Used Fuel Disposition Campaign

Deep Borehole Disposal: Preliminary Performance Assessment

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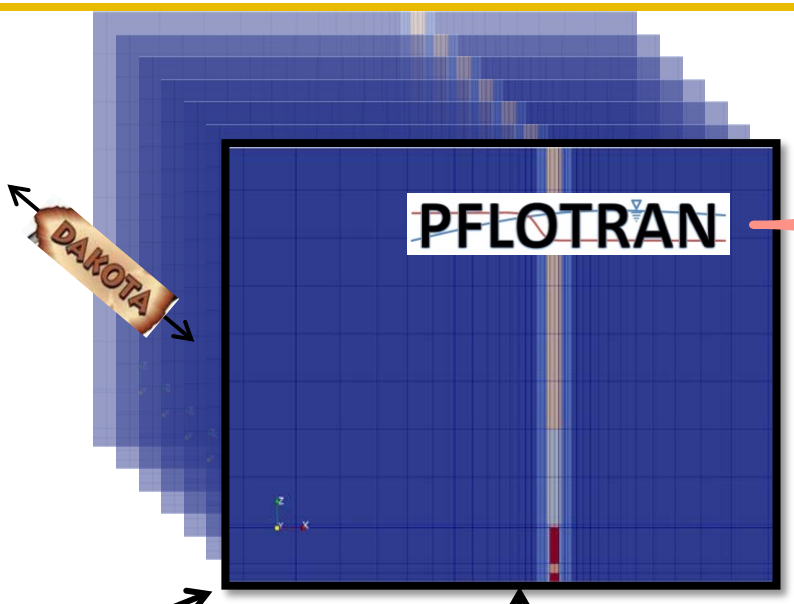
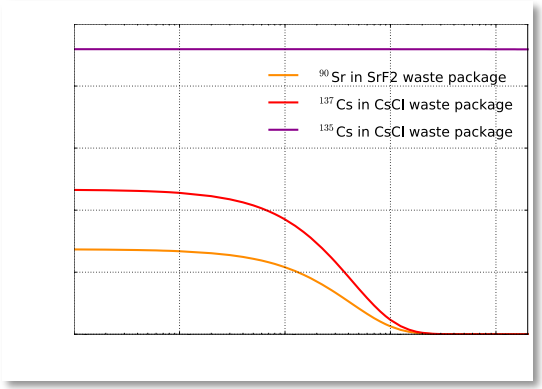
Performance Assessment



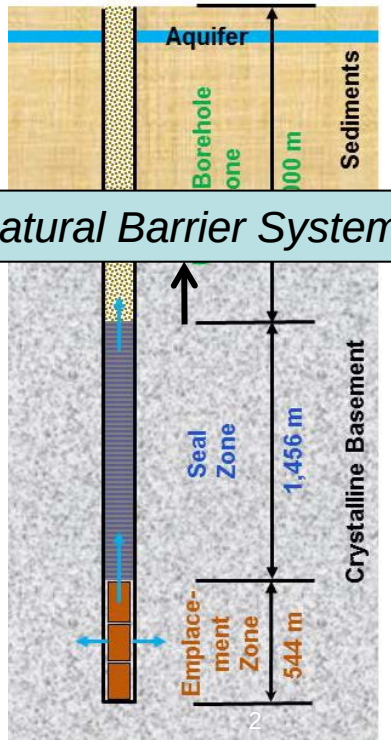
- Coupled heat and fluid flow
- Waste package degradation
- Waste form dissolution
- Radioactive decay and ingrowth
- Solubility, sorption
- Advection, dispersion, diffusion

