Applying the HPT-GWS for Evaluation of Managed Recharge in Unconsolidated Aquifers

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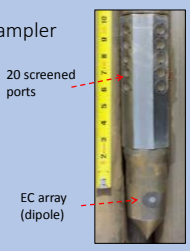
What is the HPT-GWS ?

Hydraulic Profiling Tool-Groundwater Sampler



Direct Push HPT Logging System
- Electrical Conductivity logs
- Pressure & Flow logs for permeability
- Understand hydrostratigraphy
- Identify sampling zones

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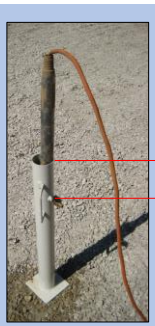
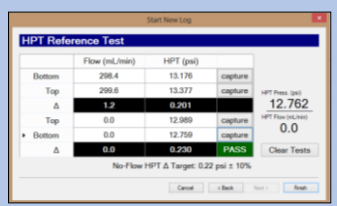
Groundwater Profiling System
- Stop at multiple depths as logging
- Purge & monitor water quality
- Collect groundwater samples

HPT Prelog QA Test



HPT Probe in Reference Tube to Verify
Δ6" Water Pressure = 0.22 psi (1.52kPa)

Determine ambient atmospheric pressure

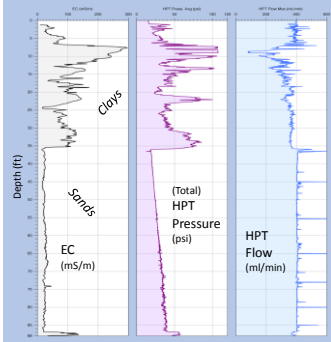


HPT Pressure Transducer Onscreen QA Report
(data saved to log file)

Site Location Map – Local Geology

Background Log Location

Background HPT Log & Interpretation



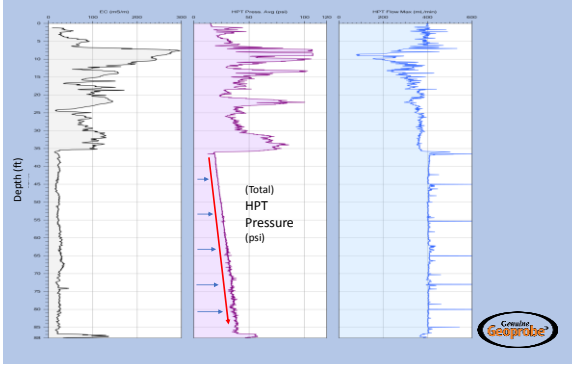
Electrical Conductivity (EC) :
In fresh water formations increase in EC indicates increase in clay content and decrease in permeability

HPT Pressure :
Higher P >>> lower permeability
Lower P >>> higher permeability

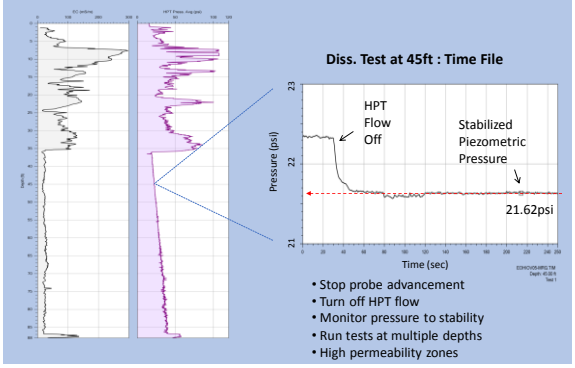
HPT Flow:
Will decrease in very low permeabililty formations

Logs guide selection of groundwater sampling intervals

Piezometric/Hydrostatic Pressure Rise

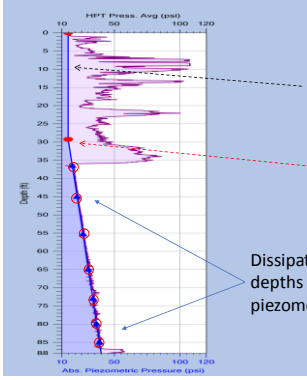


Pressure Dissipation Tests



- Stop probe advancement
- Turn off HPT flow
- Monitor pressure to stability
- Run tests at multiple depths
- High permeability zones

