U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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THE PEÑA BLANCA NATURAL ANALOGUE MODEL

Presented to:

Appendix 7 Meeting on Peña Blanca Natural Analogue Studies

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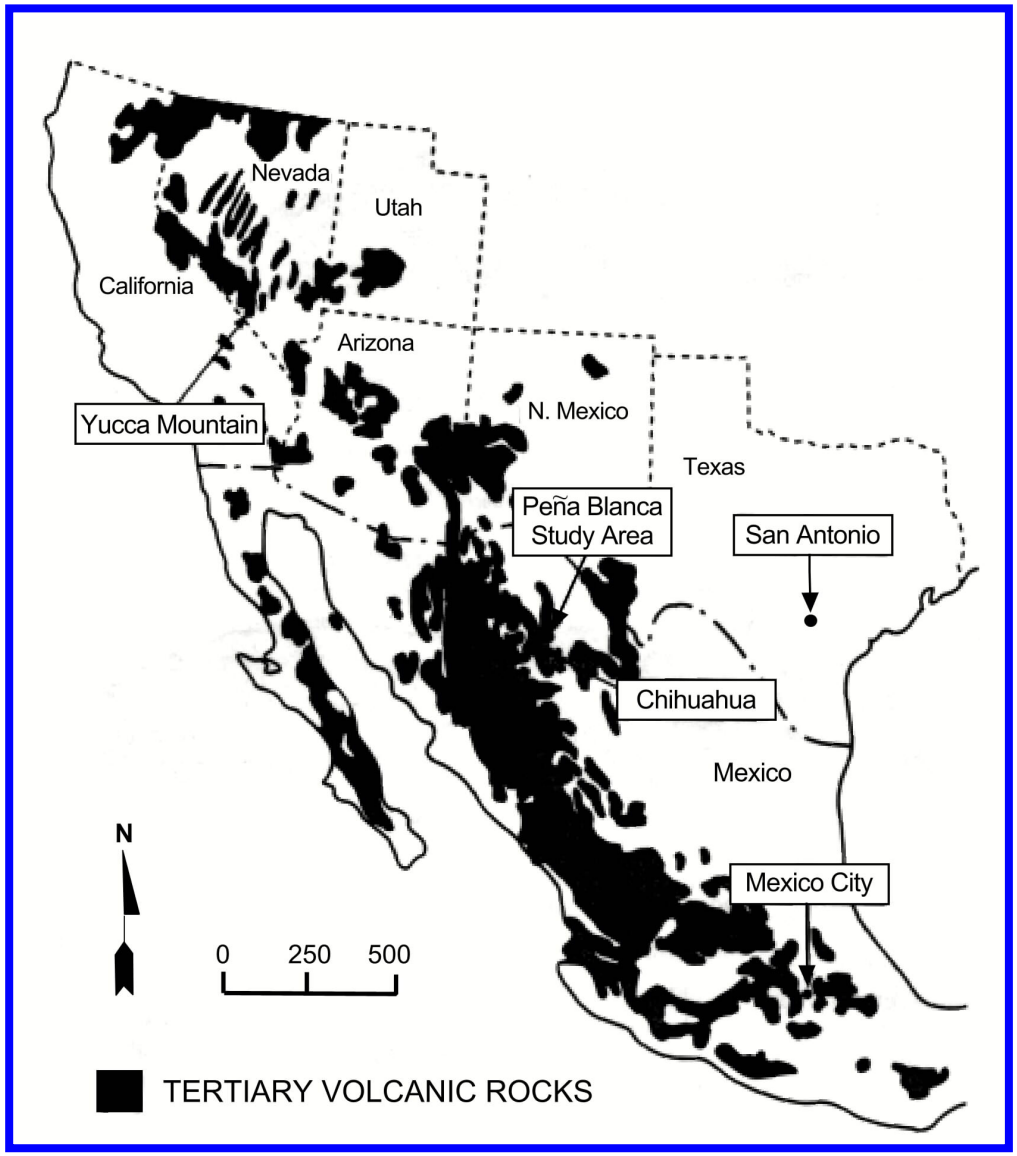
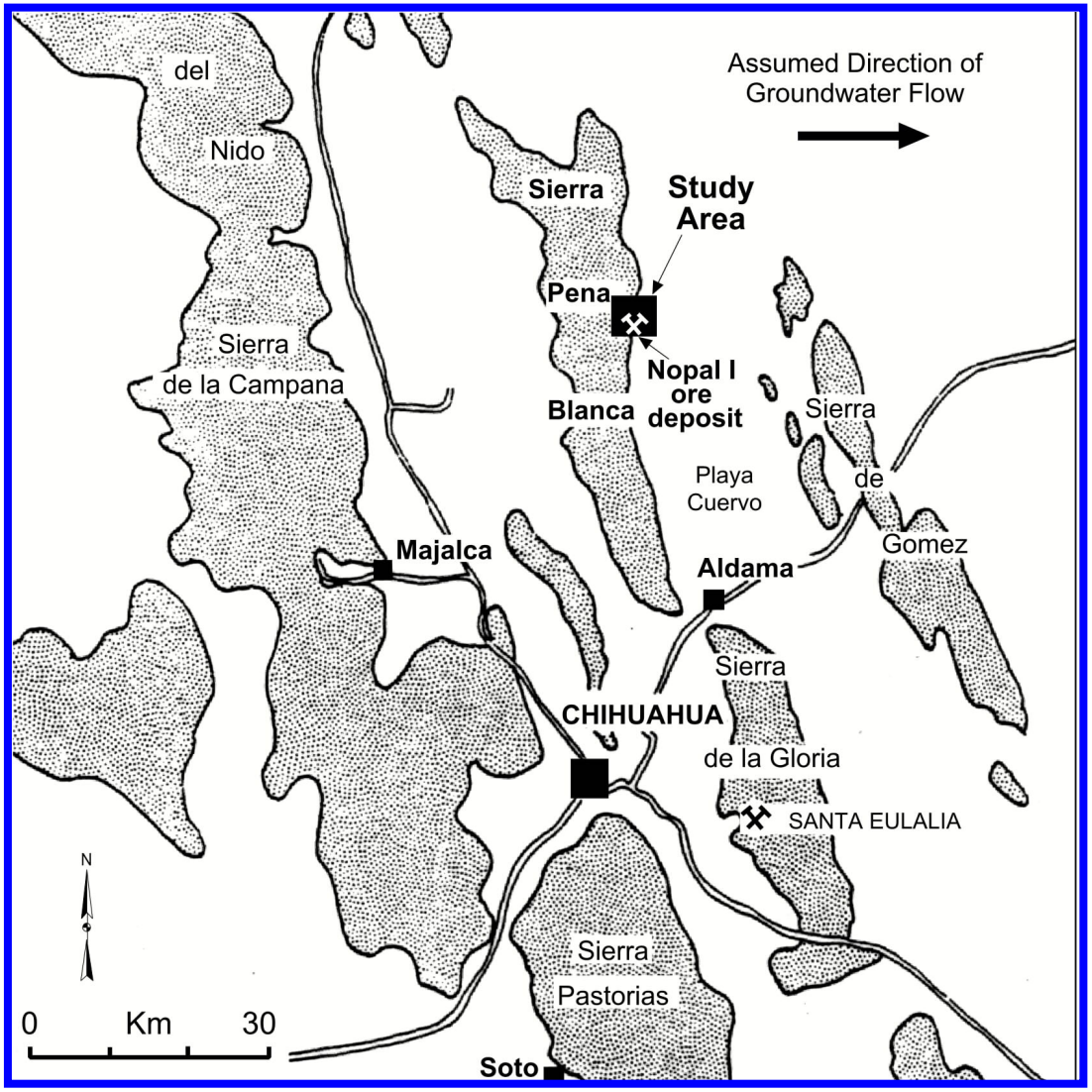
WHY A YUCCA MOUNTAIN ANALOGUE?

