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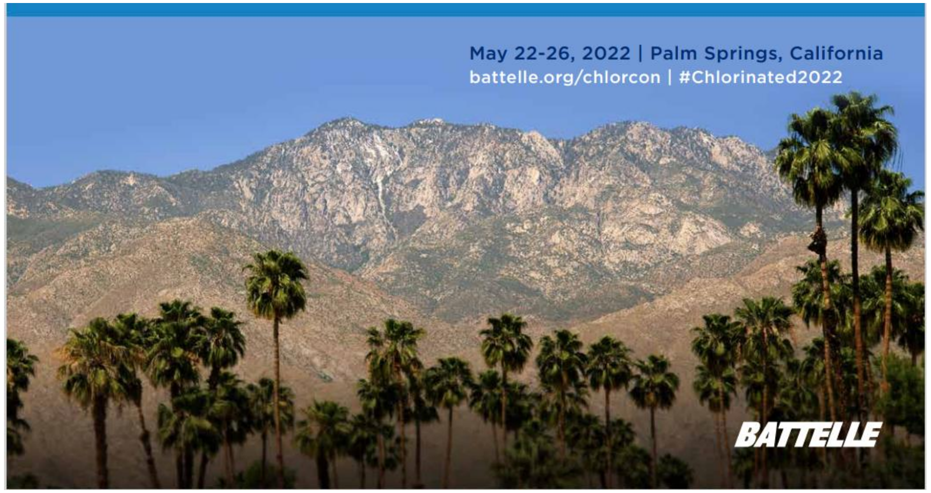
ISCO Optimization in a Low Permeability Formation Using Groundwater Recirculation



Presented by:

Richard J. Desrosiers, Vice President, LEP, PG

Benjamin Rach, Project Manager

GZA GeoEnvironmental, Inc. (Glastonbury, CT)

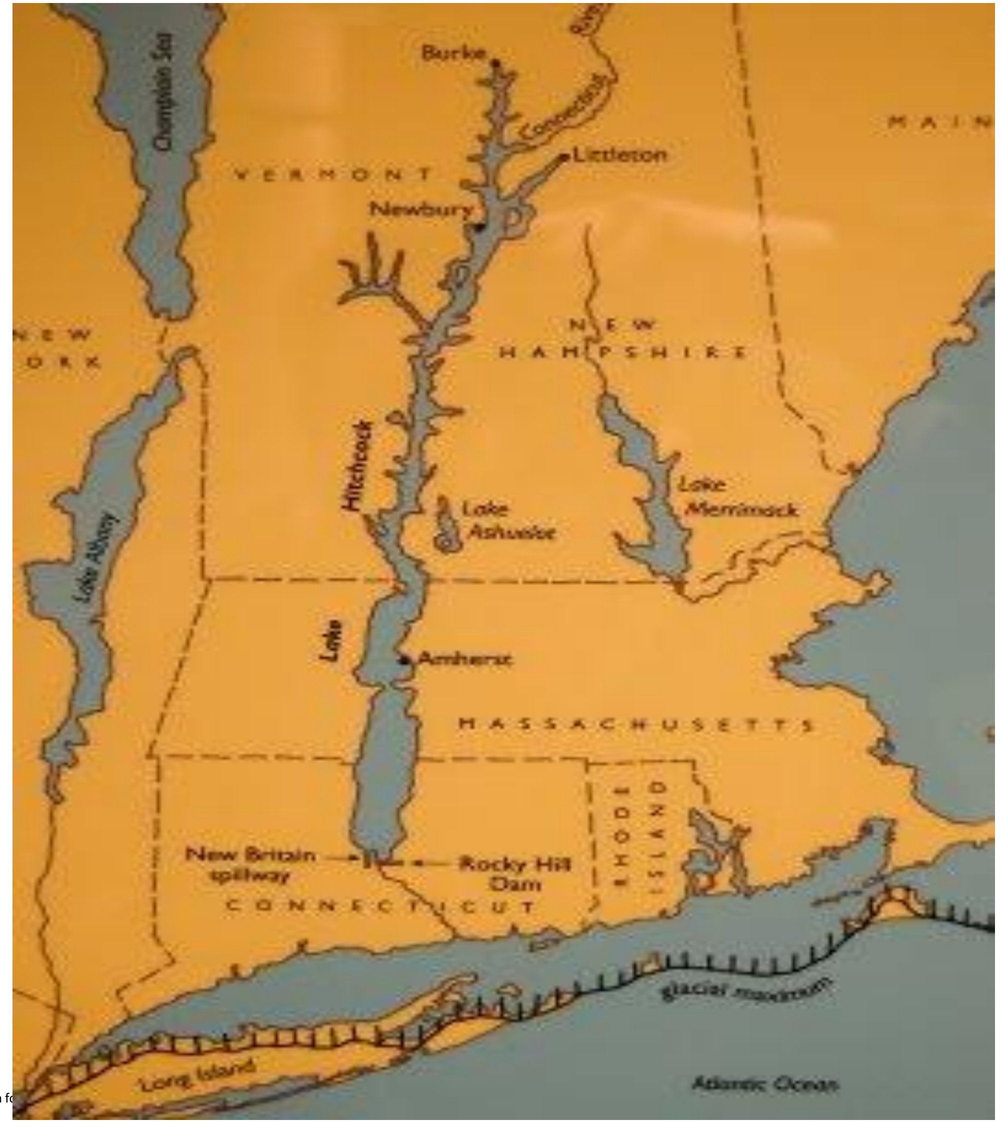
Outline

- Regional and Local Geologic and Hydrogeologic Setting
- Recirculation Design
- Recirculation Results
- Conclusions

