Oak Ridge Field Research Center

FRC Workshop
FRC Site Characterization Update
October 25, 2005

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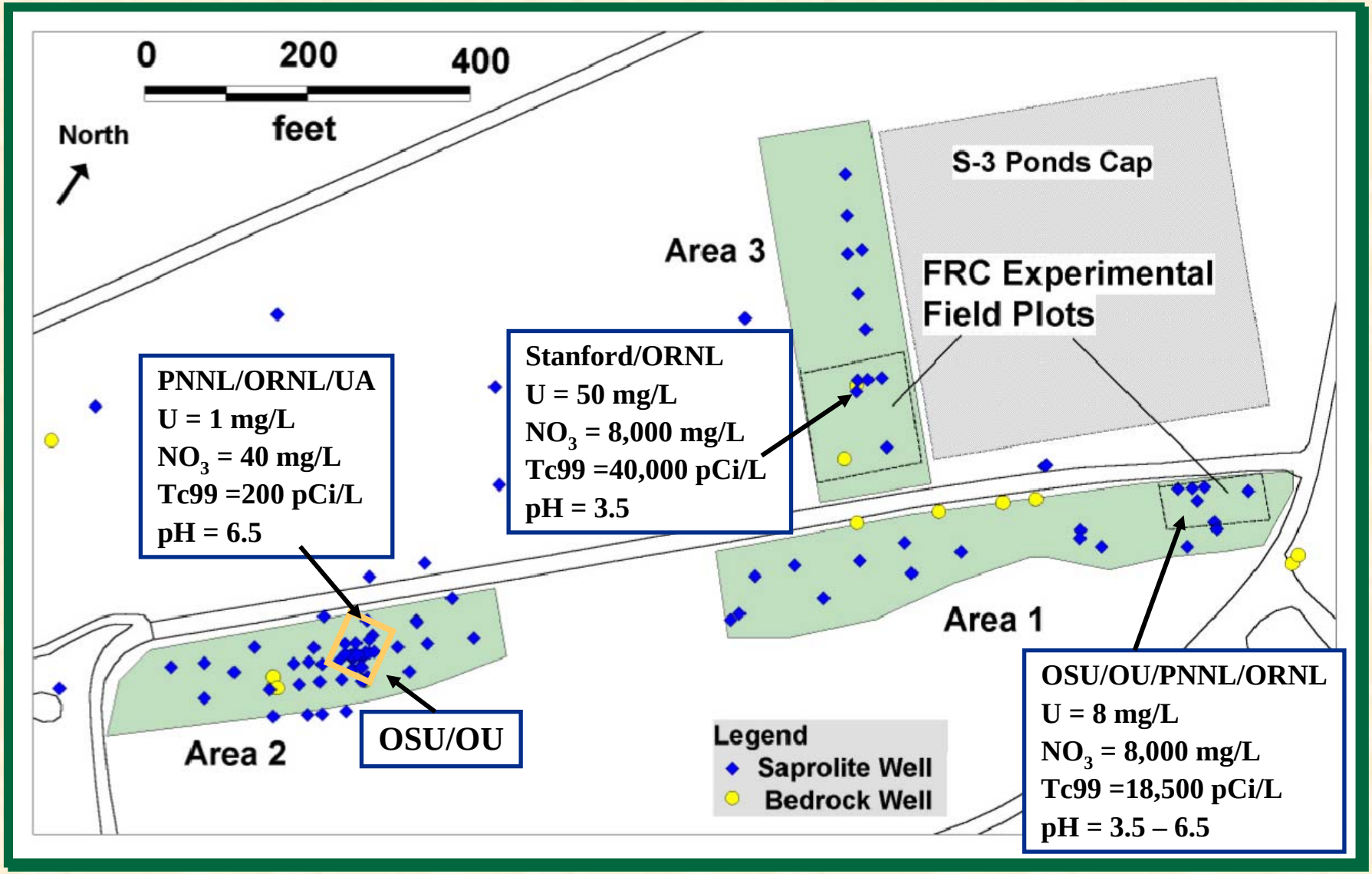
Contributors

- **Well installation, sample collection and analysis – Kirk Hyder, Kenneth Lowe, Mary Anna Bogle, Tonia Mehlhorn, Wiwat Kamolpornwijit, Scott Brooks, Jana Tarver, and George Houser**
- **Noble gas tracer test – Brian Spalding**
- **Data – Craig Brandt, Sally Mueller, Susan Holladay**
- **Modeling – Fan Zhang and Jack Parker**

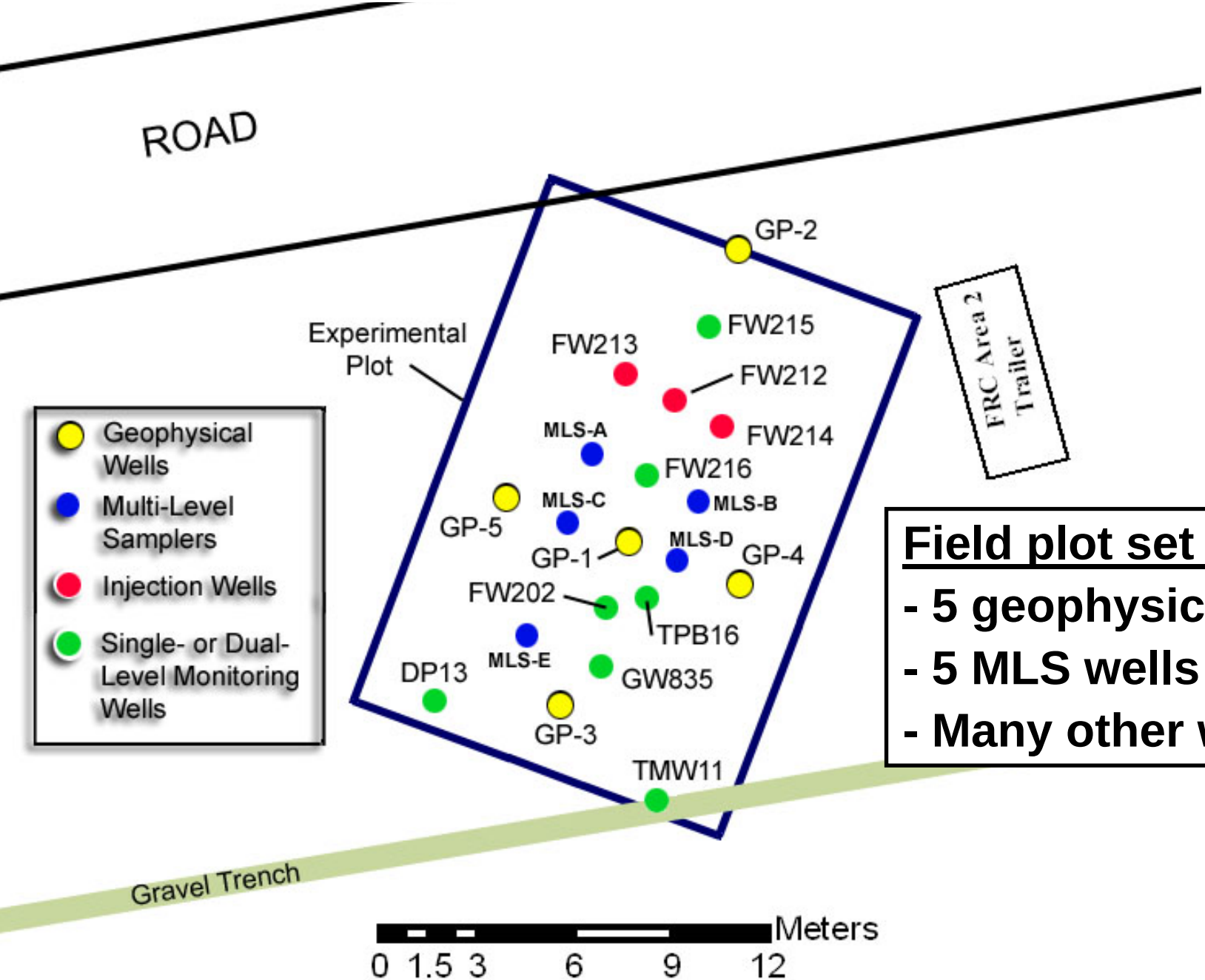
Site Characterization Activities

- **Area 2 (PNNL) field plot completed and field experiment started**
- **Area 3 (FW106 area) field plot characterization**
- **Evaluation of potential interference between Area 3 field plots**
- **Area 3 noble gas tracer test**
- **Watershed community/geochemistry characterization**

Field Plots in Contaminated Area



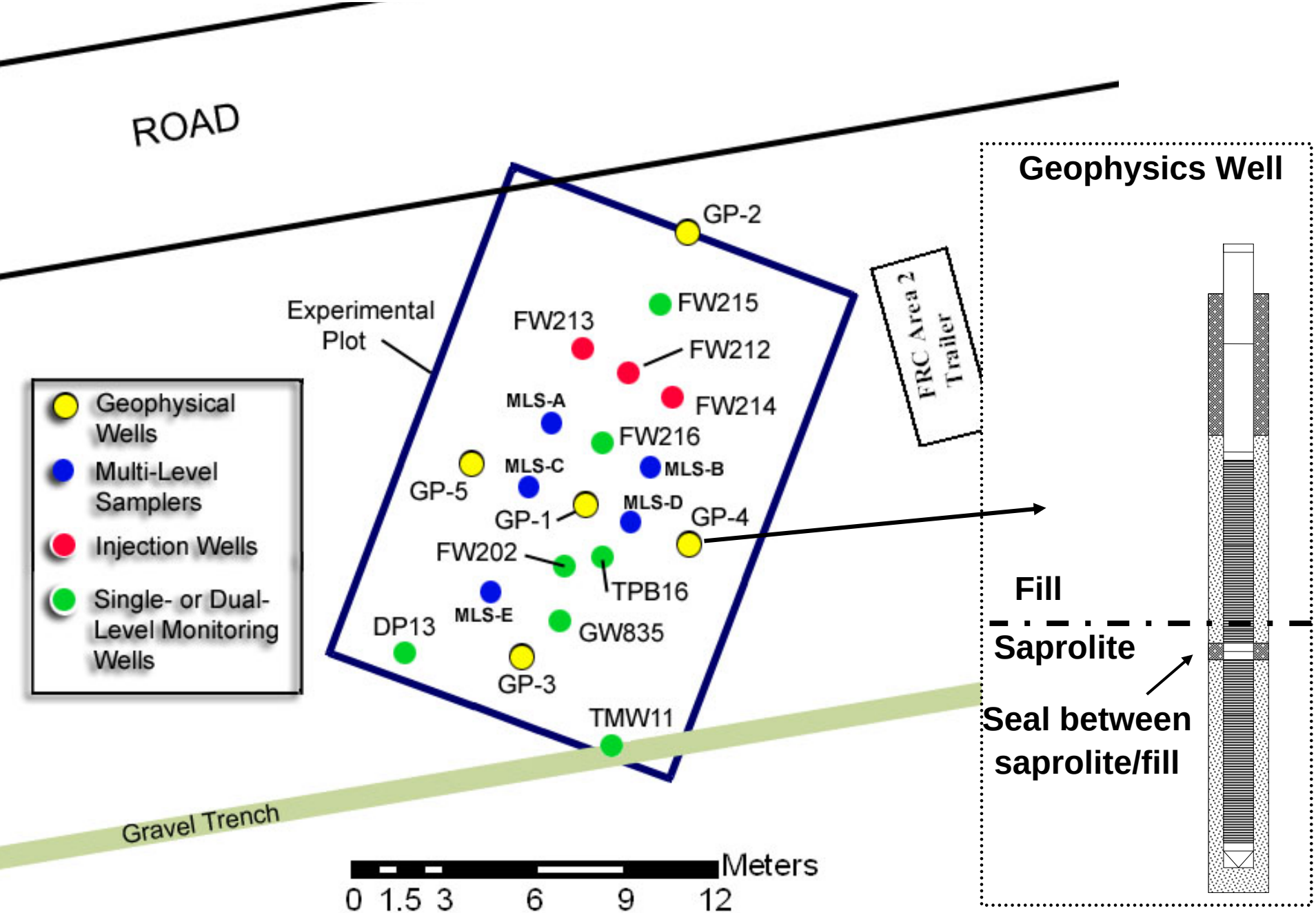
PNNL/ORNL/UA Area 2 Field Plot



Field plot set up

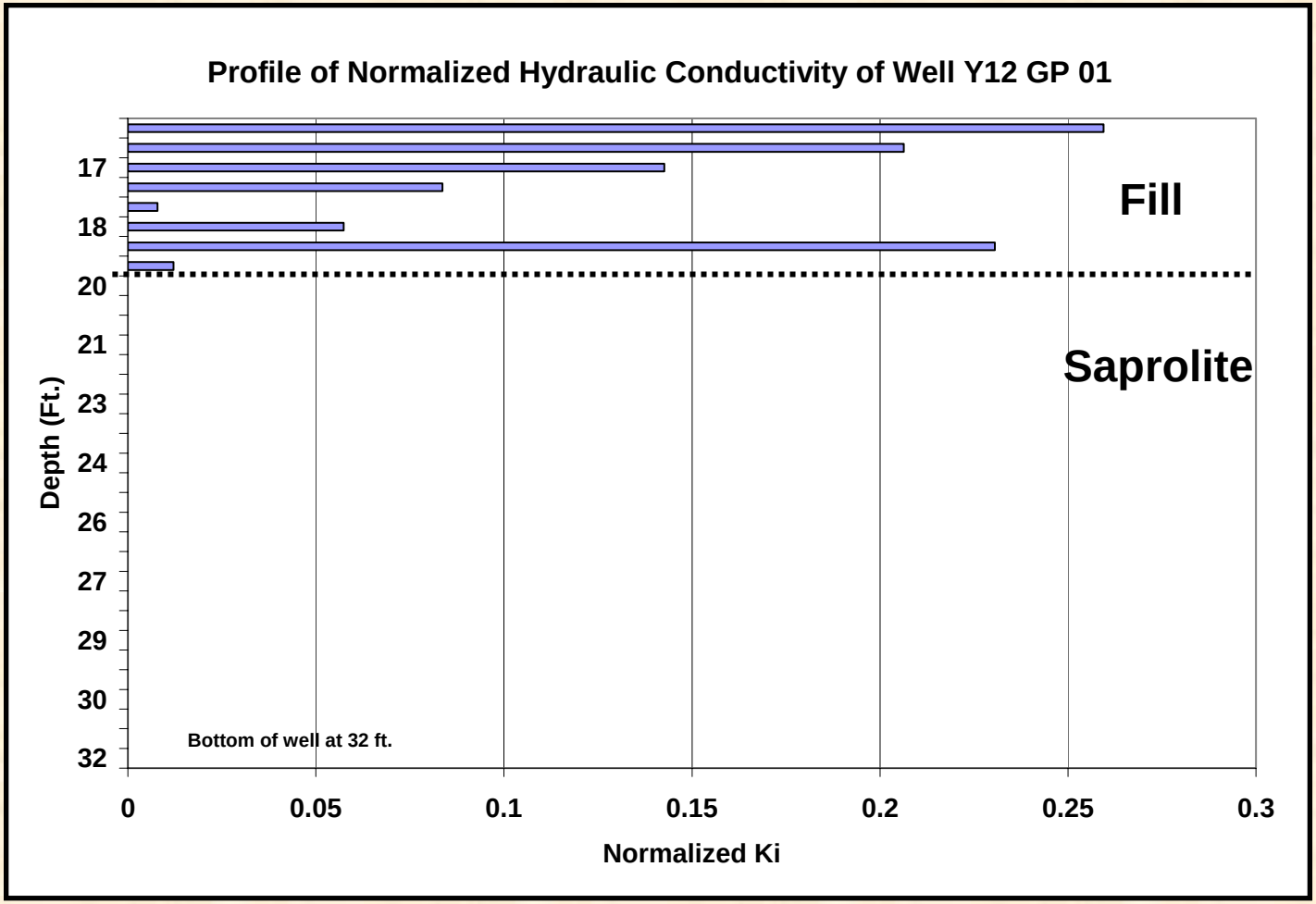
- 5 geophysics wells
- 5 MLS wells (7 ports)
- Many other wells

