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Deep Borehole Disposal Concept and Field Test

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Used Fuel Disposition R&D Campaign

Deep Borehole Science Needs Workshop
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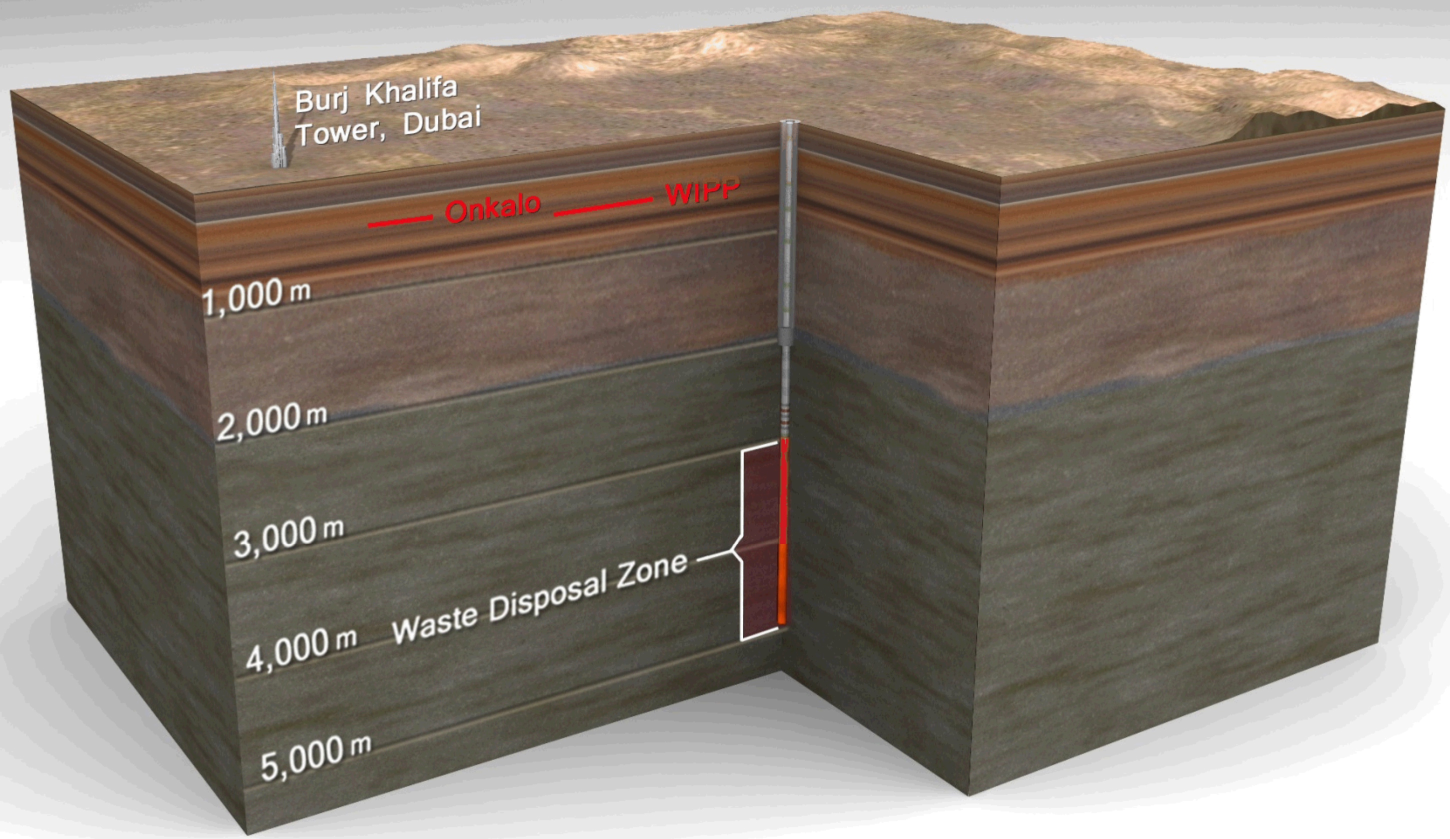
Deep Borehole Disposal Concept

- **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 could consist of DOE-managed waste forms, including some DOE spent nuclear fuel, high-level radioactive waste, or other specialized waste types**
- **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**

