Generic Disposal System Analysis: UZ Reference Case and Preliminary Simulations

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SAND2019-xxxx

SFWD

Spent Fuel & Waste Disposition

Annual Working Group Meeting

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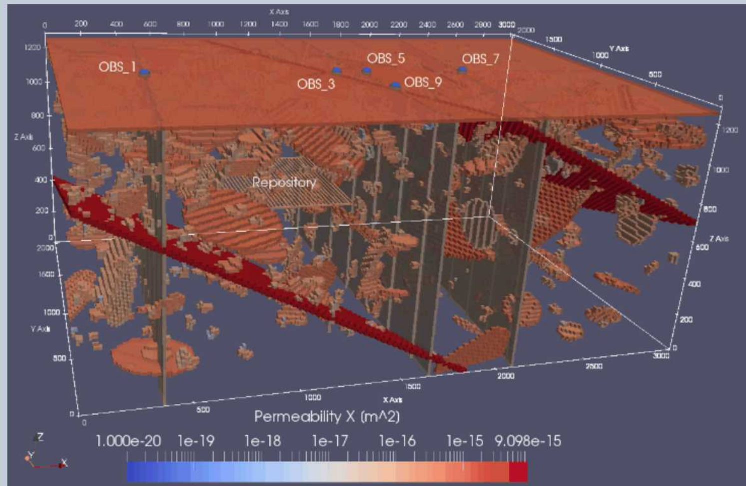
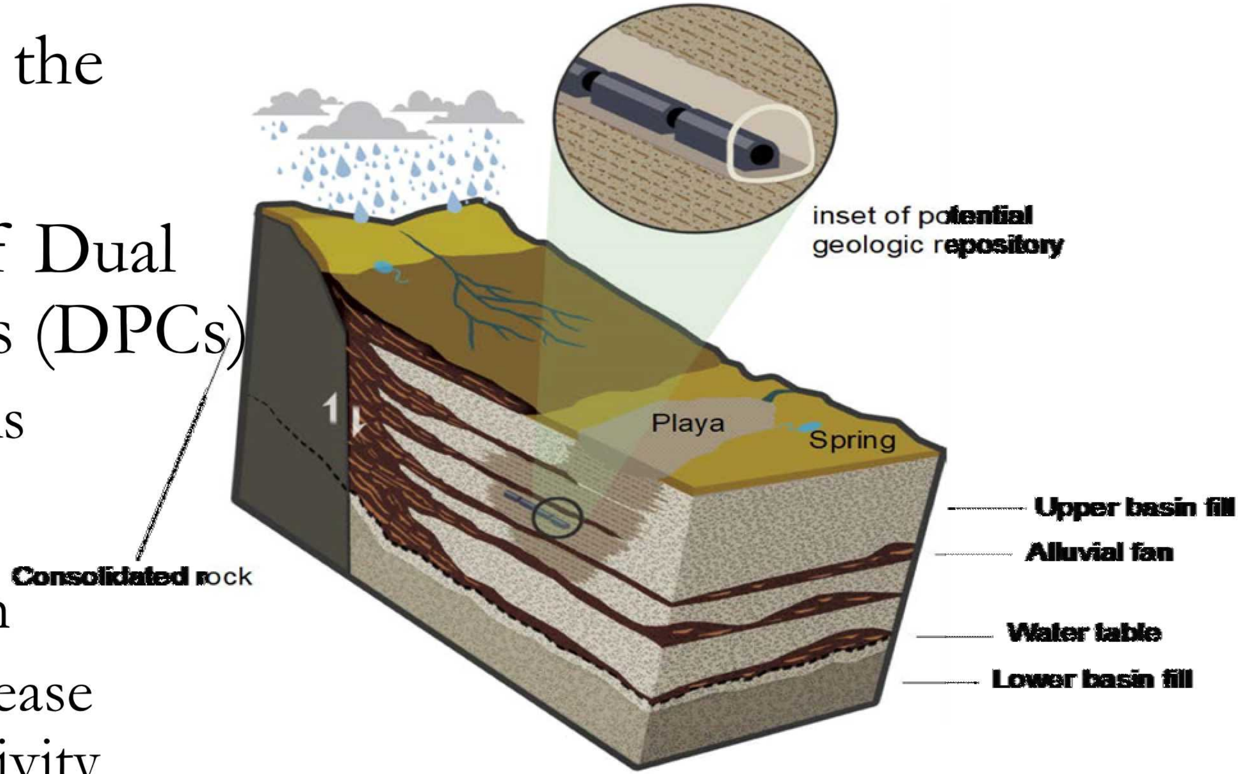
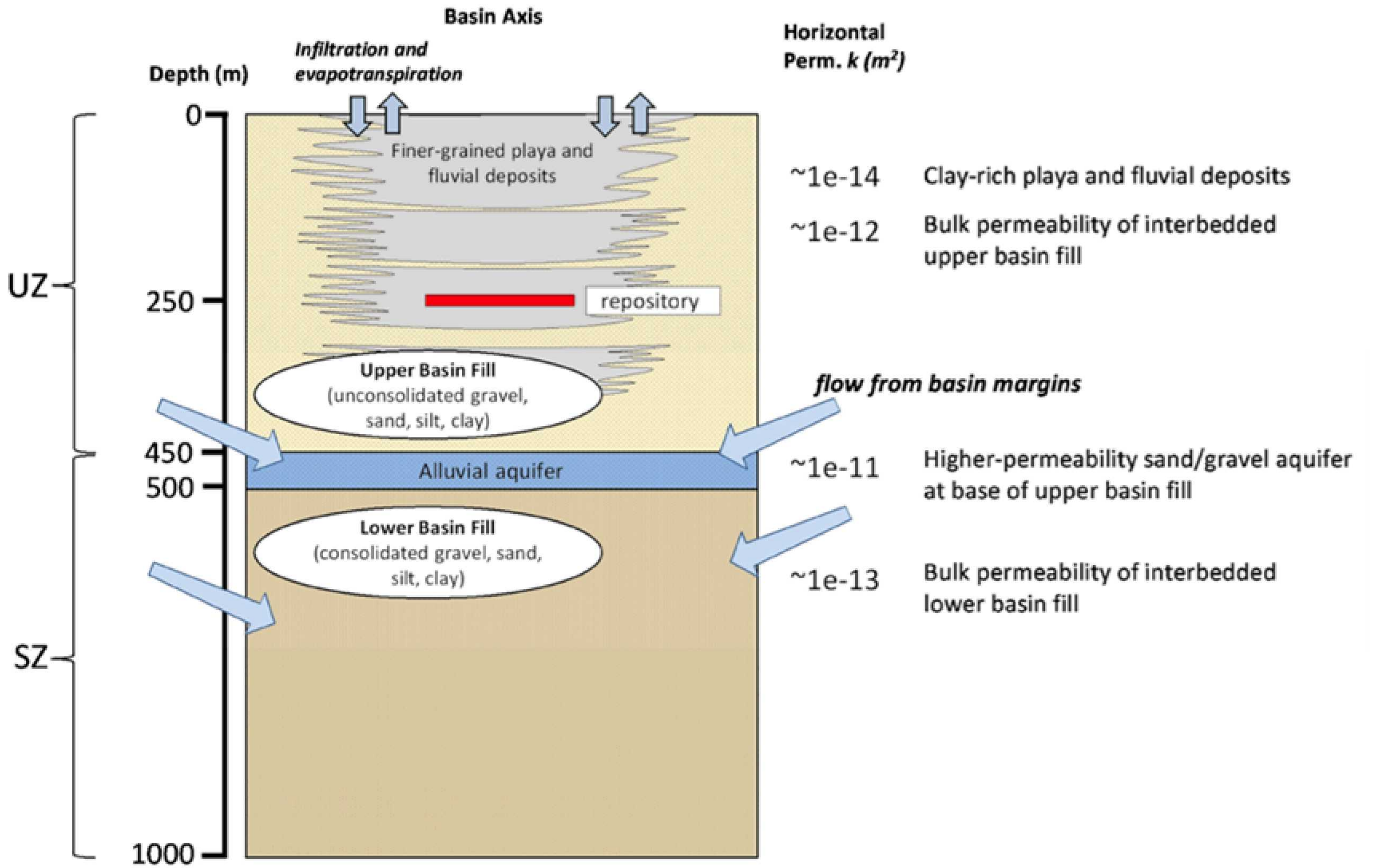


