Evolution of FLUTe Multi-level System

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Original presentation:

- Why a multi level system?
- Potential pitfalls of multi level systems
- Features that should be considered in the selection process

However, I was told that was boring to this audience and, in its final form, it was.

Speaking in broad generalities is difficult. Especially for a vendor of one of the options.

The commercially available multi level systems:

- Westbay
- Solinst Waterloo system
- Water FLUTe
- CMT system

In order of age.

I am not going compare these systems. The project objectives and the geologic/hydrologic circumstances are important to the selection of a system.

Assumptions for this presentation:

- You all know the advantages of multi level systems and the potential difficulties.
- You don't know everything about each of the systems available.
- You are scientists and interested in the science that has led to the current features of at least one system, a Water FLUTe.
- You are probably not familiar with the current state of that design and how it has evolved.

This presentation treats:

- The current Water FLUTe design
- The early designs and how those have evolved.
- The problems solved by the evolution of the design.
- What you should know about the Water FLUTe system in making a comparison with other systems.

The General Features of a Water FLUTe

- Seals the uncased or cased borehole with a continuous liner.
- Defines each sampling interval with an external spacer on the liner
- Contains all of the borehole water inside the liner.
- Draws the ground water from the formation to a pumping system interior to the liner.
- Has a dedicated pumping system for each sampling interval.
- Uses a positive gas displacement system to drive the sample water to the surface .

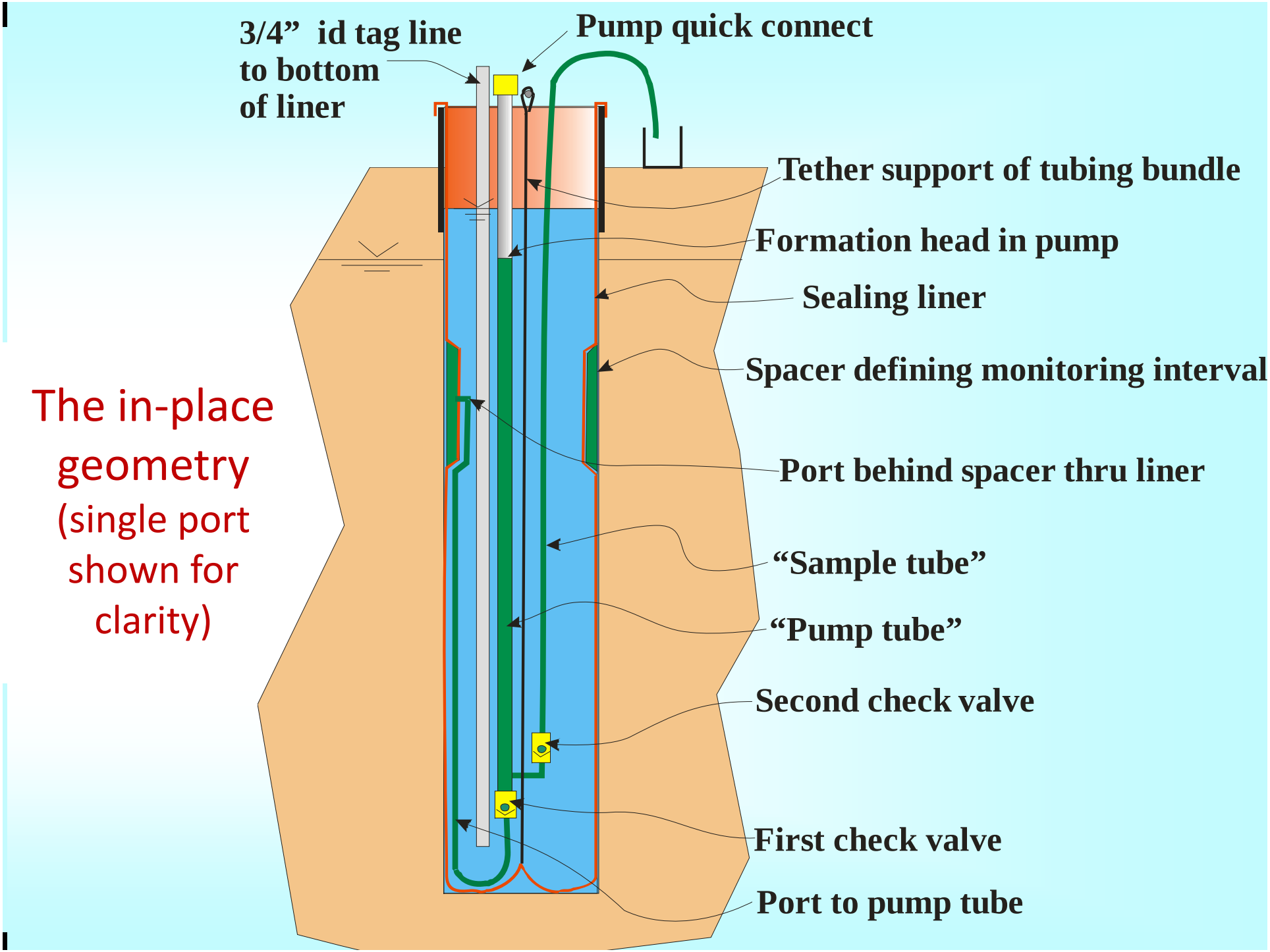
Features (continued)

