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Deep Borehole Disposal Research and Development Program

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International Technical Workshop
on Deep Borehole Disposal of Radioactive Waste
Washington, D.C.
October 20-21, 2015

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Outline

Deep Borehole (DBH) Disposal R&D Program

- DBH Disposal Concept
- DBH Reference Design
- DBH Field Test
- Conclusions

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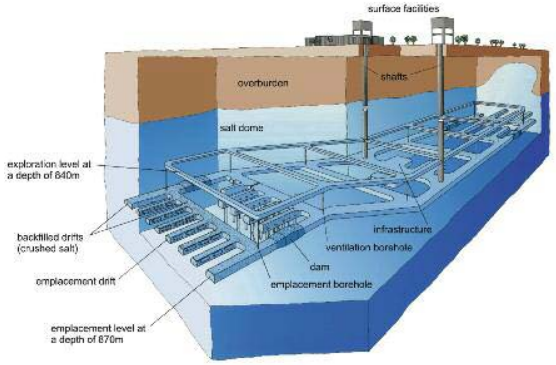
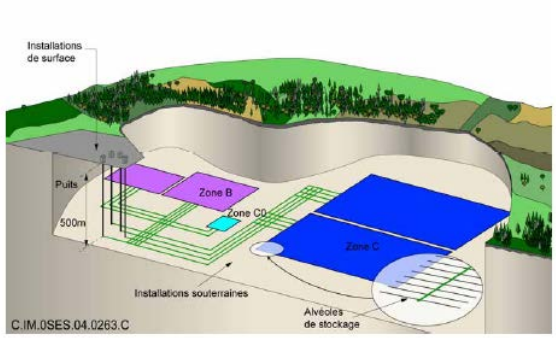
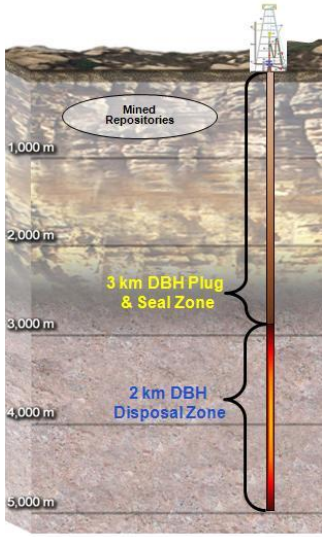
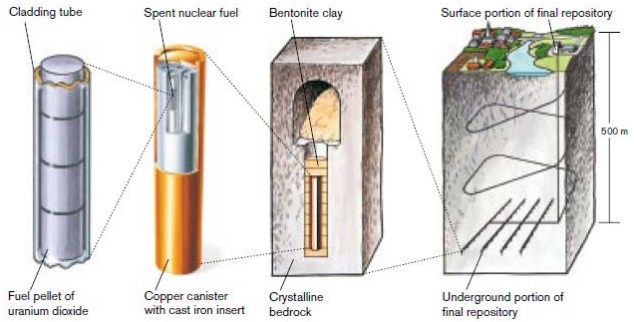
UFD Focus for Used Nuclear Fuel and High-Level Radioactive Waste Disposal

- Provide a sound technical basis for multiple viable disposal options in the US
- Increase confidence in the robustness of generic disposal concepts
- Develop the science and engineering tools needed to support disposal concept implementation









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Deep Borehole Disposal Concept

- Deep borehole disposal of high-level radioactive waste has been considered in the U.S. and elsewhere since the 1950s and has been periodically studied since the 1970s
- Disposal concept consists of drilling a borehole or array of boreholes into crystalline basement rock to about 5,000 m depth
- Waste canisters would be emplaced in the lower 2,000 meters of the borehole
- Upper borehole would be sealed with compacted bentonite clay, cement plugs, and cemented backfill

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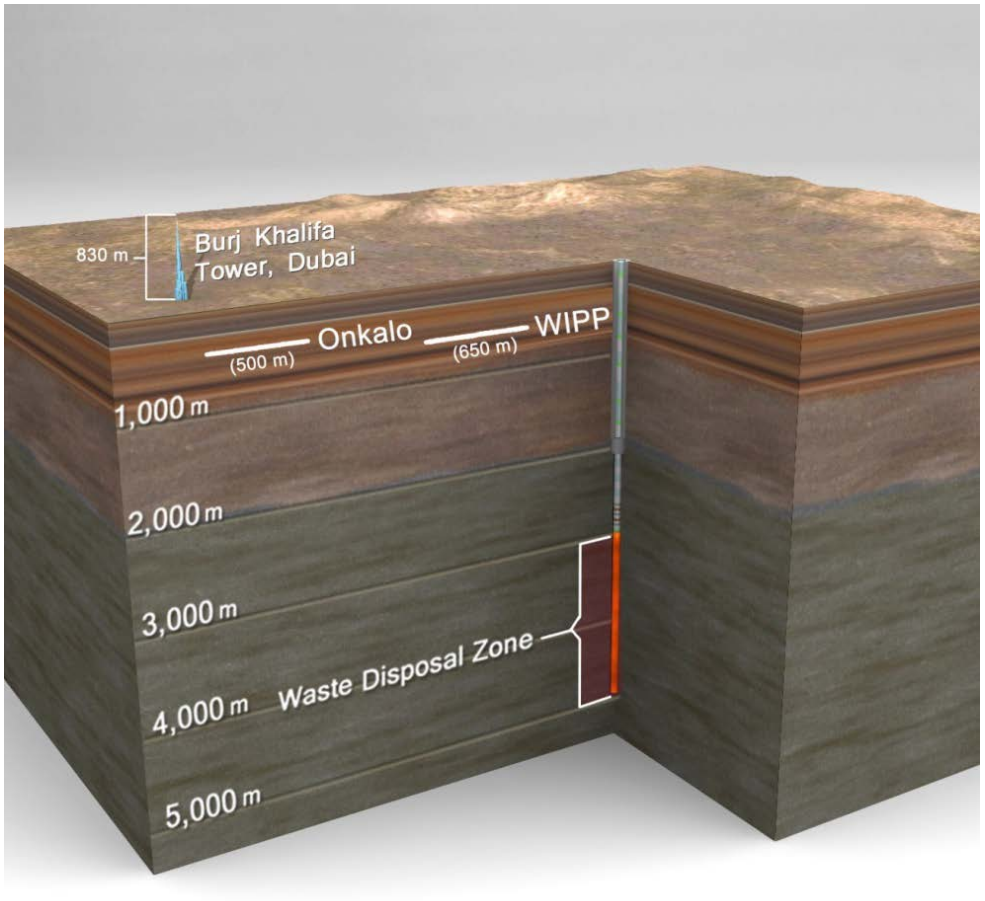
Deep Borehole Disposal Concept

