

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**

**NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING**

**SUBJECT: SETTING TESTING & ANALYSES
PRIORITIES FOR TECHNICAL SITE
SUITABILITY DETERMINATION AND
LICENSING**

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Topics Proposed by Nuclear Waste Technical Review Board

- **Waste isolation strategy for Yucca Mountain**
- **Role of thermal loading in the strategy**
- **Key technical issues associated with suitability and licensability**
- **Significant features/events/processes that could impact suitability of Yucca Mountain**
- **Information/analyses priorities for**
 - **Technical Site Suitability**
 - **License Application for Construction**
 - **License Application to Receive and Possess Waste**
 - **Alternate regulatory criteria**

Outline of Presentation

- **Waste isolation strategy**
 - Site Characterization Plan strategy
 - Strategy refinements since the Site Characterization Plan
- **Key elements of waste isolation strategy**
 - Current understanding
 - Plans for reducing uncertainties
- **Information/analyses priorities and major milestones**

Top-Level Strategy

1988 Site Characterization Plan

(Section 8.0, pgs 4-9)

- **The strategy places primary reliance on low flux conditions, slow water movement, and long radionuclide transport times in the unsaturated zone**
- **Low-probability, potentially disruptive processes and events that could have significant impacts on performance of the repository will be identified and characterized**
- **Preclosure repository designs will incorporate appropriate seismic design criteria**

STATECG.BFR/1-28,29-88

Objectives for the Elements of the Repository System

(SCP Section 8.0, pgs. 4-9)

- **Engineered-barrier system objective:**
 - **Limit release of radionuclides to the natural barrier system**
- **Natural barrier system objective:**
 - **Provide very long radionuclide travel time to the accessible environment**
- **Preclosure disposal system objective:**
 - **Construction of facility does not compromise the ability to meet other objectives, and**
 - **Provides safe operation**

STATECG.BFR/1-28,29-88

Schematic of Top-Level Strategy

(SCP Section 8.0, pgs. 4-6)

| POSTCLOSURE | | PRECLOSURE | |
|----------------------------|---|--|--|
| ENGINEERED BARRIERS | <u>COMPONENT</u> | <u>OBJECTIVES</u> | <u>COMPONENT</u> |
| | UNSATURATED ROCK/AIR GAP | LIMIT THE WATER AVAILABLE TO CONTACT AND CORRODE CONTAINERS AND DISSOLVE WASTE | SURFACE AND UNDERGROUND FACILITY CONSTRUCTION |
| | CONTAINER | SERVE AS PRINCIPAL CONTAINMENT BARRIER DURING EARLY RADIATION AND HEAT PEAK | SURFACE AND UNDERGROUND FACILITY OPERATION |
| | WASTE FORM | LIMIT DISSOLUTION AND LEACHING OF RADIONUCLIDES DUE TO LIMITED WATER CONTACT | PROVIDES BENEFICIAL OR NO IMPACT ON POSTCLOSURE SYSTEM PERFORMANCE |
| NATURAL BARRIERS | <u>COMPONENT</u> | <u>OBJECTIVES</u> | |
| | UNSATURATED ROCK UNITS BELOW THE REPOSITORY | ACT AS BARRIER TO RADIONUCLIDE TRANSPORT BY PROVIDING LONG RADIONUCLIDE TRAVEL TIMES | |
| | SATURATED ROCK BELOW THE UNSATURATED ROCK | EXTEND THE TOTAL TRAVEL-TIME OF RADIONUCLIDES | SAFE OPERATION UNDER NORMAL AND ACCIDENT CONDITIONS |
| | | | STATECG.BFR/1-28,29-88 |

Strategy Refinements 1988 - 1994

- **Increased recognition of fast flow paths**
- **Explicit focus on contribution that thermal loading could make to system performance**
- **Multipurpose canister as potential waste form**
- **In-drift emplacement mode for multipurpose canister changes backfill/airgap options**
- **Greater role for saturated zone under dose-based standard**
- **Consideration of extended retrieval period**

Thermal Strategy Perspective

- **Maintain flexibility in design to allow modifications that could improve system performance**
 - Identify key environmental and design parameters
 - Define envelope for key parameters
- **Technical Site Suitability Strategy**
 - Establish reference thermal loading based on current design concepts
 - Evaluate sensitivity to range of thermal loadings under consideration
- **Licensing Strategy**
 - Determine range of conditions over which designs work
 - Use performance confirmation to show we are within those conditions
 - Modify strategy as needed to improve performance