Deep Borehole Disposal Concept



Deep Borehole Disposal

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**

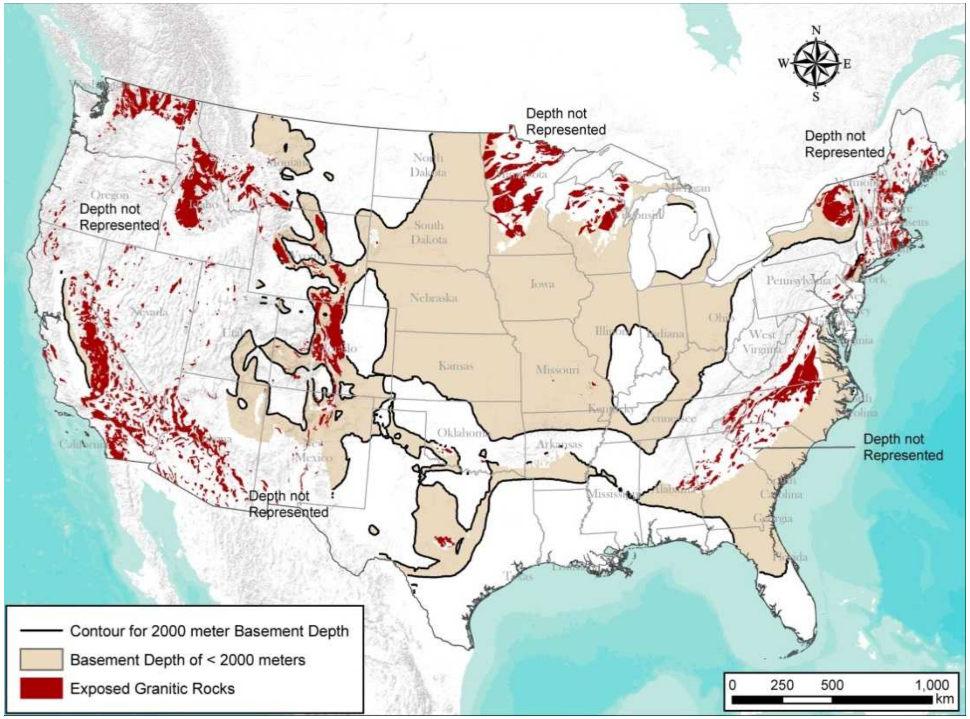
Geological Aspects of Borehole Siting

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

Undesirable 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

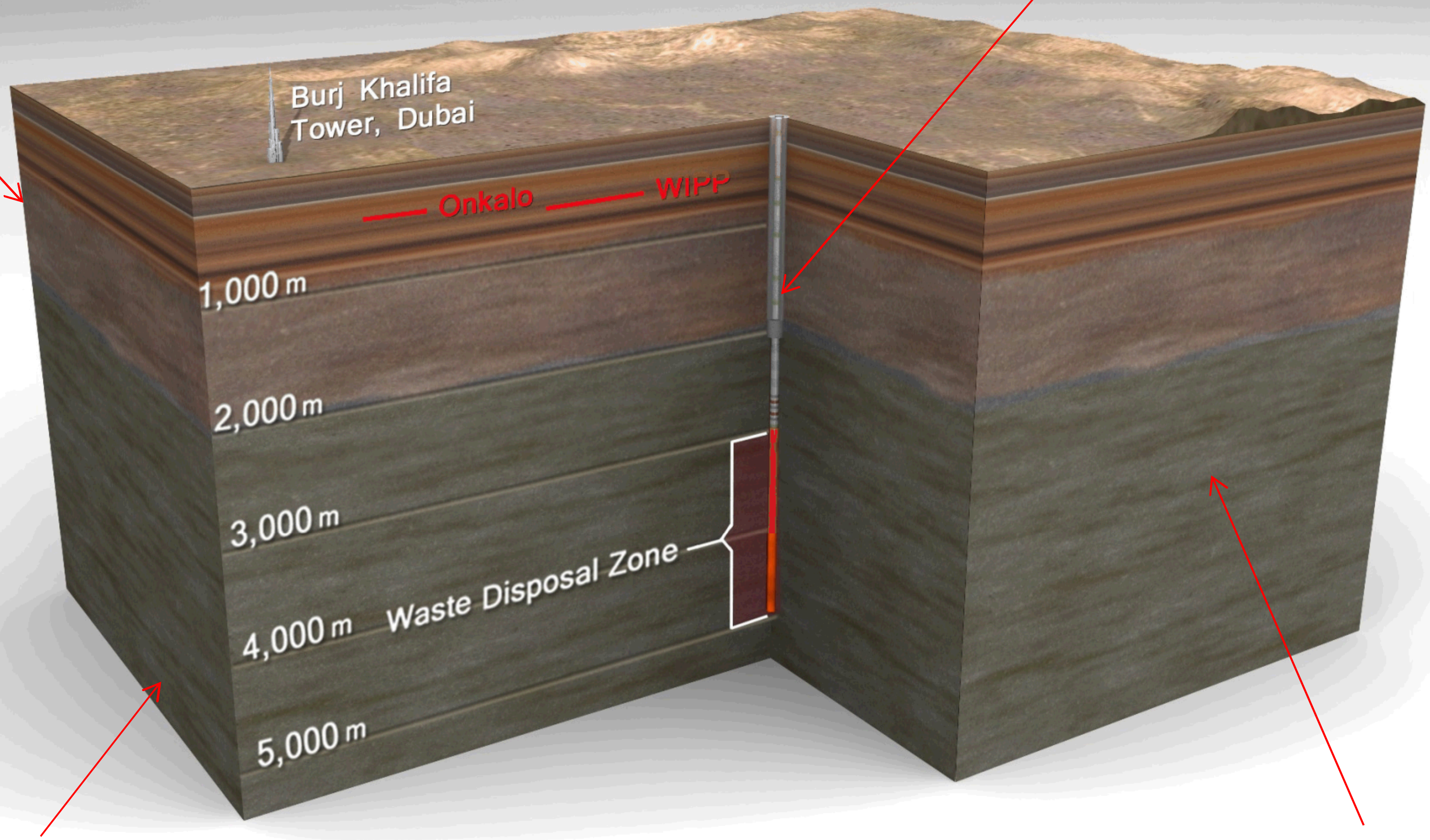


from Perry et al. (2014) Regional Geology: A GIS Database for Alternative Host Rocks and Potential Siting Guidelines, FCRD-UFD-2014-000068 .

