



# Selection, Design, and Construction of a Multilevel Groundwater Monitoring System



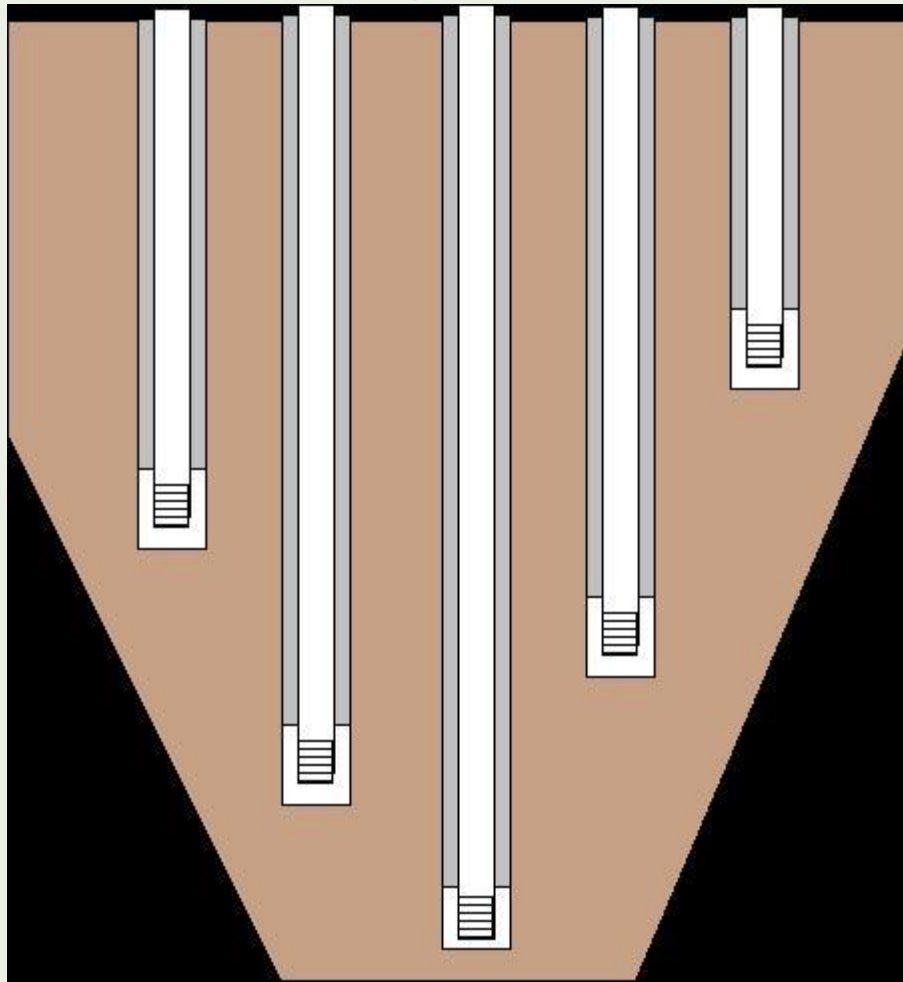
**EPA**

United States  
Environmental Protection  
Agency

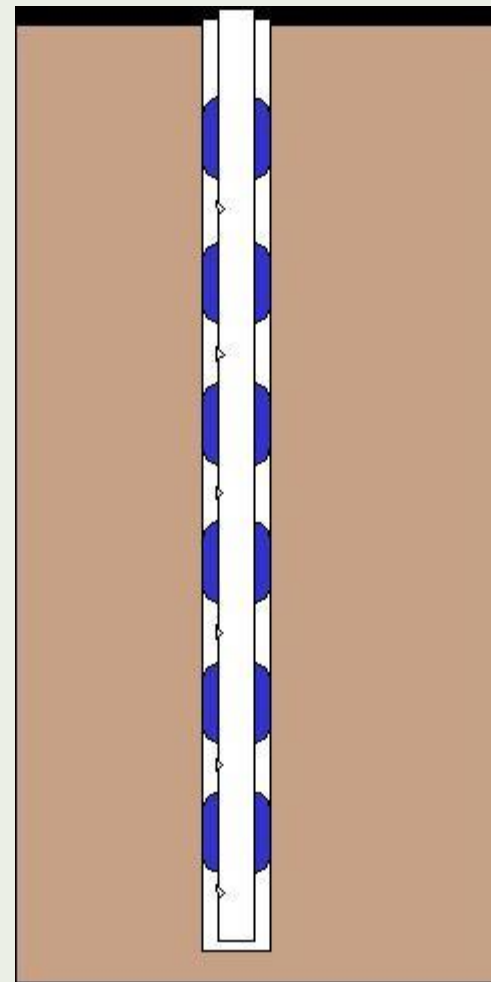
Thanks to:  
John Dougherty, CDM Smith

# What is a Multilevel Groundwater Monitoring System?

Monitoring Well Cluster



Multilevel Well



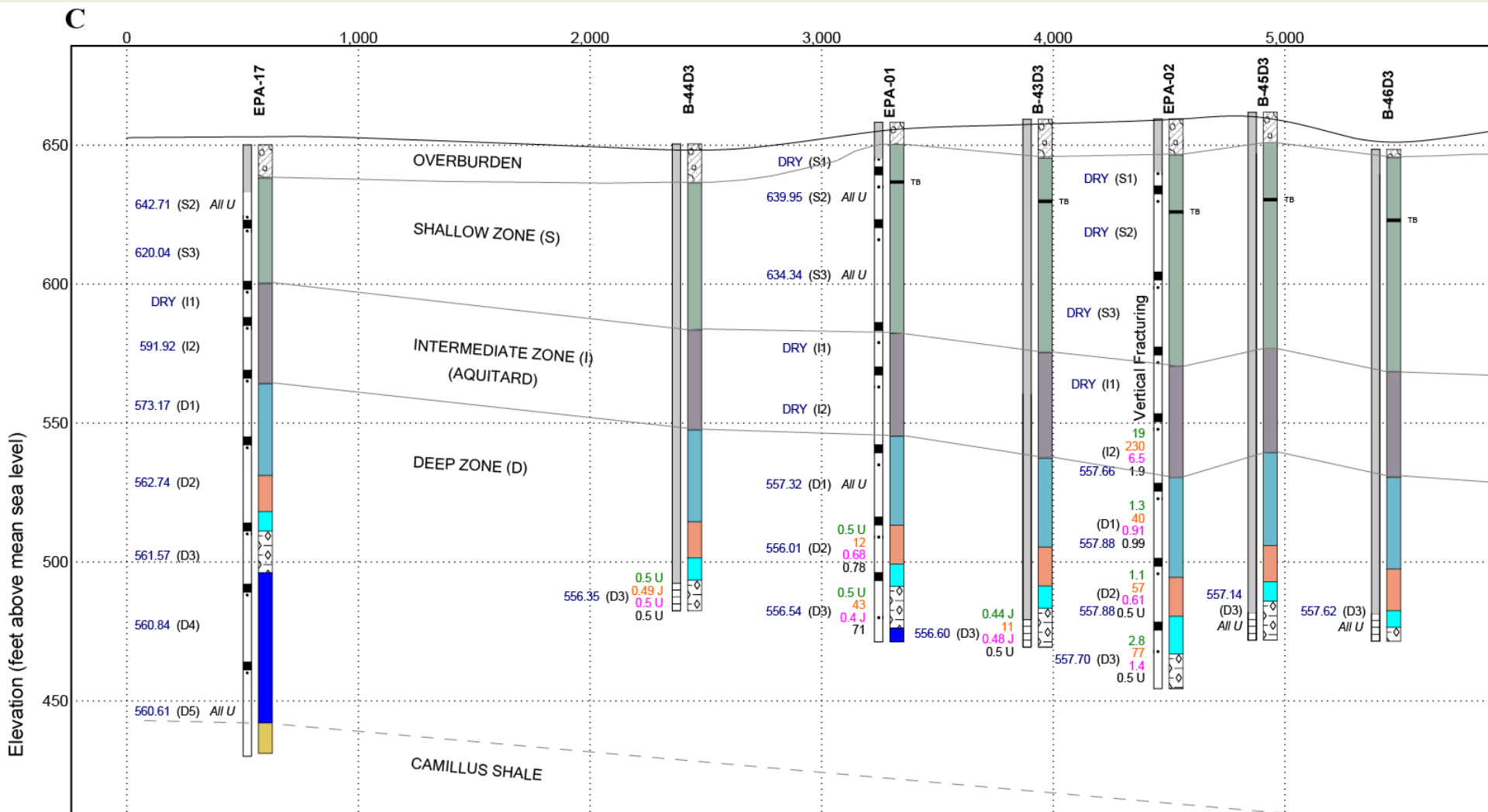
