

Large Diameter Deep Borehole Disposal Concept for HLW Glass

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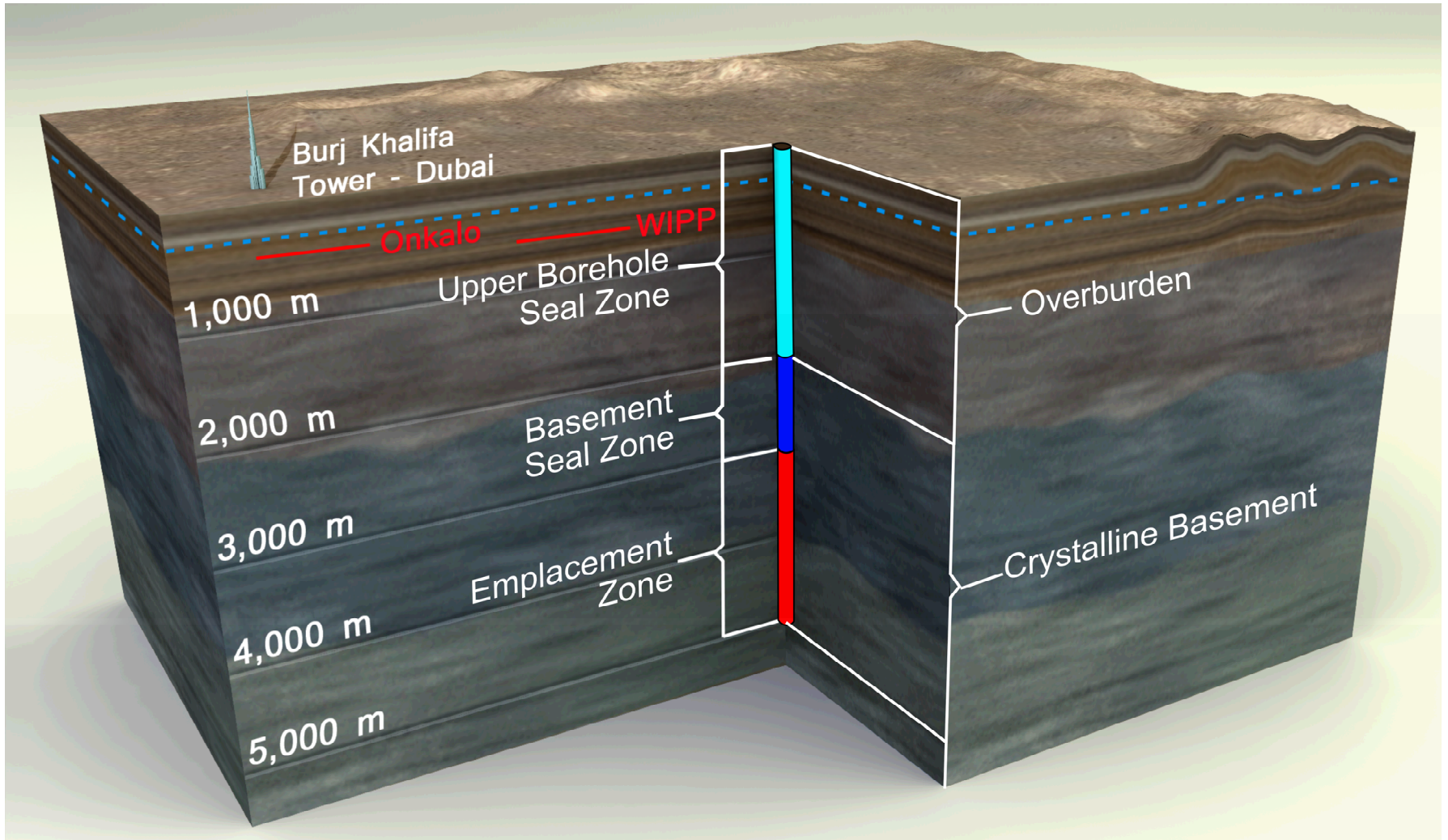
Sandia National Laboratories



Outline

- Review of Deep Borehole Disposal (DBD) Reference Design
- Precedents for Large Diameter Deep Borehole Concepts
- Large Diameter Deep Borehole Concept for vitrified HLW
- Packaging considerations for vitrified HLW disposal
- Post-Closure Performance Assessment (PA)
- Summary and Conclusions

