U.S. Department of Energy

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

Science Update

Presented to:

Nuclear Waste Technical Review Board

Presented by:

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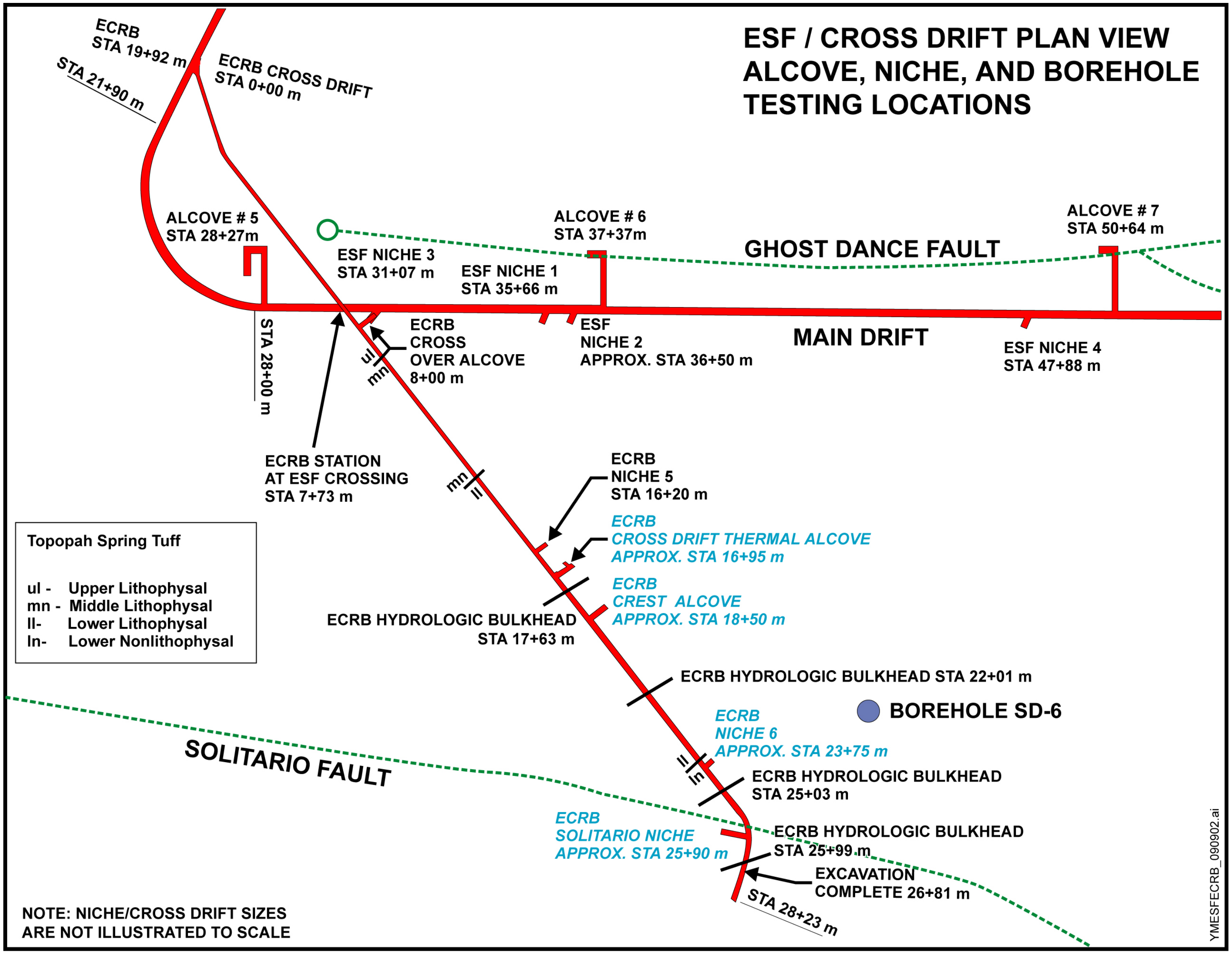
Las Vegas, NV

Outline and Context

- **Update on Science Activities**
  - **Objective is to provide status on scientific and engineering data collection and testing program in support of natural and engineered systems process models and design**
    - **Unsaturated zone processes**
    - **Saturated zone processes**
    - **Rock properties**
    - **Igneous processes**
    - **Source term processes**
- **Summary**
- **Note**
  - **The information presented here is preliminary and draft in nature in order to provide the NWTRB a current status of some areas of ongoing post-closure scientific work**
  - **Much of this work is expected to provide baseline data for Performance Confirmation or to provide supporting information for future licensing activities**

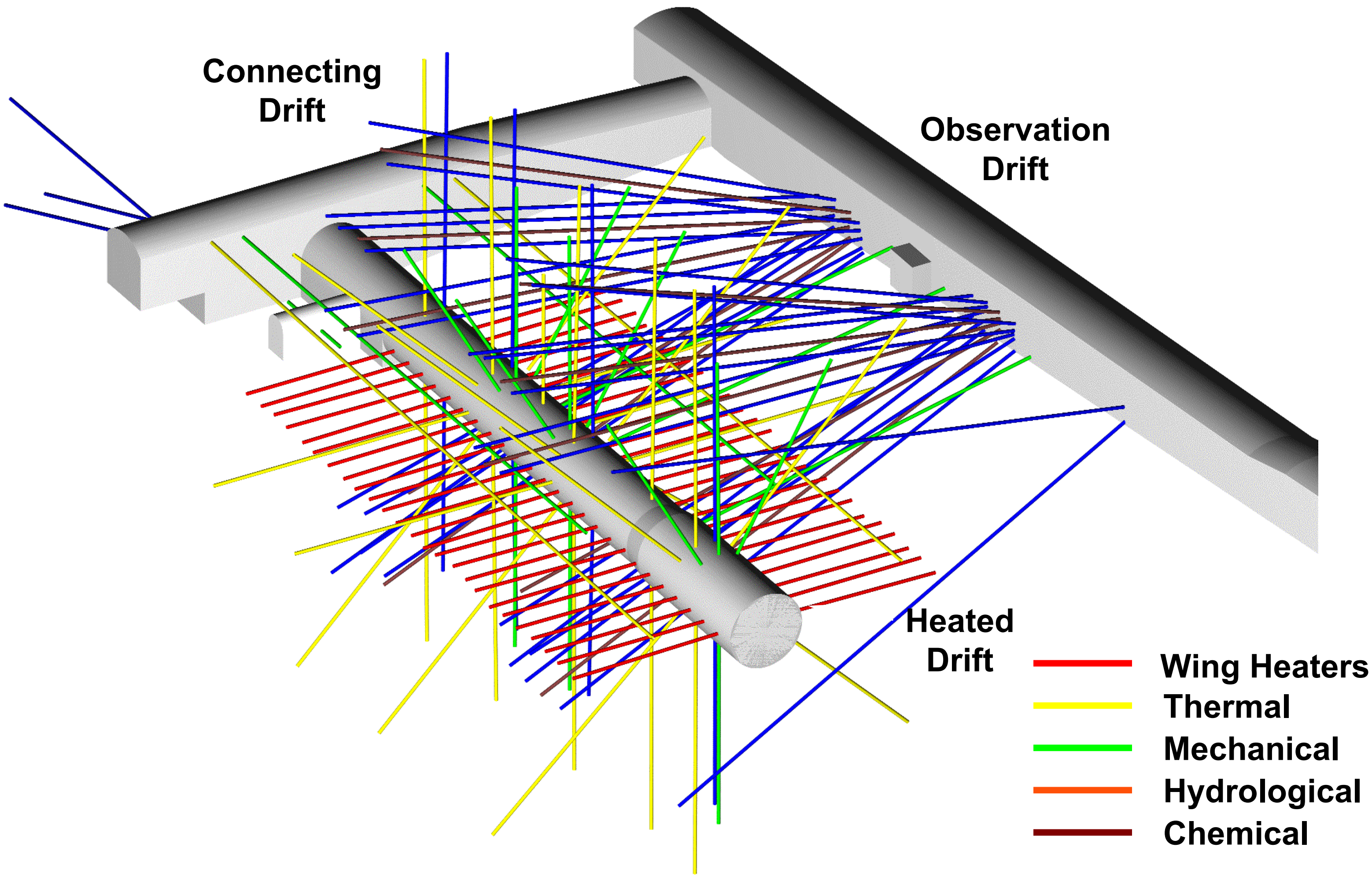
Unsaturated Zone Processes

Exploratory Studies Facility and Cross Drift

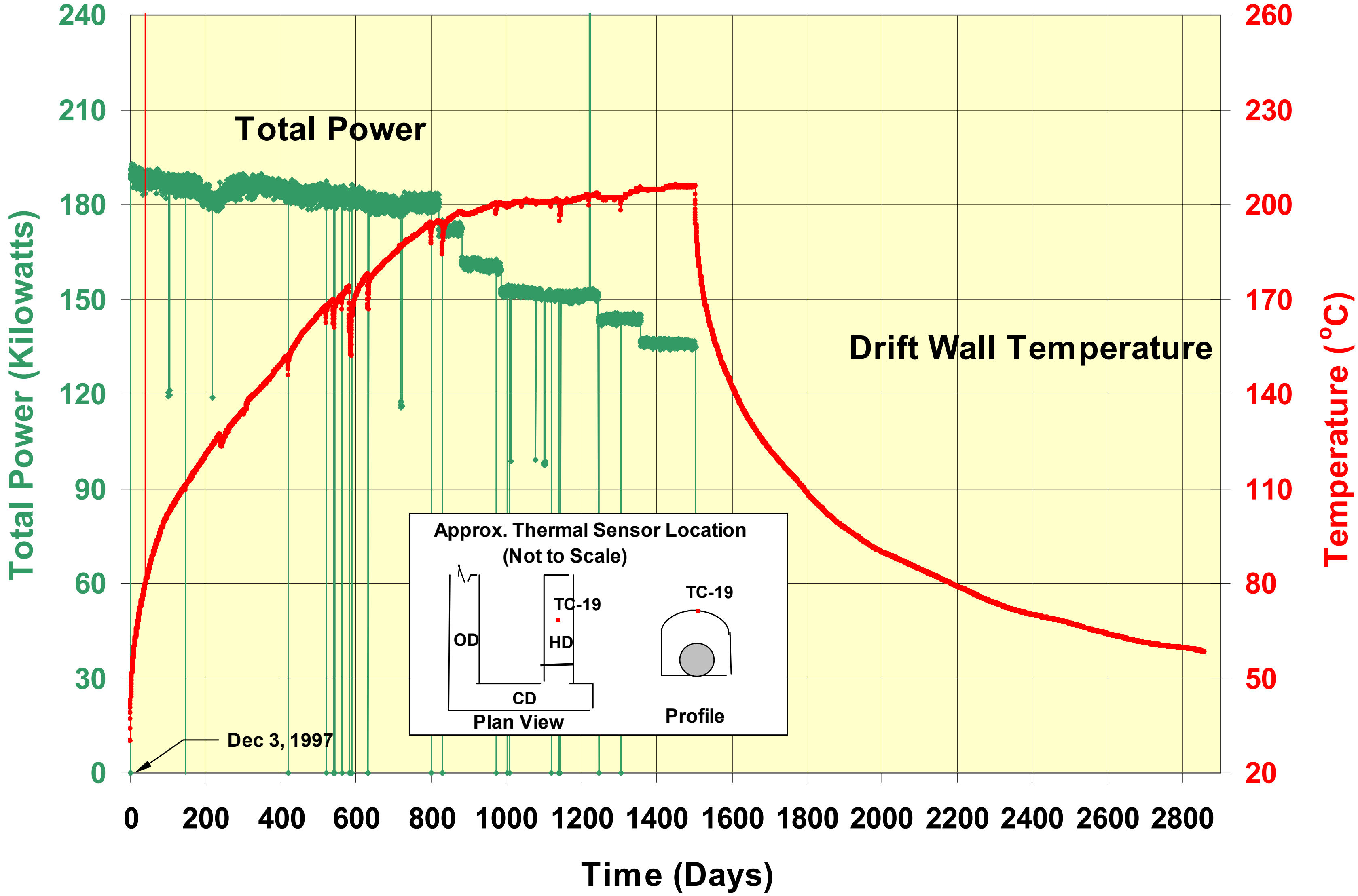


Drift Scale Test

Evaluate thermally-coupled processes in proposed repository horizon rocks at the field-scale in support of Coupled Process Models, Near-Field Environment Models, and Design