Waste Forms



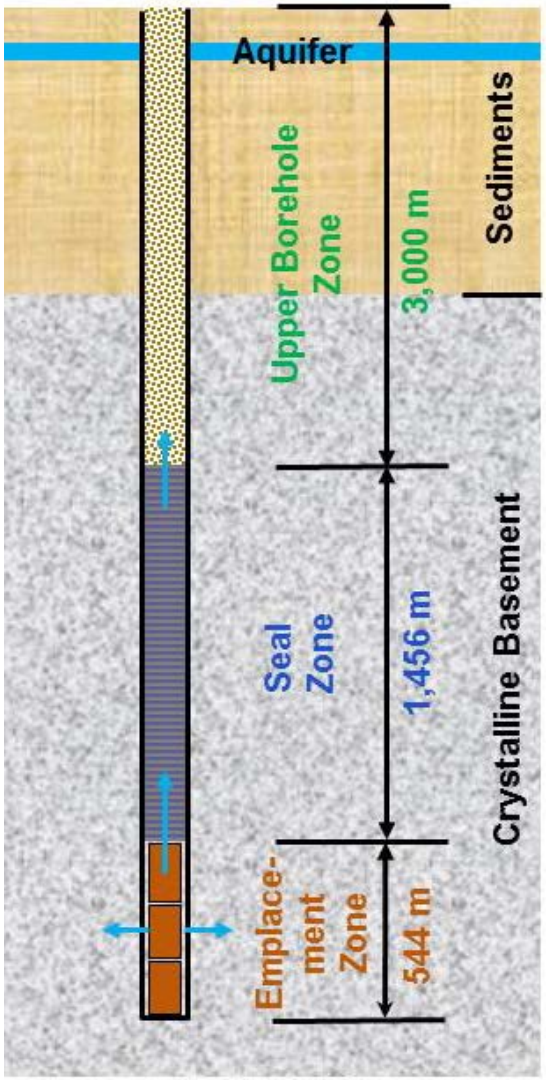
Engineered Barrier System

Natural Barrier System



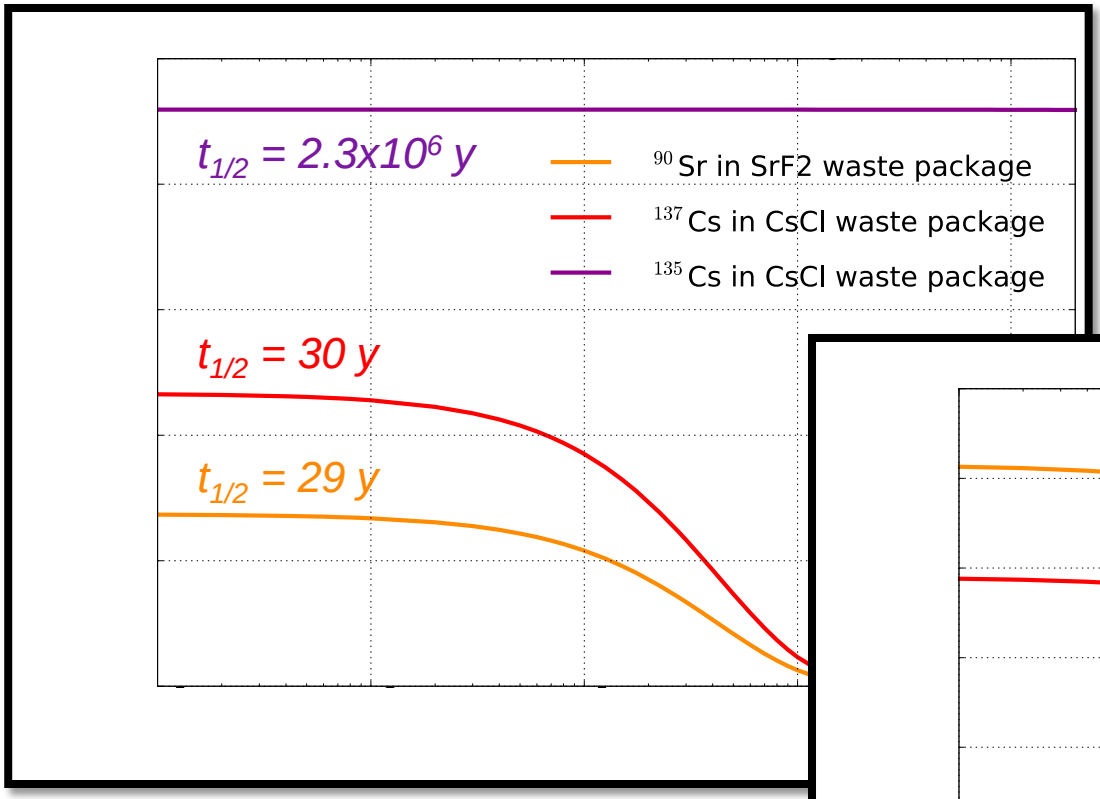
Natural Barrier System

- **Sediments** (not simulated)
  - ~2000-m thick
  - Flat-lying sedimentary sequence
- **Crystalline Basement**
  - Hydraulically isolated due to:
    - *Depth*
    - *Low permeability*
  - Sparsely fractured granite
    - $k = 10^{-18}\ m^2$, $\Phi = 0.01$
    - $\kappa = 2.5\ W/(m\,°K)$
    - $C_p = 880\ J/(kg\,°K)$
  - Sr K_d = 0.4 L/kg; Cs K_d = 5 L/kg
  - Modeled as homogeneous medium