Top-Level Waste Isolation Strategy Adapted to Current Program

- **Establish bounds on water contacting waste packages as ultimate limit on non-gaseous releases**
- **Develop long-life waste package (>1000 yr) as key to early repository safety**
- **Establish bounds on waste form dissolution rates and transport from repository for +1000 yr safety**
- **Establish expected dilution in aquifer to predict doses**

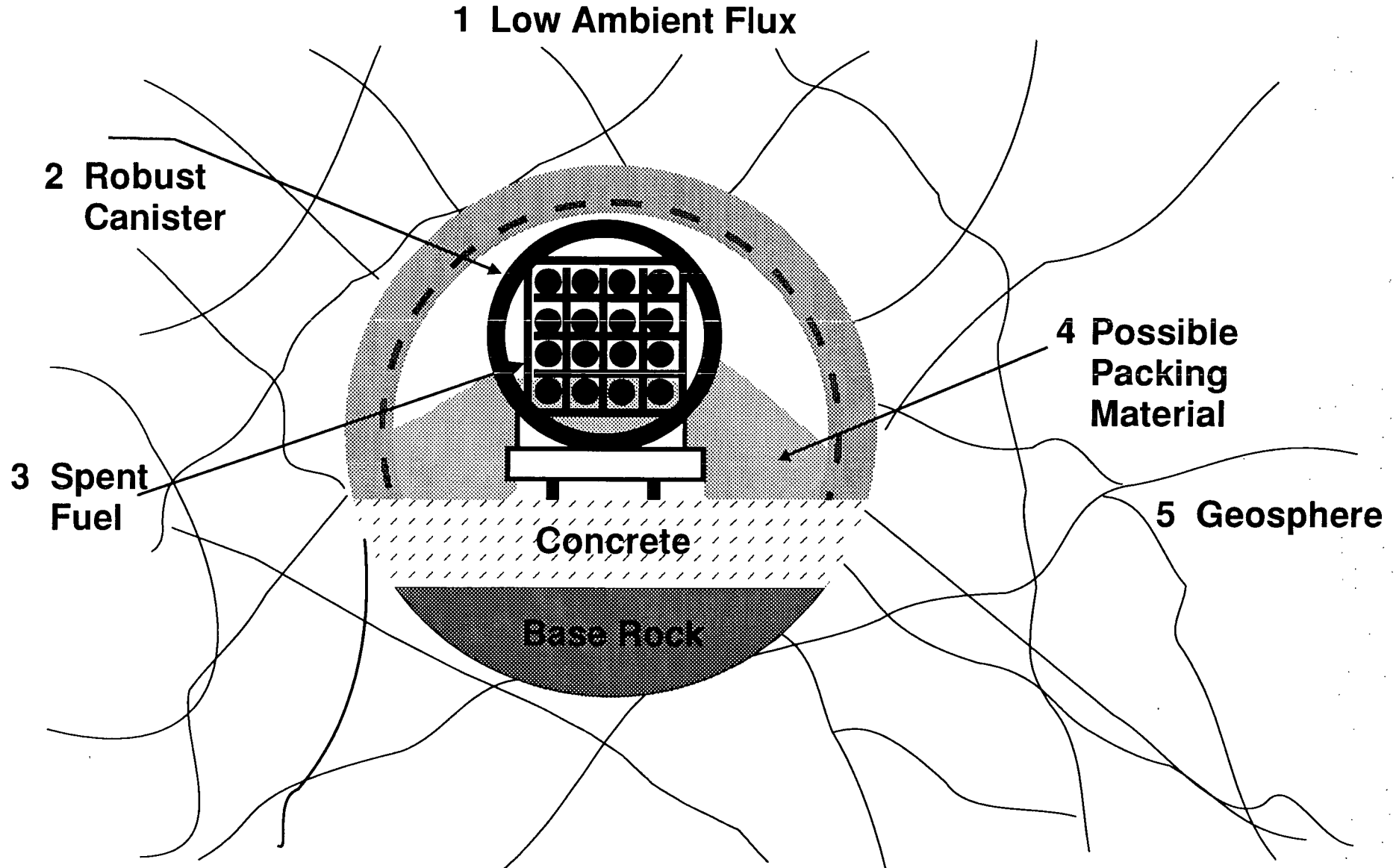
Components/Mechanisms of Current Strategy

- **Current understanding**
- **Key uncertainties**
- **Plans for reducing uncertainties**

Components/Mechanisms of Current Strategy

- ★ 1 • Dry environment around engineered barriers provided by unsaturated zone
- ② 2 • Robust engineered materials for those packages contacted by water
- ◇ 3 • Slow dissolution of waste matrix and low solubility of radionuclides
- 4 • Slow release of radionuclides through the engineered barrier
- △ 5 • Slow transport of radionuclides through the geosphere