- The system is everted into place and removable
- Has very long pumps for all ports and they can be entirely purged and sampled simultaneously.
- Can produce a large purge volume if desired.
- Has several methods for water table/head measurements which can used at the same time.

The Water FLUTe Installation

15 Ports
installed
to 328 ft.
in 2 hrs.

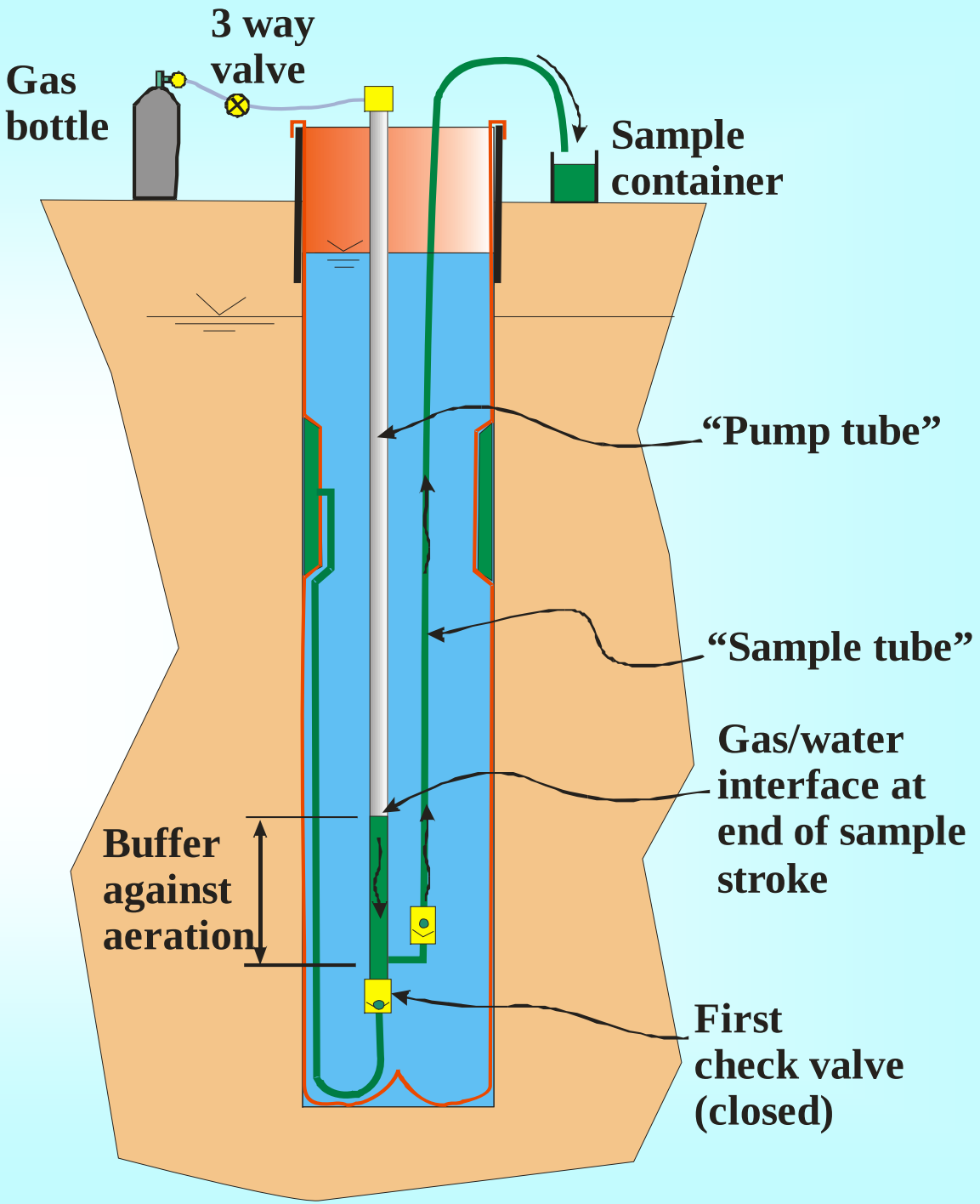
(Cambridge, Ontario)