- 5,000 m deep borehole(s) in crystalline basement rock, well below fresh groundwater resources
- Waste canisters in lower 2,000 m



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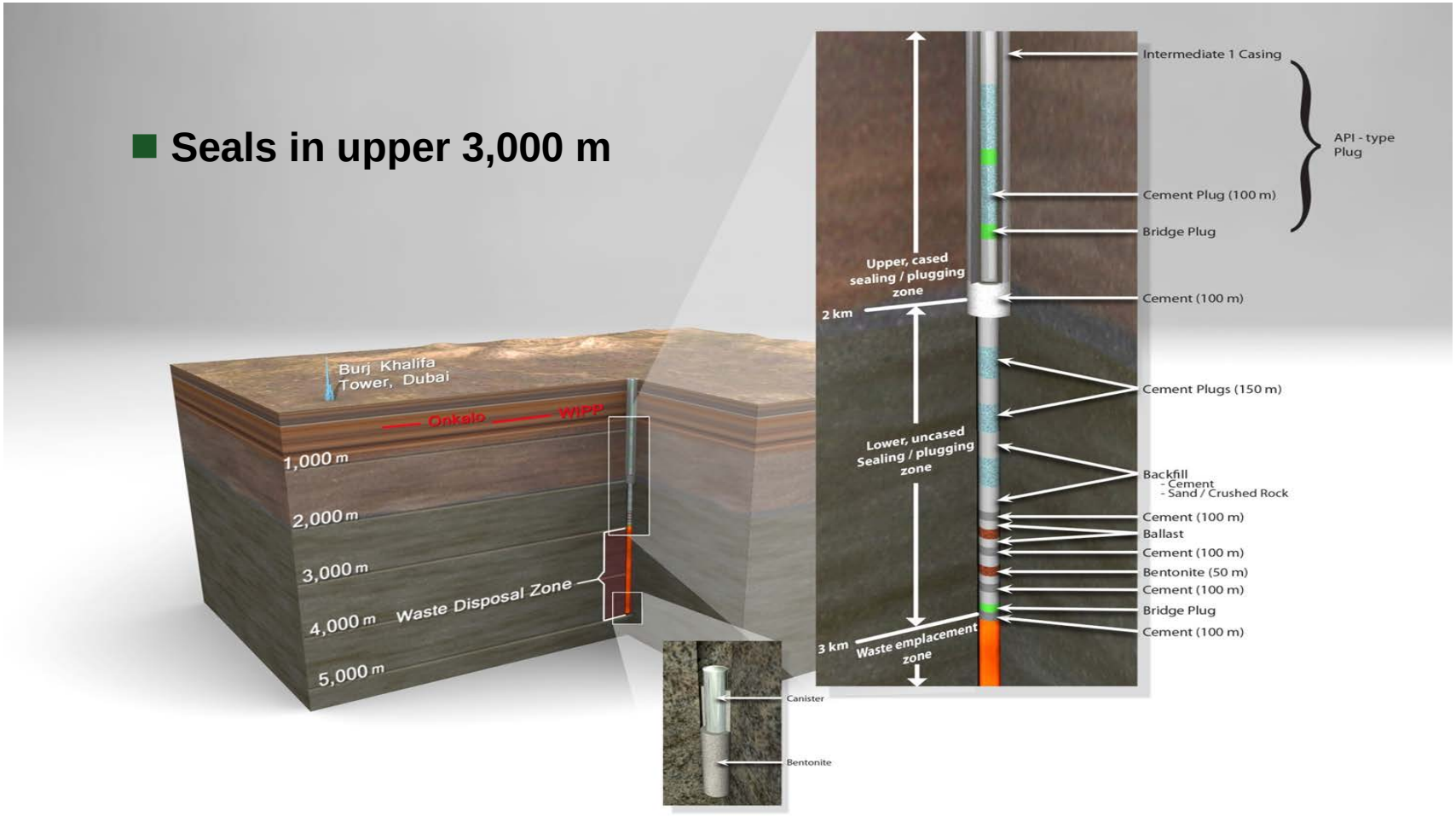
Deep Borehole Disposal Concept

- Seals in upper 3,000 m



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Deep Borehole Disposal Concept

Several factors suggest that the disposal concept may provide a technically feasible and cost-effective alternative for safe disposal of some DOE-managed waste forms:

- **Crystalline basement rocks are common in many stable continental regions**
- **Existing drilling technology should permit dependable construction at acceptable cost**
- **Low permeability and long residence time of high-salinity groundwater in deep continental crystalline basement at many locations suggests very limited interaction with shallow fresh groundwater resources**
- **Geochemically reducing conditions at depth limit the solubility and enhance the sorption of many radionuclides in the waste**
- **Density stratification of saline groundwater underlying fresh groundwater would oppose thermally induced groundwater convection**

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Deep Borehole Disposal Concept
Why Deep Borehole Disposal?

- **Potential for robust isolation:**
- **Gives DOE the flexibility to consider options for disposal of smaller waste forms in deep boreholes**
  - Potentially earlier disposal of some wastes than might be possible in a mined repository
  - Possible reduced costs associated with projected treatments of some wastes