Deep Borehole Disposal Concept

Characterize the overlying geology

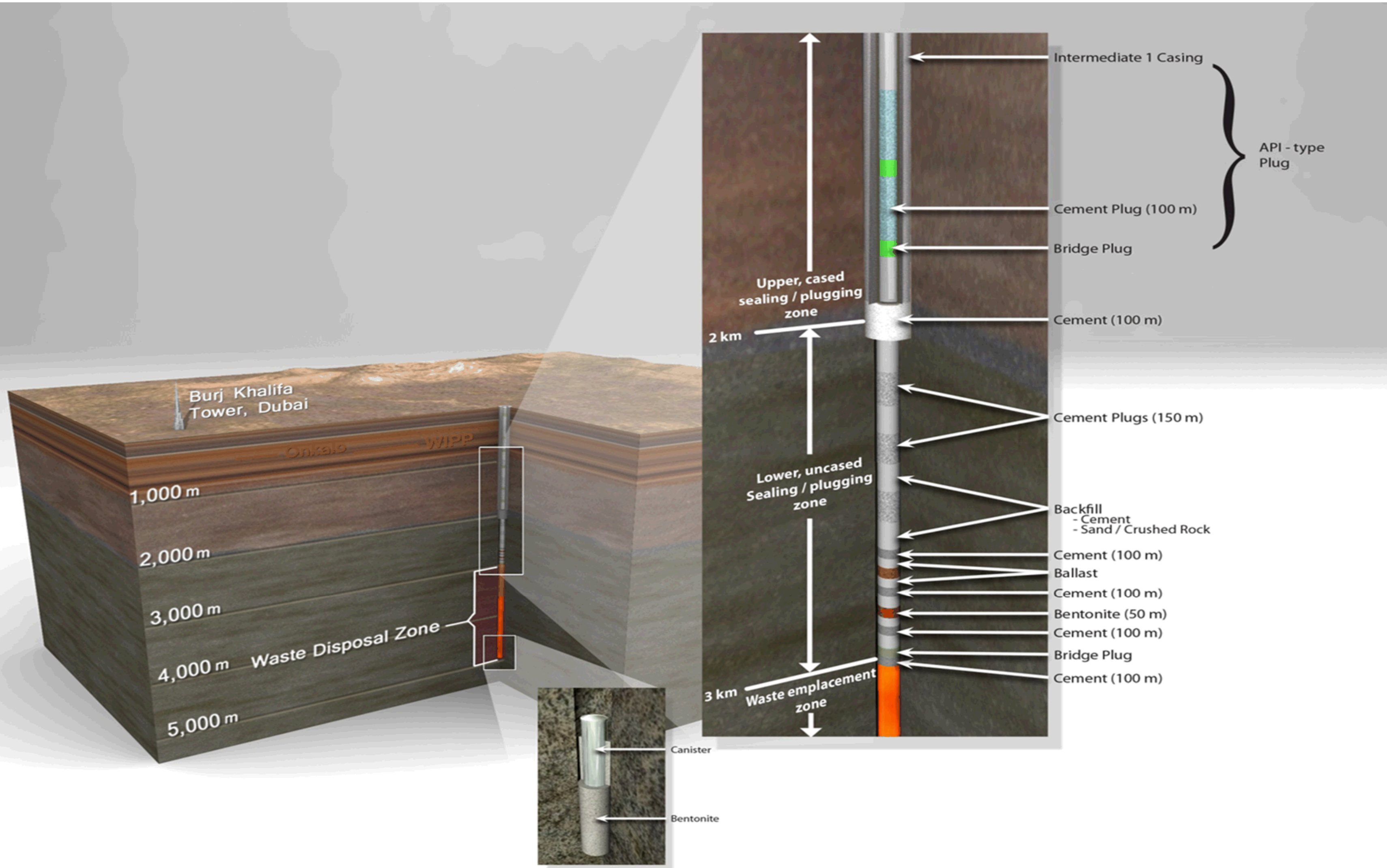
Seal Performance



Characterize the host rock

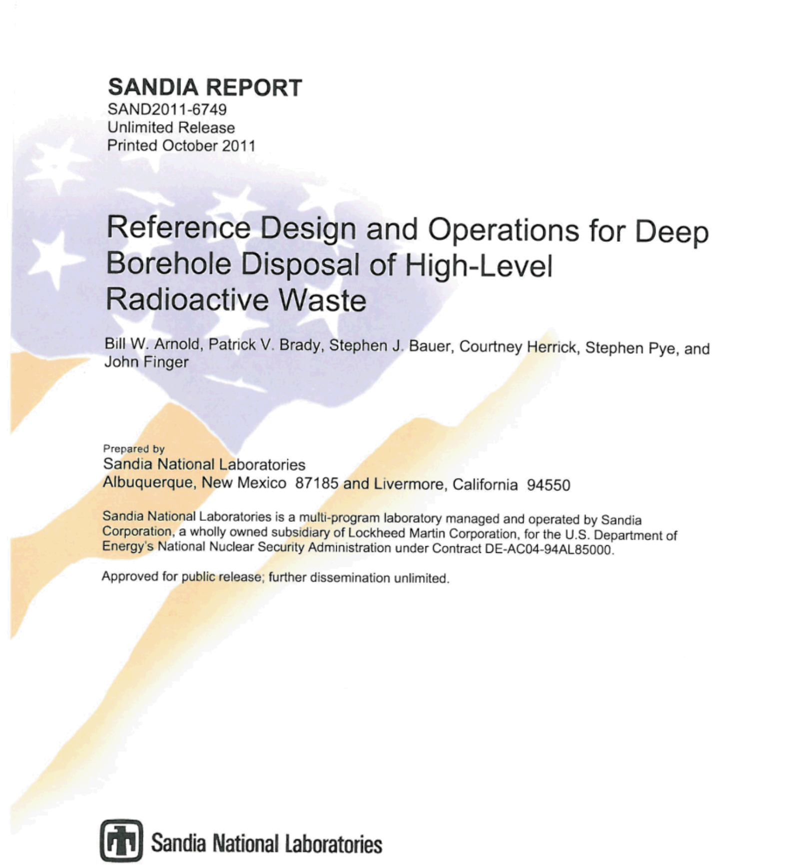
Identify undesirable features

Deep Borehole Disposal Concept



Reference Design and Operations Objectives and Requirements

- **<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**



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