- Analogous site: UO_2 uranium ore deposit = spent nuclear fuel in the repository
- Analogous geology: (i.e., Fractured, welded, and altered rhyolitic ash-flow tuffs)
- Analogous climate: Semi-arid to arid
- Analogous setting: Volcanic tuffs overlie carbonate rocks
- Analogous geochemistry: Oxidizing conditions
- Analogous hydrogeology: Ore deposit lies in the unsaturated zone well above water table

Location of the Peña Blanca Mining District



LOCATION OF THE NOPAL I URANIUM MINE



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VIEW SOUTHEAST FROM ABOVE +10 M LEVEL, NOPAL I

OBJECTIVES

- Develop a Total System Performance Assessment (TSPA) Model for the Peña Blanca Nopal I site
- Calibrate Peña Blanca Natural Analogue Model and compare predicted concentrations of uranium to observations at Nopal I, Peña Blanca
- Assist in building confidence in the modeling of total system performance of the Yucca Mountain repository

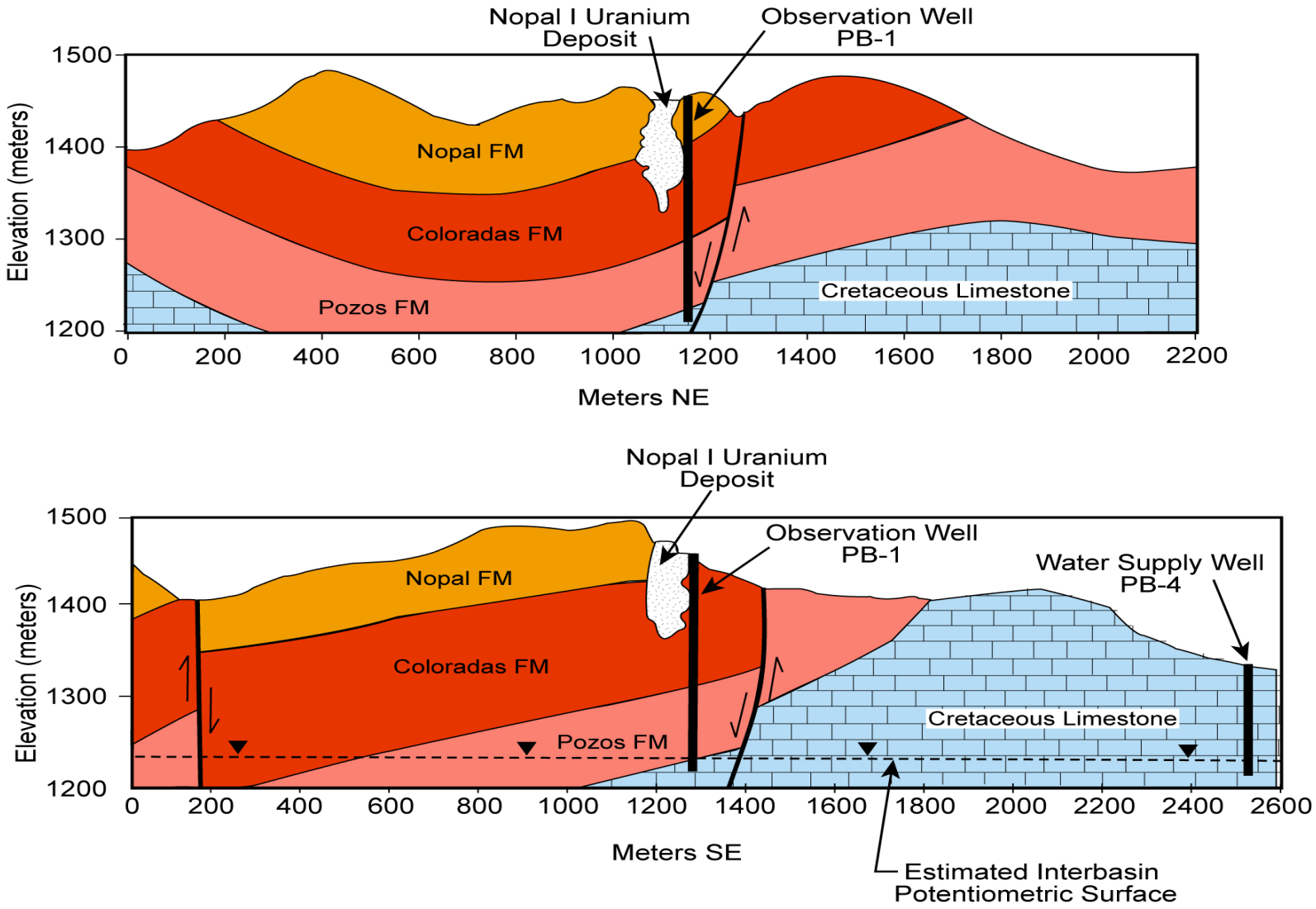
PROCESS

- Develop a TSPA Model analogous to performance assessment models developed for the Yucca Mountain repository site
- Utilize probabilistic simulations to estimate the outcomes of hydrogeologic processes operating at the Nopal I site
- Perform model simulations using available data and field observations from ongoing investigations at Nopal I

HYDROGELOGIC SETTING

- Fractured, welded rhyolitic ash-flow tuffs
- Arid climate
- Volcanic tuffs overlie carbonate rocks
- Nopal I ore deposit exposed to oxidizing conditions for 3.2 to 3.4 my
- The Nopal I ore deposit lies in the unsaturated zone above the water table