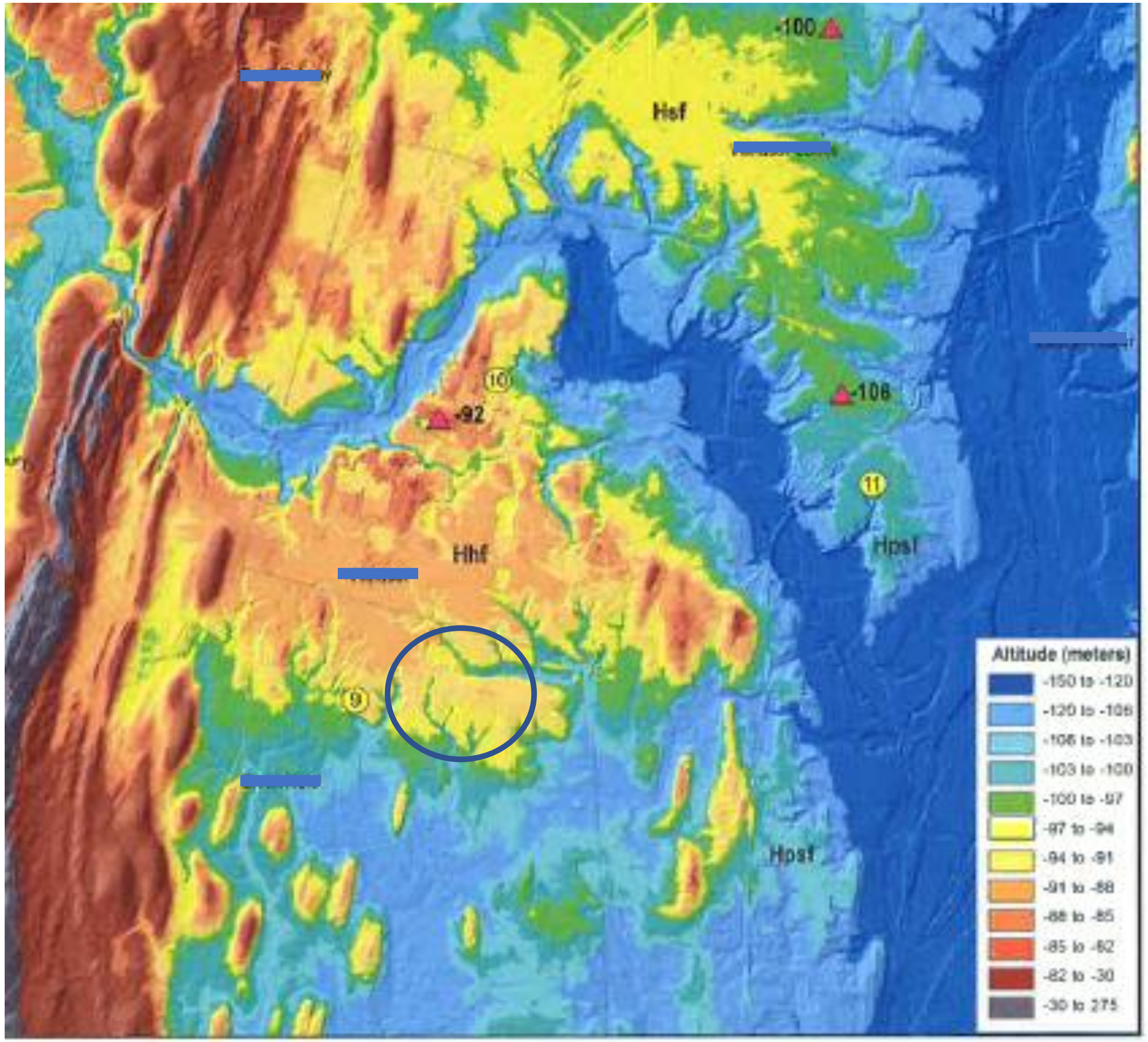
Regional Geologic Deposition

Geotechnical Environmental Ecological Water Construction Management

Glacial Lake Hitchcock

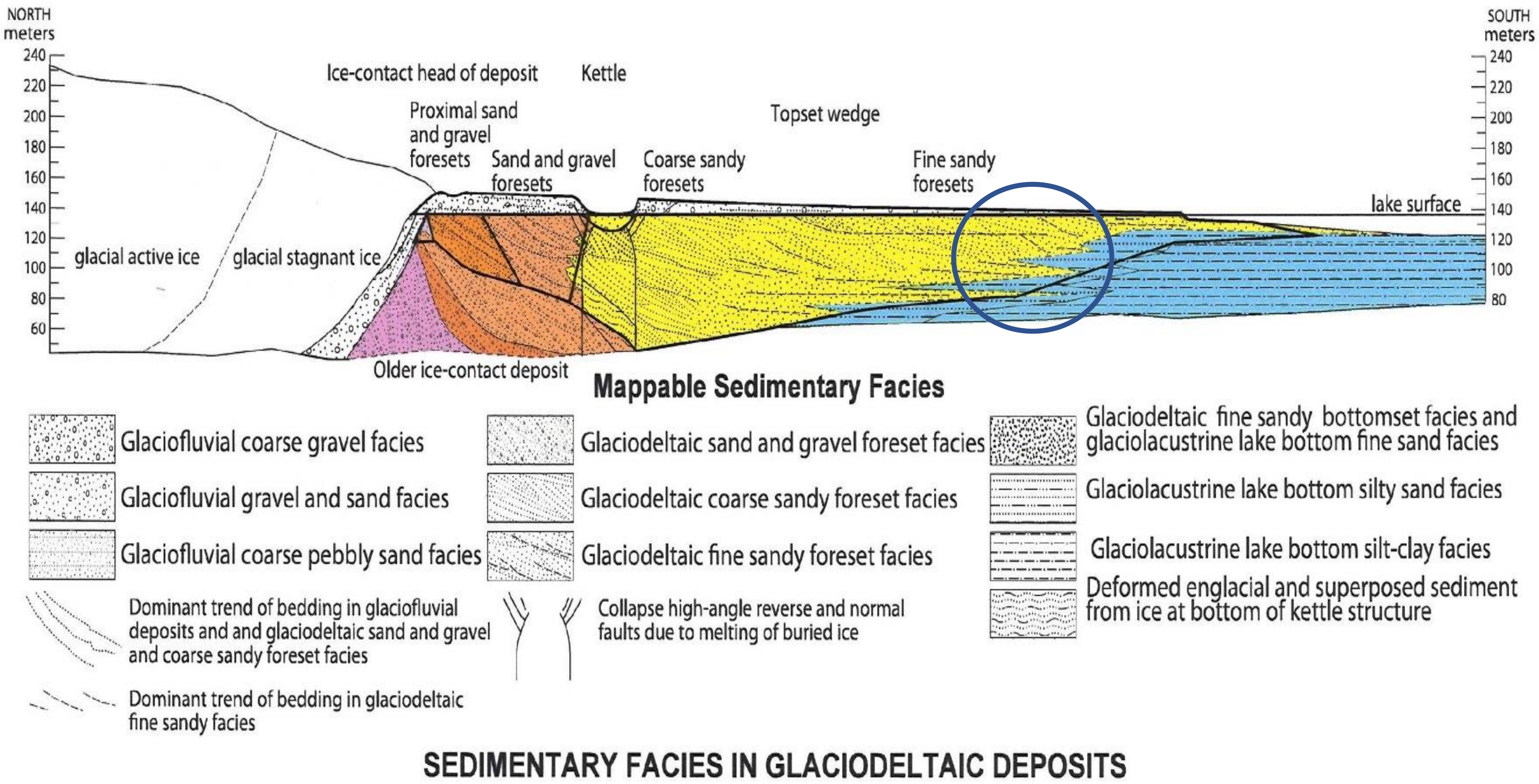


Delta Complex



Regional Sedimentary Facies

Geotechnical | Environmental | Ecological | Water | Construction Management

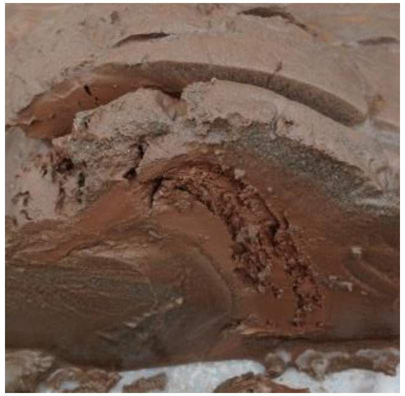


Conceptual model of mappable sedimentary facies within glaciodeltaic deposits (Stone, 2015), extended at the distal end

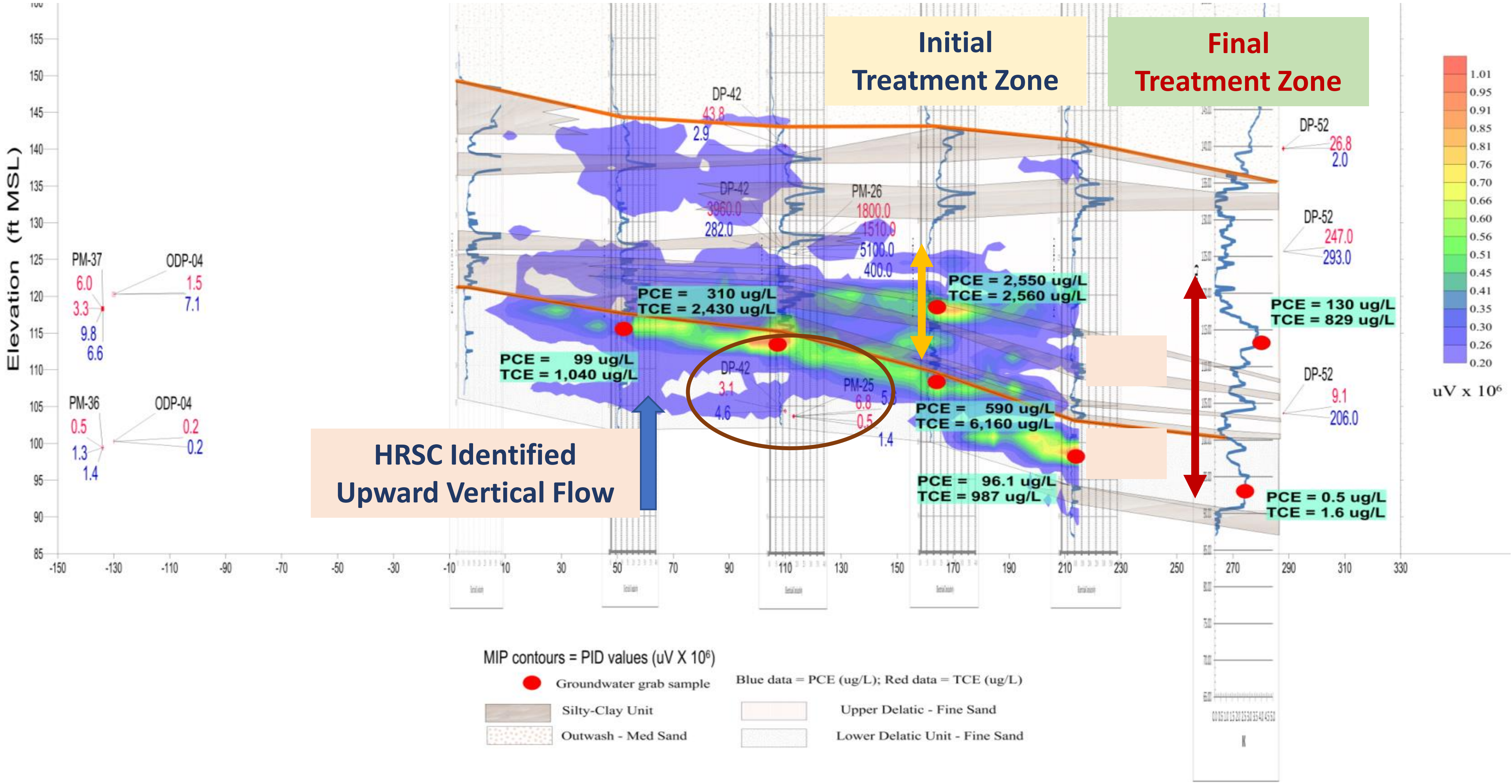
Local Geologic Depositional Units

Well ID	depth feet	Interval (inches)	PID (ppm) field Screening	Soil Description
PM-200	35	50"	0	S-1: 0-50": Gray-brown, fine SAND, little Silt
PM-200	35	4"	0	50-54": Gray-brown, fine SAND and SILT, wet, 1/2" dry platey Clay at 52.5"
PM-200	40	20"	0	S-2: 0-8": Gray-brown, Clay and SILT, trace fine Sand, 1/4" red-brown, dry, platey Clay at 1" and 4"
PM-200	40		0 - 2,537	8-20": Red-brown, SILT, trace fine Sand, 1/8" red-brown, dry, platey Clay at 13" and 20"
PM-200	40	34"	2,537 - 3,693	20-26": Gray-brown, SILT, little fine Sand
PM-200	40		3,693	26-29": Gray-brown, fine SAND and SILT, 1/8" red-brown, dry, platey Clay at 27" and 28"
PM-200	40		3,693 - 14,780	29-50": Gray-brown, fine SAND and SILT
PM-200	40		14,780	50-54": Gray-brown, fine SAND, some Silt, wet
PM-200	45	49"	0 - 4,003	S-3: 0-32": Gray-brown, fine SAND, little Silt, 1/2" red-brown, dry, platey Clay at 31.5"
PM-200	45		2,559 - 18,120	32-49": Gray-brown, fine SAND, little to some Silt
PM-200	45	4"	9,054	49-53": Red-brown-gray, fine SAND and SILT, 1/4" red, dry, platey Clay at 50.5", 1/2" at 51", wet
PM-200	50	115"		S-4: fine SAND with Silt lenses
PM-200	55		0 - 27,530	S-5: 0-45": Gray-brown, fine SAND, little to trace Silt
PM-200	55		10,080 - 4,935	45-57": Gray-brown, fine SAND, little Silt, 1/4" Silt lens at 52.5"
PM-200	55	1"	4,935	57-58": Gray-brown, fine SAND and SILT, wet
PM-200	60	30"	0	S-6: 0-12": Red-gray-brown, SILT and CLAY, 1/8" red, dry, platey Clay lens at 6", 6.5", 10"
PM-200	60		0	12-30": Gray, Clay and SILT
PM-200	60	3"	0	30-33": Gray-brown, fine SAND, some Silt
PM-200	60	37"	0	33-45": Red-gray-brown, Clay SILT, 1/4" red-brown, dry, platey Clay at 33", 1/8" red-brown, dry, platey Clay at 6.5", 1/2" red-brown, dry, platey Clay at 39", 1/4" red-brown, dry, platey Clay at 42.5", wet
PM-200	65		0	S-7: 0-25": Red-brown, CLAY and SILT, 1/4" red-brown, dry, platey Clay at 1", 1/4" gray, fine sand lens at 11.5"
PM-200	65	6"	0 - 173	25-31": Gray-brown, fine SAND, some Silt
PM-200	65	21"	173 - 0	31-52": Tightly interbedded gray SILT and red, dry, platey Clay lenses, wet

