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# Safety Case for Salt Disposal of High-Level Waste (HLW) and Spent Nuclear Fuel (SNF)

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# Outline

- Safety Case Elements

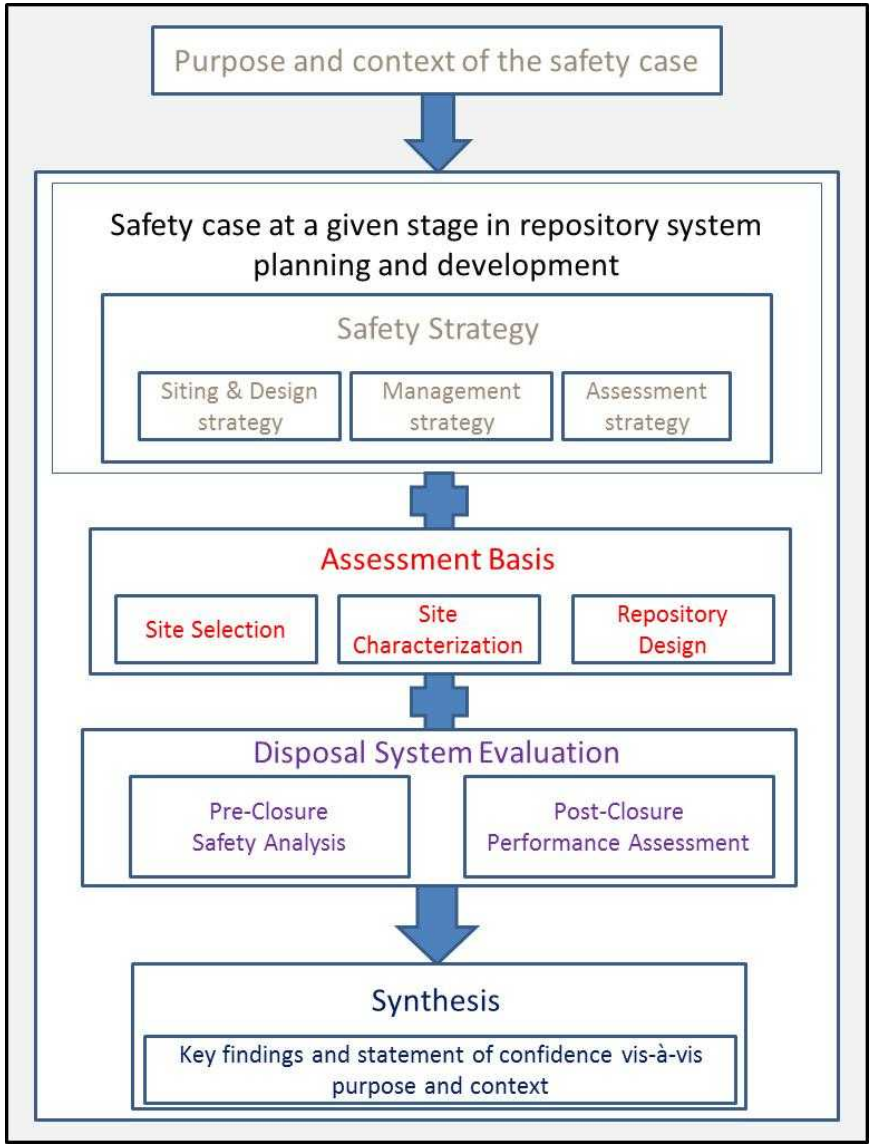
- Safety Case for salt disposal of HLW and SNF
  - Existing information relevant to the safety case elements
  - Information needs (gaps)

# Safety Case - Definition

- "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, Section 1)
  - Quantitative information – calculated values for safety indicators, including uncertainty (e.g., a safety assessment)
  - Qualitative information – supporting evidence and reasoning that gives confidence in the quality of the underlying science and conclusions (e.g., relevant literature, natural analogs)
- References – Safety Case Elements
  - NEA (1999, 2002, 2004, 2008, 2009, *2012?*)
  - IAEA (2006, 2011)
  - Bailey et al. (2011), Van Luik et al. (2011)