Unsaturated Zone Conceptual Model

- Arid environment w/ little to no infiltration
- Repository above the water table
- Direct disposal of Dual Purpose Canisters (DPCs)
  - 24- and 37-PWRs
- Backfilled drifts
  - crushed alluvium
  - amended to increase thermal conductivity



Natural Barrier System (NBS) Stratigraphy



ERS26

NBS: Host Rock Property Ranges

. Parameter	Value	Reference
Porosity (-)	0.3 – 0.5	Smyth et al. (1979, Table 1); Kwicklis et al. (2006, Table 1)
Thermal conductivity (W/m-K)	0.5 – 1.5	Hardin et al. (2012, Table D-1 and Appendix B)
Permeability (m^2)	5.7×10^{-13} – 3.7×10^{-12}	Cochran et al. (2001, Table 6-15)
Residual moisture content (-)	0.057 – 0.084	Cochran et al. (2001, Table 6-15)
Saturated moisture content (-)	0.33 – 0.41	Cochran et al. (2001, Table 6-15)
van Genuchten,1982 α (cm^{-1})	0.033 – 0.124	Cochran et al. (2001, Table 6-15)
van Genuchten, 1982 m (-)	1.4 – 2.36	Cochran et al. (2001, Table 6-15)
Compressibility (1/Pa)	5.3×10^{-11}	Kilroy (1992, Table 7)

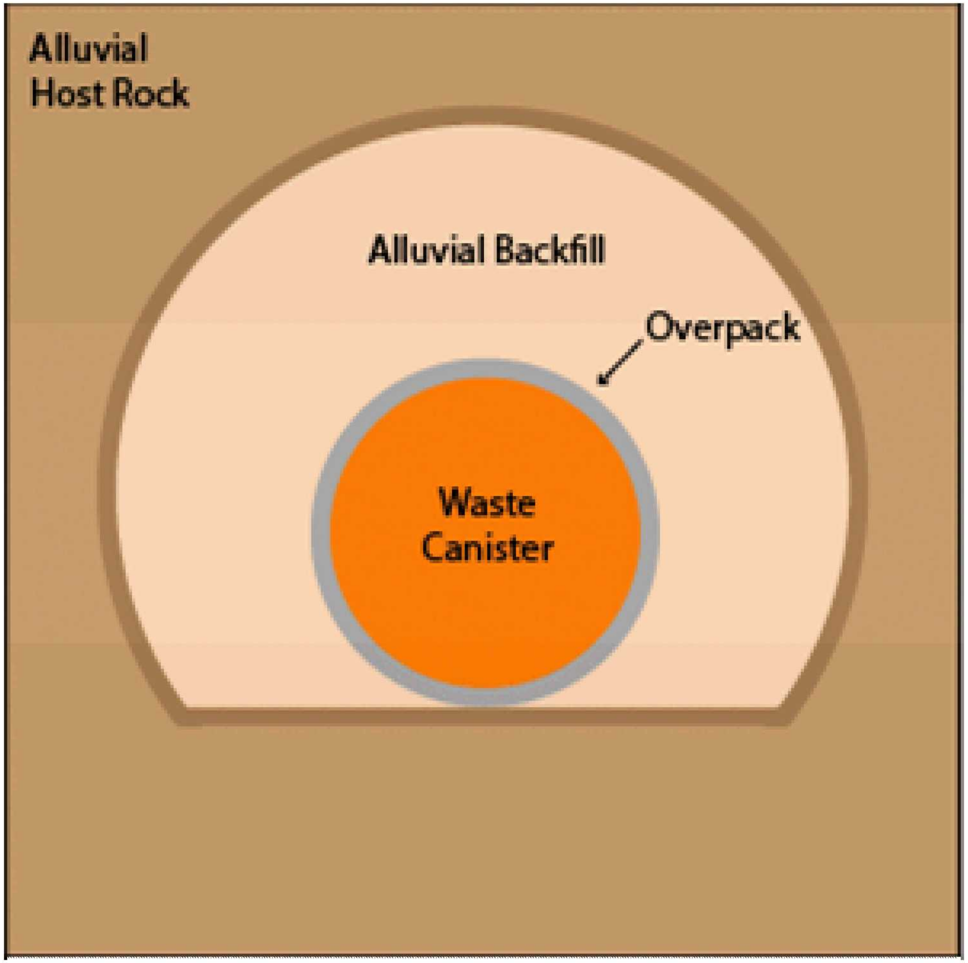
Slide 4

ERS26 This slide isn't 100% necessary and could be deleted if you are worried about time.