Target Treatment Zone



HRSC – Transect Lithology & PID Profile

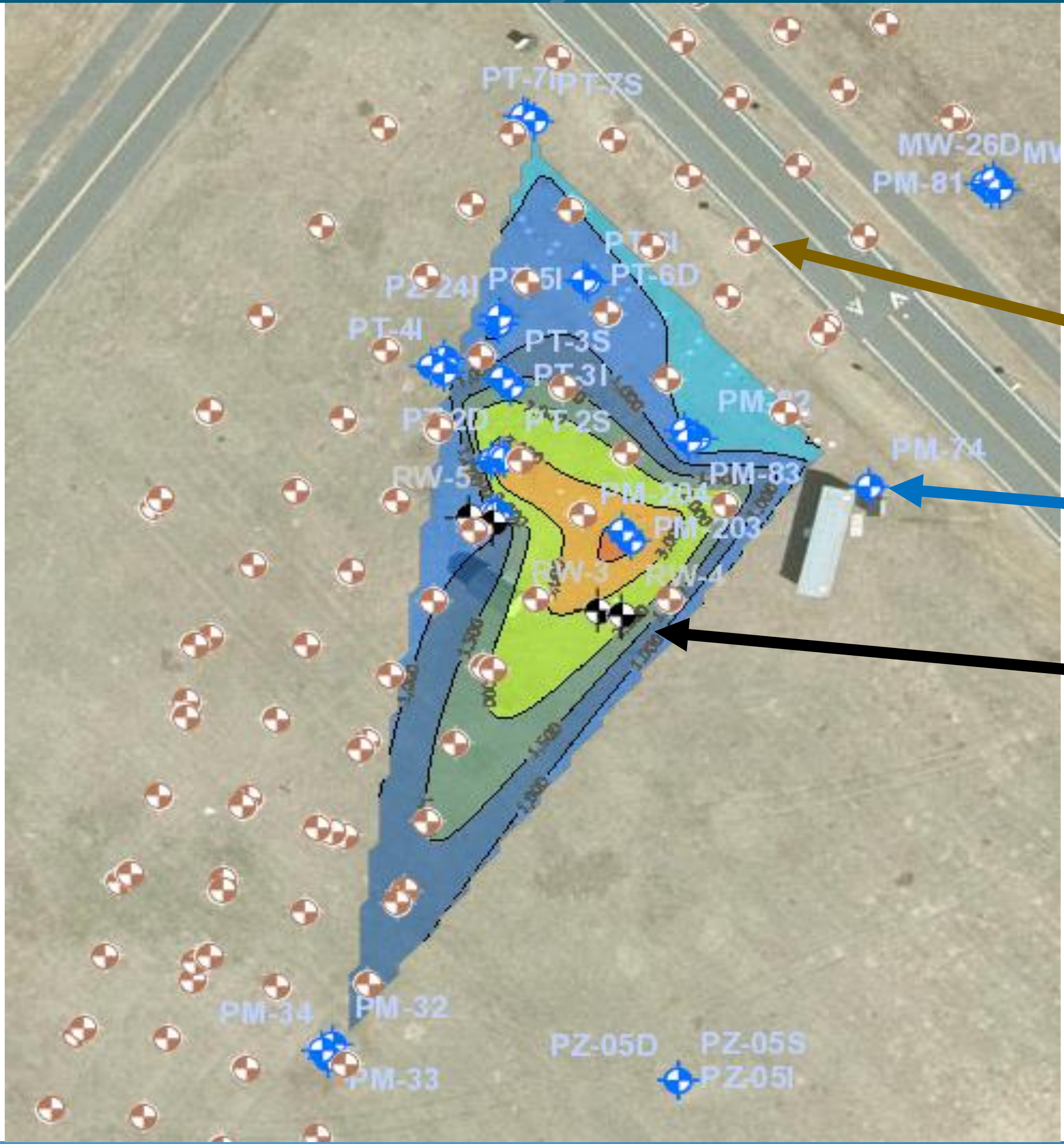


Historic Injections / Pre-Remediation Concentration

Geotechnical | Environmental | Ecological | Water | Construction Management

TCE iso-concentration plot

Post historic injections

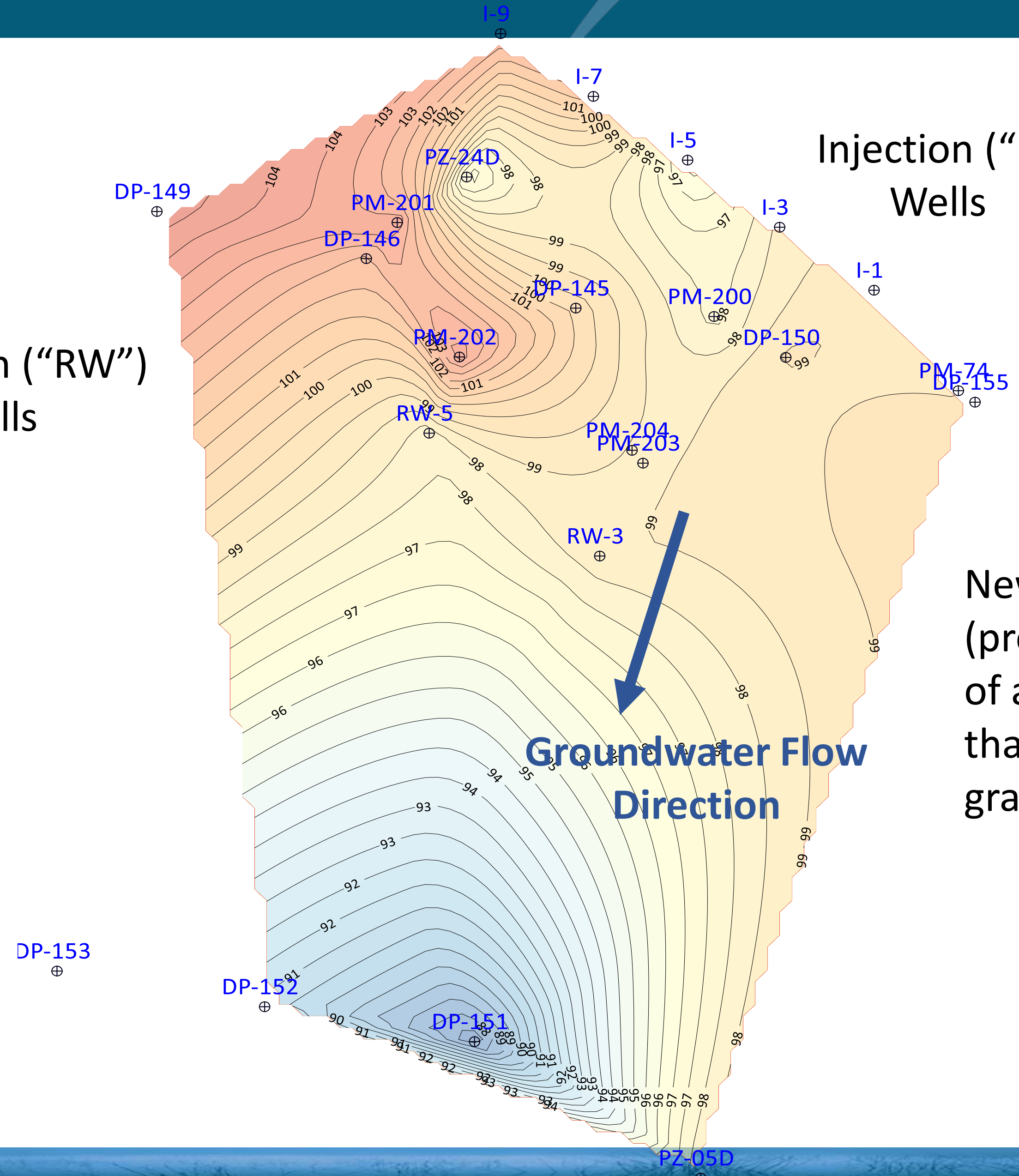


Direct Injection Points

Monitoring Wells

Extraction Wells

Lower Lacustrine Boundary Layer

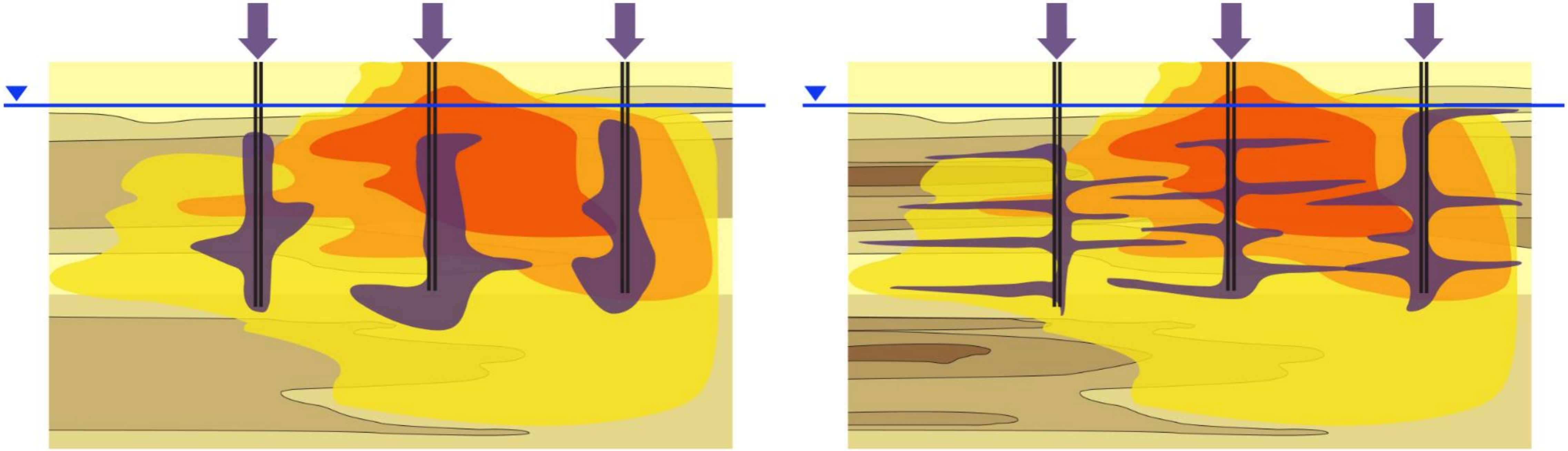


Injection ("I") Wells

Extraction ("RW") Wells

New remedial design characterization (pre-recirculation) identified the center of a north/south deltaic paleochannel that may have incised an easterly fine-grained delta lobe

Heterogeneity Effects on Injections



Heterogeneity can result in amendment preferential flow patterns and injection efficiency

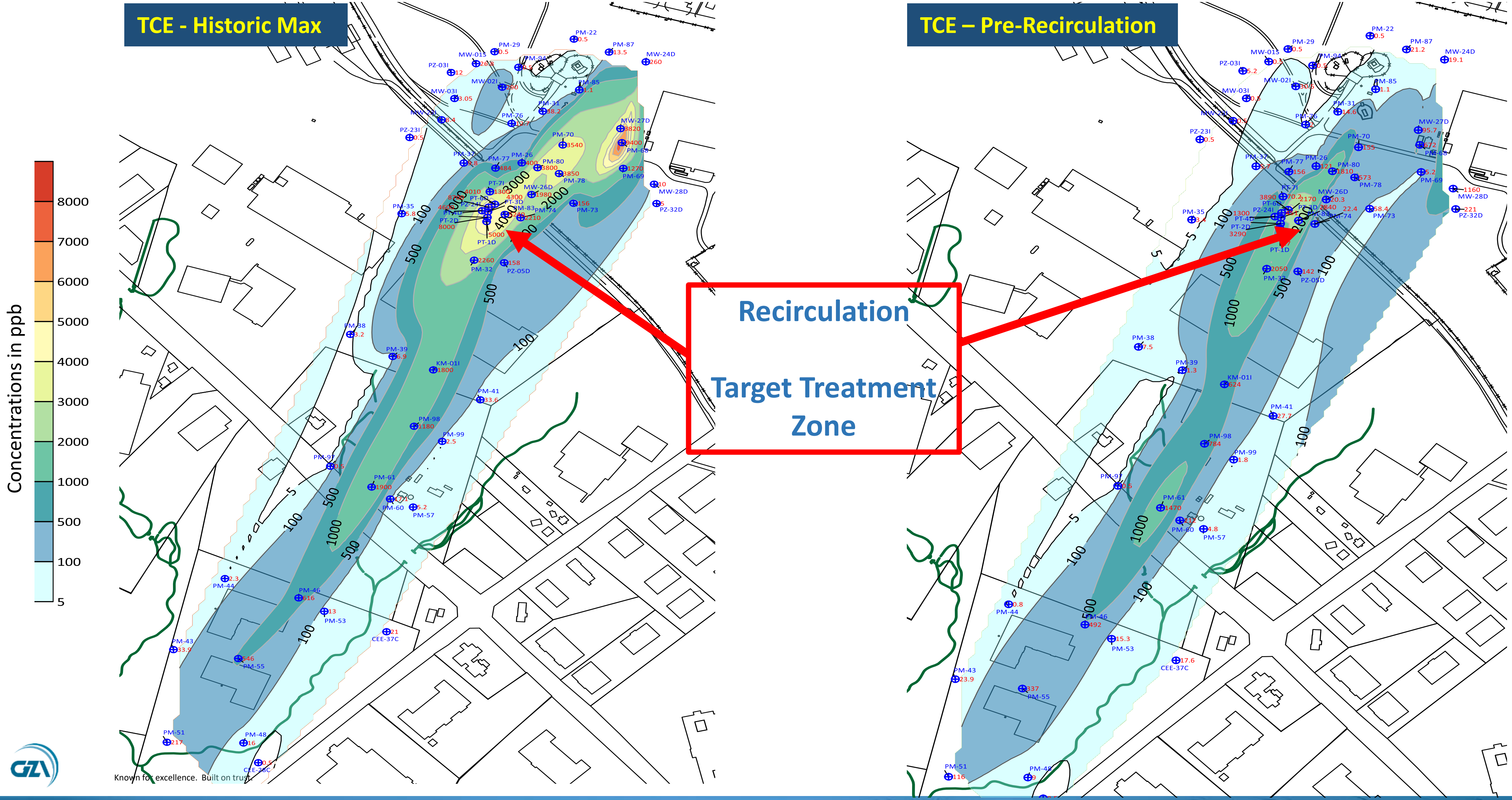
Less heterogeneous

Amendment delivered in the vicinity of injection points.