Top-Level Strategy for Waste Isolation





Dry Environment

Current Understanding

- **Spatial distribution of infiltration rates based on matrix properties and shallow neutron boreholes**
- **Saturation profiles in unsaturated zone**
- **Old age of matrix groundwater**
- **Unsaturated zone hydrologic modeling**
- **Laboratory matrix suction and imbibition experiments**



Dry Environment

Key Uncertainties

- **Extent of seeps and perched water expected in ESF**
- **Interaction of geosphere with engineered backfill/airgap**
- **Young age of some deep unsaturated zone groundwater**
- **Effect of thermal load on redistributing flux**
- **Focusing mechanisms for percolation flux (e.g., capillary barrier, perched zone)**



Dry Environment

Plans for Reducing Uncertainties

- **Continued infiltration monitoring**
- **Observations in ESF**
 - **Hydrochemistry/isotopic analyses**
 - **Matrix saturation**
 - **Behavior of seeps**
 - **Compare with pre-ESF predictions**
- **Long-duration thermohydrologic testing in ESF**
- **Site and drift-scale hydrogeologic modeling**
- **Hydrogeologic modeling and lab testing of fracture-matrix coupling**

② Robust Waste Package Materials

Current Understanding

- Degradation mode studies performed on candidate materials (literature review)
- Designation of most appropriate materials

| | <u>Primary</u> | <u>Secondary</u> |
|-----------------|----------------|------------------|
| – Inner barrier | Alloy 825 | Alloy C-22 |
| – Outer barrier | A 516 | 2.25Cr-1Mo |
- Crack growth studies of corrosion resistant materials
- Thermogravimetric testing of corrosion allowance materials
- Empirical observations of cladding life

② **Robust Waste Package Materials**

Key Uncertainties

- **Range of possible near-field environments**
- **Corrosion rates under variable humidity and temperature**
- **Pitting corrosion of corrosion-resistant materials**
 - **Alloy 825 inner waste package**
 - **Zircaloy cladding**
- **Impact of microbiologically-induced corrosion**

② **Robust Waste Package Materials**

Plans for Reducing Uncertainties

- **Consider range of near-field environments in 1988 Technical Site Suitability Evaluation and 2001-License Application**
- **Modeling and testing of pit corrosion processes**
- **Analogs showing material durability (iron, copper)**
- **Test materials for resistance to microbiologically-induced corrosion**



Low Mobilization of Radionuclides

Current Understanding

- **Spent fuel oxidation and UO₂ and spent fuel dissolution experiments for a range of possible near-field environments**
- **Radionuclide solubility experiments for a range of possible near-field environments**
- **Some data on glass dissolution and alteration**



Low Mobilization of Radionuclides

Key Uncertainties

- **Oxidation state of spent fuel**
- **Surface area of cladding breached**
- **Waste form dissolution rates in the presence of limited water (e.g. selection of rates for drip test)**
- **Existence and stability of waste form colloids**
- **Bounding neptunium and technetium solubilities for expected near-field environments**



Low Mobilization of Radionuclides

Plans for Reducing Uncertainties

- **Establish conservative, but realistic, assumptions for cladding performance**
- **Waste form dissolution testing (low saturation drip test)**
- **Establish conservative, but realistic, values for waste form dissolution rates**
- **Colloid investigation strategy**
- **Neptunium and technetium solubility experiments**

4 **Slow Release through EBS**

Current Understanding

- **Theoretical basis for predicting drift inflows in unsaturated media**
- **Theoretical considerations of advective flow through capillary barriers**
- **Laboratory measurements of diffusion rates in partially saturated media**

4 **Slow Release through EBS**

Key Uncertainties

- **Percent of waste package surface degraded to expose waste**
- **Potential for continuous liquid film to support diffusive release**
- **Emplacement strategy and layout**

4 **Slow Release through EBS**

Plans for Reducing Uncertainties

- **Use range of designs for 1998 Technical Site Suitability Evaluation and 2001-License Application**
- **Observe drift seeps in the ESF**
- **Laboratory measurements of diffusion rates in variably saturated media**
- **Determine if packing material/capillary barrier could improve performance**
- **Sensitivity analyses of a range of drift-scale thermo-hydrologic conceptual models**