Emily Stein, 5/16/2019

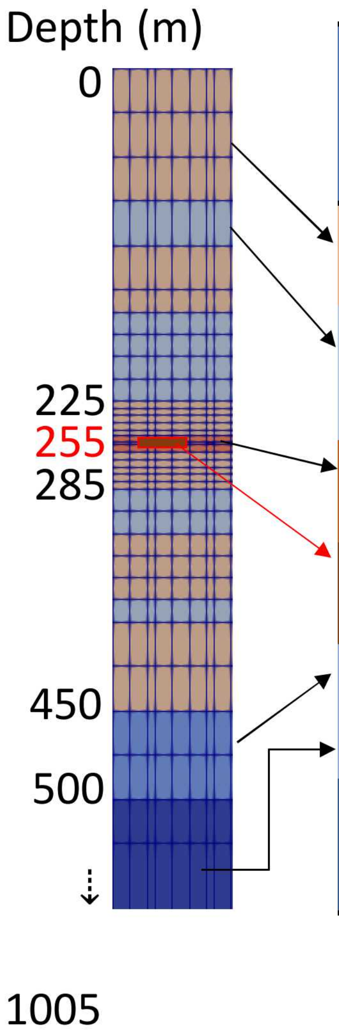
Engineered Barrier System (EBS)

- 24-PWR disposal
  - In-drift axial emplacement
  - 40-m drift spacing
  - 20-m WP spacing
- 37-PWR disposal
  - In-drift axial emplacement
  - 40-m drift spacing
  - 40-m WP spacing
- Both assume
  - Amended crushed alluvium backfill
  - Stainless steel WPs



SSD5 ERS3

EBS and NBS Base-Case Properties



	Permeability (m^2)	Porosity	Compressibility 1/Pa	Saturated Thermal Conductivity (W/m/K)	Unsaturated Thermal Conductivity (W/m/K)
Upper basin fill	1×10^{-12}	0.40	5.3×10^{-11}	2.0	1.0
Upper confining zone	1×10^{-14}	0.40	5.3×10^{-11}	2.0	1.0
Backfill	1×10^{-13}	0.40	5.3×10^{-11}	2.0	2.0
Waste Packages	1×10^{-13}	0.50	0.0	16.7	16.7
Basin fill below water table	1×10^{-11}	0.40	5.3×10^{-11}	2.0	1.0
Confining zone below water table	1×10^{-13}	0.40	5.3×10^{-11}	2.0	1.0

Slide 6

SSD5 Previous slide had a range of values for each parameter. Need to explain why these deterministic values were picked (explain in words during talk).   I guess just a "base case" for testing?

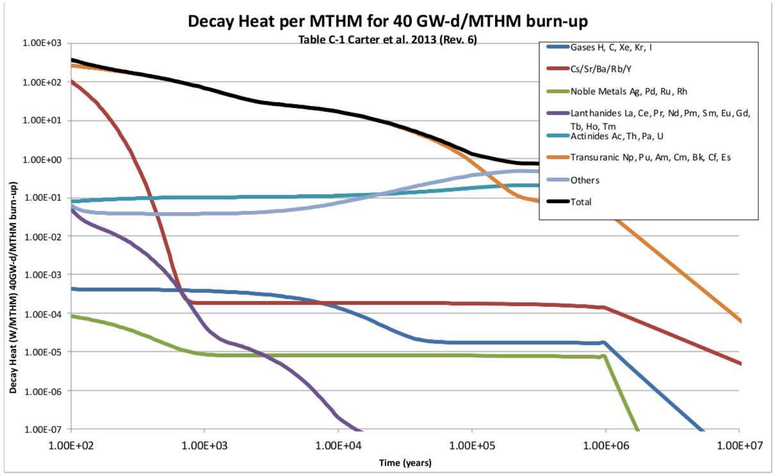
Sevougian, S David, 5/15/2019

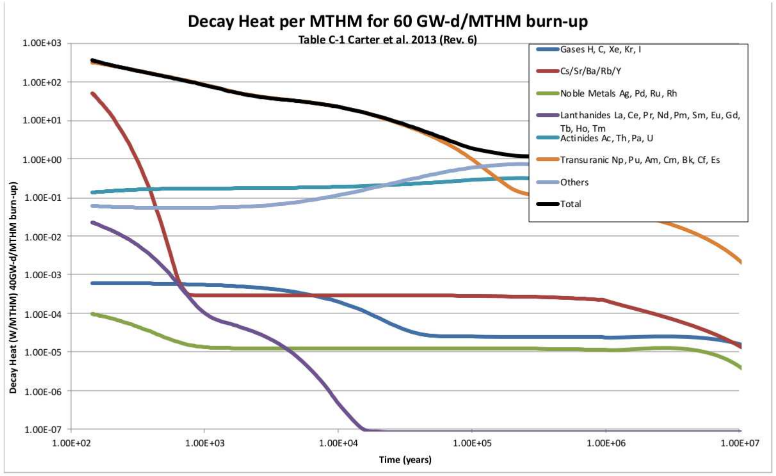
ERS3 The Van Loon and Mibus tortuosity may or may not be a good function to use for alluvial fill. It was fitted to fine-grained sediments. Tortuosity only matters for transport, so I eliminated it.

