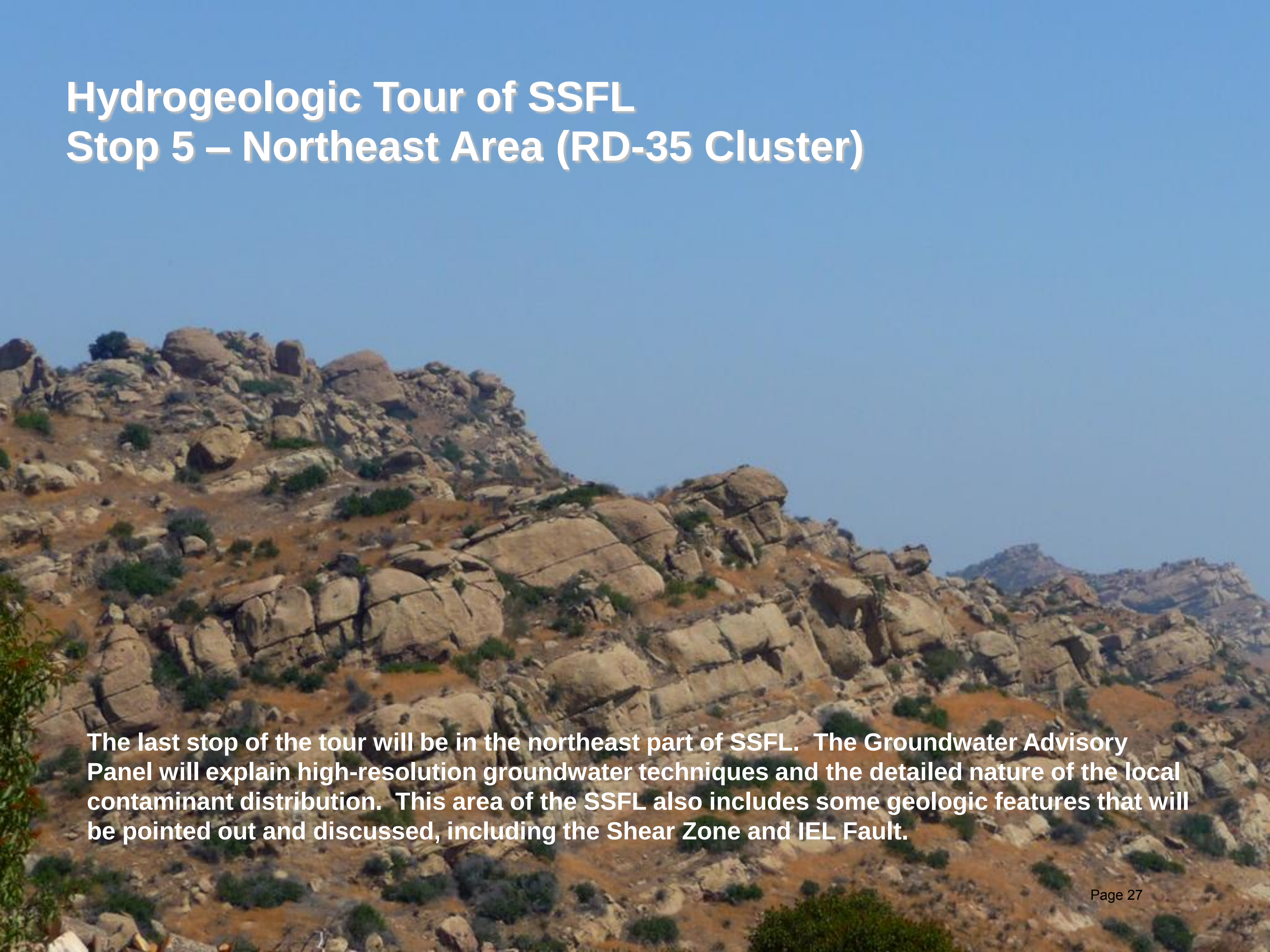


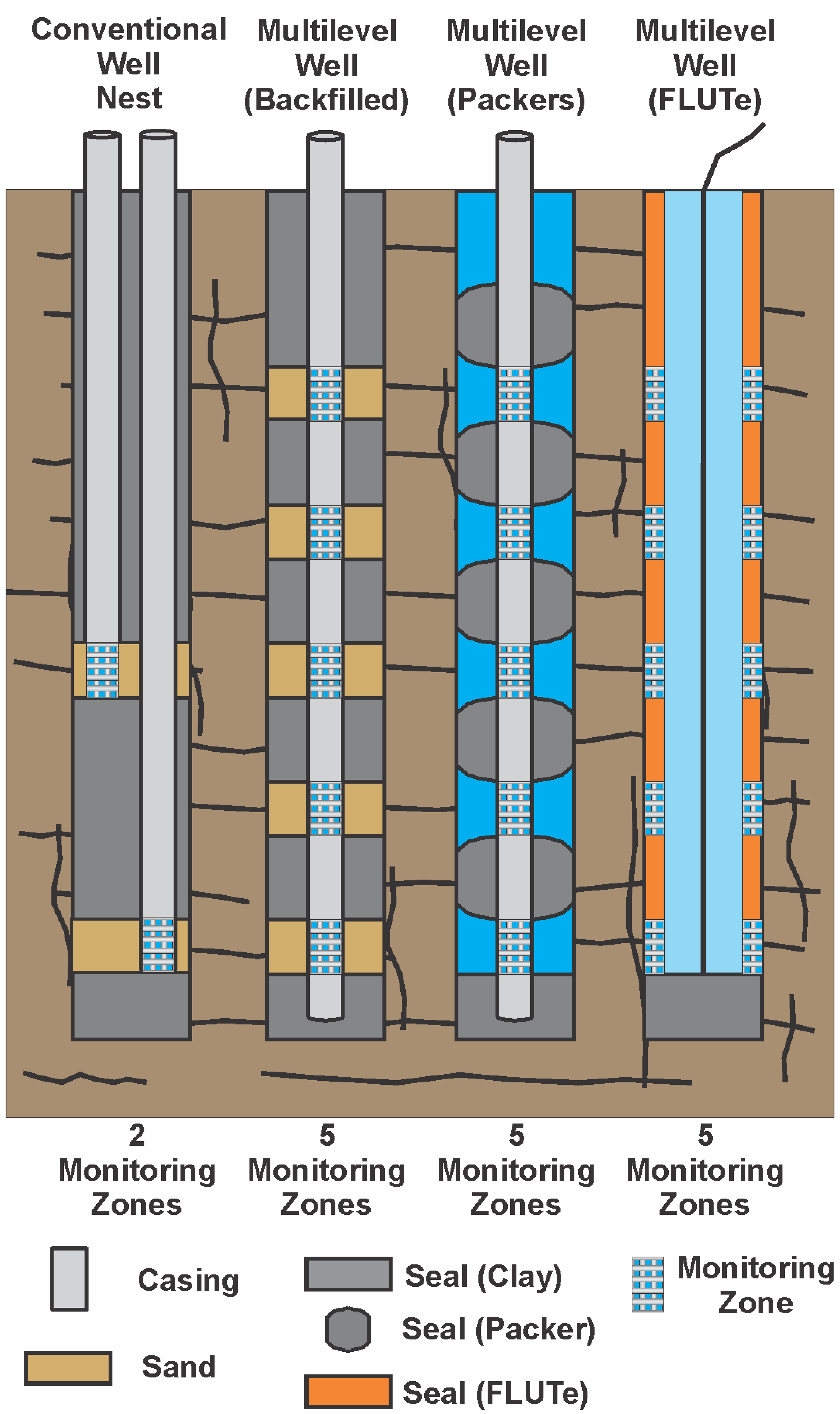
Hydrogeologic Tour of SSFL
Stop 5 – Northeast Area (RD-35 Cluster)

The last stop of the tour will be in the northeast part of SSFL. The Groundwater Advisory Panel will explain high-resolution groundwater techniques and the detailed nature of the local contaminant distribution. This area of the SSFL also includes some geologic features that will be pointed out and discussed, including the Shear Zone and IEL Fault.

Multilevel Wells for Groundwater Monitoring

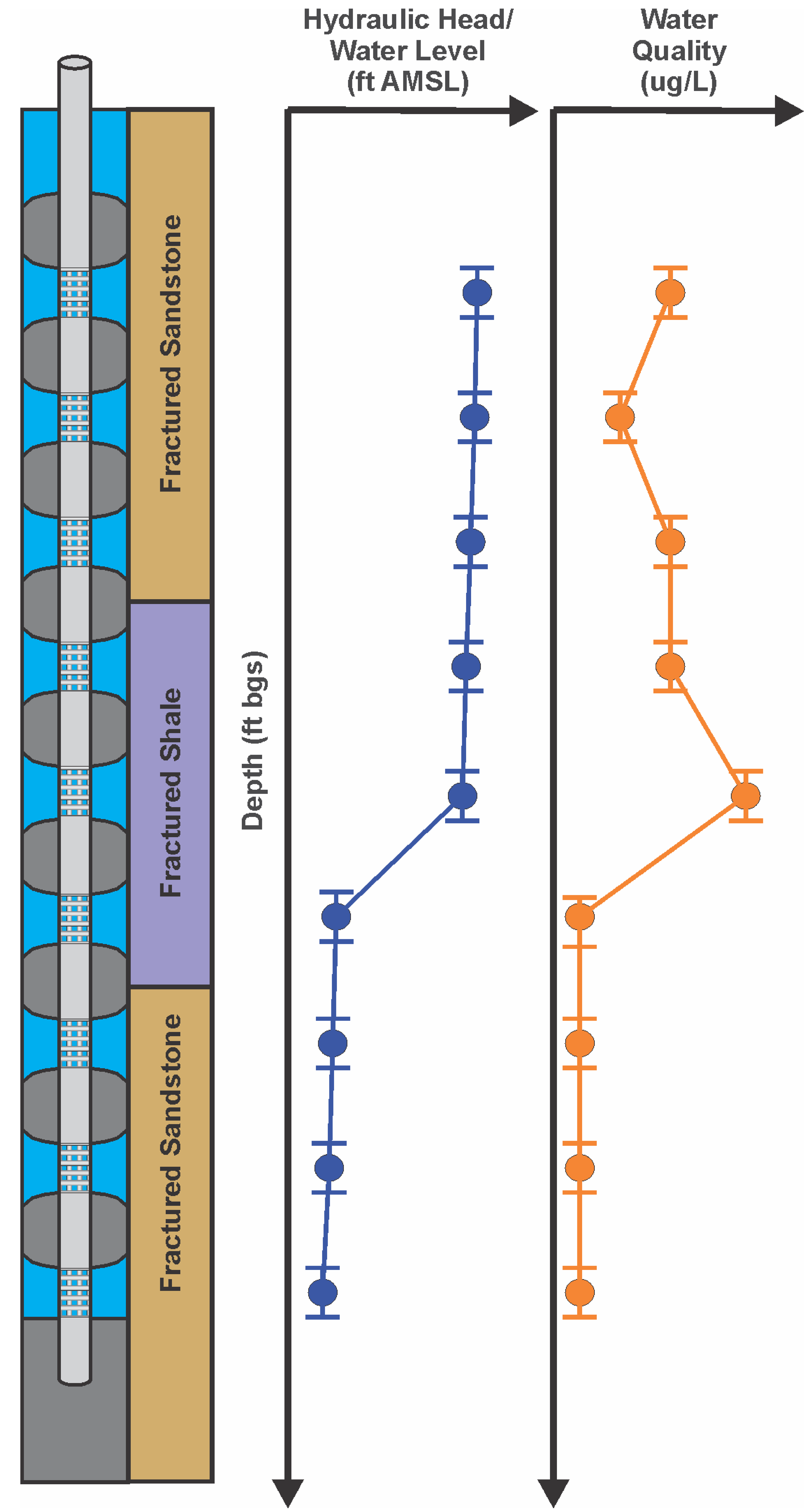
What is a Multilevel Well?

A single device installed into a borehole that divides the hole into many separate intervals for depth discrete monitoring