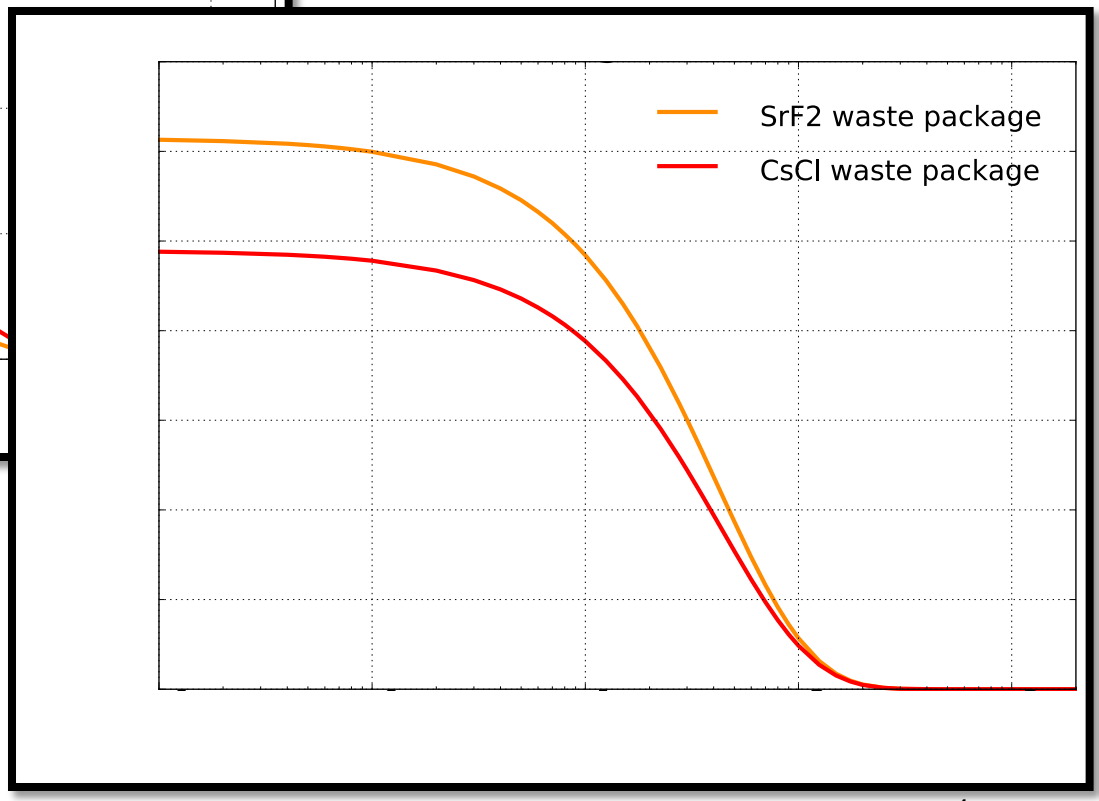


(not to scale)

Waste Inventory



- 1335 CsCl capsules
- 601 SrF_2 capsules
- 18 capsules per waste package

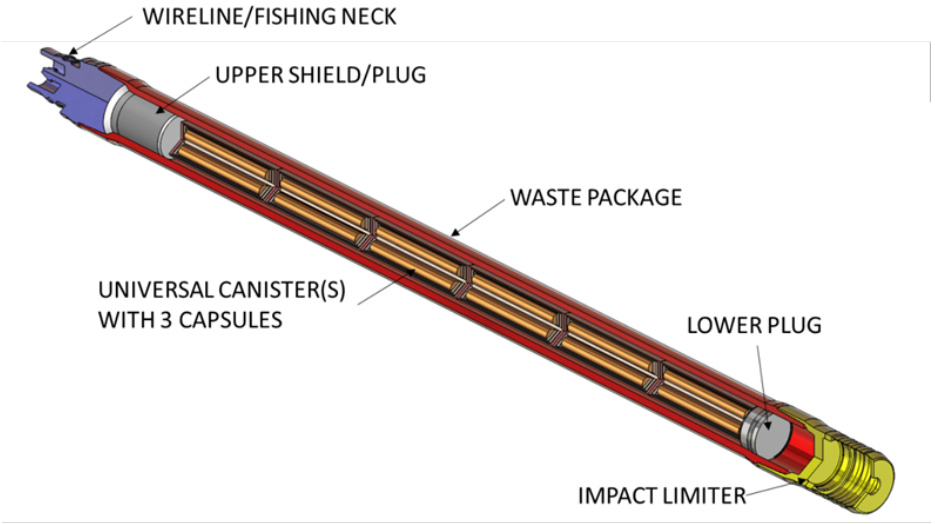


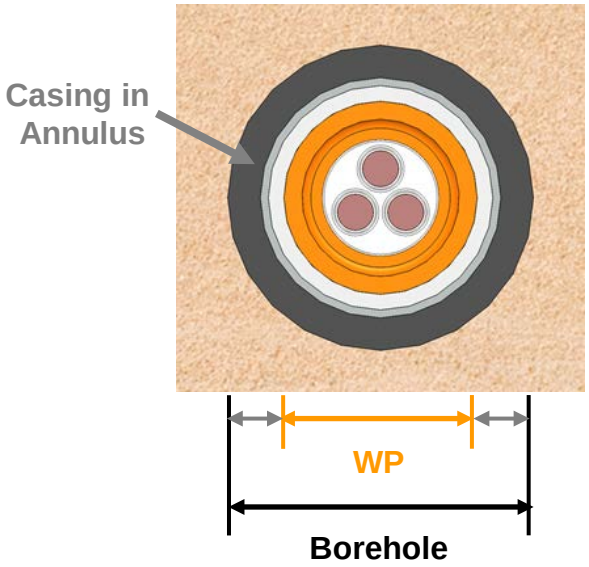
- Instantaneous degradation
- Unlimited solubility

Engineered Barrier System: Waste Package

Waste Package (WP)

- 108 WPs (~ 74 Cs, ~ 34 Sr)
- WP O.D. = 19.1 cm (7.5 in)
- WP length = 4.76 m
- Breach at 1 year
- $k = 10^{-16}$ m^2, $\phi = 0.5$
- No sorption