Slow Transport through Geosphere

Basis for Current Understanding

- **Spatial distribution of infiltration rates**
- **Saturation profiles in unsaturated zone from deep boreholes**
- **Groundwater and paleo-groundwater dating**
- **Unsaturated zone hydrologic modeling**
- **Laboratory measurements of matrix imbibition and matrix diffusion**
- **Laboratory measurements of retardation (“minimum” k_d)**
- **Hydraulic gradients in saturated zone**



Slow Transport Through Geosphere

Key Uncertainties

- **Effect of thermal loads on percolation flux**
- **Young dates for some deep unsaturated zone groundwater**
- **Conceptual model of fracture-matrix coupling in partially saturated media**
- **Effect of long-term transient infiltration rates due to climate changes**
- **Dispersion caused by small-scale heterogeneity**
- **Nature and role of steep gradient**

5 Slow Transport through Geosphere

Plans for Reducing Uncertainty

- **Evaluate range of thermal loadings for 1998 Technical Site Suitability Evaluation and 2001-License Application**
 - **Maintain flexibility to deal with range of site conditions**
- **Obtain dates for ESF seeps and additional borehole samples**
- **C-well tracer experiments**
- **Sensitivity analyses of range of unsaturated zone and saturated zone flow and transport conceptual models**
- **Calico Hills transport experiments as determined by systems study**
- **Boreholes to investigate steep gradient**

Summary: Key Uncertainties Related to Waste Isolation

- **Percolation flux distribution through repository horizon**
- **Liquid saturation in and around emplacement drifts**
- **Material degradation and dissolution rate of spent fuel in low liquid saturation environment**
- **Diffusion rate through EBS and very near-field in low liquid saturation environment**
- **Fracture-matrix interactions in flow and transport**
- **Dilution expected in saturated zone**

Other Important Considerations

- **Preclosure factors**
 - **Extent of useable host rock/constructability**
 - **Seismic hazards and design solutions**
 - **Rock stability during extended retrieval period**
- **Alternate regulatory criteria**
 - **Time frame**
 - **Dilution in saturated zone**

Information/Analyses Priorities and Key Milestones

Overview of Testing Priorities

Surface-Based Program

- Use FY95 to analyze and interpret recently acquired data
- Use existing holes for pneumatic testing with limited number of strategically placed new boreholes by 1997
- Expand geophysics program to improve predictive capabilities
- Post 1997 program focused on support to Advanced Conceptual Design (ACD) and Title 1

Exploratory Studies Facility

- Focus pre-1998 tests on geology-hydrology
- 1997 - 2000 program develops engineering parameters for construction authorization
- Post 2000 focused on completion of long-duration coupled testing and performance monitoring

Technical Site Suitability: Key Sources of Site Information

Surface Based/Lab

- C-Well tracer tests
- Volcanic boreholes (3) to test anomalies in Crater Flat
- Geologic drilling program
 - Water table boreholes (~5 before FY98)
 - Systematic boreholes (2)
 - Unsaturated boreholes (4)
- Seismic reflection
 - Deep: Amargosa Valley to Crater Flat
 - Shallow/intermediate: across block (3 EW, 2 NS) and Yucca Wash
- Trenches for tectonics and seismic hazard completed in FY95
- Borehole rock properties measurements

ESF

- Radial boreholes and hydrochemistry in alcoves 1-7
- Observe seeps/perched water
- Fault characteristics/properties
 - Bow Ridge
 - Drillhole Wash
 - Sundance
 - Ghost Dance
- Geologic Mapping
- Consolidated sampling
 - geochemistry/mineralogy/petrology
 - rock-water interaction
 - thermal/mechanical properties
- Construction monitoring

Information/Analyses Priorities

License Application (2000/2001)

- **Confirmatory hydrogeologic tests in ESF
Corrosion rate tests over range of likely materials**
- **EBS diffusion test**
- **Interim results of long-duration coupled testing**
- **Tests and analyses to bound thermohydrologic response**
- **Tests and analyses to bound fracture-matrix coupling**

Information/Analyses Priorities

LA to Receive and Possess (~2008)

- **Materials tests to confirm waste package design and cost**
- **Thermohydrologic tests to confirm repository design and cost**
- **Confirmatory hydrogeologic tests in repository drifts**
- **Long-term confirmatory tests**
 - waste package material performance
 - cladding performance
 - waste matrix dissolution rates
- **Increase confidence**
 - fracture-matrix coupling

Backup

ESF Excavation Schedule Pre-1997 Milestones

**TBM through Bow Ridge Fault & Rainier
Mesa Formation**

DEC 1994

**Alcove 2-Bow Ridge Fault alcove
complete**

2nd Quarter FY95

**Alcove 3-Paintbrush nonwelded contact
Alcove 4-Paintbrush welded contact**

2nd Quarter FY96

North ramp complete

3rd Quarter FY96

TBM past 1st Ghost Dance Alcove (6)