Diss. Tests & Piezometric Profile

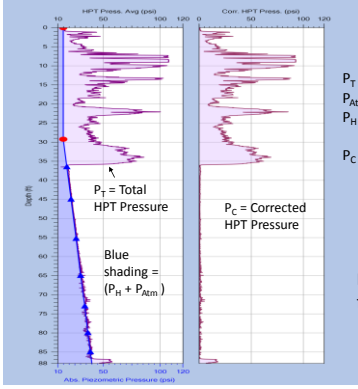


Atmospheric pressure measured during pre-log QA test

Back calculate to obtain water level

Dissipation tests at multiple depths define the piezometric profile

Corrected HPT Pressure

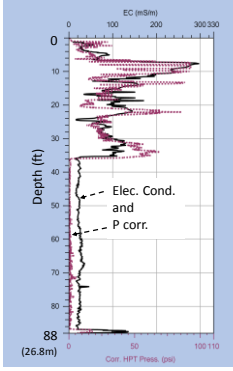


P_T = Total HPT Pressure
P_{Atm} = Atmospheric Pressure
P_H = Hydrostatic (piezometric) pressure
P_C = Corrected HPT Pressure

$$P_C = P_T - (P_H + P_{Atm})$$

P_C is a function of the formation permeability

Overlay of Background EC Log and P_C log

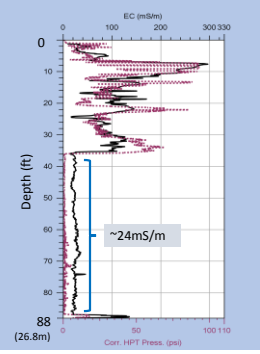


High EC and High HPT Pressure = silty clays ± sand

Low EC and Low P_C = Sand ± gravel

Collect formation samples at targeted locations and depths to confirm log interpretation

Average EC at Background in Saturated Sand

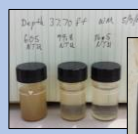


Average BULK Formation Electrical Conductivity (EC) in saturated sand
~ 24mS/m
(milliSiemens/meter)

HPT-GWS Sampling in the Field

Use Actuator to run down hole bladder pump

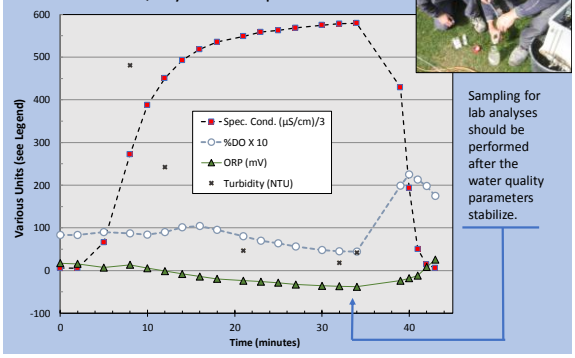
Monitor/record water quality parameters to stability before sampling at each depth



Including turbidity

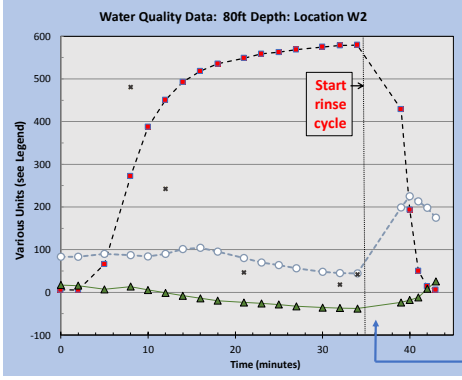
Sample collection

Stabilize Water Quality Parameters



Sampling for lab analyses should be performed after the water quality parameters stabilize.