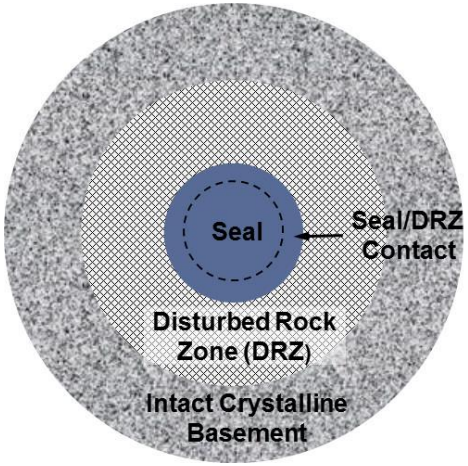


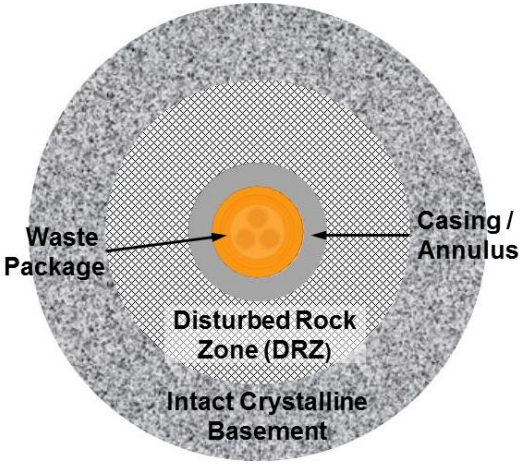
Annulus

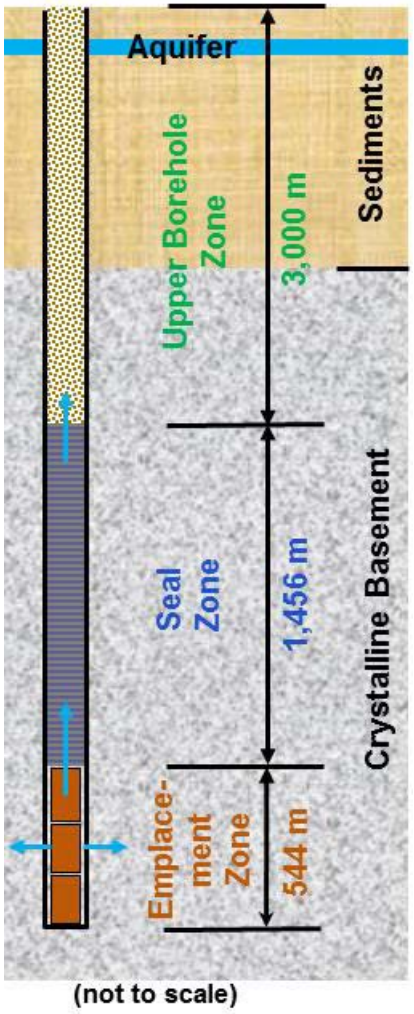
- O.D. = 31.1 cm (12.25 in)
- Contains:
  - *Steel casing (not simulated)*
  - *Brine ($k = 10^{-12}$ m^2, $\phi = 0.99$)*
  - *(or Cement: $k = 10^{-16}$ m^2, $\phi = 0.15$)*
- No sorption

Engineered Barrier System: Plugs, Seal, DRZ

- **Disturbed Rock Zone (DRZ)**
  - Length of the borehole
  - $k = 10^{-16}$ m^2, $\phi = 0.01$
- **Bentonite Seal**
  - Extends to 3000 m below surface
  - $k = 10^{-16}$ m^2, $\phi = 0.2$
  - Sr K_d = 50 L/kg; Cs K_d = 120 L/kg
- **Cement Plugs**
  - 3 plugs, above:
    - 40th WP
    - 80th WP
    - 108th WP
  - 10 m height
  - $k = 10^{-16}$ m^2, $\phi = 0.15$
  - No sorption