More heterogeneous

Results in substantial variability both horizontally and vertically.

G-1S TCE Plume



Baseline Recirculation Design Information

GEOTECHNICAL ENVIRONMENTAL ECOLOGICAL WATER CONSTRUCTION MANAGEMENT

Recirculation Target Treatment Zone	140 feet wide x 100 feet long
Treatment Zone Volume of Groundwater	417,000 gallons
Average Hydraulic Conductivity (3.5 x 10^5 to 2.8 x 10^3 cm/sec (0.1 to 8 ft/d)	8.8 x 10^4 (2.5 ft/d)
Average Hydraulic Gradient	0.0175 ft/ft
Porosity	0.25
Seepage Velocity from Injection to Extraction Wells (100 feet)	64 ft/y or 570 days (1.6 yrs.)
Oxidant Longevity from prior injections (PersulfOx)	30 to 45 days
Percent Oxidant (PersulfOx)	12 to 15 percent
Number of Extraction Wells (4)	2 shallow, 2 deep
Estimated Extraction Flow Rate 2.5 gpm/well	10 gpm
Estimated Time to Remove 1-pore volume (injection/extraction)	30 days
Number of Applications	2 (April 2018 & June 2019)
Target Treatment Concentration (RAP)	500 µg/L

Why Change Injection Strategy

A. Not achieving remedial goal of 500 ppb

B. Plugging of injection tool – clays & heaving sands
   - Required multiple downhole trips

C. Injection back pressure & clogged check valves
   - Pressure relief valves

D. Injection point pressure interaction
   - Needed to stagger injection

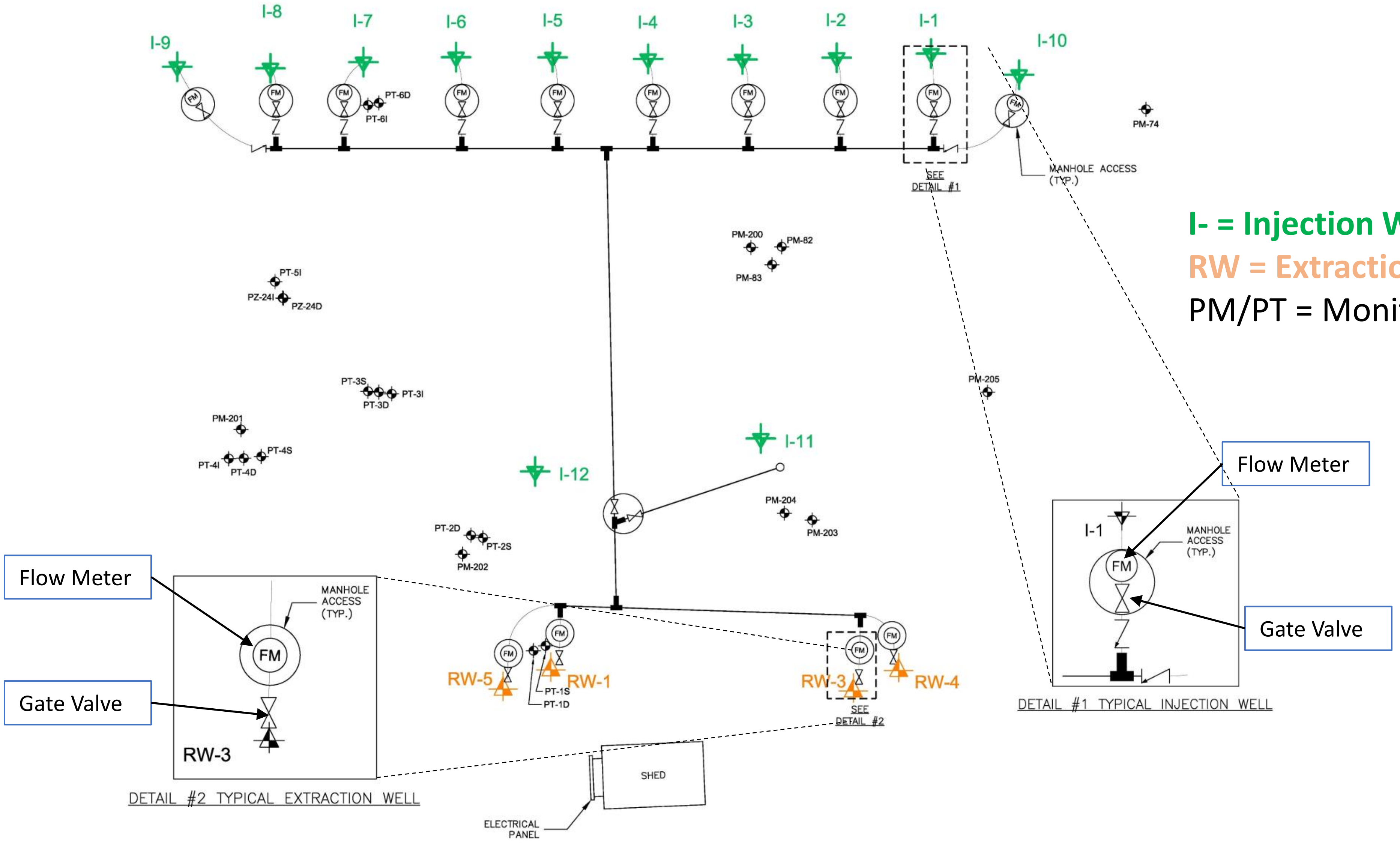
E. Oxidant was corrosive - tooling required replacement

F. Slow injection rates in low permeability units

G. Extensive daily set-up and breakdown – lost time

H. Health and Safety concerns –
   - Injection hose breaks,
   - Breaking of tooling (rods/hoses) splash/spills

Recirculation System Layout



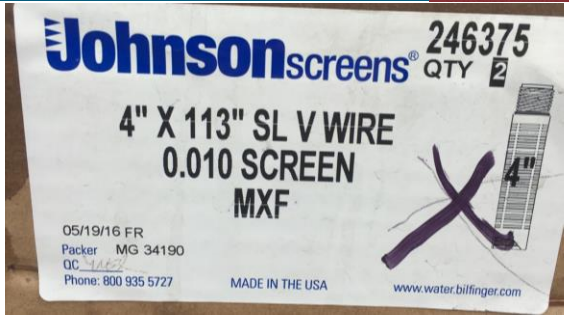
I- = Injection Wells

RW = Extraction Wells

PM/PT = Monitoring Wells

Injection/Extraction Well Construction

Filter Pack = OON Sand
Centralizers Every 10-Feet
8-Inch Borehole



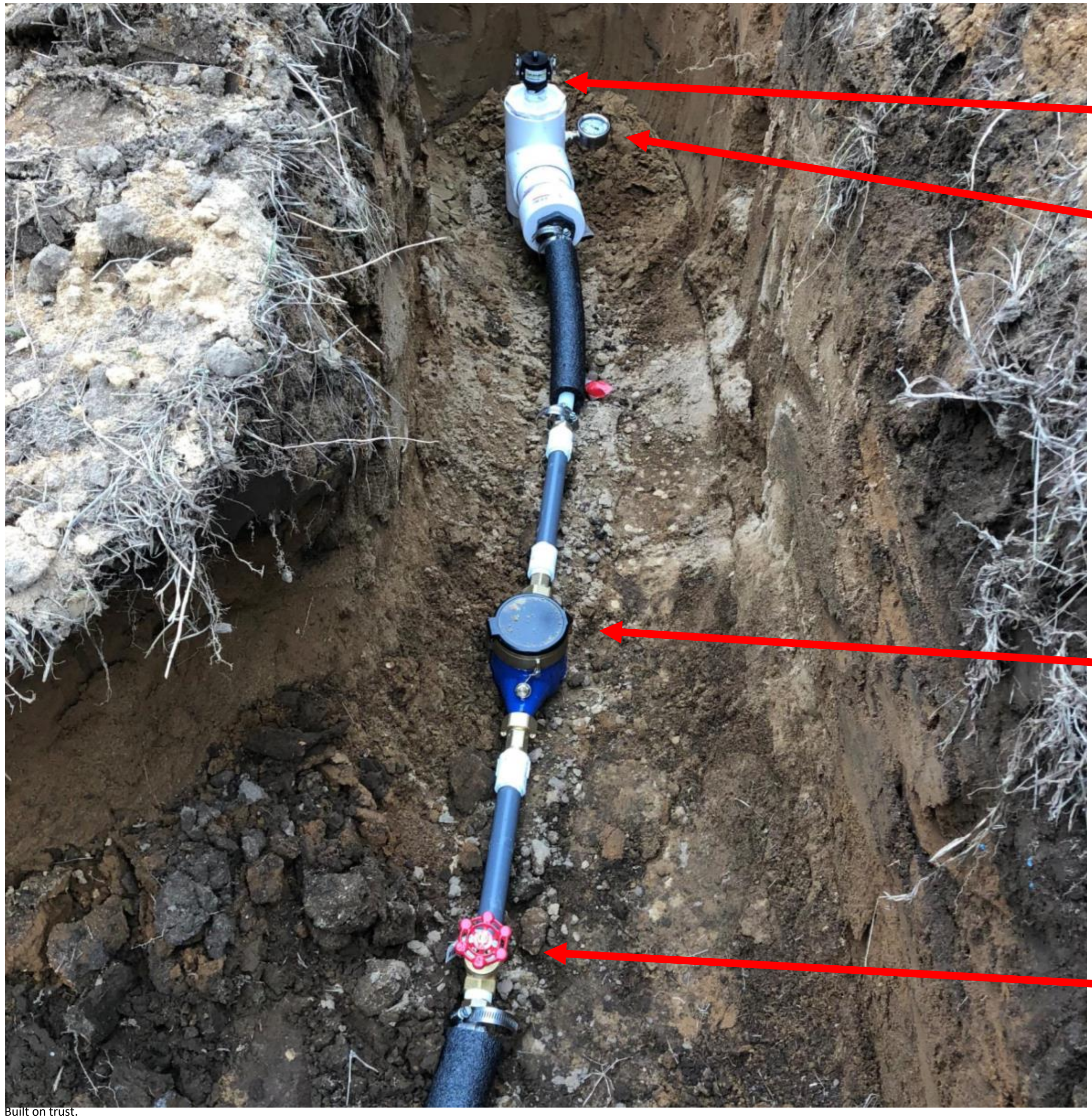
Filter Pack = OON Sand
Centralizers Every 10-Feet
8-Inch Borehole

Why V Wire??