"Rinse Cycle" to Clean Pump/Lines



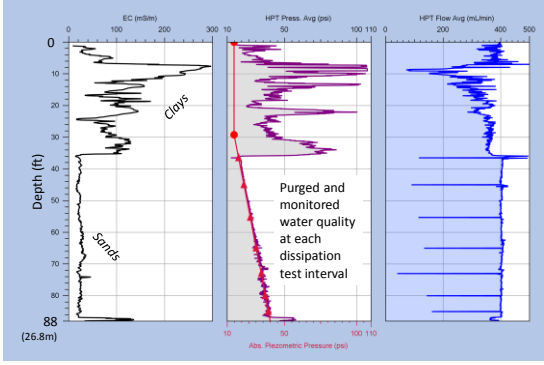
Begin purge with DI water, HPT pump & sample pump running

Background Location Water Quality Data

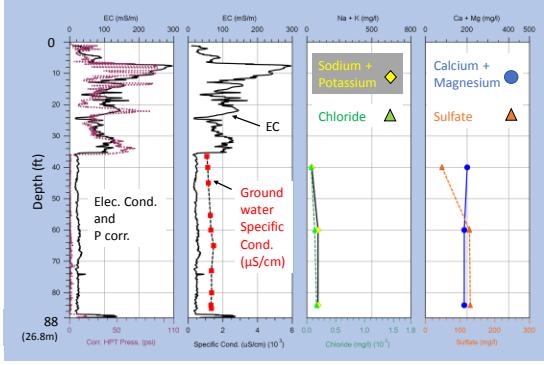
Completed logs with water quality profiles

Logs but no WQ profiling

HPT-GWS Log at Background Location



E04 Log with GW Specific Cond. & Dissolved Ions

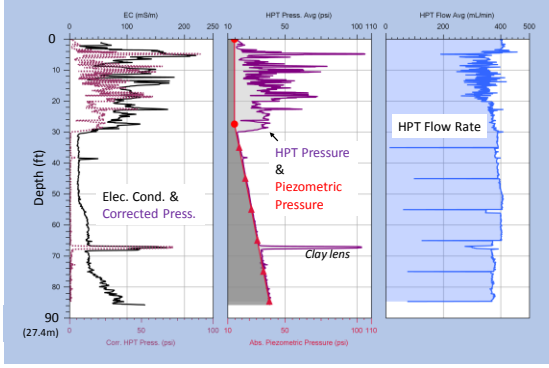


E4 Log-Sample Location

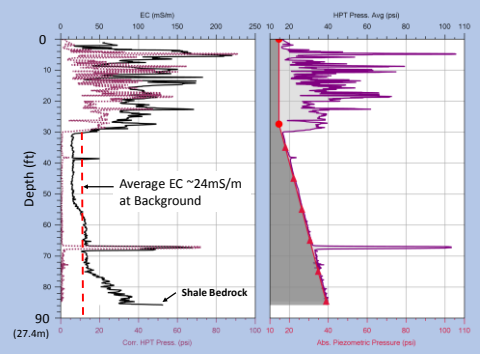
Completed logs with water quality profiles

Logs but no WQ profiling

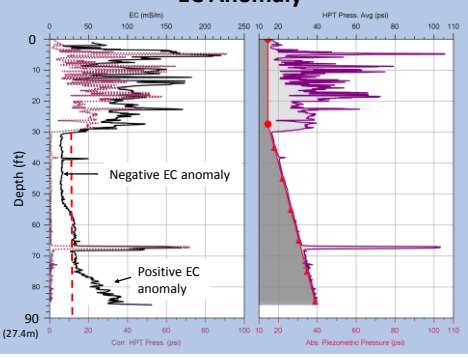
Log E04 with Corrected Pressure



Log E04: Corrected Press. = Flat : EC Variations



Corrected Press. = Flat : EC Variations "EC Anomaly"