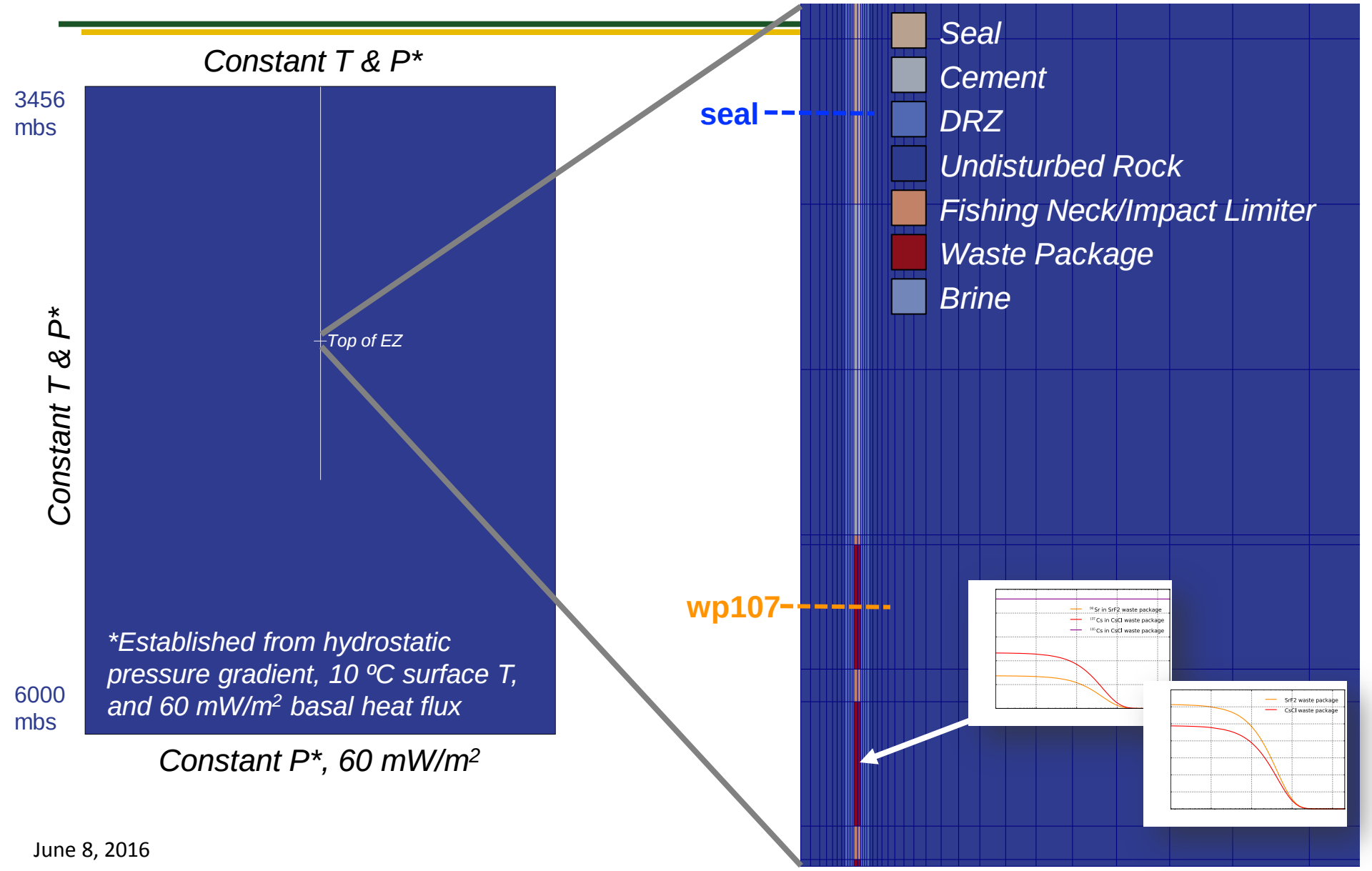




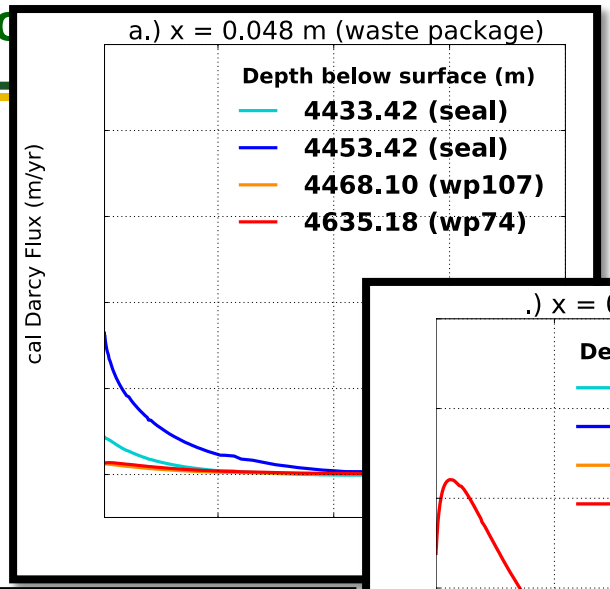


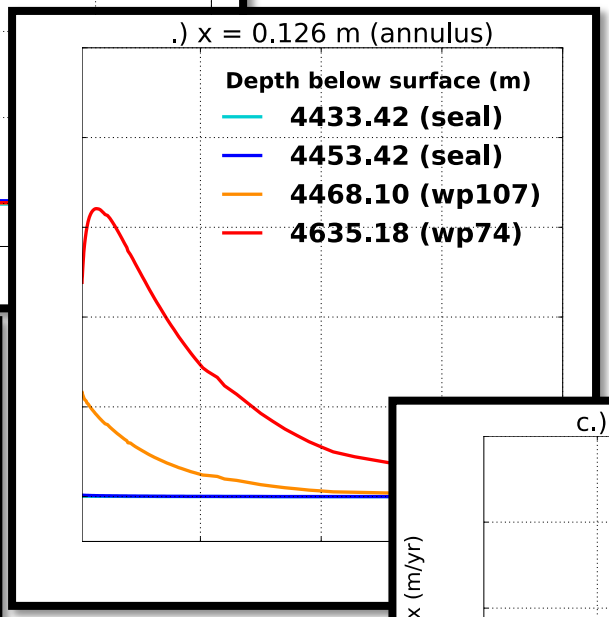
Used Fuel Disposition

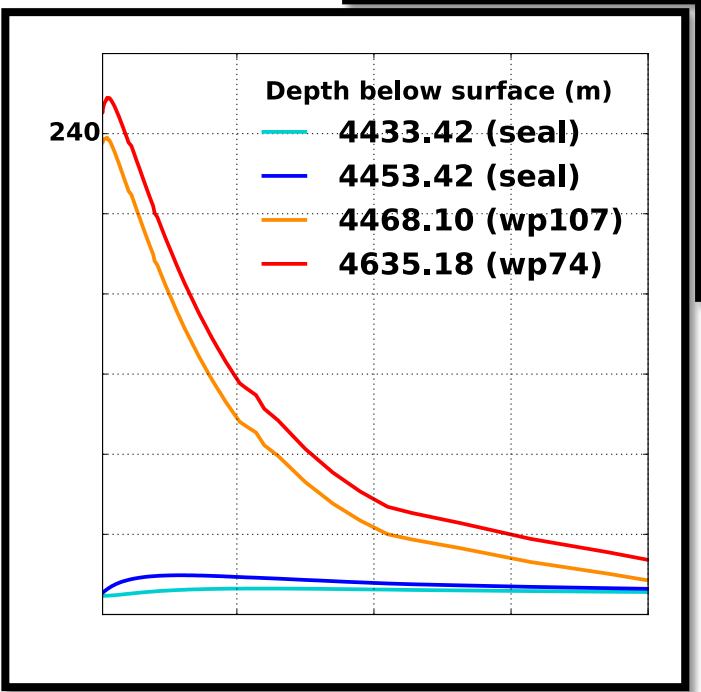
2-D Radial Domain

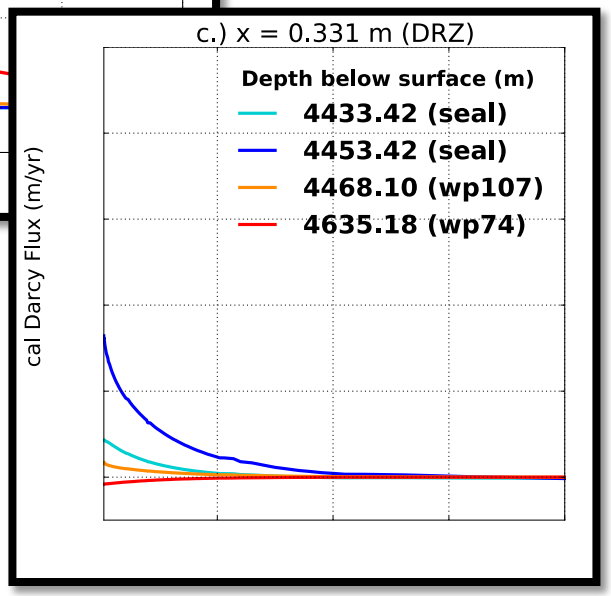