3/4” id tag line to bottom of liner
Pump quick connect
Tether support of tubing bundle
Formation head in pump
Sealing liner
Spacer defining monitoring interval
Port behind spacer thru liner
“Sample tube”
“Pump tube”
Second check valve
First check valve
Port to pump tube
The in-place geometry (single port shown for clarity)

The pumping procedure

2 purge strokes

1 sample stroke



Purging
15 ports
Simultaneously
in 6” hole.

Evolutionary features

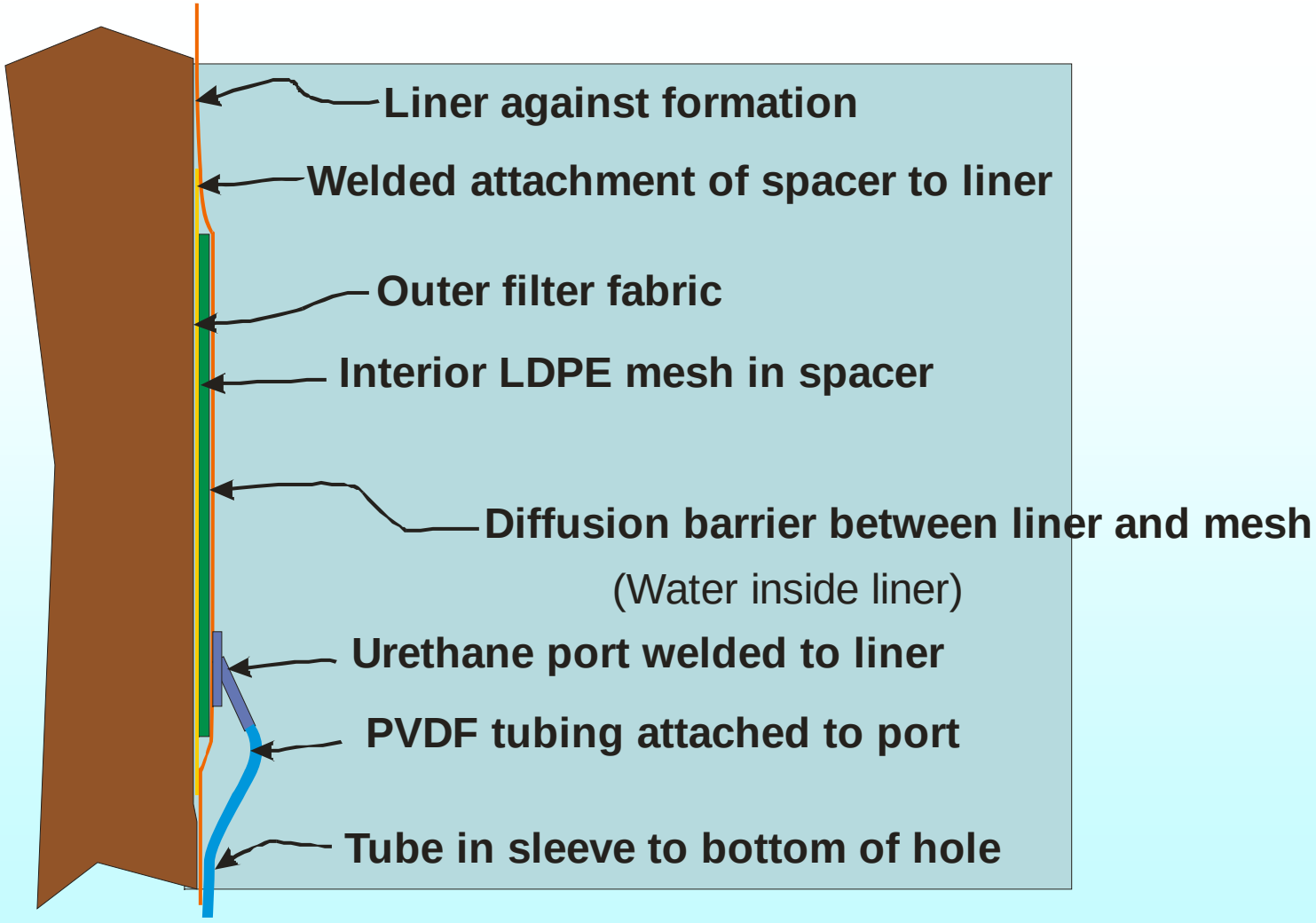
- Spacer design
- Port design
- Tubing material
- Pump design
- Liner material
- Vent valve design
- Tag tube design and use
- Liner fill material