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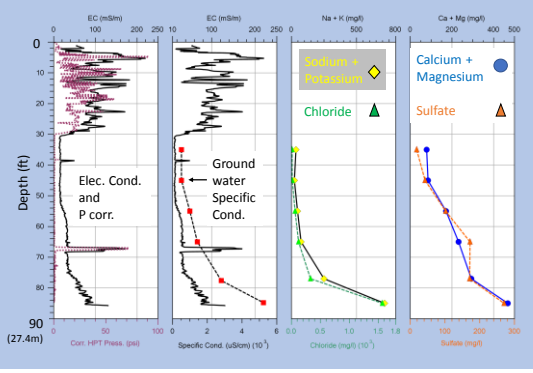
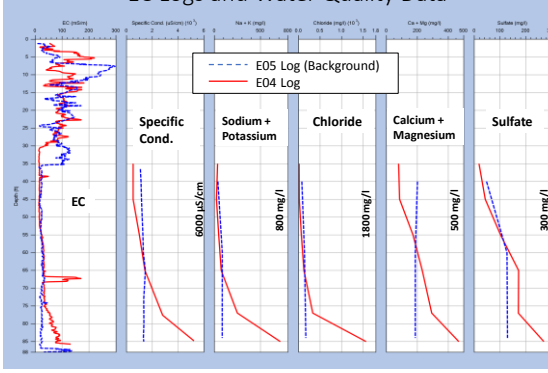


Comparing Background and E04 Location EC Logs and Water Quality Data

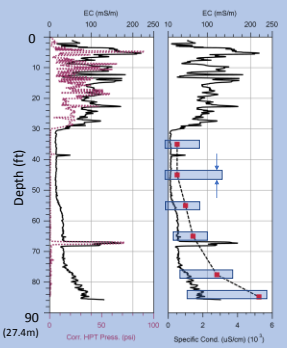


Ten Log Locations with Water Quality Profiles

Completed logs with water quality profiles

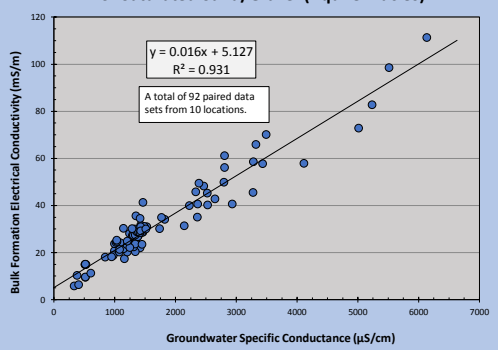
Logs but no WQ profiling

Average Bulk Formation EC at Sample Depths



Averge bulk formation EC over 1-foot intervals centered at sample depths

Bulk Formation EC versus Groundwater Specific Conductance for Saturated Sand/Gravel (Aquifer Facies)



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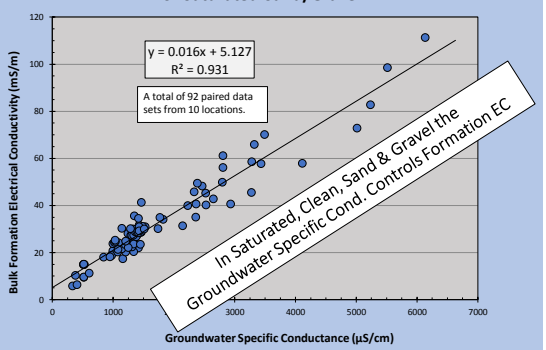
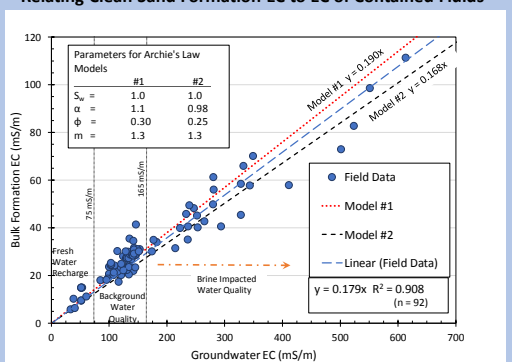
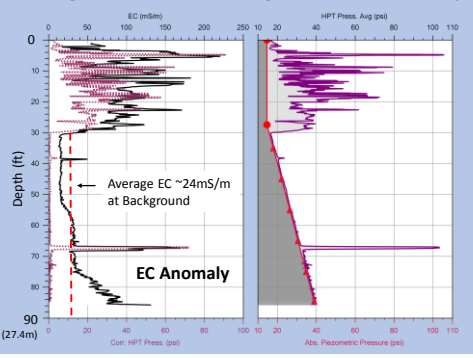