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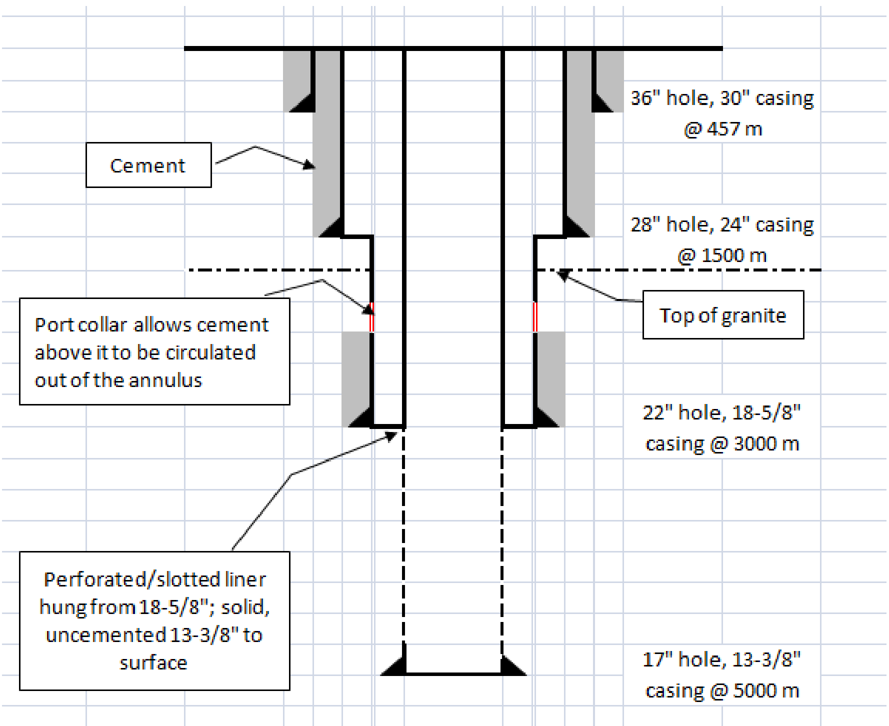
Arnold et al. (2011)

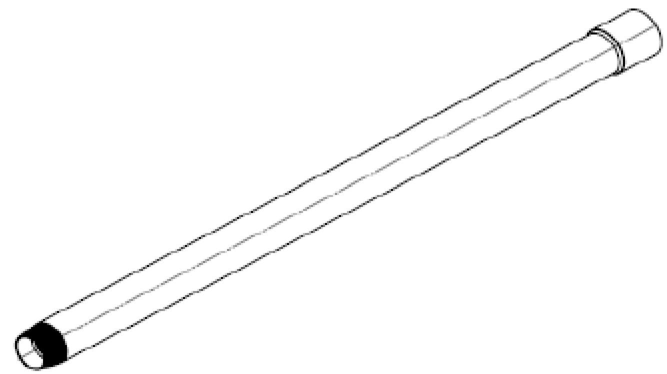
Reference Design and Operations Borehole Design

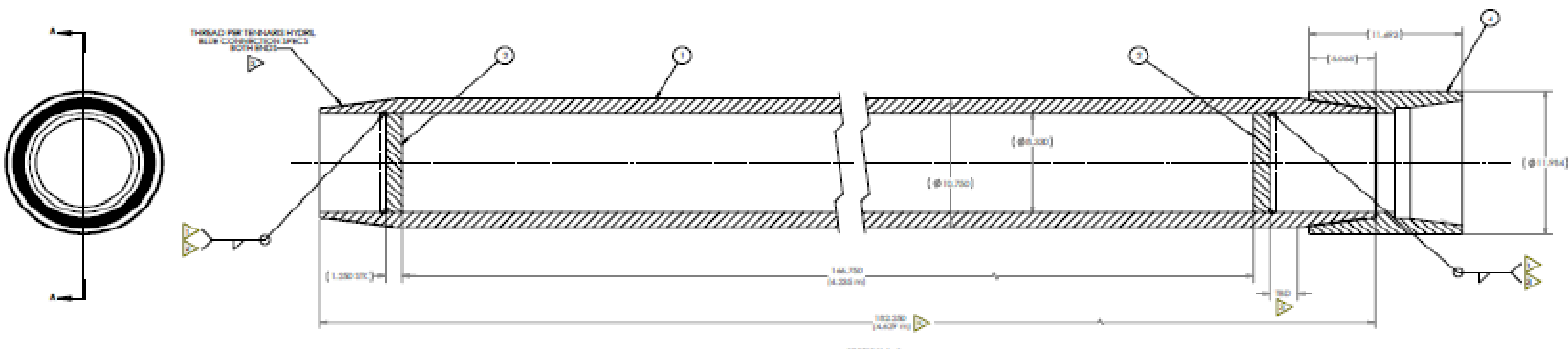
- Drilling to 5 km depth is not exceptional for geothermal development and 17 inches diameter should be feasible with current technology
- Longer rig time and challenges with testing and logging in the reference borehole, lead to consideration of a smaller characterization borehole
- A liner casing will be in place for the emplacement of waste canisters to assure against stuck canisters and facilitate potential retrieval (until the liner is pulled and seals set)
- The perforated liner will be left in place in the disposal zone, but will be removed in the seal zone, along with most of the intermediate casing