Types of Multilevel Wells

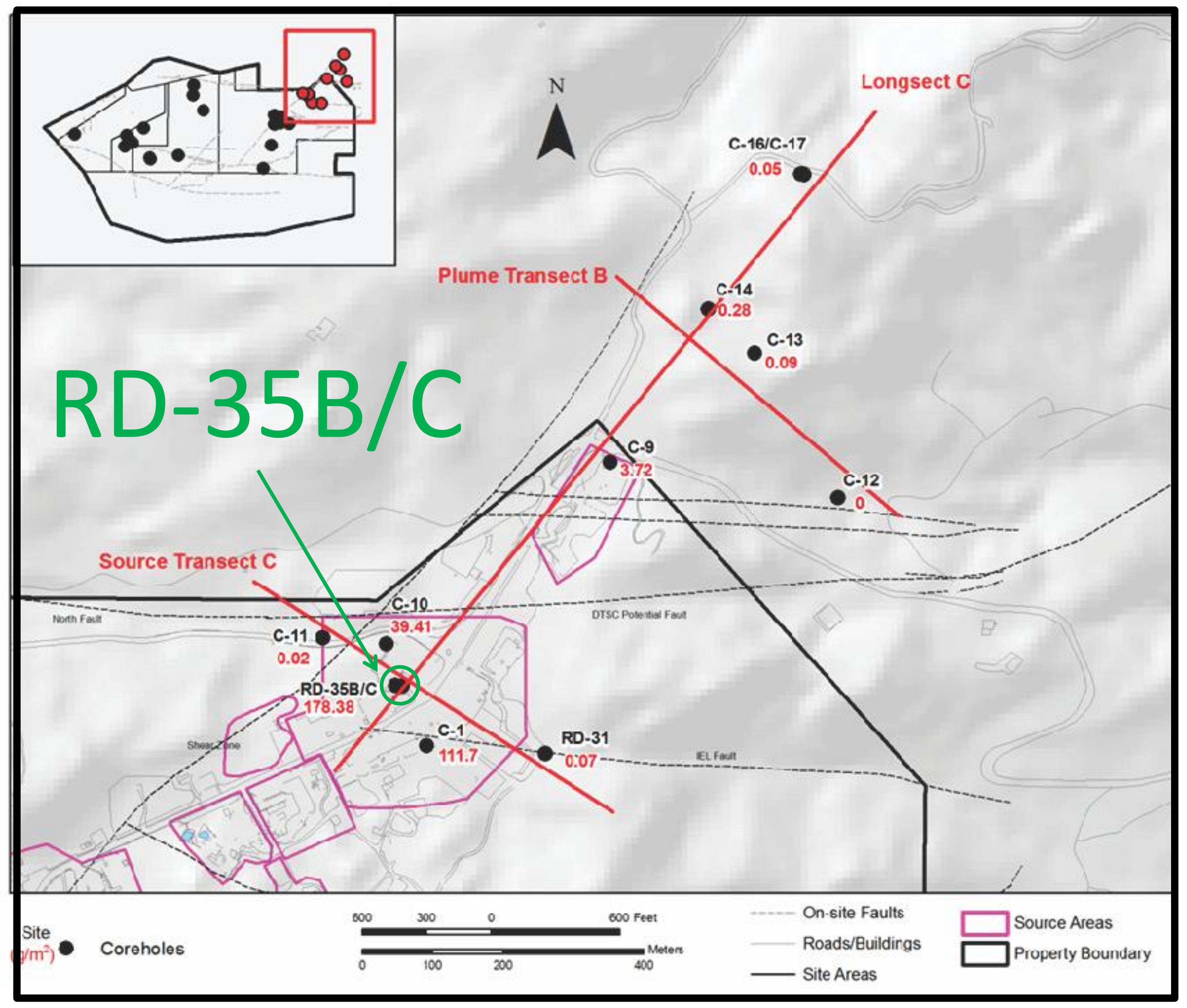
Example Datasets

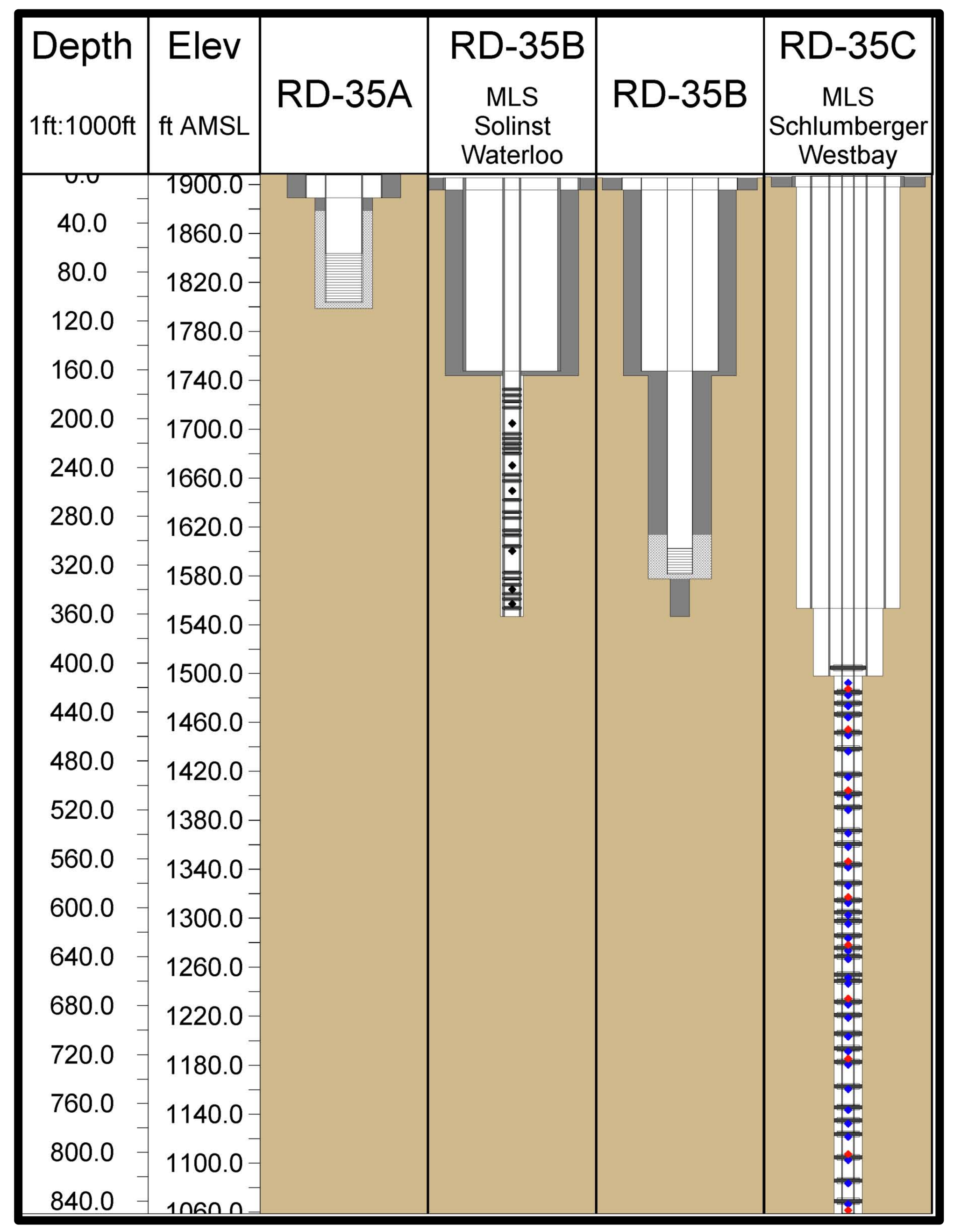


Groundwater Monitoring at SSFL Location RD-35

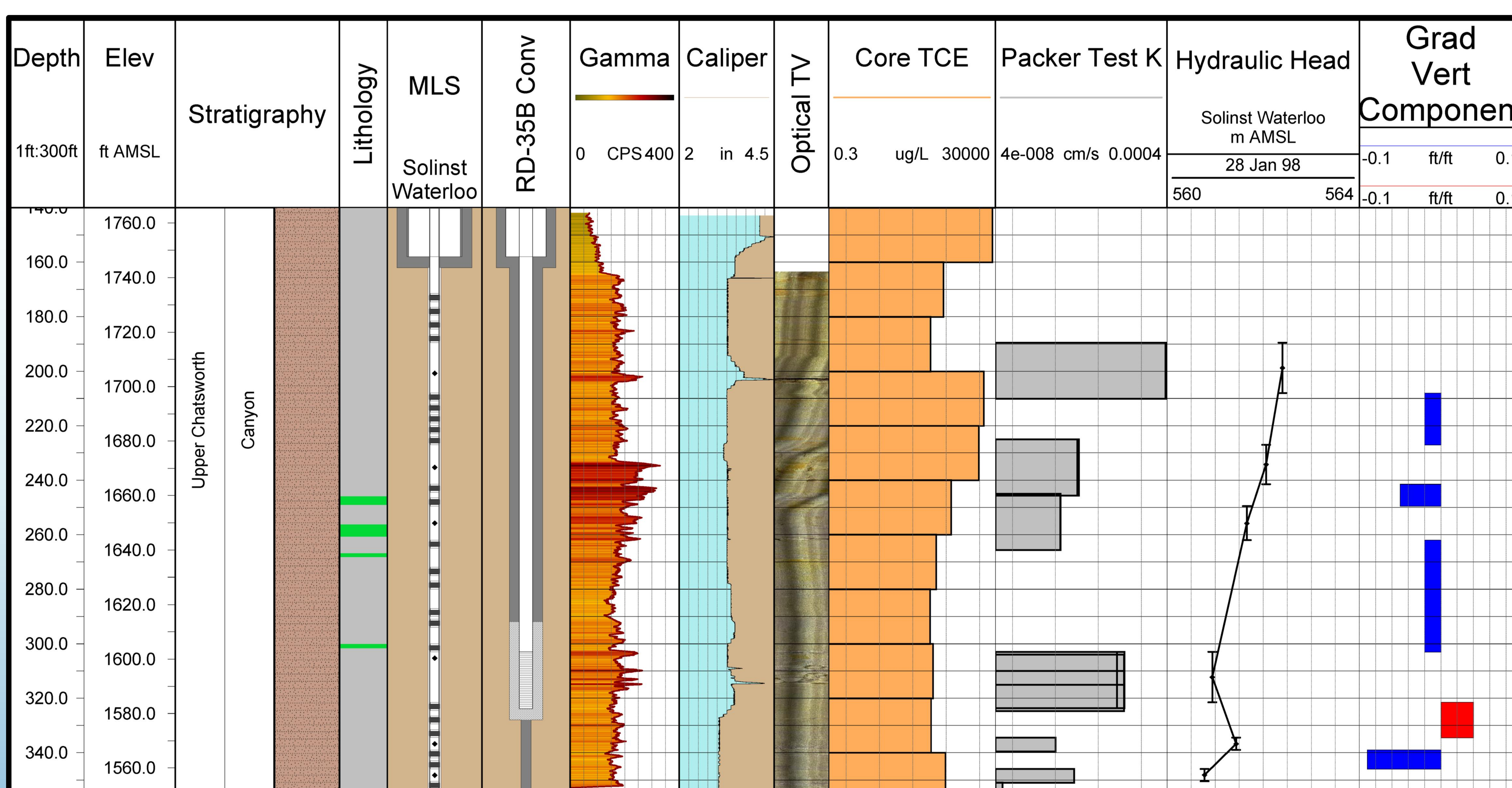
This comprehensive monitoring location has two conventional monitoring wells (RD-35A and RD-35B and a deep Westbay multilevel system (MLS). There was also a Waterloo MLS in the RD-35B hole prior to conversion to a conventional well.