Archie's Law from Petroleum Industry (1940s) Relating Clean Sand Formation EC to EC of Contained Fluids



HPT Corrected Press. = Low & Flat then Changes in EC ➡ Changes in Water Quality

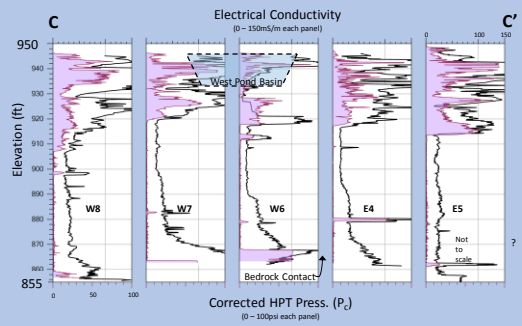


Site Map with Cross Section C – C’

Completed logs with water quality profiles

Logs but no WQ profiling

Using EC and Pc Cross Section for Hydrostratigraphy



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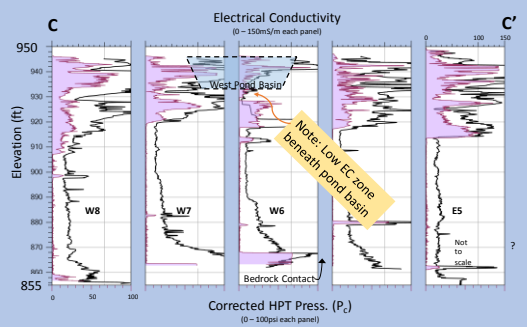

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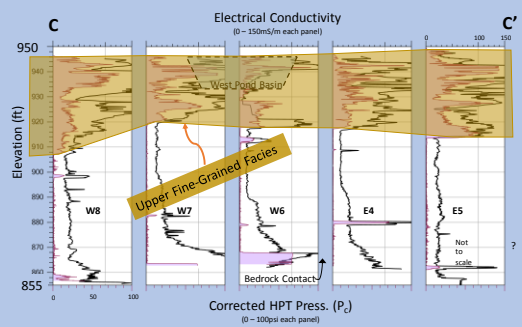
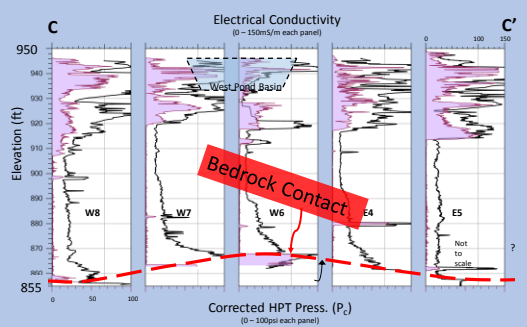