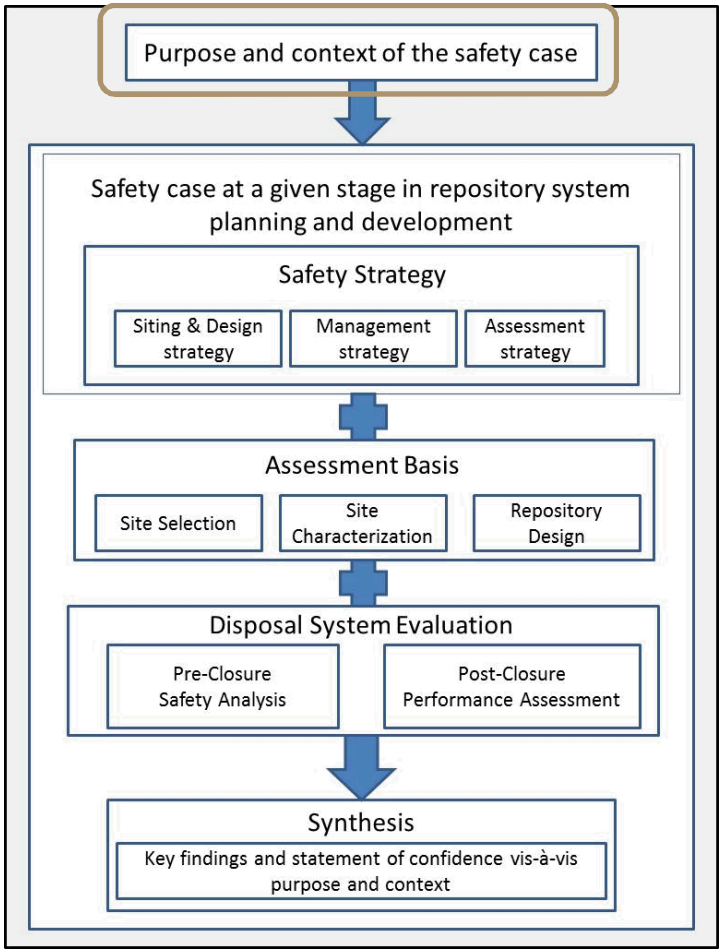
# Safety Case – Elements

- Purpose and Context
- Safety Strategy
- Assessment Basis
  - Site Selection
  - Site Characterization
    - Natural Barriers
  - Repository Design
    - Disposal Concept
    - Waste Inventory
    - Engineered Barriers
- Disposal System Evaluation
  - Pre-Closure
  - Post-Closure
- Synthesis of Findings
  - Statement of Confidence