Deep Borehole Disposal Concept



Basis for Large Diameter Deep Boreholes



Laronde Penna #3 Mine Shaft, Canada (1999)

- Deepest single-lift shaft in the western hemisphere to 7,411 ft (2,260 meters) and 18 ft (5.5 m) in diameter

Magoun No. 1 in Concordia Parish, LA (1984)

- Total depth of 25,015 ft (7.6 km).
- Drilled to 12,455 ft (3.8 km) at a diameter of 26 inches.
- A 20-inch casing weighing >2.1 million lb run and cemented over this interval.

Cannikin Borehole, Amchitka AK (1969)

- A 90-inch hole—6,150 feet (1,875 meters) cased using 54" casing
- At time, largest emplacement drill rig—1,000 ton mast.
- Drilled without blow out preventer (BOP)



SAND2010-6048

Large Diameter Deep Borehole Designs

Beswick et al., 2014* propose the following design:



Depth (m)	Hole Diameter (in.)	Casing Diameter (in.)
0-500	60	54
500-1000	48	40
1500-2500	36	30
2500-5000	24 to 26	20

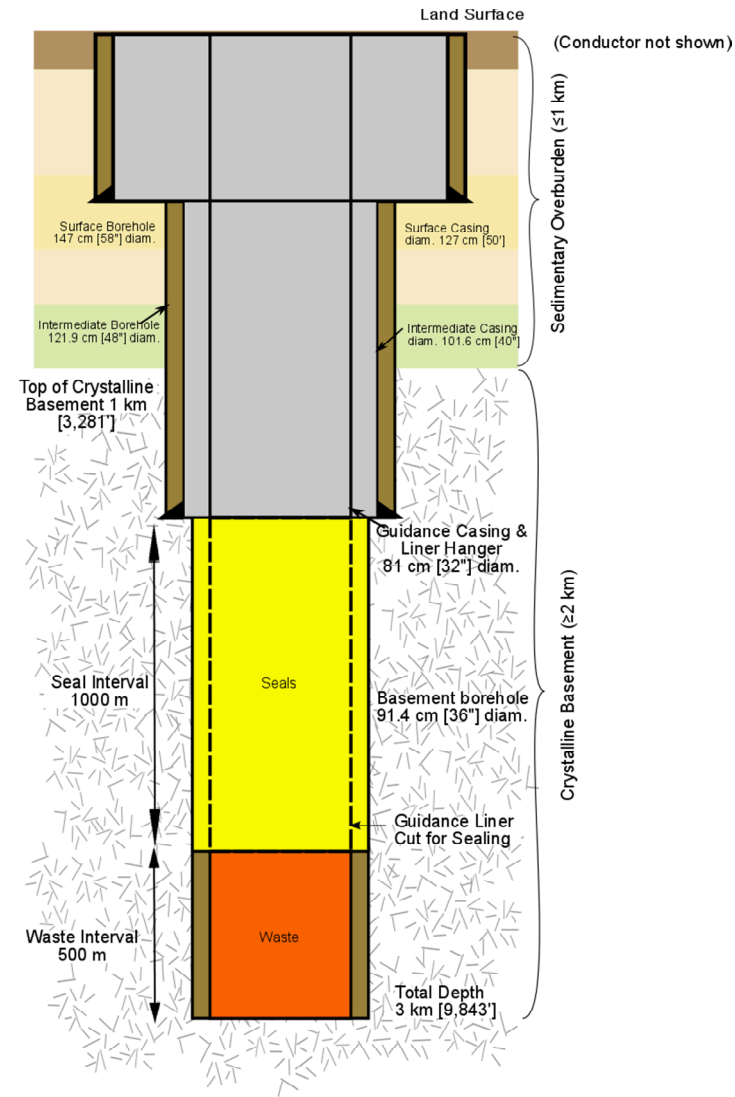
*Beswick A.J., Gibb, F.G., and Kravis, K.P. (2014) Deep borehole disposal of nuclear waste: engineering challenges. *Proceedings of the Institution of Civil Engineers*, 167, EN12. p.47-66.