PNNL/ORNL/UA Area 2 Field Plot

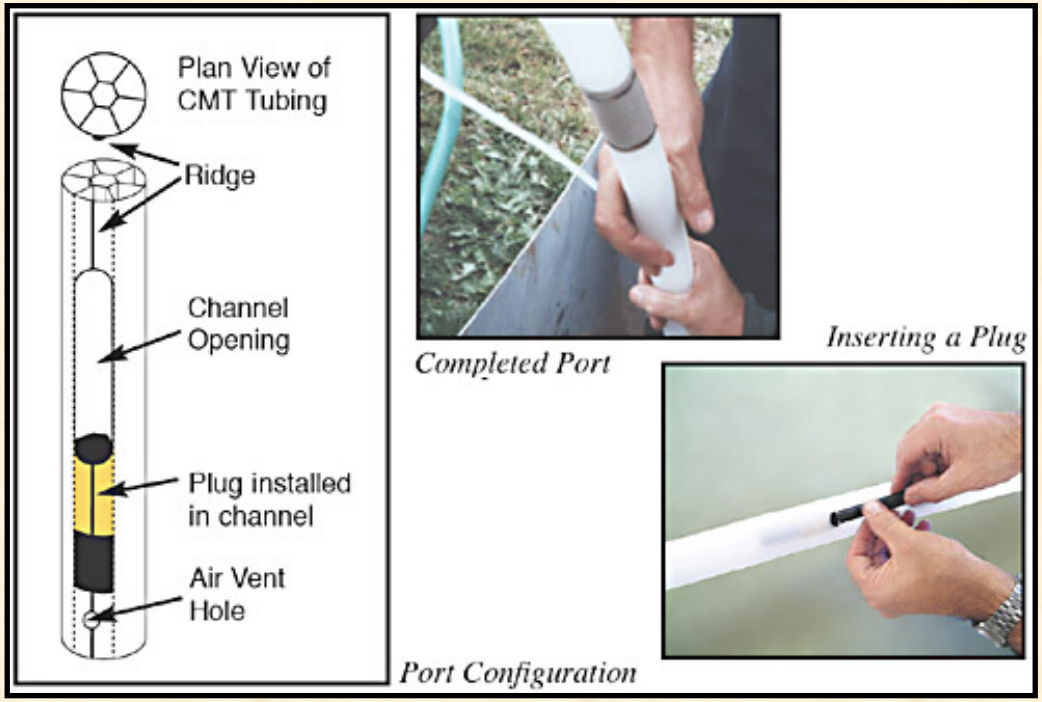


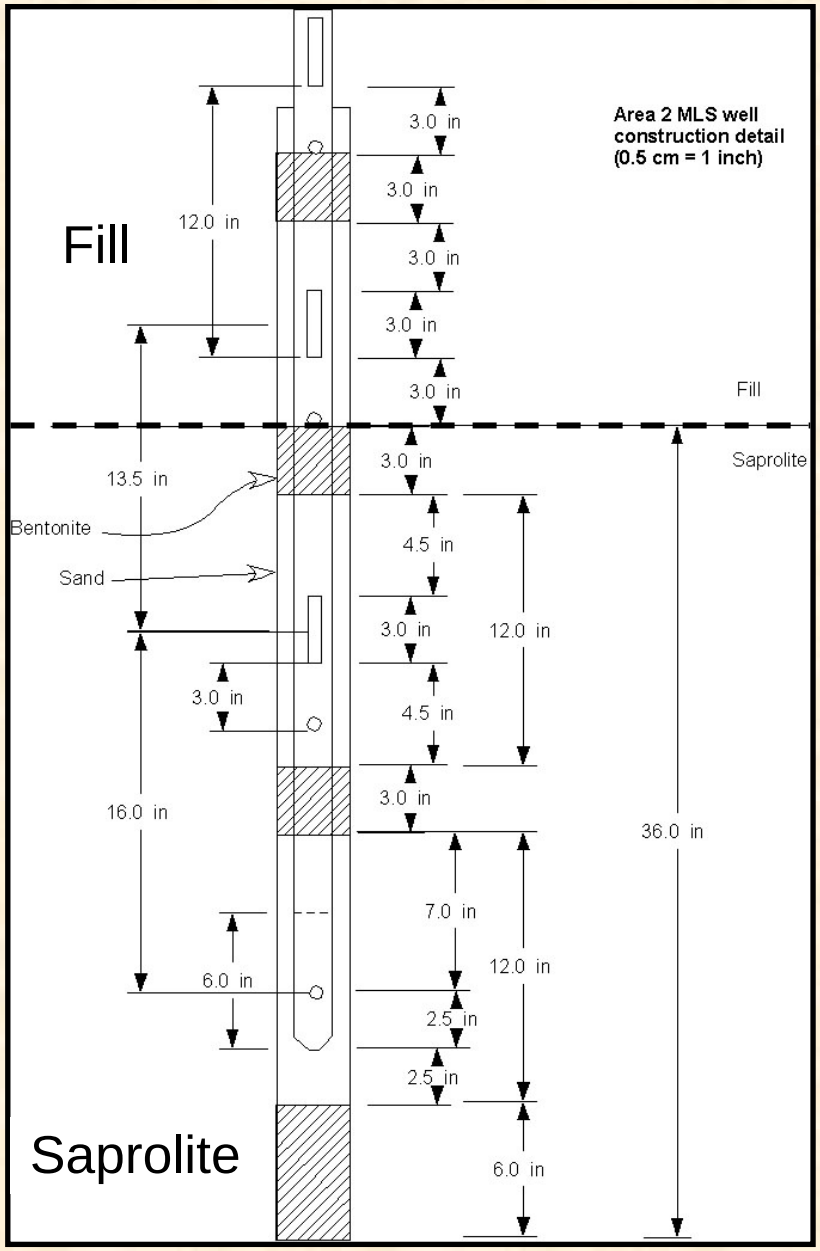
Flowmeter Testing on Area 2 Geophysics Wells

Showing high permeability of fill compared to saprolite

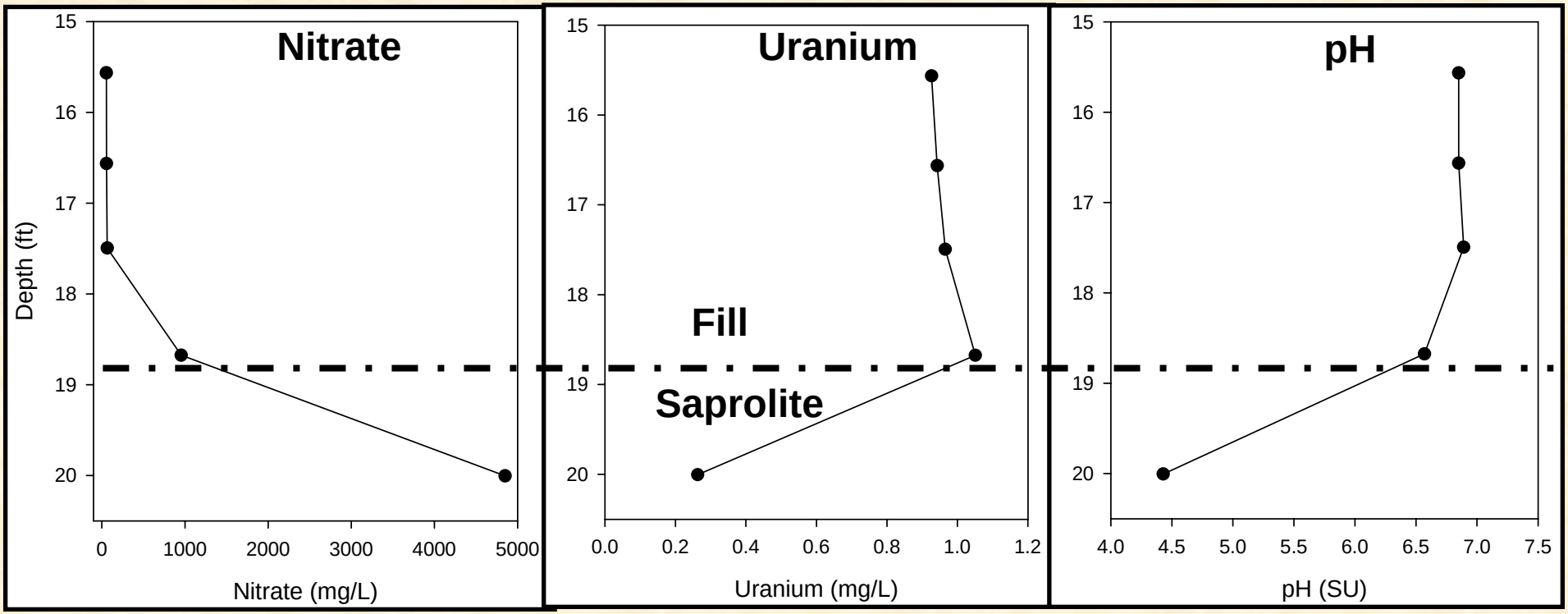


MLS Well Construction (Area 2 Field Plot)