SSFL Location RD-35

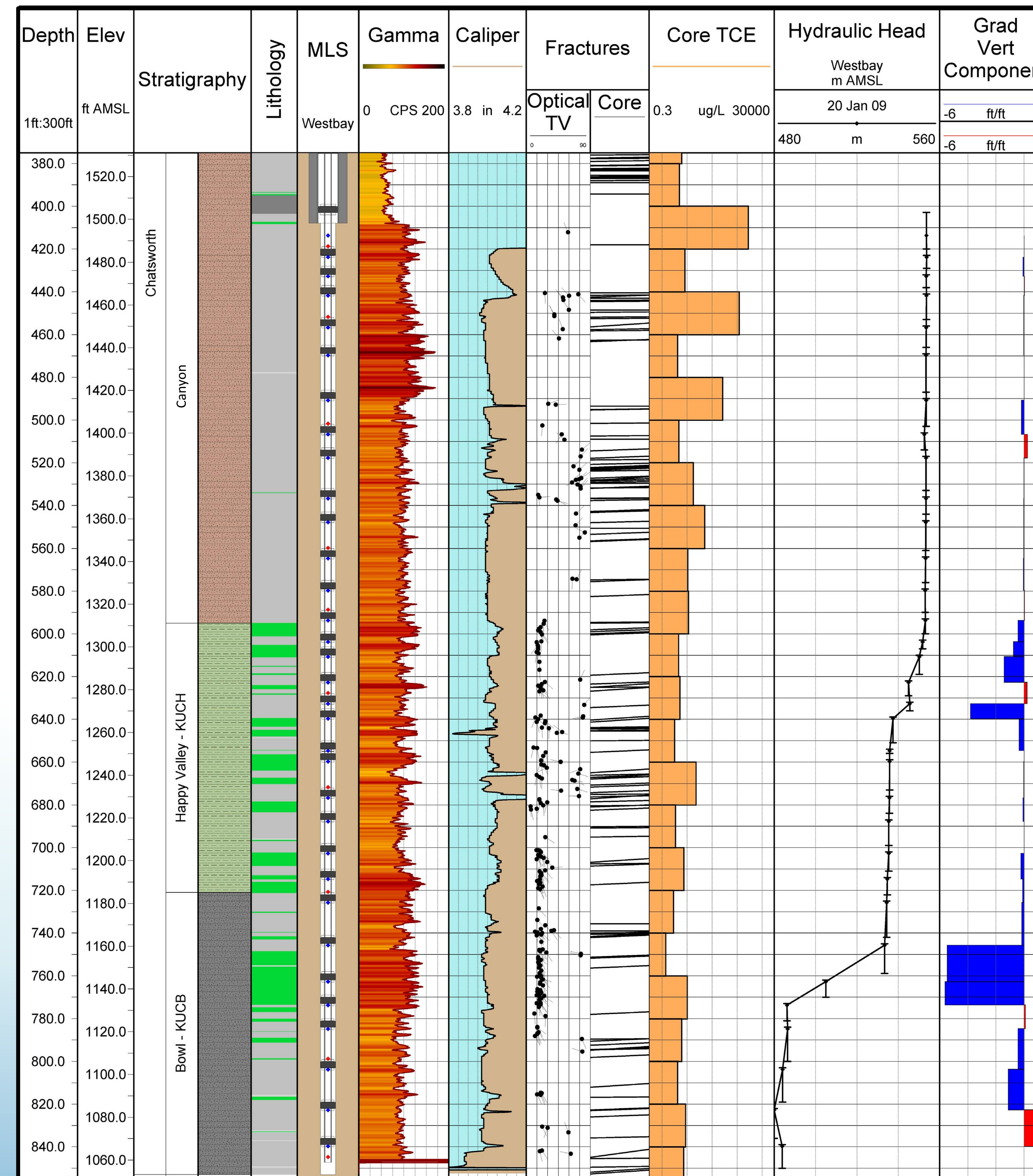




RD-35B



RD-35C

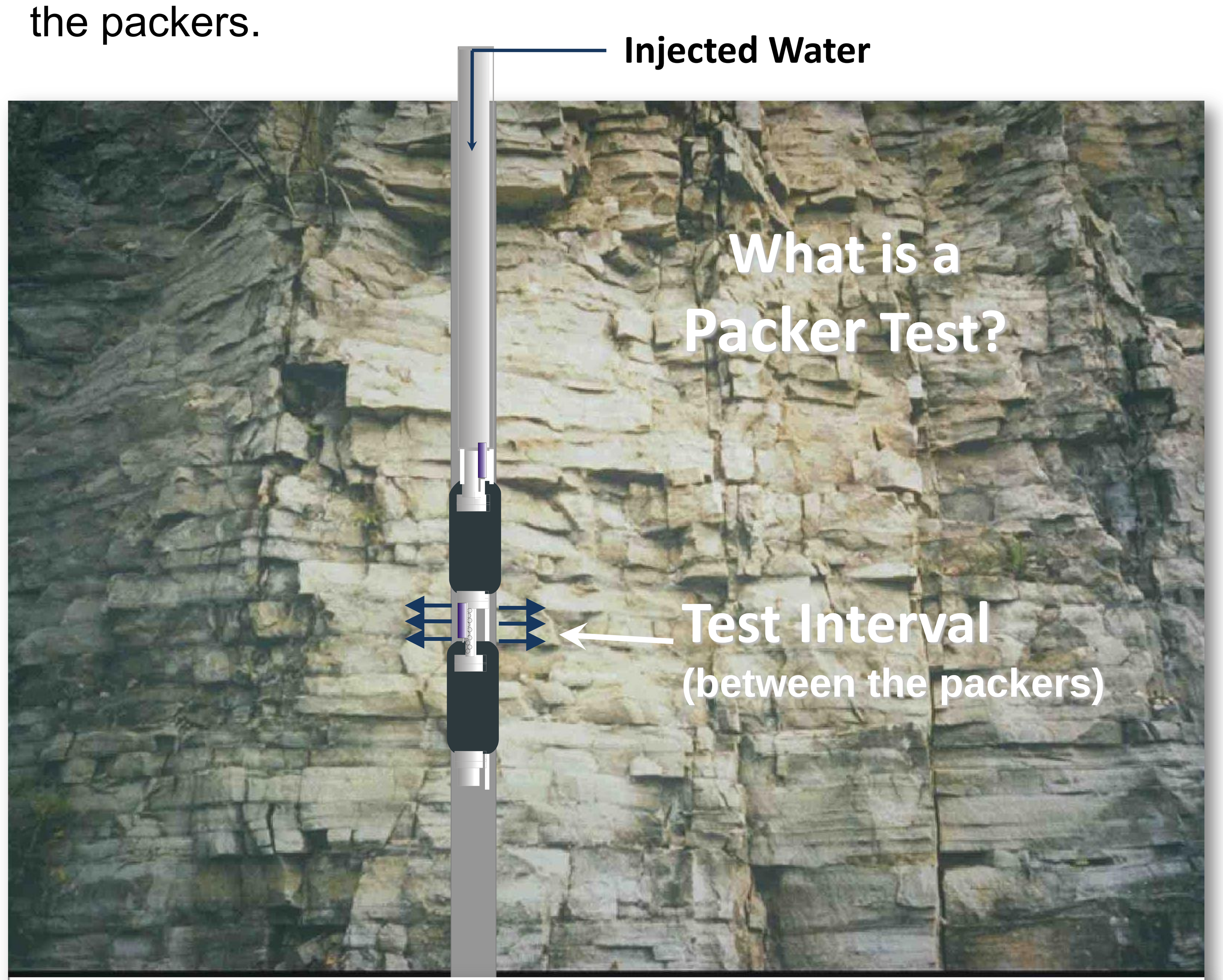


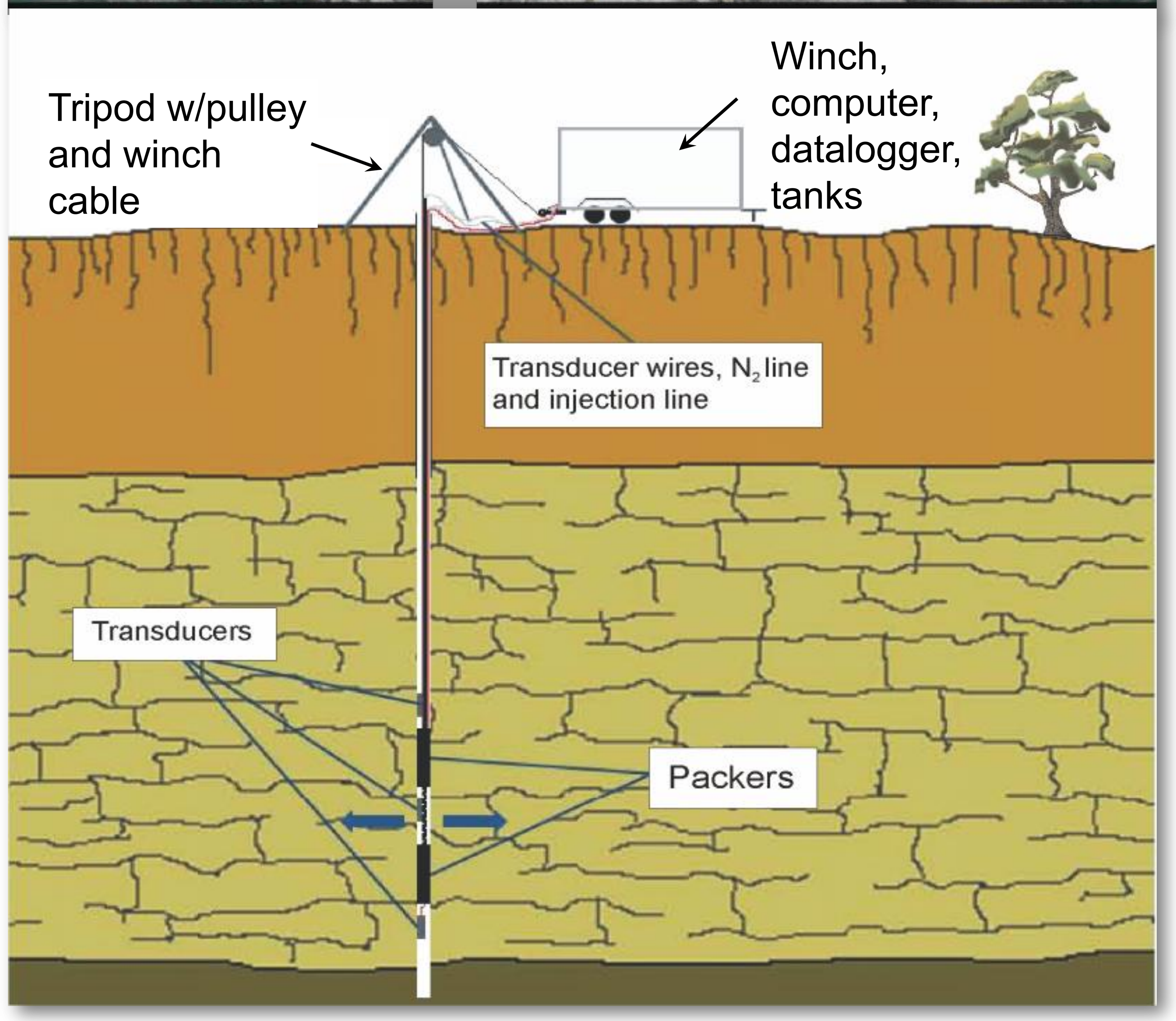
Comprehensive Hydraulic Tests using Straddle Packers

Patryk Quinn, Beth Parker, John Cherry

What is Straddle Packer Testing?

Straddle Packer testing is a method to conduct depth-discrete hydraulic tests in rock boreholes. Hard rubber packers are inflated to isolate a section of a borehole, and a hydraulic test is conducted in the borehole segment between the packers.

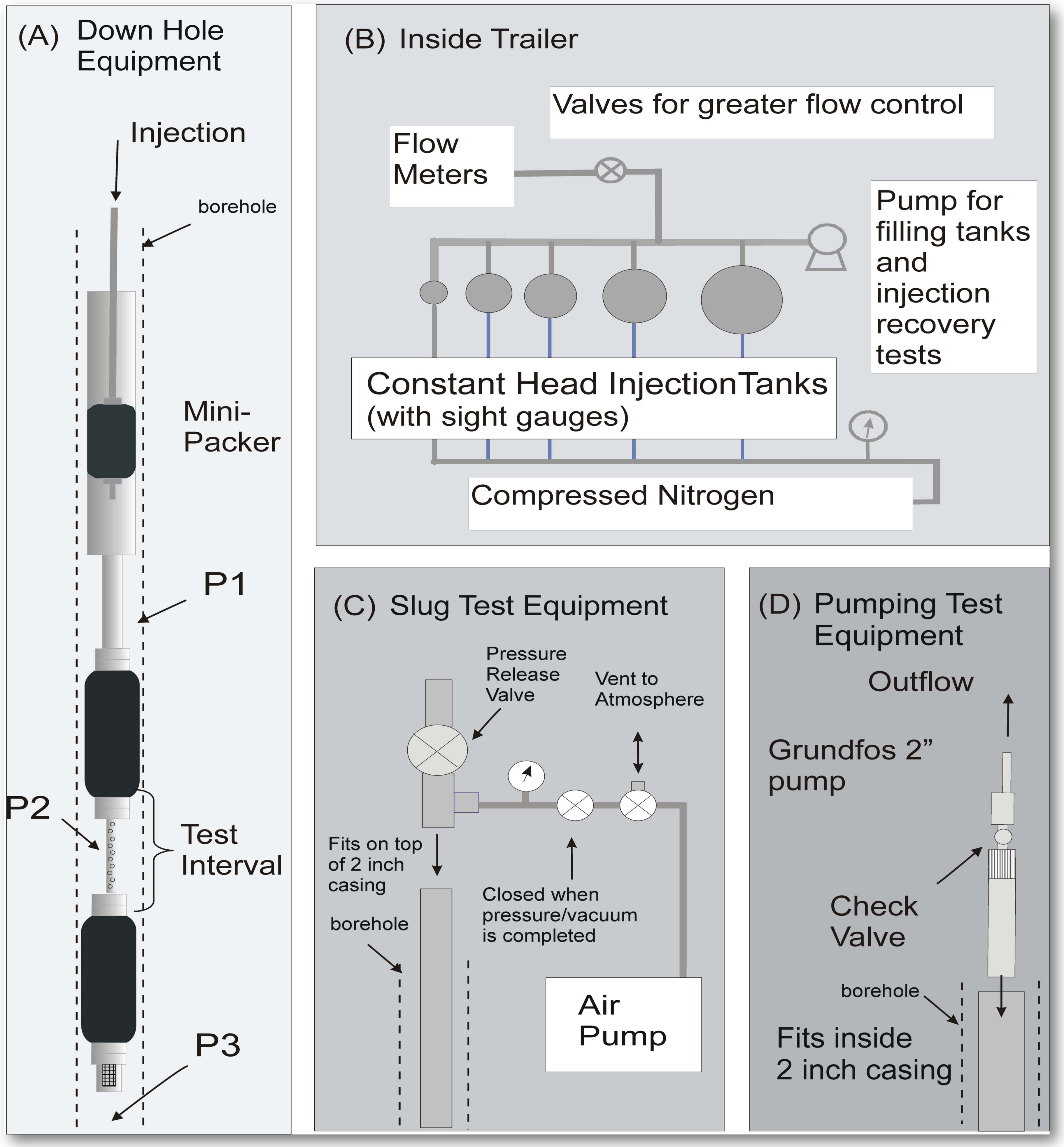




Equipment Set Up

Why do Straddle Packer Testing?

Hydraulic tests are conducted by injecting or pumping water to calculate a value for Transmissivity of the rock. Transmissivity is directly related to permeability and is a measure of the ease at which water can move through a particular section of the rock. In nearly all rock types water can move the easiest through the fractures that have developed over time due to earth stresses that cracked the rock.



P1, P2, P3 = Pressure Transducers

University of Guelph Packer Testing System

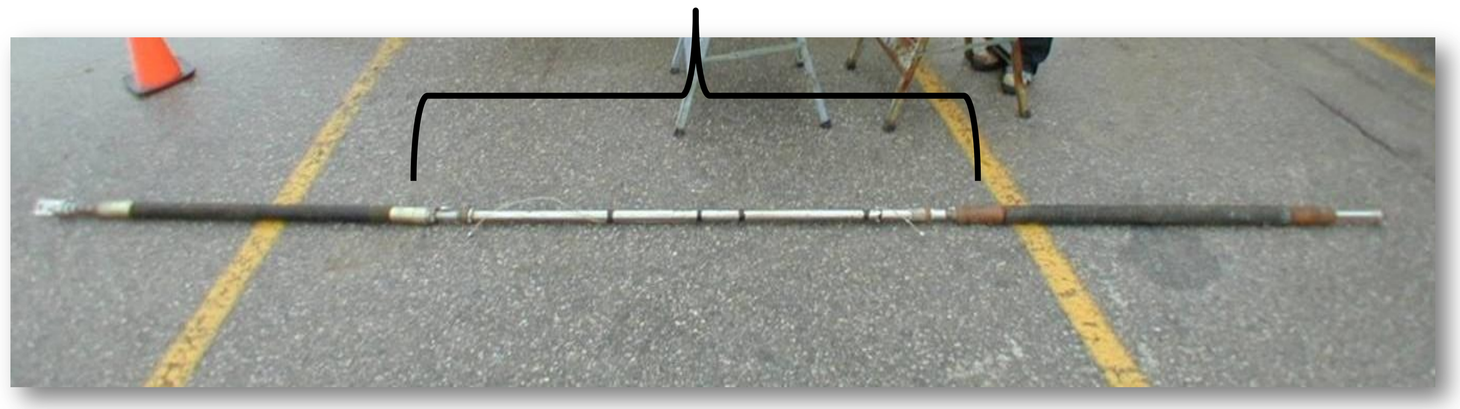
In the borehole (4-6 inch diameter) create a 2 inch well connected to each test interval.

Designed to allow tests using four methods:

1) Constant head step tests
2) Slug tests
3) Pumping tests
4) Recovery tests

Each test provides a measurement of T.

Straddle Packer Test Interval



Inflated Packer

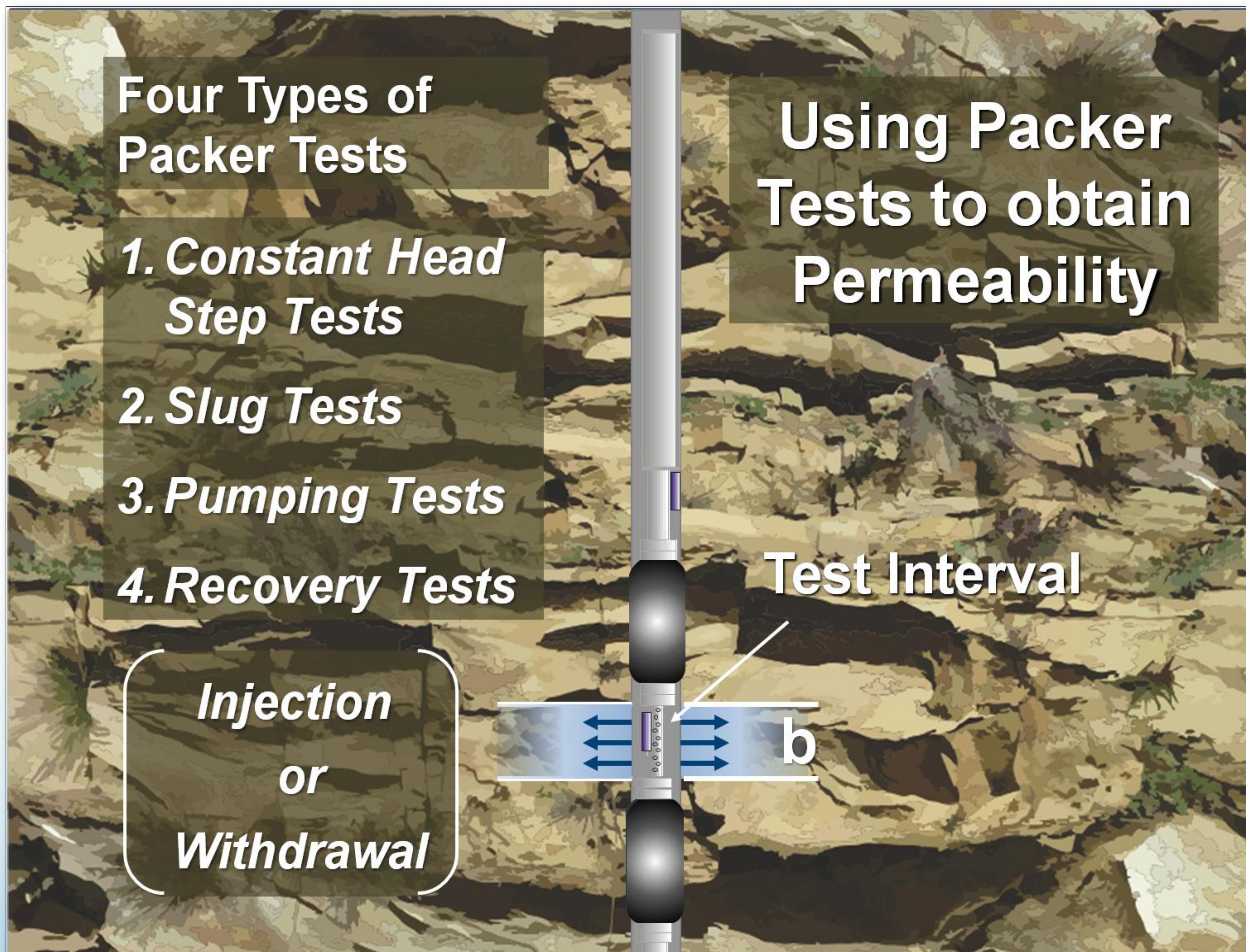
Comprehensive Borehole Hydraulic Testing using Straddle Packers

Patryk Quinn, Beth Parker, John Cherry
School of Engineering, University of Guelph, Guelph, Ontario, Canada

Why do Four Different Types of Tests?

Transmissivity (T) is a measure of the ability of the rock to transmit water. Each type of test can be used to calculate T in a unique way. Comparison of the T values from each type of test produces the most reliable and accurate representative T value for each test interval. These T values are used to calculate hydraulic aperture for fractures.

In addition to calculating T, individual tests can reveal unique information about the test interval. In this comprehensive approach each test is repeated several times at different applied pressures so that the effects of different flow rates are assessed.