Temperature and Darcy Flux



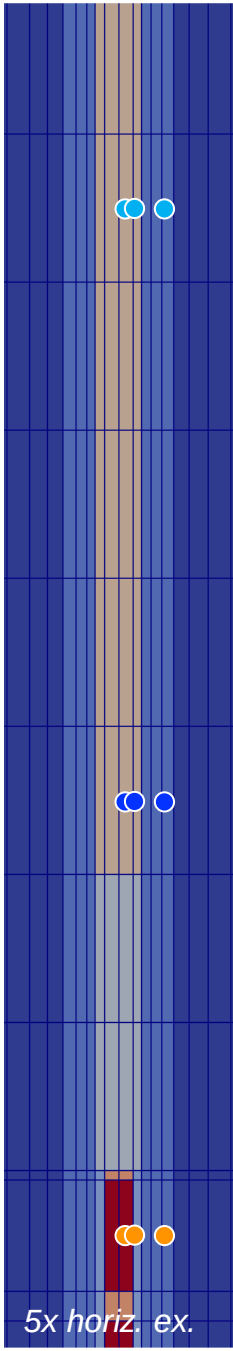






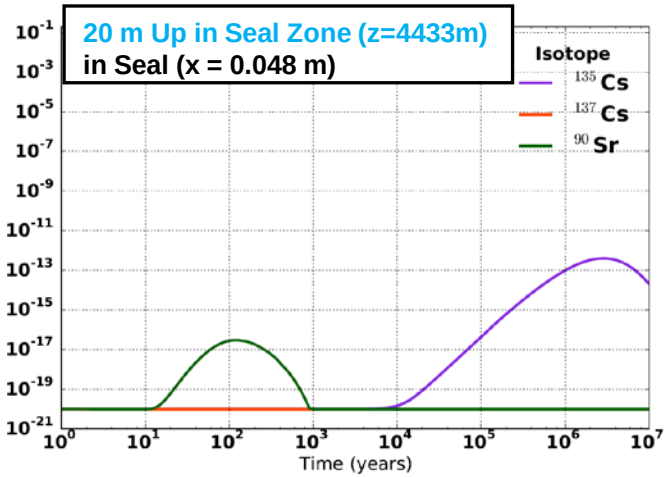
- T peaks ~5 yrs
- q peaks ~10 yrs
- H_2O in DRZ moves <50 m

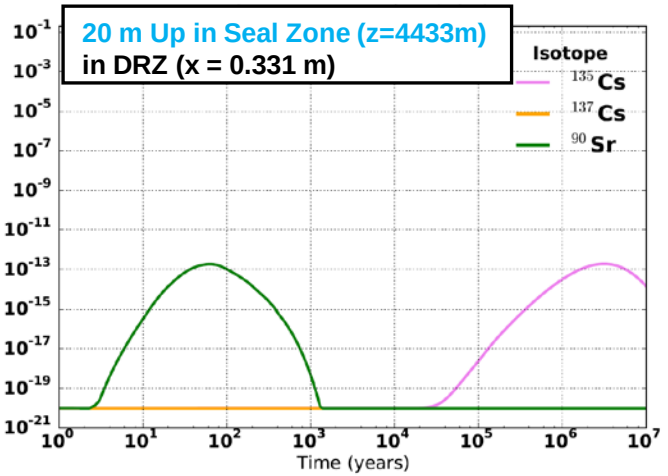
$$\frac{0.01\frac{m}{y} * 50y}{0.01} = 50\ m$$