Emily Stein, 5/16/2019

Waste Package Heat Sources

- 24-PWR DPCs
  - Initial enrichment: 3.72 wt% ^{235}U
  - 40 GWd/MTHM
  - 100 y OoR
  - 10.4 MTHM
  - Initial heat = 3881 W
- 37-PWR DPCs
  - Initial enrichment: 4.73 wt% ^{235}U
  - 60 GWd/MTHM
  - 150 y OoR
  - 16.1 MTHM
  - Initial heat = 5817 W





Calculated from radionuclide inventories in Carter et al. (2013)

37-PWR Near-Field Model

- First run a smaller near-field domain:
  - As a test problem for
    - Strongly coupled TH processes driven by DPC heat output at early times
    - Evaluating the PFLOTRAN multiphase solver options and default convergence-criteria
  - Study spacing of the 37-PWR waste packages along the drift and spacing between drifts
  - Impact of drift backfill properties to prevent undesirably high temperature and/or pressure

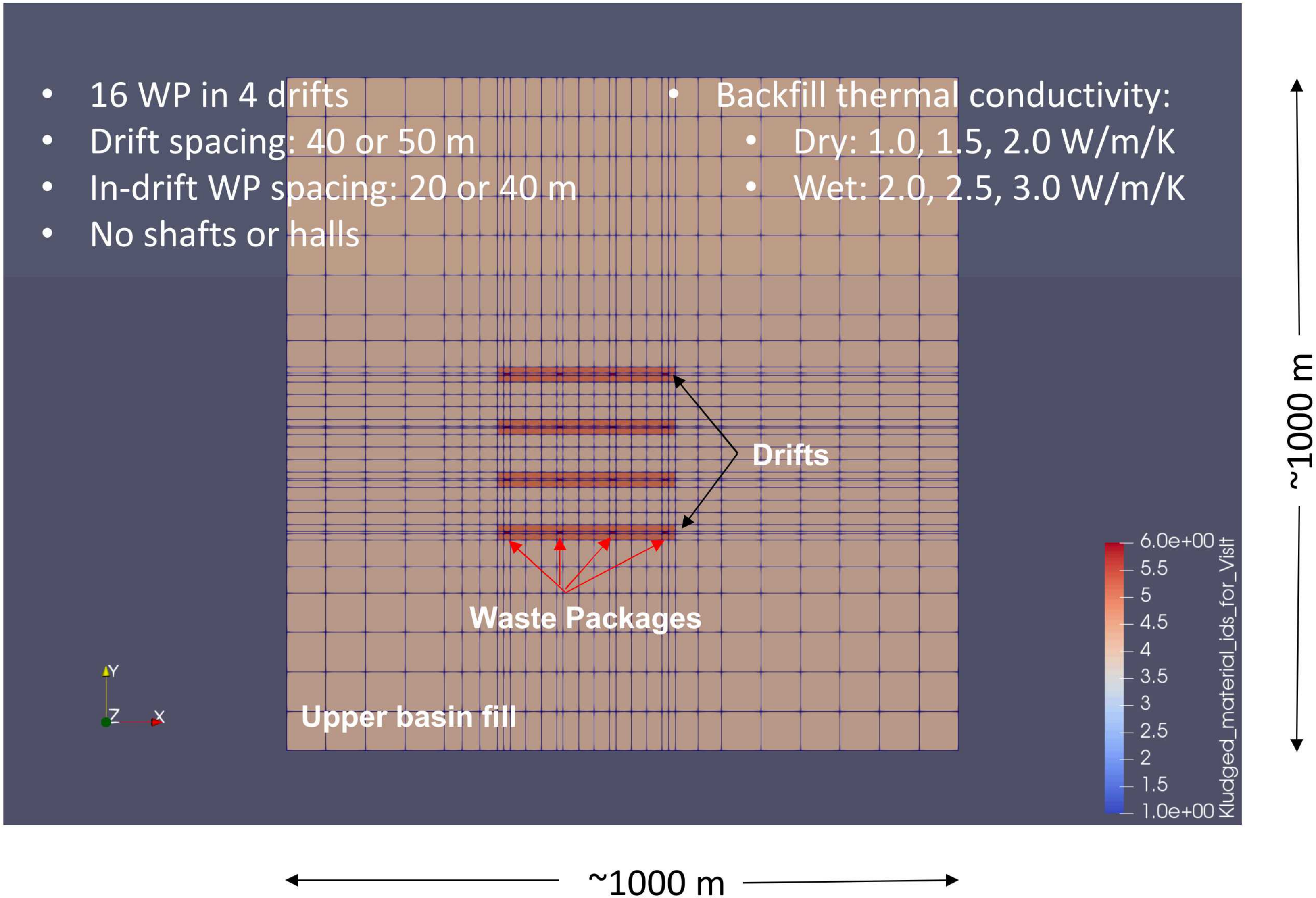
37-PWR Near-Field Model Variables

Parameter	Range	Units
Rock type at repository horizon	Upper basin fill, upper confining zone	$k=1 \times 10^{-12}$ m^2 $k=1 \times 10^{-14}$m^2
Center-to-center WP spacing	20, 40	m
Drift spacing	40, 50	m
Dry thermal conductivity of backfill	1.0, 1.5, 2.0	(W/m/K)
Wet thermal conductivity of backfill	2.0, 2.5, 3.0	(W/m/K)
Drift/backfill permeability	1×10^{-11}, 1×10^{-12}, 1×10^{-13}, 1×10^{-14}	m^2