Test Type	Test Description	Typical Test Results	Typical Analysis Graph	Unique Information from Test
Constant Head Step	A series of steps in which the flow and applied head are constsnt	Q, H vs Time	dH vs Q; T =	Identification of non-Darcian Flow
Instananeous Slug	An instantaneous increase or decrease in Head followed by recovery	H vs Time; Falling Head, Rising Head	$\ln\left(\frac{\Delta H}{\Delta Ho}\right)$ vs Time; 0; T =	Identification of well clogging
Constant Rate Pumping	A long term increase or decrease in Head	H vs Time	dH vs Log time; T =	Identification of duel permeability
Recovery after constant rate pumping	Recovery after long term increase or decrease in Head	H vs Time	dH' vs Log t/t'; T =	Identification of duel permeability

T = Transmissivity
K= Hydraulic Conductiviy
T=Kb
Q = flow rate
dH = applied head
Head = Pressure + Elevation

Assumption for all methods :
Darcy's Law is Valid $q = K\frac{dH}{dL}$

Pumping/Recovery Tests can be Injection/Recovery or Withdrawal/Recovery (Withdrawal/Recovery is shown above)

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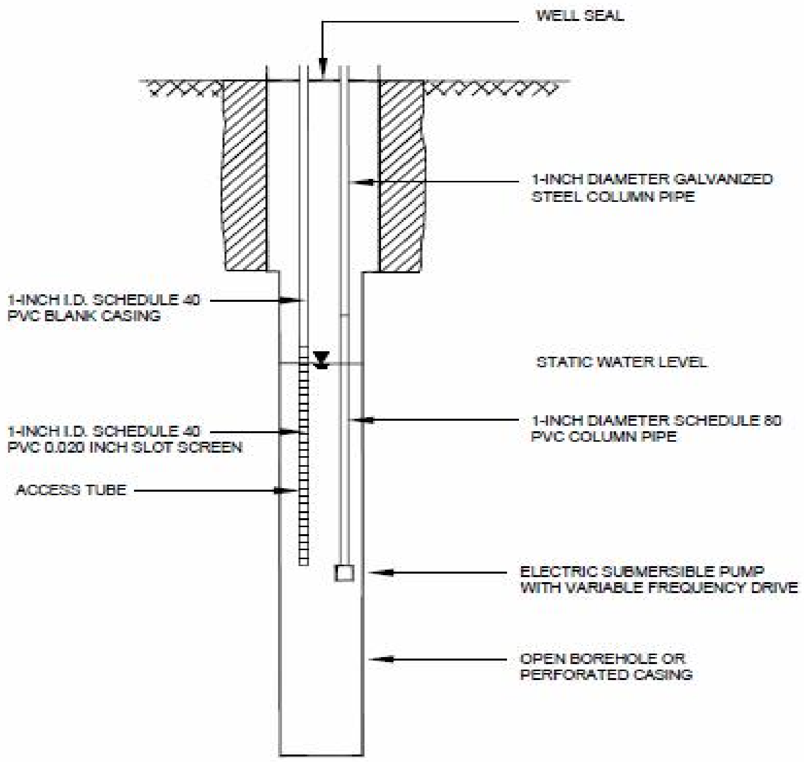
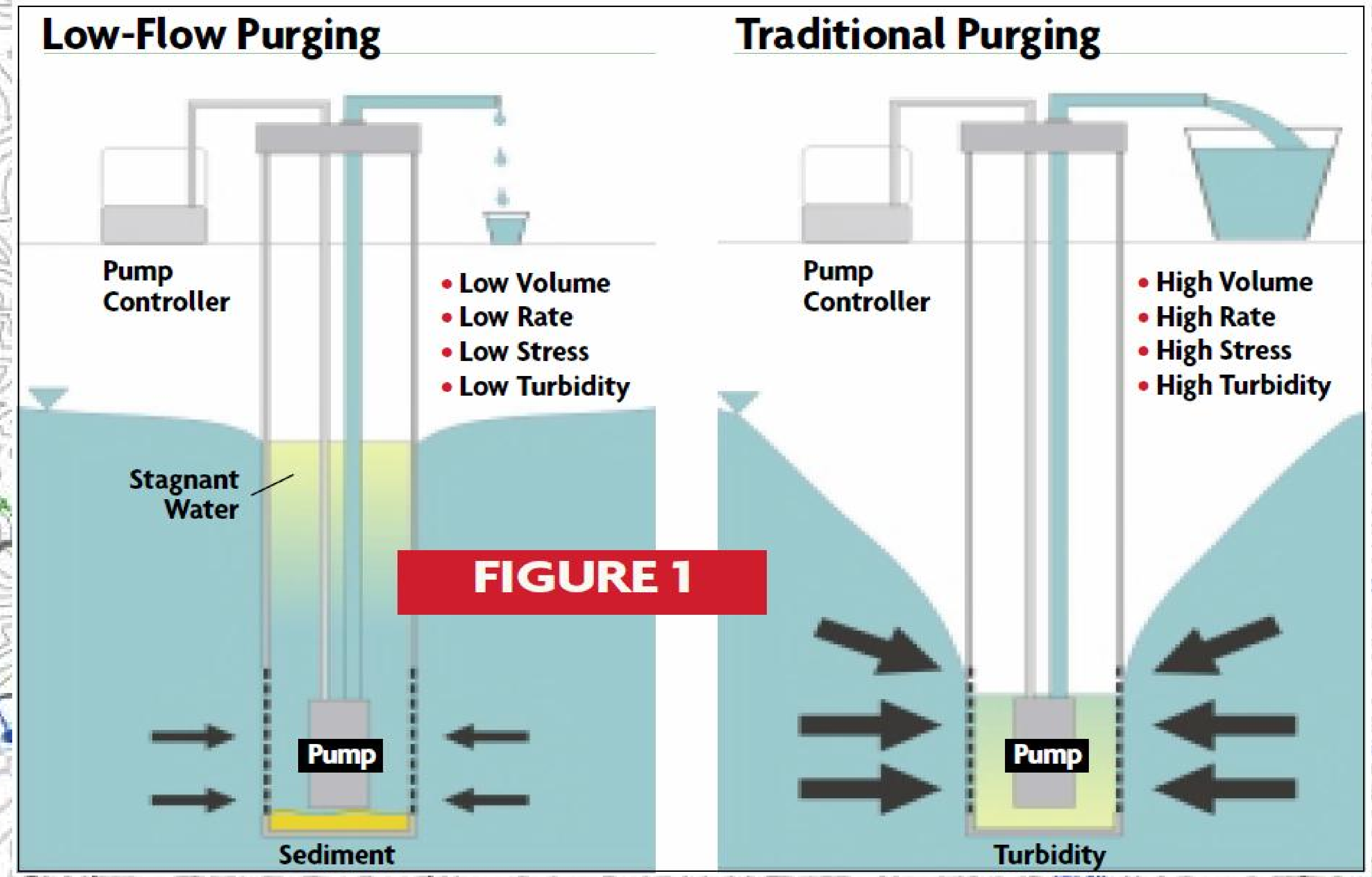
TECH SERVICES INC.

STATION 5-3: Groundwater Sampling (Conventional, Low-Flow)

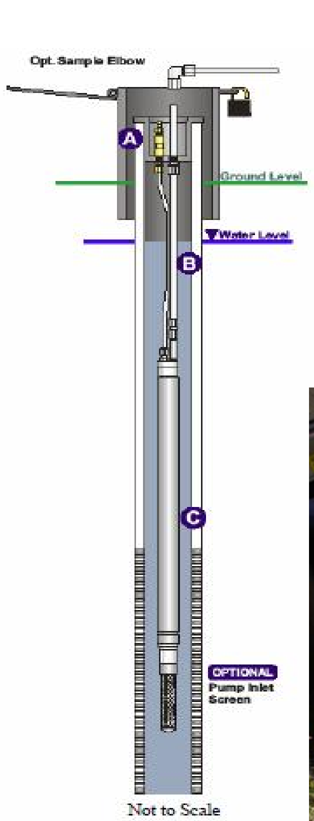
GROUNDWATER SAMPLING SPECIALISTS

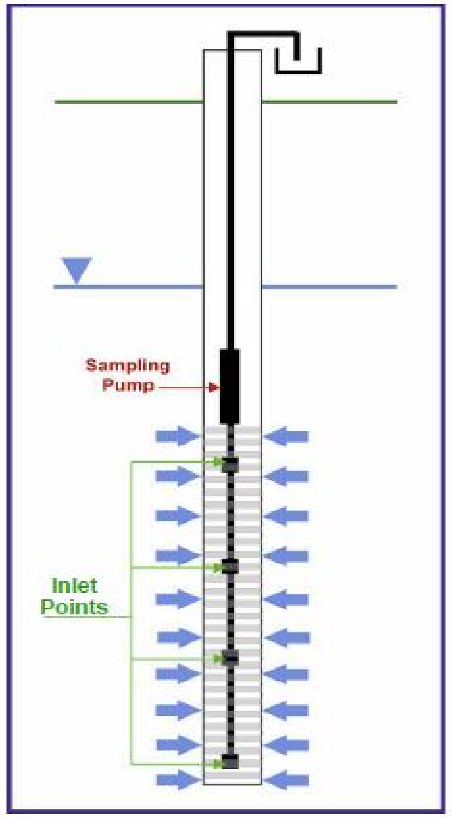
SINCE 1985





VFD shown with the Redi-Flo2® and Redi-Flo4™

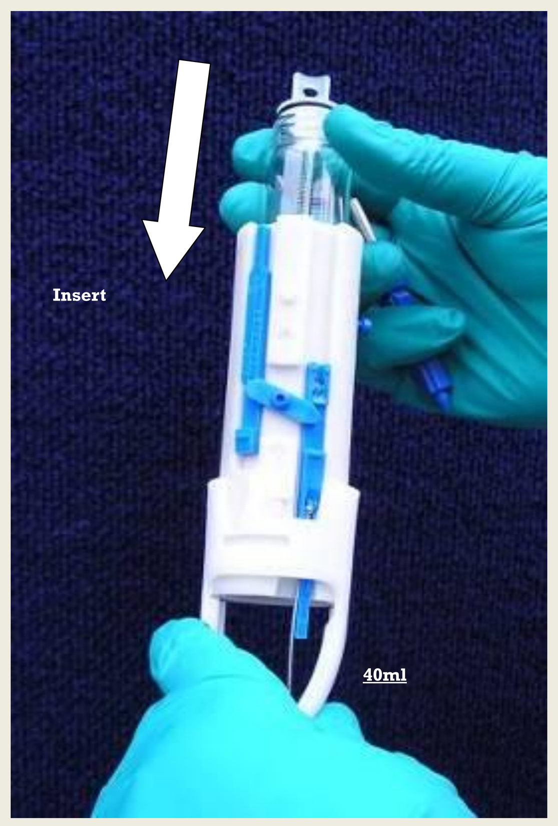




Depth Discrete Use of the Snap Sampler to Obtain Insights About TCE Degradation

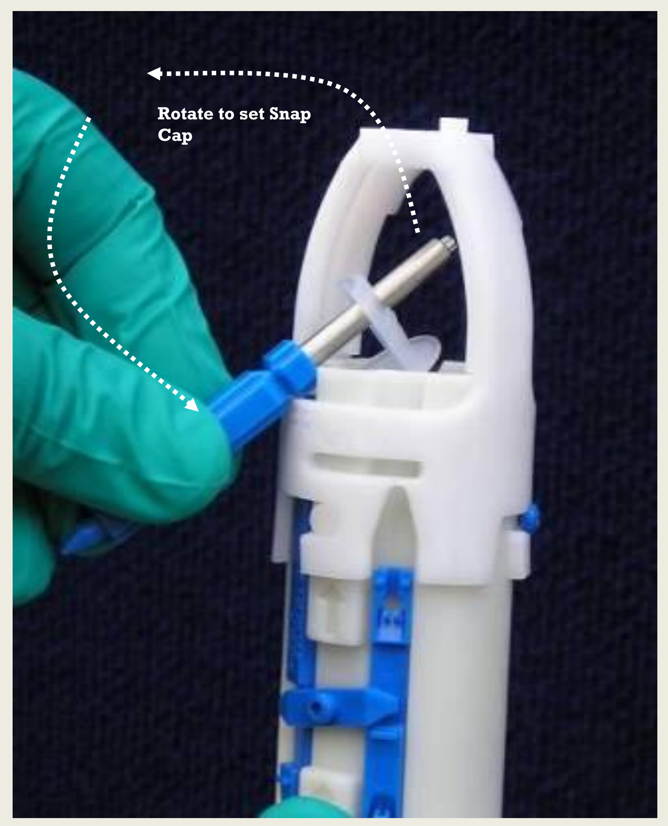
Laura Zimmerman, Beth L. Parker, Sanford Britt, and Amanda Pierce