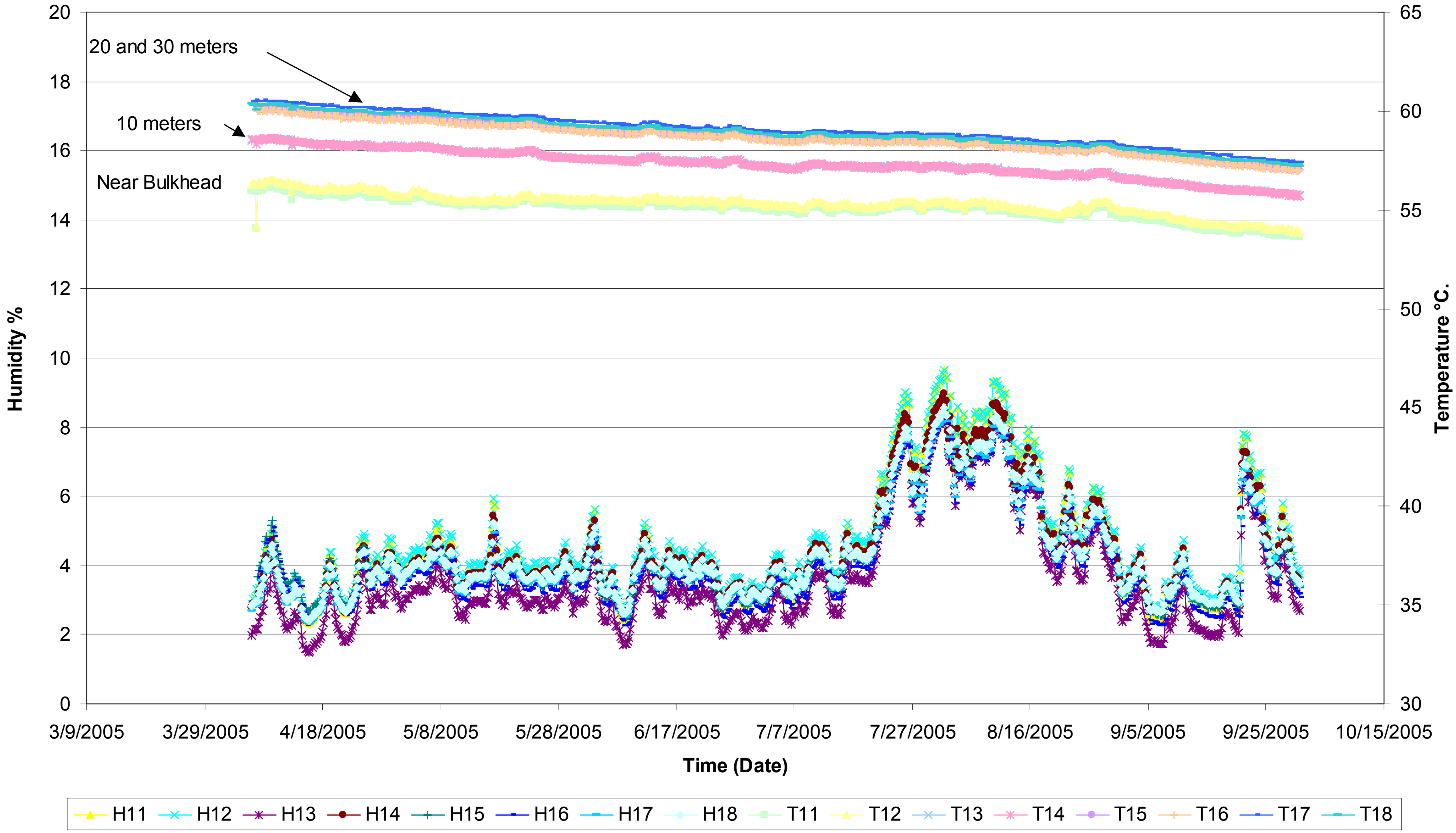
Drift Scale Test Temperature and Power



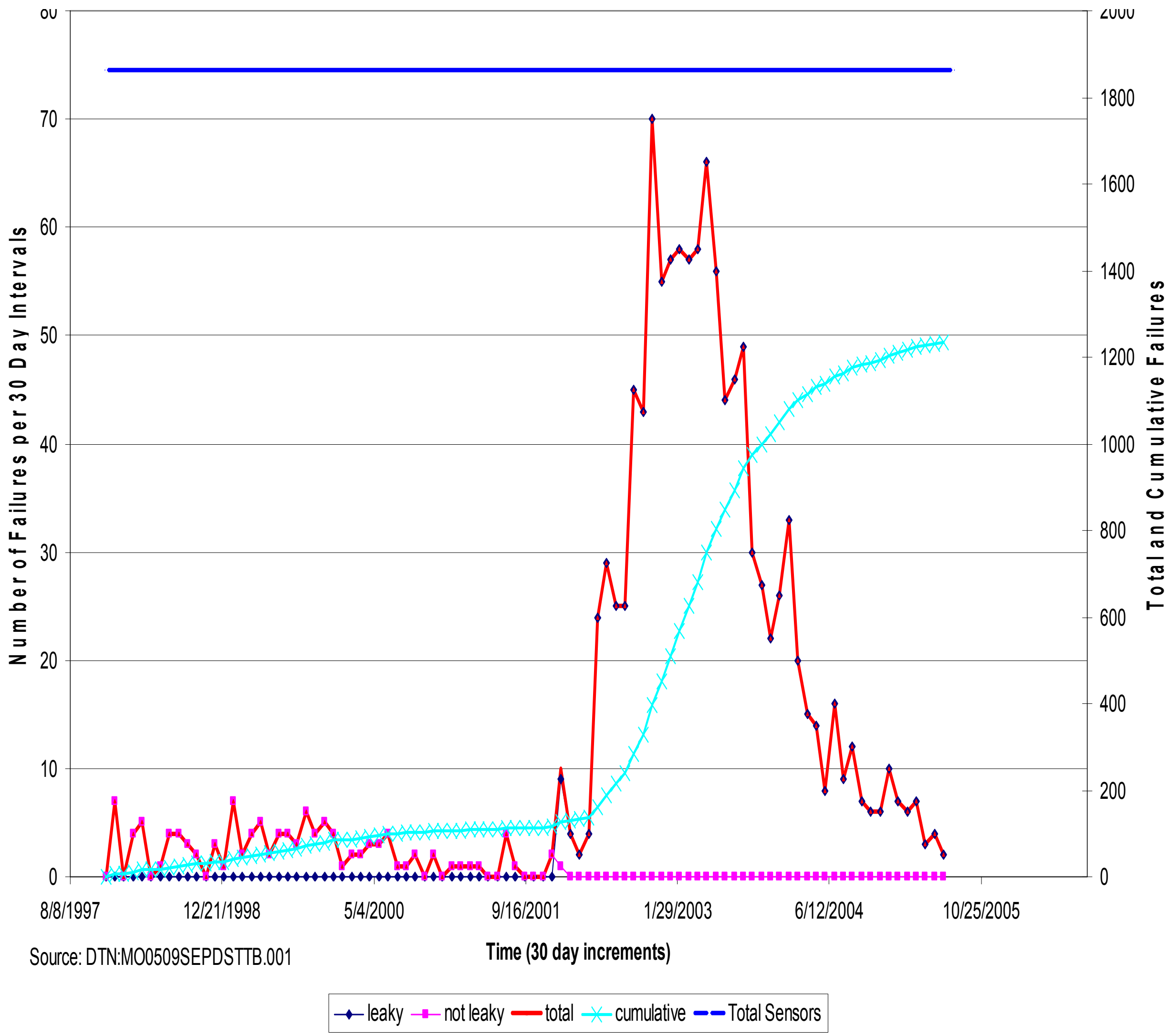
Humidity and Temperature in Heated Drift
Drift Scale Test

- **New humidity and temperature sensors installed early April 2005**
- **Gradual decline in temperature consistent with cooling of drift**
- **Temperature variation within drift shows coolest area located nearest bulkhead and the hottest area at 20 and 30m into drift**
- **Humidity generally consistent throughout drift**
- **Anomaly in humidity appears to be a response to ventilation changes**
- **Both temperature and humidity variations correspond to fluctuations in barometric pressure**

Humidity and Temperature in Heated Drift Drift Scale Test



Resistance Temperature Device (RTD) Performance In Drift Scale Test



As of July 1, 2005

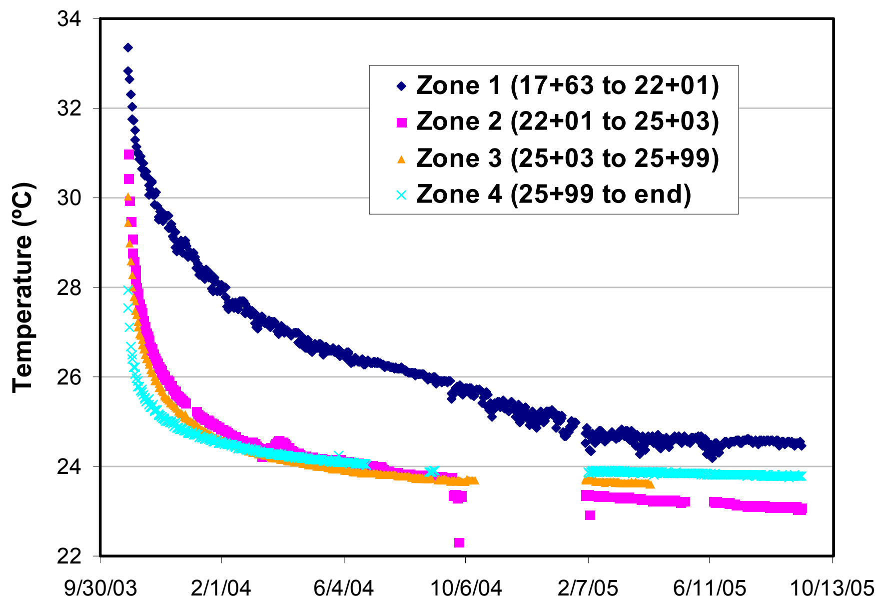
- **Total of 1,862 RTDs**
- **117 failed due to "open" faults.**
- **1,118 have failed due to electrical leakage to ground**
- **627 are functioning**
- **Distribution of failures consistent with "disruption" of instrument wiring bundles near outer limit of dry-out zone**
- **Post-test over-coring and examination could provide opportunity to assess processes and cause of failure for other long-term instrumentation needs such as Performance Confirmation**

Cross Drift Studies
Bulkhead Investigations

- **Evaluate seepage processes in potential repository horizon rocks and Solitario Canyon Fault Zone in support of UZ Seepage Model – also provides insights on in-drift convection and condensation processes**
- **Terminal 918 m of the Cross Drift isolated from ventilation to observe in situ drift conditions and re-wetting after closing bulkheads**
- **Monitor for free liquid water from either seepage or condensation**

Moisture Monitoring Behind ECRB Bulkheads

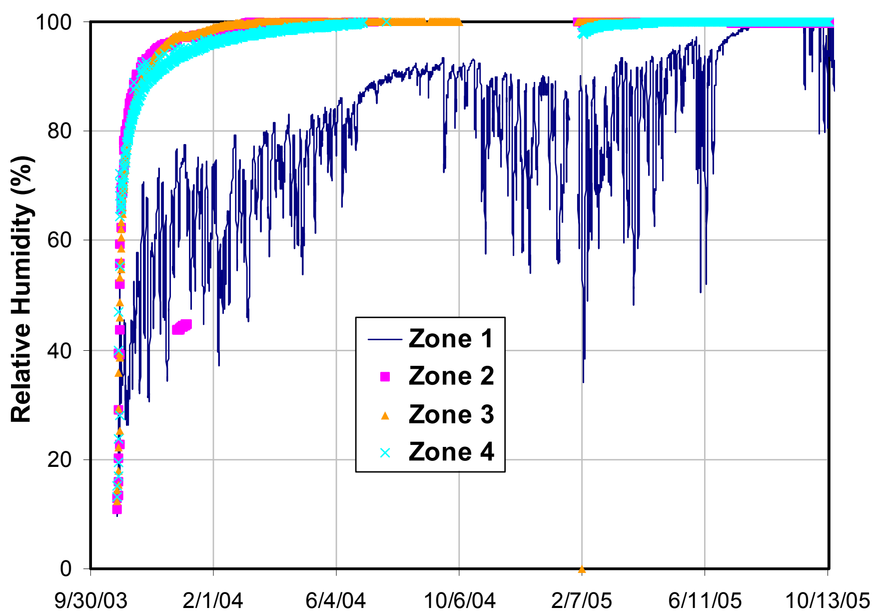
Temperatures recorded between each bulkhead after artificial heat sources were removed and ventilation was terminated



- **Gradual decrease in all four zones is a result of removing the heat sources**
- **Data show that temperature varies between isolated sections of drift suggesting the presence of temperature gradients (natural and/or ventilation-induced)**