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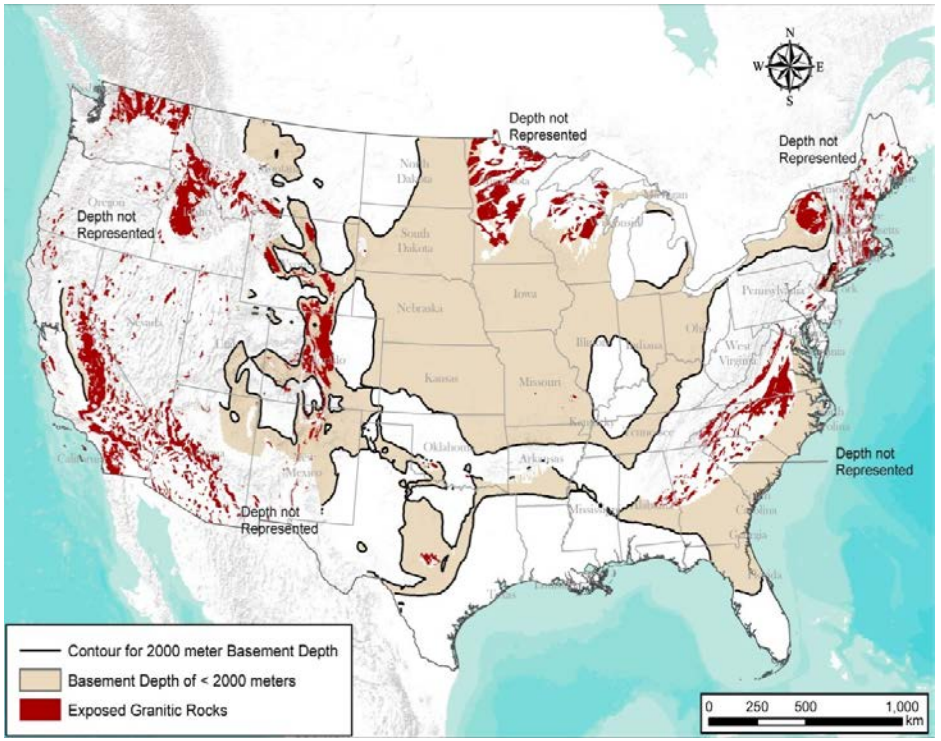
Deep Borehole Disposal Concept
Aspects of Borehole Siting

Site selection guidelines indicate that large areas with favorable geological characteristics exist in the U.S.

<u>Undesirable</u> Features

- Young meteoric groundwater
- Low-salinity, oxidizing groundwater
- Economic natural resources
- Upward hydraulic gradients
- Overpressuring
- High geothermal heat flow
- High permeability hydraulic connections to the subsurface

Depth to Crystalline Basement



from Perry et al. (2014) Regional Geology: A GIS Database for Alternative Host Rocks and Potential Siting Guidelines, FCRD-UFD-2014-000068

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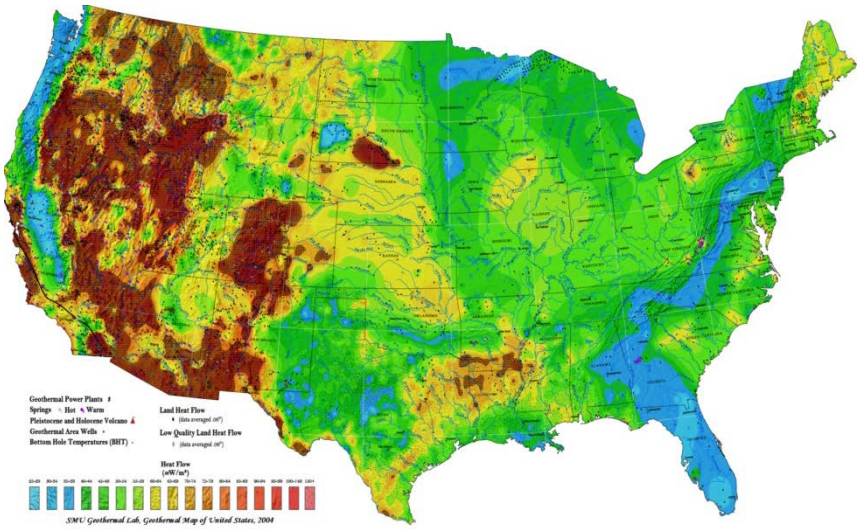
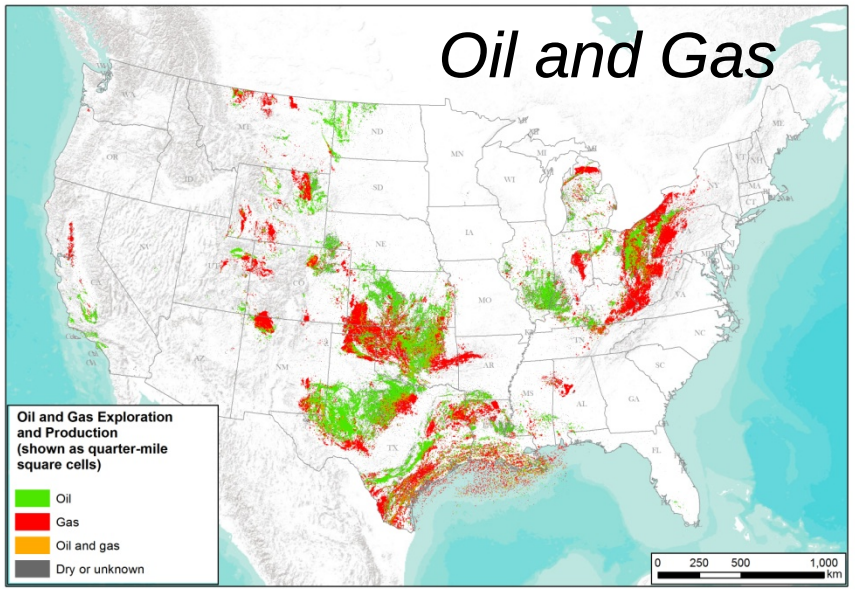
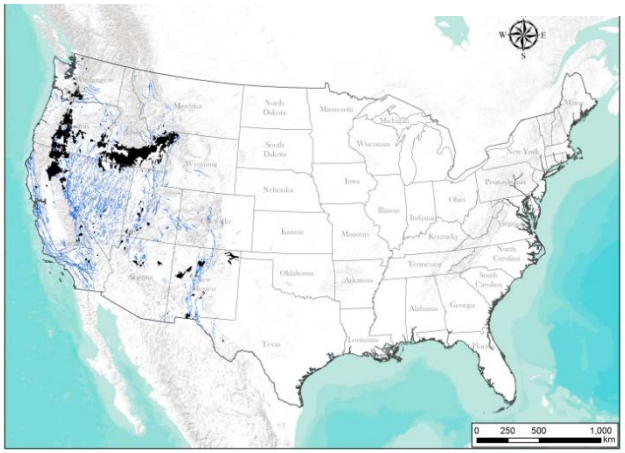
Deep Borehole Disposal Concept
Aspects of Borehole Siting

Heat Flow



Oil and Gas





Volcanoes and recent faults

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Deep Borehole Disposal Concept