Open Sampler



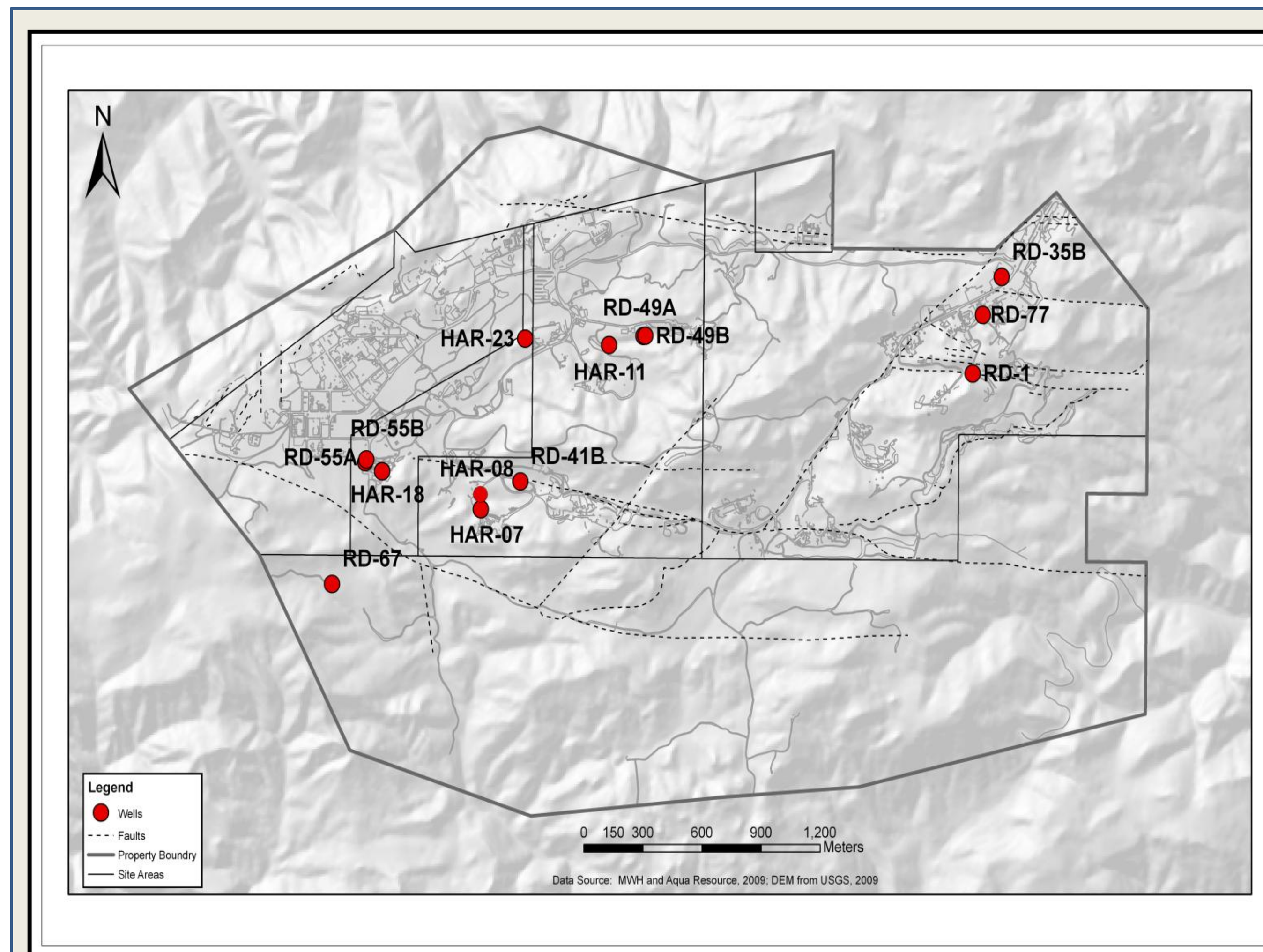
Insert Bottles

Set Bottles Open

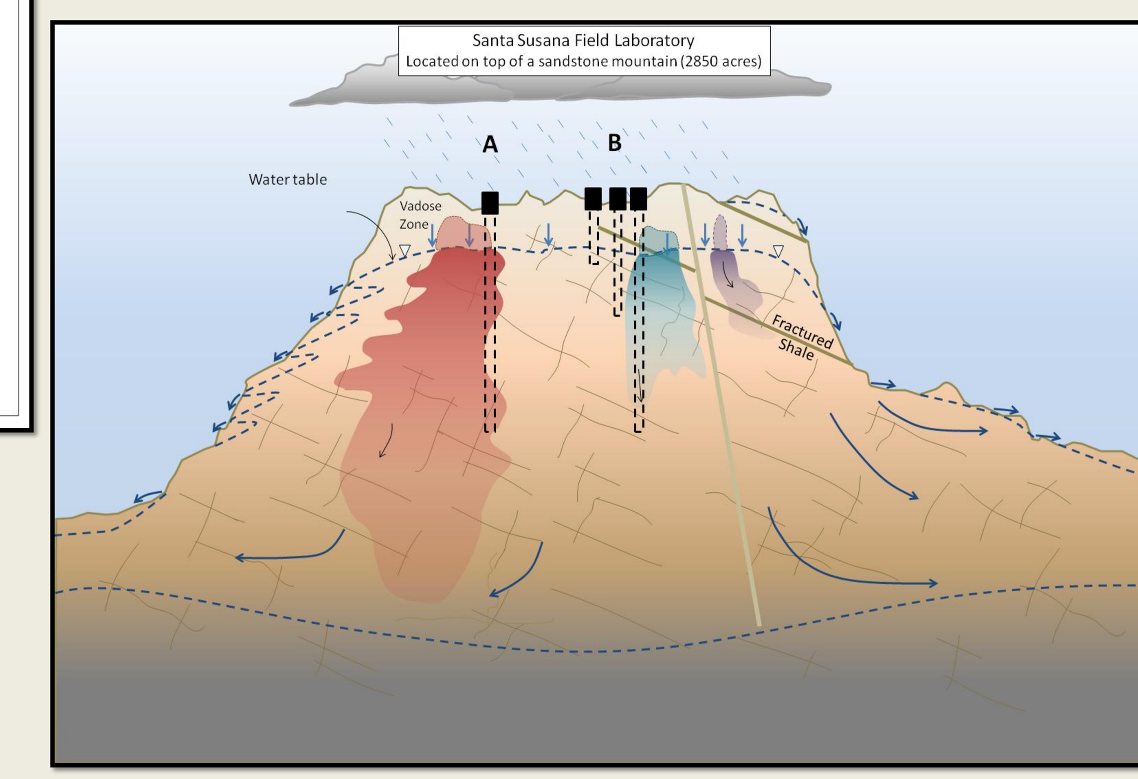


Sampler "string"

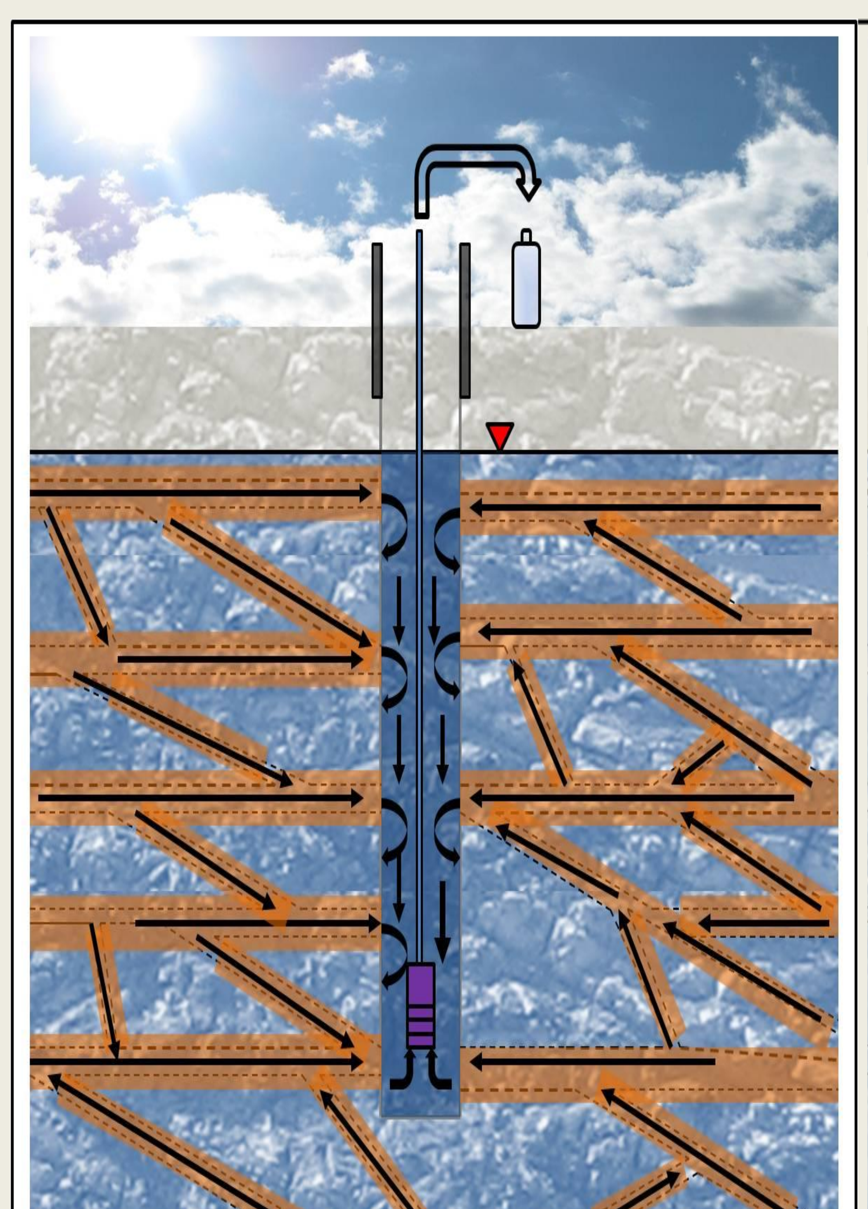
The Snap Sampler is used to collect depth discrete in-situ groundwater samples in a water column in an open borehole or monitoring well. Samples are collected by pulling the trigger, sealing the water in each of the bottles beneath the surface. Samples are sent to directly to the lab without ever being opened.



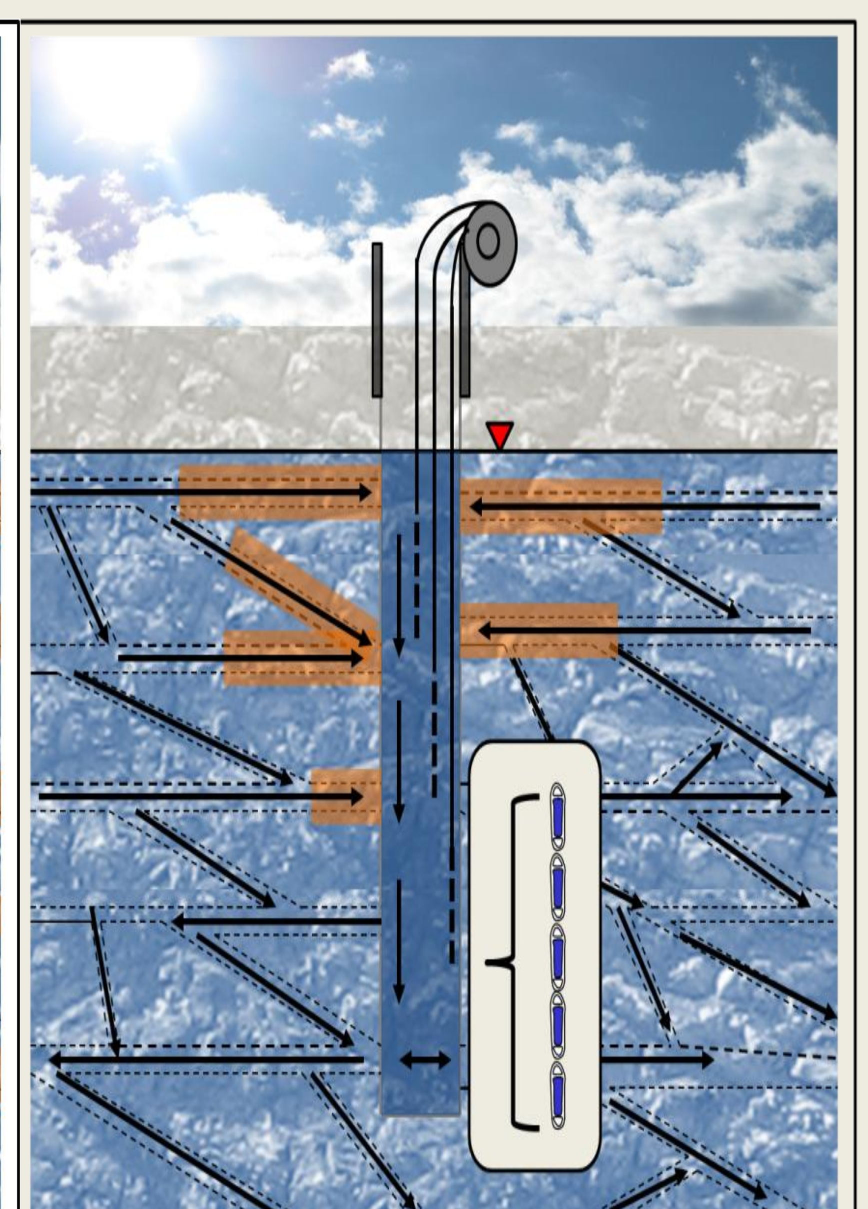
- **12 wells were sampled using the Snap Sampler at SSFL**



- **Conventional long screen and cluster wells were both sampled**

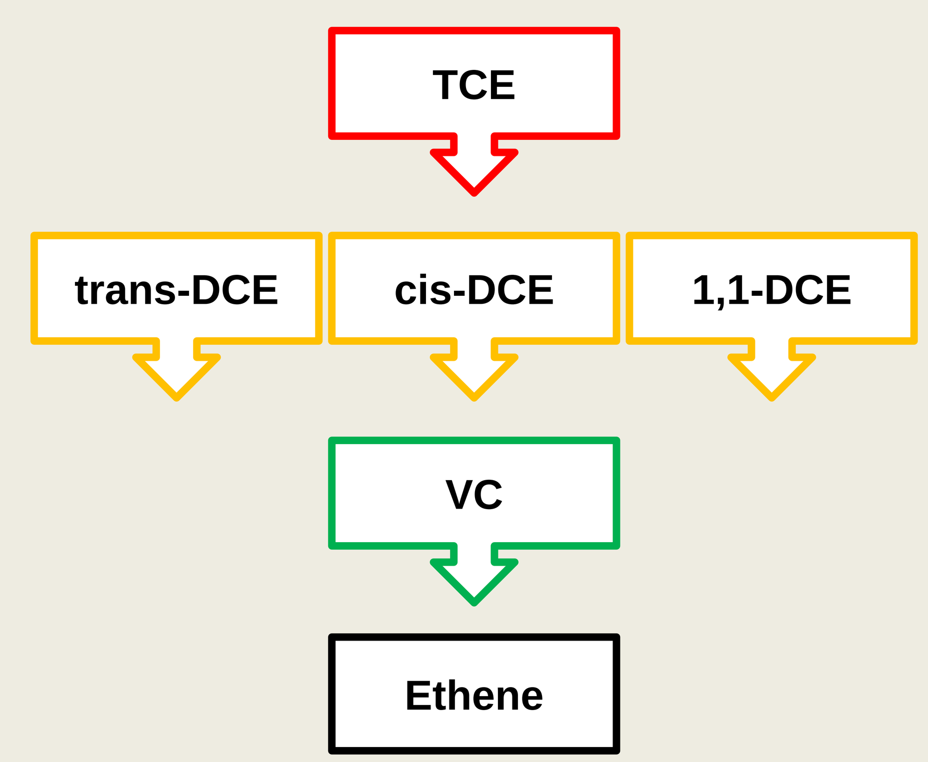


Conventional Purging

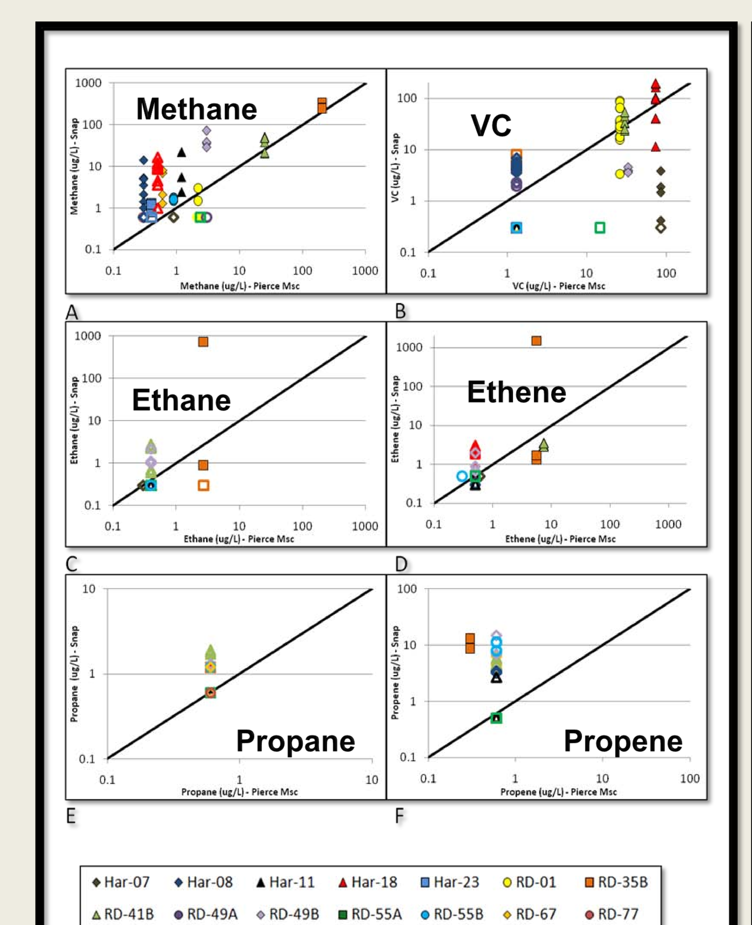


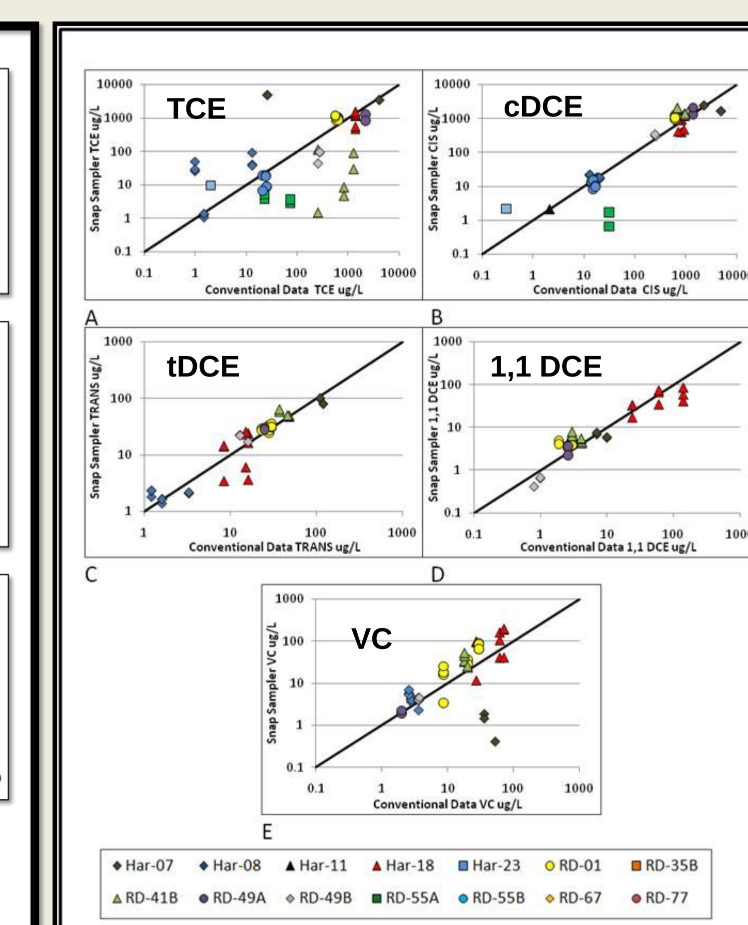
Snap Sampling

- **Conventional purge samples are mixed from many fractures.**
- **Snap samples are mixed from water flowing in the open well bore under non-pumping conditions.**



TCE Degradation Pathway
Microbial Reductive Dechlorination





Groundwater samples collected using the Snap Sampler have higher measured concentrations of degradation products, including dissolved gases such as vinyl chloride and ethene. Making these samples more representative of in-situ conditions.