# Multilevel Systems

- **Major systems are on the market**
  - Model 401 Waterloo Multilevel System (Solinst)
  - Westbay (Schlumberger)
  - Water FLUTE™ (Flexible Liner Underground Technologies, Ltd. Co)
  - Solinst Continuous Multichannel Technology (CMT) system
  - All are good quality and widely used
- **Other systems not covered in this presentation**
  - BESST Barcad and ZIST

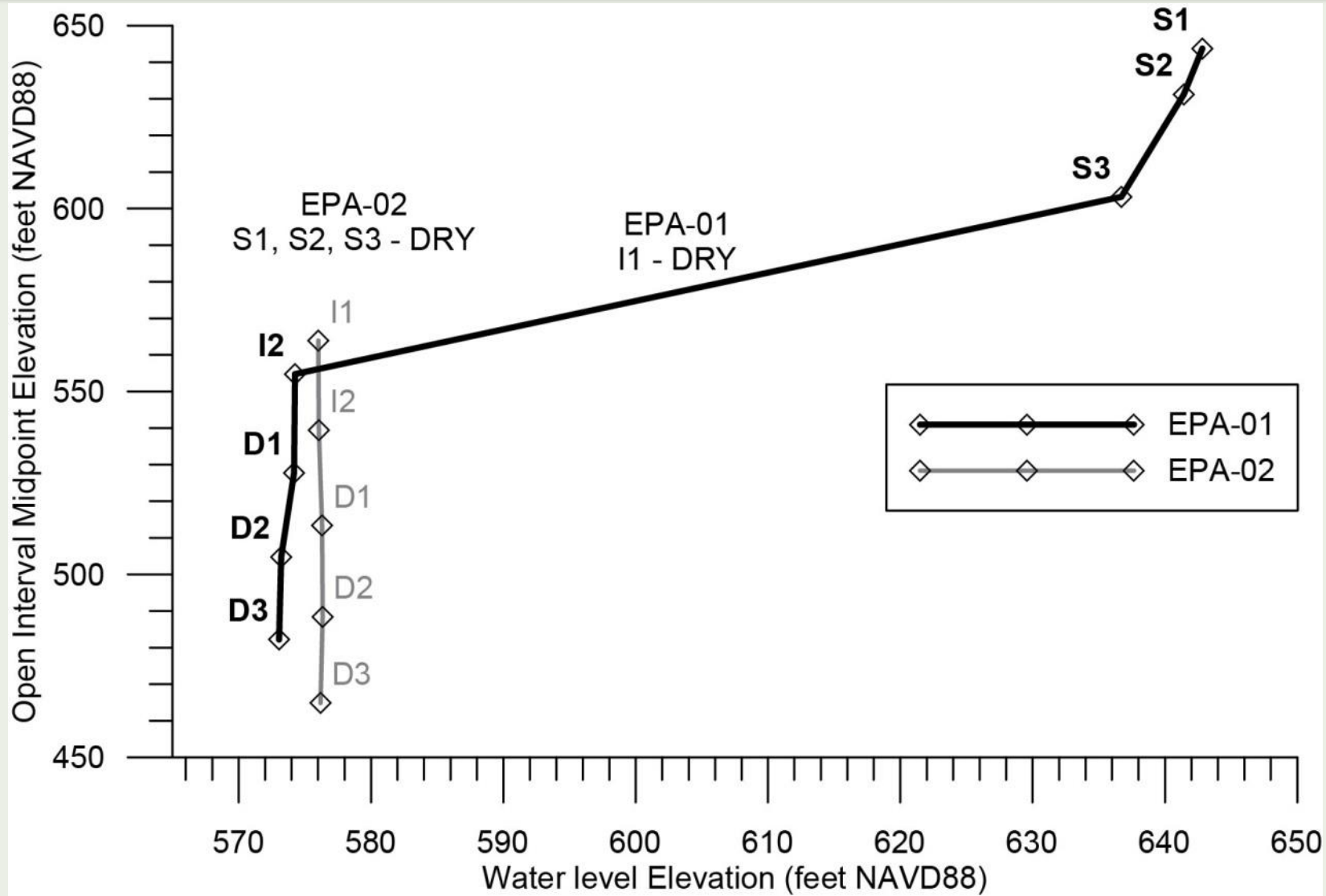
# Why Use a Multilevel System?