HYDROGELOGIC SETTING



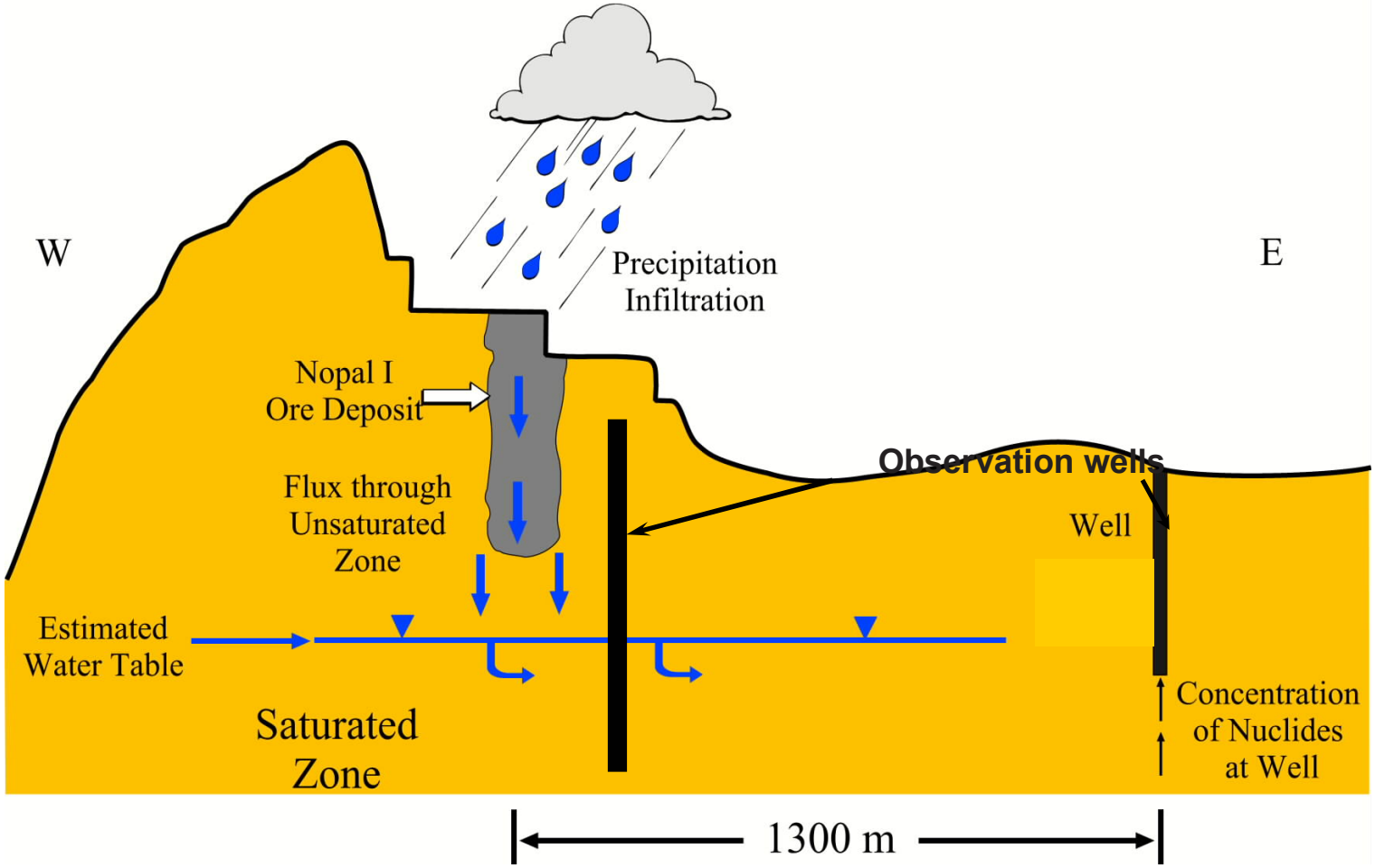
CONCEPTUAL MODEL

- Nopal I ore deposit exposed to oxidation for ~3 million years
- Nopal I ore deposit extends from land surface to a depth of ~120 m, ~130 m above saturated zone
- Percolation of recharge through Nopal I ore deposit is the primary means of release of radionuclides

CONCEPTUAL MODEL (cont'd)

- Simulate dissolution and release of uranium using the Yucca Mountain TSPA spent-fuel dissolution model
- Generate and release of three uranium species, technetium-99, and thorium
- Assume the Nopal I source term consists of two cells analogous to two waste packages containing uranium oxide
- Use a defined steady-state dissolution rate

CONCEPTUAL MODEL (cont'd)