Large Diameter Deep Borehole: Sensitivity Case Conceptual Design

Casing Length (m)	Hole Diameter (in.)	Casing Outer Diameter (in.)
0-300	58	50
300-1500	48	40
0-1500	36	30-32
1500-3000	36	30-32

Conceptual Design Challenges:

- Weight of the casing may require special emplacement and handling techniques.
- May require drilling without a blowout preventer BOP.
- Use of specialized drilling techniques and equipment.



HLW Packaging Options for Deep Borehole: Stress Analyses

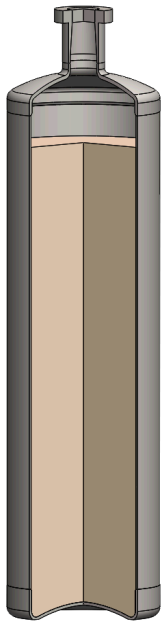
SRS Vitrified HLW Canisters

- 3 m tall
- 24 in diameter
- 0.375 in wall thickness
- 90% Filled with Glass

Assumptions:

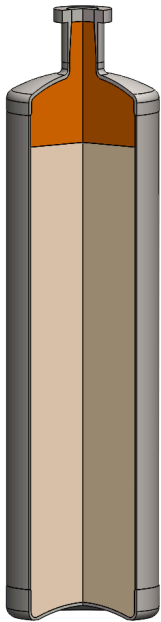
- Cyclic symmetry for analysis (1/4 cylinder model)
- 30 Mpa down hole hydrostatic pressure at 170 C