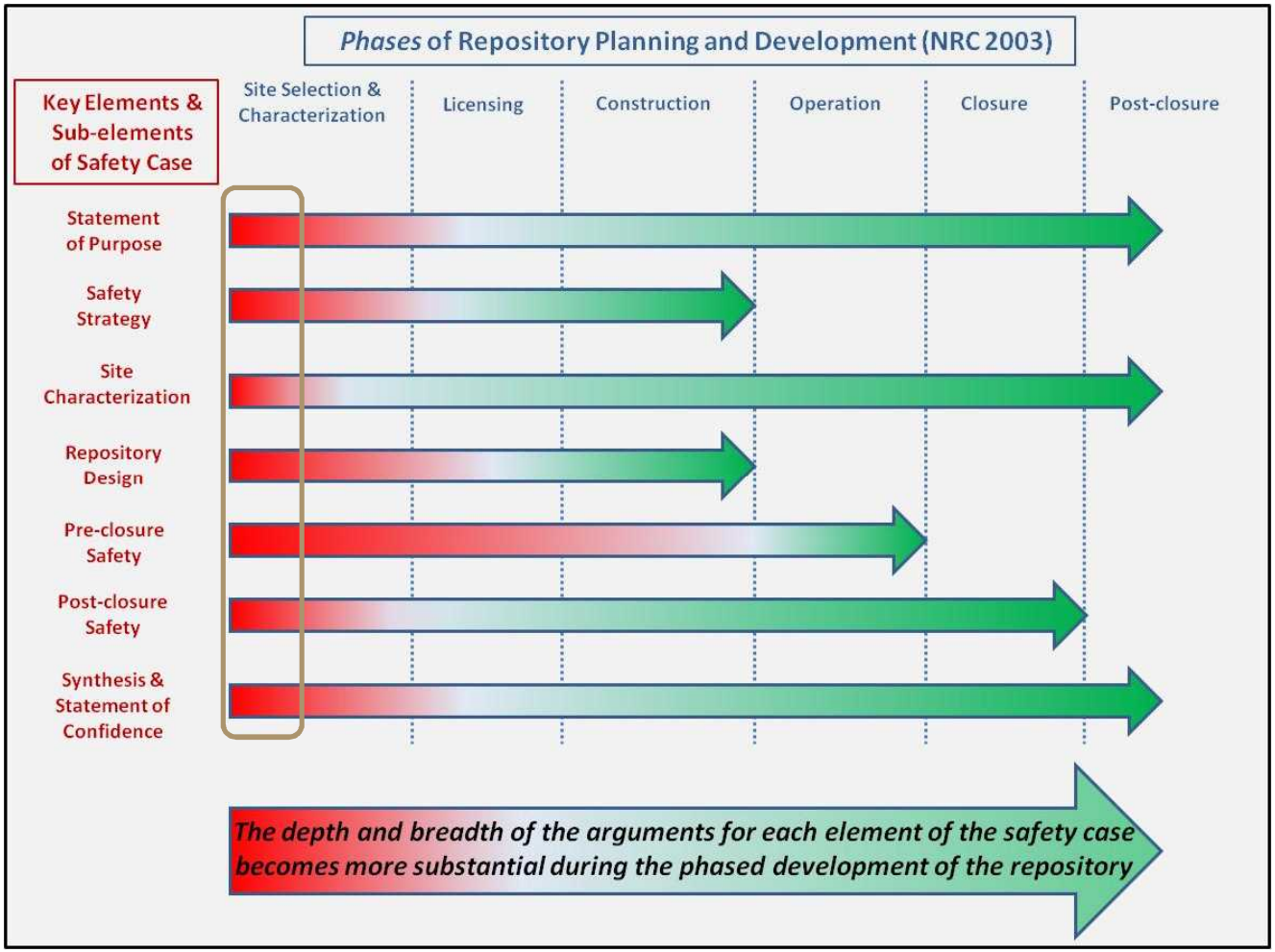
# Purpose and Context

- Describes the current stage or decision point within the program
  - Repository planning
  - Site screening and selection
  - Site characterization and repository design
  - Licensing
  - Construction
  - Operation
  - Closure