MODEL PARAMETERS & ASSUMPTIONS

- **Nopal I ore deposit consists of 408 metric tons uraninite, an analogue to commercial spent nuclear fuel**
- **Ore deposit is a idealized as a vertically oriented ovoid cylinder 18 x 30 x 100 meters**
- **Peña Blanca Natural Analogue Model for Nopal I assumes percolation = infiltration at 6 mm/yr or 3.24 m^3/yr**

MODEL PARAMETERS & ASSUMPTIONS

- Assume groundwater flows generally west to east
- Hydraulic parameters of ore deposit
- Porosity 0.075 (unaltered) to 0.30 (altered)
- K_d Tc-99 = 0
- K_d U, varied between 0 and 1

RADIONUCLIDE INVENTORY

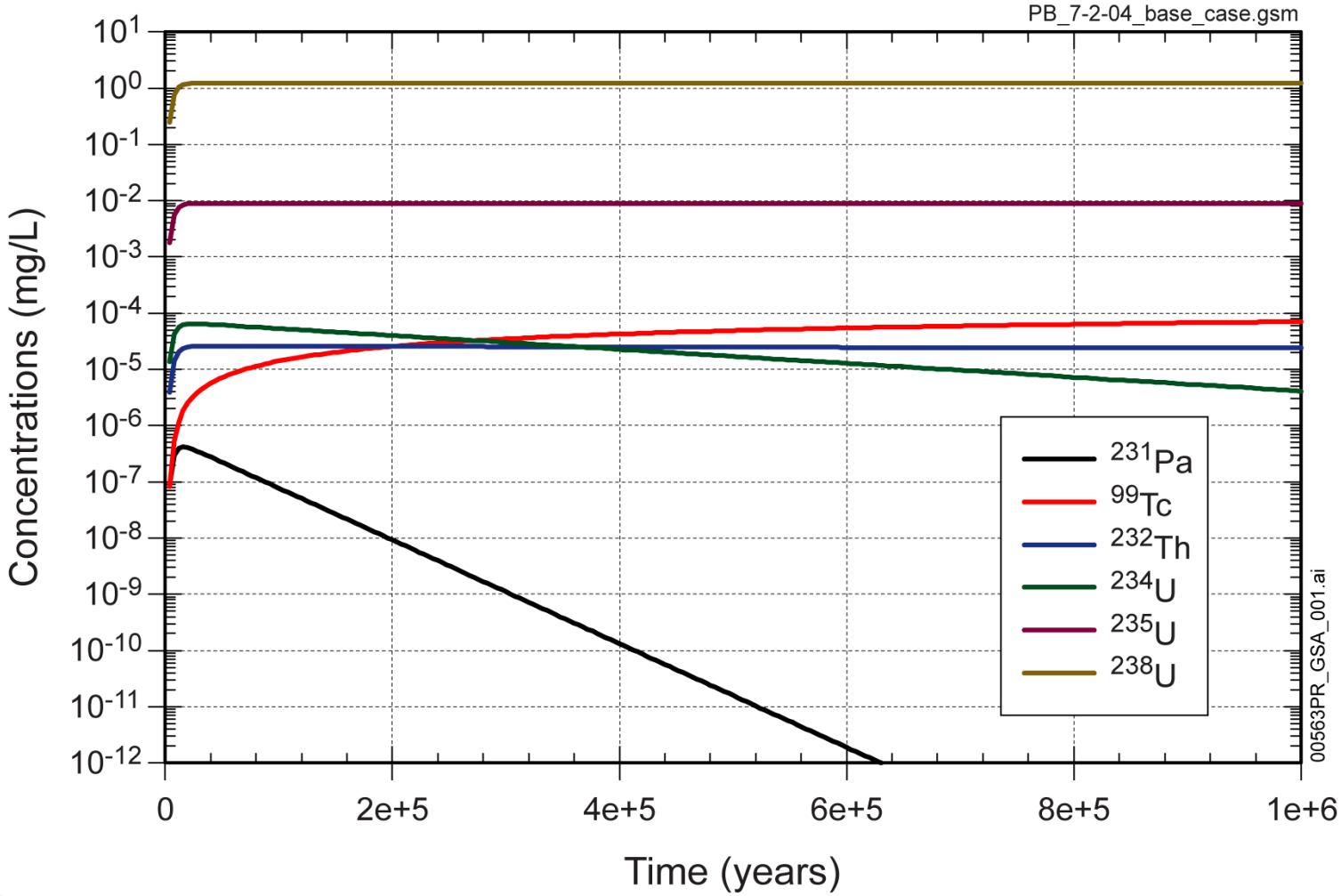
- Estimates based on 99.5% uranium-238
- Extrapolations from vegetation study (Leslie et al., 1999)
- Technetium from Curtis et al., (1999)
  - Tc-99 = 0.025 atoms/min/g U-238
  - Tc-99/U-238 = 1.57 E-12
- Radioactive decay assumed for radionuclides
- Radium based on site investigations