-Continuous Slot
-Greater % of Open Area for water to pass through

Well Screen Construction			
Well Diameter (inches)	Screen Slot (inches)	Open Area (in^2/ft)	
		Slotted Screen	Vee Wire
3	0.02	6.07	16.5
4	0.01	3.12	11.6
2.5 x Open More Area			
3.7 x Open More Area			

Injection Point Configuration



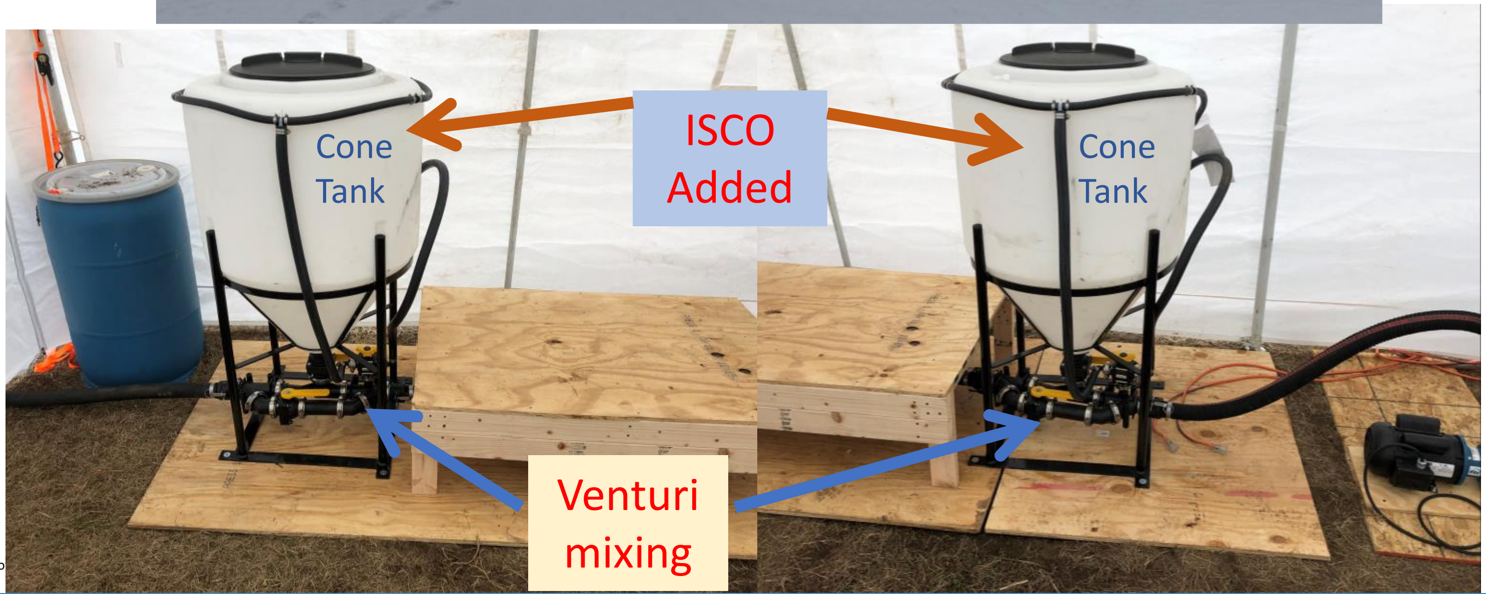
Injection Port

Pressure Gauge

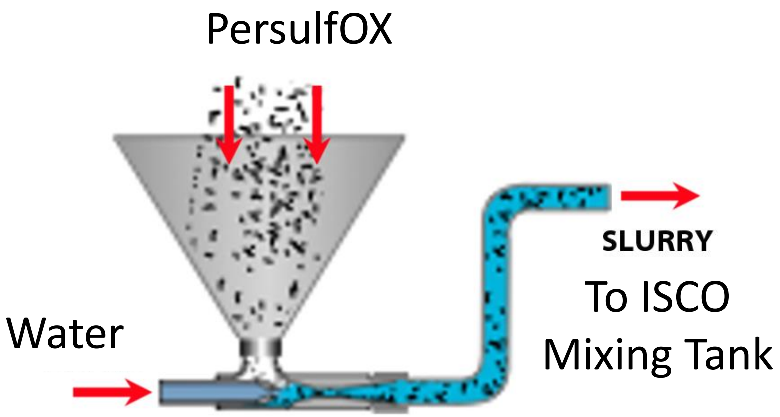
Flow Meter (calibrated)

Gate Valve

Mixing Process



Venturi Mixing System

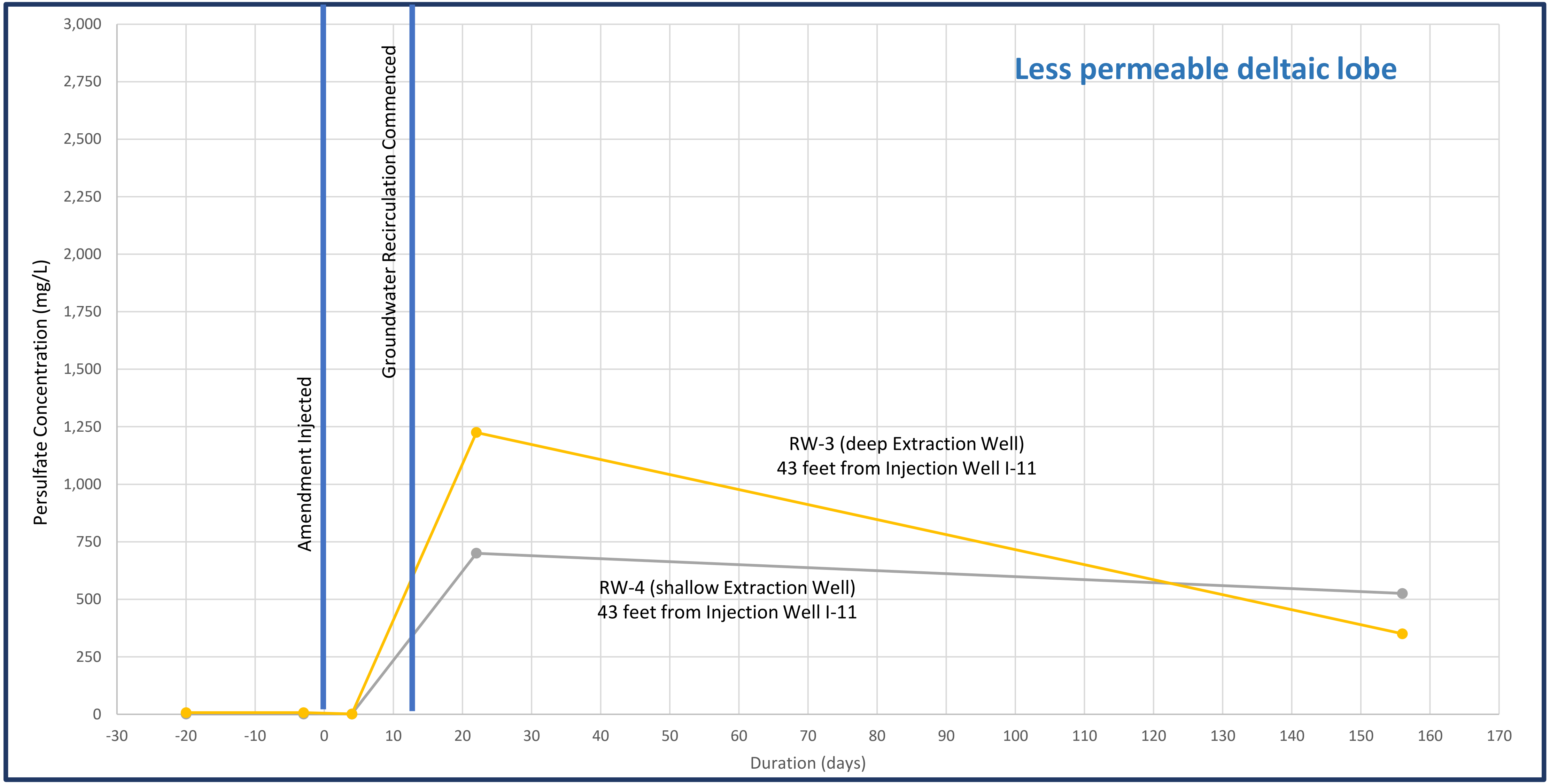


Recirculation Compared to Direct Push Injection

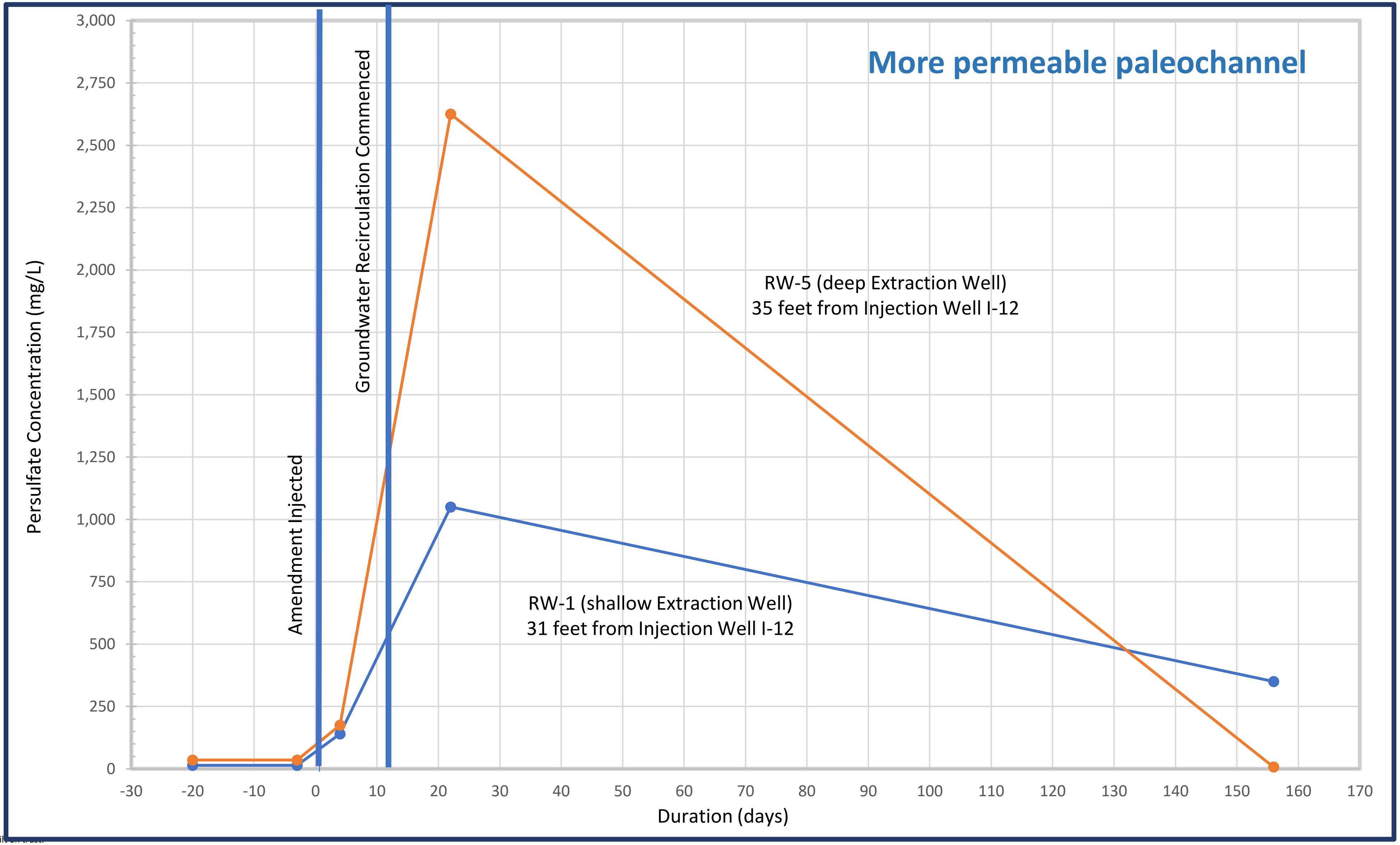
Geotechnical Environmental Ecological Water Construction Management