Potential Wastes for Deep Borehole Disposal

- **Waste could consist of DOE-managed waste forms, including some DOE spent nuclear fuel, high-level radioactive waste, or other specialized waste types**
- **Several DOE-managed small waste forms are potential candidates for deep borehole disposal (SNL 2014)**
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site
  - Untreated calcine HLW currently stored at INL in sets of stainless steel bins within concrete vaults
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels could be packaged in small canisters as they are produced
  - Some DOE-managed SNF currently stored in pools at INL and SRS

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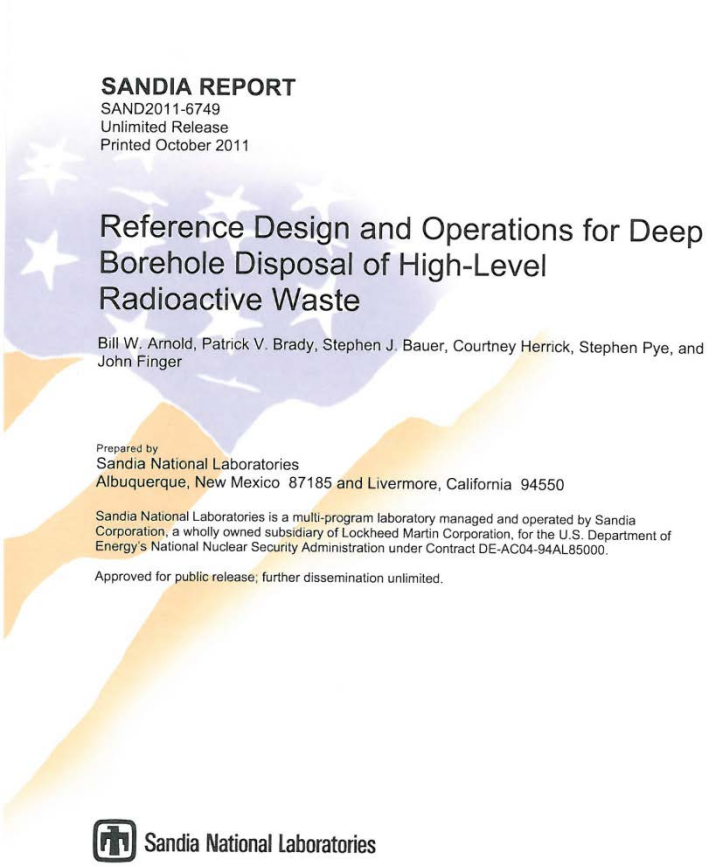
Deep Borehole Disposal
Reference Design

- **<u>Overarching objective</u>: A simple and achievable, internally consistent system for waste disposal that meets regulatory requirements for operational and public safety**
- **Update and refine the conceptual design presented in Brady et al. (2009)**
- **Consider preliminary design alternatives**
- **Provide a reference design for performance assessment and risk analysis**
- **Provide a reference design for more accurate cost estimates**
- **Numerous viable design alternatives exist – this reference design is one choice that provides a basis for the objectives stated above**


SANDIA REPORT
SAND2011-6749
Unlimited Release
Printed October 2011

Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste

Bill W. Arnold, Patrick V. Brady, Stephen J. Bauer, Courtney Herrick, Stephen Pye, and John Finger

Prepared by
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Sandia National Laboratories

Arnold et al. (2011)

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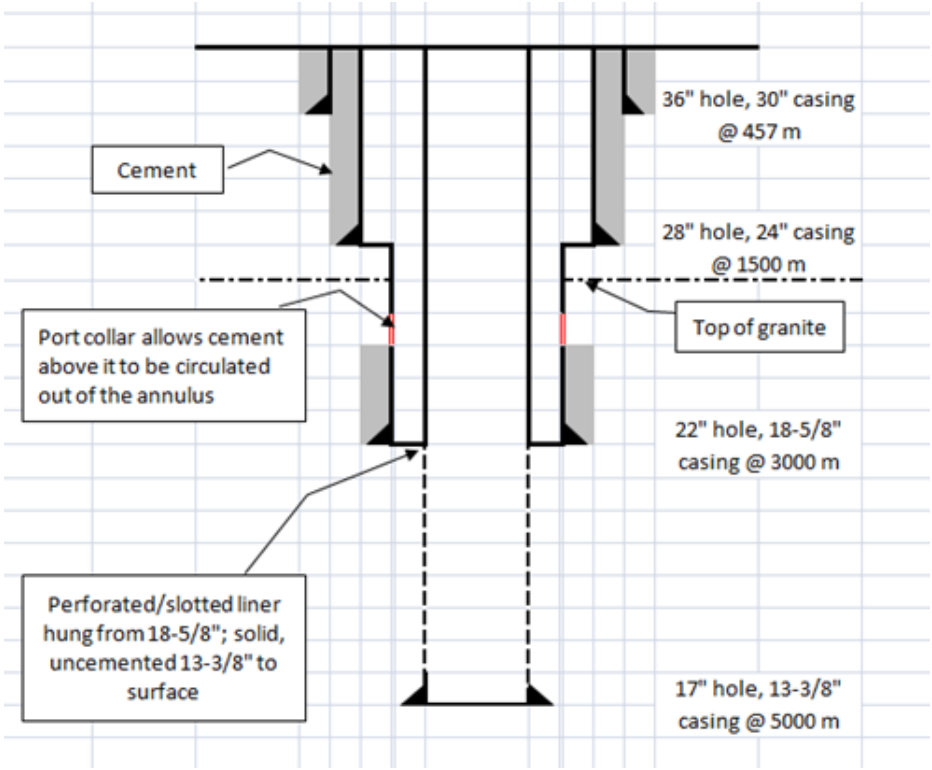
Reference Design and Operations

Borehole Reference Design

- Borehole casing or liner would assure unrestricted emplacement of waste canisters
- A liner casing would be in place for the emplacement of waste canisters and facilitate potential retrieval (until the liner is pulled and seals set)
- The perforated liner would be left in place in the disposal zone, but will be removed in the seal zone, along with most of the intermediate casing