PEÑA BLANCA NATURAL ANALOGUE MODEL RESULTS

- Base case simulations estimated dissolved concentrations of Tc-99 and uranium in the saturated zone beneath the Nopal I ore deposit
- Results sensitive to uranium solubility, infiltration rate, surface area available for dissolution, and K_d
- Observed concentrations bracketed by the range of Peña Blanca Natural Analogue Model Results, within the uncertainty of the source-term dissolution parameters

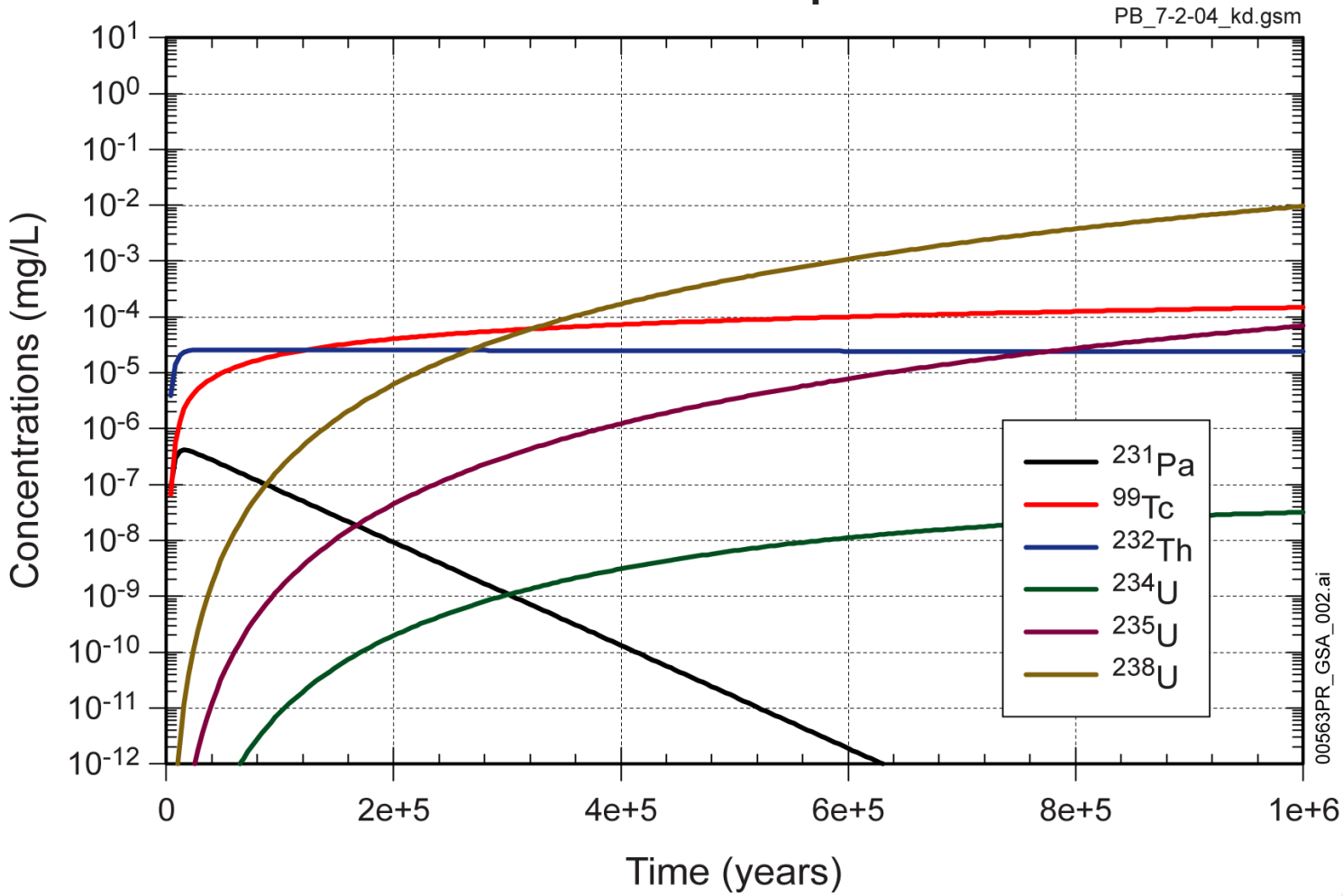
PEÑA BLANCA NATURAL ANALOGUE MODEL RESULTS