Earlier spacer with brass port and knit polyester and polypropylene mesh

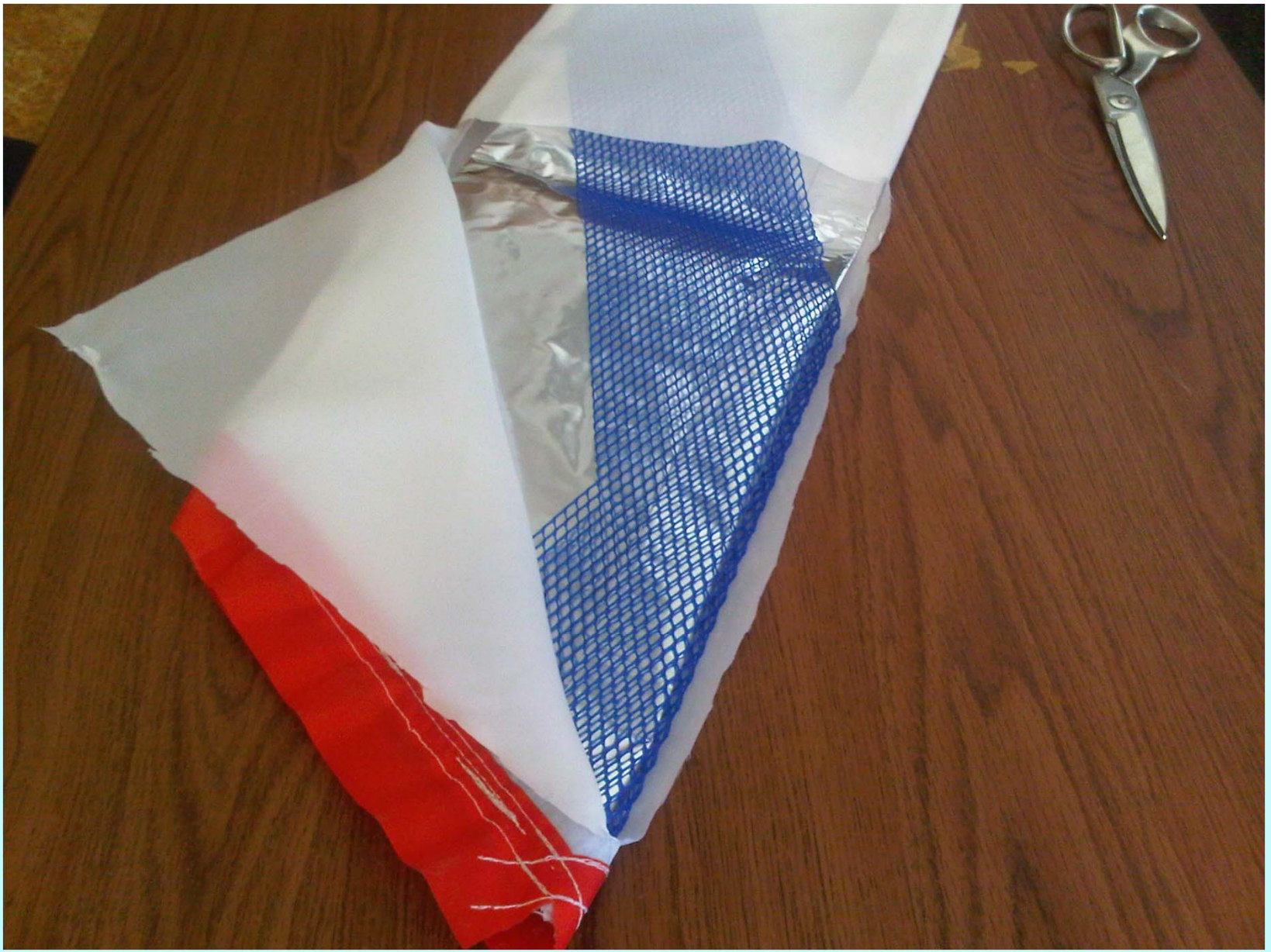
Spacer design changes:

- Changed interior mesh from knit polypro. to LDPE extruded mesh. – to provide better flow in plane of mesh and to avoid washing for knitting oils.
- Diffusion barrier between mesh and liner. –to avoid concern about absorption or leaching from liner.
- Double helix shape of mesh vs. full cylinder. – to allow easier eversion of the spacer for shallow water tables and slender holes.