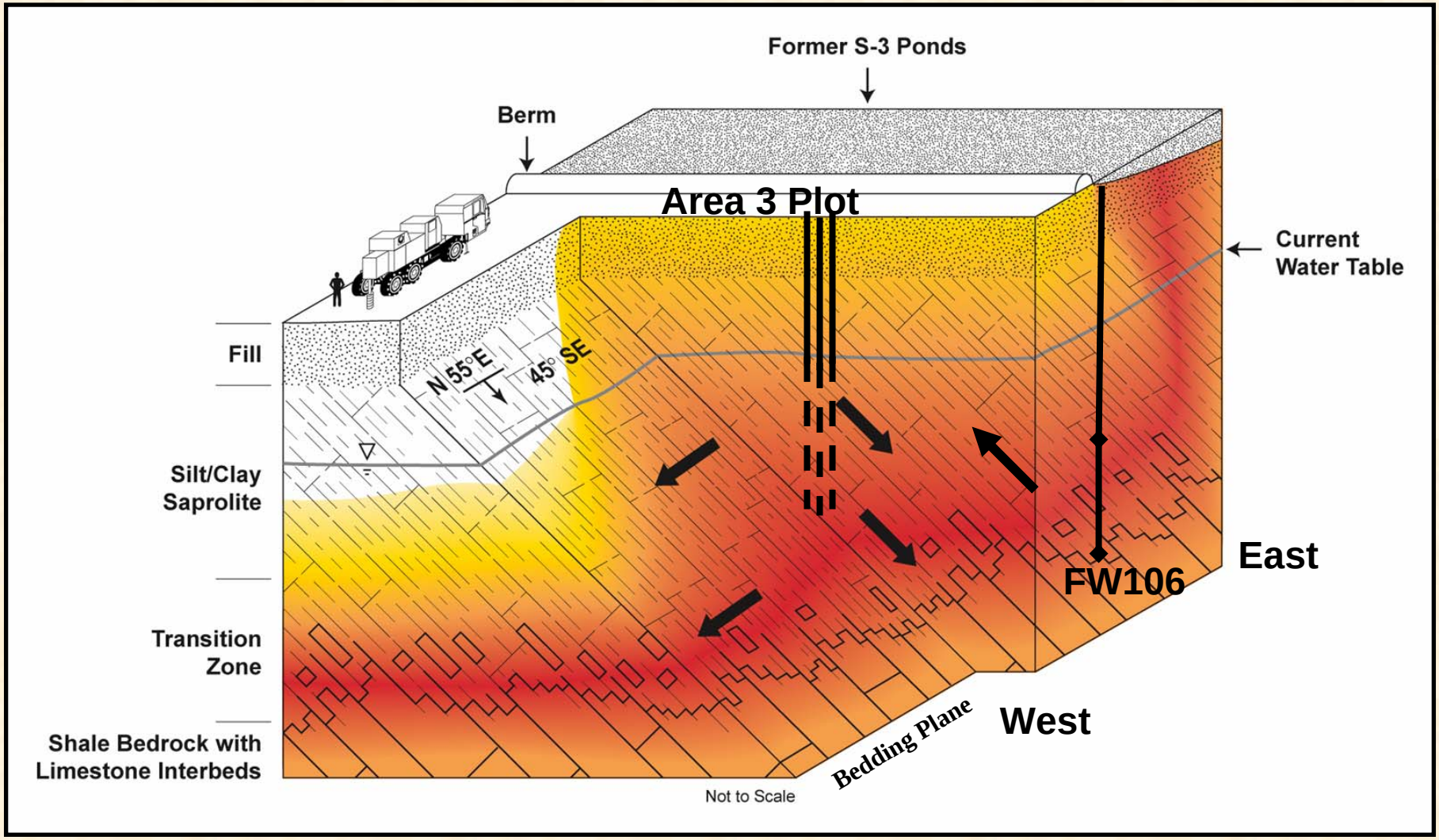




Groundwater Depth Profiles at Well MLS-D 06/21/05 Sampling Event



FW106 (Area 3) Evaluations



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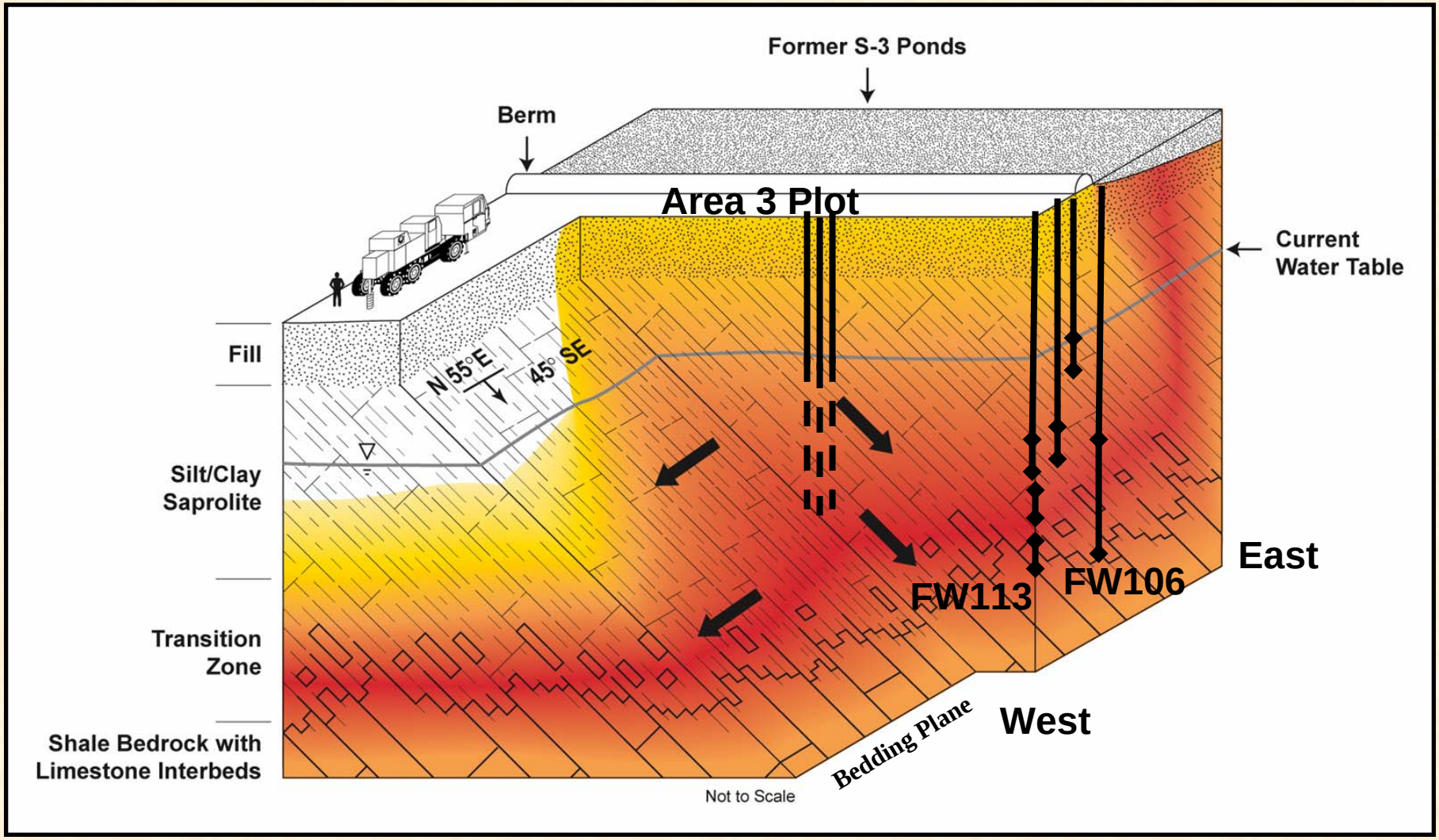
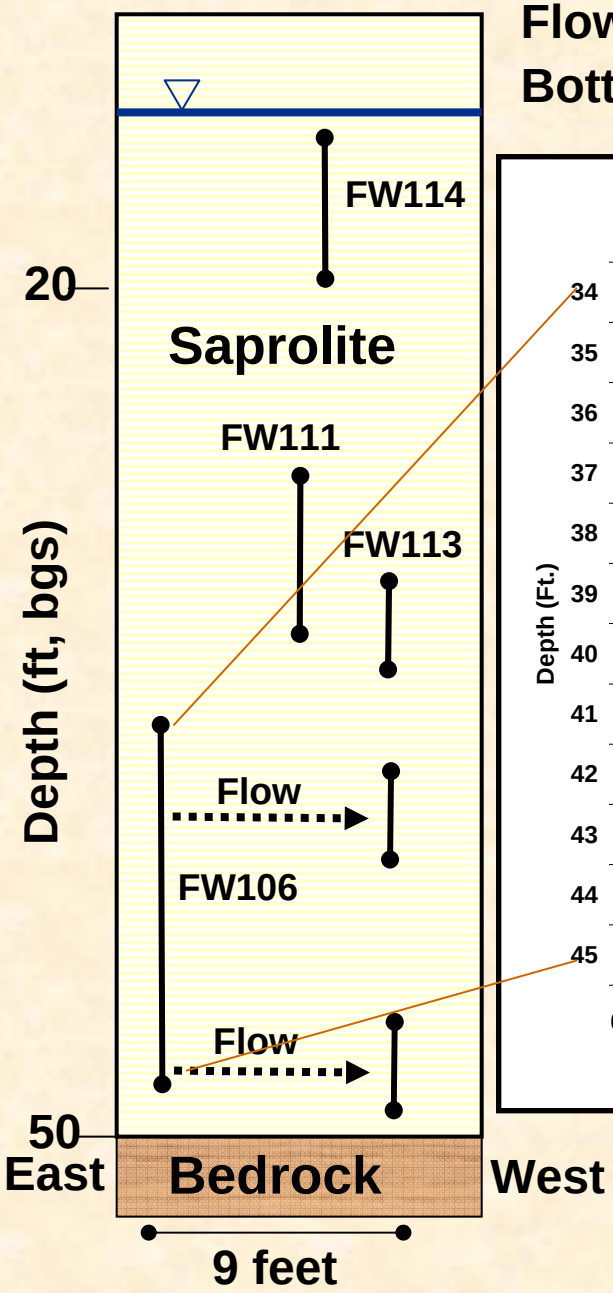
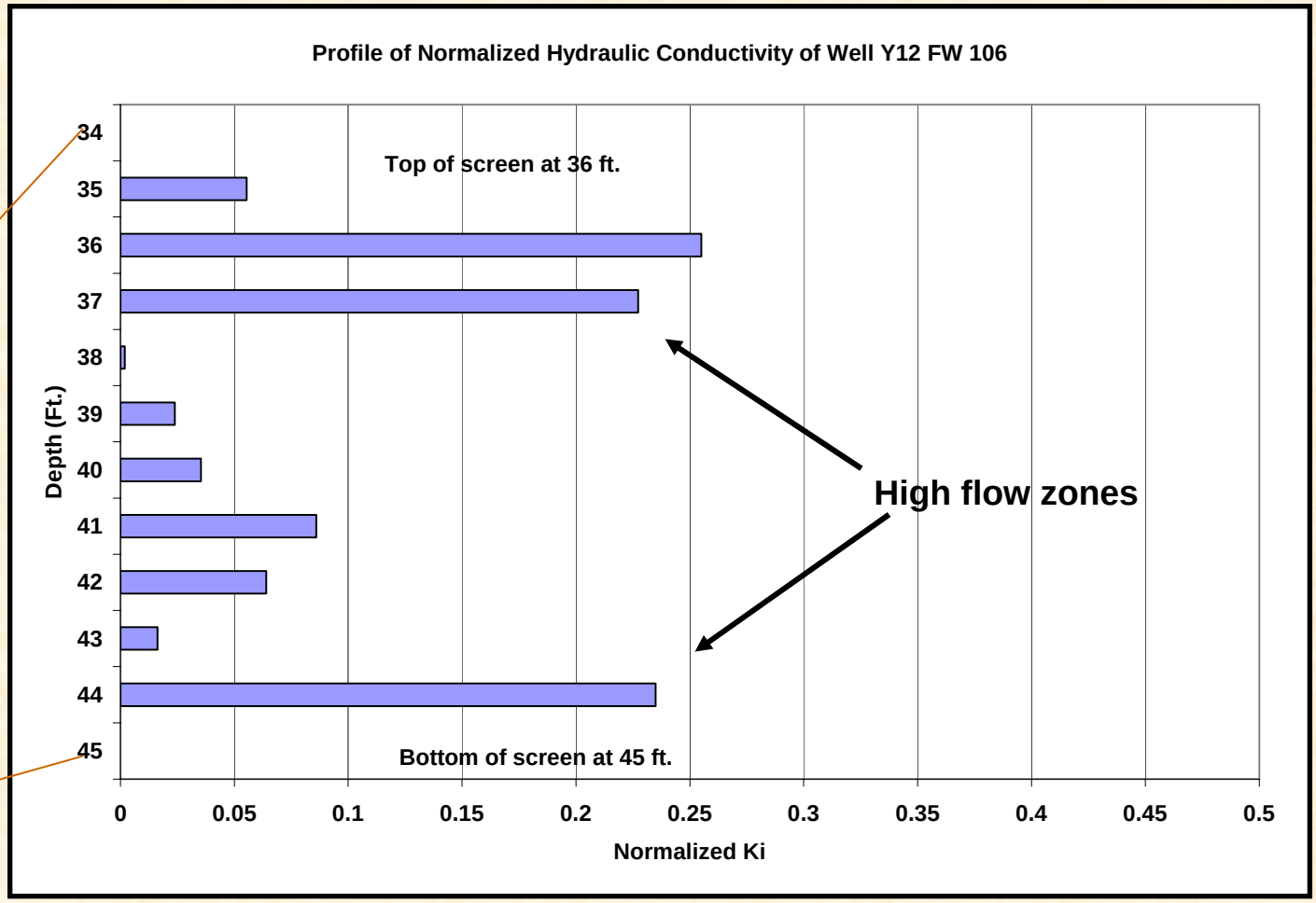


FW106 Area Characterization

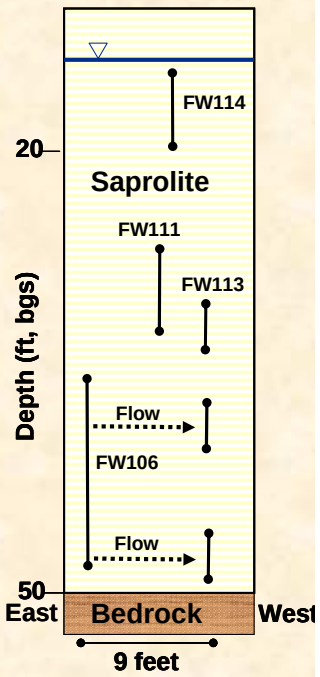
Flowmeter profiling data from FW106 was used to target Bottom 2 ports of FW113 in high flow zones