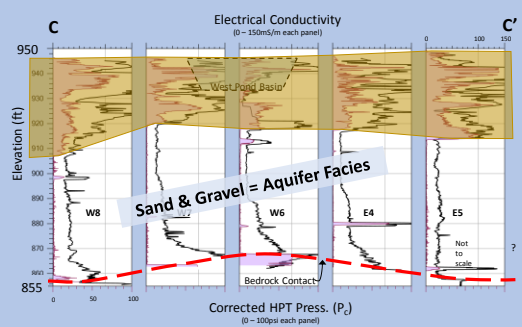
Bedrock Contact / Shale

Based on Pc, EC and Refusal

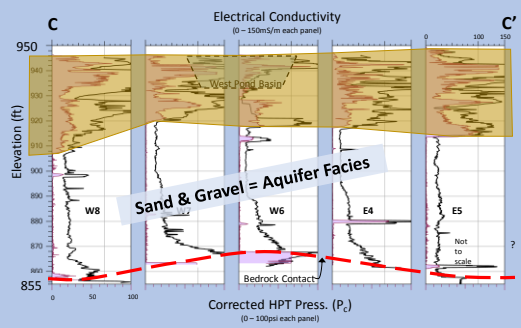


Sand & Gravel = Aquifer Facies

Based on Low Pc



Compare EC and Pc Logs in Aquifer Facies to Assess Changes in Water Quality



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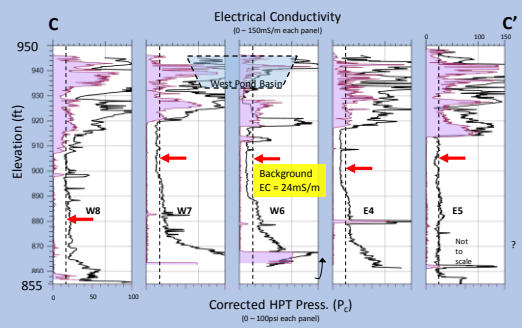

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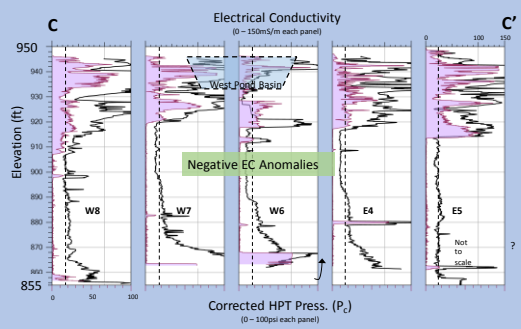

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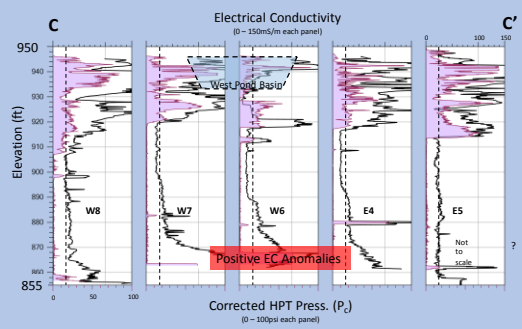
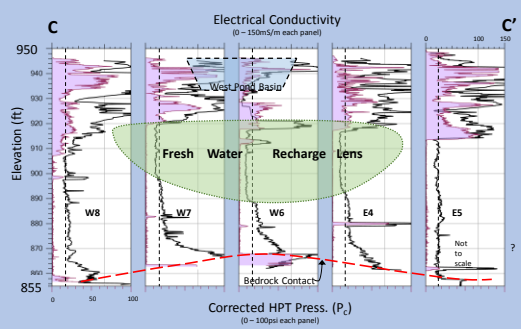


Using Pc and EC to Map Water Quality Zones



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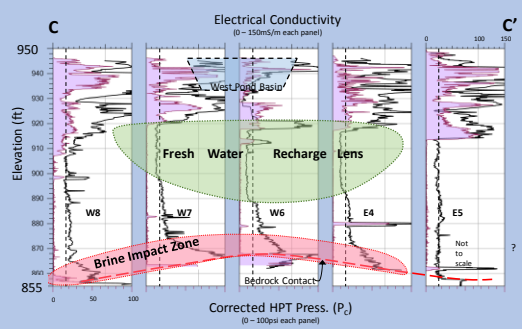
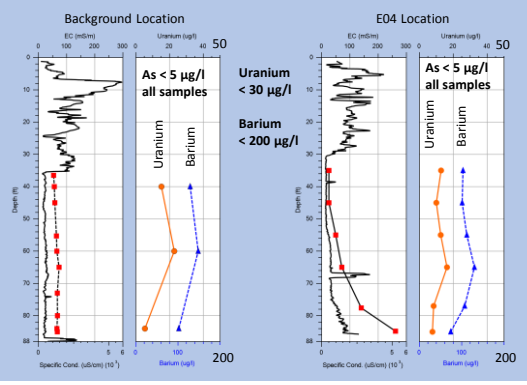