Injection Parameters	Direct Push Injections	Injection Wells
Vertical Intervals	• 10 to 15 feet	• 10-foot shallow/deep screens in upgradient wells (10) • 15-foot screens in central injection wells (2)
Flow Rates	• 2 to 8 gallons per minute	• 7 to 10 gallons per minute
Pressures Observed	• 10 to 60 psi	• 12 to 25psi
Volume Injected	• 80 to 125 gallons per foot or 800 to 1,875 gallons per point	• Upgradient - 300 gallons per foot / 3,000 gallons per well • Central - 430 gallons per foot / 6,450 gallons per point
Measured ROI	• 12 to 18 feet	• 20 to 30 feet

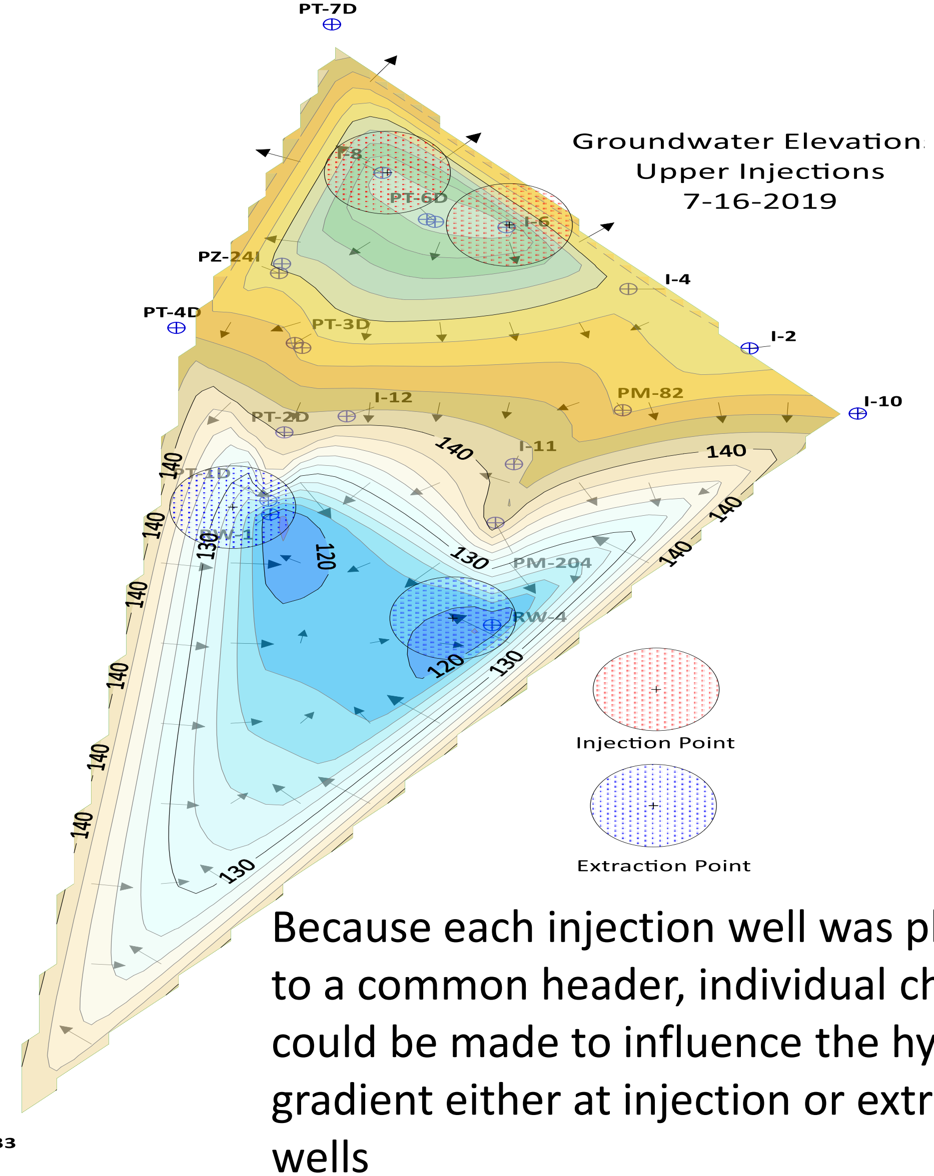
Persulfate Arrival Time – Eastern Extraction Wells

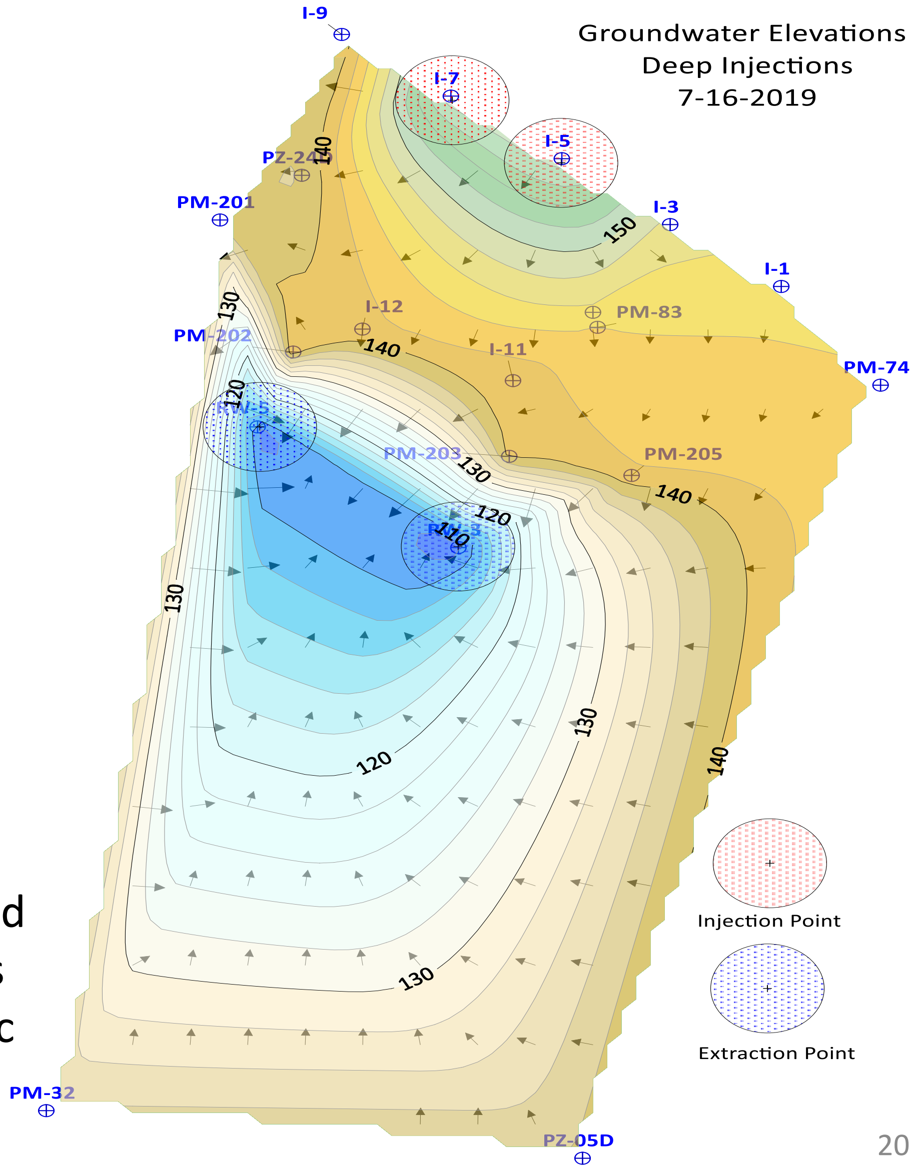


Persulfate Arrival Time – Western Extraction Wells



Hydraulic Gradient Changes (Shallow & Deep)





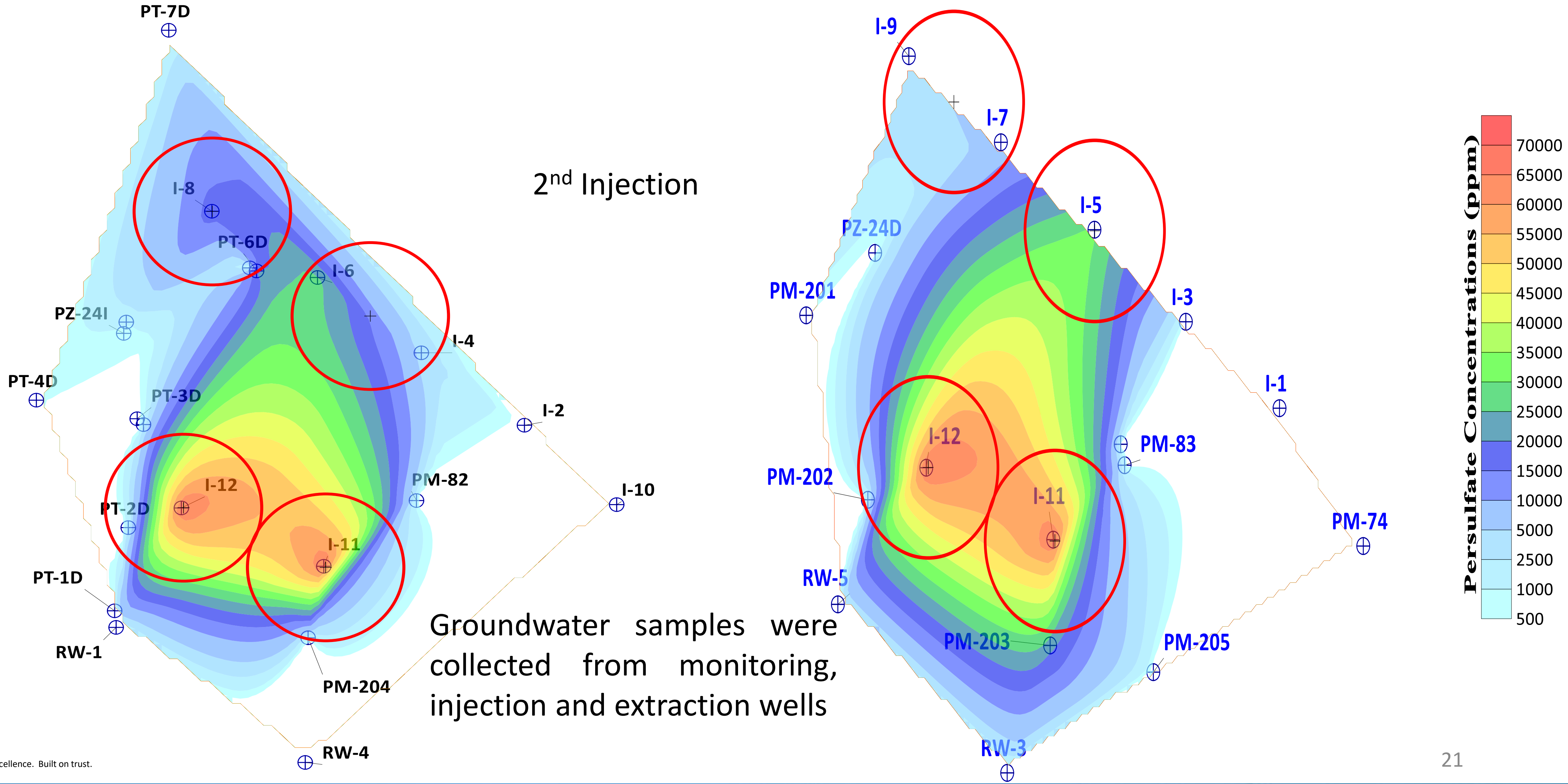
Because each injection well was plumbed to a common header, individual changes could be made to influence the hydraulic gradient either at injection or extraction wells

Persulfate Concentration Distribution (Shallow & Deep)