- **The decision to use a multilevel system is driven by the site conceptual model that includes elements, such as:**
  - Project objectives
    - Need to characterize complex site conditions
  - Hydrogeology
    - Depth to water
    - Aquifer Thickness
  - Stratigraphy
  - Vertical and lateral extent of groundwater contamination

# Site Characterization Using Multilevel Well Data



# Comparison of Vertical Head at Wells EPA-1 and EPA-2



# Selection of a Multilevel Groundwater Monitoring System



**EPA**

United States  
Environmental Protection  
Agency

# Selection Considerations

- ◆ Sustainability
- ◆ Equipment downhole
- ◆ Surface support equipment
- ◆ Water level monitoring
- ◆ Groundwater sampling
- ◆ Post installation problems
- ◆ Operations and maintenance
- ◆ Decommissioning
- ◆ Driller support (subcontractor)
- ◆ Layout area
- ◆ Construction procedure
- ◆ Installation issues
- ◆ Surface completion
- ◆ Development



# Advantages of a Multilevel System

- ◆ **Depth discreet water quality and water level elevation data**
- ◆ **Reduced footprint/increased sustainability**
  - » Install one well with many ports versus multiple borings and wells
- ◆ **Reduced drilling costs/increased sustainability**
  - » One borehole
  - » Reduced investigation derived waste (IDW)
  - » Deal with difficult drilling conditions one time
- ◆ **Reduced sampling costs relative to the same number of conventional wells**

# Disadvantages and Assumptions of a Multilevel System

## ◆ Disadvantages

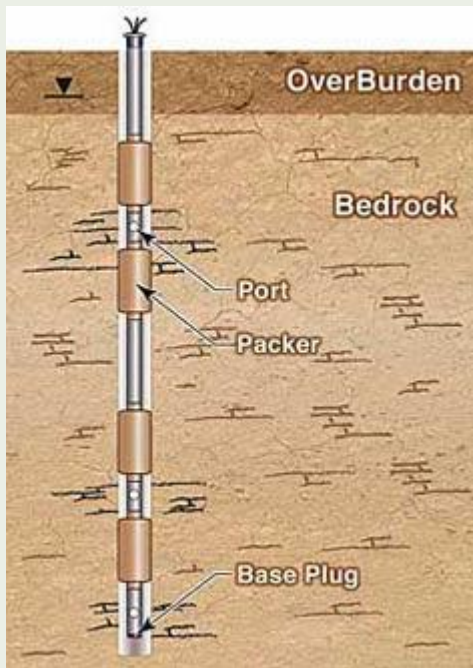
- » Requires specialized support equipment and training
  - › Waterloo and FLUTe™: gas drive pump/bladder pump
  - › Westbay: wire line tool
- » Limited use as observation wells during aquifer testing

## ◆ Assumptions

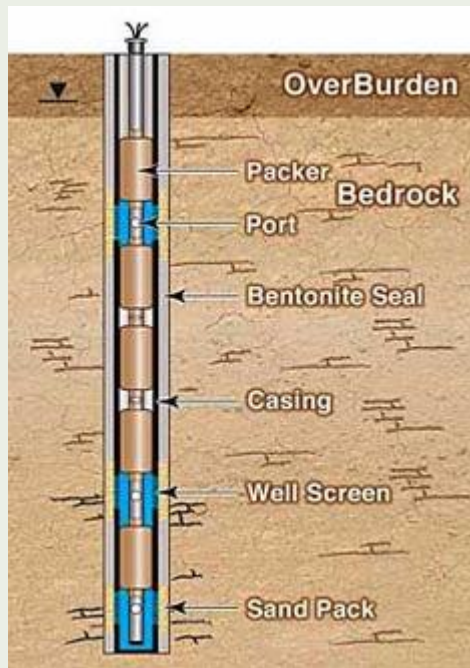
- » All systems assume that ambient groundwater flow maintains representative groundwater at the sampling port
- » Stakeholders must agree