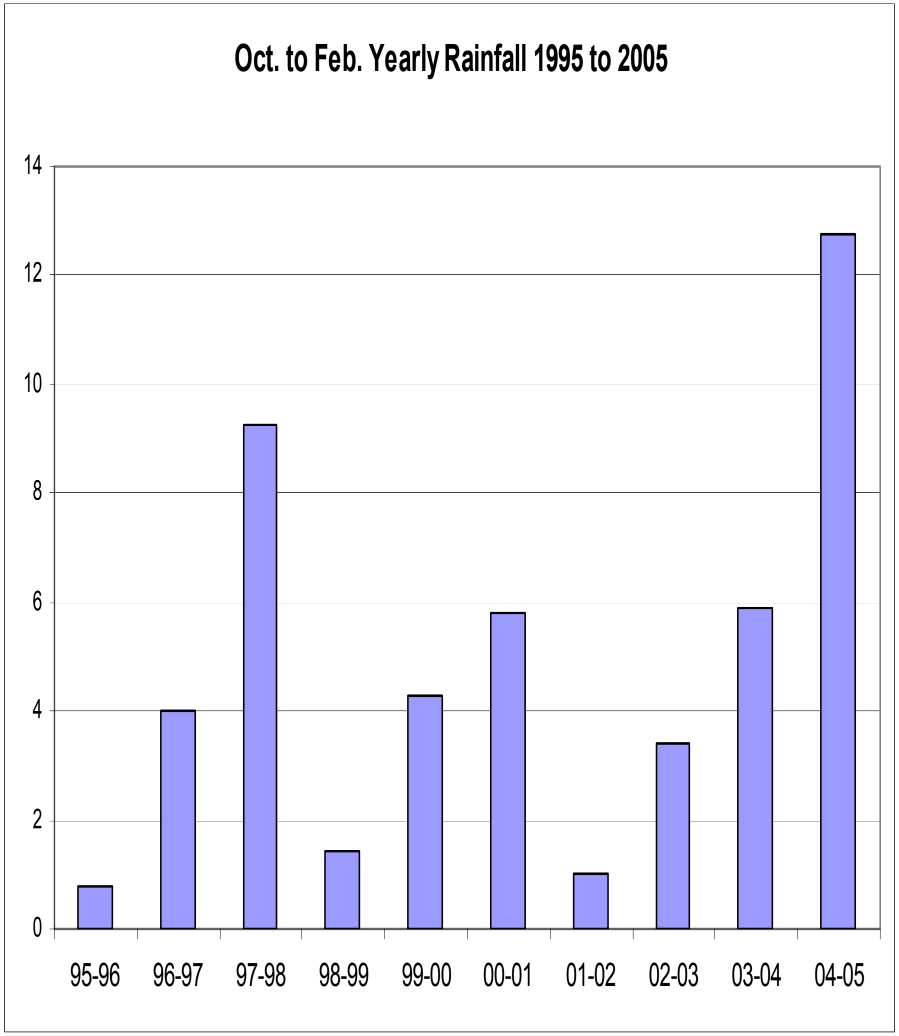
Moisture Monitoring Behind ECRB Bulkheads

Zone 1 was ventilated for 2+ years prior to data collection



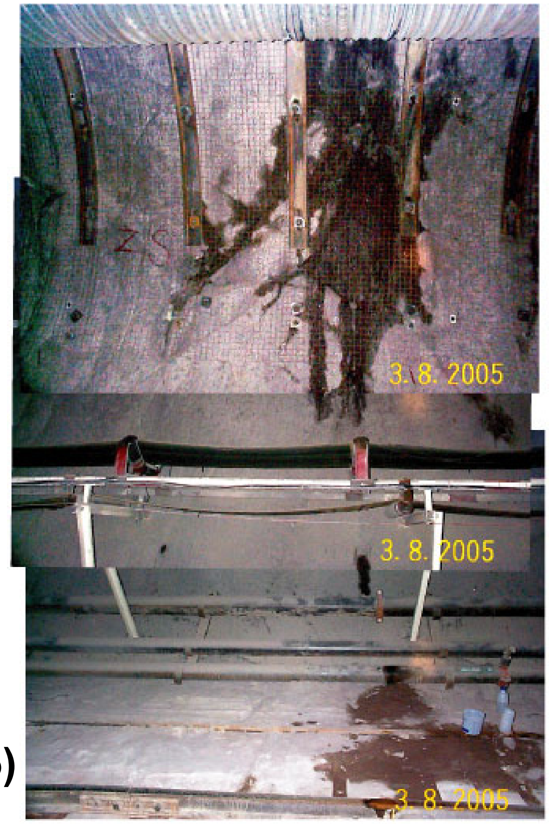
- **In all zones, except the one closest to ventilated drift (Zone 1), relative humidity (RH) rapidly approaches 100% and persists**
- **RH in Zone 1 is likely influenced by the engineered ventilation**
- **Rapid rise in relative humidity when bulkheads closed indicates surrounding wet rock communicates efficiently with drift**
- **Multiple lines of evidence (e.g., water chemistry, moisture distribution) show that observed moisture is from condensation resulting from temperature differences within drift, and between drift and surrounding rock**

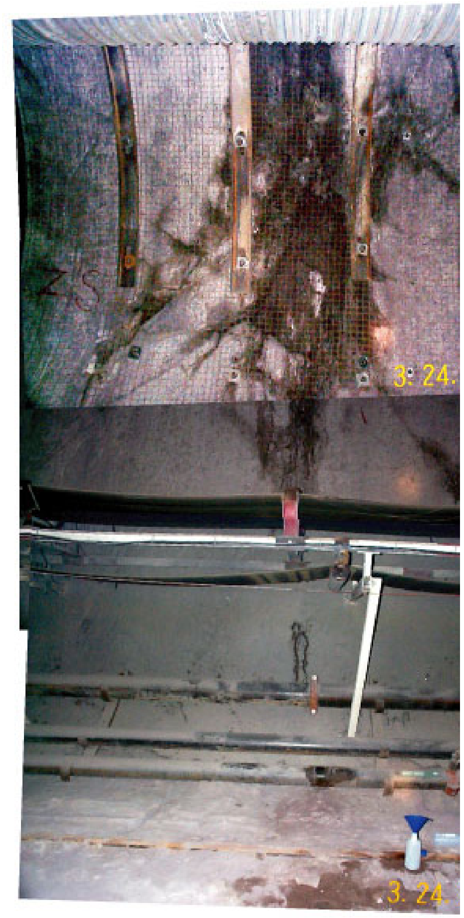
Moisture Monitoring in the South Ramp



- Chart shows rainfall amounts (inches) for the October to February period over the last ten years
- Average annual rainfall is 5 inches, which was exceeded by nearly 8 inches during 04-05 season
- Mean annual precipitation in the UZ models is 7.5 inches for present-day climate
- Seeps were first observed in the Exploratory Site Facility (ESF) South Ramp main drift on February 28, 2005

Moisture Monitoring in the South Ramp



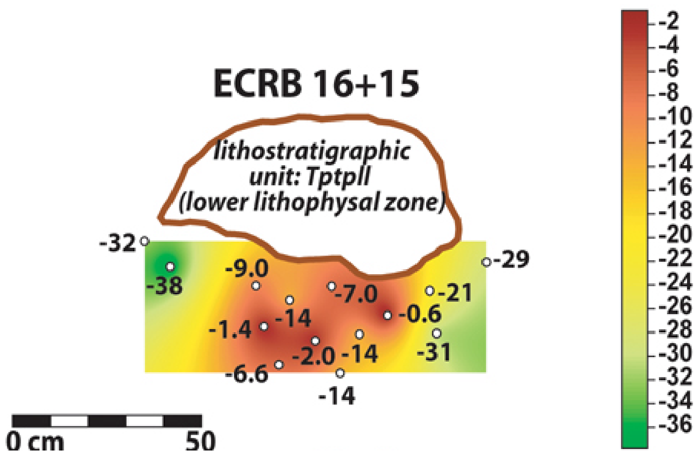


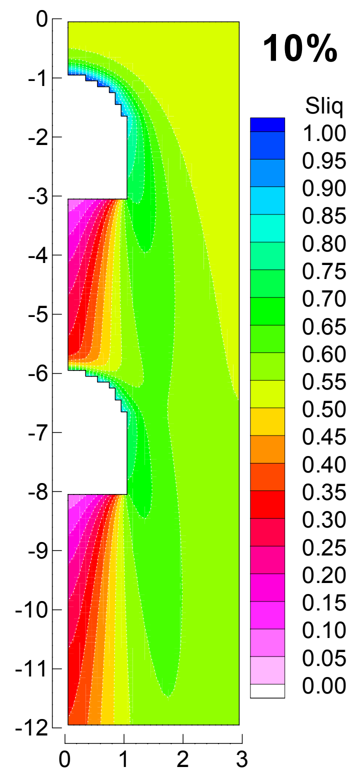
- **Water seepage from fractures at station 76+00 (photos over a 3 week period beginning 3/2/2005)**
- **Ongoing modeling and analysis of the seepage observation to verify that the ambient seepage model is consistent with the observation**

Drift Shadow

Testing the Concept of Drift Shadow (at Yucca Mountain, ECRB)

Preliminary isotopic results:
$^{234}U/^{238}U$ Activity Ratios values in per mil deviation from secular equilibrium





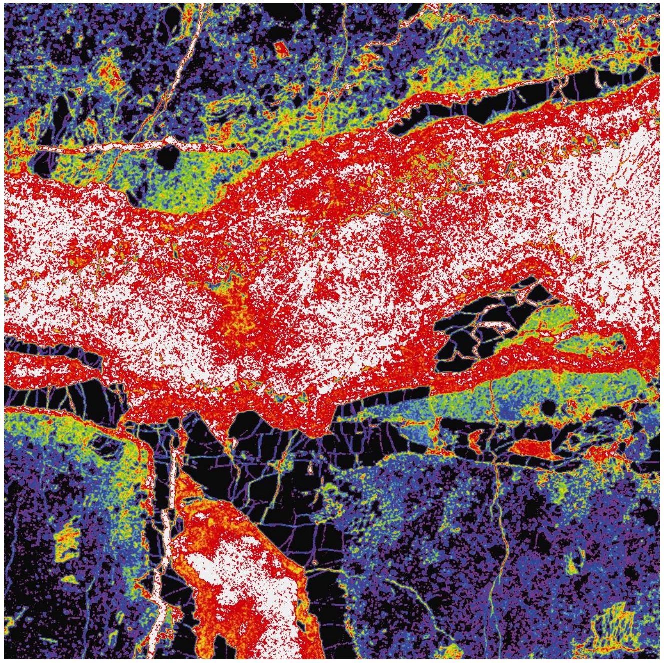
Nature of Drift Shadows at Analogue Sites (Hazel-Atlas Mine)

Peña Blanca Natural Analogue

Investigation of radionuclide transport at a site with characteristics analogous to the proposed nuclear waste repository at Yucca Mountain. Use the results to test a comprehensive process model and total system performance assessment

Accomplishments (Selected):

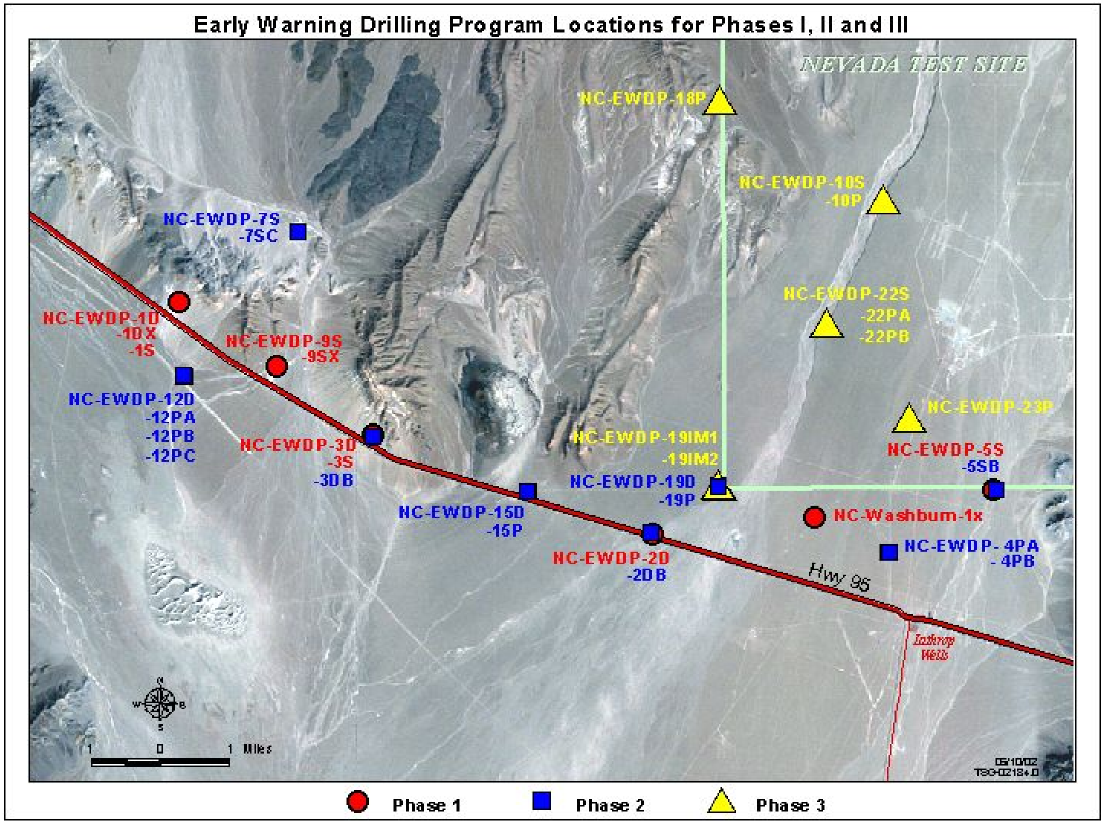
- Two successful field trips
- Design, construction and installation of seepage collection system in Nopal +00 adit, collecting data since April 2005
- Spectroscopic and electron microscopy analysis of rock samples
- Uranium concentration and isotopic activity ratio of water collected from three wells over several months. An advection–dispersion model yielded estimates of saturated zone groundwater velocity (1–20 m/yr) and dispersion coefficient (10^{-5} to 10^{-3} cm^2/s)
- Modeling the Ra-222, Pb-210, and Po-210 contents of well-water samples indicates that migration rates of the isotopes are three to six orders of magnitude slower than groundwater movement.
- Organized special session for the 2005 Geological Society of America annual meeting, well attended and well received



Map of uranium distribution in fractured tuff. Uranium abundance increases from black (lowest) to blue to red to white (highest). Image width is 1.2 mm.