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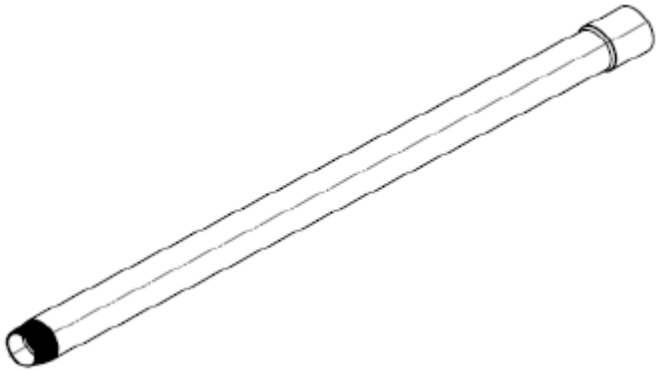
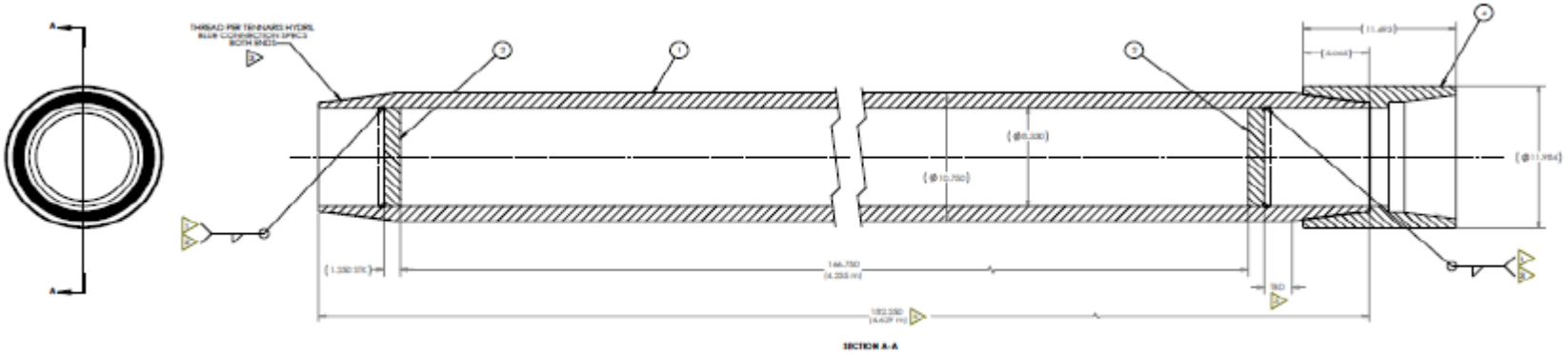
Reference Design and Operations
Waste Canister Reference Design

- Waste canisters consist of carbon steel tubing with welded plugs and threaded connections
- Canisters are designed to withstand projected hydrostatic pressure and mechanical load of overlying canisters
- Waste canisters would retain their integrity until after the borehole is loaded and sealed





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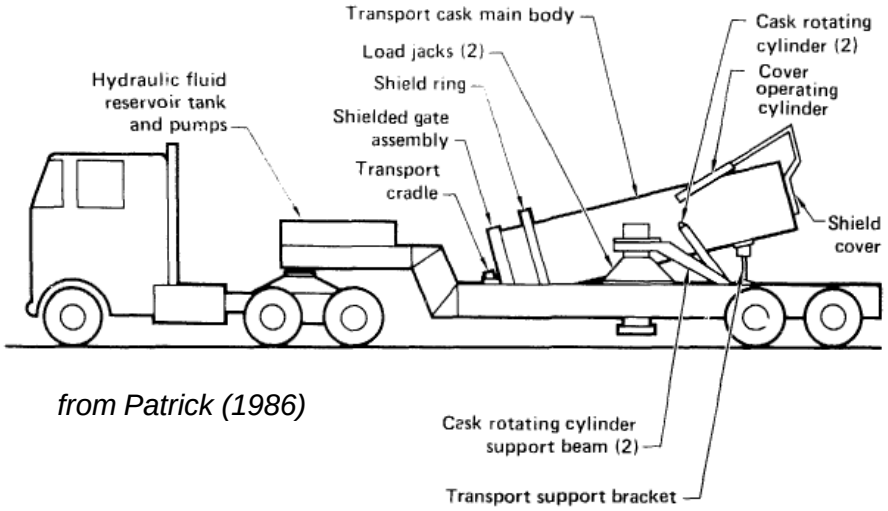
Reference Design and Operations
Waste Canister Emplacement

- **Engineering feasibility has been demonstrated for surface handling and borehole emplacement of waste canisters with the Spent Fuel Test – Climax (SFT-C) at the Nevada Test Site (NTS) (Patrick, 1986)**
- **Spent fuel assemblies were transported to NTS, packaged in canisters, lowered down a 420-m borehole, emplaced in the underground granite thermal test facility for 3 years, and removed to the surface via the borehole**
- **Waste handling and emplacement operations were conducted within operational safety requirements and without incident**



from Patrick (1986)

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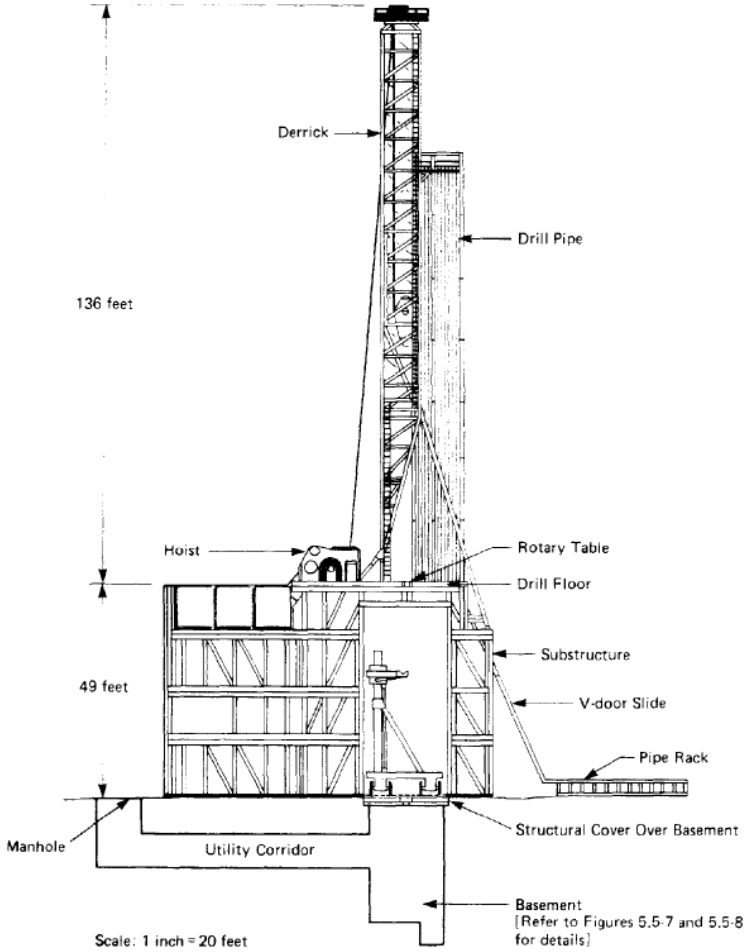
Reference Design and Operations
Waste Canister Emplacement