Geotechnical Environmental Ecological Water Construction Management

Shallow Injection Zone

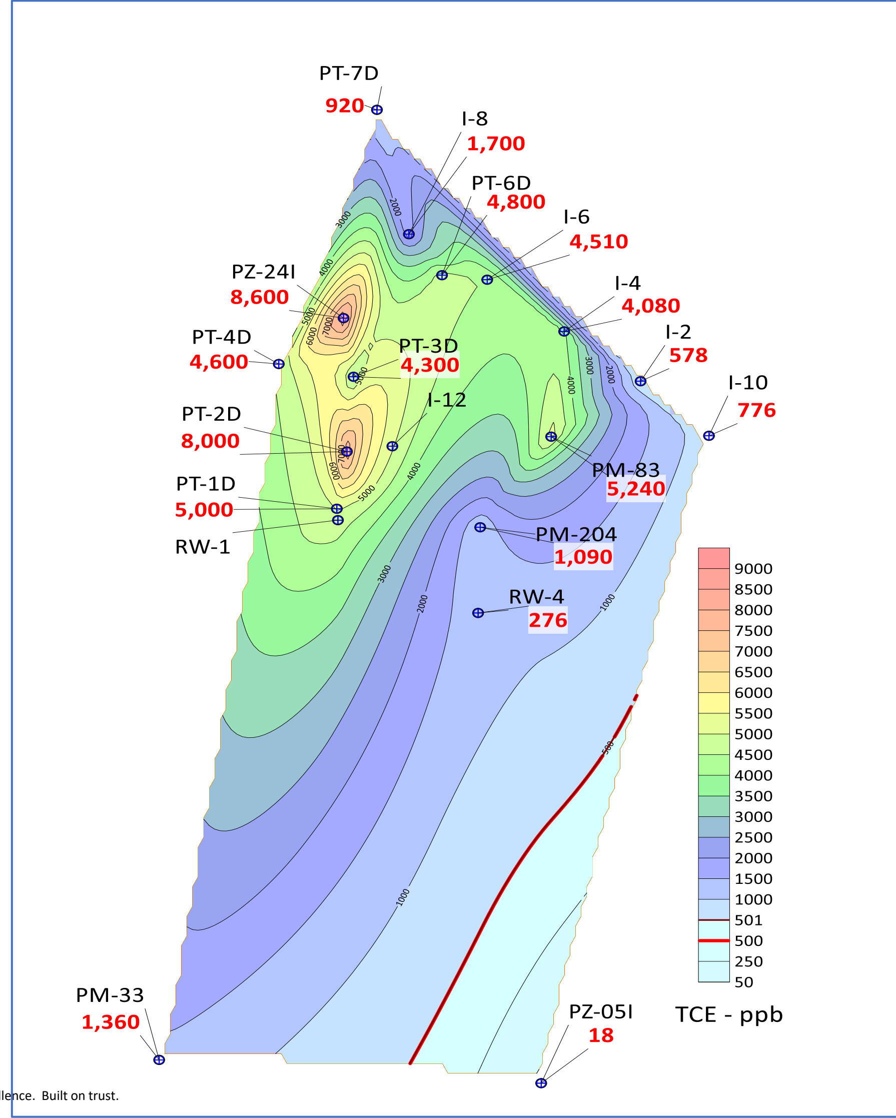
Deep Injection Zone



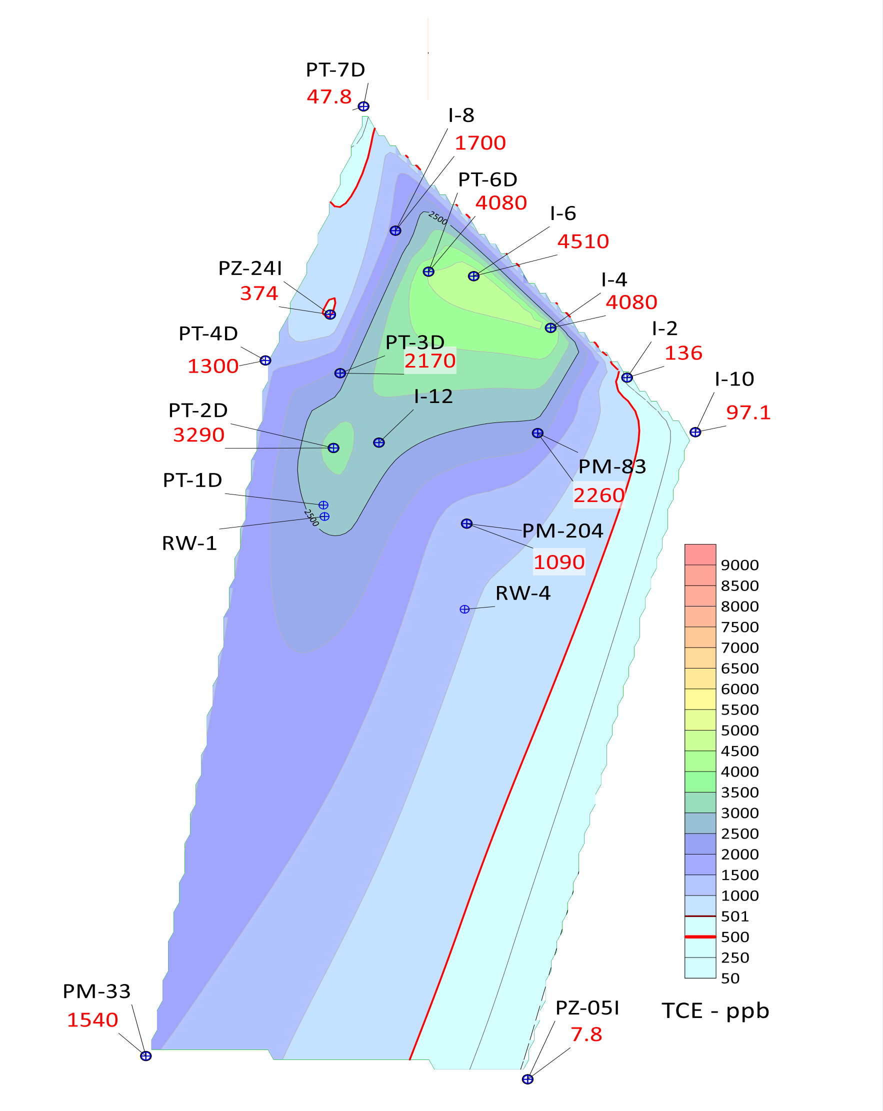
Groundwater samples were collected from monitoring, injection and extraction wells

TCE Concentrations (Shallow Wells)

Maximum Historic Concentrations

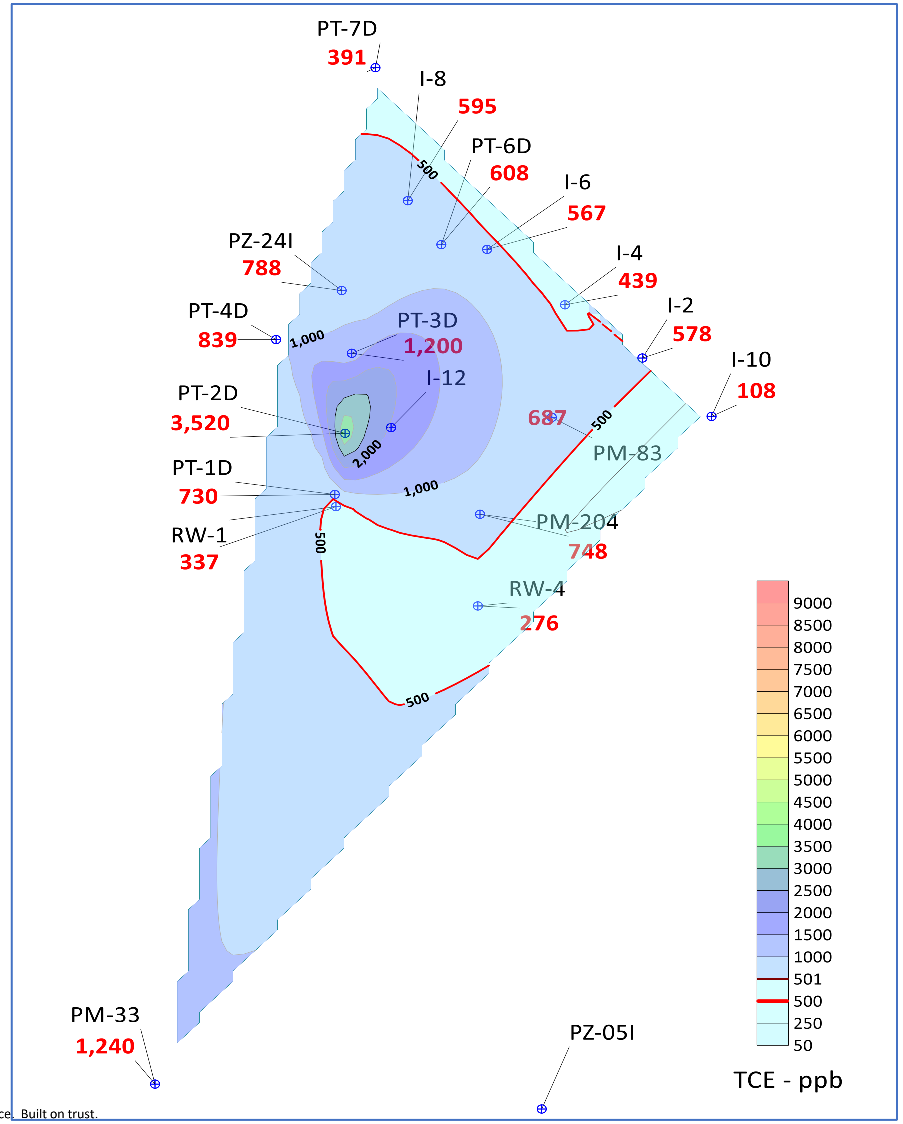


Pre-Recirculation Concentrations

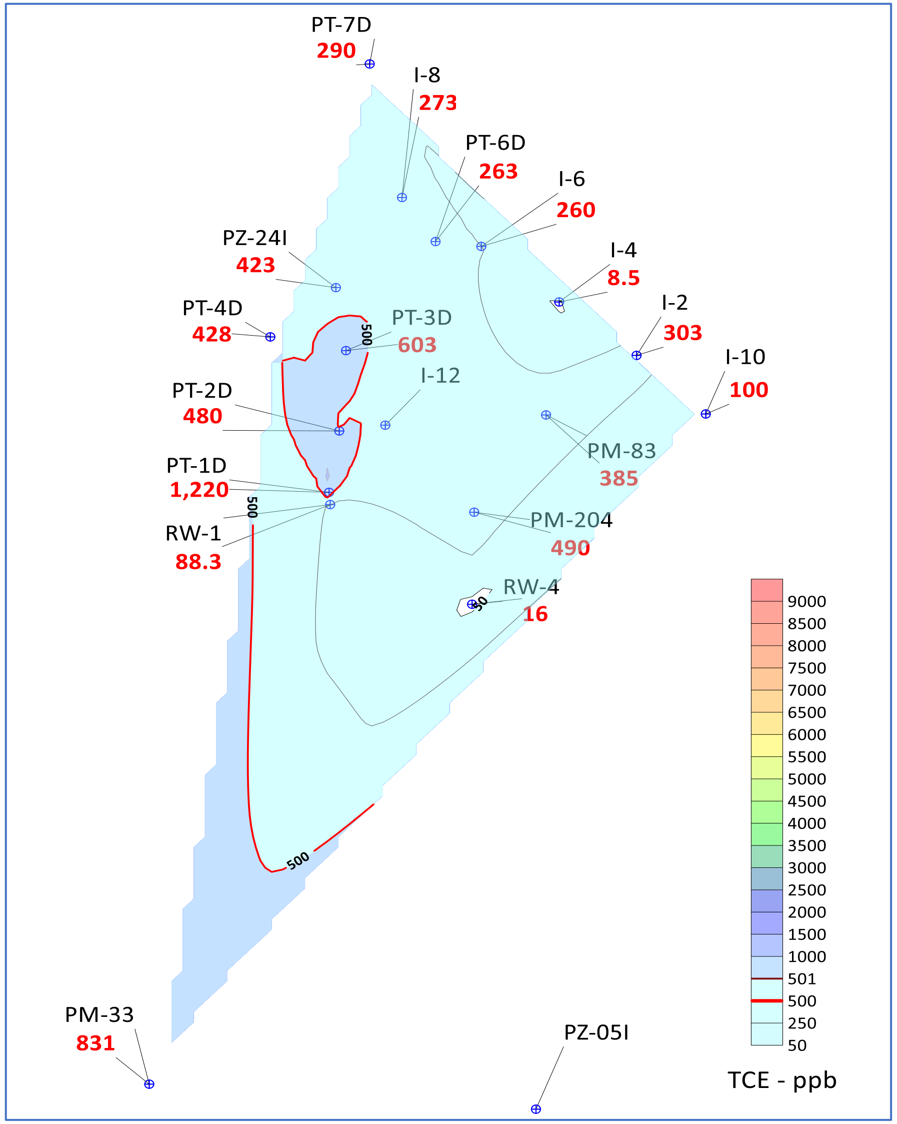


TCE Concentrations - Post-Recirculation (Shallow Wells)