Option 1



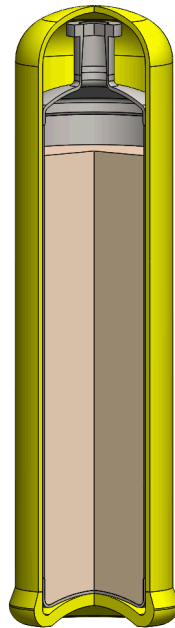
As Packaged

Option 2



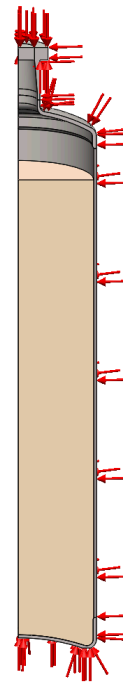
Filled w/
Hydro-Stone®
Cement

Option 3

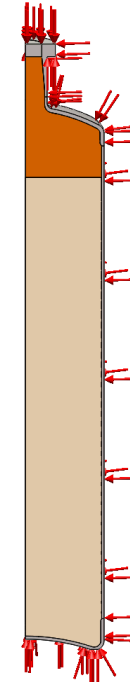


As Packaged
in 1" Overpack

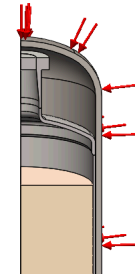
Option 1



Option 2

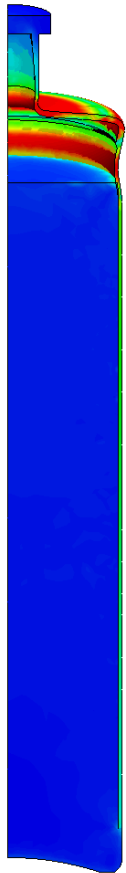


Option 3