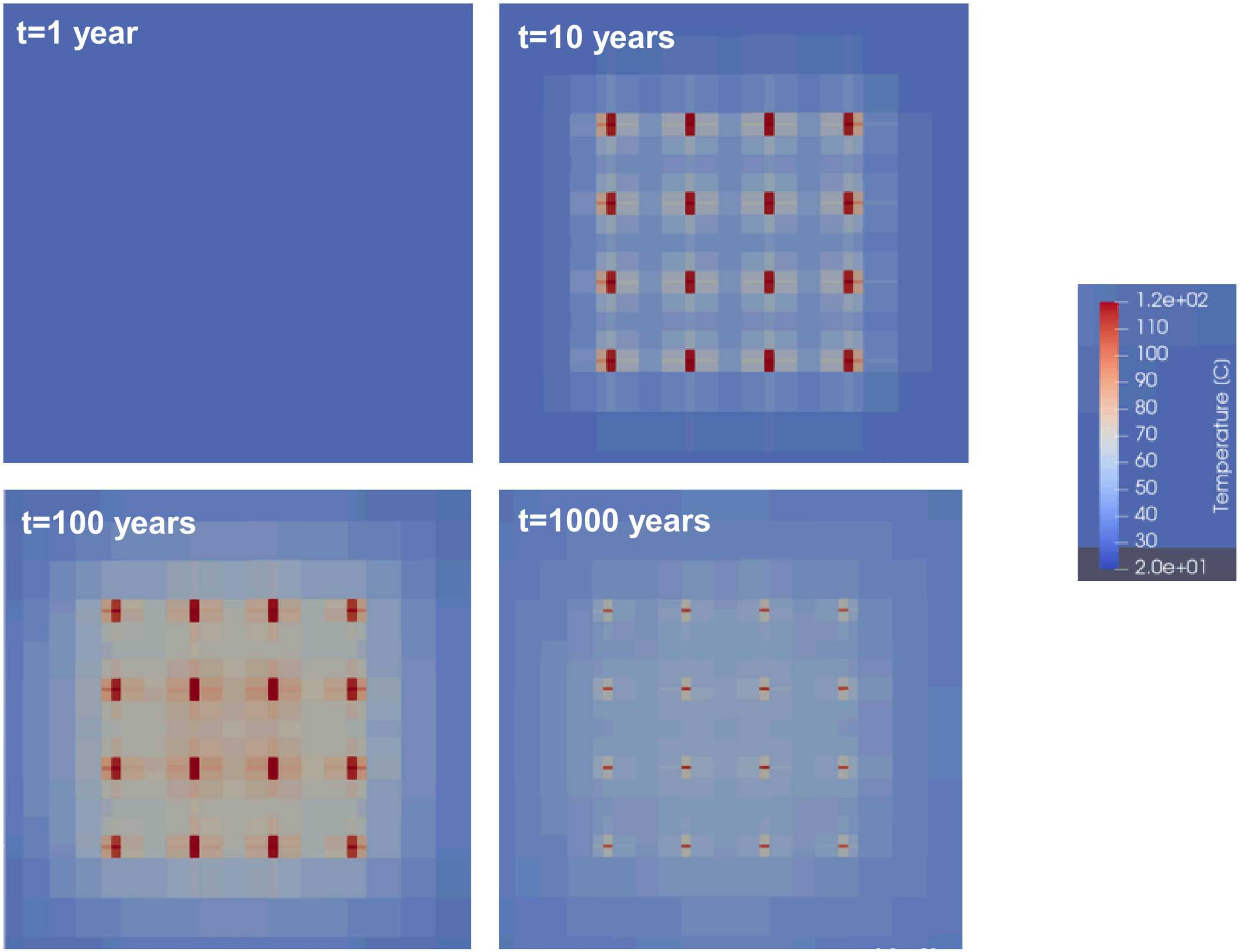
Layout: 37-PWR Near-Field Model

- 16 WP in 4 drifts
- Drift spacing: 40 or 50 m
- In-drift WP spacing: 20 or 40 m
- No shafts or halls

- Backfill thermal conductivity:
  - Dry: 1.0, 1.5, 2.0 W/m/K
  - Wet: 2.0, 2.5, 3.0 W/m/K