Current spacer design



Current spacer for slender hole



Port design:

Current design is molded urethane shown welded to the liner. Earlier design was the brass fitting shown lying on liner.

The brass fitting was less flexible, bulky, more likely to snag, and sometimes pulled out of the liner if the tubing was under high tension.

The urethane fitting is very flexible, bonds very strongly to liner and is much more fair.

Tubing material changes:

In 2001, two customers failed to follow the recommended purge procedures. So, they both obtained samples with low TCE and high TOC.

The first customer launched a major technical review of the cause.

The other customer published his results world wide erroneously attributing the cause to interaction with the liner .

The first customer, and several national labs, determined that Nylon tubing harbors microbial growth and is absorptive of VOCs. They also concluded that the prescribed purging avoids the problem.

To avoid any question about tubing effects, FLUTe tubing was changed to PVDF in 2002 with a 15% increase in the cost of the system.

(Louise Parker and Tom Raney have publish an excellent series of reports showing PVDF as far superior to Nylon, which is superior to LDPE, for sample tubing.)

Additional differences of PVDF:

- The nylon samples also showed significant N-butylbenzenesulfoneamide, a plasticizer in nylon. PVDF has no such plasticizer.

- PVDF is 70% more dense than Nylon and sinks well in water, but adds to the hanging load upon installation. Special braking systems have been designed to support the additional weight.

Pump changes:

Old pump of stainless tubing, side access for first check valve, smaller valves.

New pump, larger valves, more compact, more flexible, less likely to be clogged by silt.

(transducers shown with both pumps)

Liner changes:

- Earliest liners were of urethane coated nylon oxford cloth 200 denier. Coated on one side. Nice and flexible, but somewhat fragile. All contained the mil. spec. fungicide.
- Next, used a heavier 420 denier single coated fabric for blank liners and double coated for Water FLUTes.
- Next, went to a stronger 400 denier double coated fabric.
- Added 210 denier of nearly same strength, but more flexible for slender holes.
- Now, use the last two fabrics but without any arsenic in the coating.
- For potassium permanganate contact, we use a polyester liner. Permanganate attacks the nylon.

Some of the liner stock

Welding procedures have evolved a great deal.

- First we used hot air hand welding with rollers for spacers and splices.
- Then we went to spring loaded welders with electric heaters.
- Then we went to pneumatic pressure, electric heaters, with automatic temperature monitors.
- Now we have evolved to a higher state with timed welding of a more refined kind.
- Liners have always been seamed into tubular form with RF welding.

We learned the hard way that our vent valves needed to be improved

- Early venting of air from the closed end of the liner was via a long tube to the surface, no valve. It flowed air too slowly and delayed installation by formation of a balloon in the closed end of the liner.
- A short tube with a duck bill valve was much better until lint was caught in the duck bill and we replaced two “leaking liners” before we discovered they were not leaking, the valve was open, and had been reused.
- Now we use two valves of different design in series in the vent tube to avoid a common mode failure. We have had no more problems.

Tag tube use variations:

- The tag tube shown was primarily for measuring the water level in the liner. It extends now to the bottom of the liner for several advantages
  - Mud or grout can be injected to the bottom of the liner as will be discussed hereafter.
  - It can be used as an air lift pump for removal of water from a liner in a slender hole with many ports (i.e., a large tubing bundle)
- The tag tube can be used as a bubbler to measure the water level in the liner.
- Earlier designs had an additional water removal pumping system which has been replaced by the multiple uses of the tag tube.