# Waterloo System

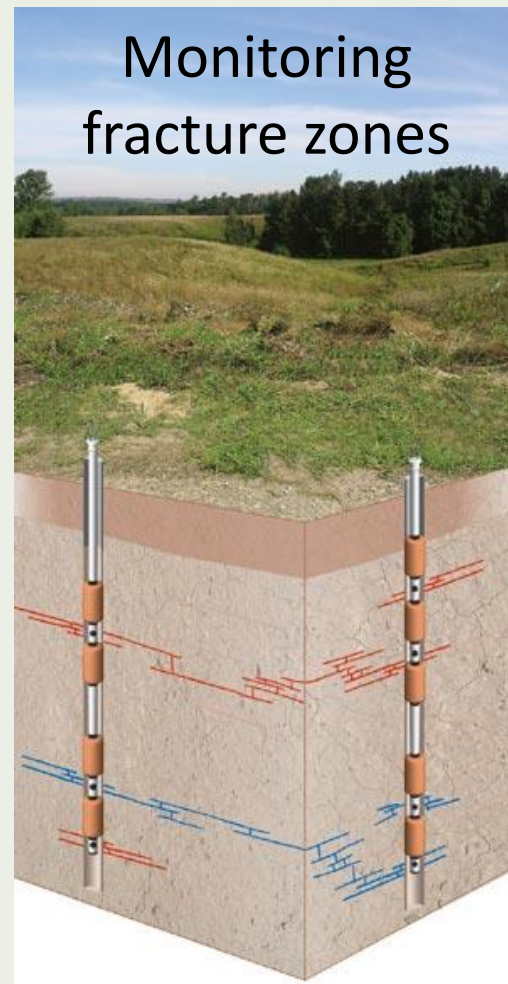
Installation in an open borehole



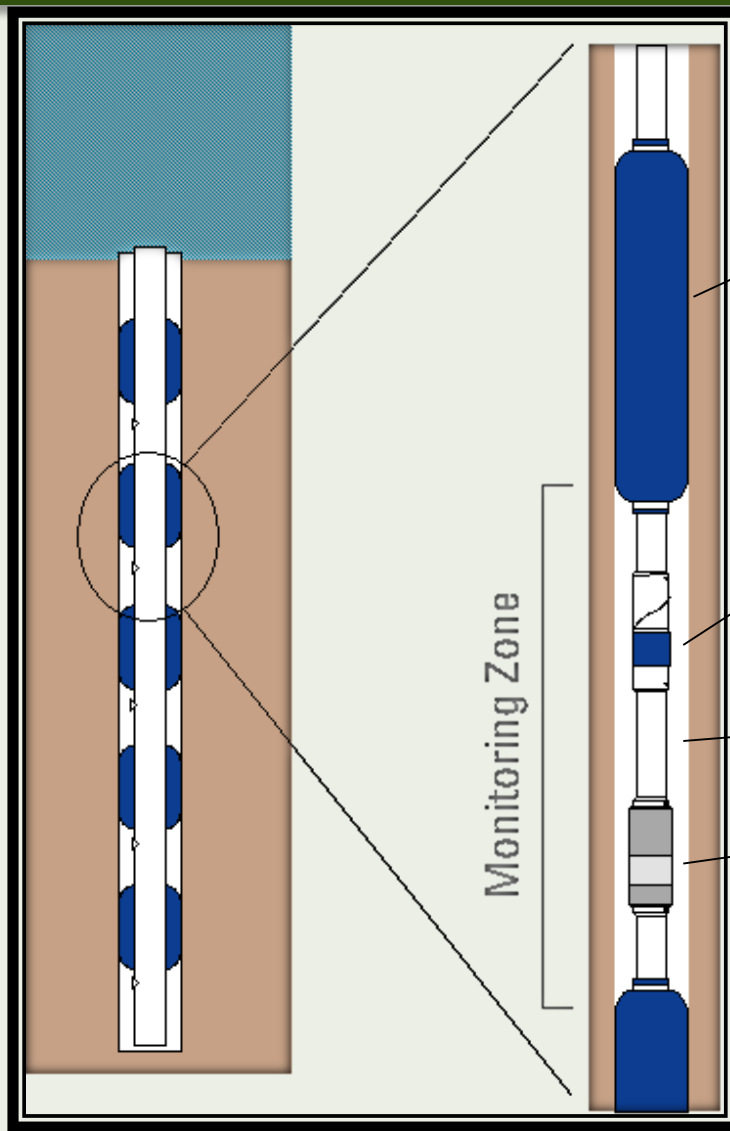
Installation in a well



Monitoring fracture zones



# Westbay System



Packer

-reliable seal for a range of borehole sizes

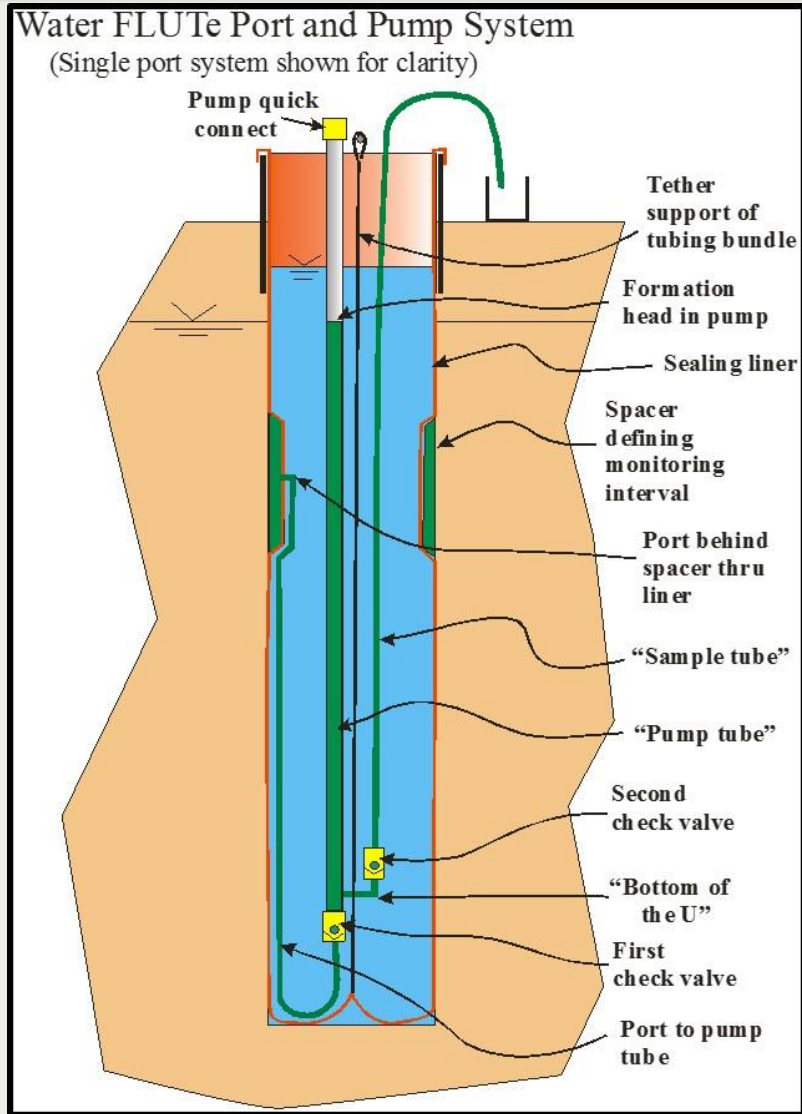
Measurement port

-for fluid sampling and in-situ measurement

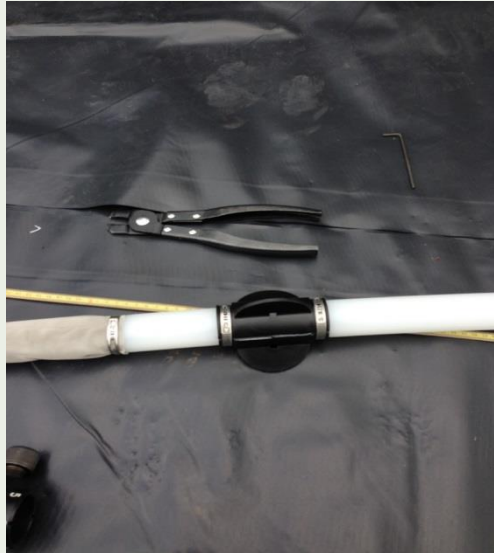
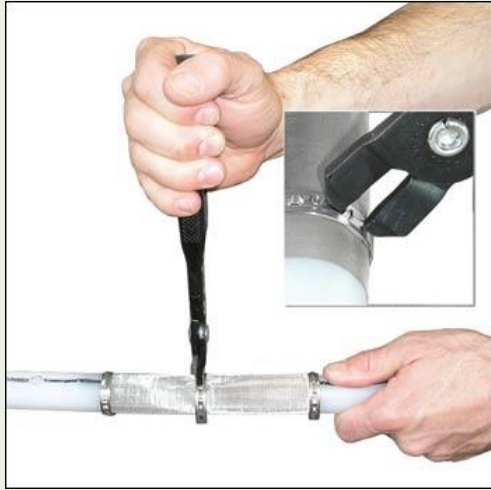
Casing: variable lengths

Pumping port

-hydraulic conductivity testing and purging



# CMT



# Design of a Multilevel Groundwater Monitoring System



**EPA**

United States  
Environmental Protection  
Agency

# Design Considerations

## ◆ **A good multilevel system design is based on:**

- » Good site conceptual model
- » Clear objectives
- » Vertical and lateral hydrostratigraphic data
- » Groundwater quality data

## ◆ **Overburden:**

- » Lithologic and groundwater sampling during borehole drilling using direct push, sonic drilling, or hollow stem auger