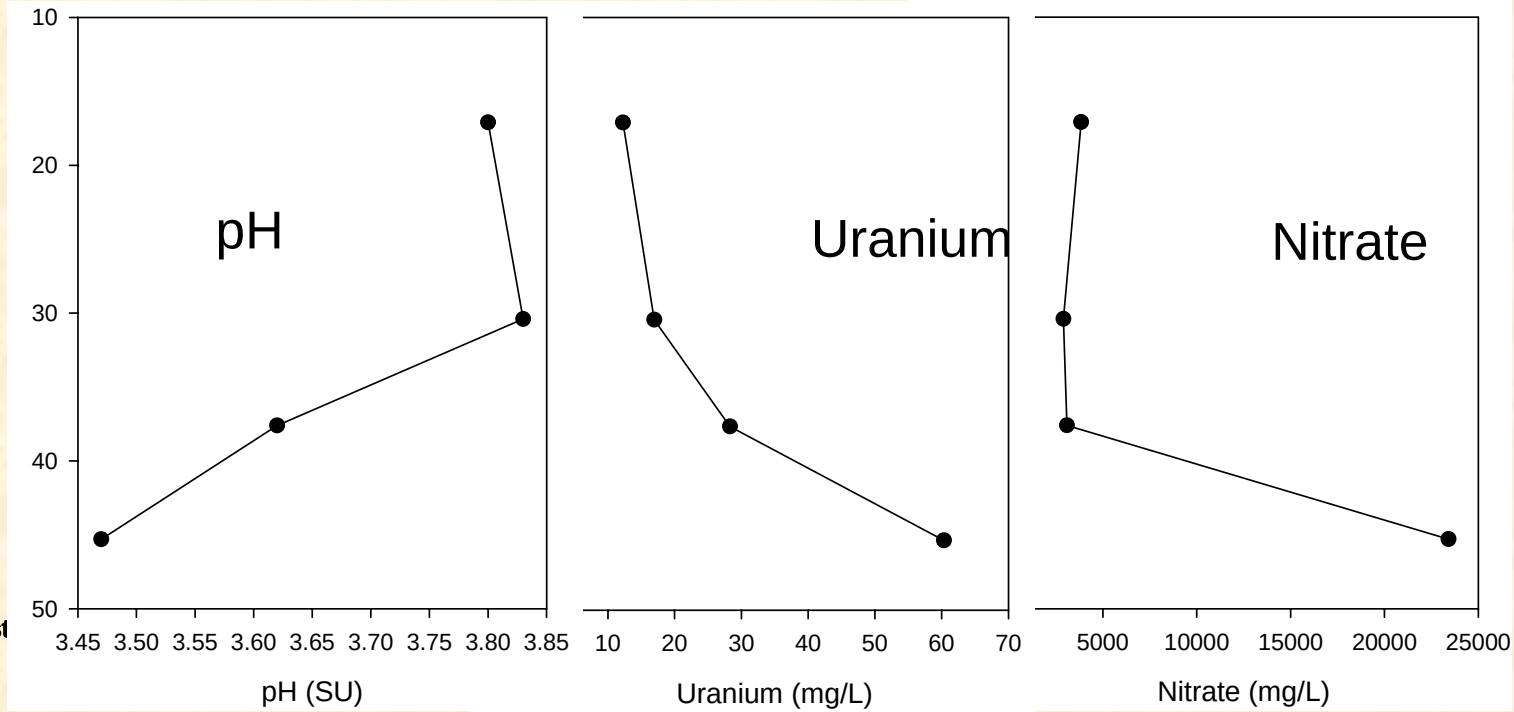




FW106 Area Characterization

Contaminants increase with depth

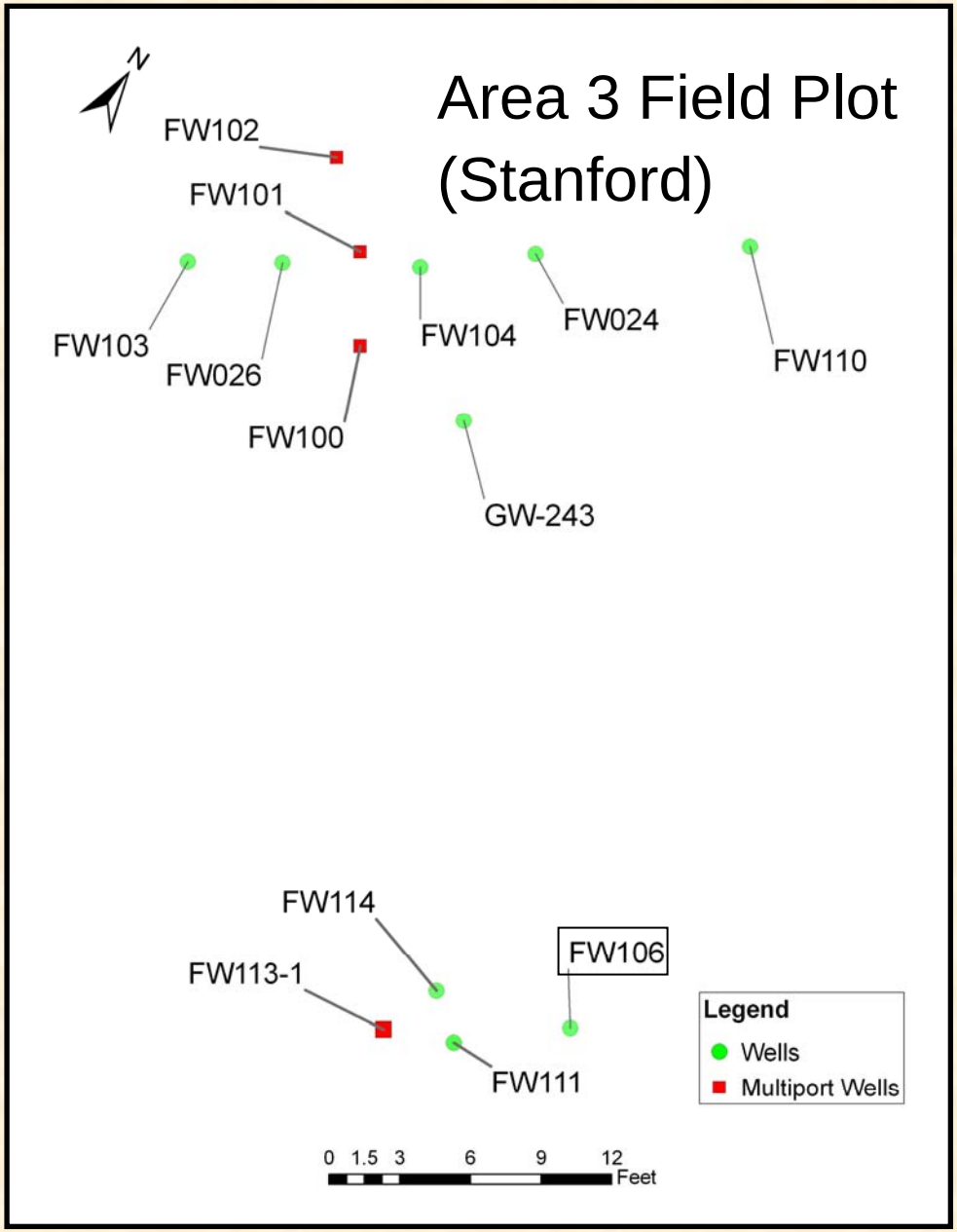




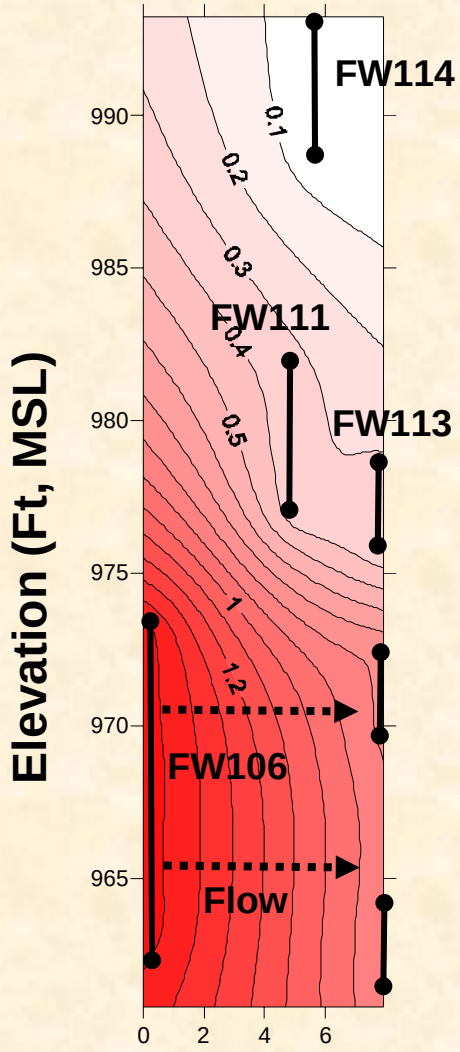
Location	Sampling Date	Depth (ft)	pH (SU)	DO (ppt)	Nitrate (mg/L)	Sulfate (mg/L)	Uranium (mg/L)
FW114	09/01/05	20	3.80	4.48	3841	1480	12.25
FW111	11/22/04	30	2.90	3.40	1456	2360	15.97
FW113-32	08/31/05	32	3.83	0.53	2892	4488	16.95
FW113-38	08/31/05	38	3.62	0.24	3082	4386	28.28
FW106	09/02/05	45	3.65	0.56	3367	4404	24.71
FW113-47	09/01/05	47	3.47	0.17	23409	3798	60.36

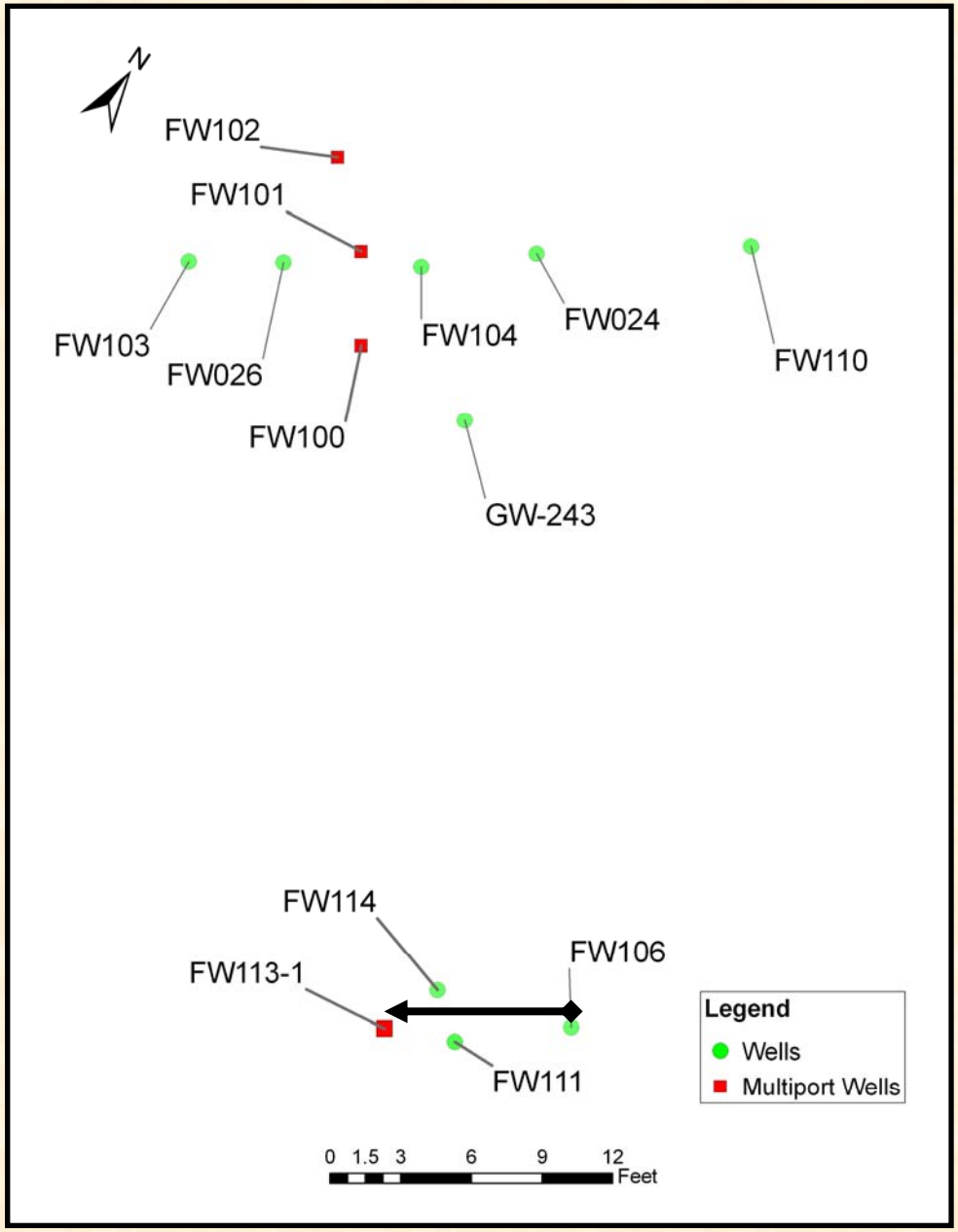
FW106 Pumping Test

- **FW106 pumped at 0.75 L/min**
- **Wells near FW106 and Area 3 Field Plot (Stanford site) monitored**
- **Other wells in Area 3 and 4 also monitored**
- **T = 0.3 cm^2/sec**
- **High permeability zone K=0.003 cm/sec**



Drawdown (feet) During FW106 Pumping Test





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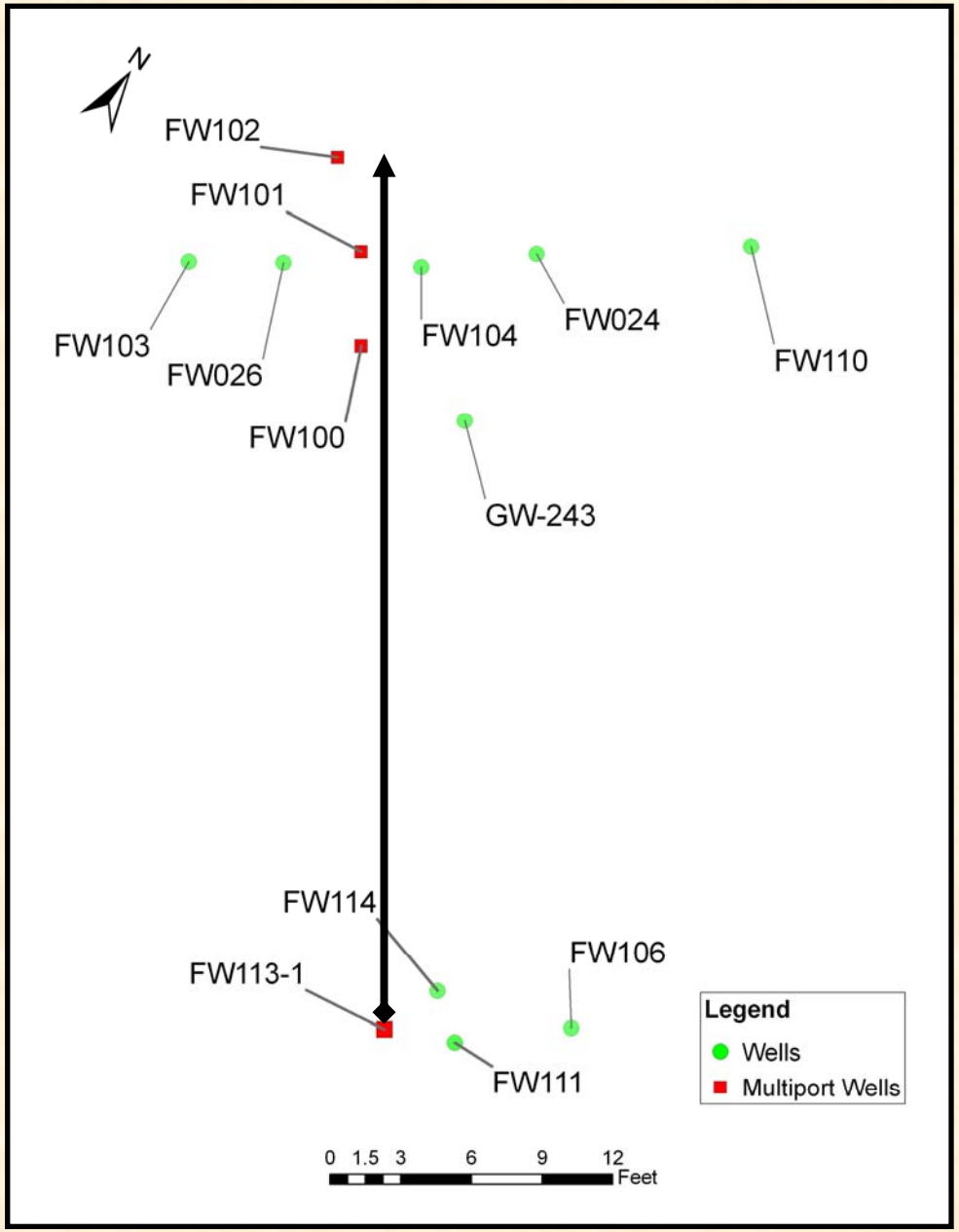
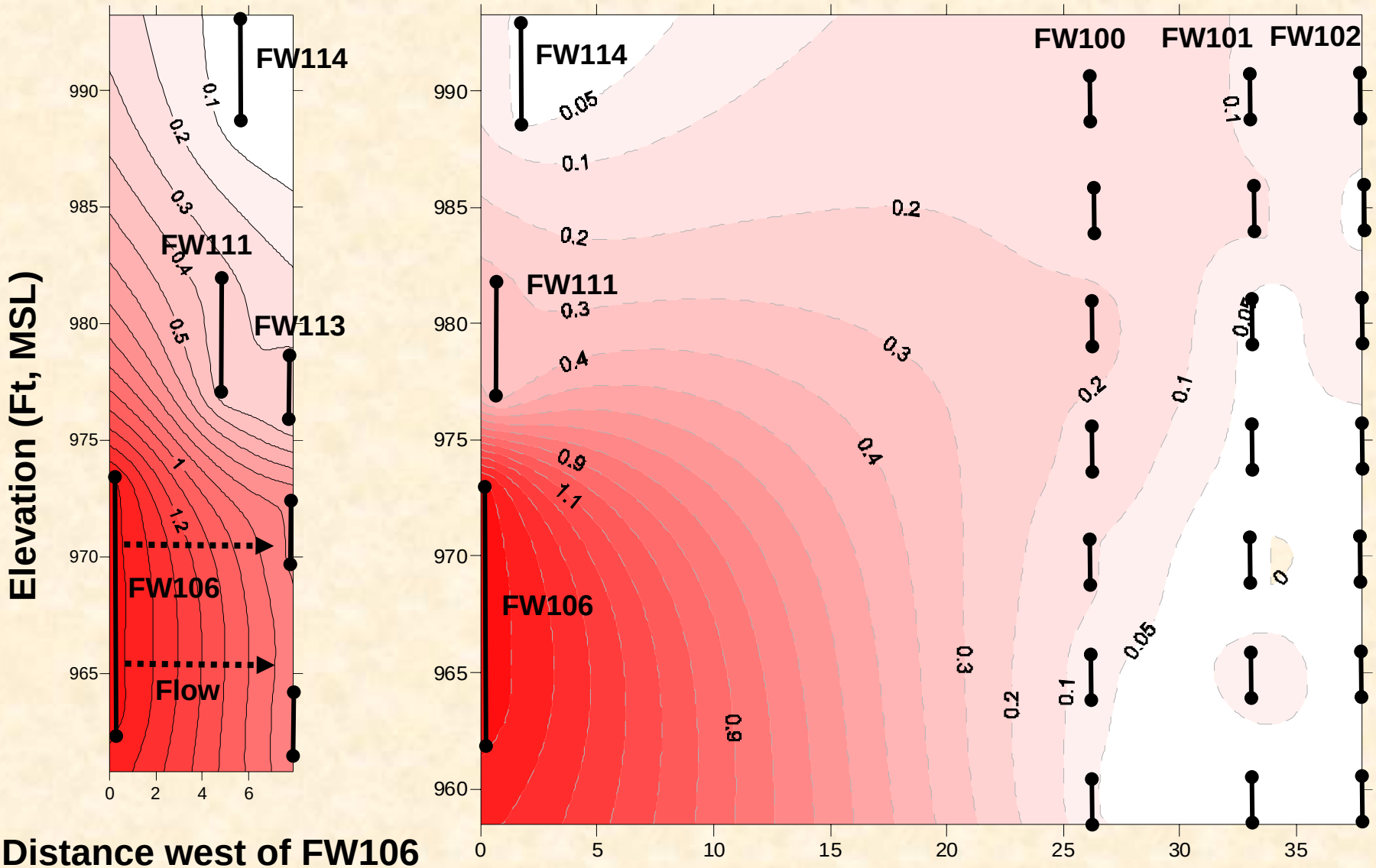


