

Selection, Design, and Construction of Multilevel Groundwater Monitoring Systems

Session: E1. Fractured Rock Site Characterization

John N. Dougherty,
PG

April 9, 2018

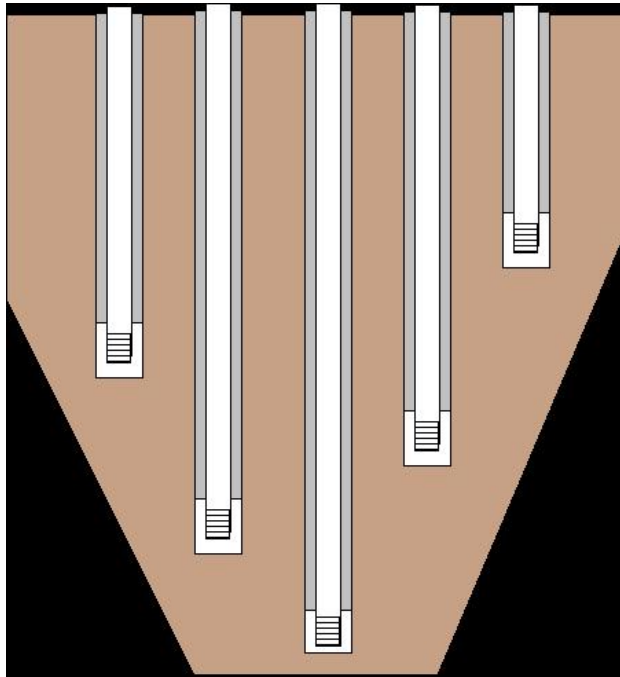


**CDM
Smith**

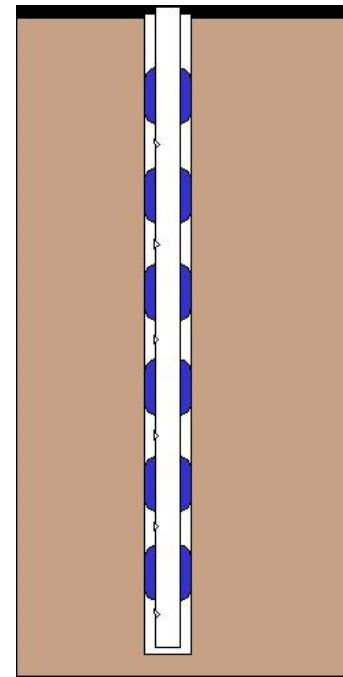
Eleventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds
April 8-12, 2018 | Palm Springs, California

What is a Multilevel Groundwater Monitoring System?

Monitoring Well Cluster

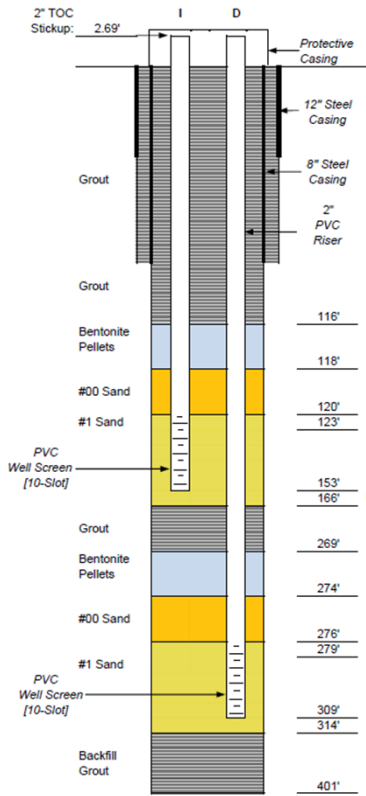


Multilevel Well

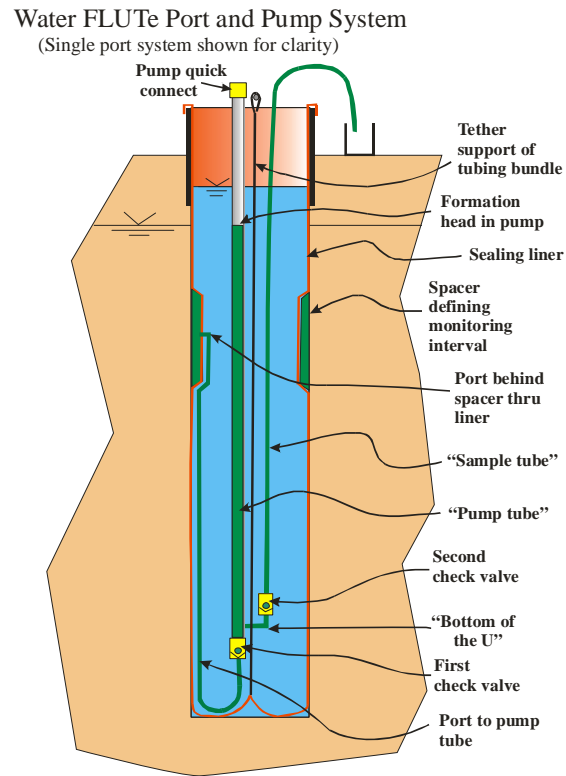


Common Multilevel Systems

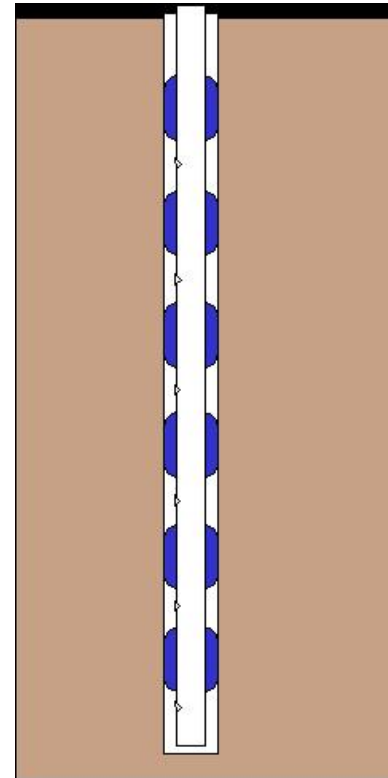
Nested Well



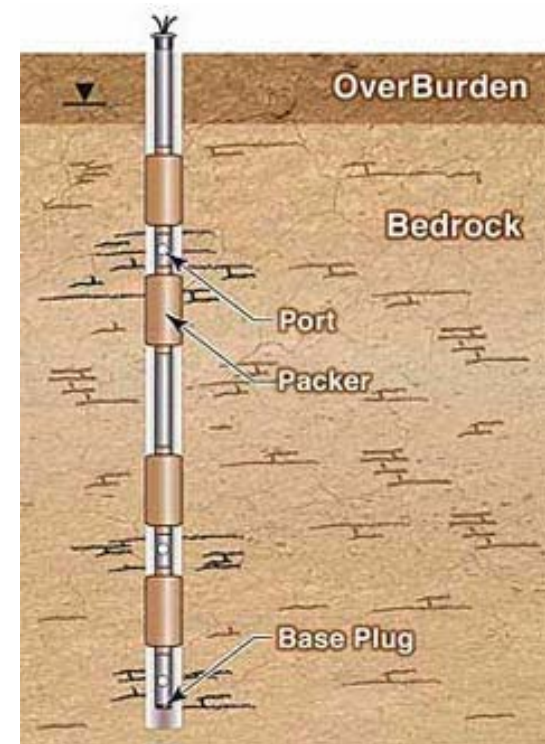
Water FLUTE



Westbay



Waterloo



Why Use a Multilevel System?

- Right location for a multilevel system?
 - Prevent vertical movement of contamination or DNAPL
- Depth discrete data from multiple vertical intervals
- Complex site conditions
 - Hydrogeology
 - Stratigraphy
- Large plume: Laterally and vertically
- Characterization and remediation objectives
 - Extent and nature of contamination
 - Mass flux/mass discharge assessment
 - Compliance point monitoring

Advantages of a Multilevel System

- Reduced footprint/increased sustainability
 - Install borehole with multiple screens or versus multiple boreholes
- Reduced drilling costs/increased sustainability
 - One borehole
 - Reduced investigation derived waste (IDW)
 - Deal with difficult drilling conditions one time
- Reduced sampling costs
 - Do not need to install and remove a pump
- Can purge multiple intervals

Limitations and Assumptions – Multilevel Systems

- Not as flexible as a standard well due to specialized function:
Multiple zones in one borehole
- Complements monitoring wells (e.g., dilution test, PFM)
- Specialized sampling equipment and training
- Long-term water level monitoring using pressure transducers is more complex
- Purging assumptions
 - Waterloo and FLUTE: Purge sampling lines, continue and measure water quality parameters
 - Westbay: zero purge, grab sample
 - Groundwater flow maintains representative sample at the port



Selection

Selection Considerations

- What are your project objectives?
- Project stage, location, and purpose of wells?
 - Characterization?
 - Remediation?
 - Transect to monitor mass flux/mass discharge?
 - Monitoring?
 - Length (volume) of vertical sampling interval?
- Which fractures or zones need to be monitored or sealed?
- What volume of the borehole do you need to monitor?
- Multilevel systems and monitoring wells complement each other

Selection Factors

	Nested Wells	Water FLUTE	Westbay	Waterloo
Number of Zones	2 or 3	6 to 15	<u>20 per 100 ft</u>	5 to 8
Length of Zone	Variable			
Sampling Method	Gas Drive Pump	Gas Drive Pump	<u>Wireline</u> grab sample (1 l/trip)	Gas Drive Pump
Water Quality Parameters	Flow through cell	Flow through cell	<u>Grab</u>	Flow through cell
Water Level Monitoring Method	Indicator or Transducer	Indicator or Transducer (dedicated/ non-dedicated)	<u>Wireline</u> tool One zone: Indicator or transducer	Indicator or Vibrating Wire Transducer
Seal Between Zones	Backfill	<u>Liner</u>	Packer	Packer
Field Adjust Zones?	Yes	<u>No</u>	Yes	Yes
PFOA/PFOS	Ok	Ok	Addressing	Alternative Mat.