## ◆ **Bedrock:**

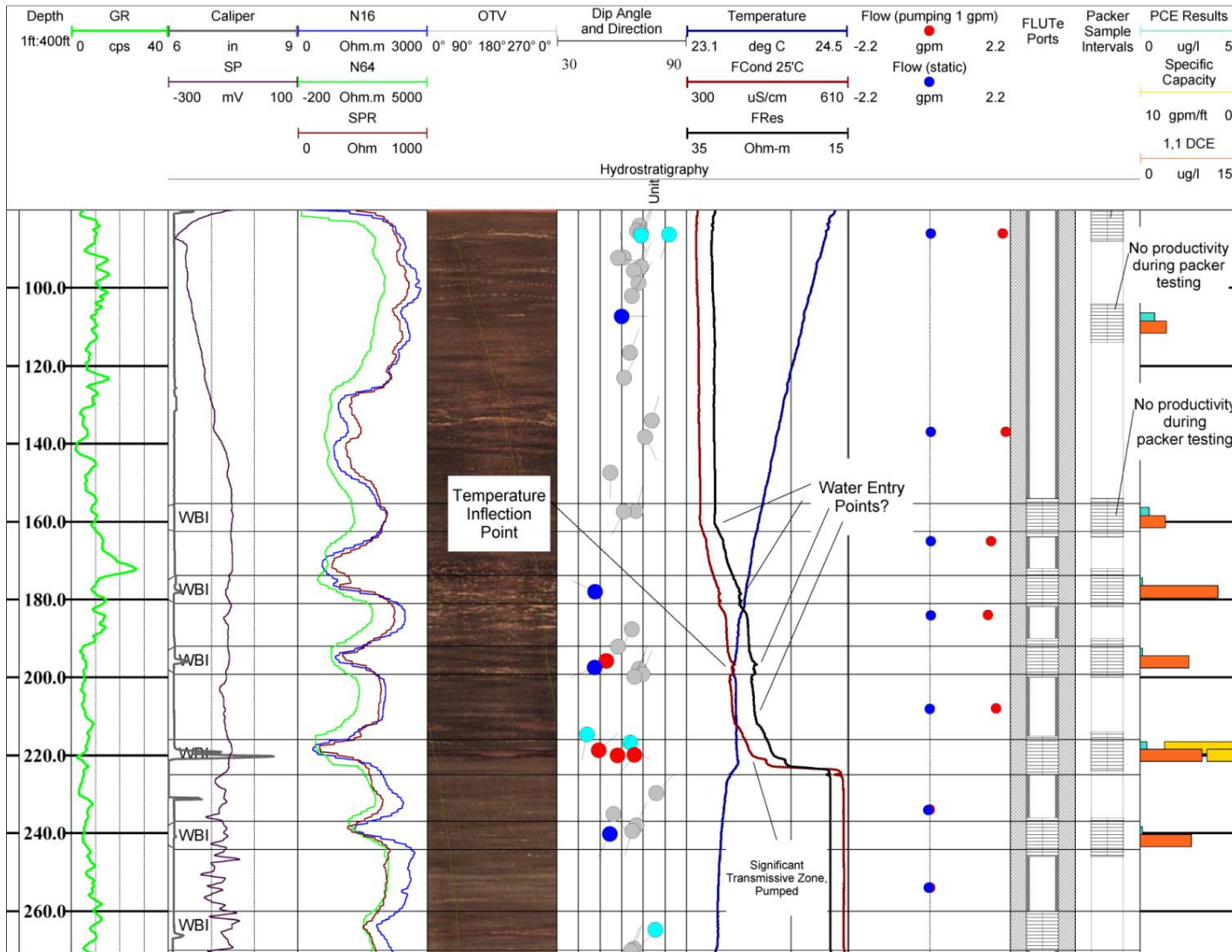
- » Rock core, air rotary, casing advance
- » Borehole geophysical logging
- » Packer testing or fluid sampler



# Design Considerations

- ◆ Optimum borehole or well diameter
- ◆ Installation in open borehole or well in bedrock
- ◆ Installation in unconsolidated formation
  - » Direct burial
  - » Completion inside well
- ◆ Number of ports
- ◆ Port interval length
- ◆ Maximum depth of installation
- ◆ Packer system

# Design Using Packer Testing and Borehole Geophysics



# Construction: Waterloo System



**EPA**

United States  
Environmental Protection  
Agency

# Waterloo System Advantages

- ◆ Gas drive sampling (double valve or bladder pump)
- ◆ Practical to obtain large sample volumes (important at Superfund sites)
- ◆ Can run a “low-flow” type method and collect water quality parameters
- ◆ Minimizes IDW
- ◆ Proven technology

# Waterloo System Disadvantages

- ◆ **Relatively complicated installation process**
- ◆ **Requires significant work area**
  - » Equipment must be laid out on ground
- ◆ **Transducers and pumps are downhole**
  - » Cannot be recovered in the event they fail (unless removable packers are used)
- ◆ **Water level readings: can take instantaneous readings but can't use a data logger.**
- ◆ **Can't do slug tests**
- ◆ **Tubing vulnerable to kinks during installation**
  - » Kinks only discovered during final testing before packer inflation

# Waterloo System Layout



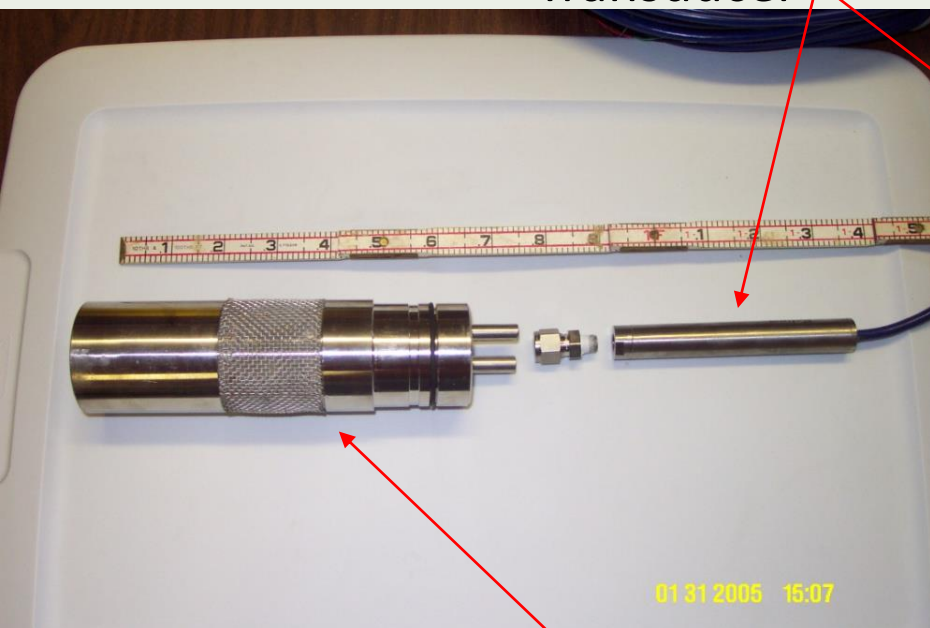
# Waterloo Components Going Downhole



# Pump, Transducer and Port Installation

Bladder Pump

Transducer



Sampling Port





# Waterloo Sampling



# Construction: Westbay System



**EPA**

United States  
Environmental Protection  
Agency

# Westbay System Advantages

- ◆ Relatively simple installation
- ◆ Requires relatively small work space
- ◆ Transducer and sampler are on a wire line
- ◆ Joints are pressure tested during installation
- ◆ Packers are inflated with water to a specific pressure
- ◆ Transducers can be installed in each port to monitor water levels
- ◆ Can be converted into a monitoring well open to one zone for long term water level monitoring using transducers and slug testing
- ◆ Minimizes IDW
- ◆ Long term maintenance requirements are low
- ◆ Proven technology

# Westbay System Disadvantages

- ◆ Requires specialized sampling equipment (subcontractor)
- ◆ Instrumentation for pumping test very complicated/expensive
- ◆ Interval cannot be purged before sampling
- ◆ Maximum volume per trip is 1 liter
- ◆ Not always possible to obtain reliable water quality data especially dissolved oxygen (DO)
- ◆ Technology is static