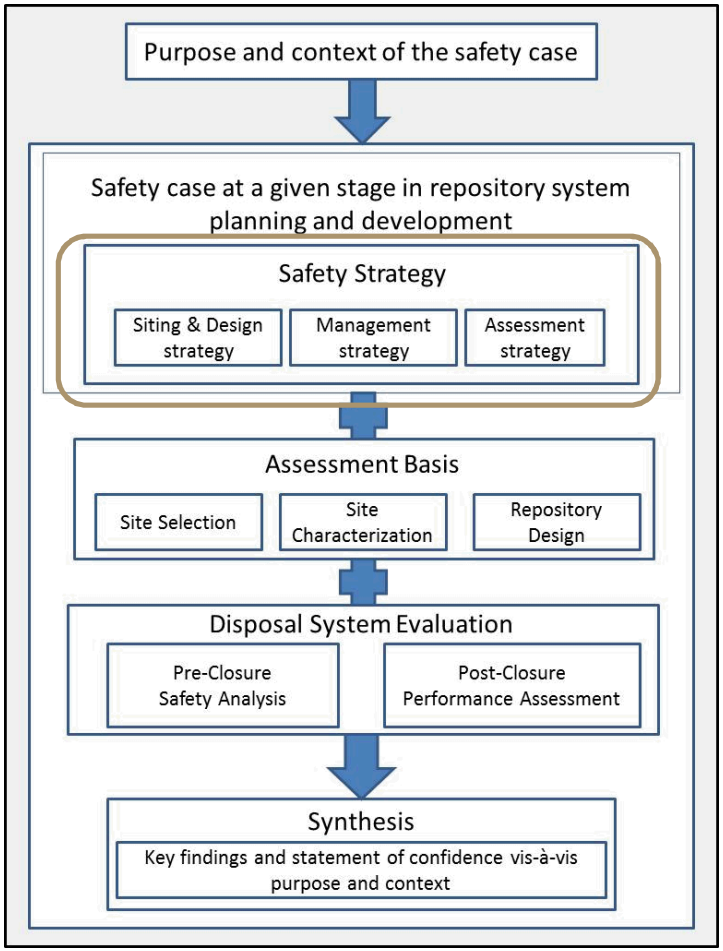
# Purpose and Context

- U.S. is at an early stage – more qualitative and generic
  - Preliminary Salt Safety Cases - Vaughn et al. (2012), MacKinnon et al. (2012)



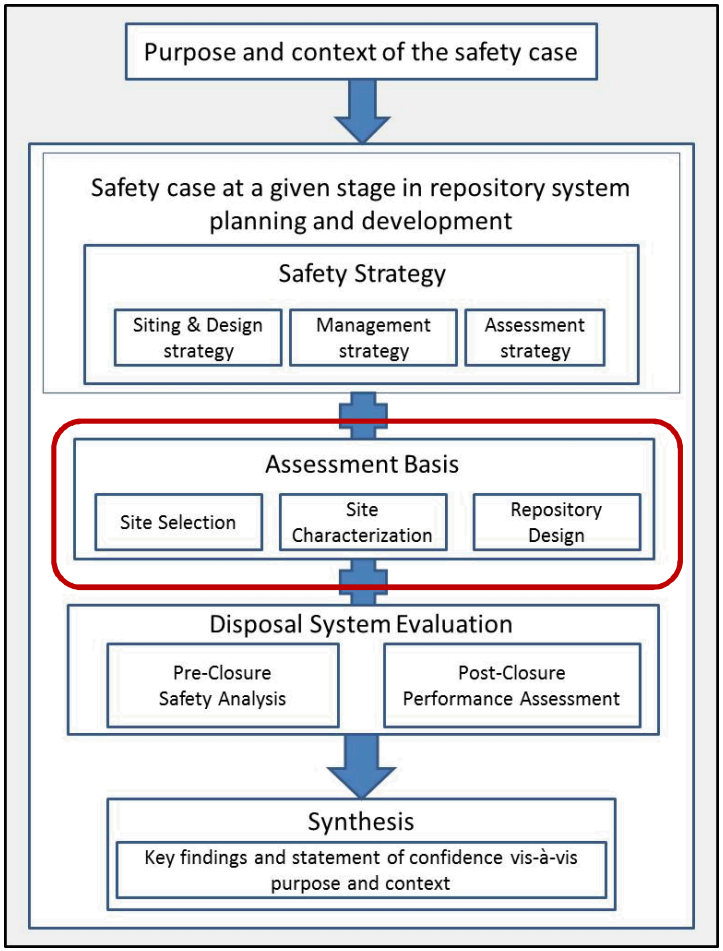
# Safety Strategy

- High-level approach for achieving safe disposal
  - Siting and Design
  - Management
  - Assessment
- Key interfaces:
  - Alignment with legal and regulatory framework
    - Currently uncertain in U.S.
  - Public and stakeholder involvement



# Assessment Basis

- Describe the primary characteristics and features of the disposal system
  - Location and layout of the repository
  - Waste inventory and waste forms (i.e., SNF and HLW)
  - Engineered barriers
  - Natural barriers
  - Biosphere
- Iterative with features, events, and processes (FEP) analysis and scenario development