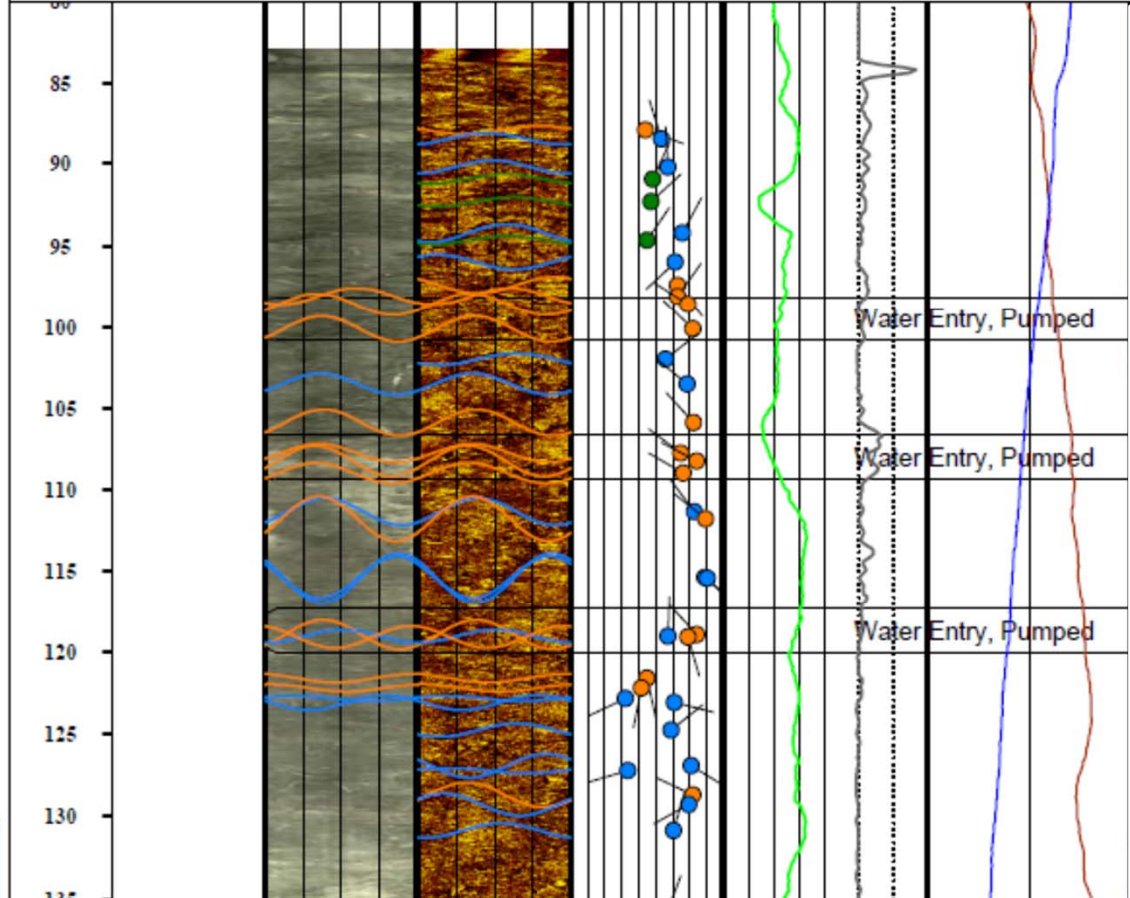


Design

Design Process

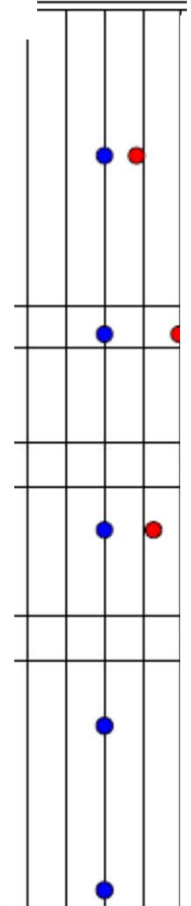
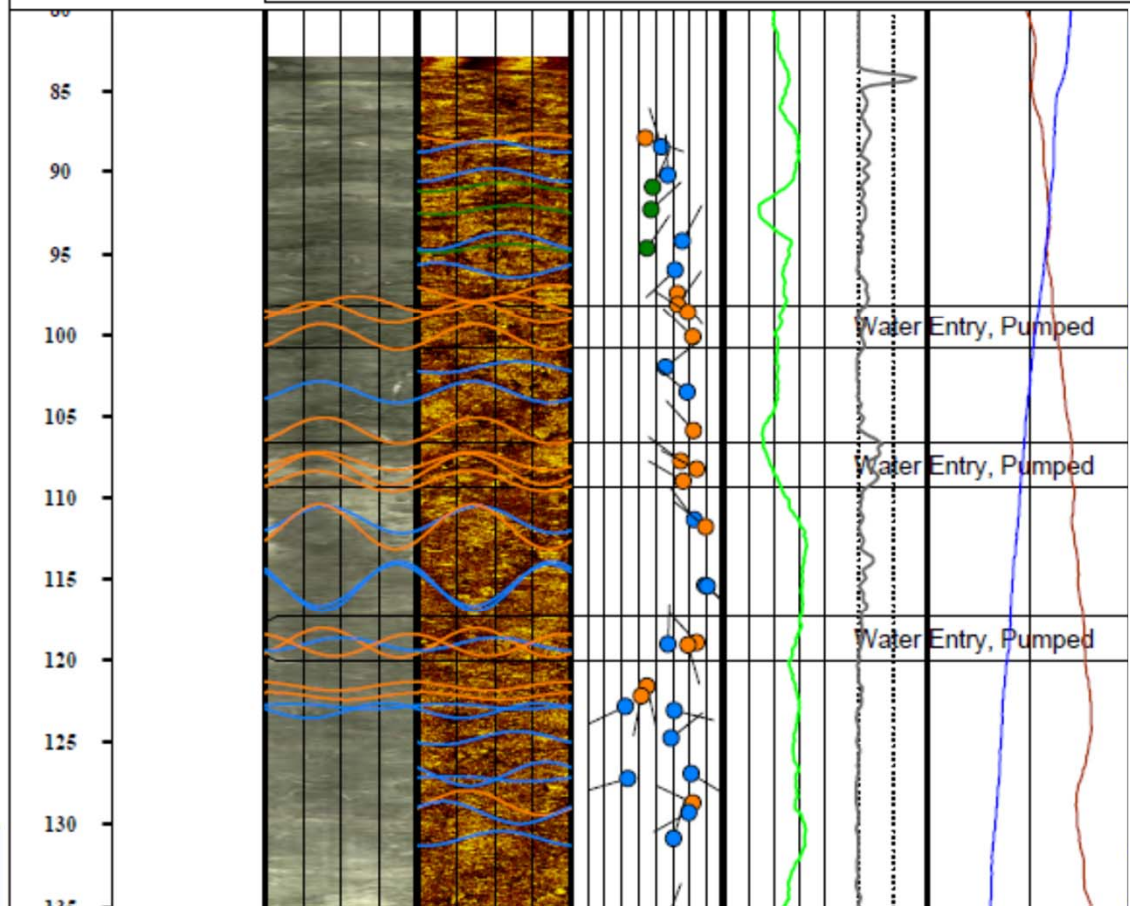
- Need lithologic, fracture, and groundwater quality data to design the system
 - Available data?
 - What additional data are needed?
- Drill borehole
 - Preferred methods: Rock core, air rotary
- Sample during drilling
 - Water quality, rock matrix
- Borehole geophysical logging
- Transmissivity profile (FLUTe drop test)
- Packer testing: Hydraulic and water quality data
- Prevent vertical fluid migration (line borehole, construct promptly)
- **Design the system**