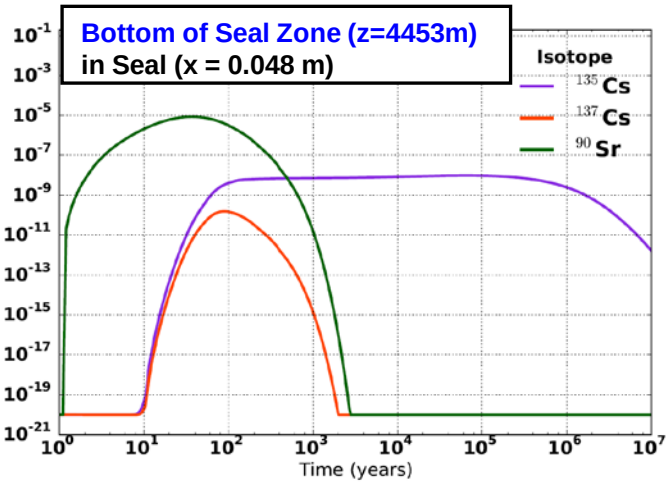


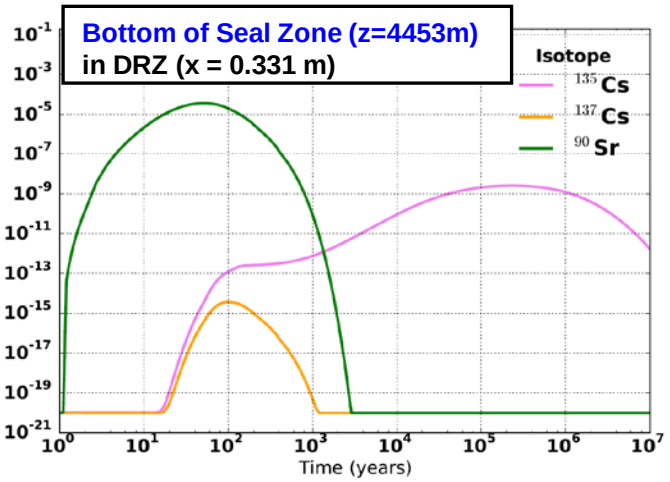
Radionuclide Transport

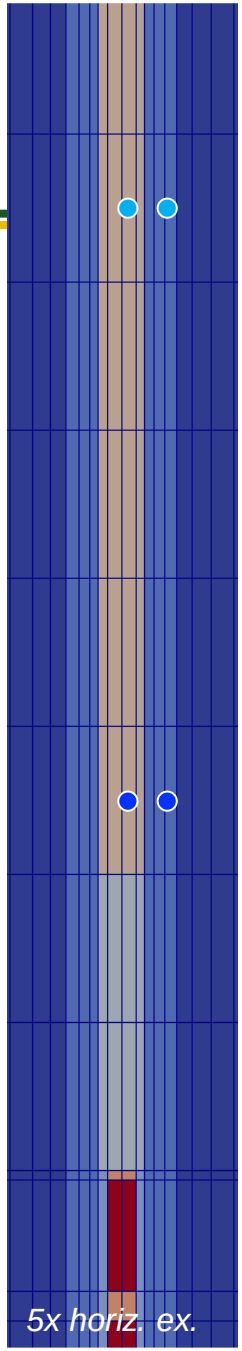
- ^{90}Sr: early arrival from top of EZ, less sorption in SZ, short half-life
- ^{137}Cs: later arrival from bottom of EZ, more sorption in SZ, short half-life
- ^{135}Cs: later arrival from bottom of EZ, more sorption in SZ, long half-life