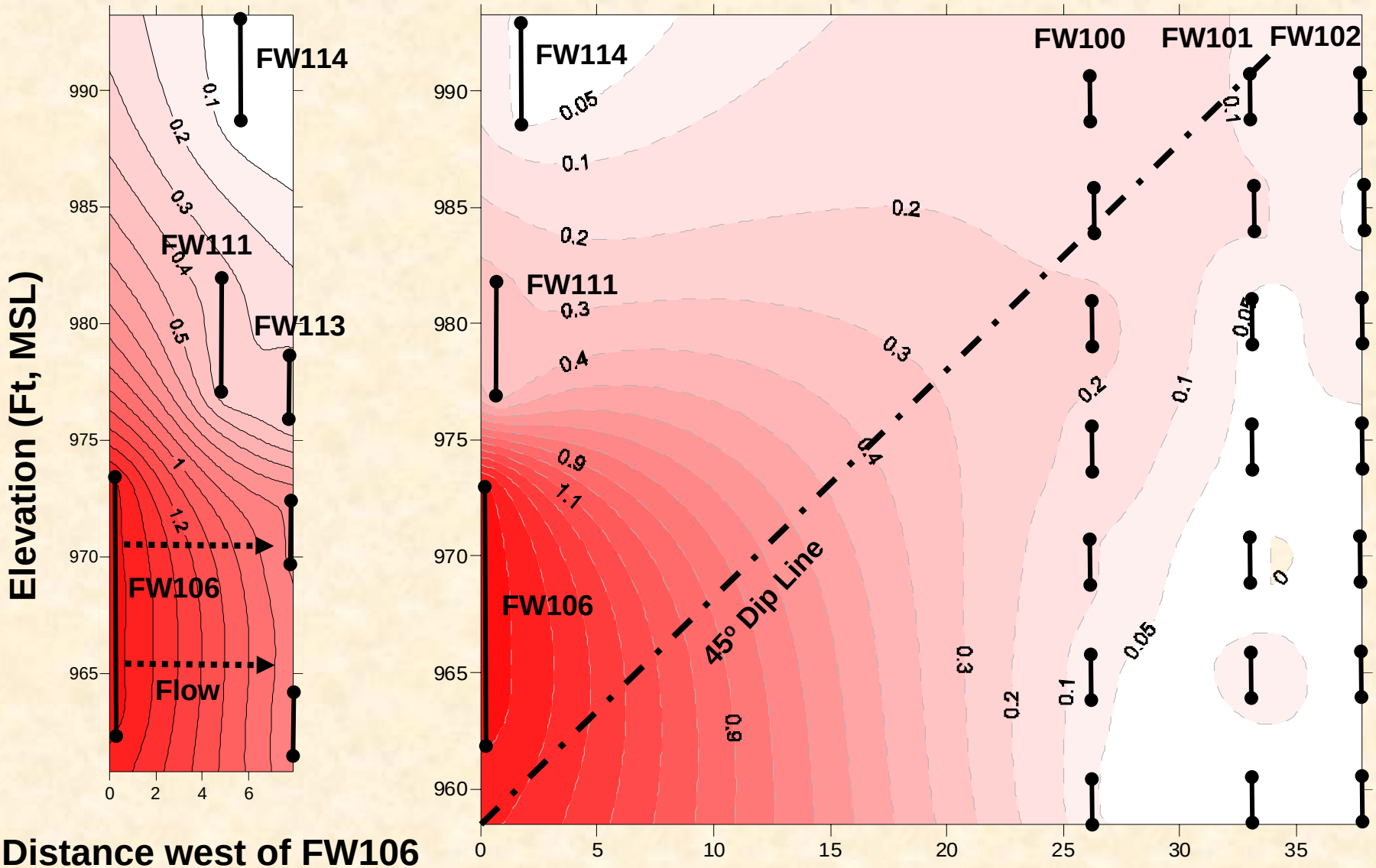
Drawdown (feet) During FW106 Pumping Test



Distance west of FW106
(along flow or strike)

Distance north of FW106 (feet)
(Up dip direction or perpendicular to flow)

Drawdown (feet) During FW106 Pumping Test

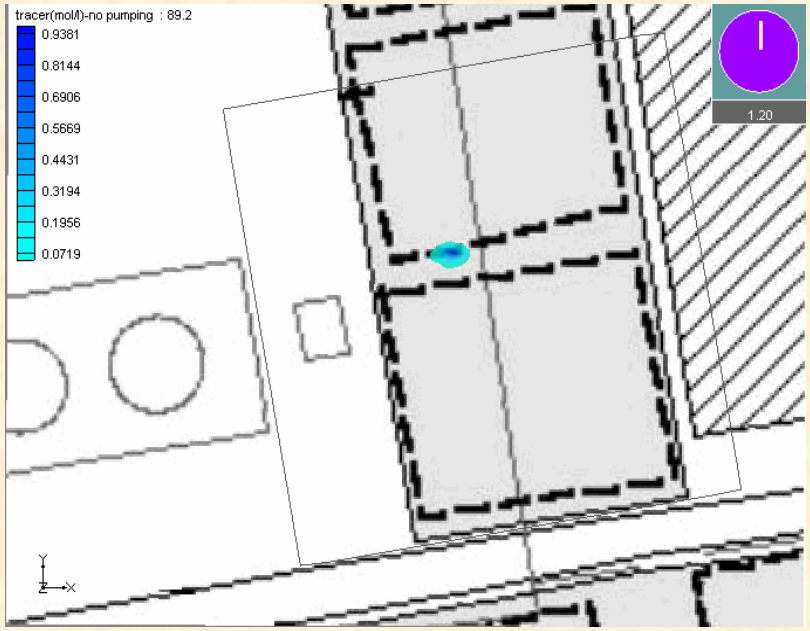


Distance west of FW106 (along flow or strike)

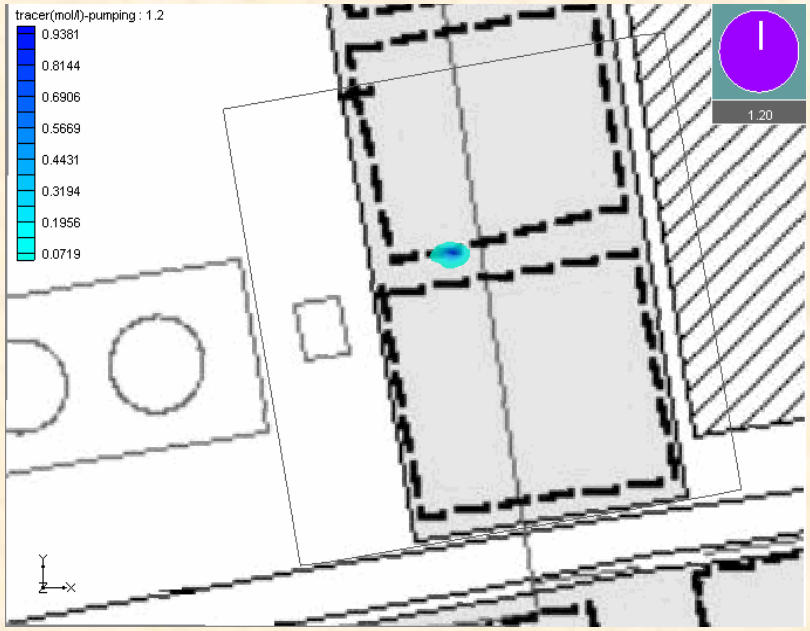
Distance north of FW106 (feet) (Up dip direction or perpendicular to flow)

Simulation of Impact of Pumping FW106 on Area 3 (FW024) Tracer Test

The difference of simulated tracer concentration for the cases without and with pumping (1 l/min) at FW106 ranges from -0.028 to 0.018 relative concentration.



Without pumping



With pumping

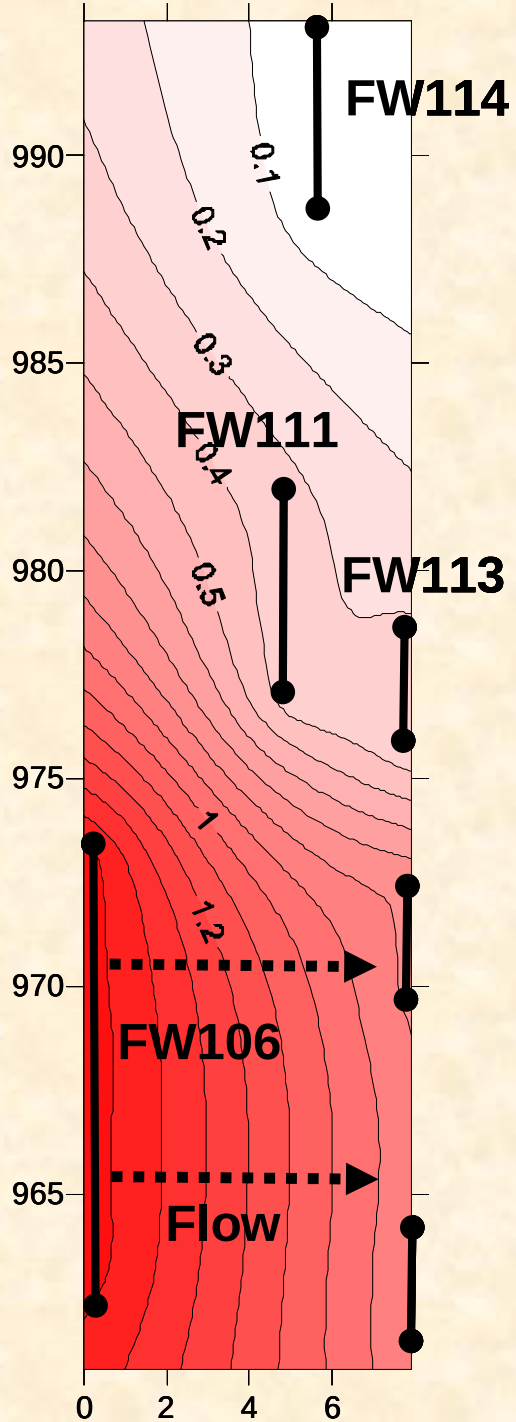
Conclusions from Area 3 Pumping Test

- **Permeability of saprolite is very anisotropic with highest K along strike parallel to bedding and lowest perpendicular to bedding**
- **Low injection and extraction rates <1 L/min are not likely to significantly impact testing being conducted at nearby adjacent field plots located in different bedding planes**
- **Higher rates of injection and extraction >1 L/min may have impacts on flow field of adjacent field plots**

FRC Area 3 Helium/Neon Groundwater Tracer Test

- **Begun October 9, 2005**
- **60% Ne/40% He diffused into Well FW106**
- **Monitoring of breakthrough and recession in proximate wells under ambient hydraulic gradient**
- **Determine groundwater velocity, direction, and accessible porosity in area 3**
- **Determine influence of relict stratigraphic controls on groundwater dynamics**
- **Adapted from established groundwater gas tracer techniques developed by Sanford and Solomon et al. (1996, 1998)**

Noble Gas Injection Scheme



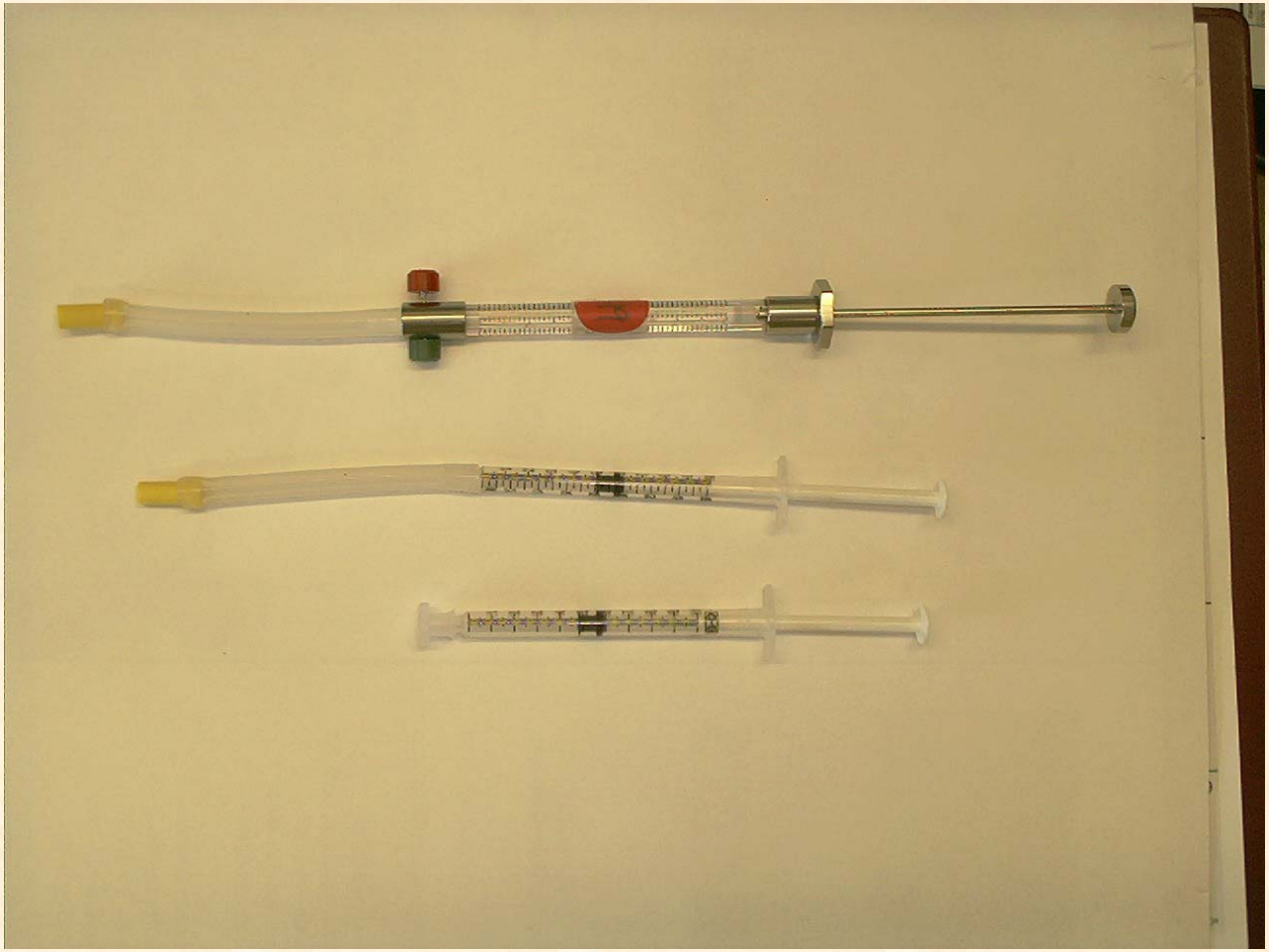
He/Ne gas tracer injection interval

UT-BATTELLE

Neon/Helium Gas Mixture Delivered by Metal Tubing to Deep Screened Interval of Well