Saturated Zone Processes

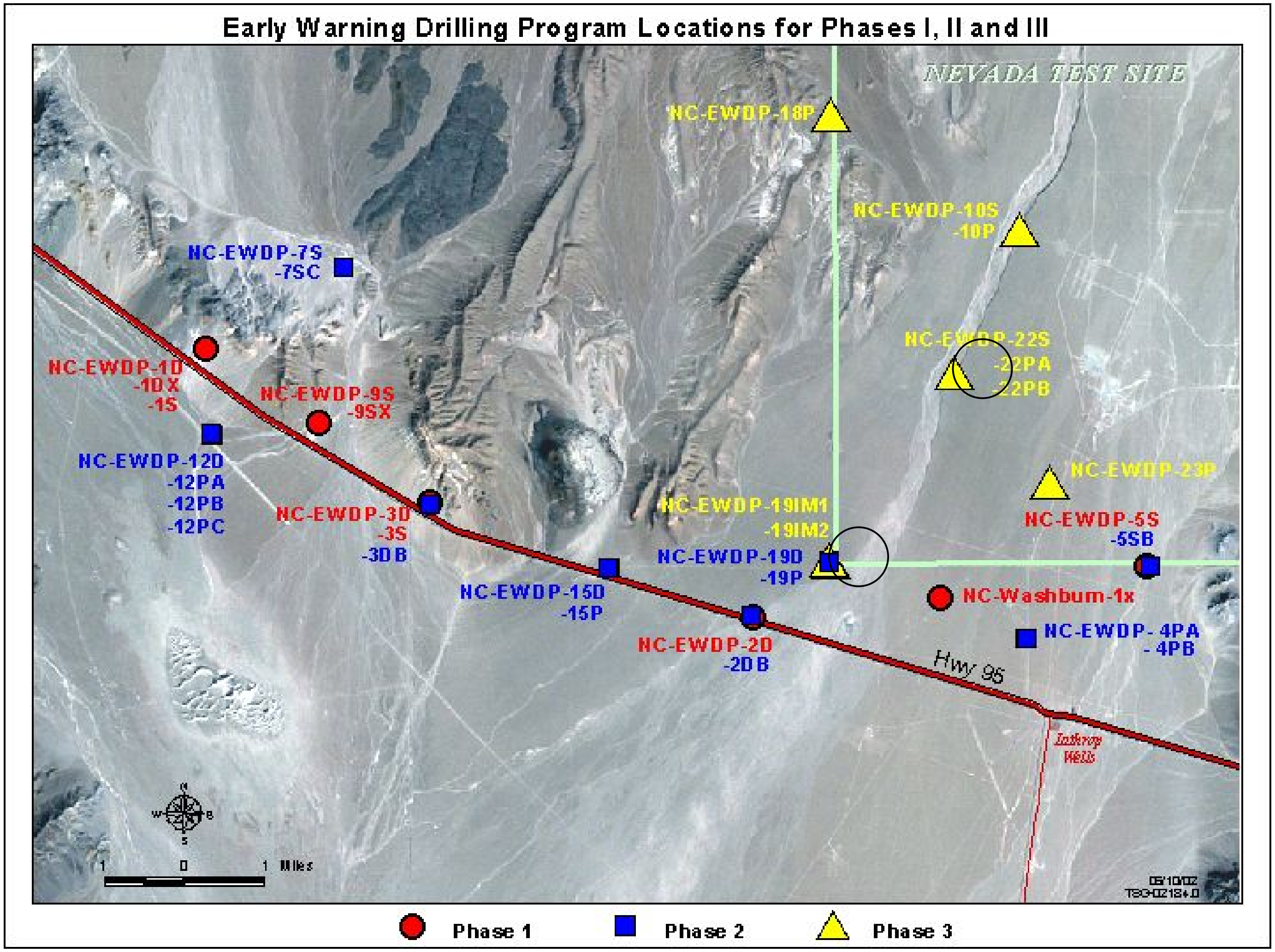
Saturated Zone
Nye County Early Warning Drilling Program



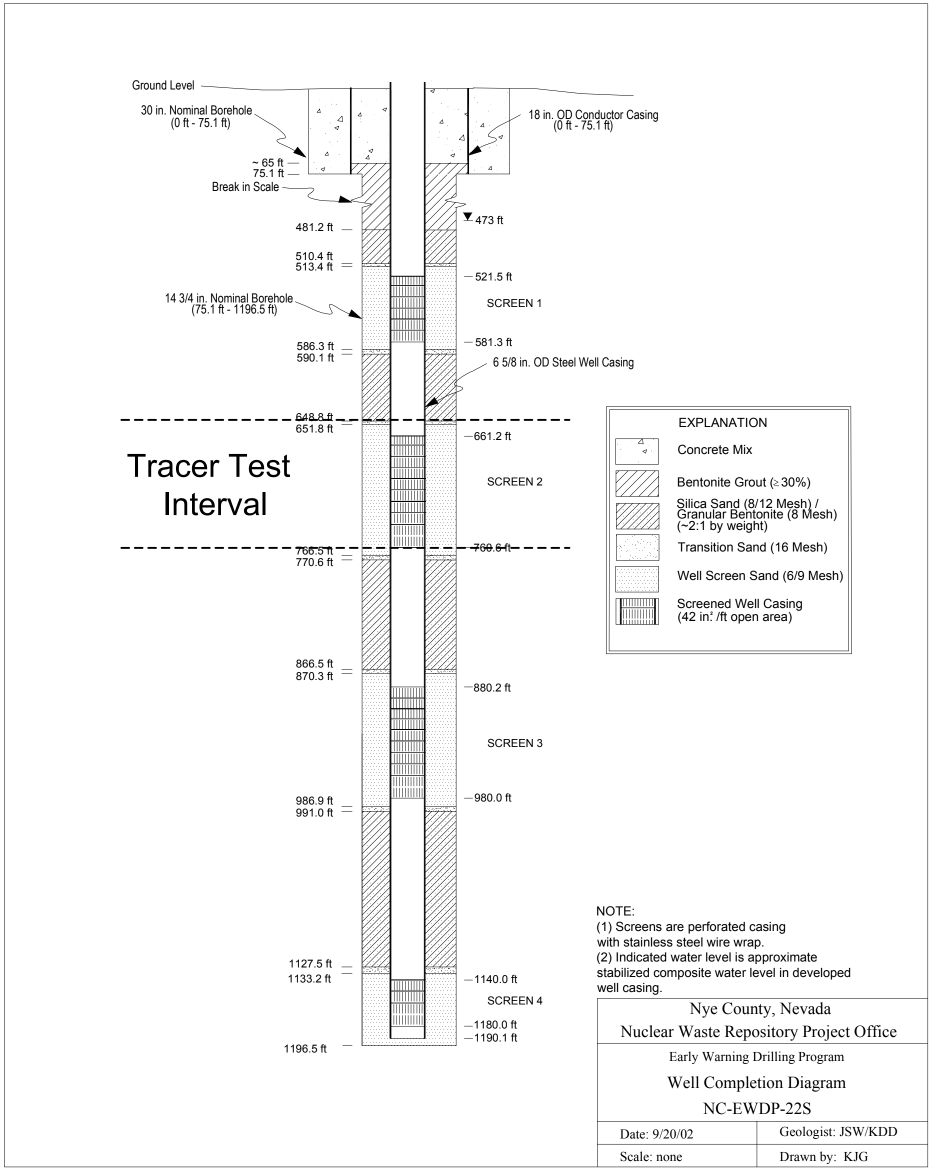
Site-scale data being collected in support of the SZ Flow and Transport Model:

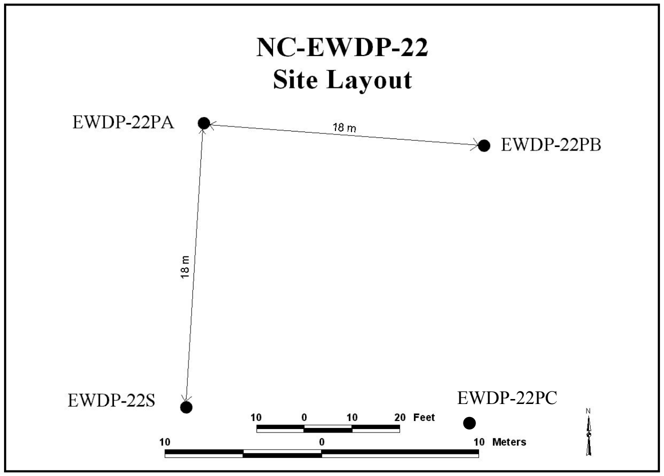
(1) Lithologic data into the hydrogeologic framework model
(2) Water-level data for flow field calibration
(3) Hydraulic testing data for flow and transport models
(4) Laboratory sorption measurements (^{237}Np, ^{129}I, and ^{99}Tc) on alluvium for process models and TSPA
(5) Hydrochemistry data for flow field calibrations
(6) Eh/pH data for use in flow and transport models
(7) Hydraulic and transport testing of alluvial aquifer for flow and transport models