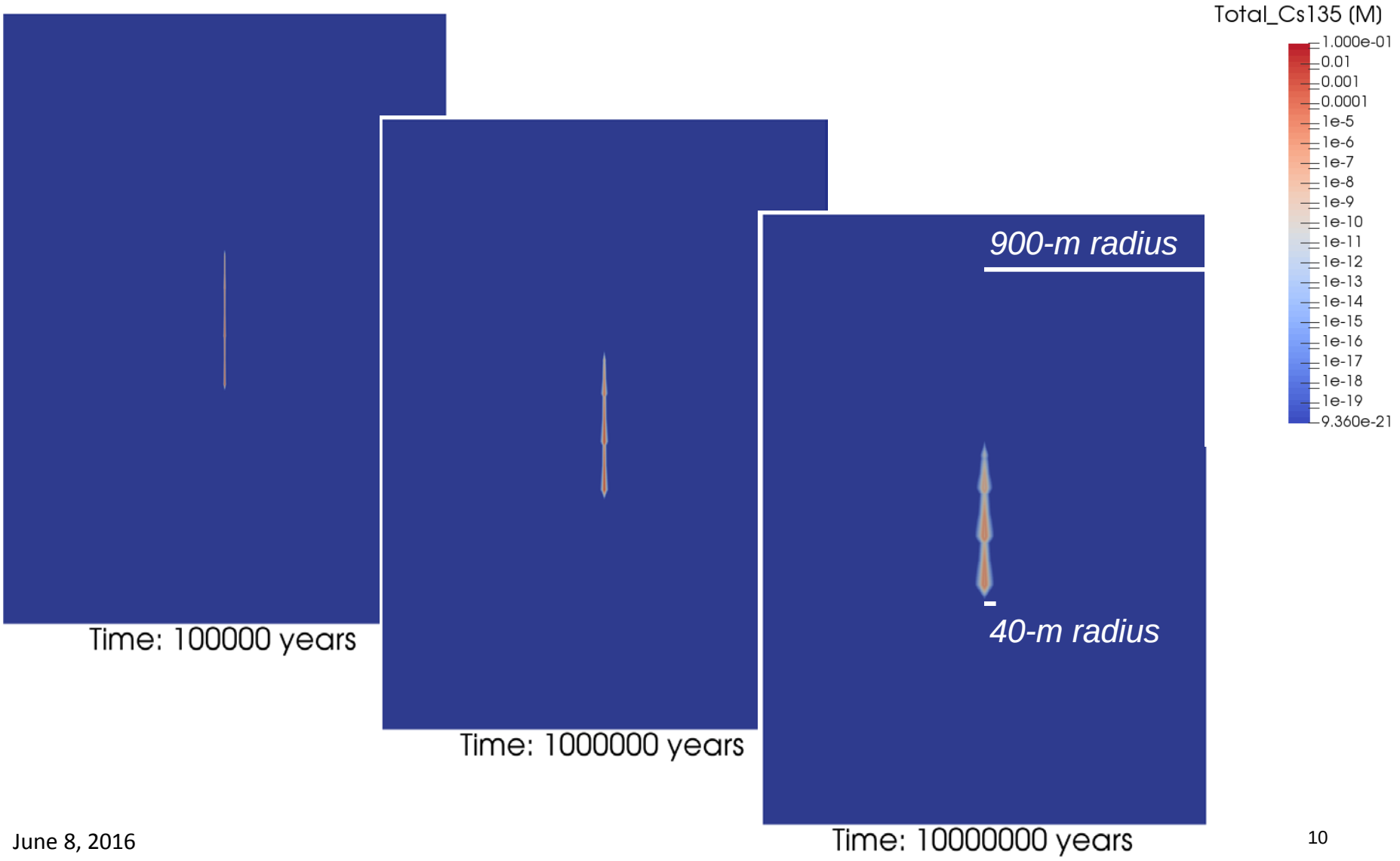








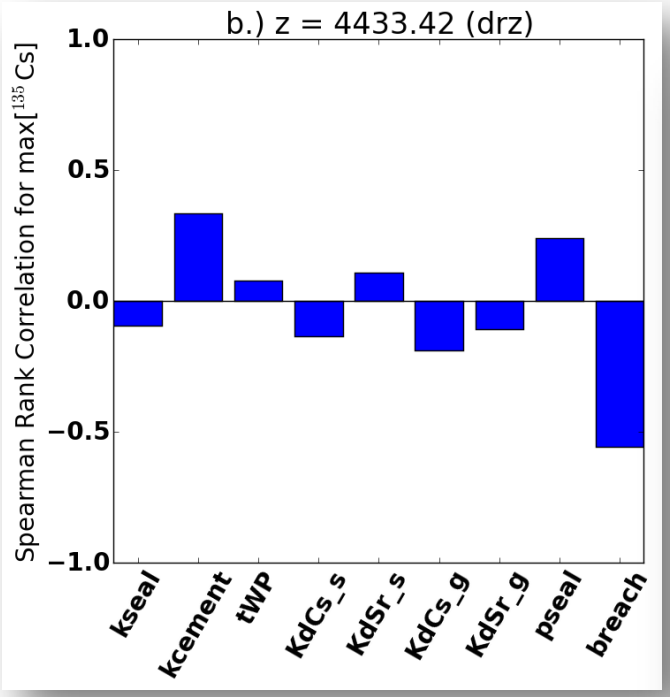
Radionuclide Transport



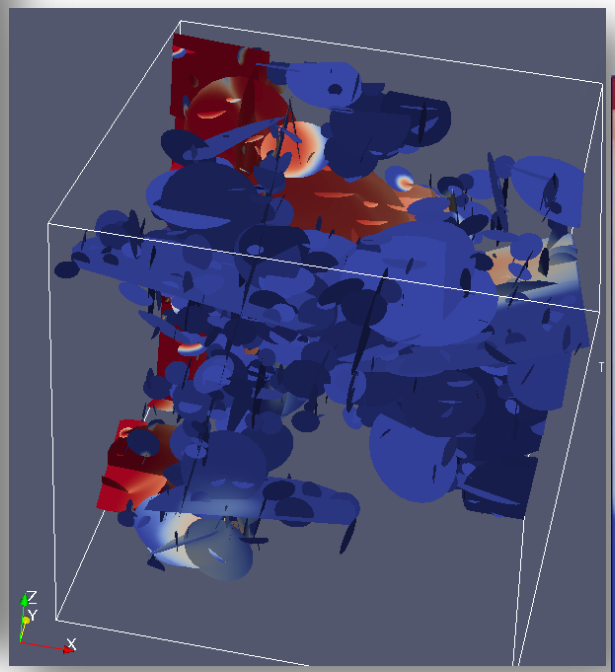
Summary and Next Steps:

- Preliminary results from post-closure PA calculations suggest minimal radionuclide releases beyond the disposal zone and zero dose at biosphere.
- Soon to be implemented PA model enhancements include:

Uncertainty and Sensitivity



High Permeability Pathways



Salinity-Dependent Density