# Assessment Basis - Site Selection

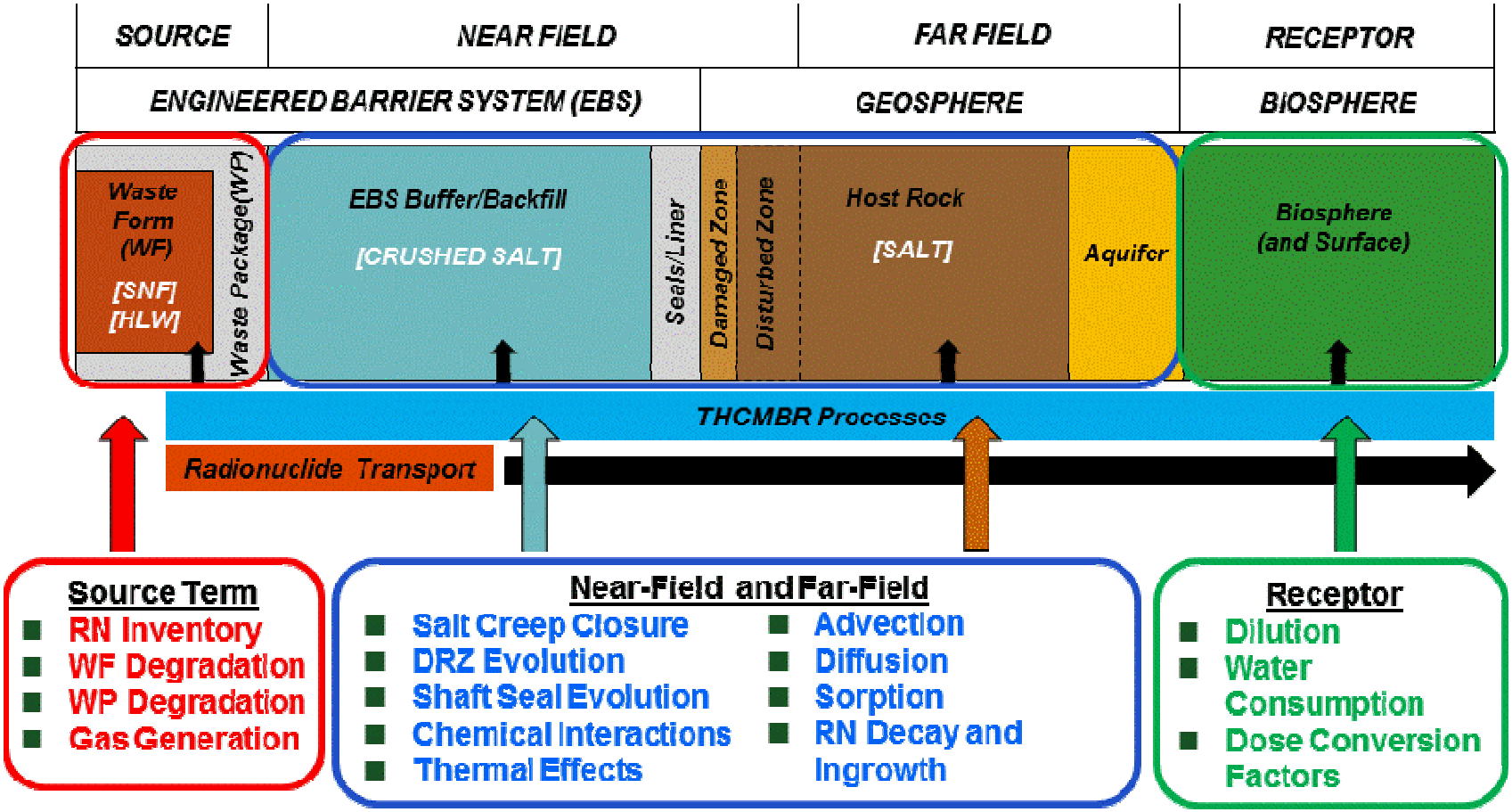
- Identification of potential sites
  - Several bedded and domal salt deposits in U.S.
- Preliminary site characterization information
  - thermal-hydrologic-chemical-mechanical-biological-radiological (THCMBR) properties
- Siting criteria
  - Geology – e.g., topography, stratigraphy, depth, lateral extent
  - Hydrology – e.g., subsurface flow and transport, surface waters, climate
  - Tectonic Stability – e.g., seismic activity, igneous activity, fracturing
  - Socio-economic – e.g., natural resources, population density, land jurisdiction, public acceptance