- Loaded waste canisters would be transported to the site by tractor trailer using shipping casks
- Surface handling would rotate the shipping cask to a vertical position, move the cask by a short rail system over the borehole, attach the canister to the canister string and lower it into the borehole by remote operation
- Strings of 40 canisters (about 200 m) would be attached to the pipe string and lowered to the disposal zone
- Each canister string would be separated from overlying canister strings by a bridge plug and cement plug



from Woodward-Clyde Consultants (1983)

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Deep Borehole Field Test

- **Additional research and development is necessary in several important areas for further consideration of deep borehole disposal of radioactive waste, including:**
  - Evaluation of drilling technology and borehole construction to 5 km depth with sufficient diameter for cost effective waste disposal
  - Verification of deep geological, geochemical, and hydrological conditions at a representative location
  - Evaluation of canister, waste, and seals materials at representative temperature, pressure, salinity, and geochemical conditions
  - Development and testing of engineering methods for waste canister loading, shielded surface operations, waste canister emplacement, and borehole seals deployment

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Deep Borehole Field Test

- **The R&D objectives for deep borehole disposal are being met with a borehole field test that is conducted to a depth of 5 km in a representative location (without emplacement of radioactive wastes)**
  - Obtain a suitable test site
  - Design, drill and construct the Characterization Borehole to requirements
  - Collect data in the Characterization Borehole to characterize crystalline basement conditions and confirm expected hydrogeochemical conditions
  - Design, drill and construct the Field Test borehole to requirements
  - Design and develop surface handling and emplacement equipment systems and operational methods for safe canister/waste package handling and emplacement

Deep Borehole Field Test

Conducting a Deep Borehole Field Test:

- Allows further evaluation of the feasibility of the deep borehole disposal concept
- Is consistent with the UFD Mission
- Implements a recommended near-term action of the *Blue Ribbon Commission on America's Nuclear Future* (BRC 2012)
- Is consistent with the Administration's *Strategy for the Management and Disposal of used Nuclear Fuel and High-Level Radioactive Waste* (DOE 2013)
- Economic and scientific benefits of a deep borehole field test are of interest and could be valuable to local, state, and regional stakeholders

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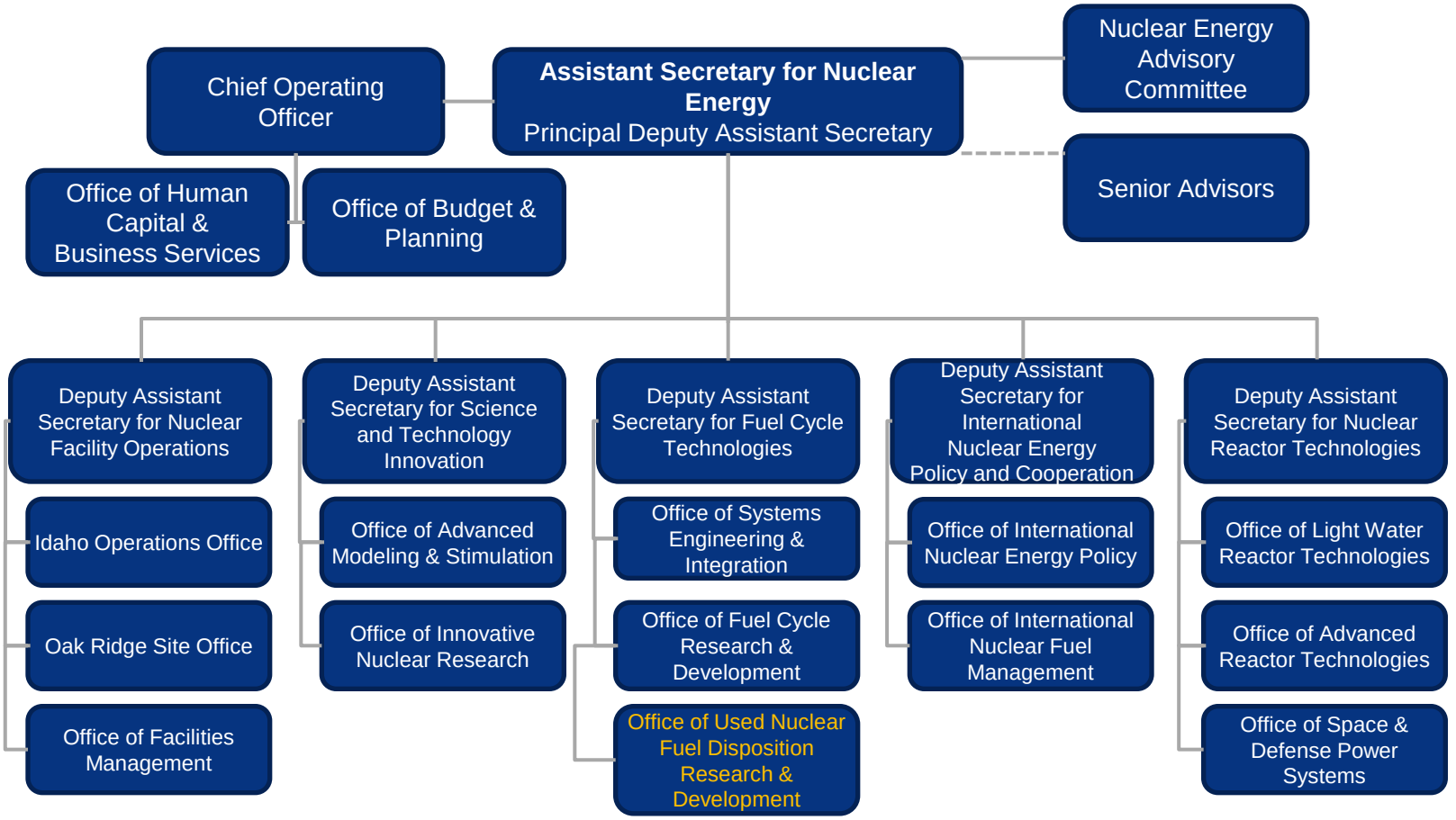
Organizational Structure of the Office of Nuclear Energy