Depth 1ft:150ft	Lithologic Log	OTV	ATV	Tad Pole	N. Gamma	Caliper	Fluid Conductivity
		0° 90° 180° 270° 0°		0 90	25 125 5 in 8	13.5 uS/cm 14	
		Transmissive Features	Features			Fluid Temperature	
	0° 90° 180° 270° 0°	0° 90° 180° 270° 0°			25 °C 26		
Hydrostratigraphy (WBI = water bearing i							
Comments							

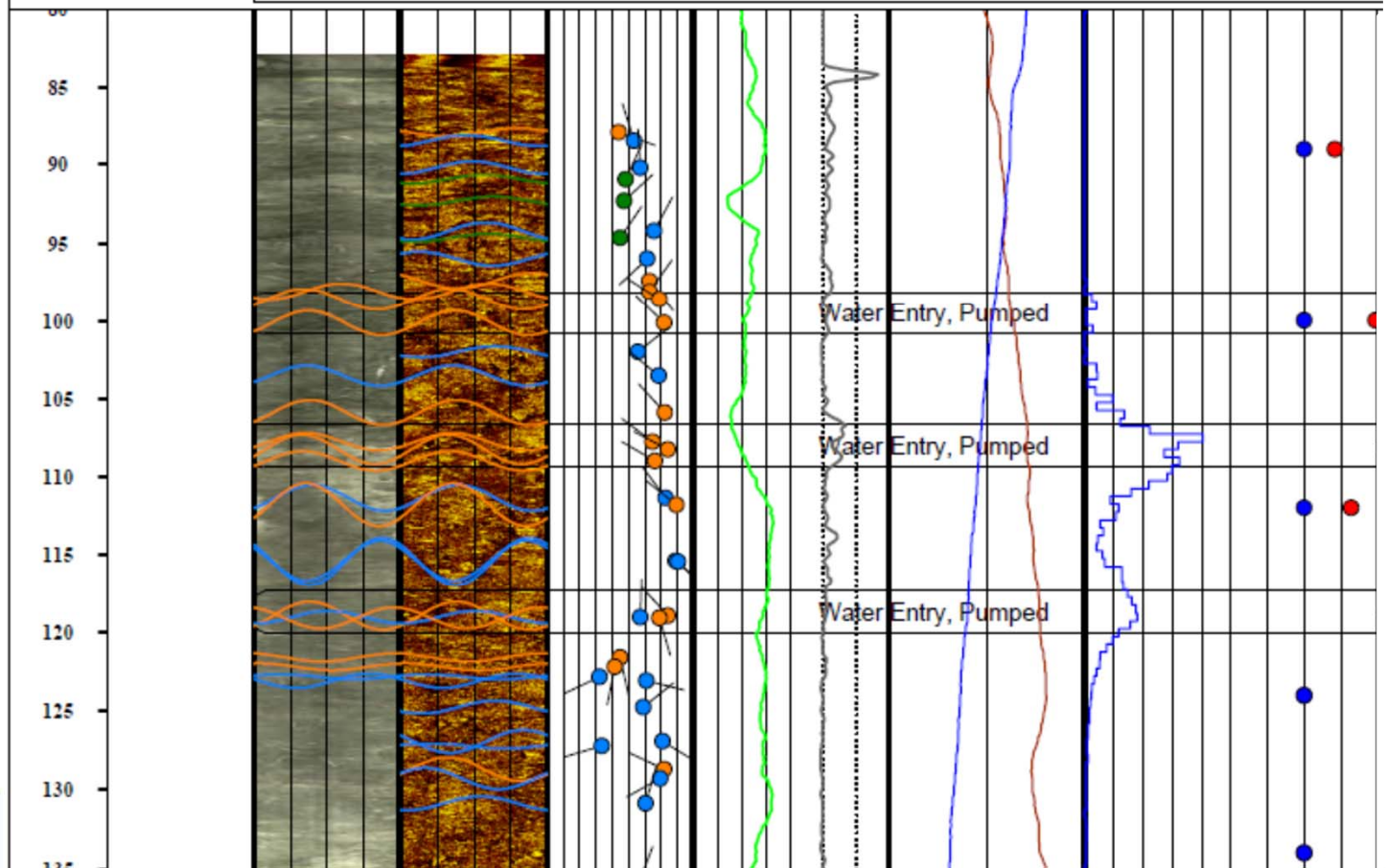


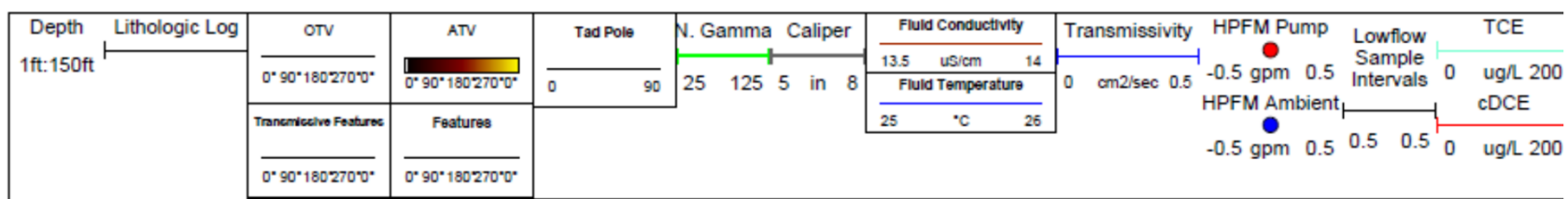
Depth	Lithologic Log	OTV	ATV	Tad Pole	N. Gamma	Caliper	Fluid Conductivity
1ft:150ft		0° 90° 180° 270°	0° 90° 180° 270°	0 90	25 125 5 in 8		13.5 uS/cm 14
		Transmissive Features	Features				Fluid Temperature
		0° 90° 180° 270°	0° 90° 180° 270°				25 °C 26
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Comments							

HPFM Pump
 ● -0.5 gpm 0.5
 ● -1PFM Ambient
 ● -0.5 gpm 0.5



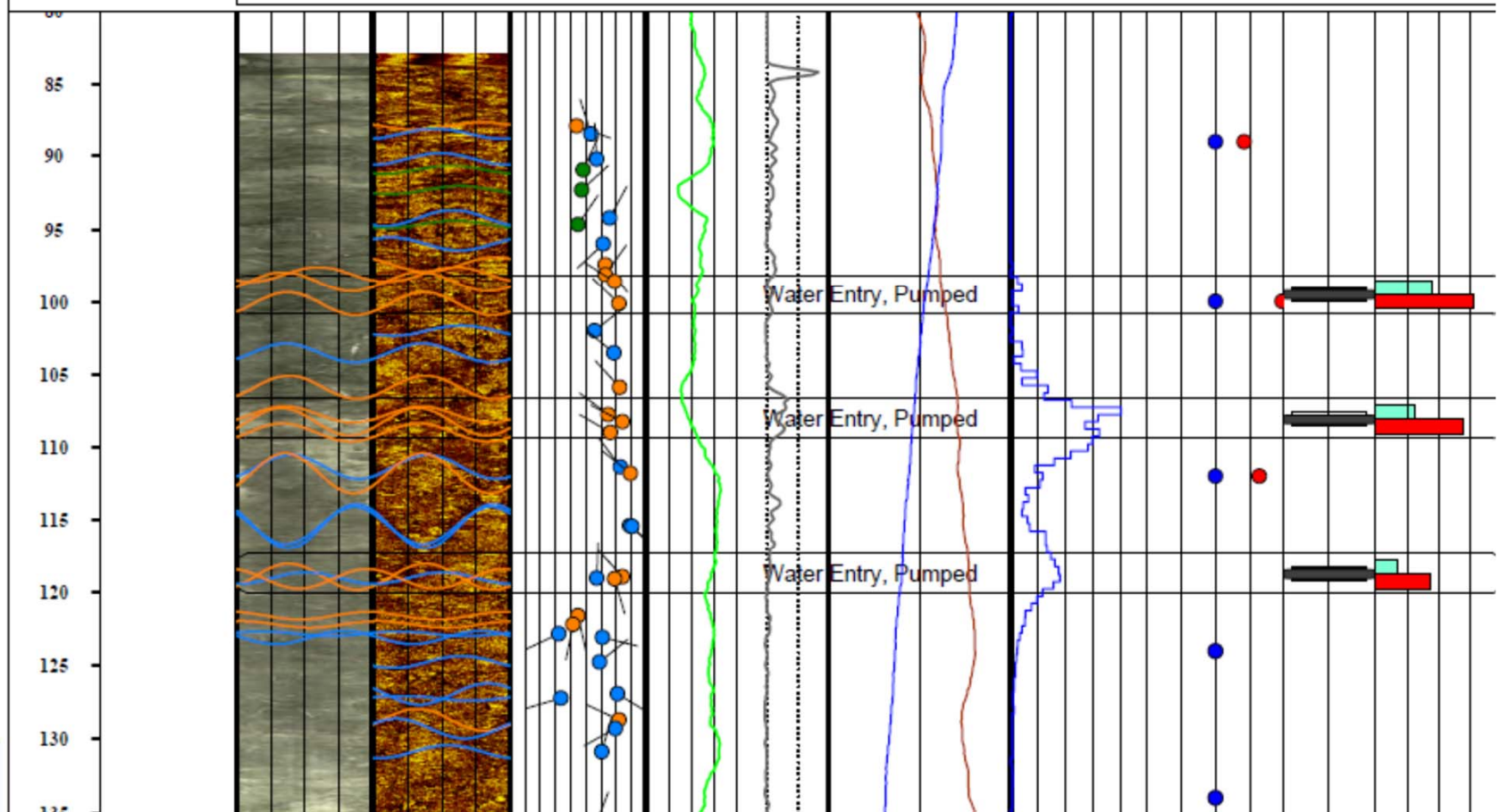
Depth	Lithologic Log	OTV	ATV	Tad Pole	N. Gamma Caliper	Fluid Conductivity	Transmissivity	HPFM Pump
1ft:150ft		0° 90° 180° 270° 0°	0° 90° 180° 270° 0°	0 90	25 125 5 in 8	13.5 uS/cm 14	0 cm2/sec 0.5	-0.5 gpm 0.5
		Transmissive Features	Features			Fluid Temperature		HPFM Ambient
		0° 90° 180° 270° 0°	0° 90° 180° 270° 0°			25 °C 26		-0.5 gpm 0.5
Hydrostratigraphy (WBI = water bearing interval)								
Comments								