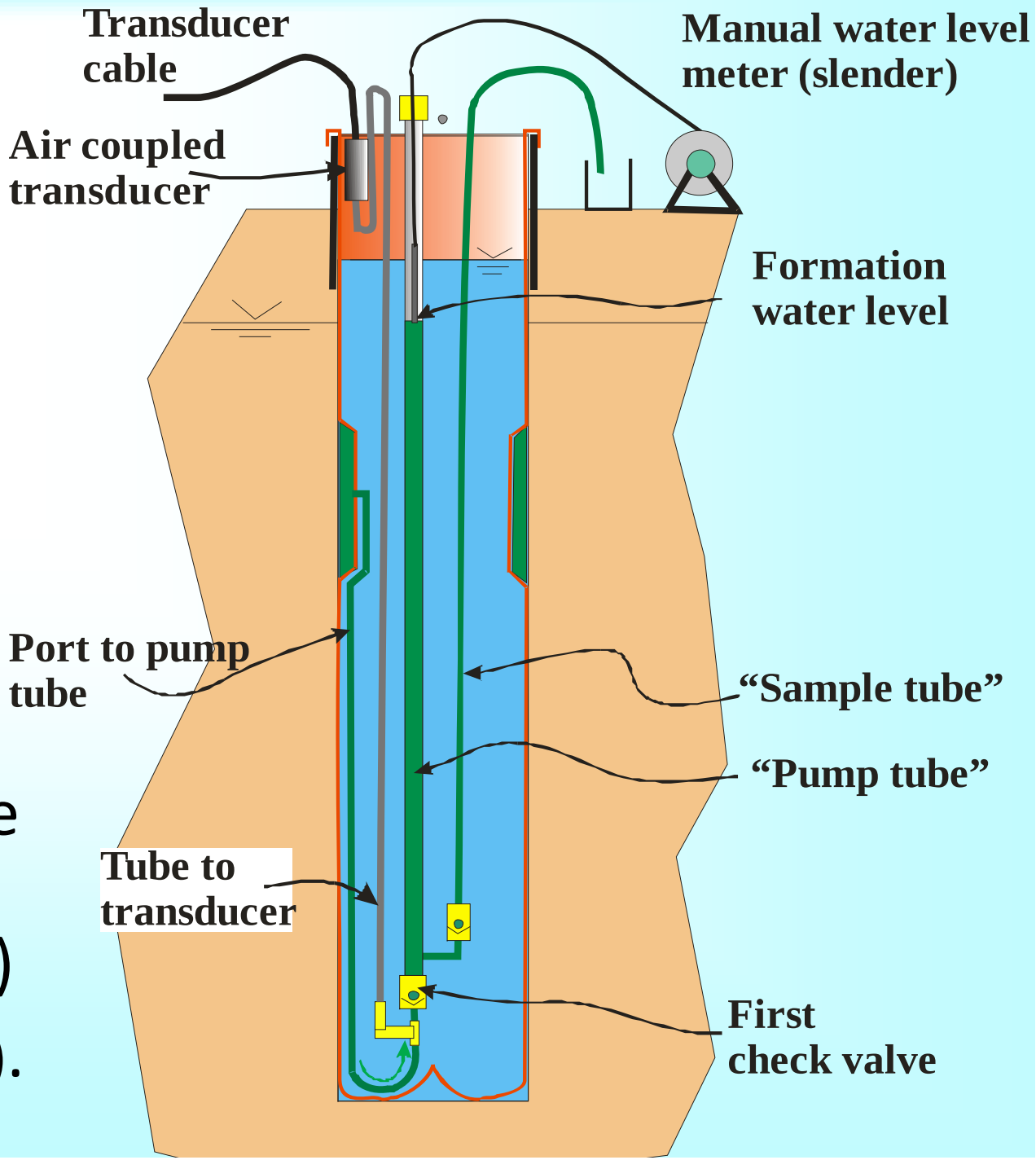
Liner fill fluids have evolved substantially

- The first liners were vadose systems installed with air pressure.
- Then water was used to install Water FLUTes.
- Then a weighted mud (heavy water) was used to provide sufficient sealing over-pressure for shallow water tables or artesian conditions. The liner is still removable.
- Now we have filled many liners with a bentonite/cement grout to prevent failure of the liner due to excessive differential pressure (e.g., when a nearby well (20 ft away) is pumped to 90 ft below the normal water table). This is also good insurance for situations with extreme water level variations such as in Texas or near production wells.
- When filled with grout, the liner is no longer removable.