Calculated radionuclide concentrations directly beneath the Nopal I ore deposit



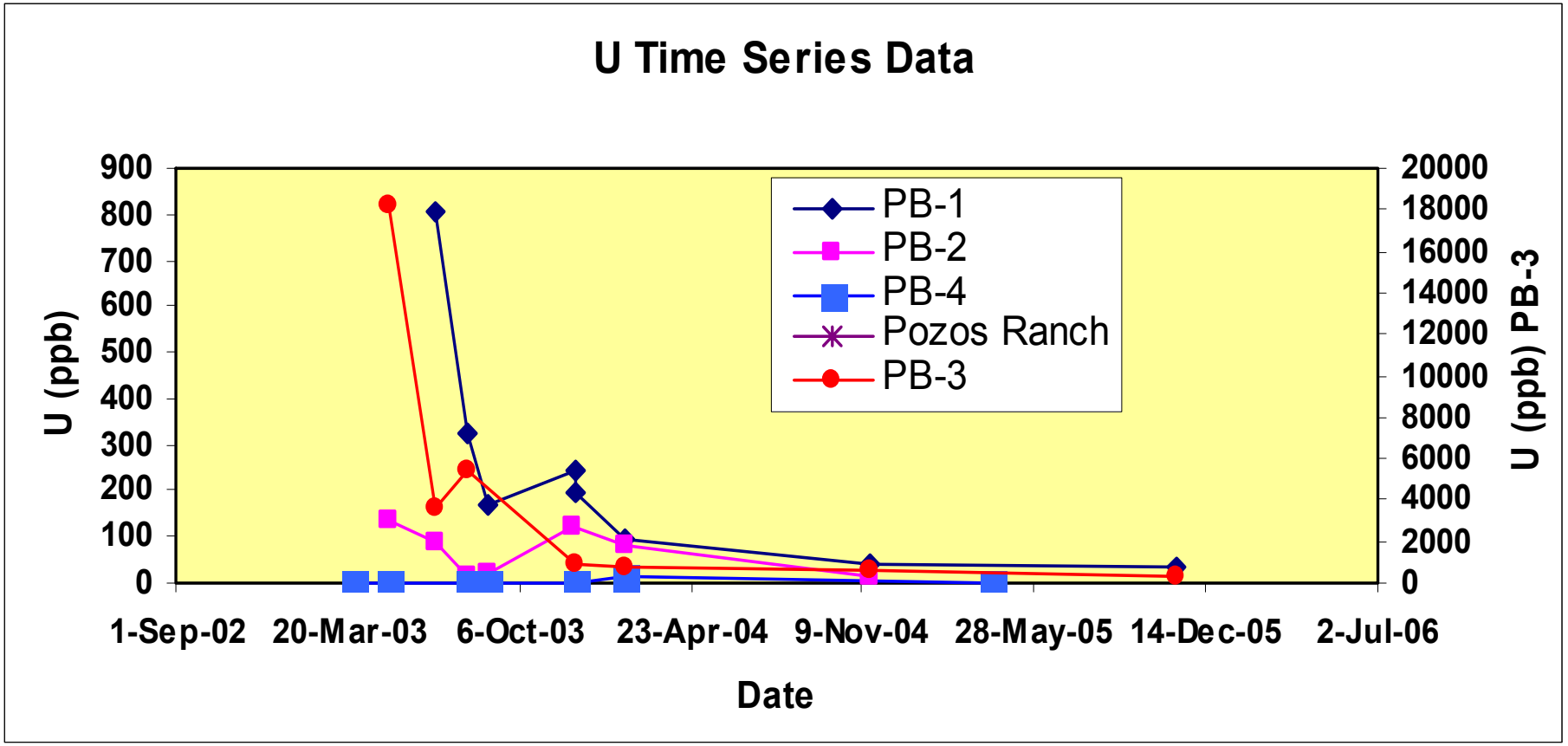
PEÑA BLANCA NATURAL ANALOGUE MODEL RESULTS

Calculated radionuclide concentrations beneath Nopal I using high Kd for all Uranium species