NC-EWDP-19 and -22 Sites

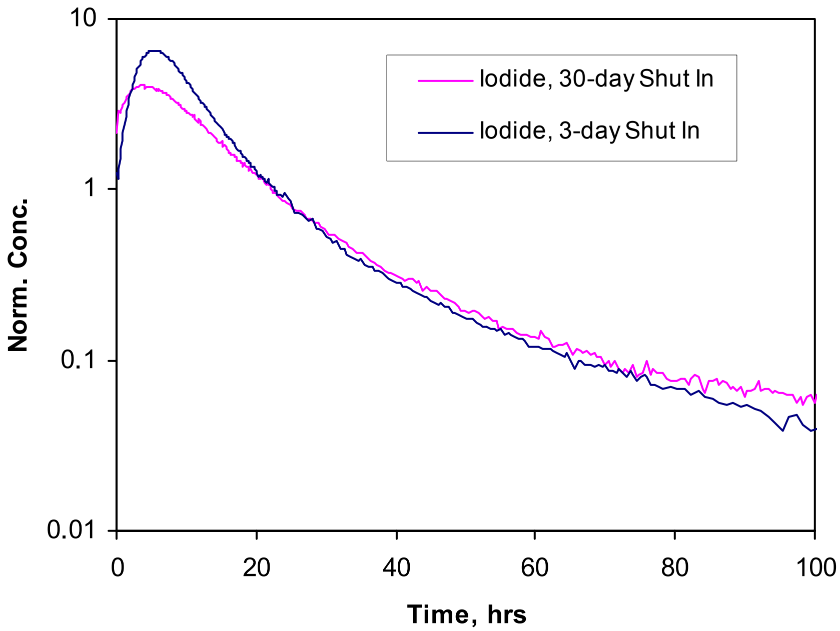


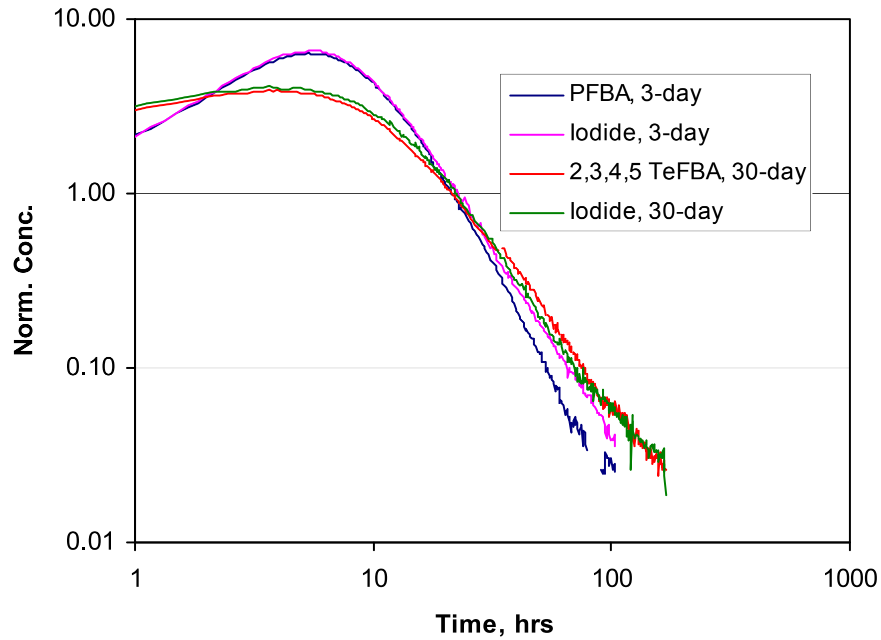
NC-EWDP-22 Site





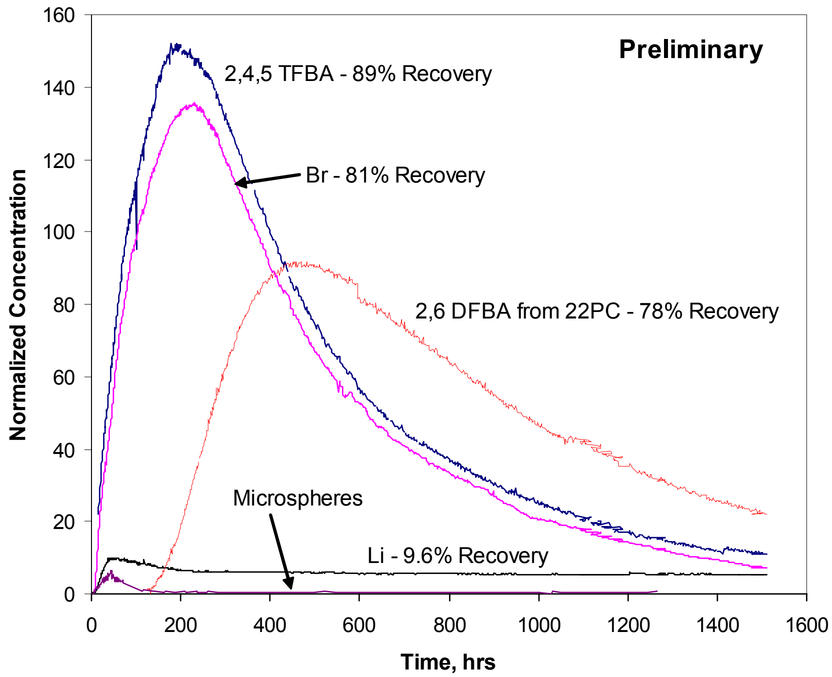
22S Single-Well Tracer Testing

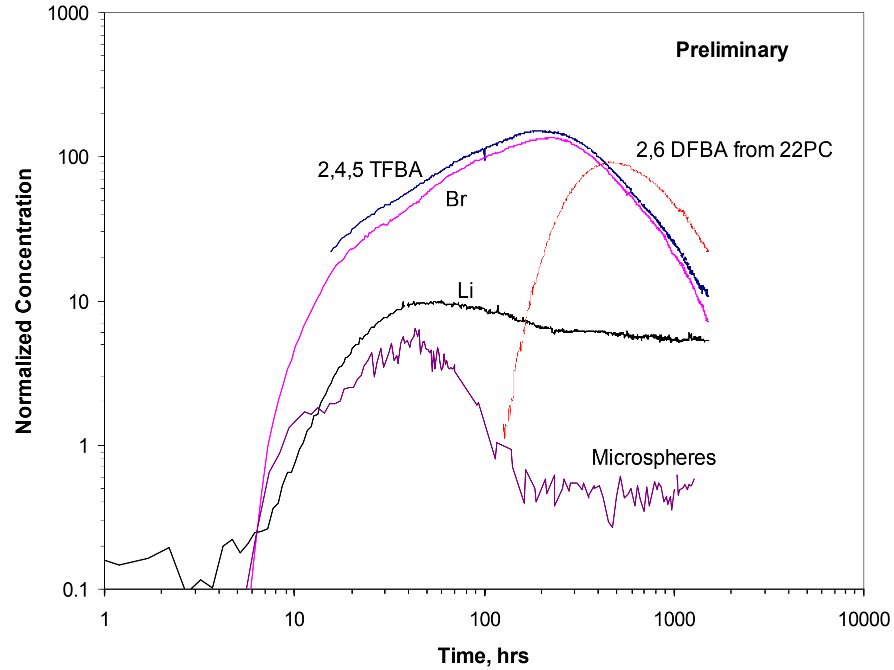




- Specific discharge estimates from differences in peak and mean arrival times range from 0.4 to 1.0 m/yr (ϕ = 0.05 to 0.3)
- Specific discharge estimates from differences in "tail" arrival times range from 2.4 to 6.0 m/yr (ϕ = 0.05 to 0.3)
- Seepage velocity estimates range from 3.4 to 8.4 m/yr (peak and mean) and 20 to 49 m/yr (tail) for ϕ = 0.3 to 0.05
- Specific discharge estimates at EWDP-19D ranged from 1.2 to 9.4 m/yr

22S Cross-Hole Tracer Testing

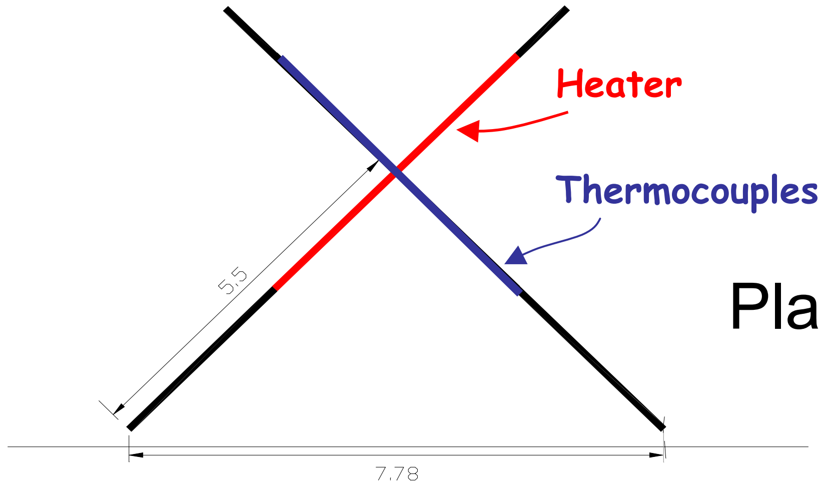




- Higher tracer recoveries than in fractured rock
- Odd-shaped 22PA-22S breakthrough curves
- Significant attenuation of lithium ion (but some early arrival)
- Significant colloid attenuation (perhaps filtration)

Rock Properties

Thermal Conductivity Tests – Overview



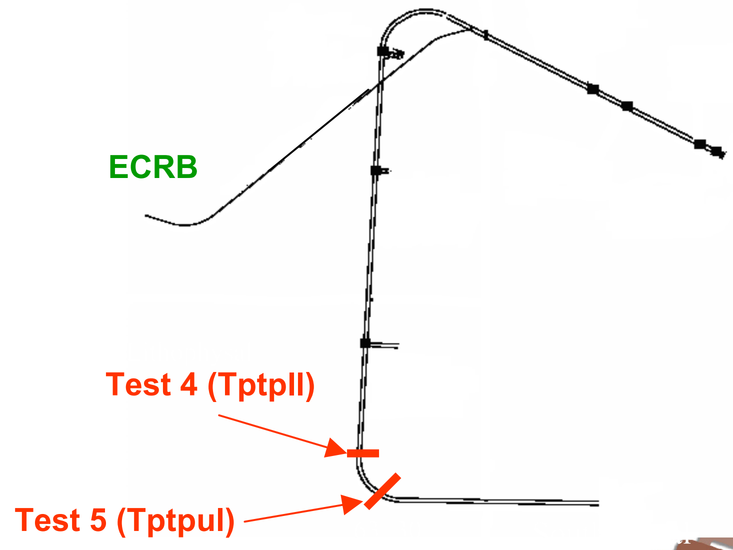
Plan View

- **5 tests have been completed, with 3 configurations of heaters and thermocouple arrays**
- **Test region is slowly heated, thermal properties are measured under in situ moisture conditions**
- **Temperatures are increased to above boiling, temperatures stabilize as region dries out**
- **Heater power is then stepped up to measure properties under dry conditions**

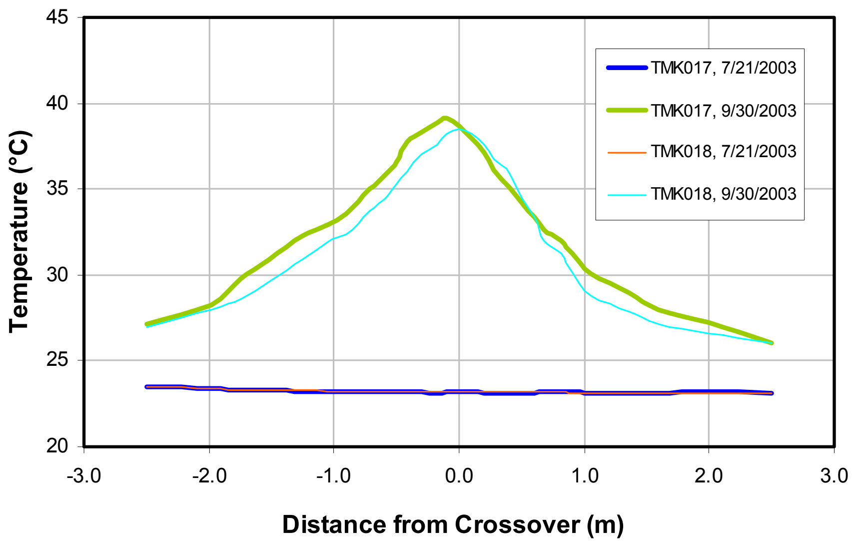
Thermal Conductivity Tests – Test Arrays 4 and 5

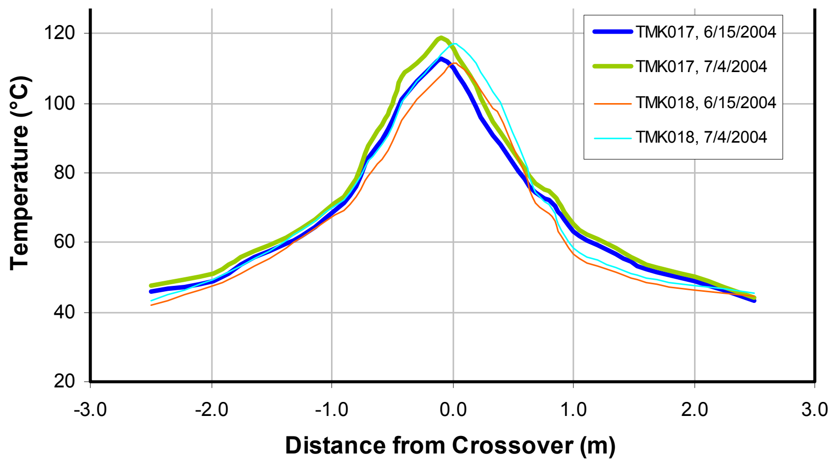
- **Test Arrays 4 and 5, were conducted in ESF near the bend between the main north-south tunnel and the south ramp**
- **Array number 4 was located in the Topopah Springs lower lithophysal stratigraphic unit at ESF station 57+90**
- **Array number 5 was located in the Topopah Springs upper lithophysal stratigraphic unit at ESF station 63+30**
- **Heater power to both arrays was initiated on 7/21/2003 and terminated to both on 7/11/2004**

Location for Tests 4 and 5



Thermal Conductivity Tests – Thermal Profile





- **Graphs show temperature data used to calculate wet (top graph) and dry (bottom graph) thermal conductivity values for Test Array #5**
- **Temperature profiles are the same above (TMK18) and below (TMK17) the heater. Implies impact of moisture convection on heat transport is not evident**
- **Central region of thermal conductivity (TC) strings reached above boiling temperatures by 6/15/2004**

Field Test Results and Model Predictions

Test Identifier	Field Thermal Conductivity		Model Report*	
	Wet (W/mK)	Dry (W/mK)	Saturation Condition	(W/mK)
Test Array 1 (2- Hole Test)	1.74	–	85%	1.66 ± 0.25 (Figure 7-12)
Test Array 2 (6- Hole Test)	2.03 – 2.18	1.59 – 1.63	85%	1.69 ± 0.25 (Figure 7-13)
Test Array 3 (3- Hole Test)	1.73 – 1.76	1.47	85%	1.62 ± 0.25 (Figure 7-14)
Test Array 4 (4- Hole Test)	1.76	1.28	Wet	1.90 ± 0.25 (Table 6-6)
Test Array 5 (4- Hole Test)	1.96	1.33	Wet	1.77 ± 0.25 (Table 6-6)

* MDL-NBS-GS-000005, Rev 01

Range of values used in the Multiscale Thermohydrologic Model ANL-EBS-MD-000049, Rev 03: Tptpll 2.14 W/mK (wet) to 1.03 W/mK (dry); Tptpul 2.04 W/mK (wet) to 0.99 W/mK (dry)