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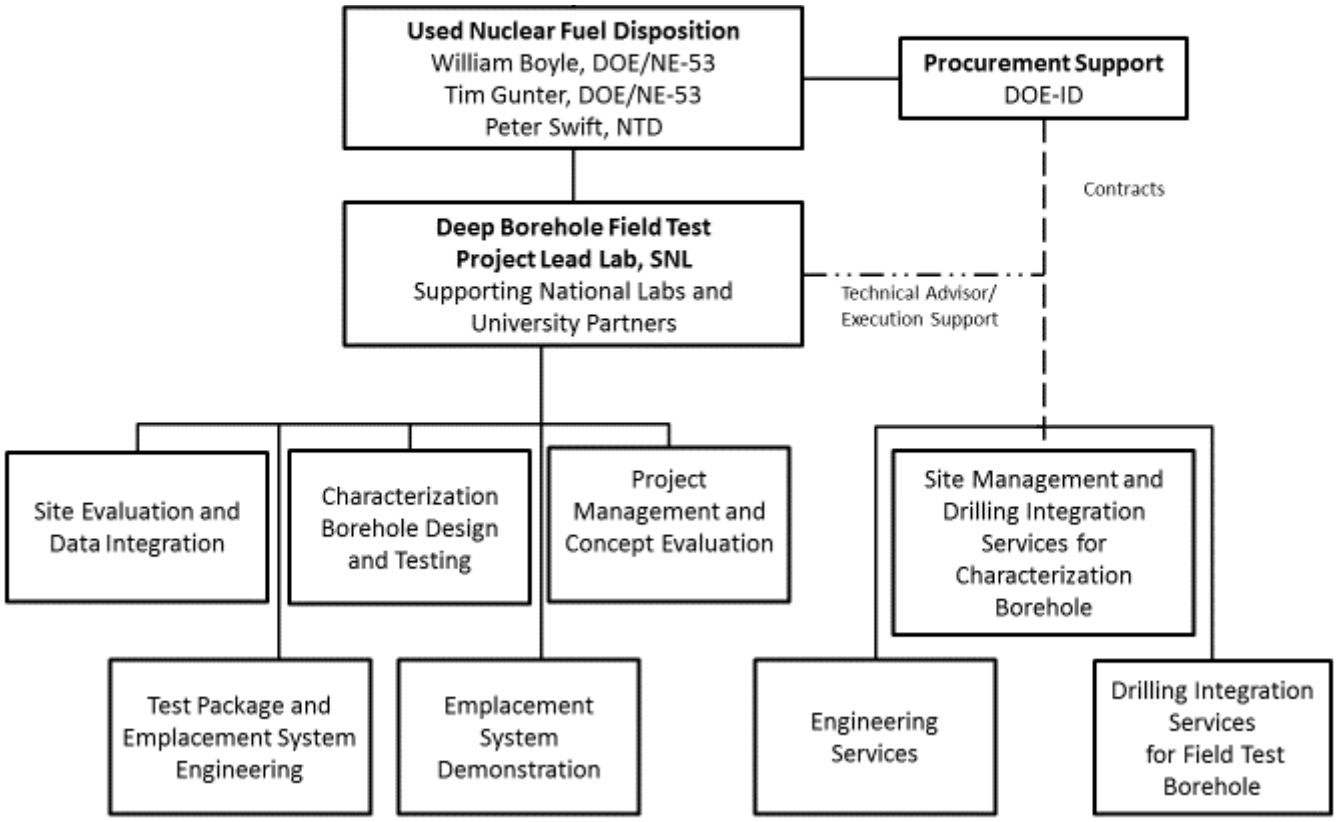
DBFT Project Organization



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Deep Borehole Field Test Participants

- **Six National Laboratories**
- **AREVA Federal Services, LLC**
- **Site Services and Drilling Contractor**
- **Universities and other consultants**

Sandia National Laboratories

Los Alamos National Laboratory

Pacific Northwest National Laboratory

Berkeley Lab

INL Idaho National Laboratory

ornl Oak Ridge National Laboratory

AREVA forward-looking energy

Site Services and Drilling Contractor TBD

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International and Other Projects

- **International**
  - KAERI – Borehole tracer test in granite
  - U. of Sheffield - R&D to Support the DBFT (FTBH Design, BH Seal Design and Performance Criteria)
- **Nuclear Energy University Program**
  - MIT – Optimization of Deep Borehole Systems for HLW Disposal
- **Small Business Innovative Research**
  - RESPEC - Rock Melt Borehole Sealing System (Electric Heater)
  - OLYMPIC RESEARCH - Development of thermally formed plugs for deep borehole waste disposal applications (Thermite formula Heat Source and Sealant)
  - IMPACT TECHNOLOGIES / Massachusetts Institute of Technology / DoD AFRL- Deep Bore Storage of Nuclear Waste using MMW (Millimeter Wave) Technology {Microwave heat source}
  - CIMENTUM - Unique Cimentum Cement for Cementing & Grout in Deep Boreholes for Radioactive Waste Disposal
  - Kapteyn-Murnane Labs - Laser technologies for ultrasensitive groundwater dating using long-lived isotopes
- **Subsurface Technology and Engineering RD&D (SubTER)**
  - SNL/LBNL/UNM - Fit-for-Purpose Cement for Rock-Cement Interfaces in SubTER Applications