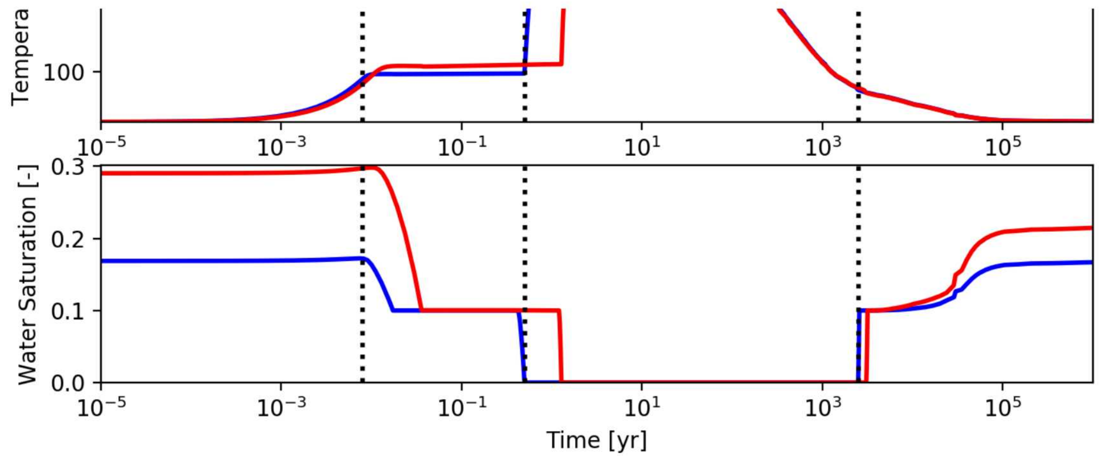


RESULTS: 37-PWR NEAR-FIELD MODEL



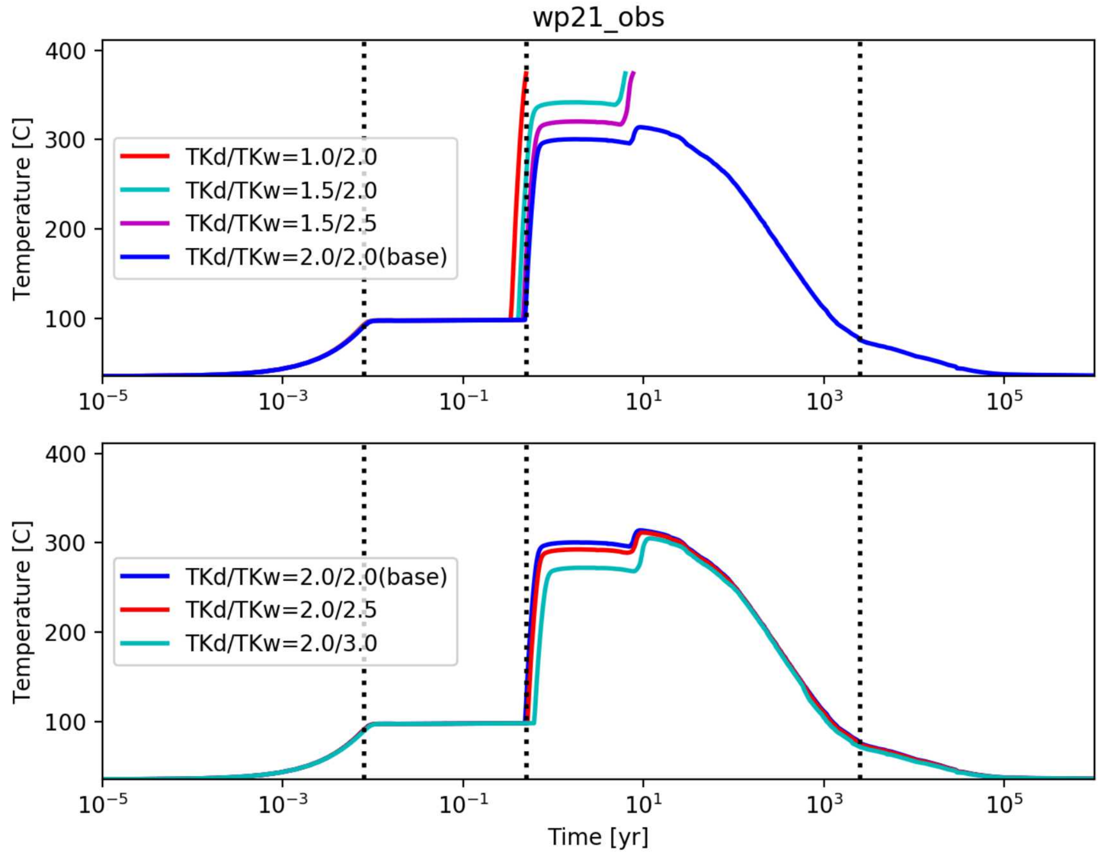
RESULTS: 37-PWR NEAR-FIELD MODEL

basin fill



Pressure (top), Temperature (middle) and Water Saturation (bottom) inside the centermost waste package as a function of log time with the repository located in the upper basin fill (blue) and in the confining zone (red)

RESULTS: 37-PWR NEAR-FIELD MODEL



Temperature at the hottest waste package for a series of dry (top) and wet (bottom) thermal conductivities as a function of log time. Simulations stop if the critical temperature of water (374°C) is reached.

Slide 13

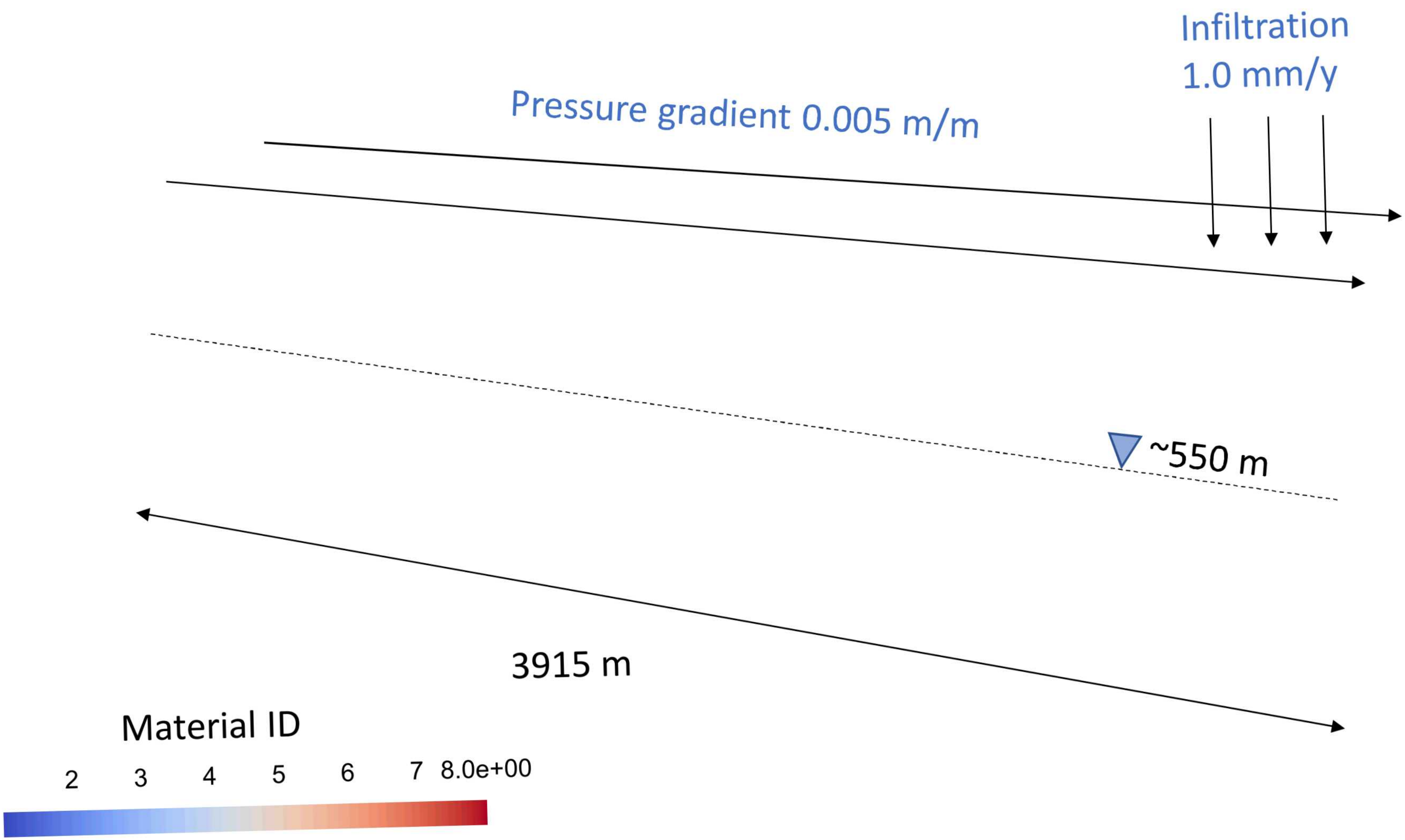
ERS18 I suggest practicing this slide so that you can explain stopping at critical T of water without having to explain that PFLOTRAN equation of state has improved since you ran the simulation.