Geotechnical Testing Program FY04-FY05

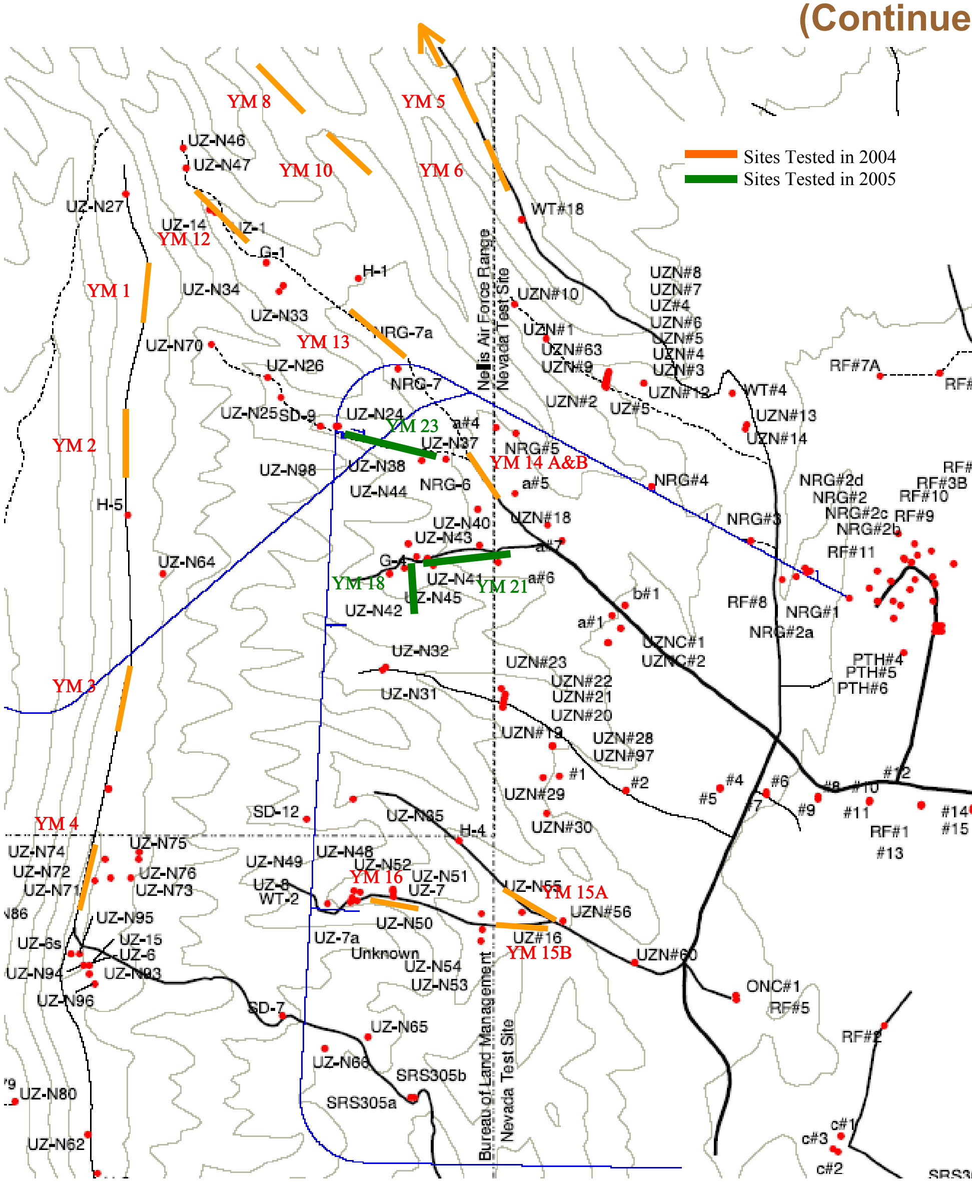
- **Testing completed to characterize the north portal facilities area, aging pad, and waste emplacement areas:**
  - **Drilled 20 boreholes in aging pad and north portal facilities area to characterize alluvium depths**
  - **Performed surface and underground spectral analysis of surface wave (SASW) testing**
  - **Performed laboratory testing on > 100 samples, representing rock units at, above, and below the repository**
- **Work supports evaluation/update of pre-closure and post-closure ground motions for detailed design and licensing**

Geotechnical Testing Spectral Analysis of Surface Waves (SASW)

- Tested 25 sites distributed over repository footprint and surrounding areas
- Tested 28 locations throughout the North Portal Facilities Area
- Tested 6 locations within Aging Pad Quadrant #1
- Tested 44 locations distributed throughout the underground

Geotechnical SASW Surface Testing

(Continued)

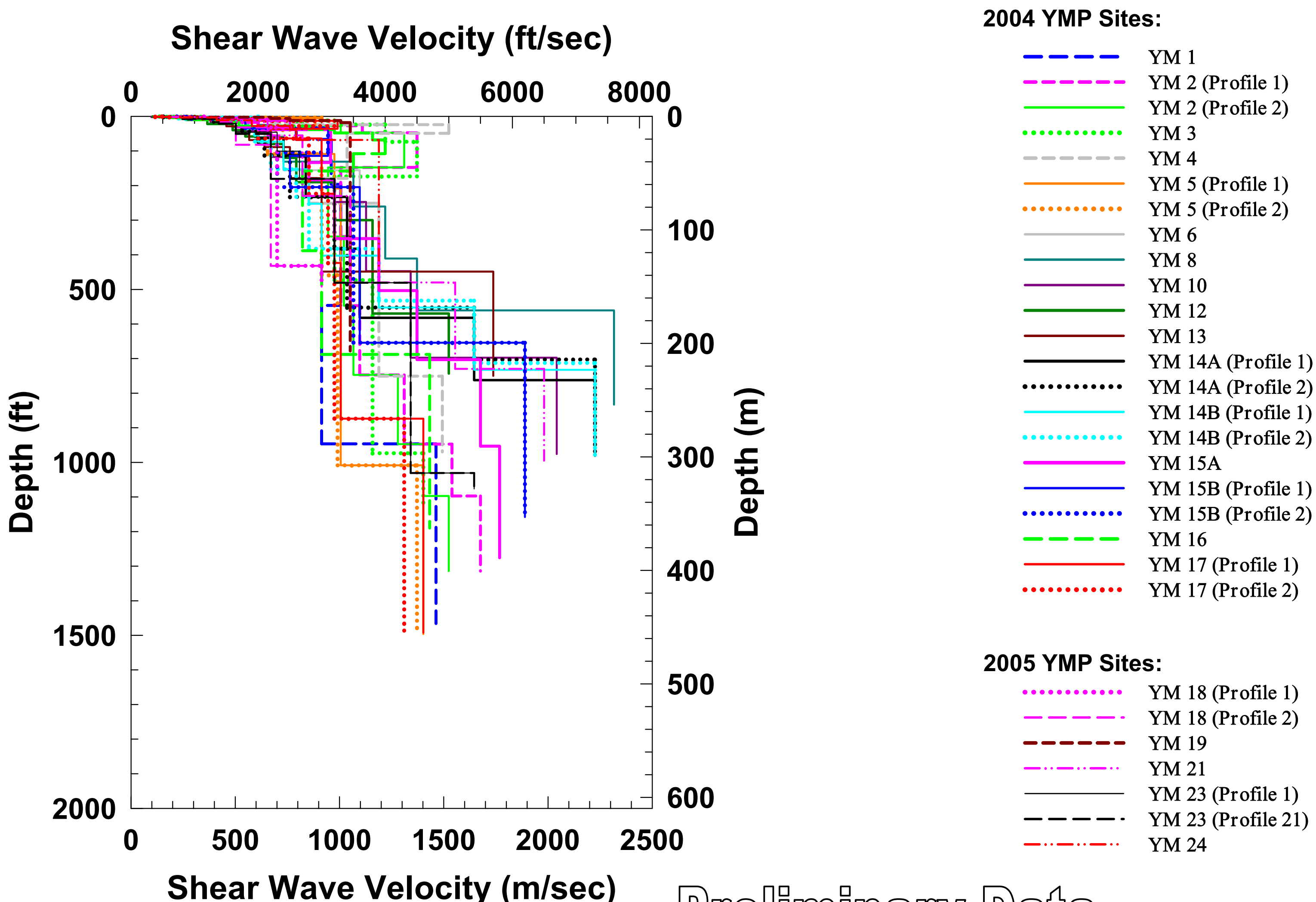


- **Many locations tested multiple times using sensor spacings starting at 10’ from the source and progress to > 2000’ from the source**
- **This testing augments 20 sites tested in 2001 (These sites are not displayed.)**
- **Data provide velocity interpretations from the surface to depths below the repository horizon**

Geotechnical SASW Surface Testing

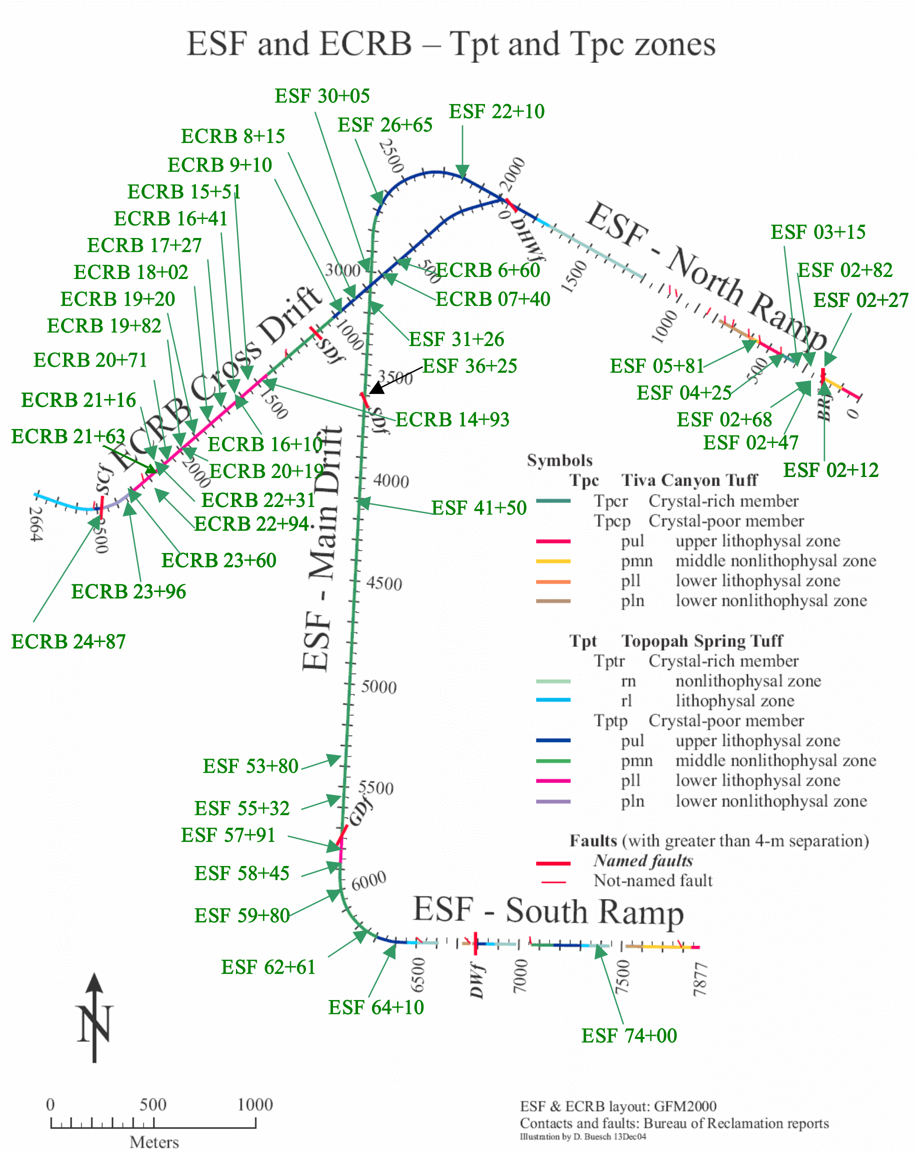
(Continued)

V_s Profiles for 2004 and 2005 Repository Block Sites



Preliminary Data

Geotechnical SASW Underground Testing



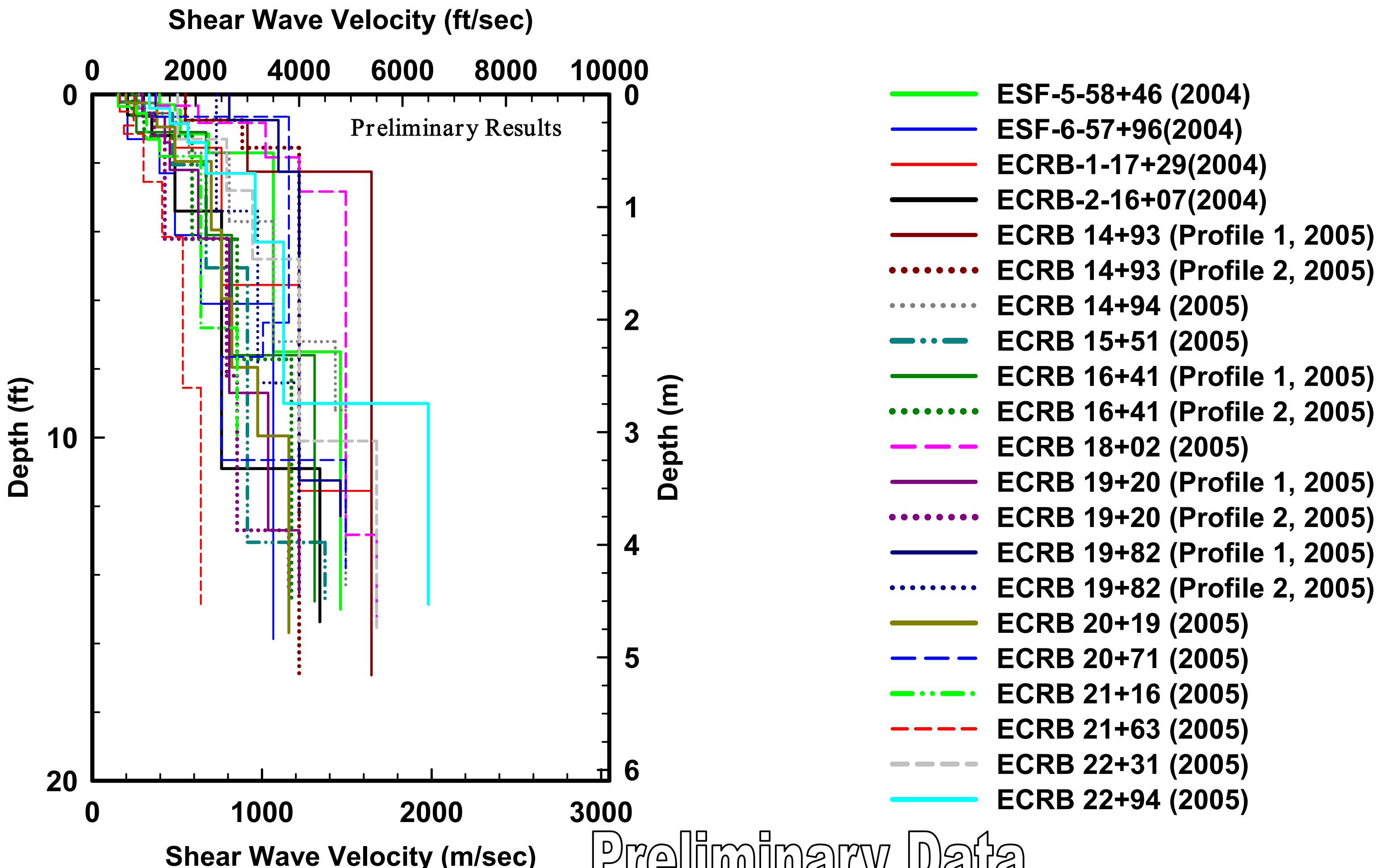
- **Locations selected to cover those units exposed in the underground**
- **Heavy emphasis on testing Tptpll as it represents 85% of repository**
- **Several locations tested coincide with areas of detailed fracture mapping by the USGS**
- **Several areas tested coincide with the LBNL tomography measurements**