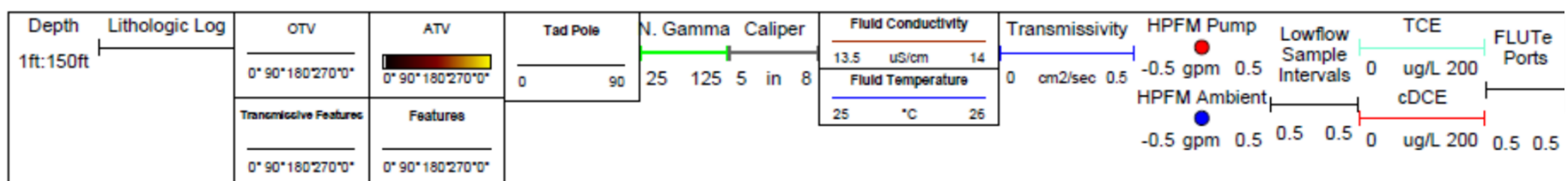




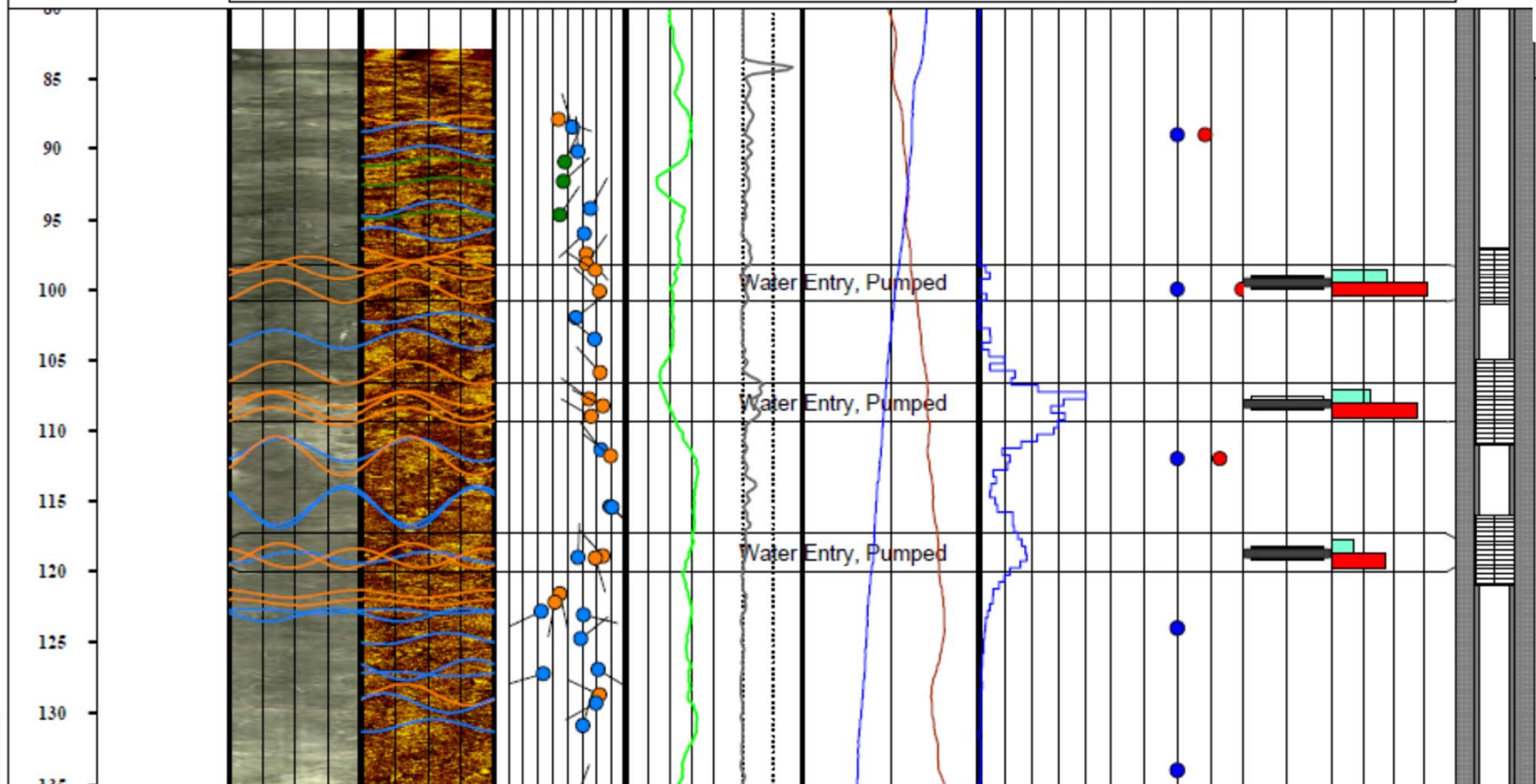
Hydrostratigraphy (WBI = water bearing interval)