# Assessment Basis – Site Characterization and Repository Design

- Identify characteristics and features of the disposal system
  - Location and layout of the repository
  - Waste inventory and waste forms (i.e., SNF and HLW)
  - Engineered barriers
  - Natural barriers
  - Biosphere
- Conceptualize initial state and evolution of the disposal system
  - Undisturbed (nominal) and disturbed (e.g., human intrusion) evolution
    - THCMBR processes and properties governing disposal system performance
    - Spatial and temporal variability and uncertainty in the THCMBR properties and processes associated with the initial state of the disposal system and its evolution over 10,000 years or more

# Assessment Basis - Undisturbed

- Schematic of “generic” components (features) and undisturbed (nominal) processes for a salt repository

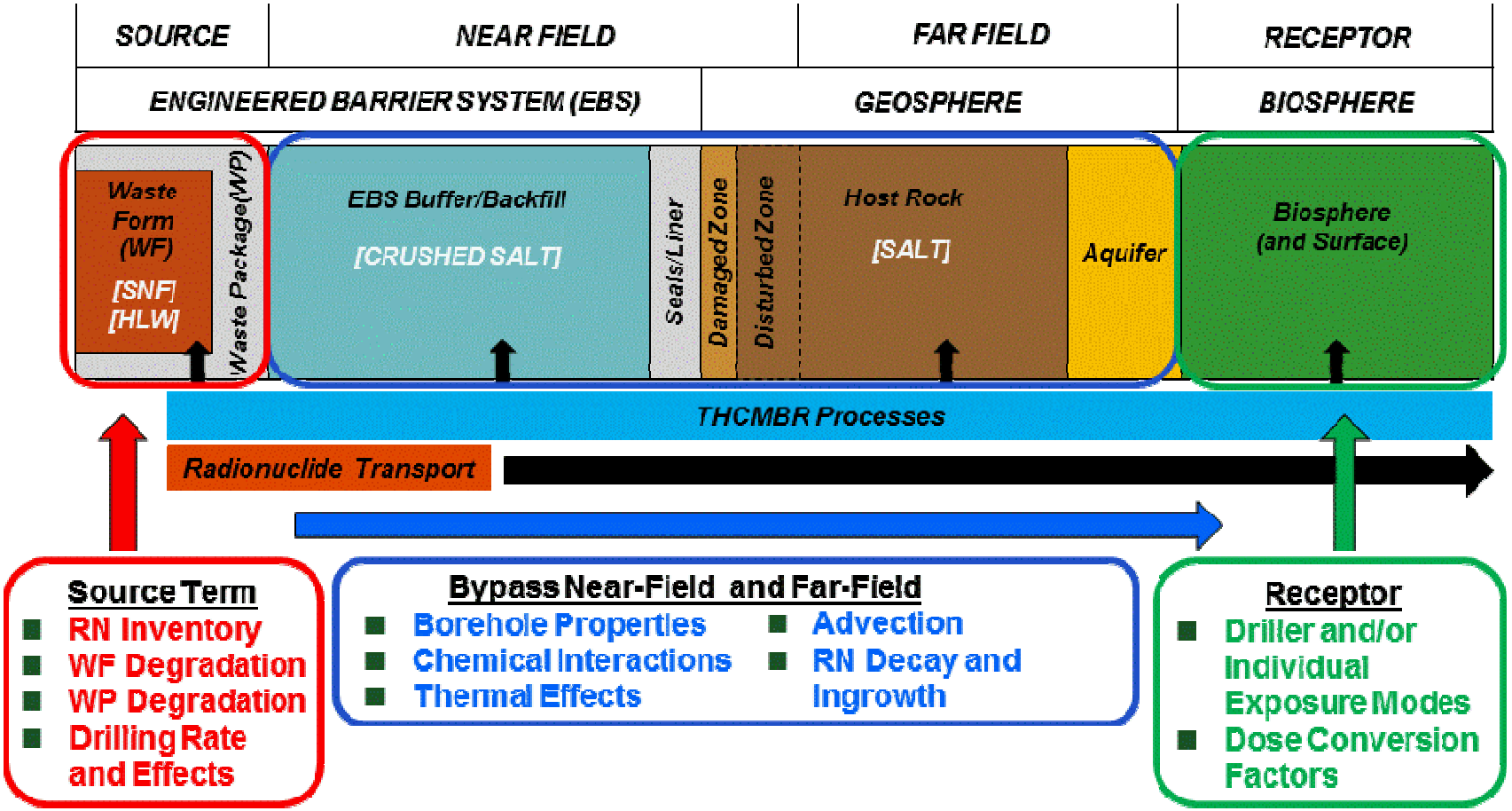


# Assessment Basis - Undisturbed

- Salt is most promising method for HLW disposal (NRC 1957)
- Salt is essentially impermeable, self-sealing, and thermally conductive