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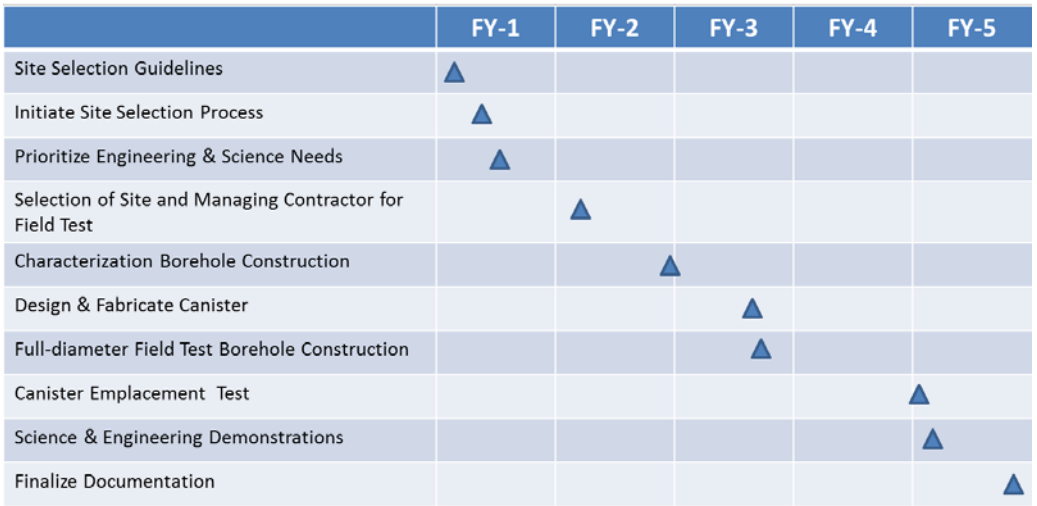
Deep Borehole Field Test

- Major components of deep borehole field test include:
  - Field Test Site Selection
  - Borehole Drilling and Construction
  - Science Thrust
  - Engineering Thrust
- Science thrust includes hydrogeological, geophysical, and geochemical investigations of deep borehole environment and engineered materials behavior
- Engineering thrust includes drilling, canister testing, simulated waste handling, simulated waste emplacement operations, seals design and closure, and operational retrievability



The projected cost for the deep borehole field test is approximately $80 million over the five-year life of the test

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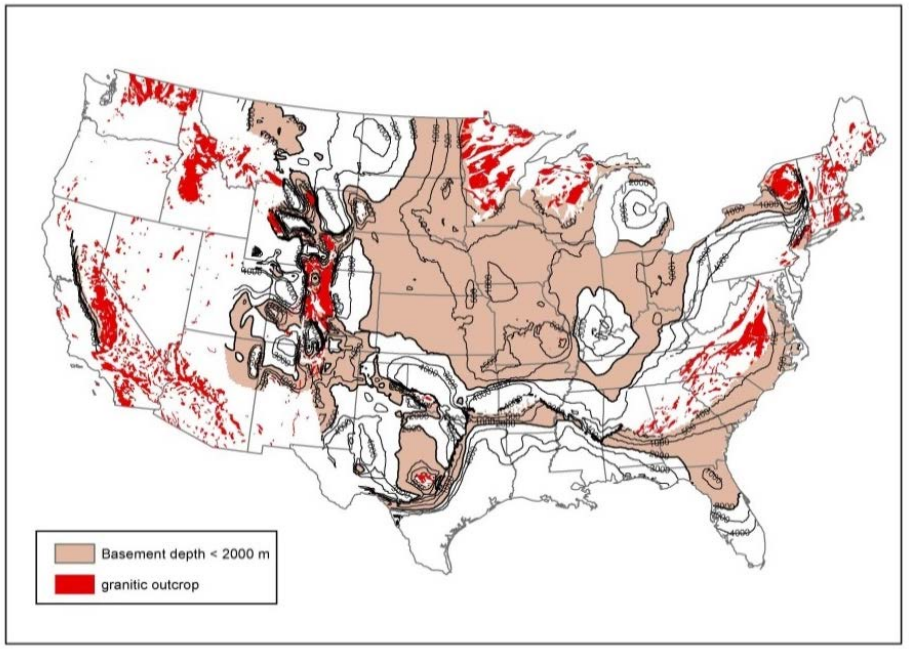
Deep Borehole Disposal Field Test

Site Selection Guidelines

- Site selection guidelines include depth to crystalline basement, lithology, basement structural complexity, horizontal stress, geothermal heat flux, topographic relief, Quaternary faulting and volcanism, and logistical considerations
- Field Test site selection guidelines indicate that large areas with favorable geological characteristics exist in the U.S.



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Deep Borehole Field Test
Schedule

	FY15	FY16	FY17	FY18	FY19
Site & Characterization Borehole – Issue Draft RFP	◆ 04/07/15				
Field Test – Award Engineering Services Task Order	◆ 06/22/15				
Site & Characterization Borehole – Issue Final RFP	◆ 07/09/15				
Documentation – Borehole and Field Test Design	◆ 09/15/15				
Site & Characterization Borehole – Proposals Due	◆ 09/23/15				
Site & Characterization Borehole – Award Site, Management, and Drilling Services Contract		◆ 02/05/16			
Characterization Borehole – Start Drilling		◆	09/01/16		
Field Test Borehole – Award Management and Drilling Services Contract			◆ 01/13/17		
Characterization Borehole – Complete			◆ 02/27/17		
Field Test Borehole – Start Drilling			◆ 07/07/17		
Field Test Borehole – Complete				◆ 01/07/18	
Field Test – Start Emplacement Demonstration				◆ 01/17/18	
Field Test – Complete Emplacement Demonstration				01/17/19 ◆	
Documentation – Field Test Analyses and Evaluation				09/30/19 ◆	

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Deep Borehole Field Test
Acquisition of Site and Services

- **Request for Information solicited input and interest from States, local communities, individuals, private groups, academia, or any other stakeholders who were willing to host a DBH Field Test**
  - Posted to via Federal Business Opportunities (FedBizOps, www.fbo.gov) on October 24, 2014
  - Responses received on December 8, 2014 (45 days)
- **Sources Sought and Draft Request For Proposal (RFP)**
  - Posted on FedBizOps on April 7, 2015
  - Feedback received on May 5, 2015
- **Final RFP (Solicitation Number DE-SOL-0008071)**
  - Pre-solicitation notice posted on June 22, 2015
  - Final RFP posted on FedBizOps on July 9, 2015
  - Proposals due September 23, 2015
  - Contract award anticipated in early 2016

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Deep Borehole Disposal R&D
Conclusions

- Multiple factors have indicated that the deep borehole disposal concept could provide an alternative to safe disposal of radioactive waste for widely available locations with favorable geological and hydrological characteristics
- Implementation of deep borehole disposal with a simple reference design and operations could be feasible, cost effective, and have sufficient capacity to accommodate smaller DOE owned wastes
- A deep borehole field test (without emplacement of radioactive wastes) is the next logical step in evaluating this waste disposal option
- Economic and scientific benefits of a deep borehole field test for local, state, and regional stakeholders could be valuable
- DOE is moving forward with the deep borehole field test

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References

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