4th Quarter FY96

1st Ghost Dance Alcove complete

4th Quarter FY96

TBM past 2nd Ghost Dance Alcove (7)

1st Quarter FY97

2nd Ghost Dance Alcove complete

3rd Quarter FY97

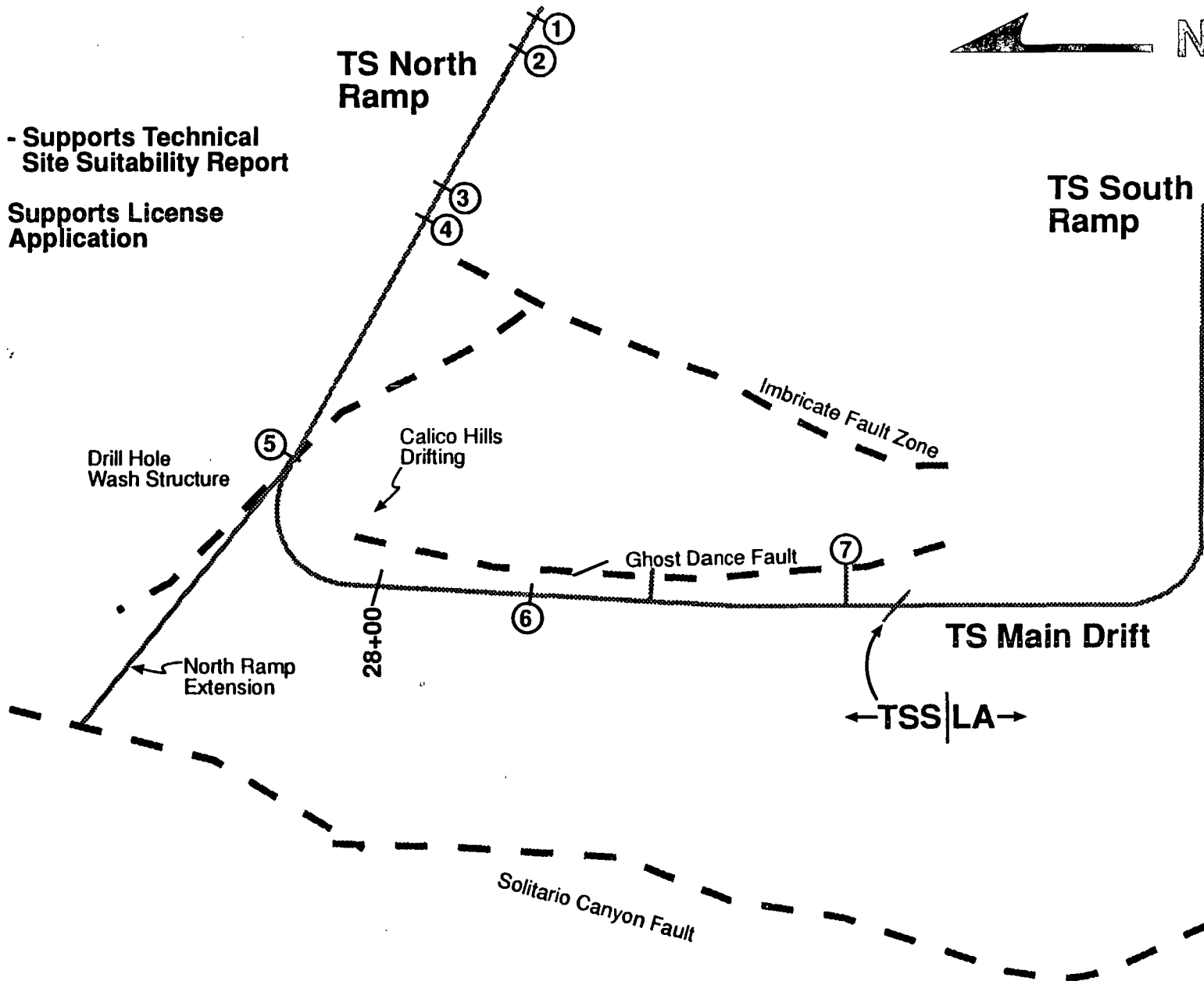
Daylight at South Portal

Schematic ESF Layout



TSS - Supports Technical Site Suitability Report

LA - Supports License Application



Schematic of Surface-Based Drilling Program