Uranium, Arsenic & Barium



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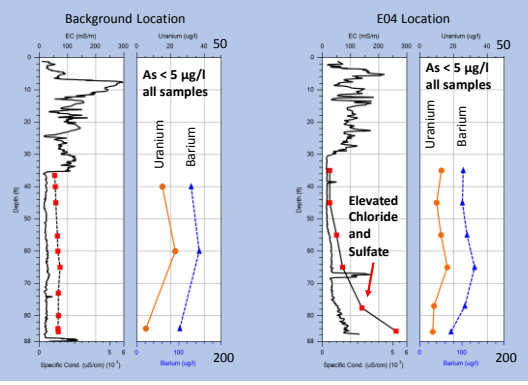


Summary & Conclusions

HPT-GWS probe provides injection pressure and EC logs

Allows for defining hydrostratigraphy at the inch-scale in unconsolidated formations

Use targeted core sampling to confirm logs

HPT-GWS allows for groundwater profiling in permeable formations

Water quality monitoring & sampling for low level contaminants or tracers can be performed

Summary & Conclusions

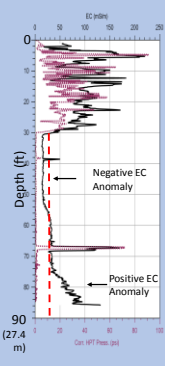
In saturated coarse-grained formations HPT Pc is low & flat

When HPT Pc is low & flat changes in EC often indicate changes in water quality

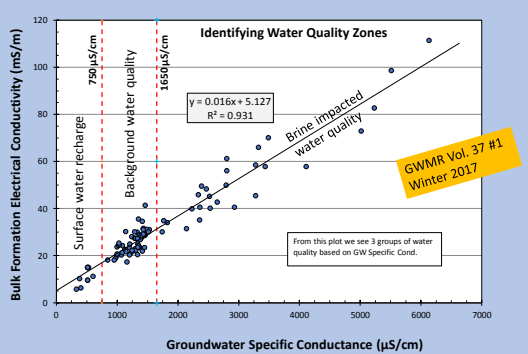
In this saturated coarse-grained formation changes in groundwater specific cond. control bulk formation EC and follow Archie's Law

Map water quality zones based on EC logs in clean sandy formations (contrast with Pc log)

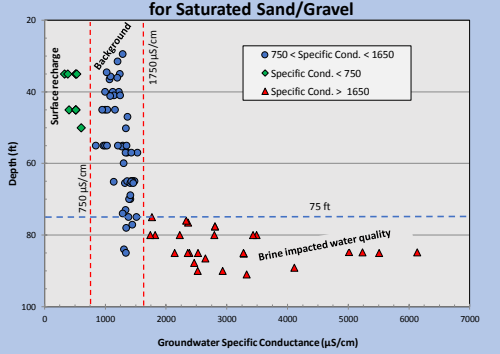
Use Pc & EC log data to site ASR recharge basins &/or wells and map recharge plumes



Questions ?



Groundwater Specific Conductance vs Depth for Saturated Sand/Gravel

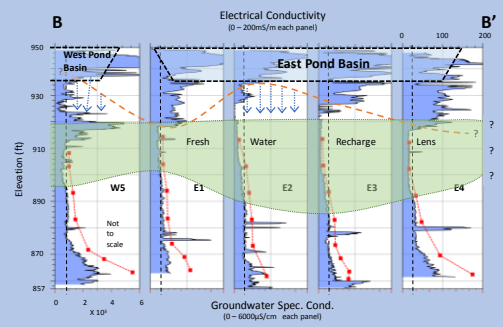


Site Map with Cross Section Location

Completed logs with water quality profiles

Logs but no WQ profiling

Aquifer Recharge Beneath Stormwater Retention Ponds



Base of Clays ~50mS/m

Archie's Law in Terms of Electrical Conductivity

$$C_B = (1/\alpha)\, C_W\, \phi^m\, S_w^n$$

- C_B = EC of the fluid saturated bulk formation
- C_W = EC of the fluid (groundwater or brine = measured)
- S_w = Fluid saturation (fully saturated with water = 1.0)
- n = Saturation exponent
- α = Tortuosity factor (typically between 0.5 and 1.5)
- ϕ = Porosity (typically 20% to 35% for unconsolidated sands±gravel)
- m = Cementation exponent (typically 1.3 for unconsolidated sands)