Reference Design and Operations
Waste Canister Design

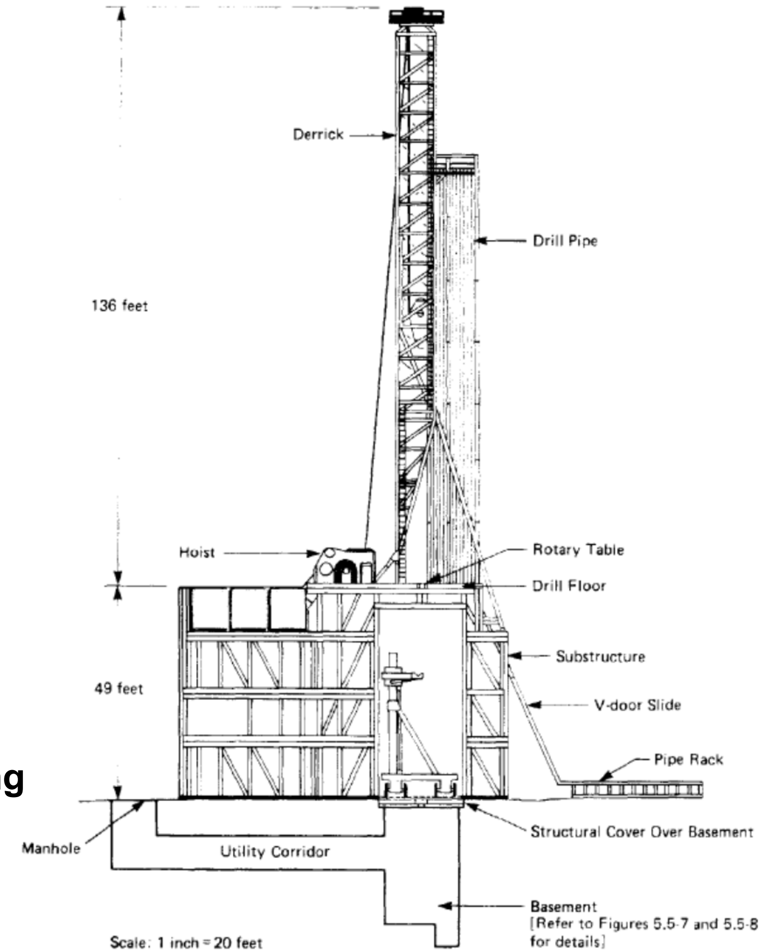
- Waste canisters consist of carbon steel tubing with welded plugs and threaded connections
- Canisters are designed to withstand projected hydrostatic pressure and mechanical load of overlying canisters
- Waste canisters would retain their integrity until after the borehole is loaded and sealed





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 with a J-slot assembly and lowered to the disposal zone
- A synthetic oil-base mud with a high bentonite concentration would be present in the disposal zone, forming a grout around the waste canisters
- Each canister string would be separated from overlying canister strings by a bridge plug and cement plug



from Woodward-Clyde Consultants (1983)

DBFT will be used to validate proof of concept

- Demonstrate site selection and site characterization methods
- Demonstrate drilling technology and borehole construction to 5 km depth with sufficient diameter for cost effective waste disposal
  - *CBH – 11/16/2016*
  - *TBH – 12/01/2017*
- Characterize and verify geological, geochemical, and hydrological conditions at a representative location
- Develop and test engineering methods for waste canister loading, shielded surface operations, waste canister emplacement, and borehole seals deployment
- Evaluate canister, waste, and seals materials at representative temperature, pressure, salinity, and geochemical conditions
- Analyze and assess the viability and safety of deep borehole canister emplacement – *Complete by 09/30/2019*