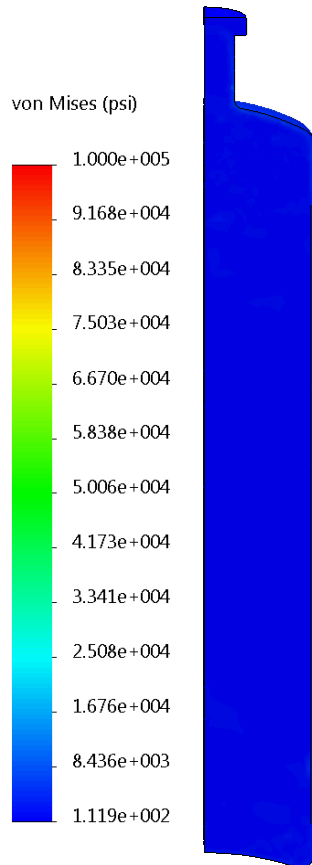


HLW Packaging Options for Deep Borehole: Analyses Results

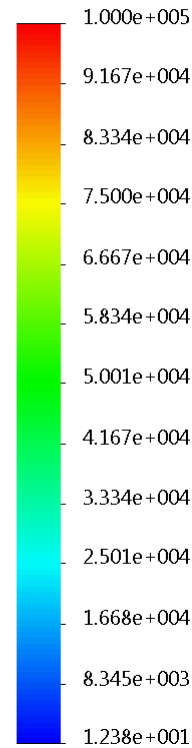
Option 1



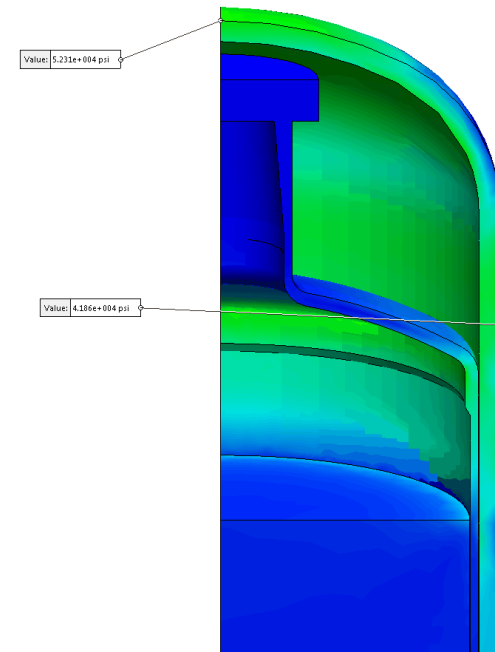
Option 2



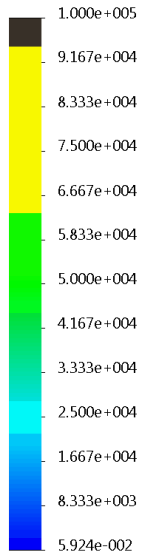
von Mises (psi)



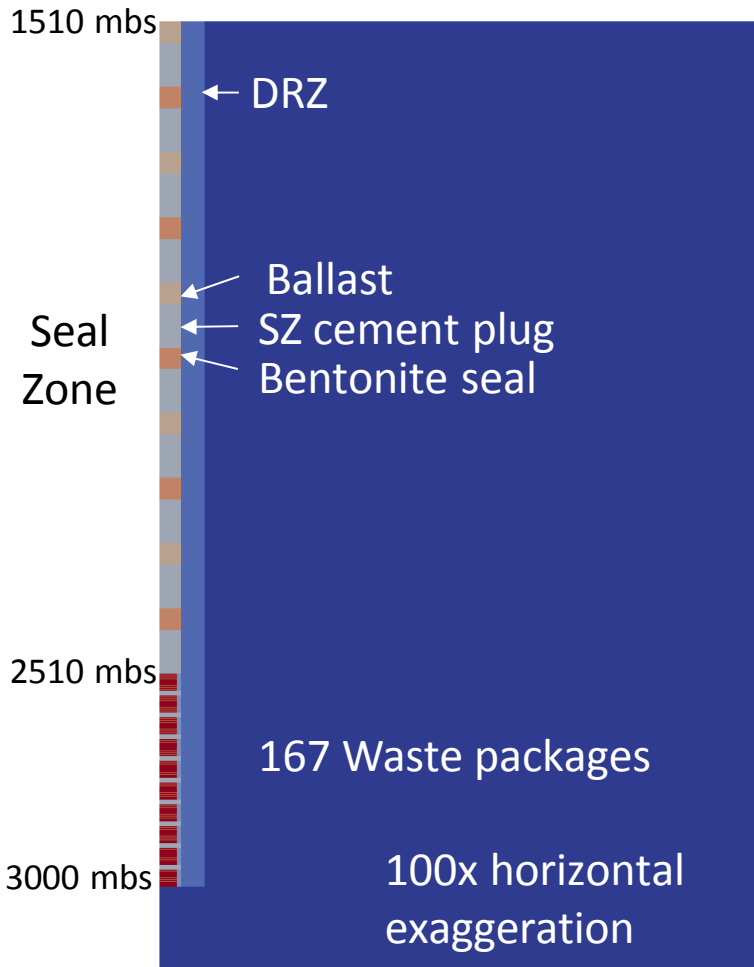
Option 3



von Mises (psi)