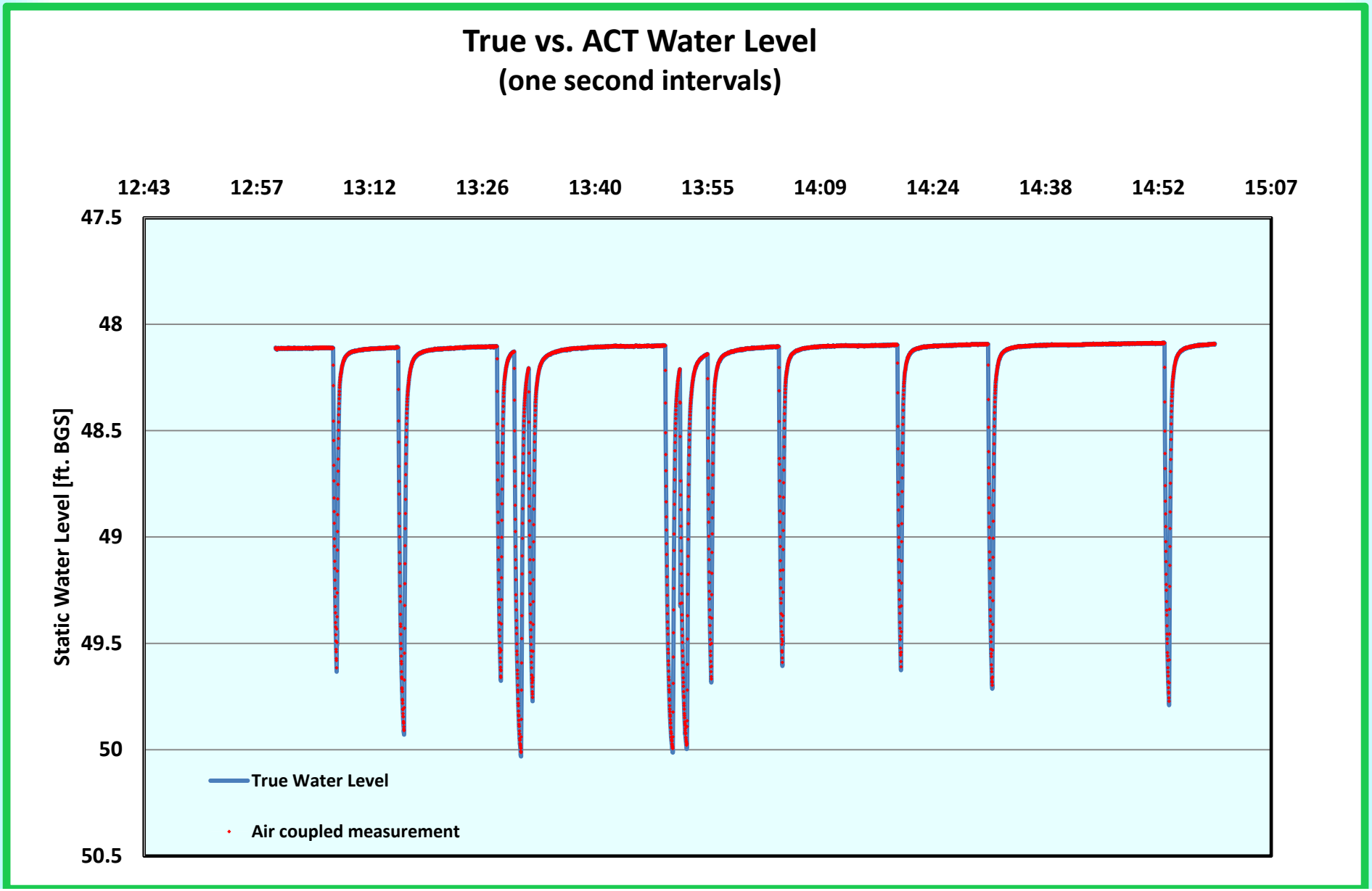
Transducers are easily added to each port for continuous monitoring

But the really convenient transducer connection is the air coupled transducer (ACT)