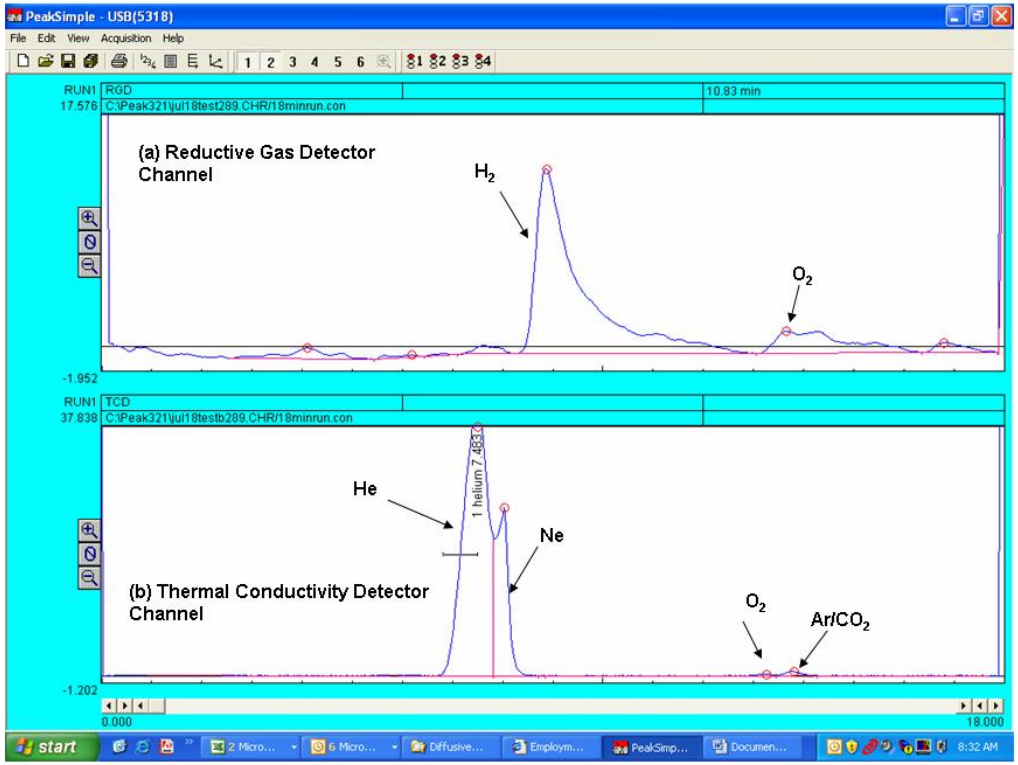
Gas diffused into groundwater at desired depth through coil of teflon tubing

Gas phase in equilibrium with groundwater is sampled passively using small volume (2 mL) silicone tubing attached to 0.5 mL syringe for direct injection into gas chromatograph. Syringe is suspended in groundwater at the target depth for at least 24 hours.

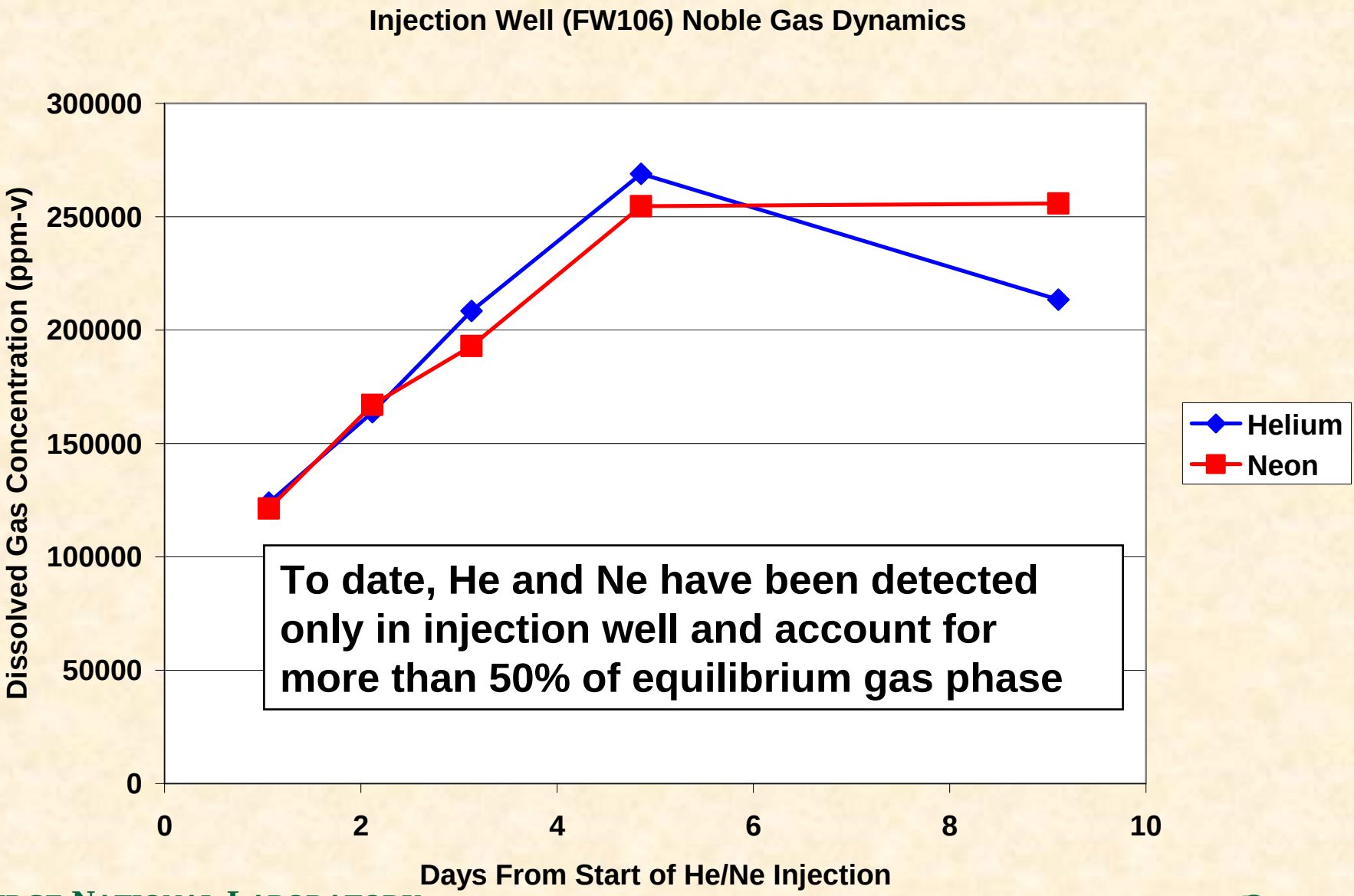


Gas Chromatograph with dual thermal conductivity and reductive gas detectors with controlling PC.

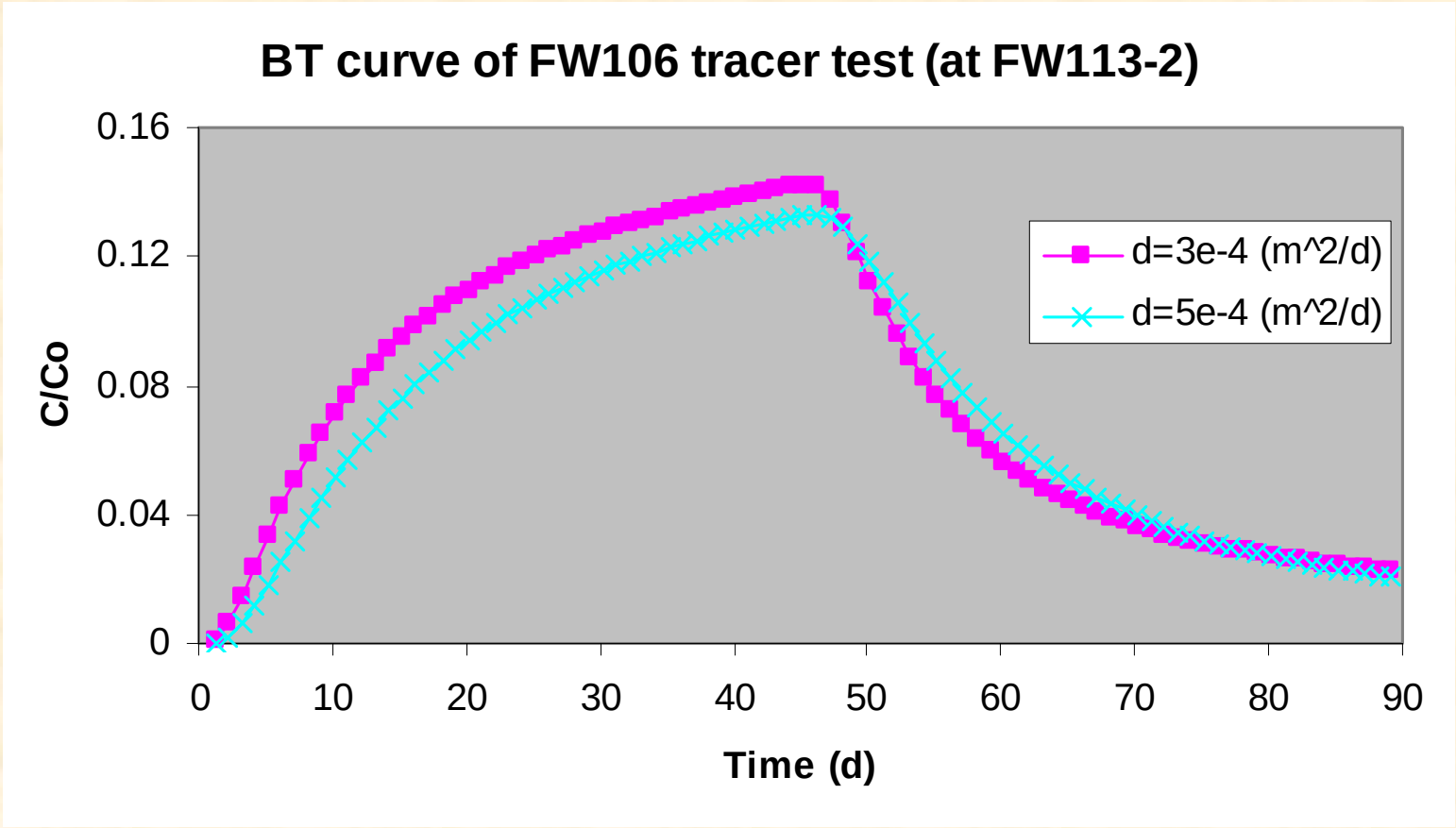
Typical gas chromatograms for He, Ne, and H_2 detection.