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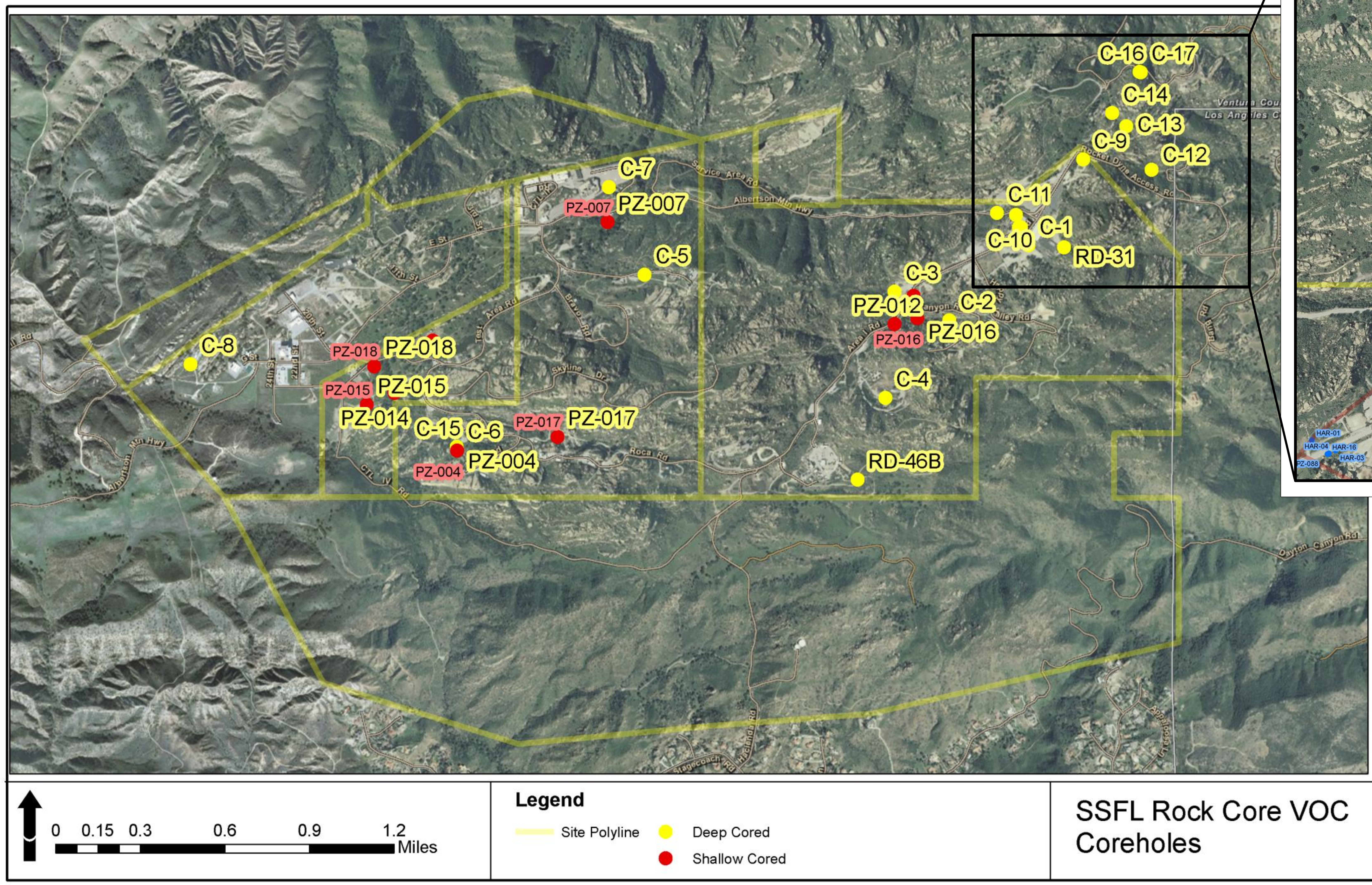
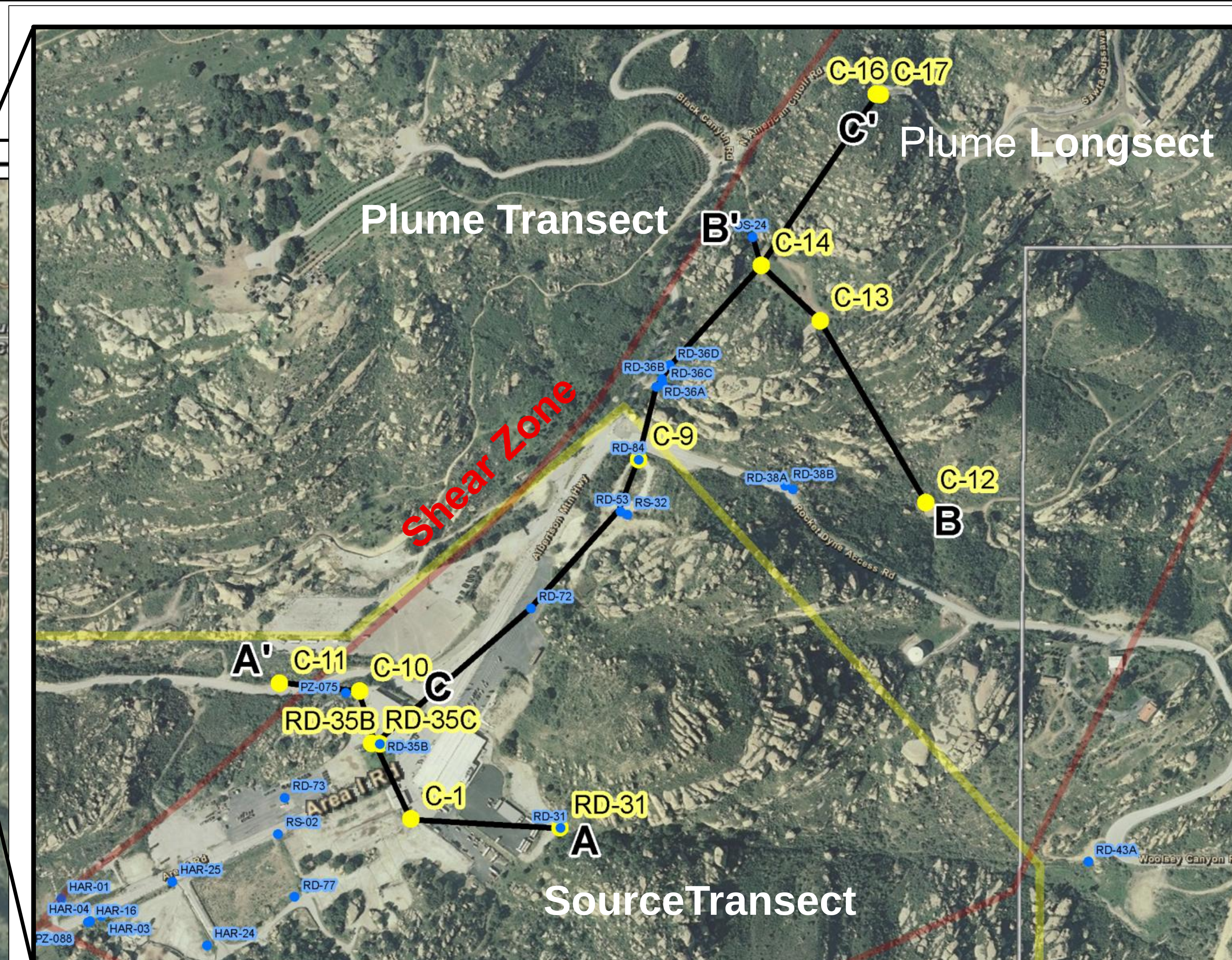
Locations of the North-Eastern Plume Rock Core Transects

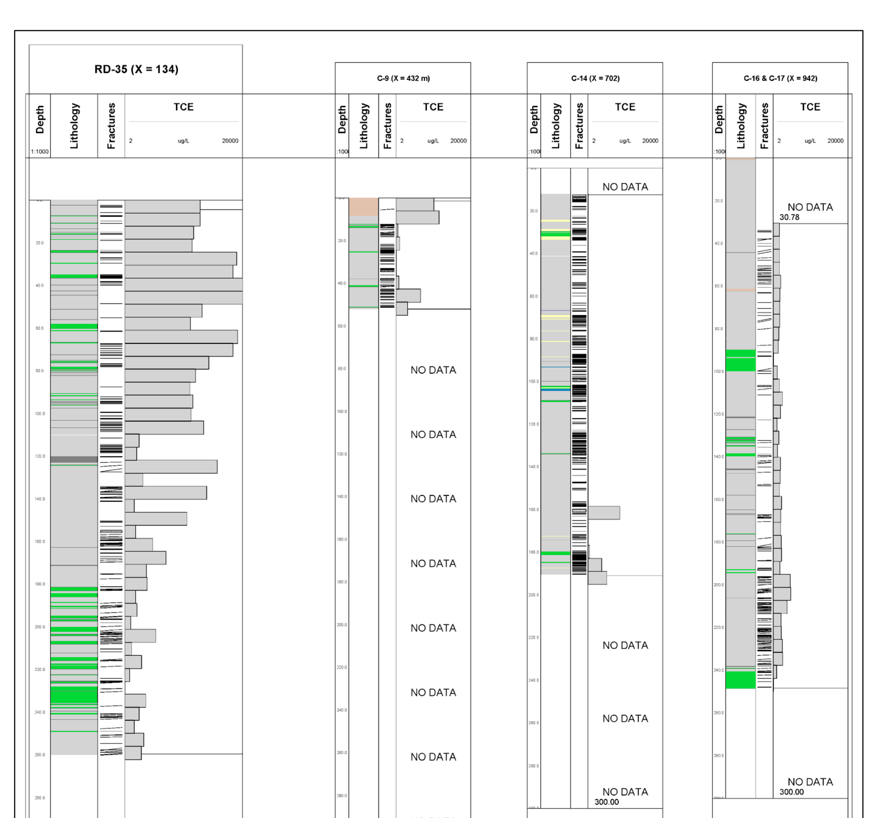
Locations of the Rock Core VOC coreholes at the SSFL





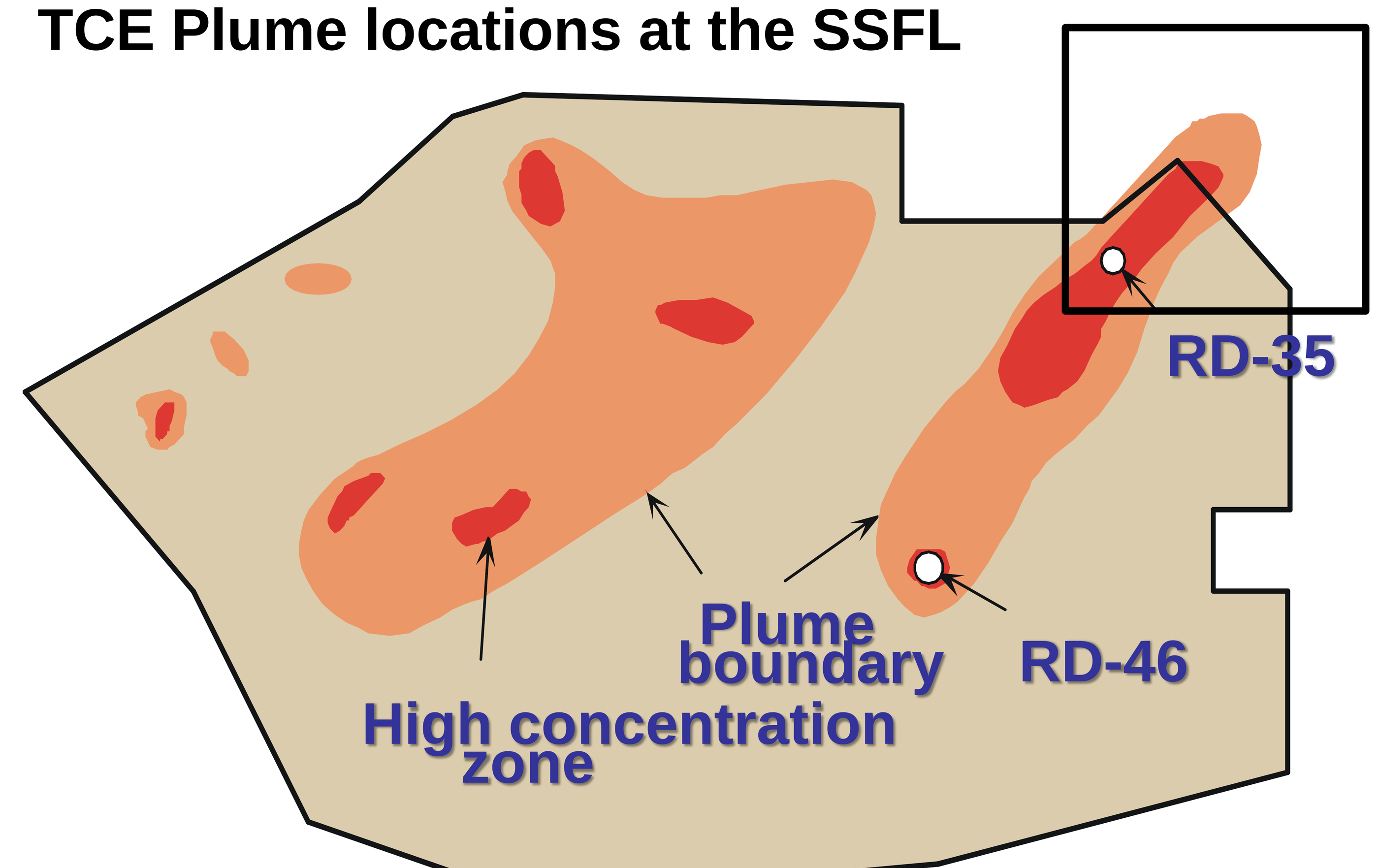
The transect approach was applied to the Northeastern TCE plume. In the North Eastern portion of the SSFL groundwater flow is primarily to the Northeast so a series of coreholes were oriented to be perpendicular to groundwater flow. This assists in determining the areal extents of the plume. Rock Core VOC holes were also drilled along a 'longsect' (along the plume centerline) to determine the maximum distance of contaminant migration.