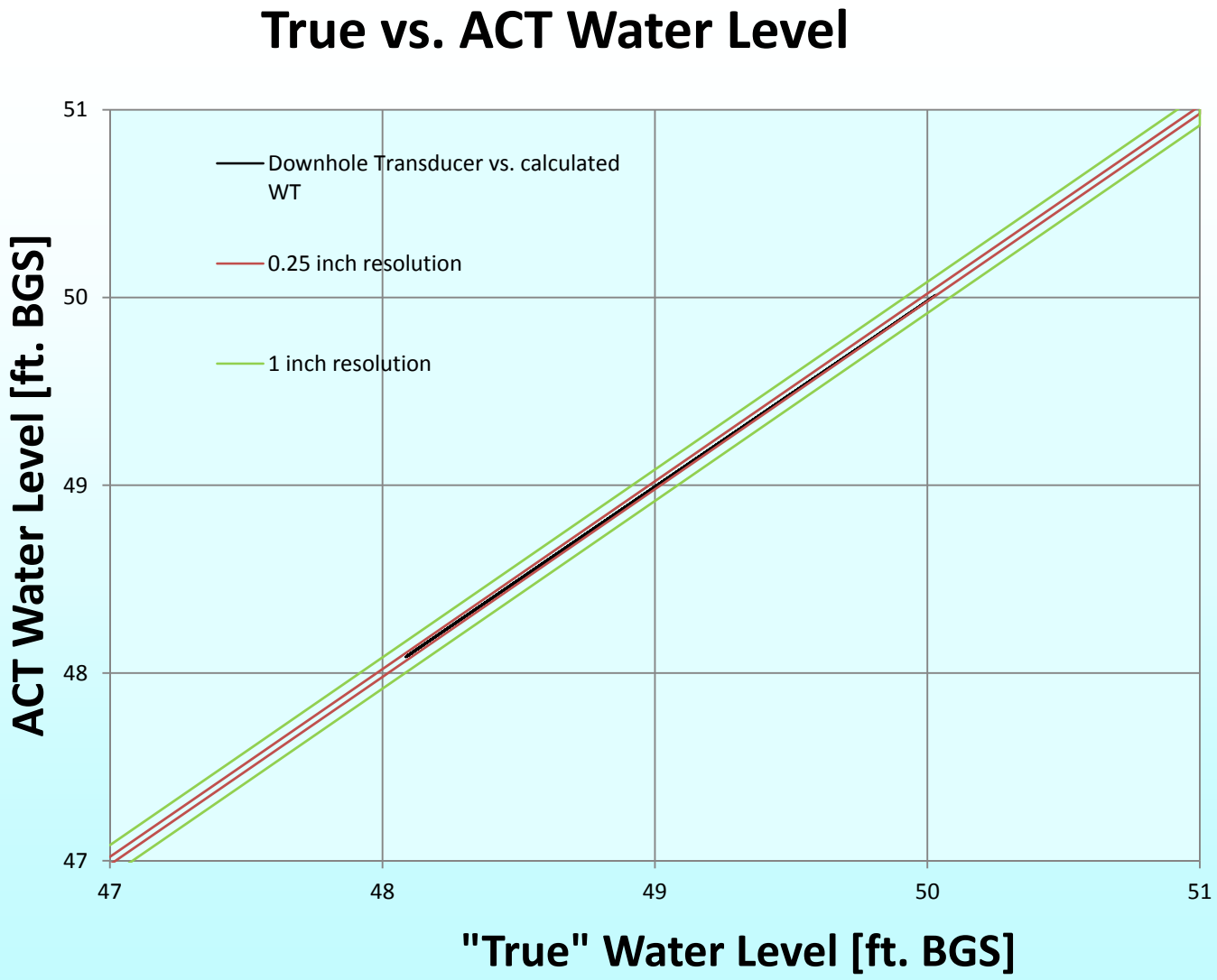
(Less than 1 yr. old).



The ACT resolution under good conditions



ACT was within ¼” of true value



What about the cost comparison?

- FLUTe is the only MLS supplier who publishes its prices on the web.
- Life cycle costs are important to the comparison
  - Initial cost (hardware and installation)
  - Extra equipment cost (sampling hardware, transducers)
  - Labor of sampling
  - Abandonment costs
- Warranty differences?

Water FLUTe Characteristics

- The liner seals the entire hole except for the sampling intervals.*
- The borehole water is inside the liner and there is little storage of water in the system, so the samples are drawn directly from the formation.* -and pressure changes are accurate.
- Sampling is as easy as turning a faucet (i.e., the three way valve). (The sampling hardware is included in the base price.)
- There is little risk of aeration of the sample with the long buffer between the gas/water interface and the bottom of the pump.*
- There is no grout contamination of the sample with no grout in contact with the formation, even if the liner is filled with grout.

* unique to Water FLUTe system.

Additional features:

- The system is entirely removable.*
- All ports can be purged and sampled simultaneously with only three strokes of the pumping system because the pumps are of the same length independent of the port elevations.*
- Many ports are available depending upon hole diameter (6 in 4”, 10 in 5”, 15 in 6”, …)
- The manual water level measurement does not conflict with the transducer measurement, and the use of transducers does not conflict with the number of ports available. *
- The pressure drop and recharge during sampling can be monitored with the recording transducers at all adjacent ports.
- Easy to install (1-4 hr. typically)*

* unique to Water FLUTe system.

Conclusions

- Over the last 14 years there has been a steady evolution of the Water FLUTe system based upon experience.
- There have also been many improvements in reliability/simplicity and corrections of mechanical and material deficiencies.
- Finally, there have been numerous inventions such as the ACT, and fabrication and installation procedures that improve the value of the technique.
- The system has grown well past some earlier occasional difficulties and current sales growth is a good testament to the state of the art.
- The sealing blank liner, the hydraulic conductivity profiling method, and the Water FLUTe have become a good “trio” for high resolution hydrologic measurements.

Thanks for your attention

Questions?

Arguments?

More information and publications are available at our website: www.flut.com