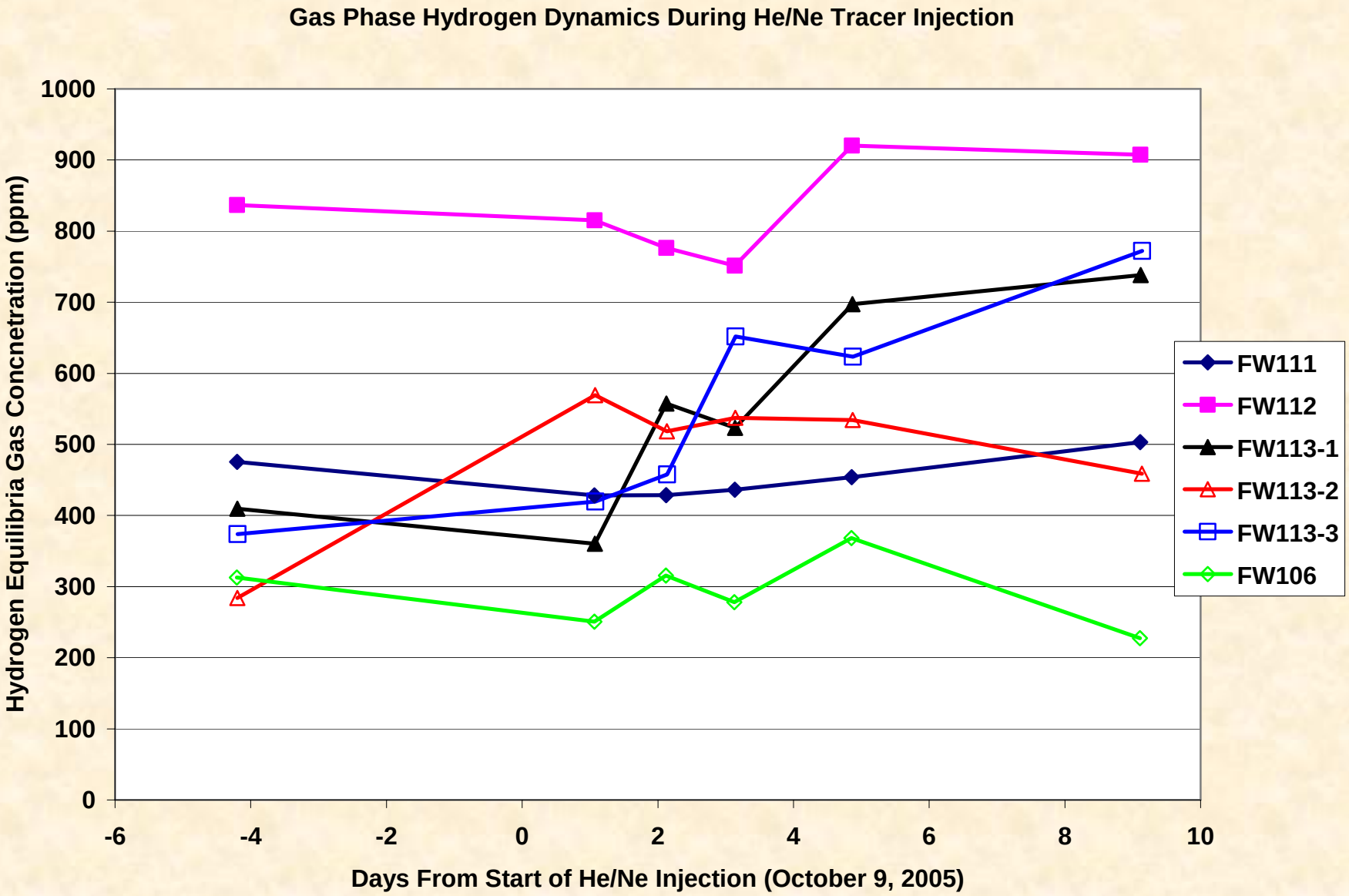


Results from Injection Well



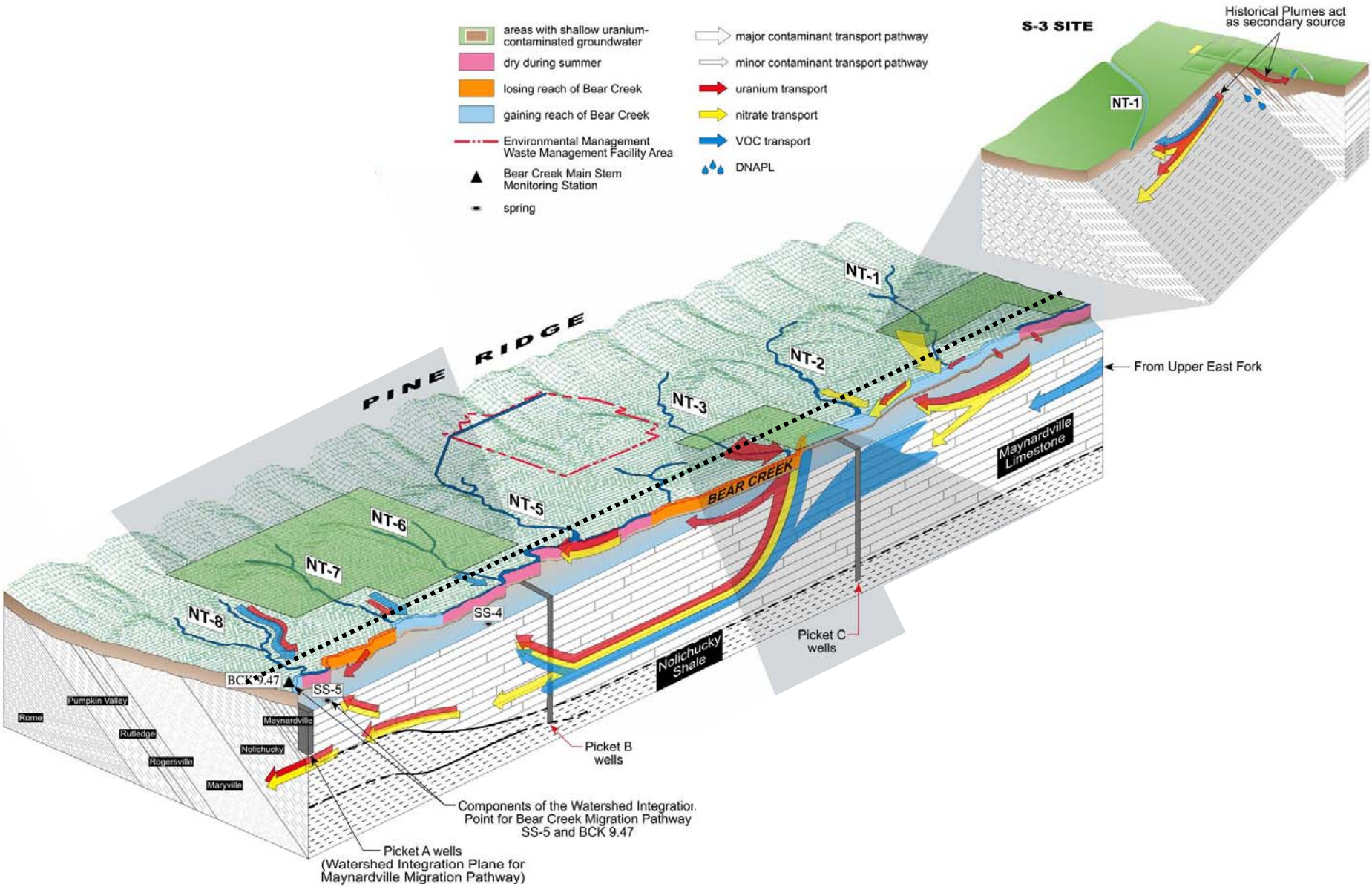
Simulated Breakthrough Curve for 2 Tracers with Different Diffusion Rates





Hydrogen has been observed in relatively high concentrations in all wells in area 3! (Typical groundwater gas phase is ca. 5-10 ppm and standard atmosphere only 0.5 ppm)

Watershed Community/Geochemical Characterization Study



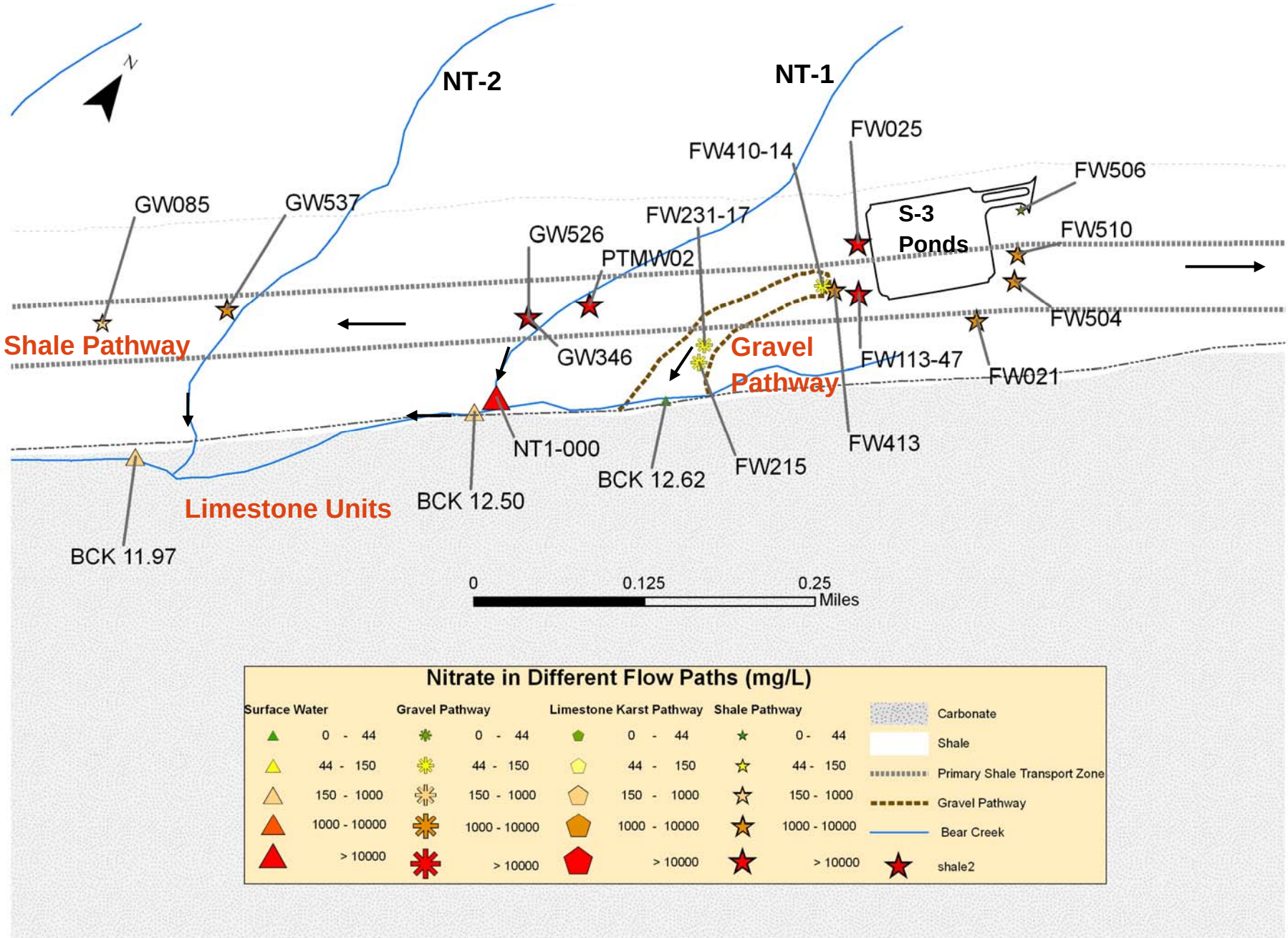
Watershed Community/Geochemical Characterization Study

- **Objectives**
  - **Assess changes in microbial communities along plume transects and possibly with different flow conditions (seasonally, high and low flow, and/or recharge events)**
  - **Assess correlation of microbial communities and populations to geochemistry**
  - **Assess well construction and sampling protocol impacts on populations**
  - **Select wells for genomic sequencing**

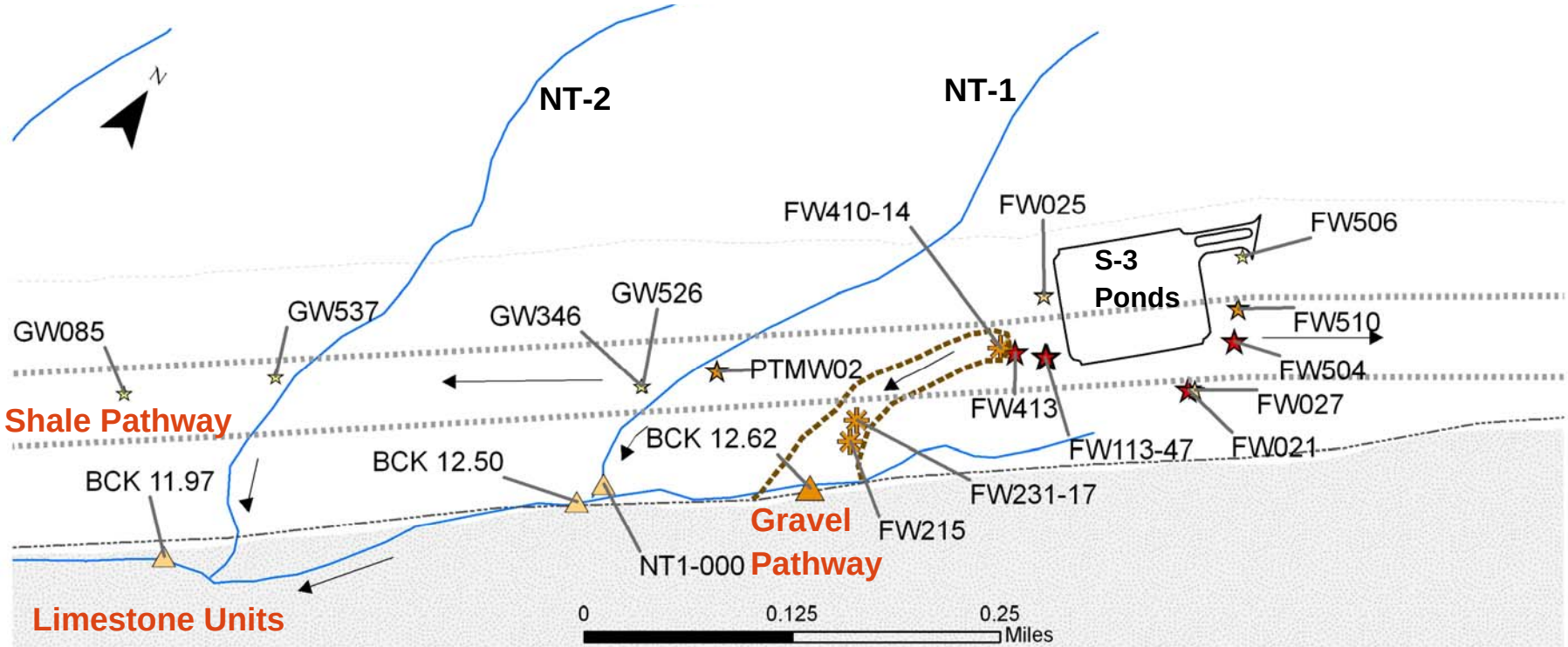
Watershed Community/Geochemical Characterization Study

- **Groundwater and surface water sample locations**
  - **Low flow conditions (representative groundwater inflow)**
  - **23 wells (shale saprolite, limestone, and gravel pathways)**
  - **7 surface water (Bear Creek and tributaries)**
  - **2 springs (major limestone groundwater discharge points)**
- **Microbial Analyses**
  - **Frozen filters from 1-2 liters filtered water**
  - **T-RFLP coupled with bromodeoxyuridine (BrDU) activity analysis – Kerkhof and Kostka**
  - **Microarray, 16S, sequencing – Zhou, Gentry, Fields**
- **Geochemistry - FRC**
  - **Cations/metals by ICP/MS**
  - **Anions by IC**
  - **TOC/TIC**
  - **Field Parameters (pH, EC, temperature, and DO)**

Nitrate Concentration Near S-3 Ponds



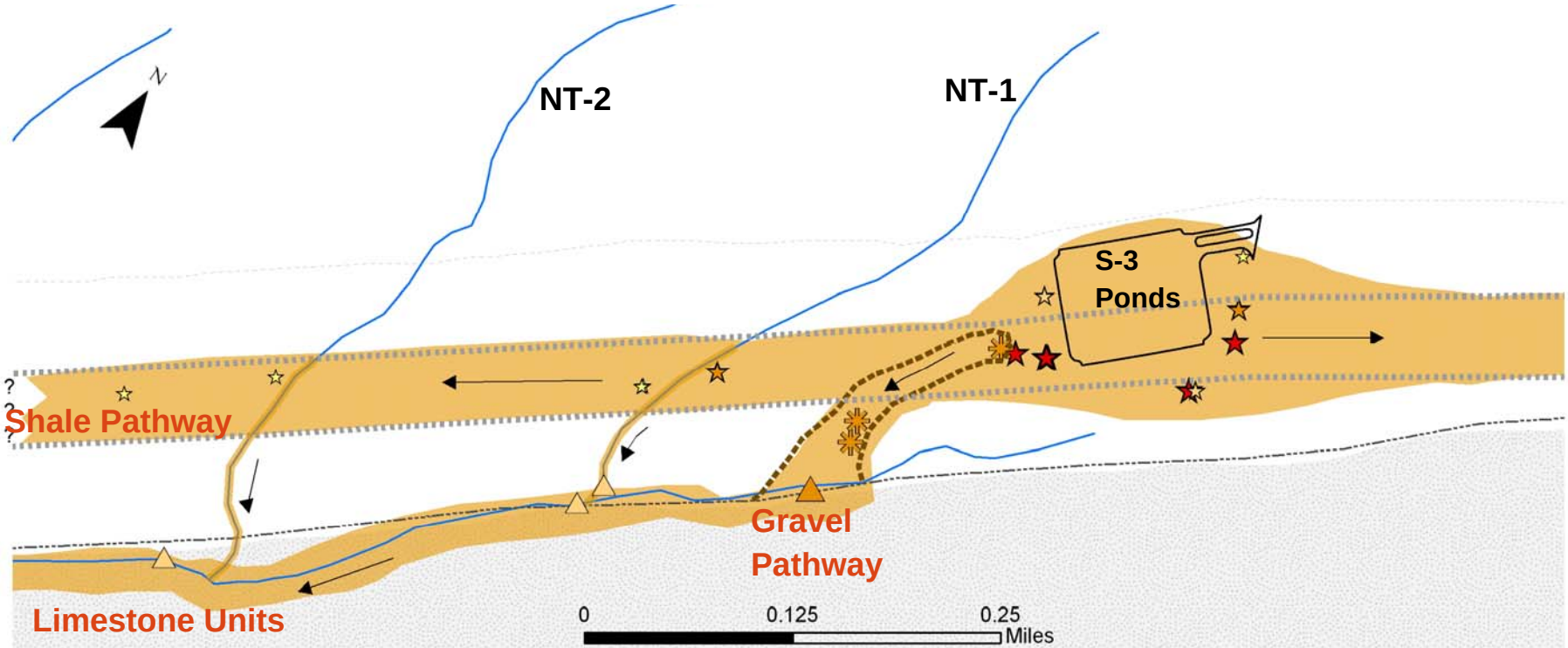
Uranium Concentration Near S-3 Ponds



Uranium in Different Flow Paths (mg/L)