Geotechnical SASW Underground Testing

(Continued)

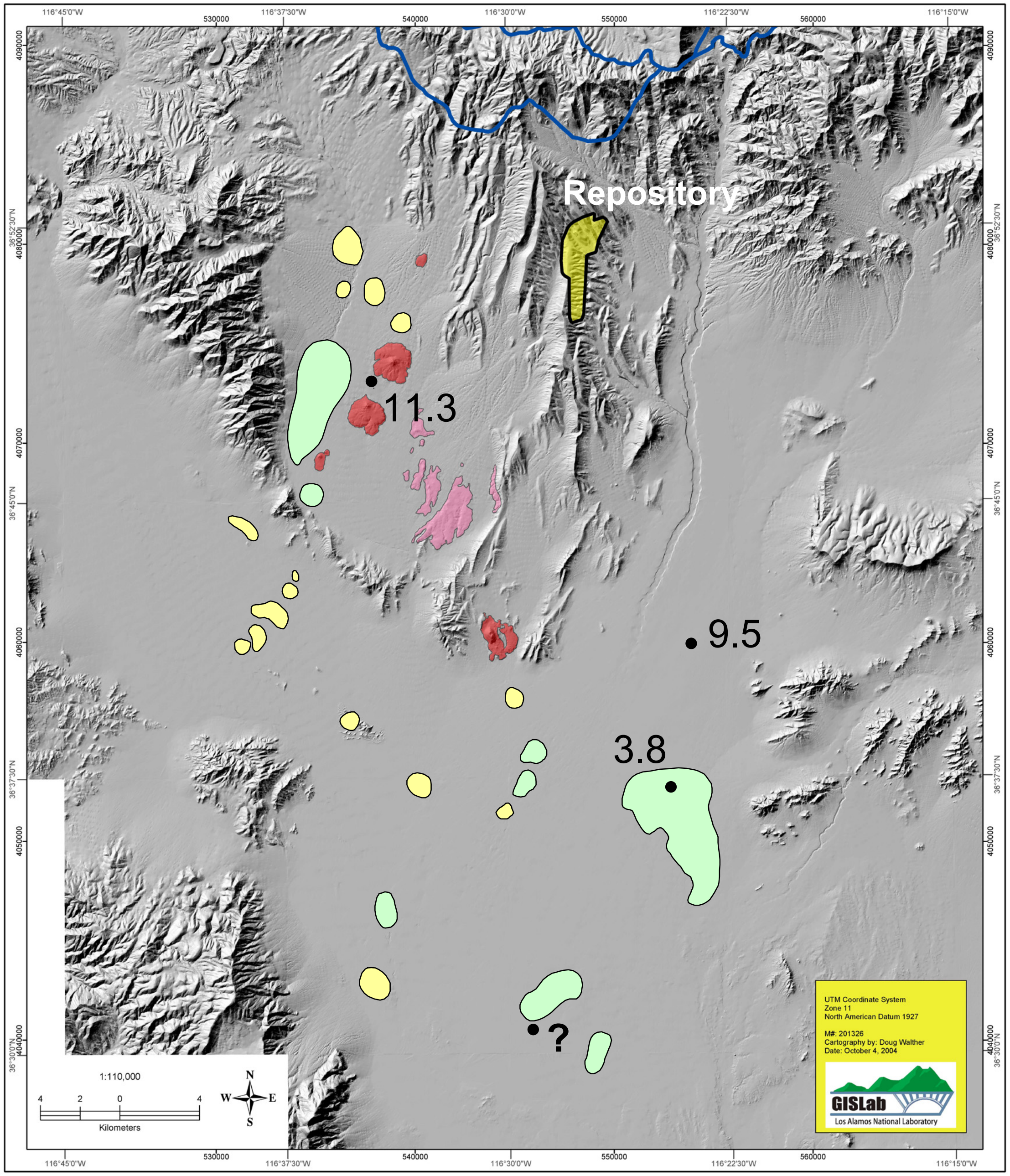
Comparison of Tptpll Type Rock Site Data

(Tptpll = Topopah Spring Tuff: crystal - poor, lower lithophysal zone)



Preliminary Data

Igneous Processes

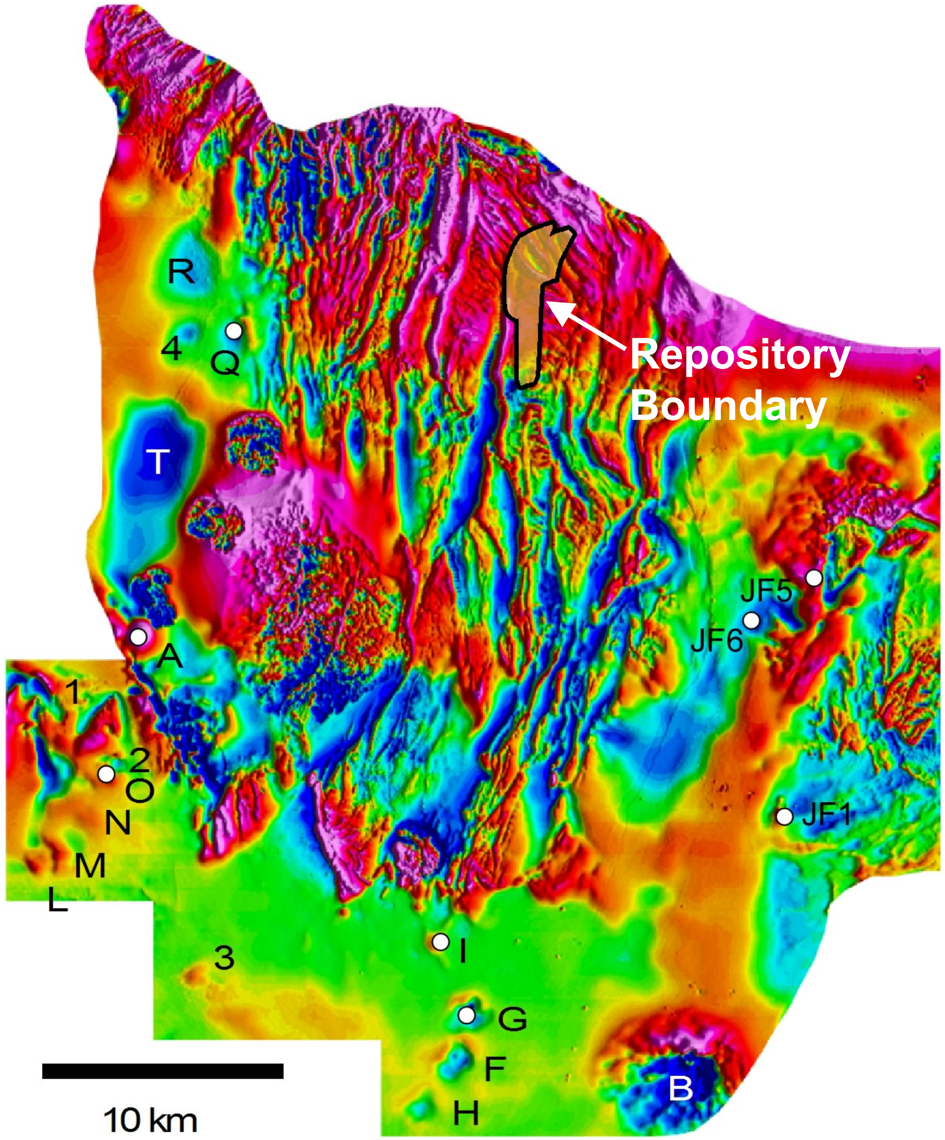


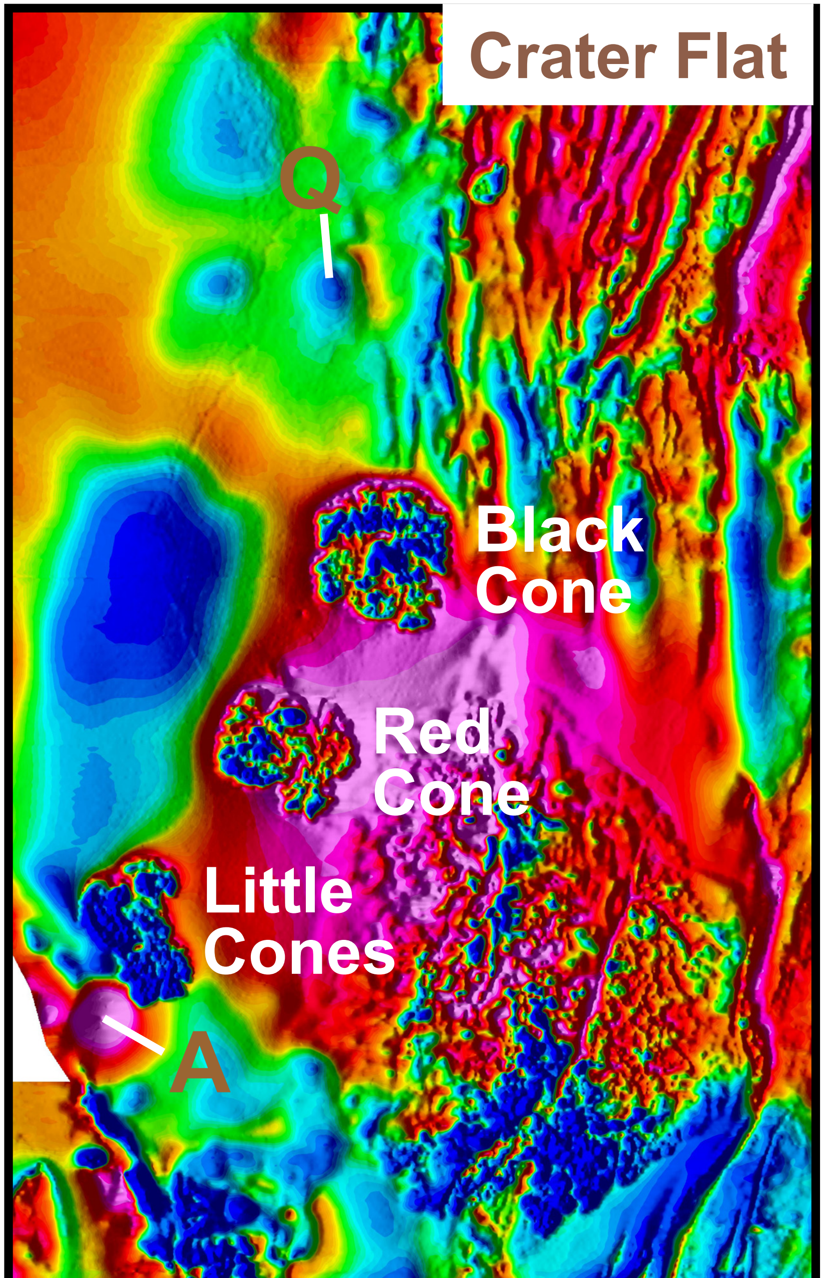
Probability of an Igneous Event

- Six Quaternary basaltic volcanoes (red) within 20 km of the repository site
- Eight aeromagnetic anomalies (green) representing possible buried basalt known at time of 1996 Probabilistic Volcanic Hazard Analysis (PVHA)
- Fifteen additional anomalies identified since 1996 in later ground and aeromagnetic surveys

Anomaly

Aeromagnetic Anomaly Borehole Drilling Targets for Detection of Buried Volcanic Centers





Probability of an Igneous Event

- **Three of seven anomalies drilled to evaluate anomalies**

  <u>Anomaly Q (New)</u>

  - Modeled as tuff at a target depth of > 190 m

  - Encountered basalt at 141 m

  - Consisted of 4 separate lava flows similar in characteristics to the 11.3 Ma sequence of flows encountered in borehole VH-2

  <u>Anomaly A (Previously recognized as buried basalt)</u>

  - Modeled as basalt with target depth of >150 - 200 m.

  - Encountered a massive basalt unit at 148 m with total thickness of 62 m.

  - Feature is possibly a sill or ponded basalt flow

  <u>Anomaly O (Previously recognized as buried basalt)</u>

  - Modeled as a tuff with target depth to tuff of 75 - 145 m.