# Westbay Equipment Layout



# Westbay Pumping (gray) and Measurement Port



# Packer Installation and Pressure Testing



# Westbay Sampling Equipment





# Construction: FLUTe System



**EPA**

United States  
Environmental Protection  
Agency

# FLUTe™ System Advantages

- ◆ Liner seals entire borehole wall
- ◆ Relatively simple installation process
- ◆ Relatively small work area
- ◆ Gas drive sampling
- ◆ Practical to obtain large sample volumes
- ◆ Can run a “low-flow” type method and collect water quality parameters
- ◆ Minimizes IDW
- ◆ Innovative company
- ◆ Proven technology

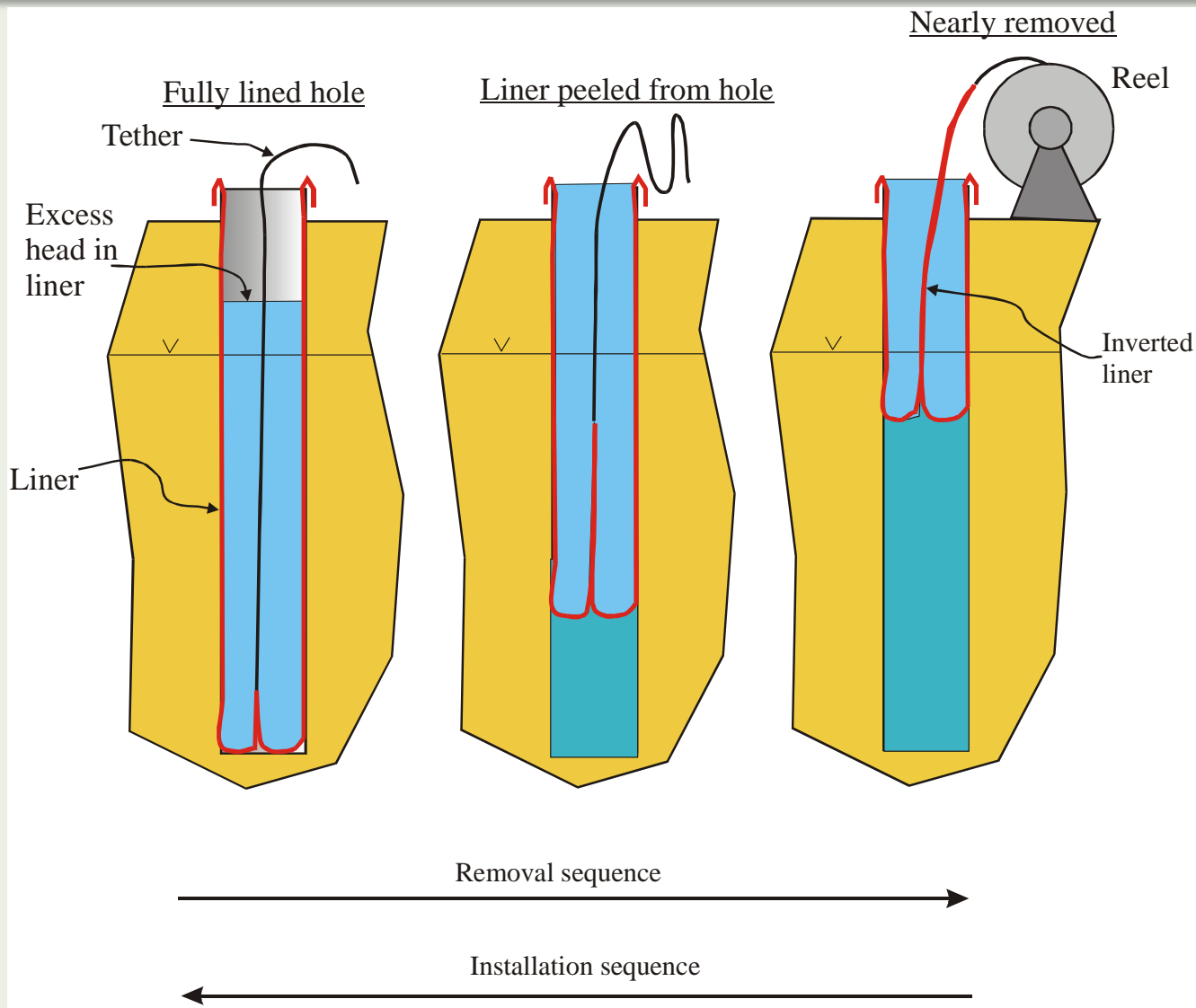
# FLUTe™ System Disadvantages

- ◆ Pumps are downhole
  - » Transducers can be installed downhole or at the surface
- ◆ Fabric liner can tear on sharp bedrock borehole wall
- ◆ Water must be purged from gas lines to obtain current water level readings
- ◆ The water level inside the liner must be checked and maintained above the static head in the formation
- ◆ Can't conduct slug tests
- ◆ Transducers can be used for long term water level monitoring but implementation is complex