Comments

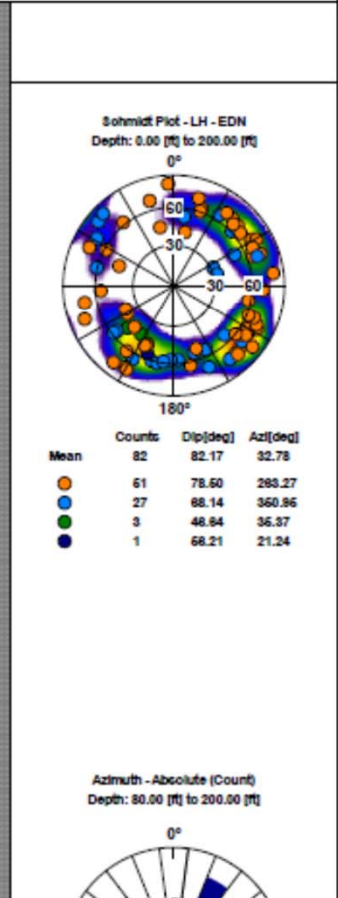
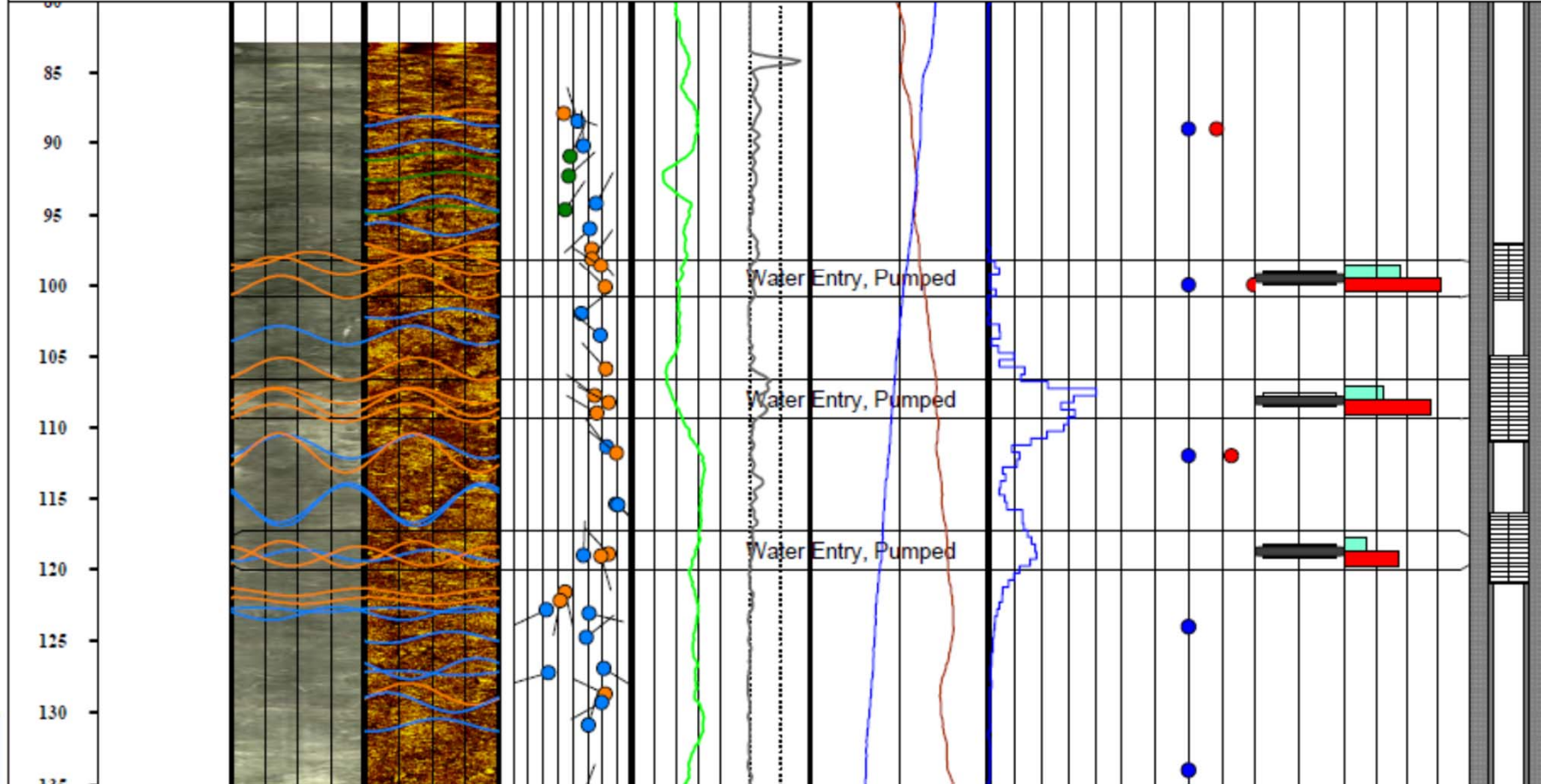




Hydrostratigraphy (WBI = water bearing interval)
Comments



Depth 1ft:150ft	Lithologic Log	OTV 0° 90° 180° 270° 0°	ATV 0° 90° 180° 270° 0°	Tad Pole 0 90	N. Gamma 25 125 5 in 8	Caliper 13.5 uS/cm 14 25 °C 26	Fluid Conductivity	Fluid Temperature	Transmissivity 0 cm2/sec 0.5	HPFM Pump -0.5 gpm 0.5	HPFM Ambient -0.5 gpm 0.5	Lowflow Sample Intervals 0.5 0.5	TCE 0 ug/L 200 cDCE	FLUTE Ports 0.5 0.5	Stereo Net (Dip)	Dip Azimuth Rose Diagram
Hydrostratigraphy (WBI = water bearing interval)															Transmissive Features Stereonet	
Comments															Schmidt Plot - LH - EDN	

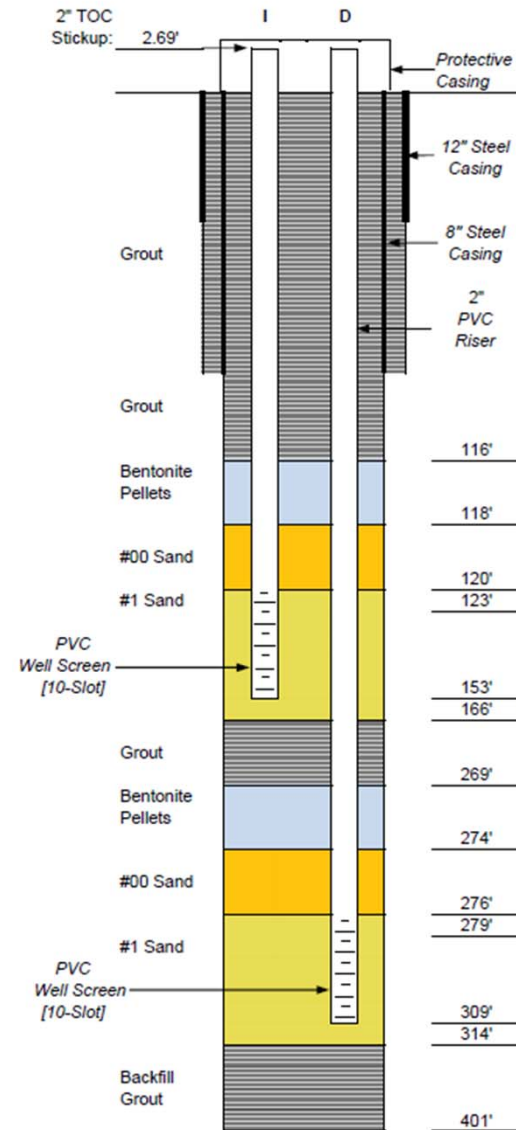




Construction: Nested Well

Nested Well

- 2 screens
- 12-inch casing installation
- 12-inch borehole to depth
- 8-inch casing installation
- 8-inch borehole to depth
- Installation of deep well
 - Partial backfill
- Installation of shallow well
 - Partial backfill
- Challenges
 - Backfill installation
 - Especially grout



Nested Well Takeaways

- Faster completion than commercial multilevel systems
- Drilling contractor can install rather than vendor
- Versatile
 - Slug tests
 - Borehole dilution tests
 - Passive flux meter deployment
- Standard monitoring equipment can be used
- Relatively complicated installation process: Back fill must be placed with precision
- Limited to 2 or 3 screens due to borehole size required