  - Significant experience base from past studies (e.g., WIPP)
  - Ongoing Salt R&D Studies
- Thick and areally extensive salt formations exist
- Effects of heat-generating waste (i.e., FEPs) need further study
    - Waste package corrosion from acidic brine
    - Waste package buoyancy
    - Salt creep, disturbed rock zone (DRZ), and backfill evolution
    - Pressure buildup
    - Radionuclide solubility
    - Brine movement
    - Vapor-phase transport
    - Radiolysis of waste

# Assessment Basis - Disturbed

- Schematic of "generic" components (features) and disruptive events (human intrusion borehole) for a salt repository

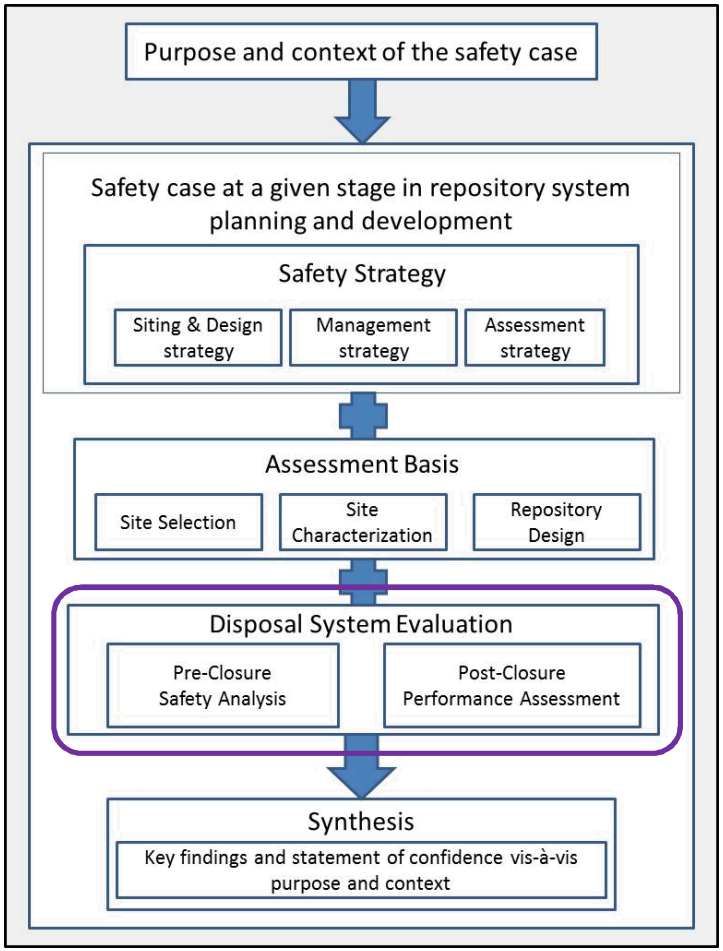


# Assessment Basis - Disturbed

- Human intrusion tends to dominate dose calculations for salt repositories
  - No releases under undisturbed conditions
- Effects of human intrusion are influenced by:
  - Siting considerations
    - away from natural resources, where possible
  - Regulatory assumptions