# Water FLUTe™ and Blank Liner



# FLUTe™ Installation



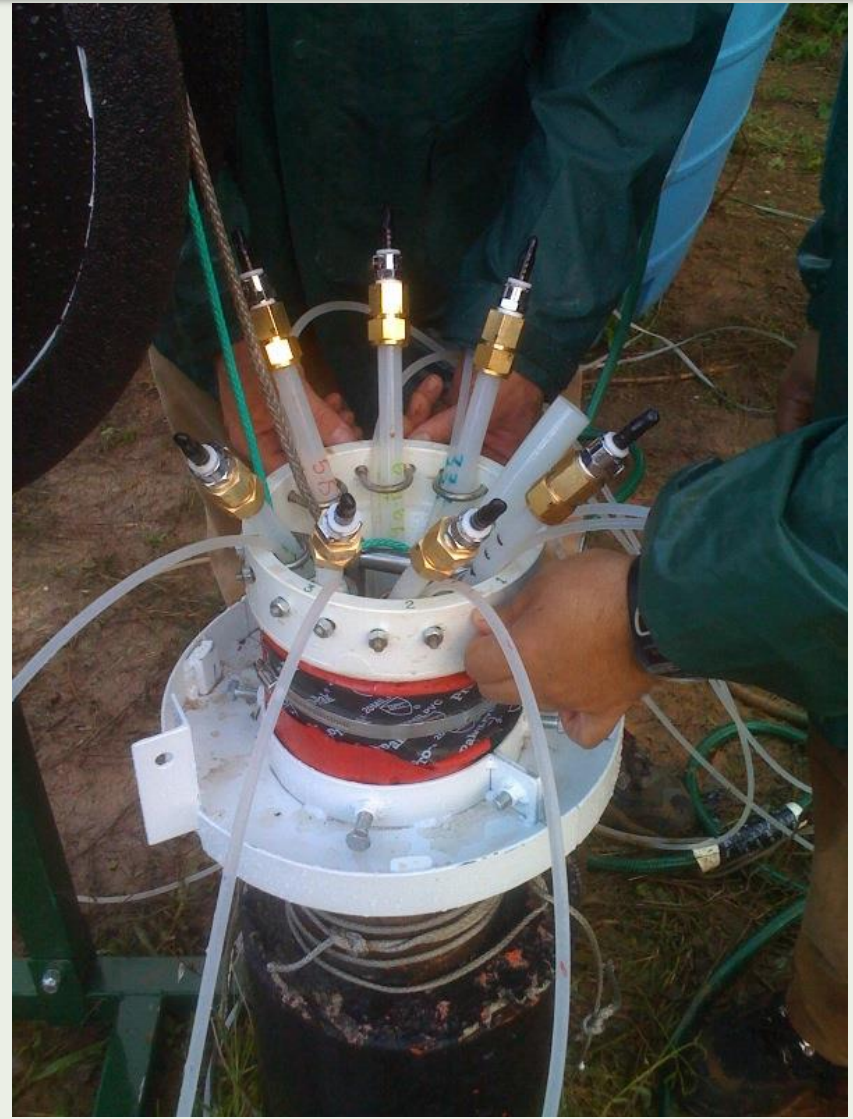
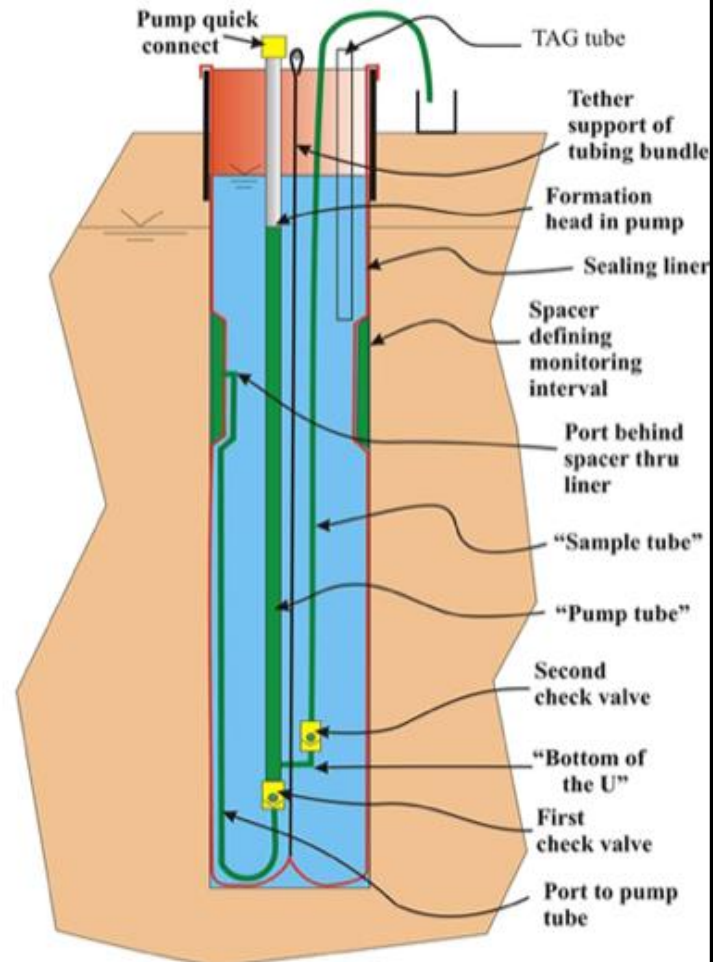
# FLUTe™ Installation



# Water FLUTE™ Sampling Procedure

## Water FLUTE pump system

(Single port system shown for clarity)



# Construction: CMT Continuous Multi-Channel System



**EPA**

United States  
Environmental Protection  
Agency



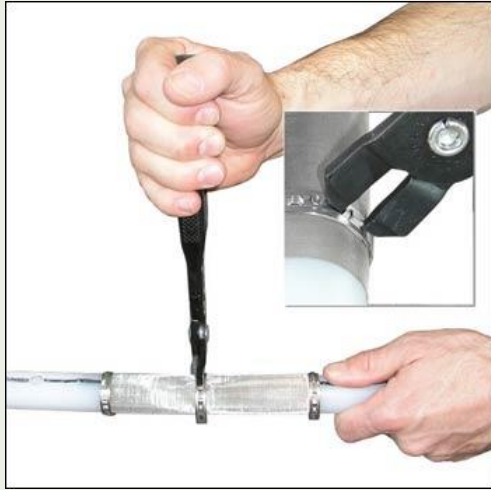
# CMT Advantages

- ◆ Inexpensive – one piece construction
- ◆ Standard screen/seal well construction
- ◆ No packers needed
- ◆ Can be installed in rough/collapsing boreholes
- ◆ Up to 7 ports per boring
- ◆ Very flexible port/screen length
- ◆ Samples collected by peristaltic or inertial pumps

# CMT Disadvantages

- ◆ One piece construction – challenging for deep installations
- ◆ Very small port size
- ◆ Difficult to develop/potential for clogging
- ◆ Very small channel size
- ◆ Limited ability to instrument
- ◆ Requires inertial pump if water table is deep
- ◆ Can be difficult to obtain large volume samples