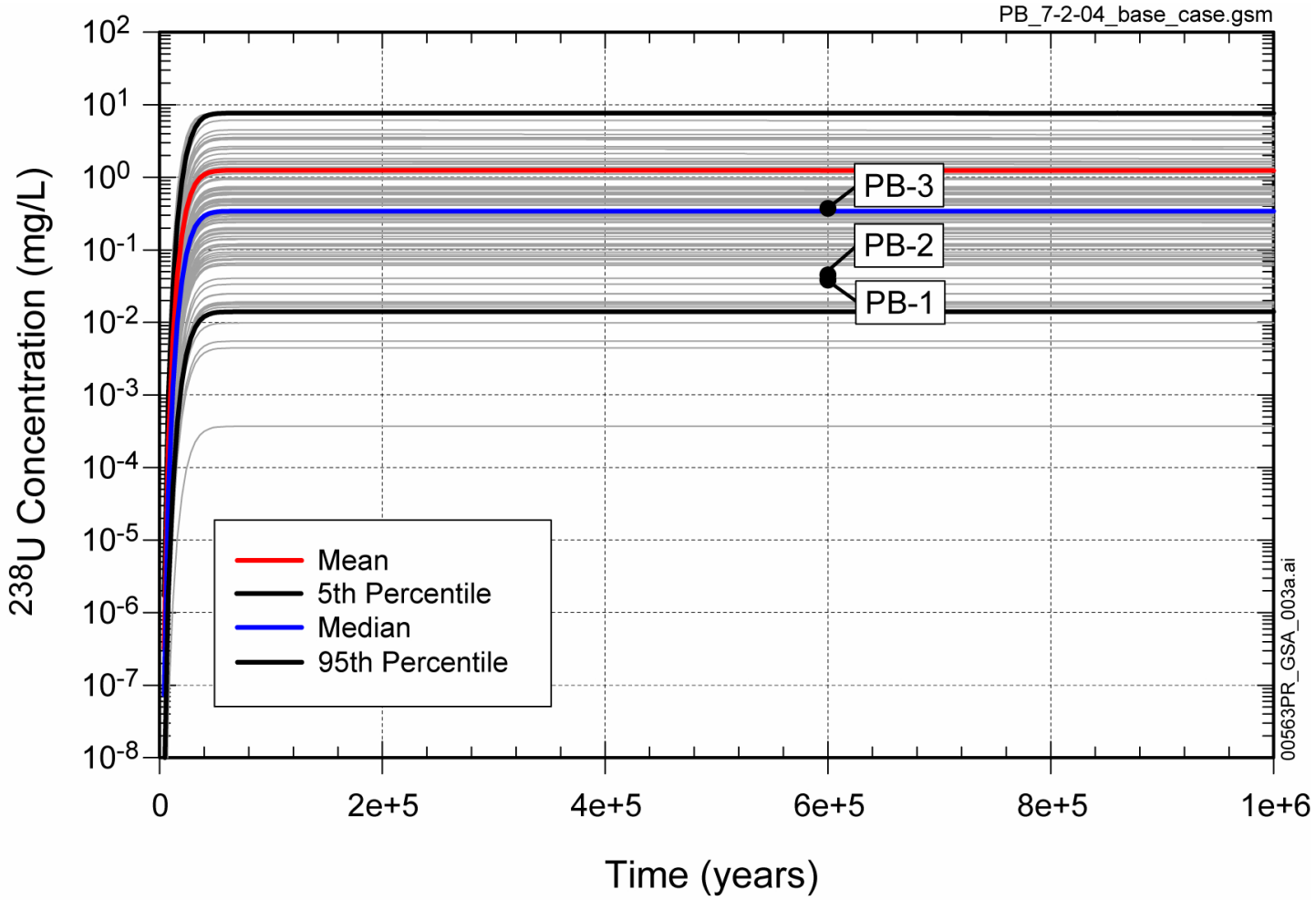
NOPAL I URANIUM CONCENTRATIONS

Uranium concentrations in water samples from Nopal I observation wells



PEÑA BLANCA NATURAL ANALOGUE MODEL RESULTS

Results of the base case simulation for ^{238}U at 65 m for 100 realizations of the uncertain dissolution parameters for late time samples from PB-1, PB-2, and PB-3



CONCLUSIONS

- **The Nopal I ore deposit is a useful analogue**
  - Nopal I ore deposit is smaller than Yucca Mountain
  - Nopal I ore deposit has similar geology
- **Tc-99 may be detectable in picograms/L at 100 m**
- **Thorium 230, 232 predicted**
- **Uranium 238, 234 predicted but possibly limited due to mineral precipitation**

Future Plans

- Modify Peña Blanca Natural Analogue Model to reflect ongoing data collection and revised versions of Yucca Mountain process models
- Analyze water samples for Tc-99
- Vary thorium K_d
- Add radium to model inventory
- Revisit model inventory after completion of University Texas El Paso investigations