  - Tuff encountered at approximately 111 meters

- **Drilling provides confirmation of buried basalts**
- **Basalts encountered in boreholes are being age dated**
- **Information will be provided to expert panel for elicitation process to update PVHA of 1996**

Consequences of an Igneous Event

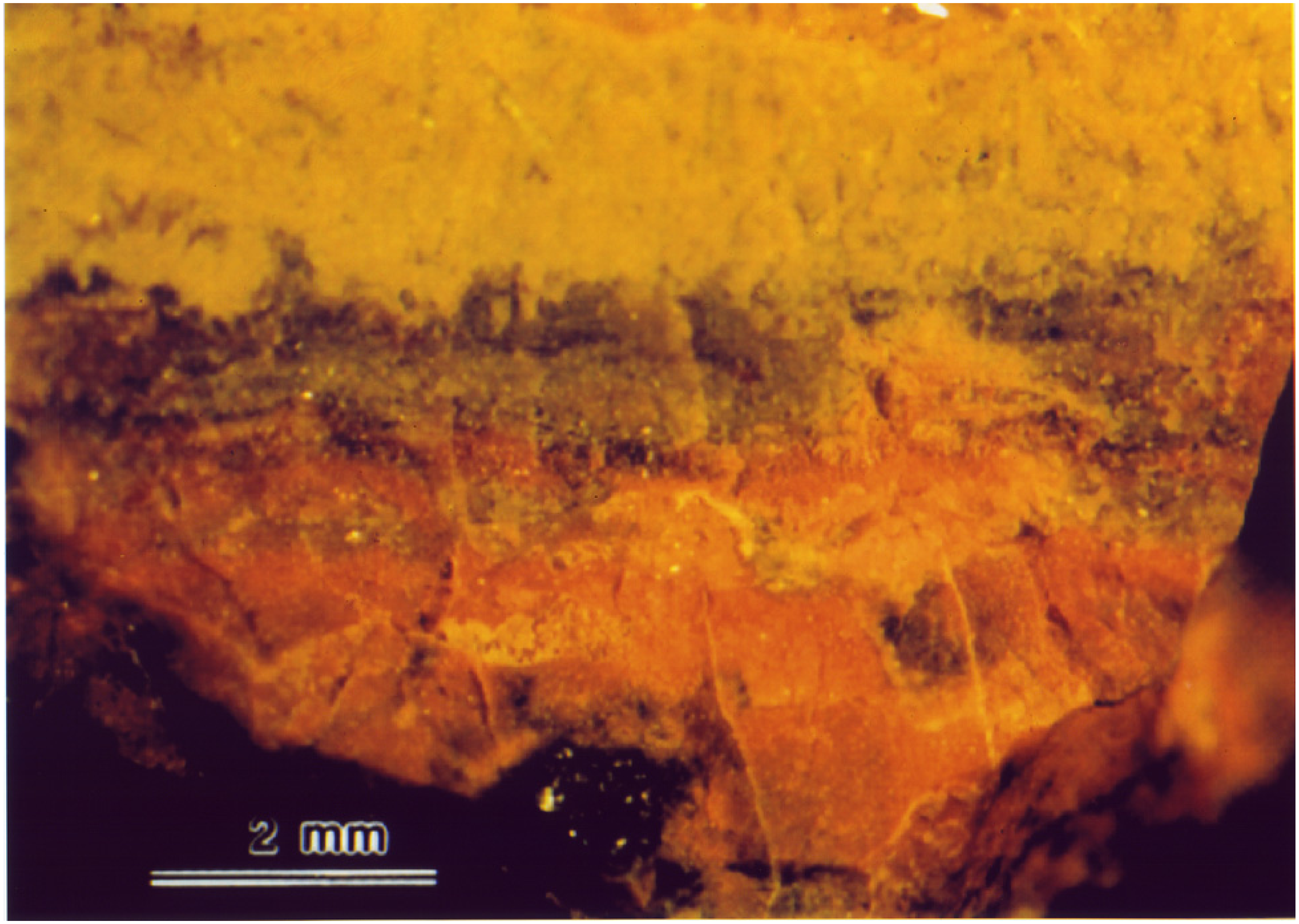
- Developed and qualified computational fluid dynamics code (GMFix) that represents multiphase (pyroclastic) flow to:
  - Assess pyroclastic flow behavior in repository drifts
  - Address potential for secondary breakout from the repository horizon
- Analyzing behavior of effusive magma as it moves over top of backfill in backfilled main drifts.
  - Preliminary results confirm assumptions that magma moving through 30 cm gap will freeze in approximately 500m (drift length)
  - Will consider influence of drip shield and waste packages on magma movement
- Analyzing for influence of geologic structures (normal faults) on dike propagation

Source Term Processes

Source Term
Critical Processes

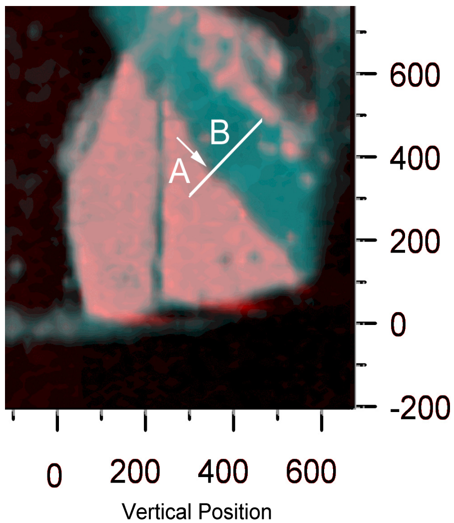
- Kinetics of waste form corrosion
- Formation of secondary, alteration phases
- Sorption/reduction on the surfaces of near-field materials
- Formation and mobility of colloids

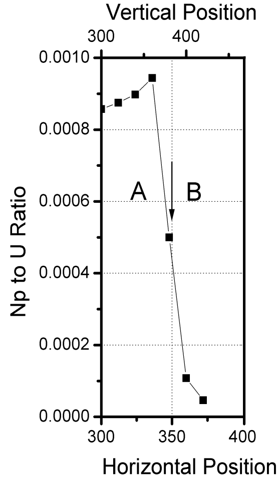
Corrosion of UO_{2+x}



Finch and Ewing (1992) ***Journal of Nuclear Materials***

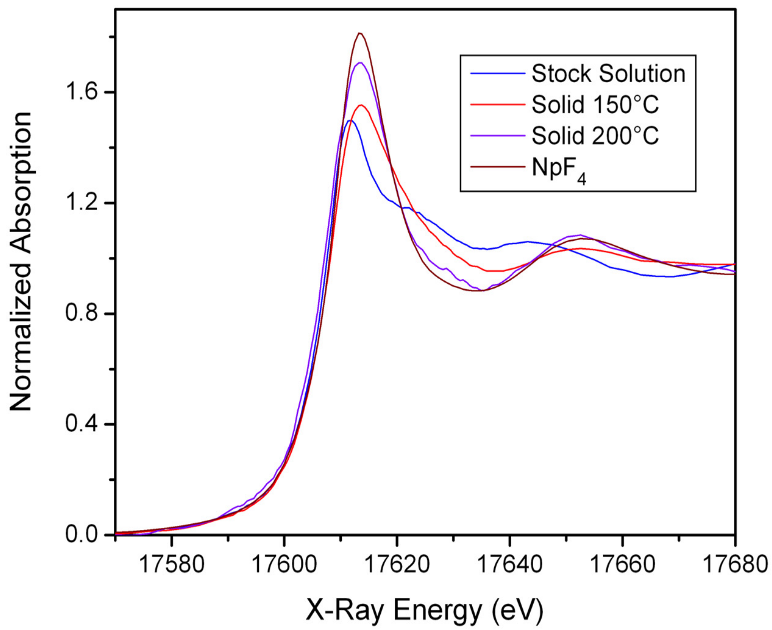
Np Behavior Near Corroded Spent Nuclear Fuel (SNF) Surface





- **Np present as Np(IV) in the fuel matrix**
- **Evidence that Np/U ratio peaks near the corroded fuel surface**
- **Np/U ratio decreases in ~50μm mixed-valence U(IV)/U(VI) region adjacent to the corroded fuel surface**
- **Results provide evidence that redox conditions at and near the corroding fuel surface control Np oxidation and dissolution**

Np Precipitation from Np(V) Solution



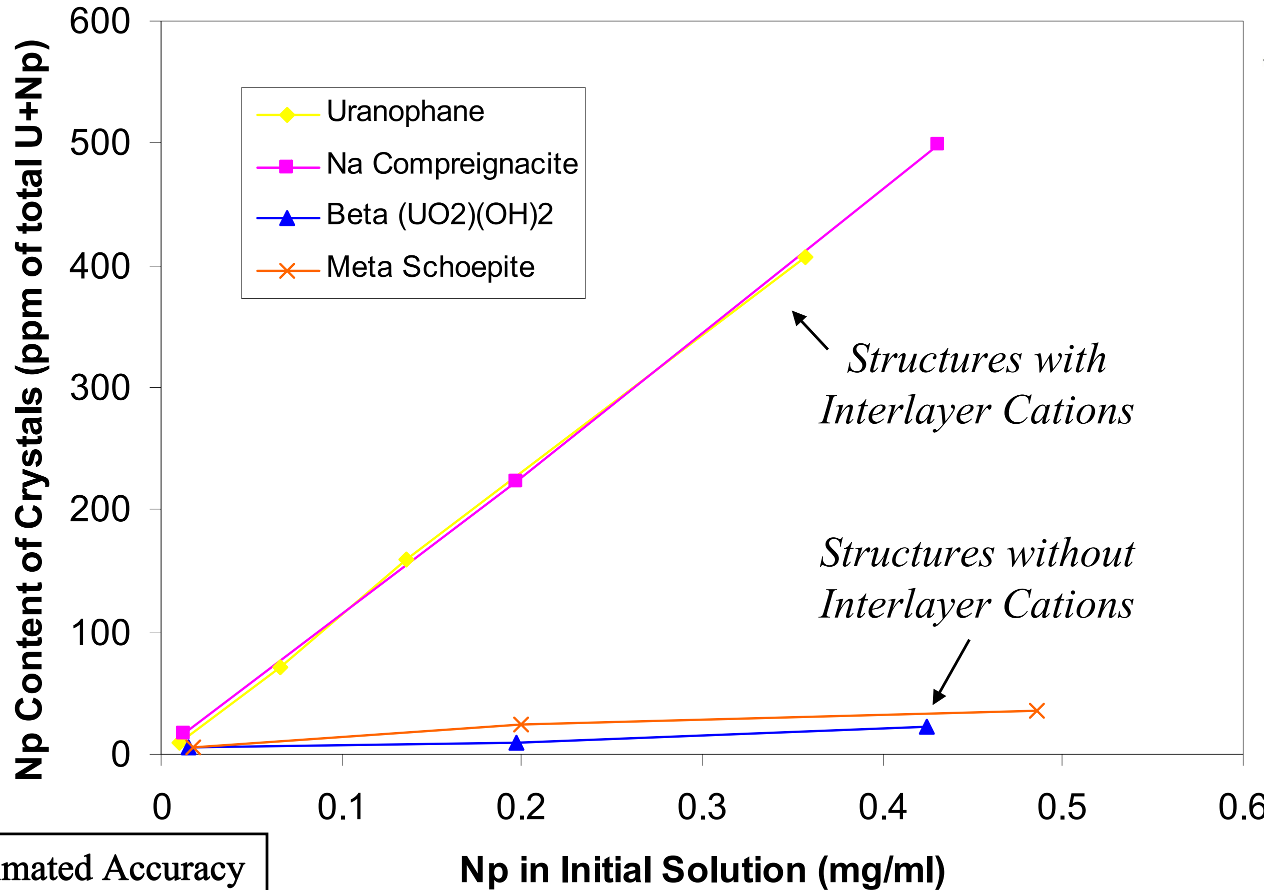
- **$NpO_2^+(aq) + 0.5H_2O = NpO_2(s) + H^+(aq) + 0.25O_2(g)$**

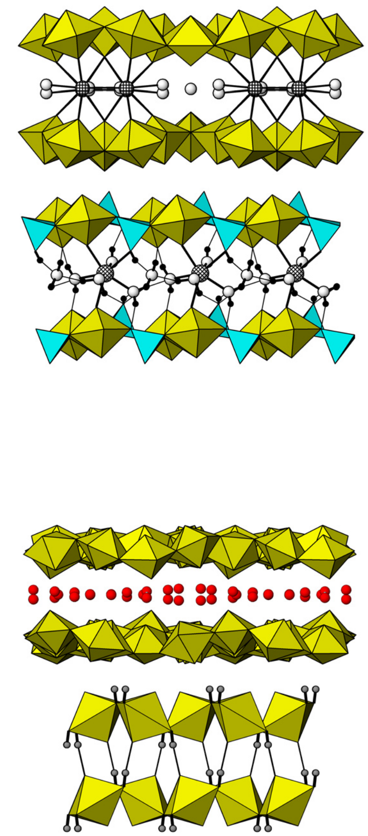
  (Roberts et al. @ 200°C)

- **NpO_2(s) precipitation observed at 200, 250 and 280°C (Electron Diffraction and XAS); Mixed valence Np(IV)/Np(V) precipitate observed at 150°C (XAS)**

- **Ongoing work addressing homogenous and heterogeneous precipitation at lower temperatures**

Np^{5+} Incorporation into Uranyl Phases





Estimated Accuracy
±10% Np

Burns et al. (2004): Radiochimica Acta 92, 151-159

Summary

- Collection of scientific data continues
- These data are being used to support the models and parameters used in support of the TSPA, performance confirmation, and future licensing activities