# CMT Construction



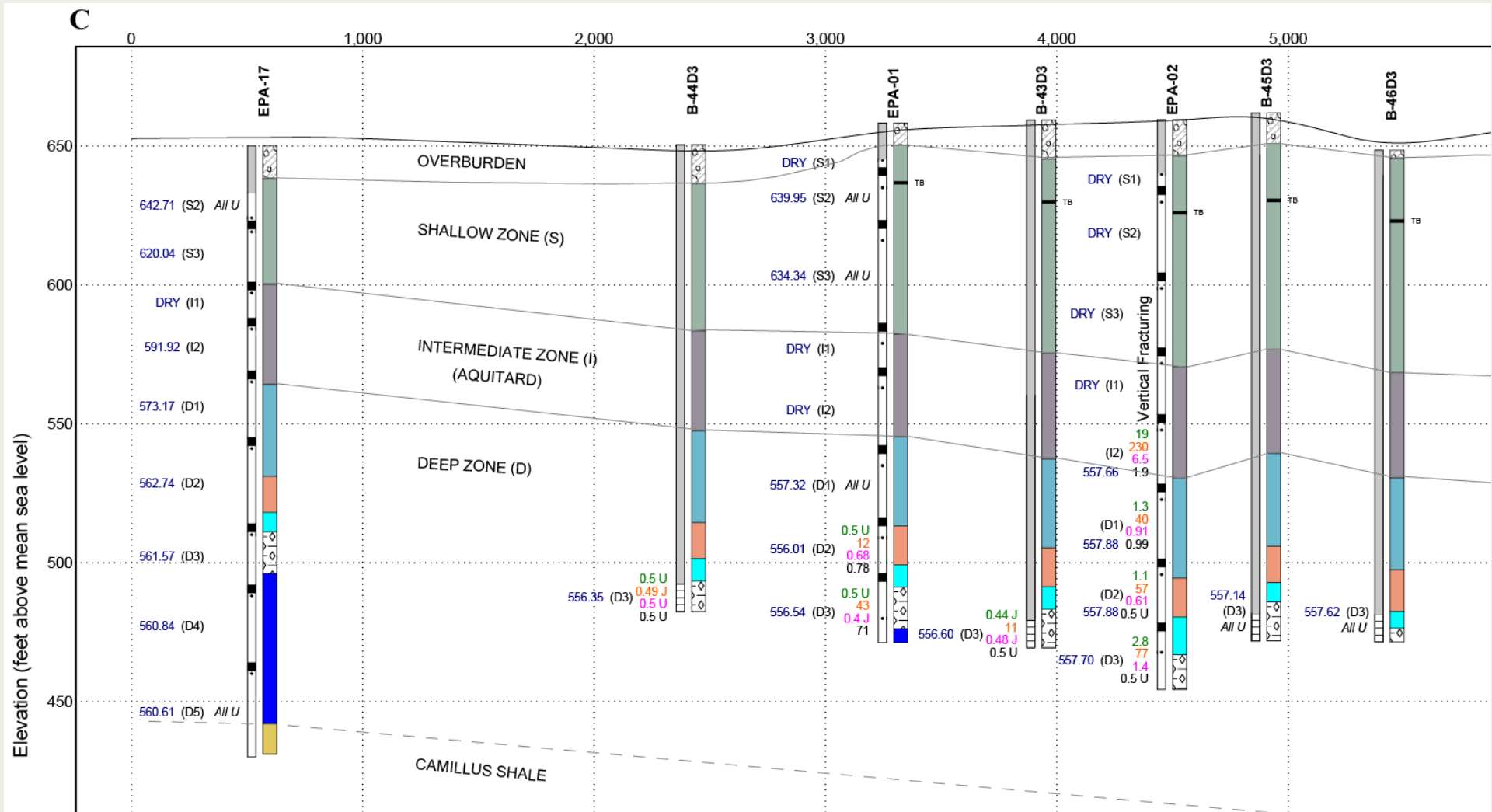
# Site Characterization Using Multilevel Well Data



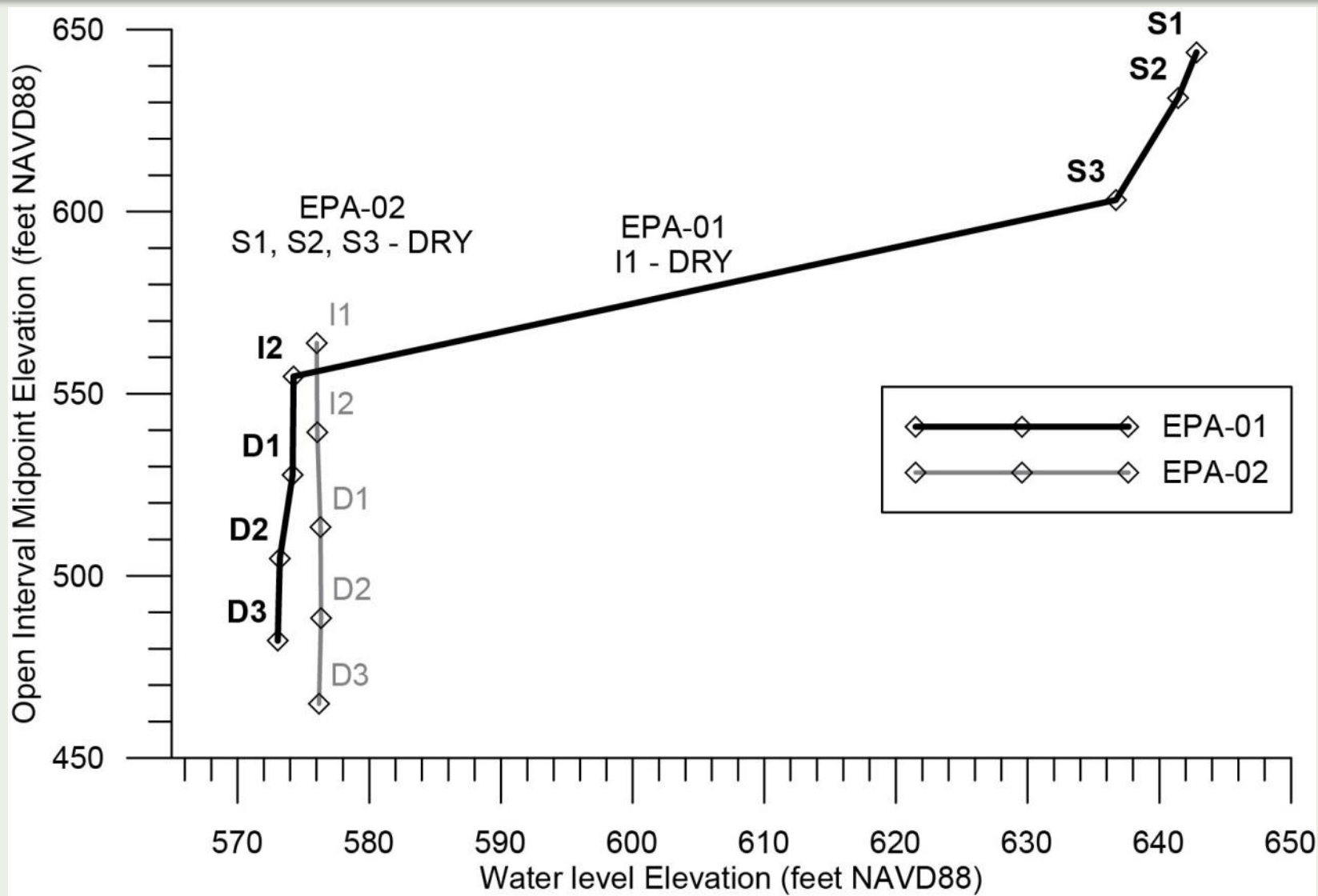
**EPA**

United States  
Environmental Protection  
Agency

# Site Characterization Using Multilevel Well Data



# Comparison of Vertical Head at Wells EPA-1 and EPA-2



# Takeaways

- ◆ Select a multilevel groundwater sampling system based on:
  - » Project objectives
  - » Hydrogeologic conceptual model
  - » Site conditions
- ◆ Design of a multilevel system requires significant hydrogeologic and groundwater quality data collection and analysis
- ◆ Construction of multilevel systems is a team effort requiring input from the site manager, vendor, consultant, and drilling subcontractor
- ◆ When properly selected, designed, and constructed multilevel systems provide a cost effective alternative to conventional monitoring wells.

# Questions?





# Disclaimer

- ◆ Information presented in this presentation represents the views of the author(s)/presenter(s) and has not received formal U.S. EPA peer review.
- ◆ This information does not necessarily reflect the views of U.S. EPA, and no official endorsement should be inferred.
- ◆ The information is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States or any other party.
- ◆ Use or mention of trade names does not constitute an endorsement or recommendation for use.