Emily Stein, 5/16/2019

24-PWR Site-Scale Model

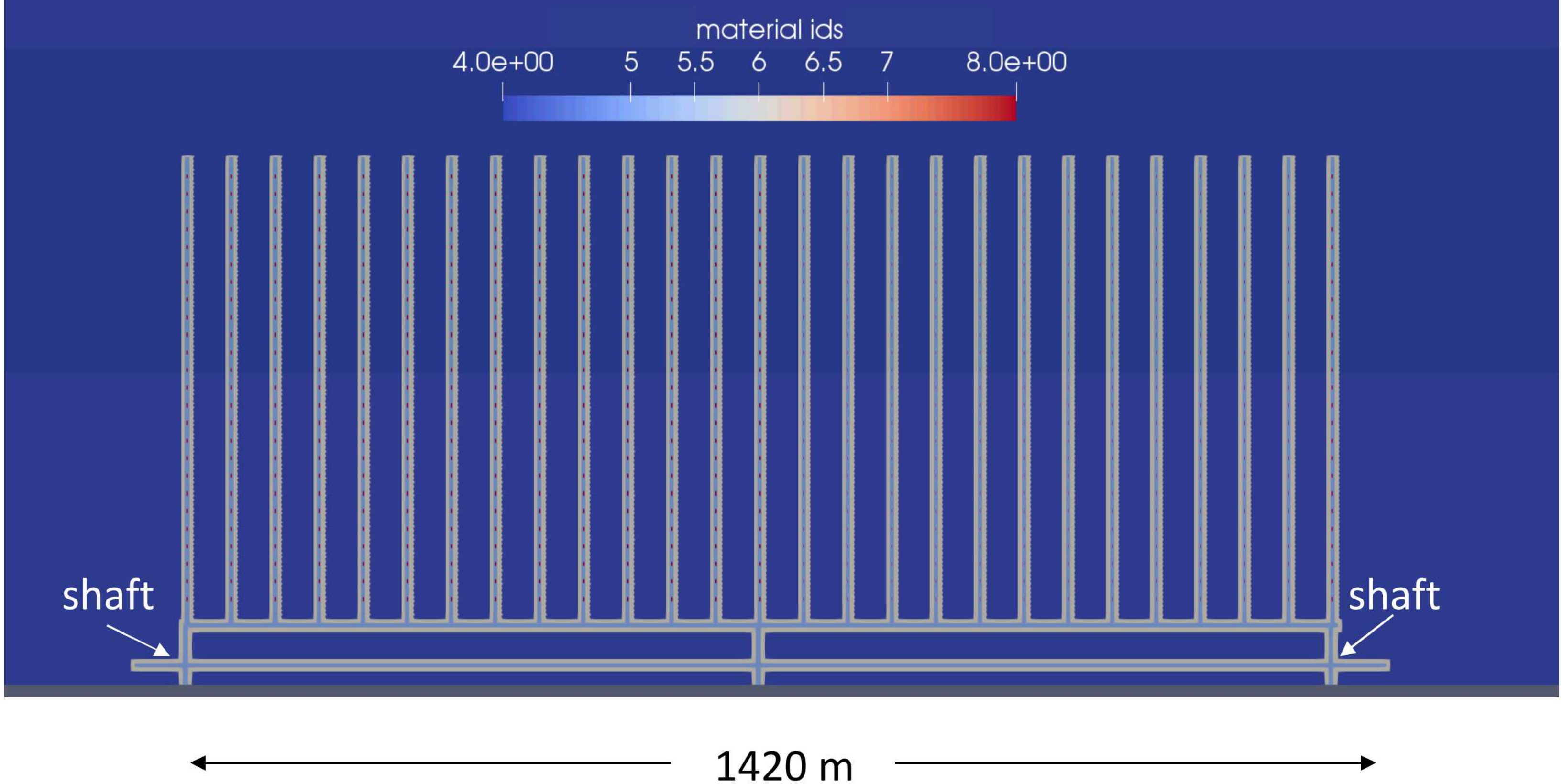
- Develop state-of-the-art PFLOTRAN's multiphase mode for Performance Assessment simulations
- Two simulation meshes
  - Coarse:
    - 214,000 cells without damage zone and some flexing of the halls away from the drifts
    - Very coarse away from repository, not suitable for transport
    - 16 core simulation
  - Fine:
    - 2.4 million cells including damage zone and shafts
    - Mesh is suitable for reactive transport modelling
    - 256 core simulation
- All parameters identical to base-case near-field model

