstration

2. Repository Concept

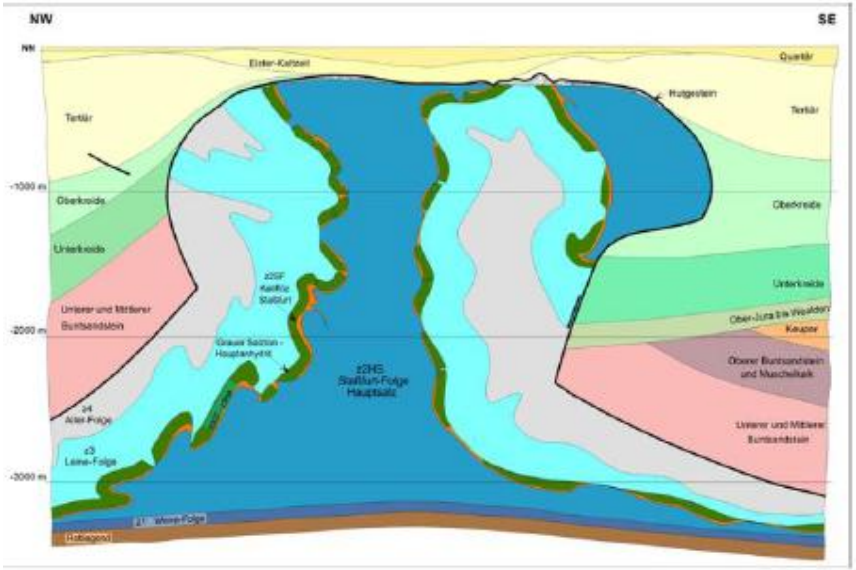
repository concept
repository design
optimisation

3. System Analyses

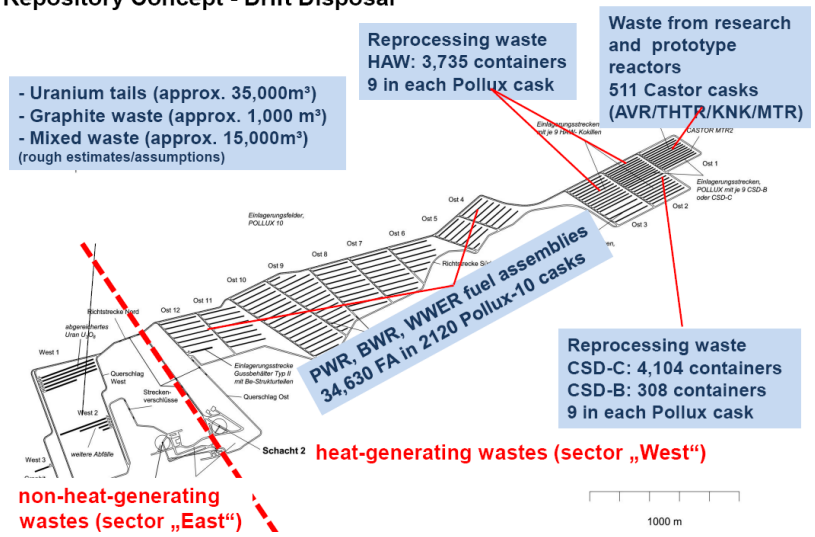
scenario development
integrity assessment of geological & geotechnical barriers
assessment of RN containment

4. Synthesis

synthesis of assessment results
future needs w.r.t. R&D and site investigation

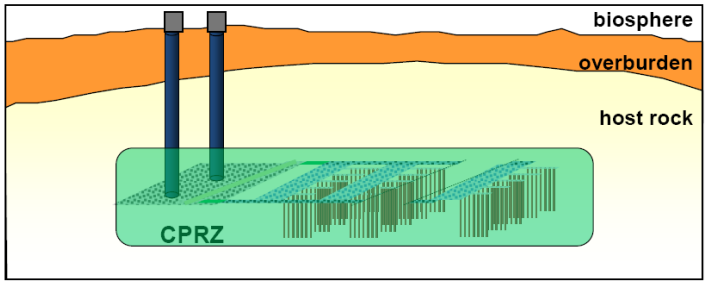


Repository Concept - Drift Disposal



The post-closure safety concept focusses on safe containment

- **Safe containment** describes the status of the repository system in which there is at the most an insignificant release of radionuclides from the containment-providing rock zone (CPRZ) during the demonstration period
- An **insignificant release** from the CPRZ is a release whose radiological consequences calculated by a biosphere model are below permissible limits and thus pose no risk to subjects of protection