Post-Closure PA: Nominal Scenario (PFLOTRAN)



Material	k (m^2)	ϕ	τ	D_e (m^2/s)	Thermal Cond. ($W\ m^{-1}K^{-1}$)	Heat Cap. ($J\ kg^{-1}K^{-1}$)	Dens. (kg/m^3)
Waste Package	1×10^{-16}	0.43	1.0	4.3×10^{-10}	17	500	7,850
EZ Annulus (Emplacement Fluid)	1×10^{-12}	0.99	1.0	9.9×10^{-10}	0.58	4192	1,100
SZ Cement Plug	1×10^{-18}	0.175	0.175	3.1×10^{-11}	1.7	900	2,700
Bentonite Seal	1×10^{-18}	0.45	0.45	2.0×10^{-10}	1.3	800	2,700
Ballast	1×10^{-14}	0.20	0.20	4.0×10^{-11}	2.0	800	2,700
Crystalline Rock	1×10^{-18}	0.005	0.20	1.0×10^{-12}	2.5	880	2,700
DRZ	1×10^{-16}	0.005	0.20	1.0×10^{-12}	2.5	880	2,700

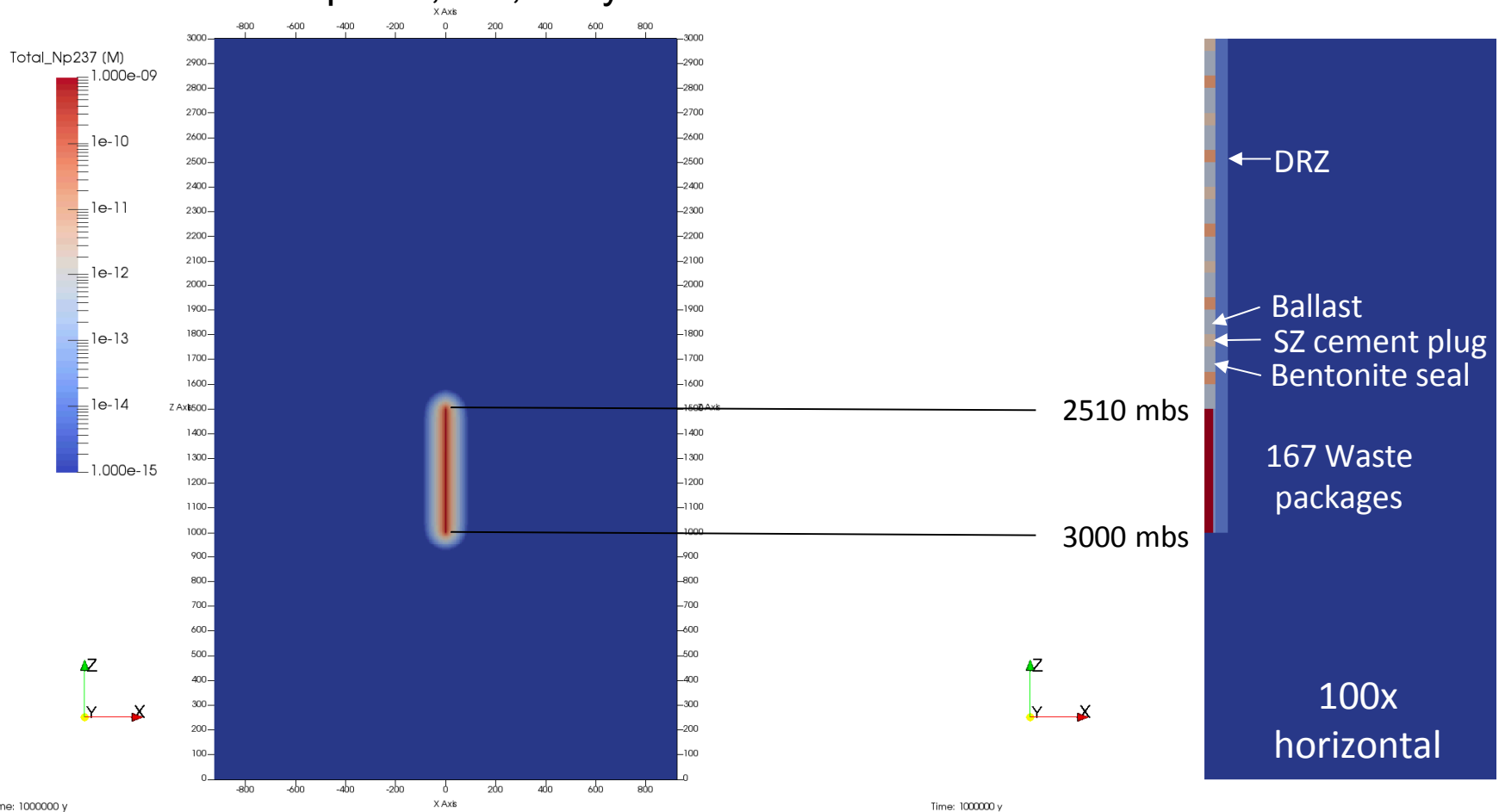
Post Closure PA: Inventory Considered



Isotope	Inventory per Canister (g)	Borehole Inventory (g)	Element Solubility Limit (mol/L)	Element K_d in Crystalline Rock (m^3/kg)
^{241}Am	8.3E+01	1.4E+04	6×10^{-6}	0.04
^{243}Am	5.9E+00	9.9E+02		
^{238}Pu	4.6E+01	7.7E+03	2×10^{-7}	0.5
^{239}Pu	2.4E+02	4.0E+04		
^{240}Pu	3.3E+01	5.5E+03		
^{242}Pu	4.8E+00	8.0E+02		
^{237}Np	3.6E+01	6.0E+03	1×10^{-9}	0.2
^{233}U	5.0E+00	8.4E+02	4×10^{-10}	0.1
^{234}U	1.0E+01	1.7E+03		
^{236}U	4.9E+01	8.2E+03		
^{238}U	1.2E+05	2.0E+07	4×10^{-7}	0.2
^{229}Th	5.6E-04	9.4E-02		
^{230}Th	5.8E-04	9.7E-02		
^{129}I	1.6E+00	2.7E+02	unlimited	0
^{135}Cs	1.8E+01	3.0E+03	unlimited	0.05
^{99}Tc	4.7E+02	7.8E+04	3×10^{-8}	0.05