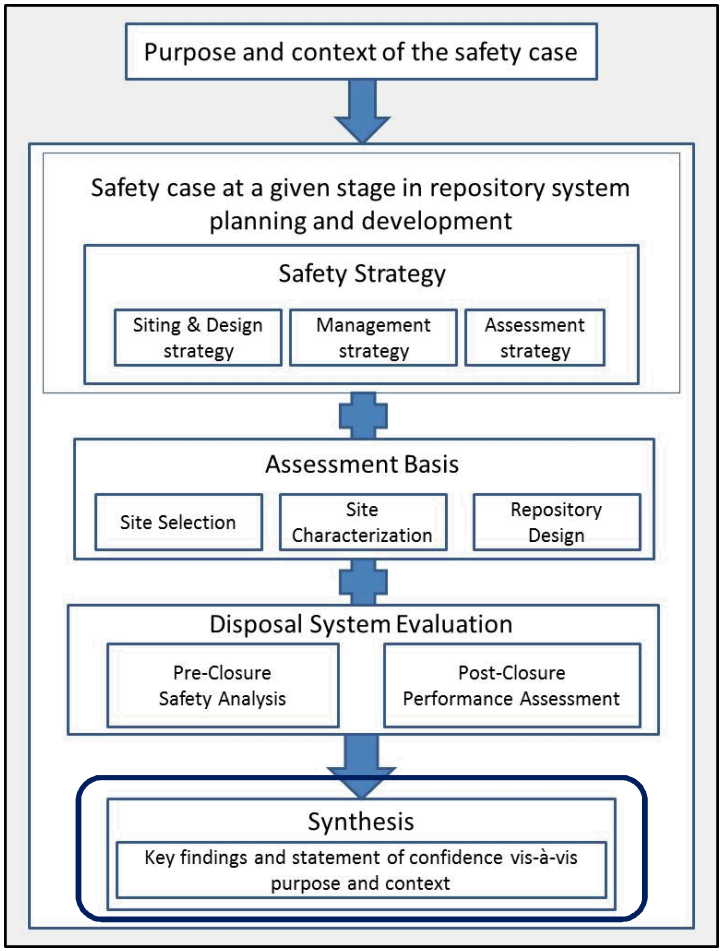
# Disposal System Evaluation

- Pre-Closure Safety Analysis
  - Waste Transportation to Site
  - Surface and Subsurface Facilities
    - Construction
    - Operations
    - Closure
- Post-Closure Safety Assessment
  - Quantitative system and subsystem performance measures
    - Simplified analyses
      - Clayton et al. (2011), Vaughn et al. (2012)
    - Complex analyses
      - Ongoing Salt R&D Studies



# Synthesis of Results

- Statement of confidence based on qualitative and quantitative information
  - Discuss completeness and open issues
  - Provide quality assurance (QA)
- Provides a structure for
  - Identification of important subsystem components and processes
  - Evaluation of evidence and gaps – to guide research and development (R&D)
    - Nutt (2011)
  - Discussion with stakeholders – address socio-political concerns



# Synthesis of Results

- **Multiple Barriers Contribute to Safety Functions of Waste Isolation and Containment**
  - 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

Salt deposits are deep, thick and expansive

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 DRZ healing
    - Waste Package – performance credit not needed
    - Shaft Seals – effectiveness demonstrated at WIPP

Extensive engineered barriers are not needed

- **Research ongoing to examine thermal effects and human intrusion**

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