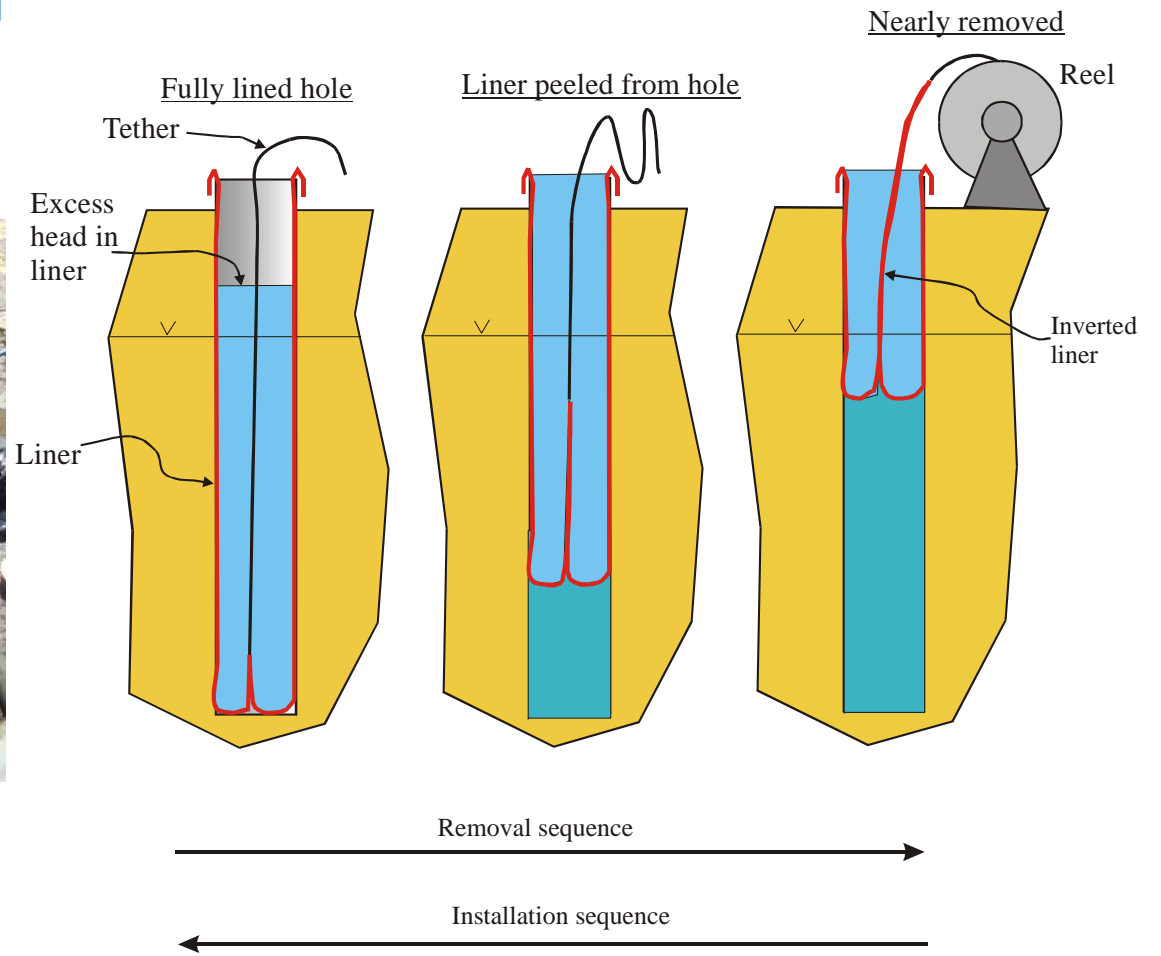


Construction: FLUTe™ System

Water FLUTe™ and Blank Liner

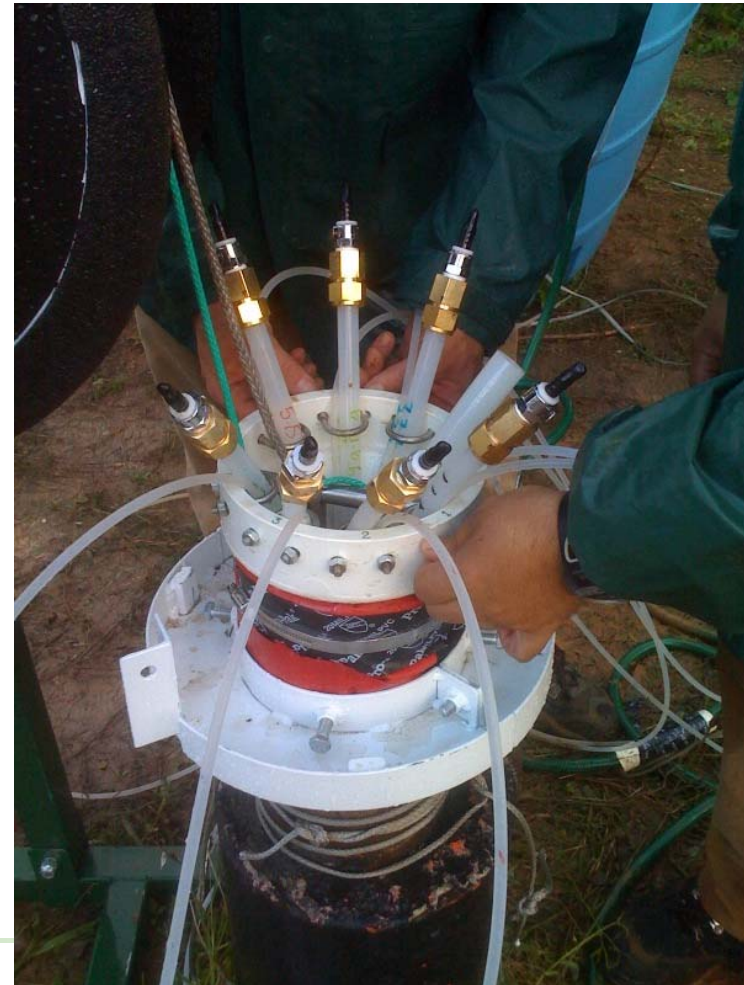
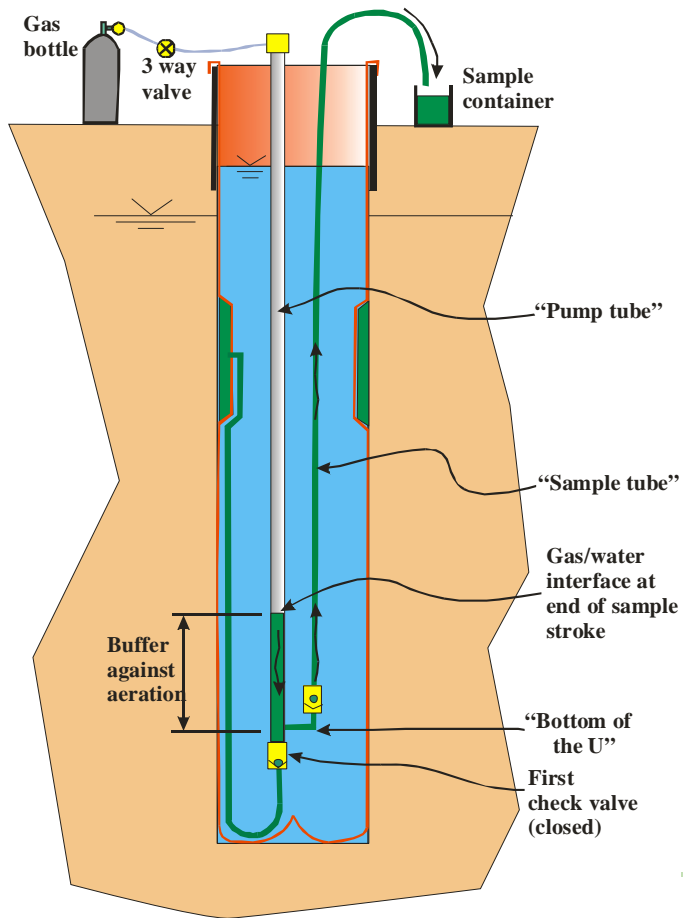


FLUTe™ Installation



Water FLUTe™ Sampling Procedure

Pumping Procedure



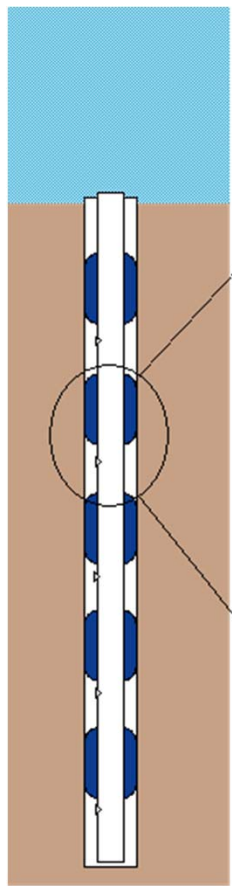
Water FLUTe™ Key Takeaways

- Liner seals borehole wall
- Removable (system is under warranty for 1 year)
- Pumps and transducers downhole
- Installation process done by FLUTe
- Air displacement transducers can be used at the surface
- Can't change the design in the field
- Must check and maintain water level inside the liner
- Limit to vertical gradient the liner can stand in an uncased borehole
- PFOA/PFOS: Not detected in components