Surface Water	Gravel Pathway	Limestone Karst Pathway	Shale Pathway	Shale Carbonate
0.00 - 0.02	0.00 - 0.02	0.00 - 0.02	0.00 - 0.02	Carbonate
0.02 - 0.10	0.02 - 0.10	0.02 - 0.10	0.02- 0.10	Shale
0.10 - 0.50	0.10 - 0.50	0.10 - 0.50	0.10 - 0.50	Primary Shale Transport Zone
0.50 - 10.00	0.50 - 10.00	0.50 - 10.00	0.50 - 10.00	Units Line
10.00 - 100.00	10.00 - 100.00	10.00 - 100.00	10.00 - 100.00	Gravel Pathway
				Bear Creek

Contaminant Pathways Near S-3 Ponds



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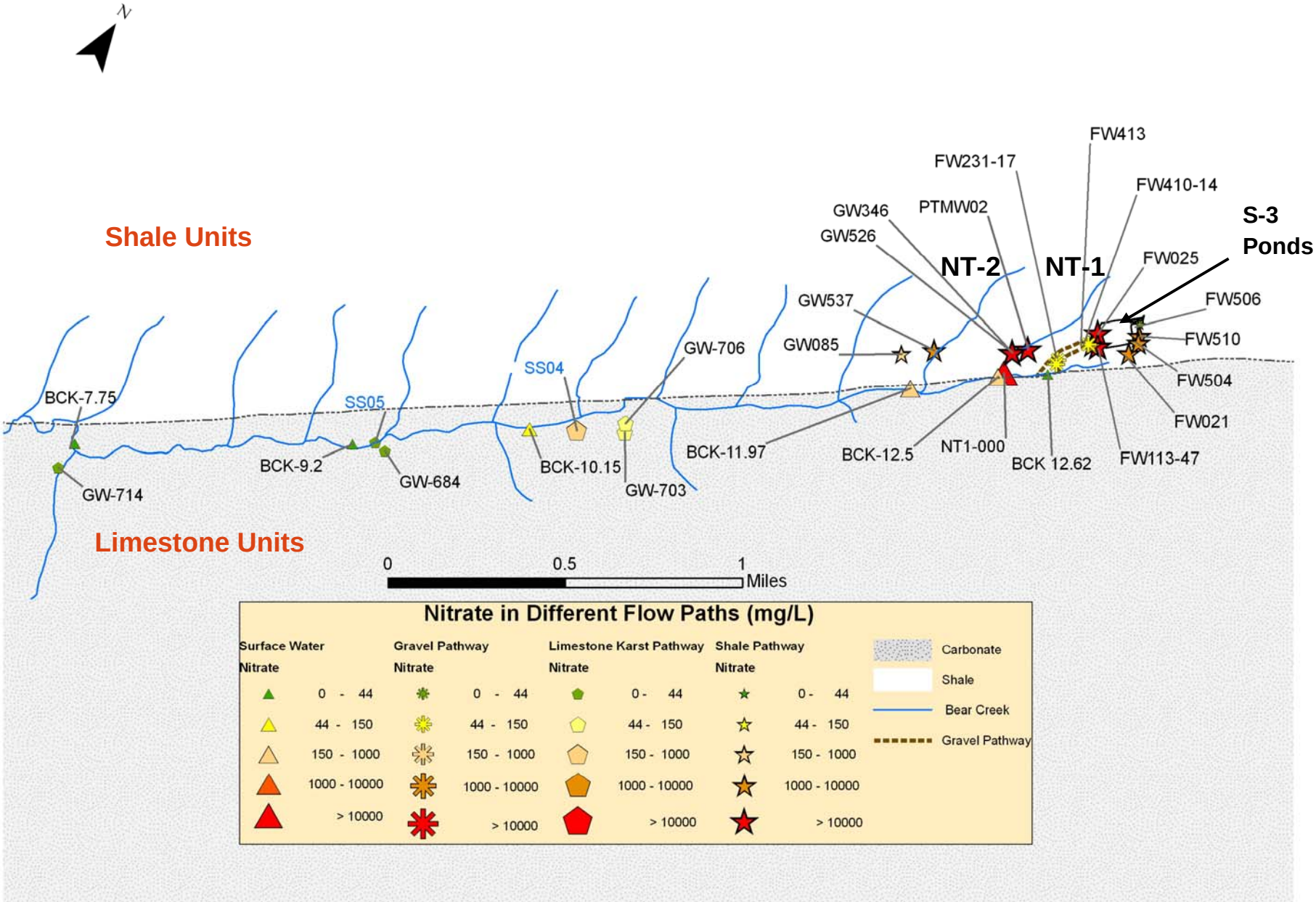
0.02 - 0.10	0.02 - 0.10	0.02 - 0.10	0.02- 0.10
0.10 - 0.50	0.10 - 0.50	0.10 - 0.50	0.10 - 0.50
0.50 - 10.00	0.50 - 10.00	0.50 - 10.00	0.50 - 10.00
10.00 - 100.00	10.00 - 100.00	10.00 - 100.00	10.00 - 100.00

Shale Carbonate

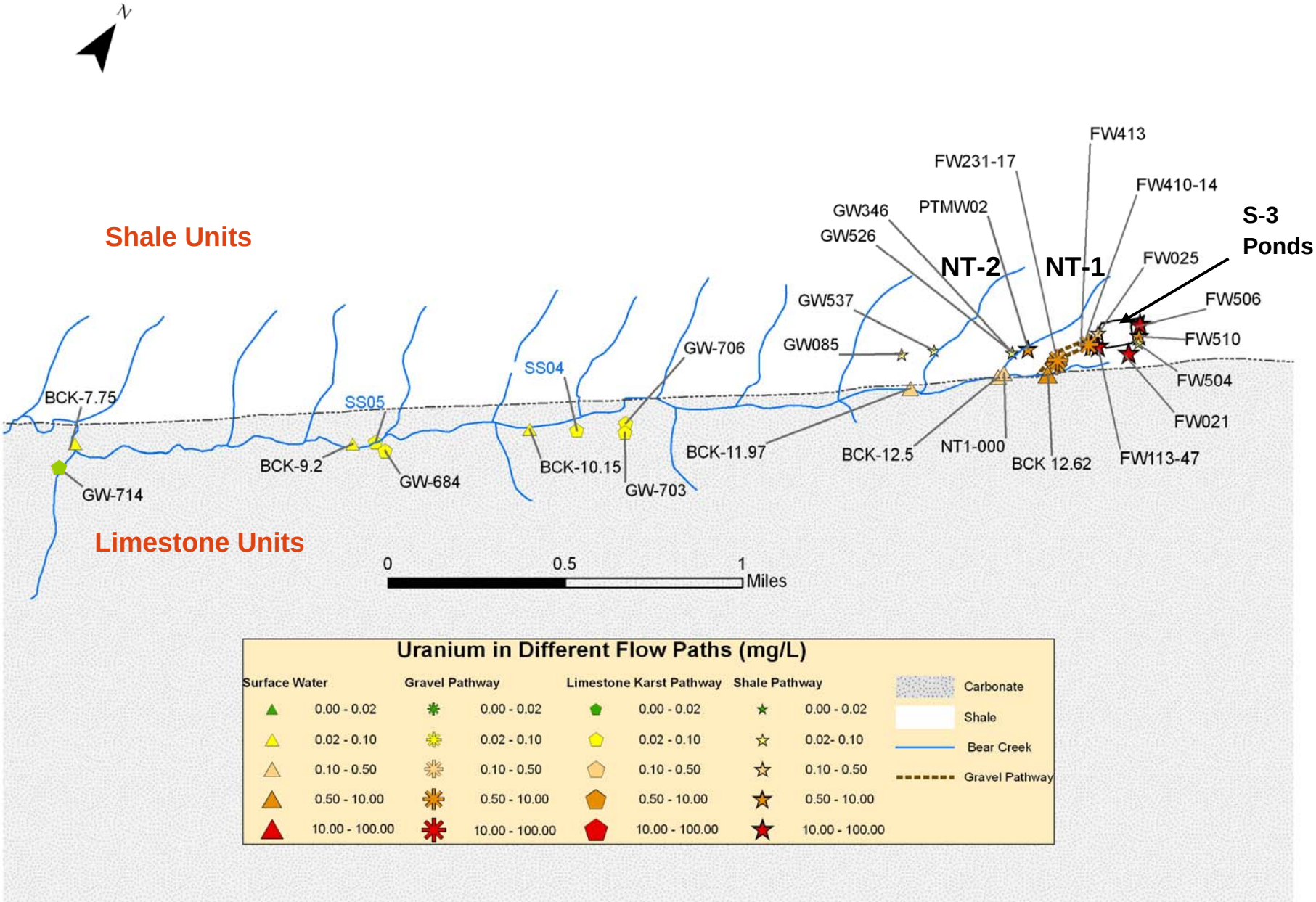
- Carbonate
- Shale
- Plumes

- Primary Shale Transport Zone
- Units Line
- Gravel Pathway
- Bear Creek

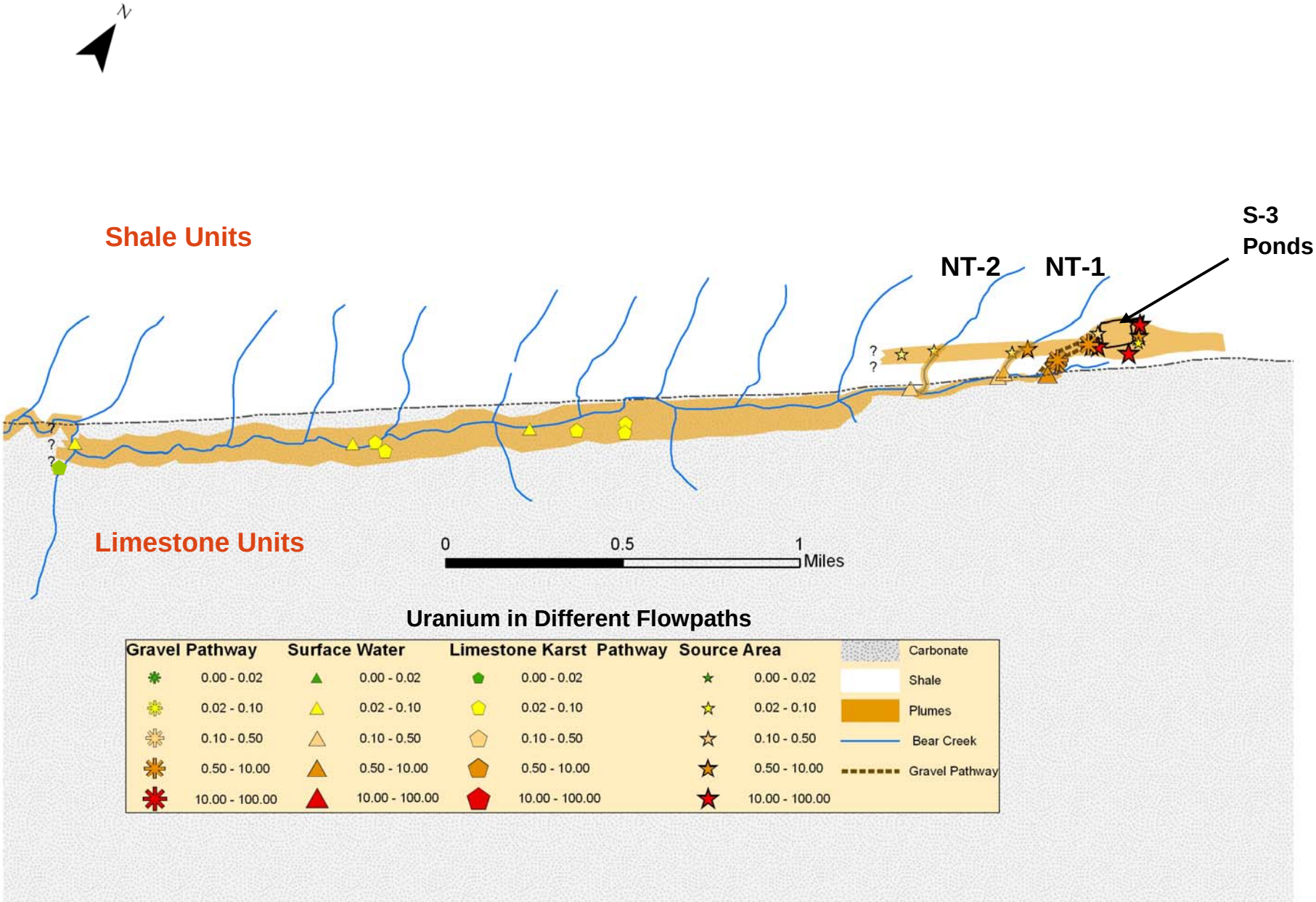
Nitrate Concentration in Watershed



Uranium Concentration in Watershed



Contaminant Pathways in Watershed



Sampling Protocol (PTMW02 Example)

- **Several wells are being sampled using different methods to determine impact on geochemistry and microbiology**
- **PTMW02 stagnant water above screen, no purging (contaminants are less)**
  - **U - 0.05 ppm**
  - **Nitrate – 1,300 ppm**
  - **Mn – 4.1 ppm**
  - **Ph – 5.7**
  - **DO - 4.9 ppm**
- **PTMW02 within screen, low flow purging**
  - **U – 2.4 ppm**
  - **Nitrate – 18,000 ppm**
  - **Mn – 57 ppm**
  - **Ph – 4.3**
  - **DO – 0.15 ppm**

Watershed Community/Geochemical Characterization Study

- **Conclusions**
  - **S-3 Ponds plume extends over 3 miles down valley in groundwater and/or Bear Creek**
  - **Primary U flux is along gravel pathway directly to Bear Creek and to a lesser extent the shale pathway and down NT-1**
  - **Primary nitrate flux is along shale pathway and down NT-1 and NT-2**
  - **The greater attenuation of nitrate (25x) compared to U (4x) over 3 miles may be related to different attenuation processes for the different contaminants and possibly other sources of U**
  - **DO is low (>1ppm) in groundwater even in carbonates where there is a strong connection to surface water**
  - **Sampling protocol is probably important**

Watershed Community/Geochemical Characterization Study

- **Potential research opportunities**
  - **Attenuation of contaminants in the watershed (U vs. nitrate vs. VOCs)**
  - **Groundwater/surface water/biological interactions**
  - **Remediation technologies and strategies**
  - **Watershed response to remediation**
  - **Hg cycling in watershed**
  - **Microbial communities associated with solid (cores) vs. groundwater (wells) matrix**
  - **Hydrogen fate (and other dissolved gases)**
  - **Sampling protocols**
  - **Characterization, sensors, monitoring tools, and model predictions**