24-PWR Site-Scale Model Domain

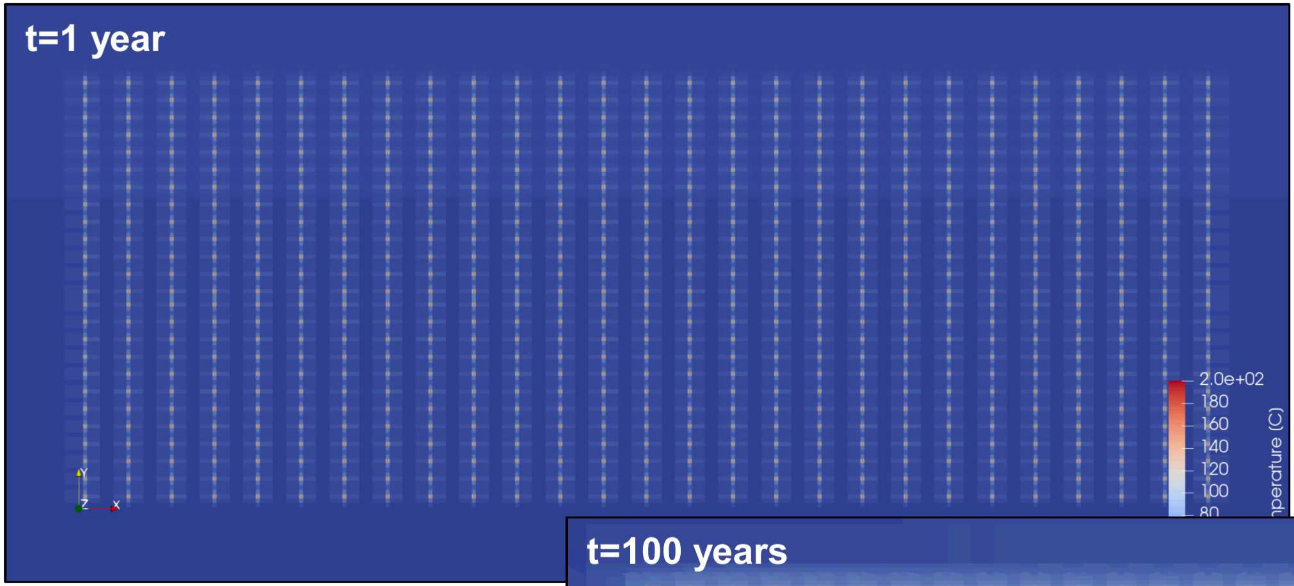


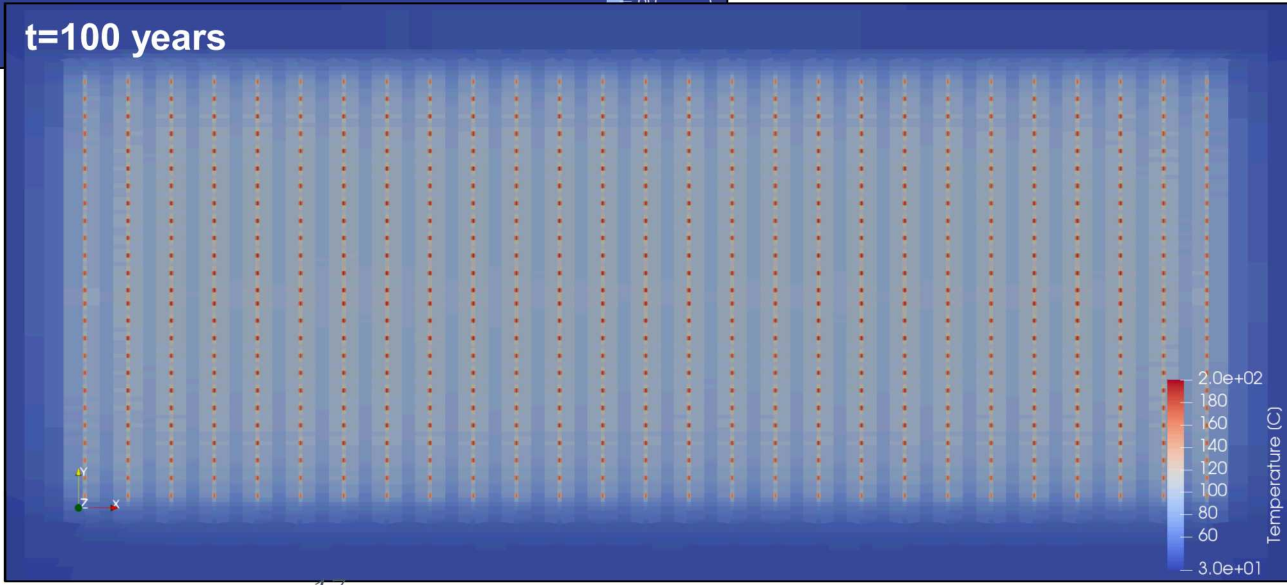
Repository Layout

- Half-symmetry domain
  - 27 530-m drifts
  - 25 WPs / drift
  - 675 WPs
  - 24 PWR: 7,020 MTHM
- Reflected
  - 54 530-m drifts
  - 25 WPs / drift
  - 1350 WPs
  - 24 PWR: 14,040 MTHM

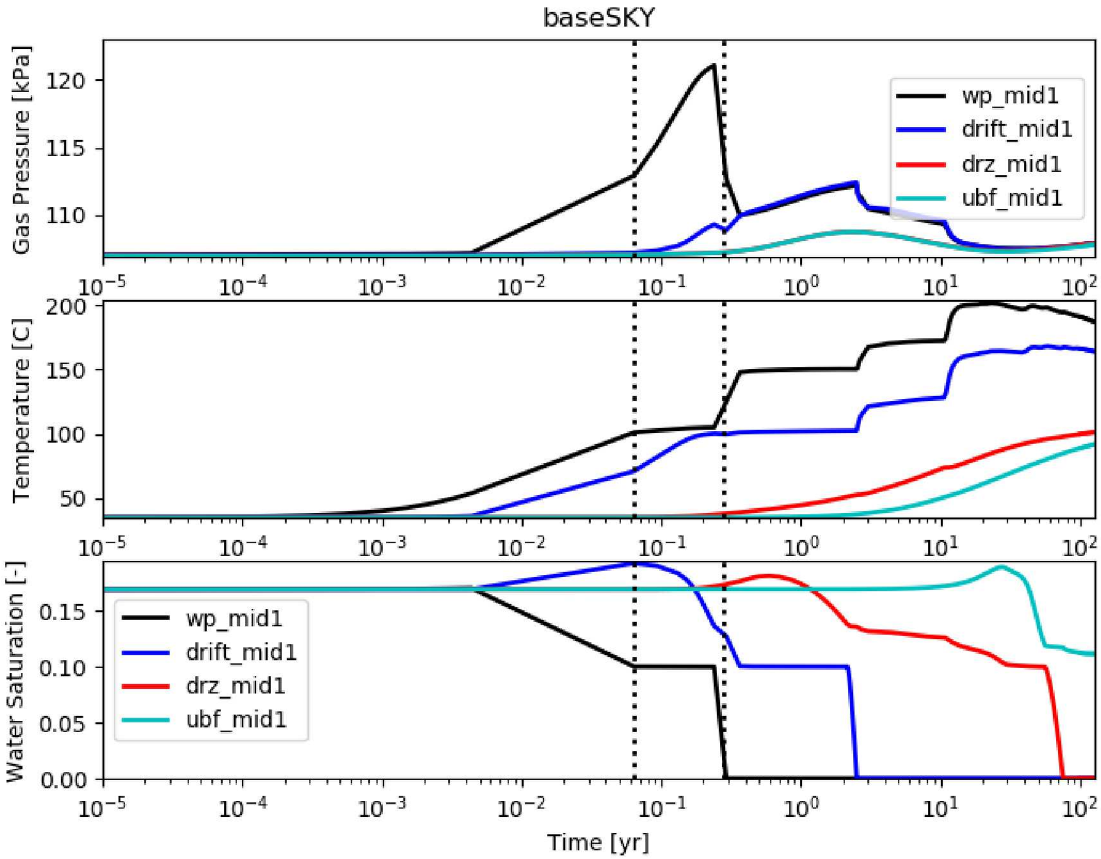


Temperature: 24-PWR Coarse Model





RESULTS: 24-PWR COARSE MODEL



Pressure (top), Temperature (middle) and Water Saturation (bottom) near the centermost waste package as a function of log time. Values in the waste package are shown in black, in the drift next to the waste package is blue, just outside the drift is red, and the midpoint between the drift and the next drift east is cyan.

Status of UZ Reference Case

- On-going simulations are informing the development of the UZ reference case
- Two models have been run:
  - Near-field 37-PWR model for 1 million years
    - Engineered backfill will be required to keep temperatures below 300^{o}C
    - Advantageous to have repository in higher-permeability region of the formation to mitigate thermal overpressuring
  - Site-scale 24-PWR model for a few hundred years
    - Temperatures increase very rapidly in the drifts
    - Sustained high temperatures resulting in dried-out zone propagating into the formation
- Future work:
  - Accelerate simulations
  - Radionuclide transport

QUESTIONS?

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