Construction: Westbay System

Westbay System



Packer

- Reliable seal for a range of borehole sizes

Measurement port

- For fluid sampling and in situ measurement

Casing: Variable lengths

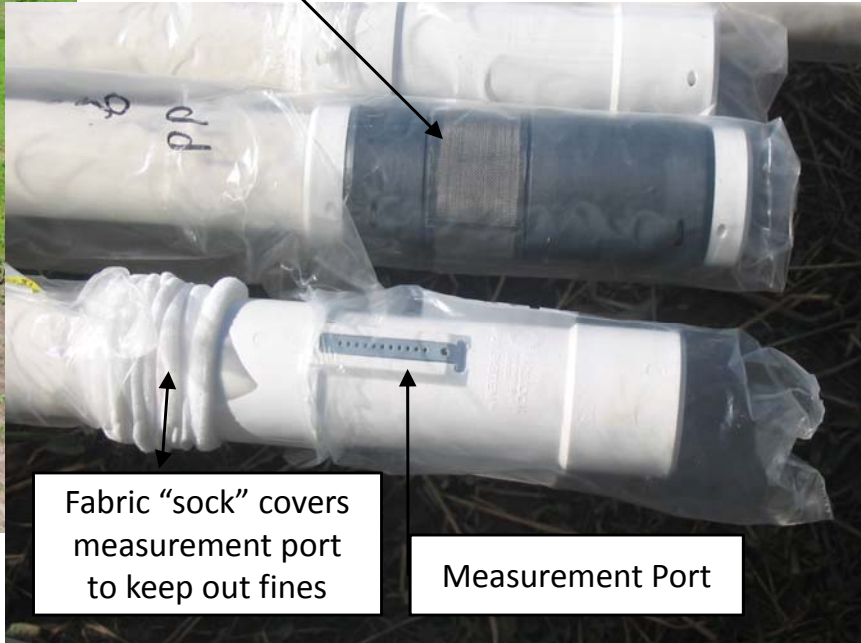
Pumping port

- For hydraulic conductivity testing and purging

Westbay Components



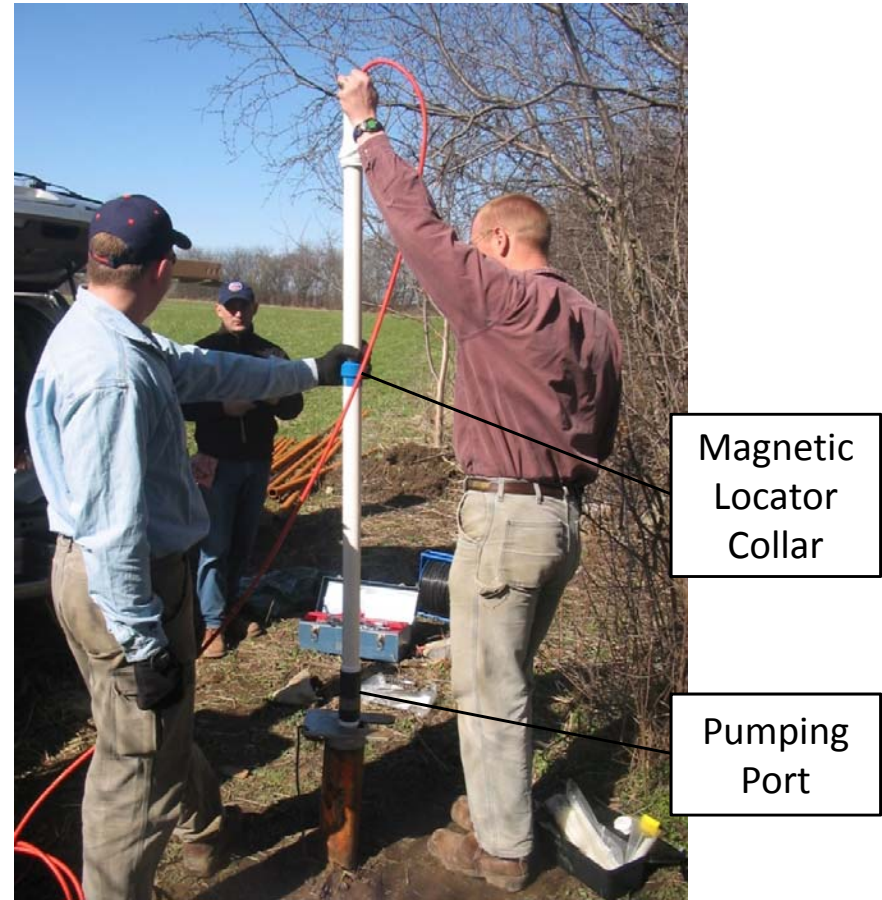
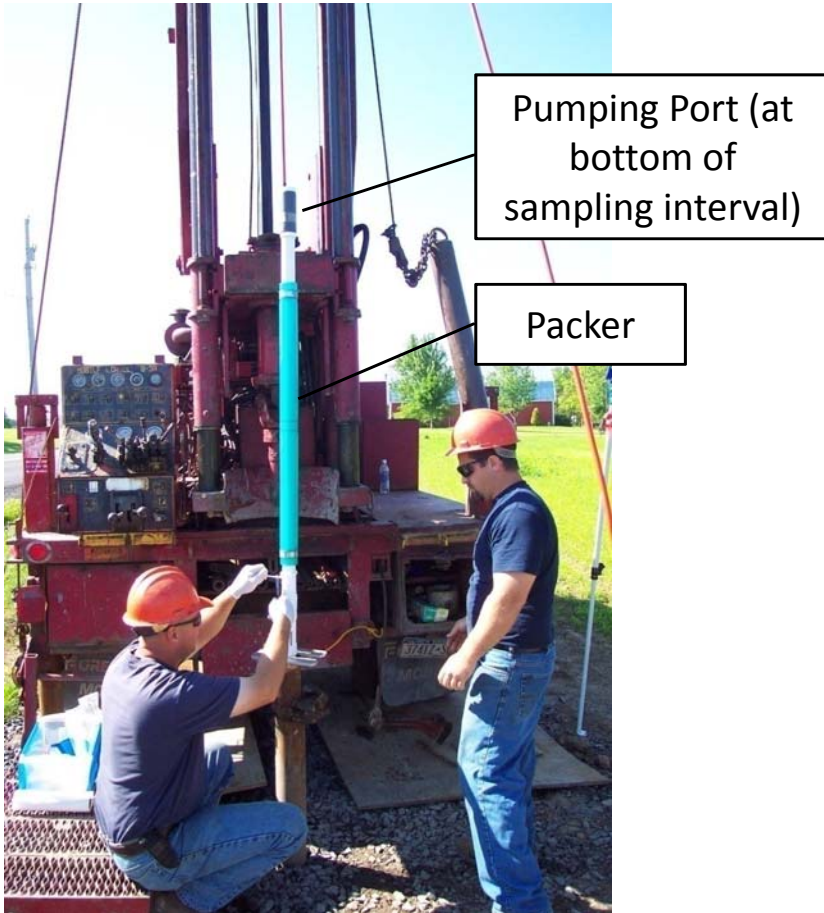
Pumping Port (can be opened to allow water from the zone to enter the Westbay pipe)



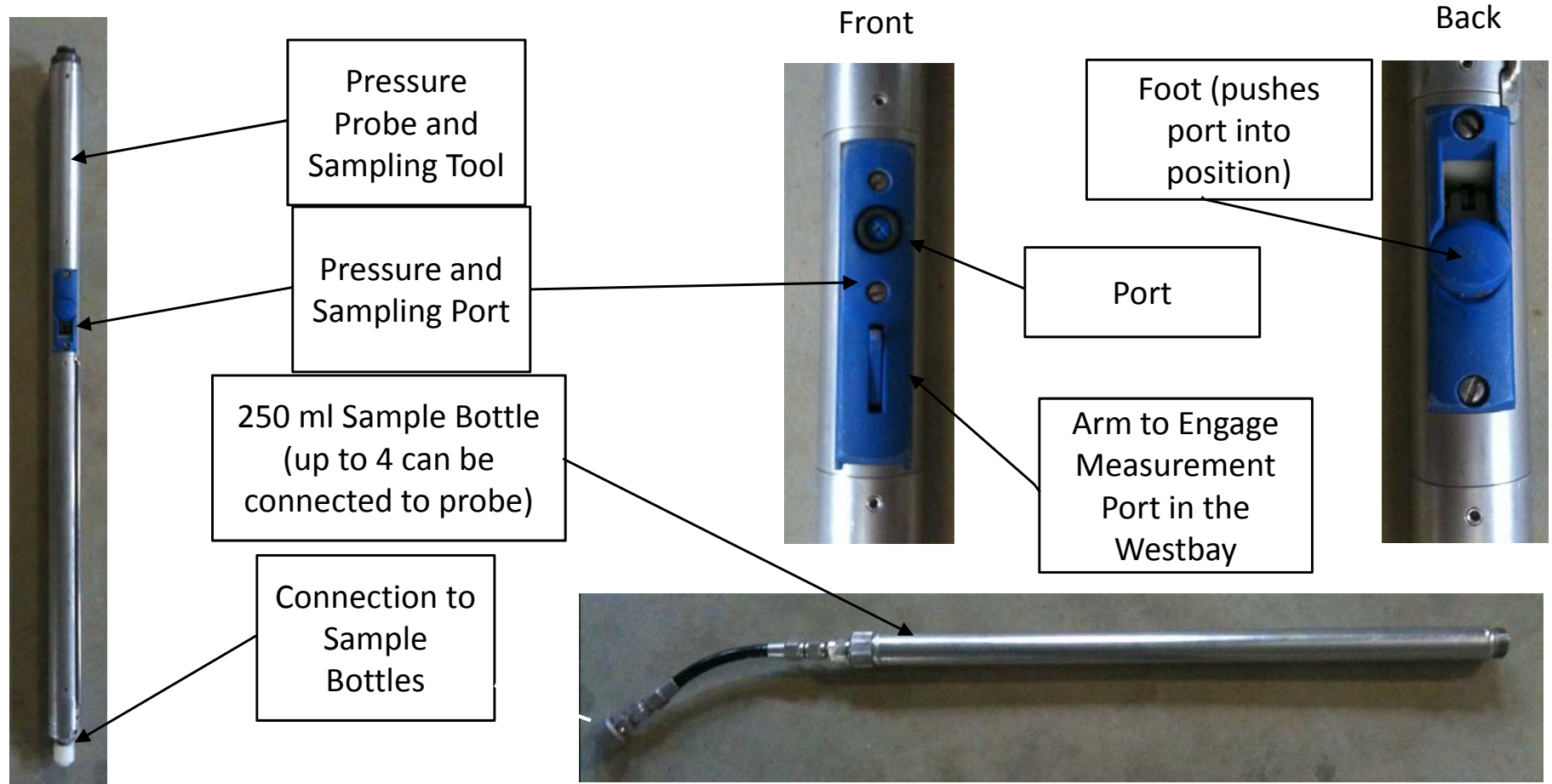
Fabric "sock" covers measurement port to keep out fines