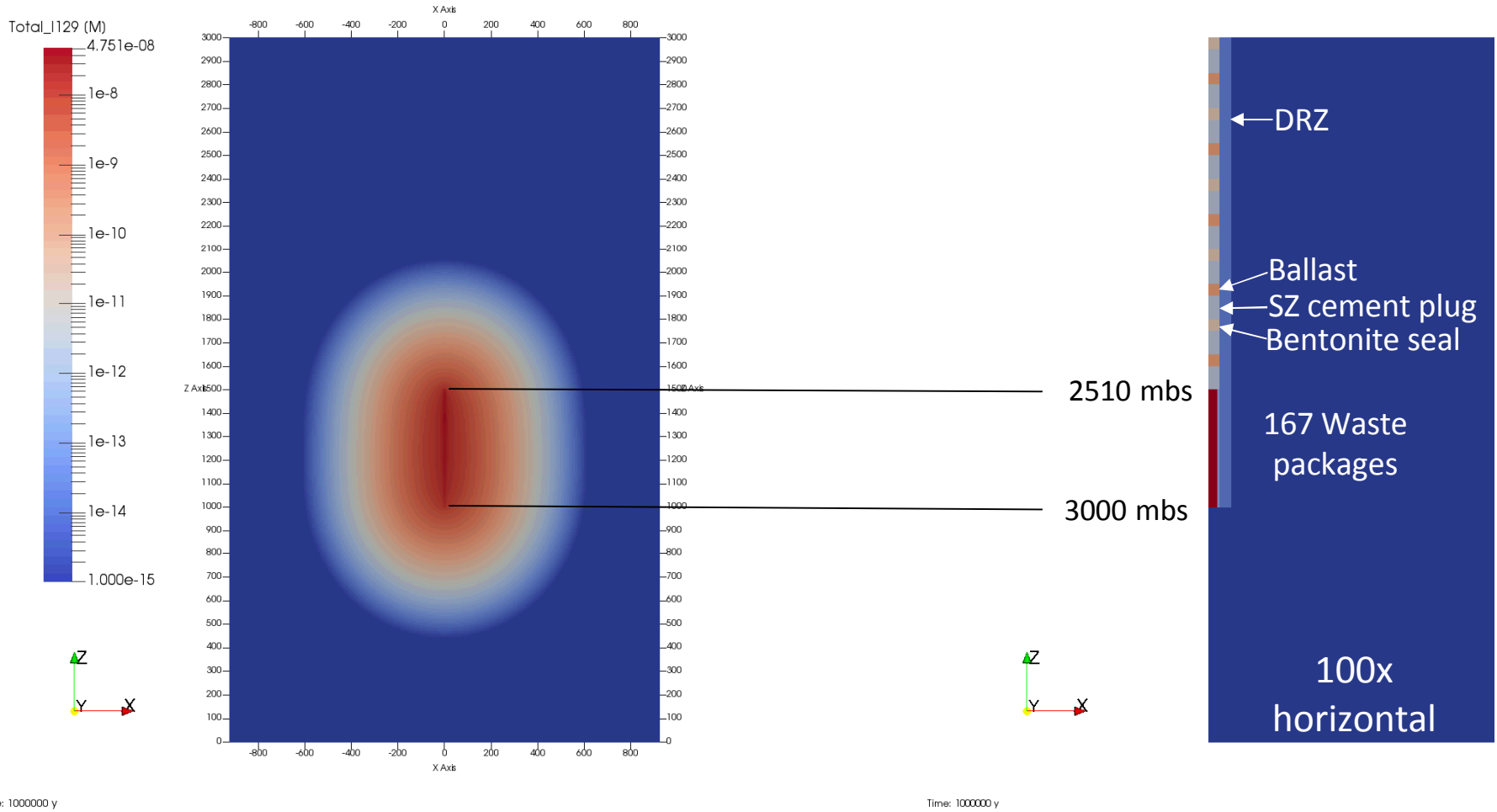
Nominal Scenario Deterministic Results: ^{237}Np Releases

Dissolved Concentrations of ^{237}Np at 1,000,000 years



Nominal Scenario Deterministic Results: ^{129}I Releases

Dissolved Concentrations of ^{129}I at 1,000,000 years



Cost Estimate-Large Diameter Deep Borehole

Interval costs		Time, hours
Drilling time cost	\$5,635,583	1803.4
Tripping time cost	\$3,986,587	1275.7
Bit cost	\$9,741,523	
Other BHA	\$4,870,762	
Mud cost	\$568,700	
Casing cost	\$7,361,304	
Cementing time cost	\$337,938	108.1
Cementing mat'l cost	\$4,468,918	
Trouble time	\$0	0.0
Trouble cost	\$0	
Directional drilling	\$1,152,483	
Logging time	\$182,760	58.5
Logging service	\$150,000	
Wellhead time	\$500,000	160.0
Other costs	\$0	
Total interval costs	\$38,956,558	
Total interval time, hr		3405.7
Total interval time, days		141.9
Additional costs and time (in days)		
Mobilization/De-mob	\$1,000,000	3.0
Site prep, cndctr, cellar	\$100,000	2.0
Pre-spud engineering	\$500,000	0.0
Wellhead equipment	\$1,000,000	0.0
Contingency	\$5,843,484	
Total well cost	\$47,400,042	
Total project time, days		146.9

Large Diameter Deep Borehole: Conclusions

- 36” diameter borehole would allow disposal of some large diameter waste canisters including 24” HLW glass canisters.
- The borehole design could require specialized drilling equipment and techniques.
 - Largest available blow out preventer (BOP) is 30”
 - Hydraulic jacking system may be required to lower casing
- Preliminary cost estimates suggest higher cost (50 million) per borehole compared to the 17” deep borehole reference design.
- Current and Projected vitrified HLW would require a minimum of 150-200 boreholes for disposal.
- Several DOE-managed small waste forms are potential candidates for deep borehole disposal however DOE has made no decision to dispose of any waste in deep boreholes