Plume Transect (B-B') Corehole C-13



Longsect geology and TCE conc.

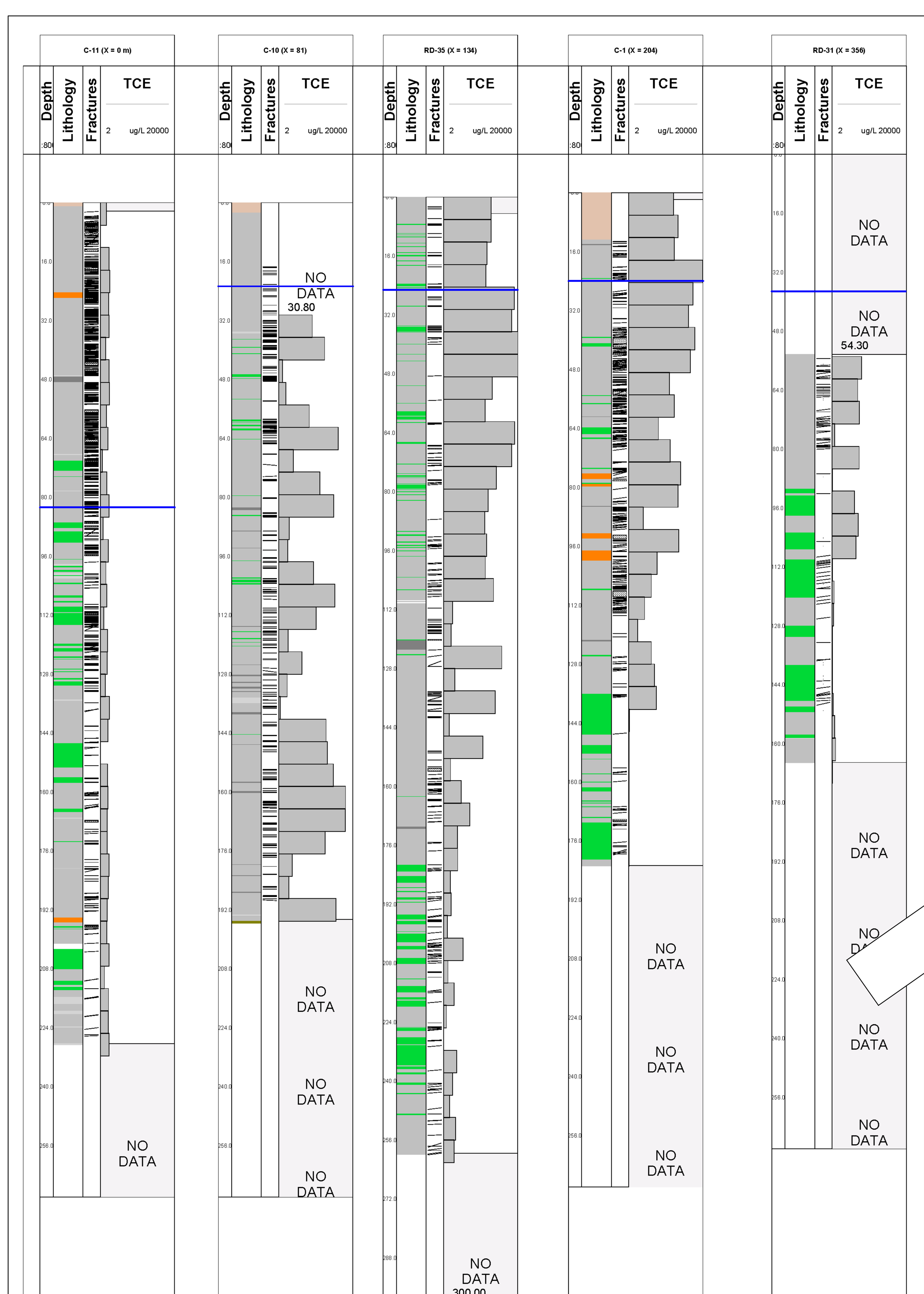
TCE Plume locations at the SSFL



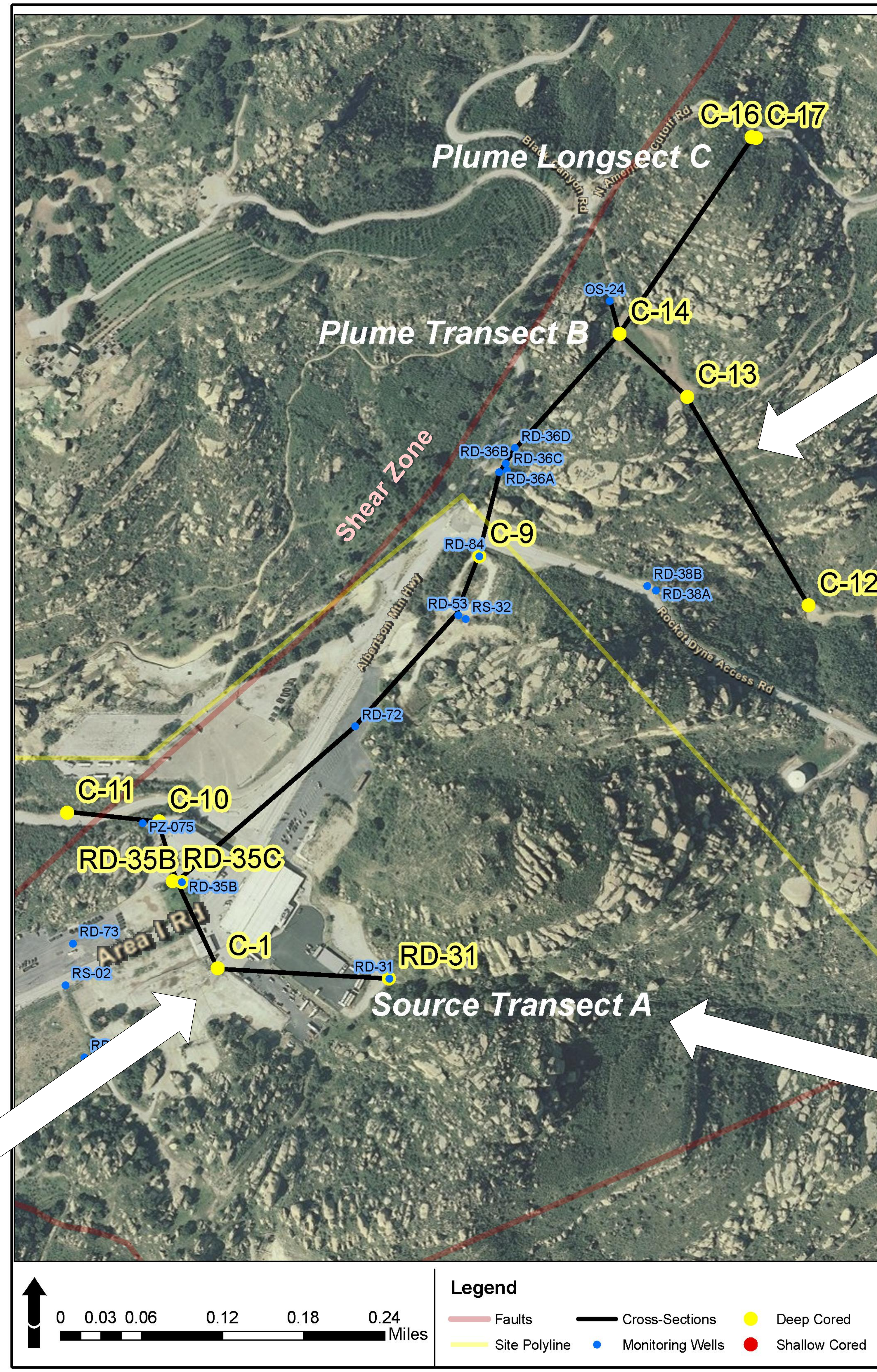
Northeastern TCE plume transects

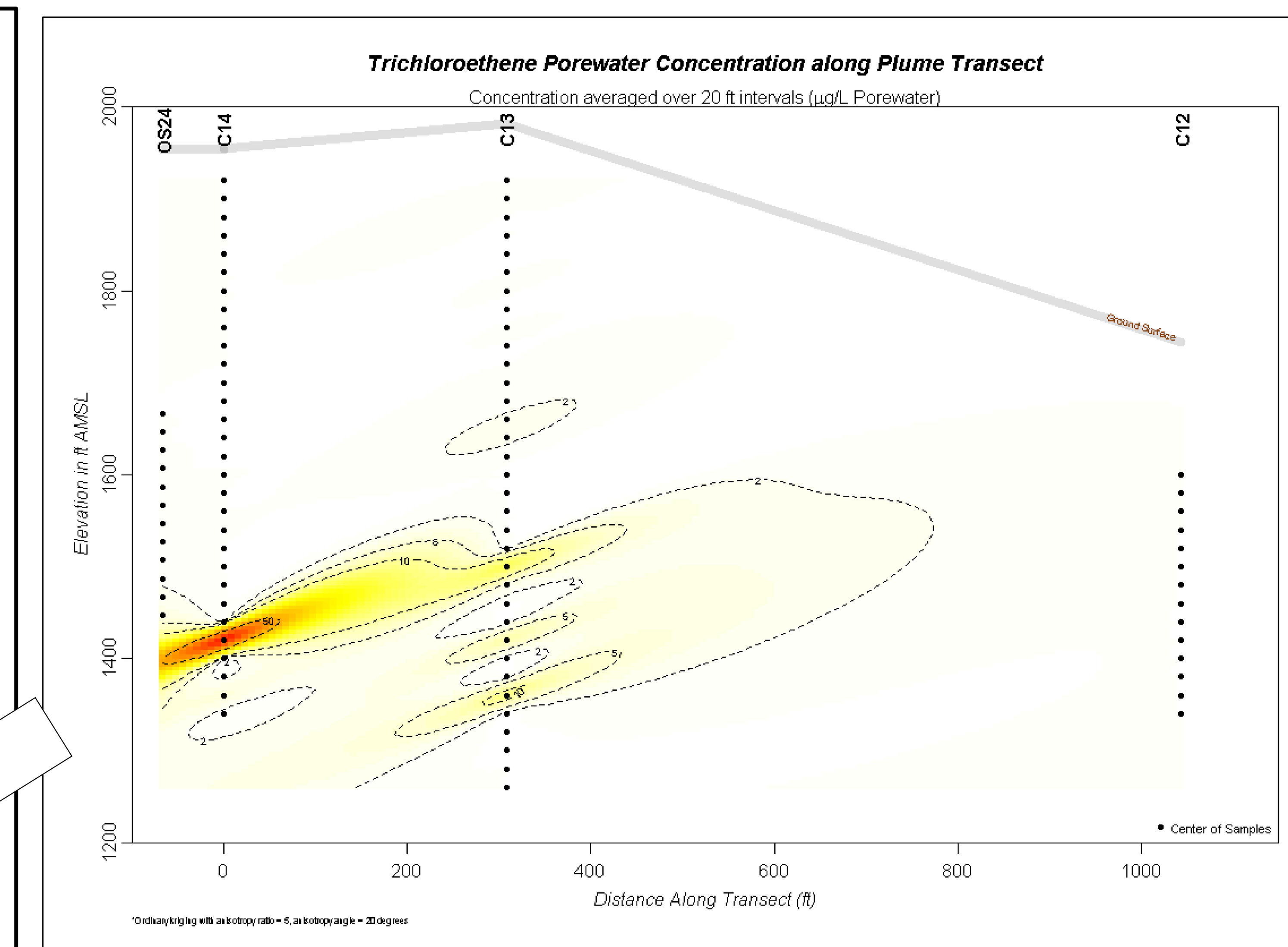
For the Northeast TCE plume 10 corehole locations were chosen to provide a network for examining the extent of contamination. Rock samples from the coreholes were taken at high sampling frequency with depth (~1/ft). Depth weighted averages for TCE concentrations were calculated to assist in the interpretation and visualization of the data. Along the transects, values were kriged (interpolated) to portray slices of the plume and source areas. These slices help to illustrate the geological controls on contaminant migration and also provide insight into the direction of groundwater flow.

Location of Plume cross-sections⟶



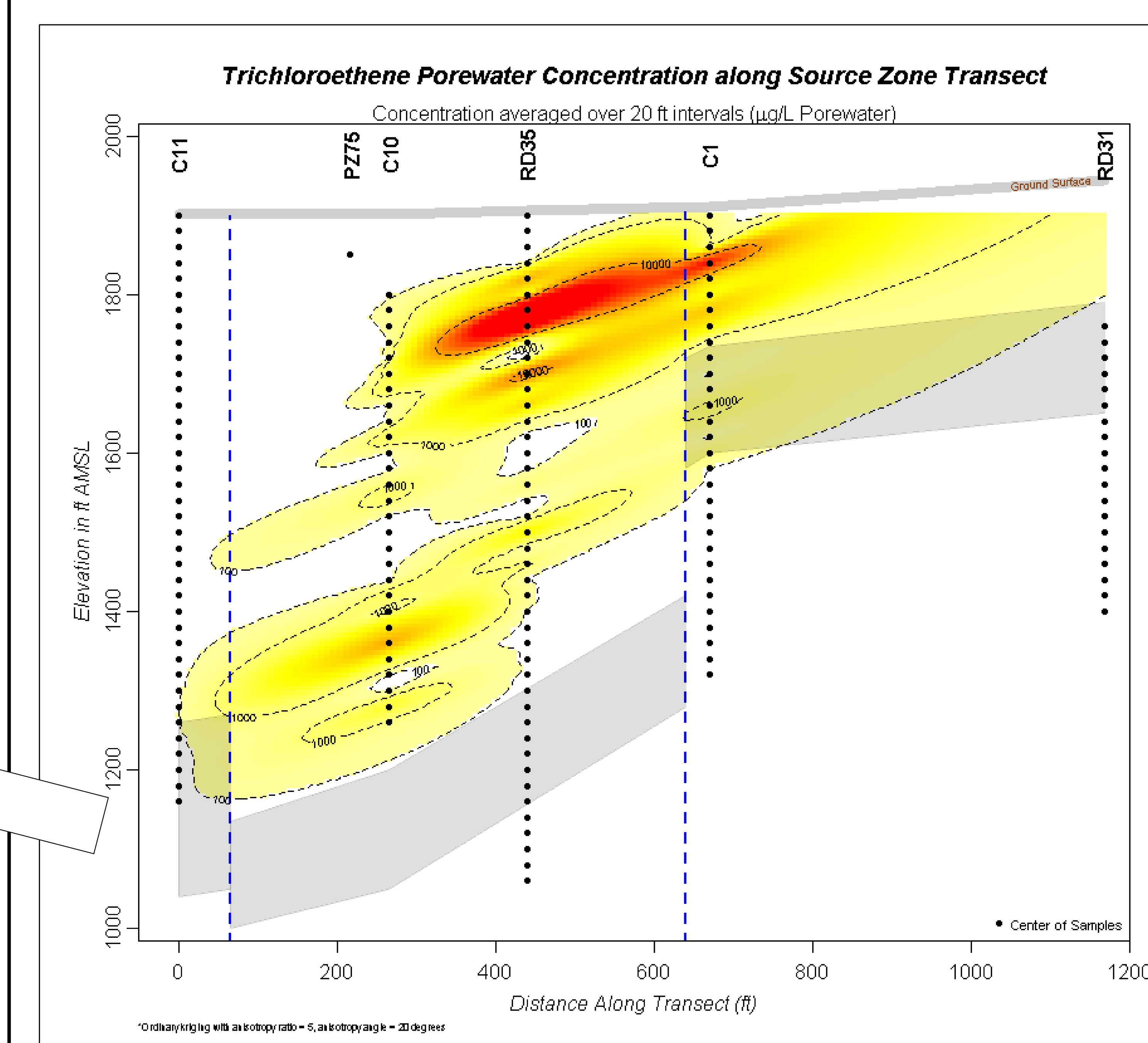
Transect Data View: Source Transect A





Plume Transect B:

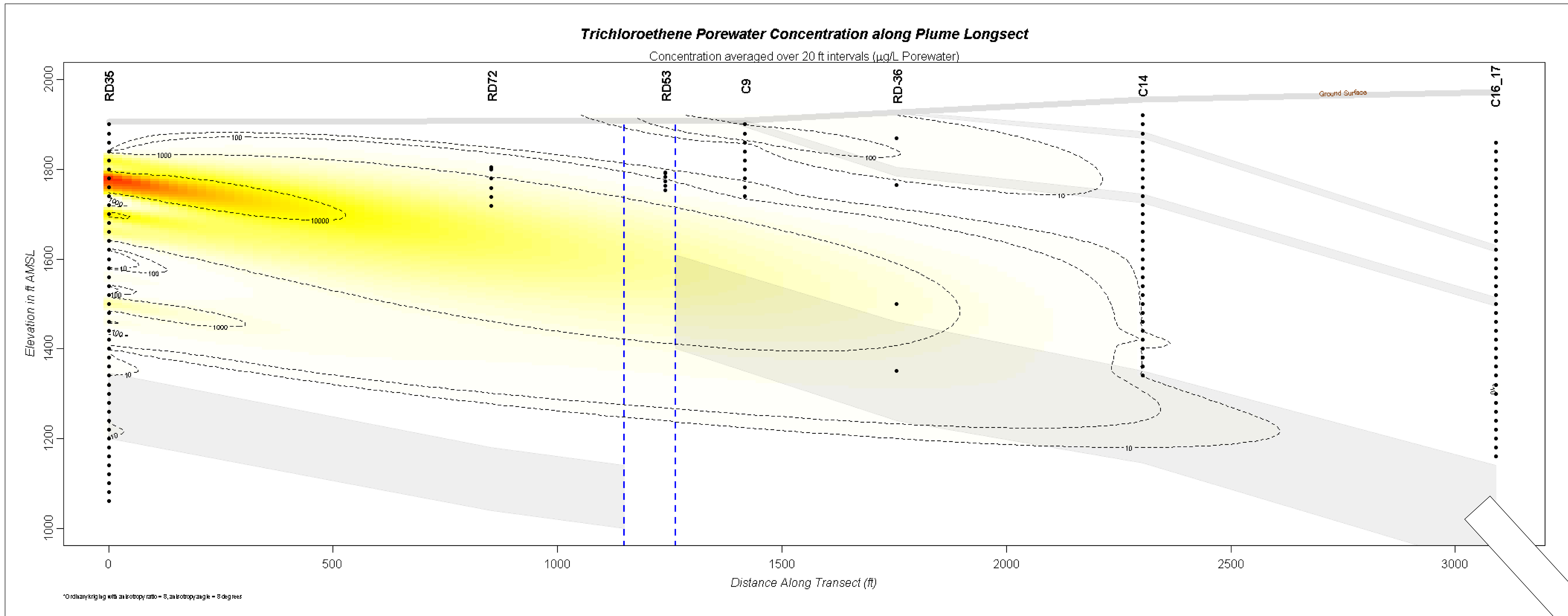
No TCE was found in C-12



Source Transect A:

Contamination migration near the source tended to follow geological controls

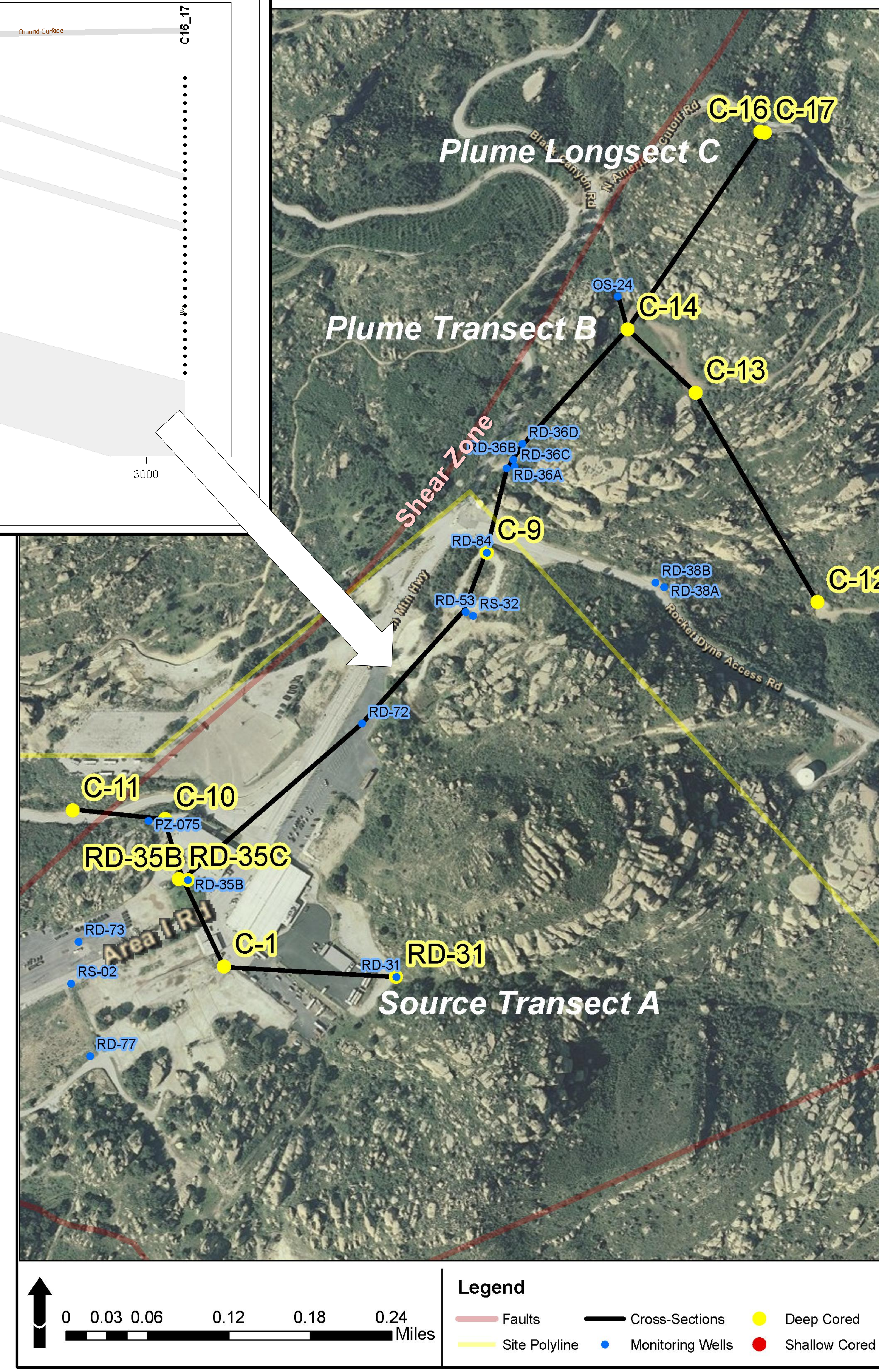
Northeastern TCE plume Longsect

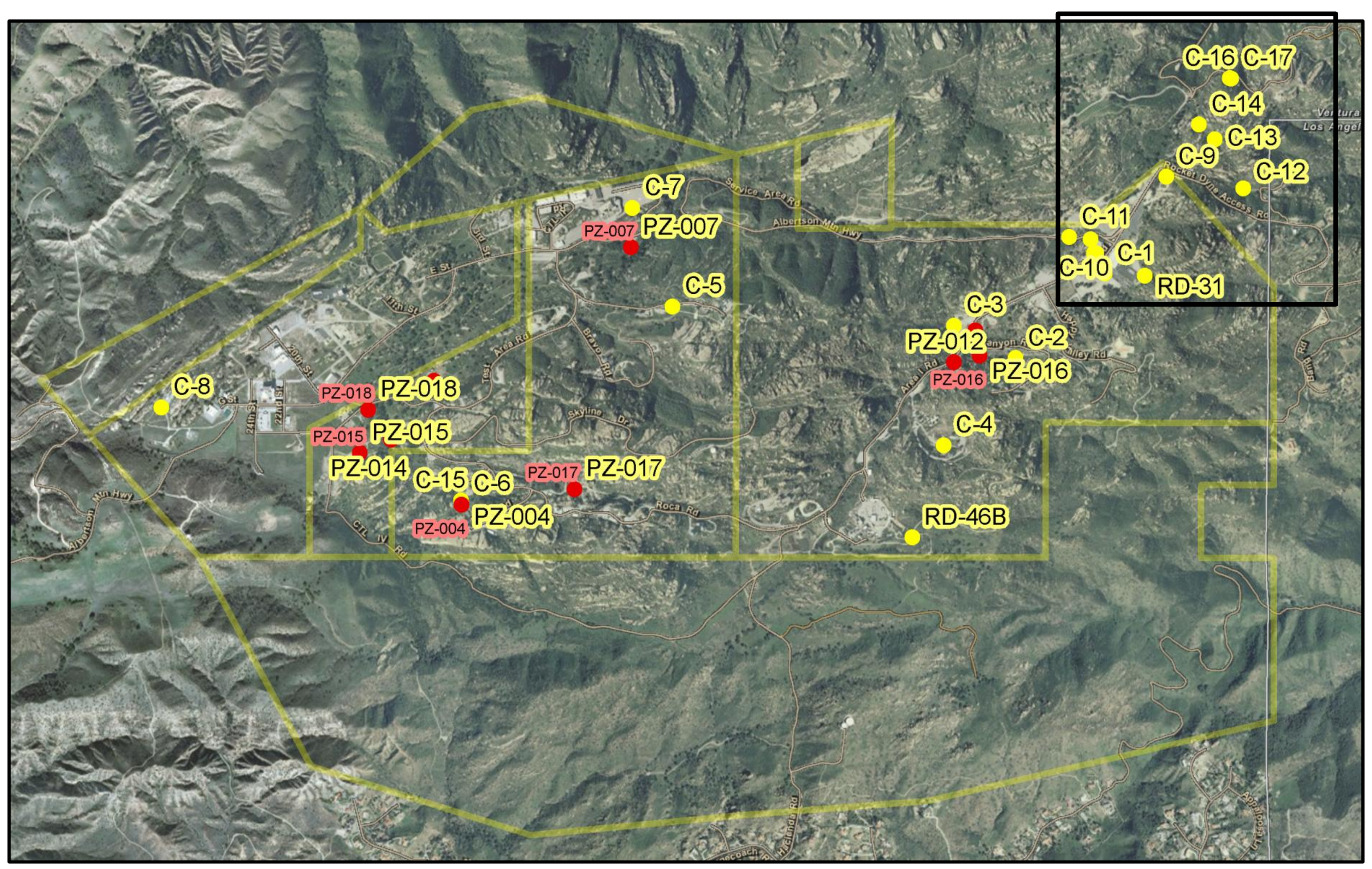


Plume Longsect C:

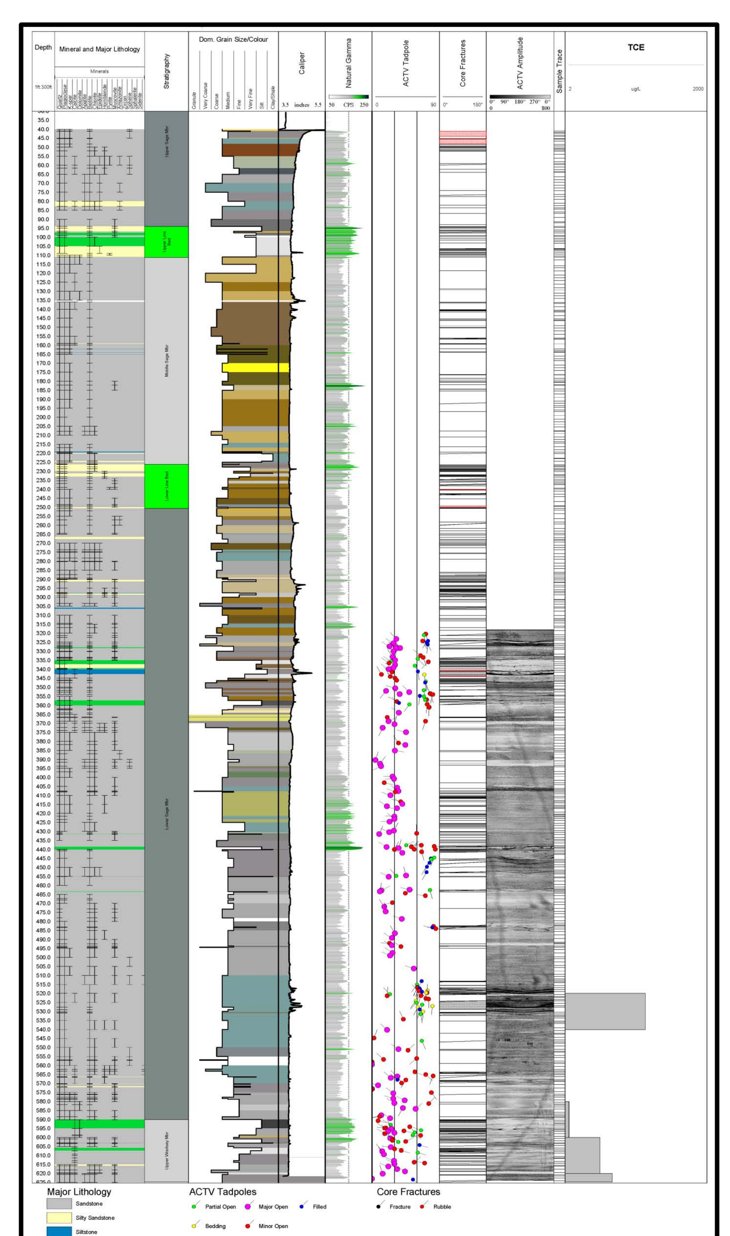
Decreasing concentration with distance from the source and increasing depth of contamination

Coreholes forming a line parallel to groundwater flow were chosen to create a longsect. The longsect is chosen to be in the highest concentration slice of the plume to provide an estimate on the maximum extent of contaminant migration parallel to flow. Used in conjunction with transects a plume can be delineated.





Areal View of the SSFL with Rock Core VOC holes shown



Example Corehole Dataset C-14