Measurement Port

Packer Installation and Pressure Testing



Westbay Pressure Probe and Sampler



Westbay Sampling

PVC
Vacuum
Connector

Pressure
Probe and
Sampling Tool

250 ml Sample Bottle
(up to 4 can be
connected to probe)



Counter



Westbay System Key Takeaways

- Packers used to seal between intervals
- Not removable (has to be drilled out)
- Transducer and sampler are on a wire line, not downhole
- Installation process done by Westbay
- No purge sampling
- Grab sample
 - Maximum volume per trip is 1 liter
 - Difficult to obtain good DO readings
- Can be converted into a monitoring well open to one or more zones
- PFOA/PFOS-free equipment available since March 2017



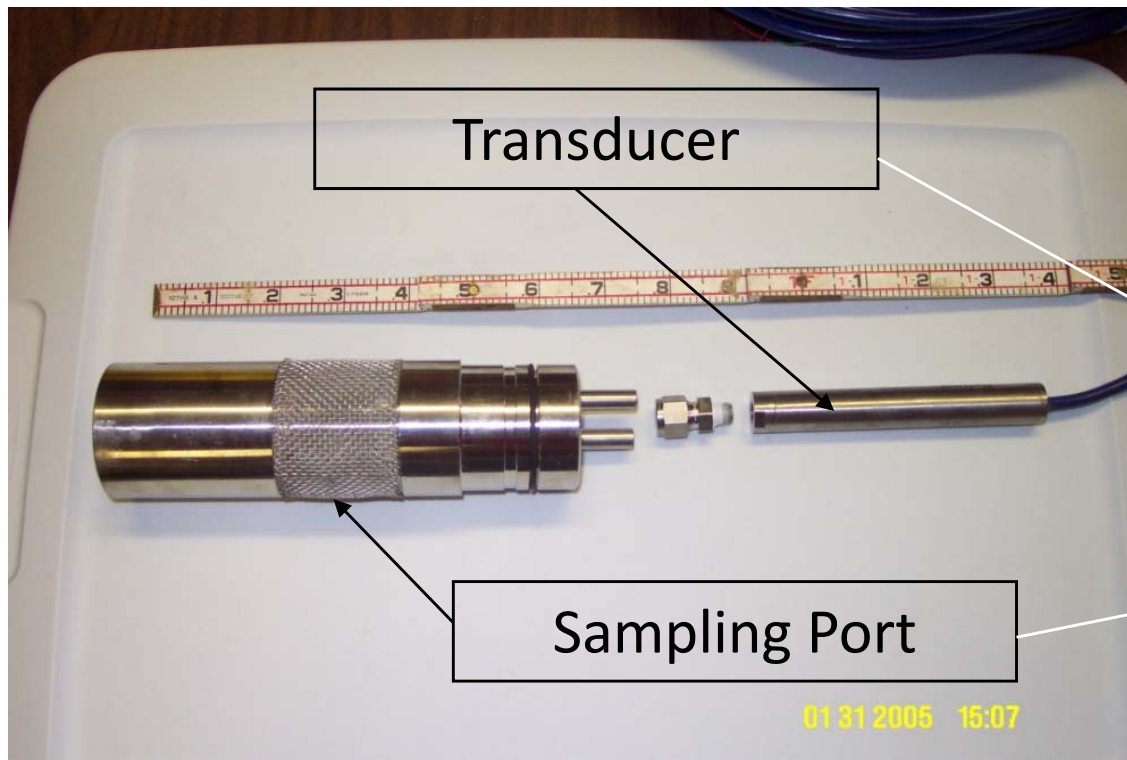
Construction: Waterloo System

Waterloo System Layout and Installation



Pump, Transducer, and Port Installation

Bladder Pump



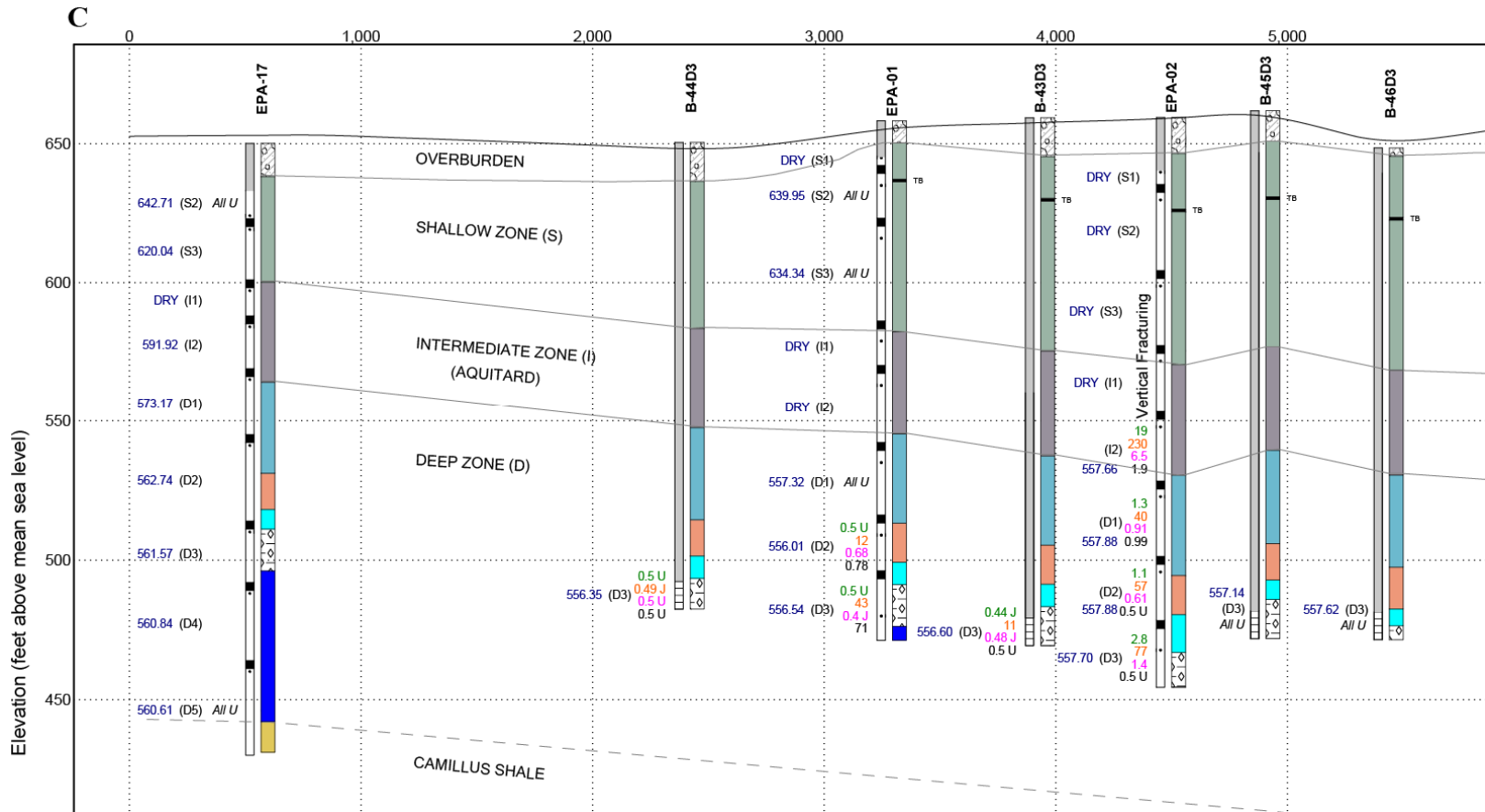
Waterloo Sampling



Waterloo System Key Takeaways

- Packers used to seal between intervals
- Not removable (has to be drilled out)
- Pumps and transducers downhole
- Installation process done by Waterloo
- Vibrating wire transducers do not use batteries
 - Can use a data logger installed at the well
- Can be installed by hand if the depth to water is less than 100 ft
- Long layout area preferred but not required
- PFOA/PFOS: Alternatives to LDPE and Teflon to work around issue

Example of Multilevel Data



Multilevel System Takeaways

- Multilevel systems complement standard monitoring wells
- Provide detailed vertical profile of water level and water quality
- Selection
 - Liner or packer?
 - Sample volume, flow through cell vs. grab (1 l/trip)
 - Sample interval (what is and is not sampled)
 - Water level monitoring needs
- Design
 - Right location?
 - Characterization data from borehole
 - Commercial systems require significant lead time to design and procure
 - Prevent vertical contaminant migration (line borehole)
- Construction
 - Commercial systems are installed by the vendor
 - Nested wells can be installed by the drilling contractor

Acknowledgments

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- Jim Romig, CDM Smith

Questions and Answers