Backup Slides

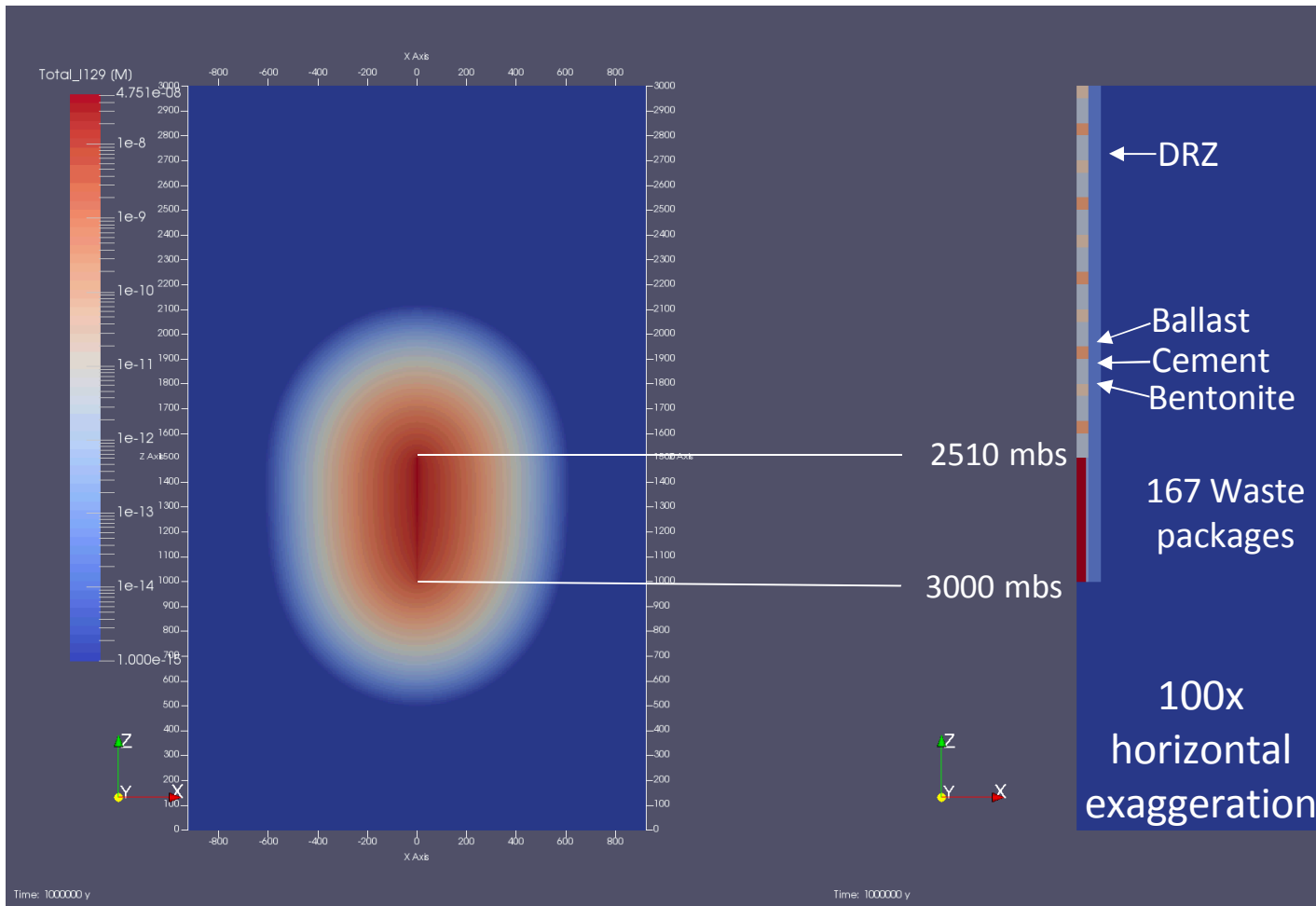
Nominal Scenario Deterministic Results: ^{129}I Releases

Dissolved Concentrations
of ^{129}I at 1,000,000 years

Granite
 $K = 10^{-16}$

DRZ
 $K = 10^{-14}$

$\Phi = 0.01$



Nominal Scenario Deterministic Results: ^{237}Np Releases

Dissolved Concentrations of ^{129}I at 1,000,000 years

Granite
 $K = 10^{-16}$

DRZ
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$\Phi = 0.01$