* Text and graphics from J. Monig 2012, GRS, OECD-NEA Salt Club Meeting

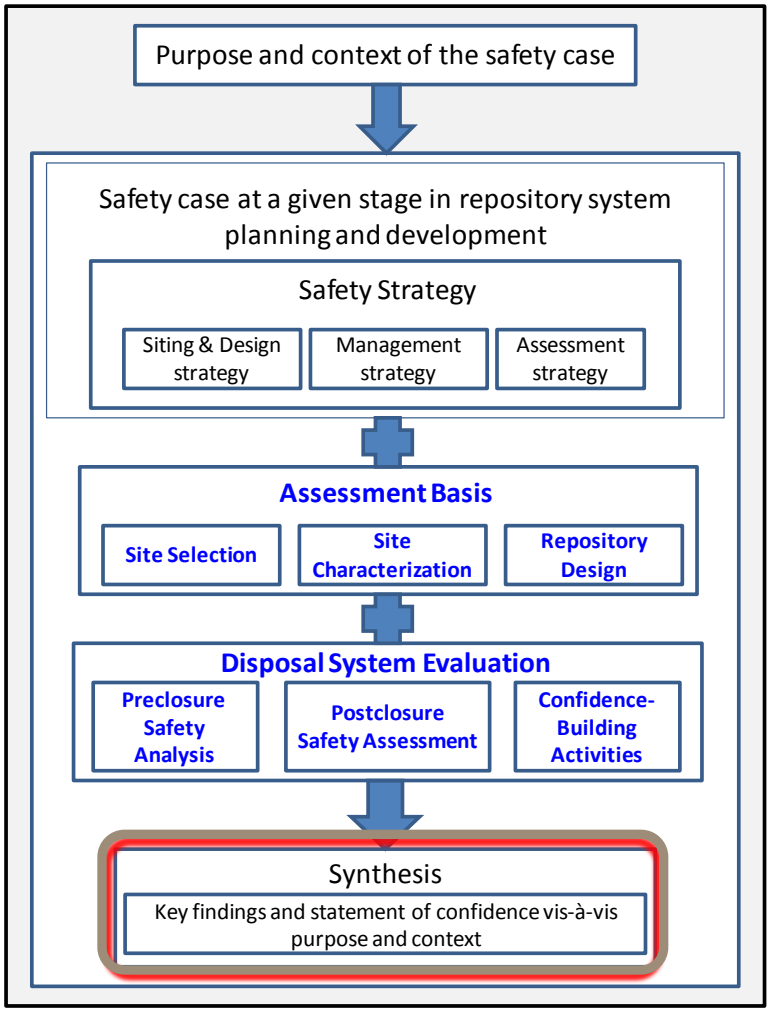
Confidence-Building Activities, including *In-Situ* Testing

Sandia National Laboratories

- An important aspect of the Safety Case is "confidence building" vis-à-vis the current level of understanding of repository safety
- Confidence-building includes
  - Comparisons to natural and anthropogenic analogs
  - Qualitative arguments about the intrinsic robustness of site and design
  - International peer review and collaboration
  - Transparent discussion of remaining uncertainties/issues
- *In-situ* testing, e.g., in an underground research laboratory (URL), can build confidence in both the scientific bases and the safety evaluations by examining processes at a large scale:
  - Field-scale effects of coupled mass, momentum, and energy transport
  - Demonstration of design options
  - Preclosure safety and operations
- Testing *in-situ* should be risk-informed by current PA analyses and stakeholder input, such that tests that most reduce uncertainty and build confidence receive a higher priority

Synthesis of Results

- Statement of confidence based on qualitative and quantitative information
  - Completeness and robustness of current arguments and analyses
  - Importance of remaining uncertainties
  - Path forward to next phase of repository development
  - Focal point for engagement with stakeholders
  - Provide quality assurance (QA)



Synthesis – the Case for Bedded Salt

Sandia National Laboratories

- Multiple barriers contribute to safety functions of waste isolation and containment, but the natural barrier alone is sufficient for the nominal scenario:

Natural barriers:

- Slow diffusion-dominated transport with sorption
- Long migration distance to receptor (undisturbed)
  - Host salt - very slow brine movement
  - Interbeds - absence of well-connected fractures

Transport to an aquifer in an undisturbed case will not occur

Engineered barriers:

- Slow waste dissolution due to reducing chemistry
- Salt creep closure of repository and EDZ healing
  - Waste Package - performance credit not needed
  - Shaft Seals - effectiveness demonstrated at WIPP

Extensive engineered barriers are not necessary

- Additional R&D to reduce uncertainties associated with thermal effects from heat-generating DOE HLW/SNF, e.g.,
  - Brine movement and vapor-phase transport; backfill reconsolidation; EDZ evolution; gas generation; radionuclide solubility; waste package buoyancy

Conclusions

- A strong initial safety case can be developed expeditiously for a geologic repository for DOE HLW and DOE SNF waste, if it were to be sited in Delaware Basin bedded salt
  - Extensive knowledge base in salt repository science and operations, based on past U.S. and international investigations (compiled in SITED archive)
  - Successful and safe operational and transportation activities (WIPP)
  - Performance assessment (PA) methodology for nuclear waste disposal has been developed, matured, and applied successfully in the certification of WIPP
- Early development of a structured safety case for DOE waste will
  - Leverage previous investments and experience at WIPP
  - Identify potential remaining issues (FEPs) associated with DOE heat-generating waste
  - Guide future R&D, including lab and in-situ field testing