14 Months: Post-Recirculation Concentrations

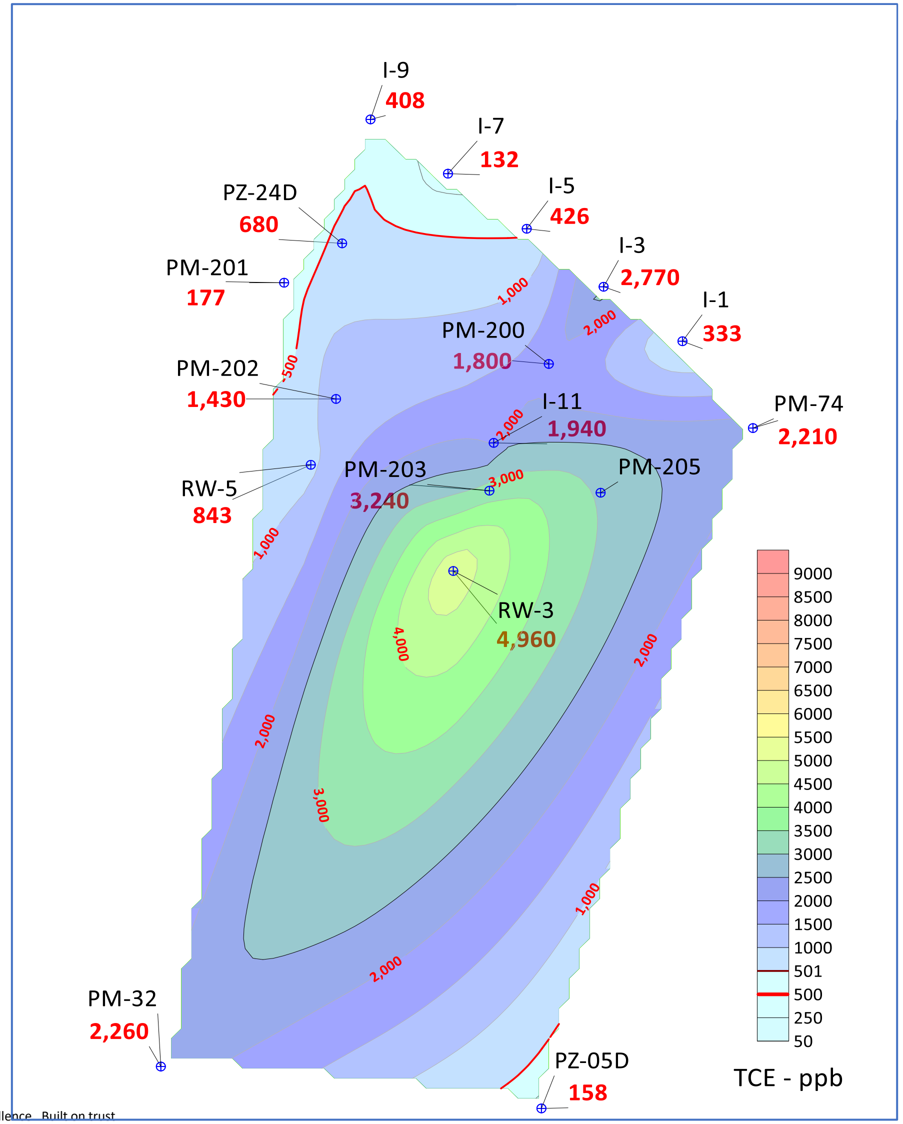


26 Months: Post-Recirculation Concentrations

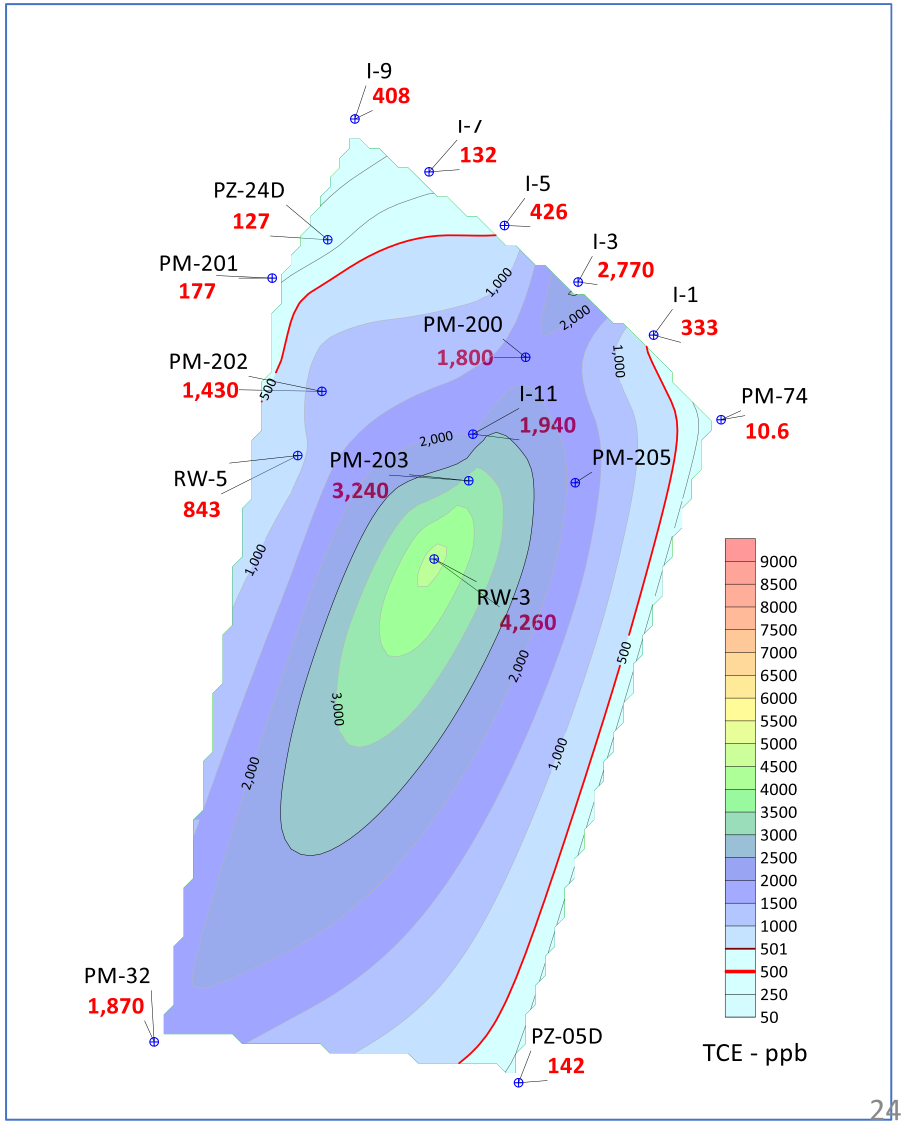


TCE Concentrations (Deep Wells)

Maximum Historic Concentrations

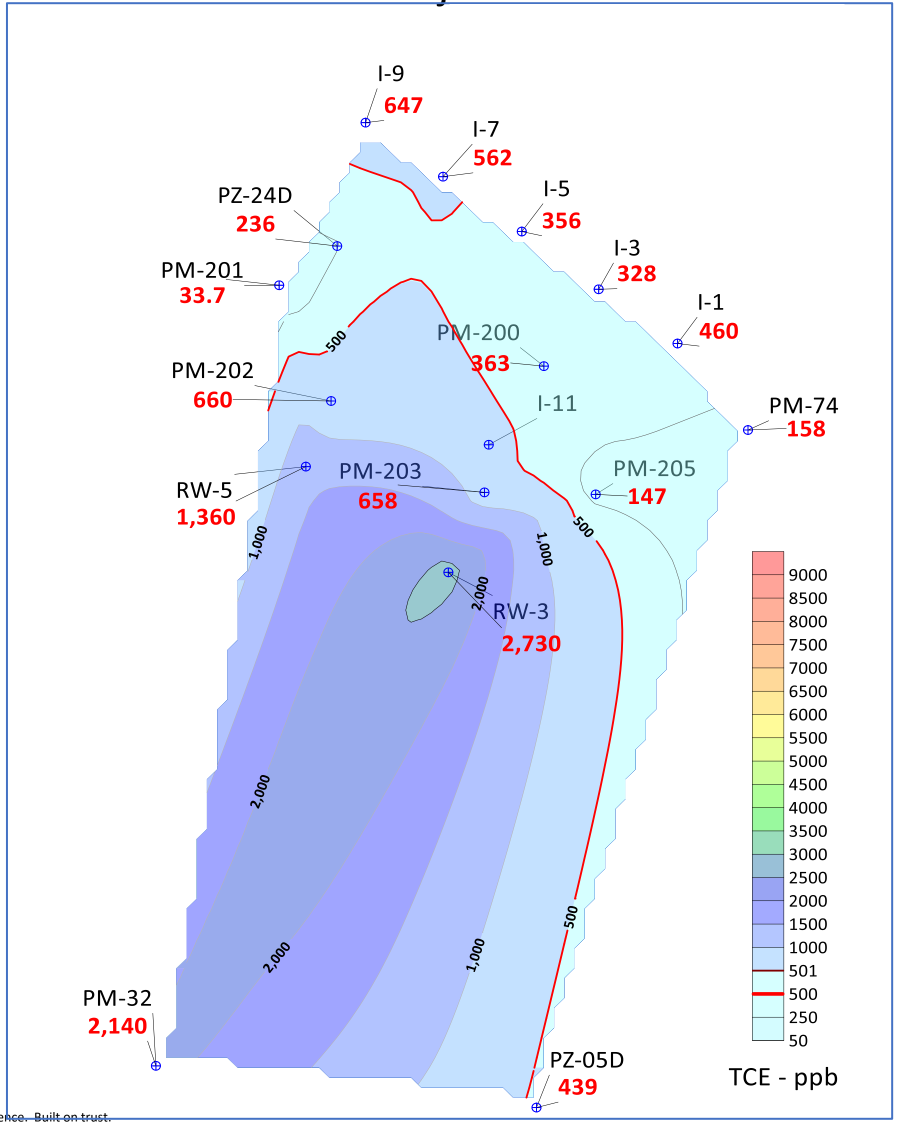


Pre-Recirculation Concentrations

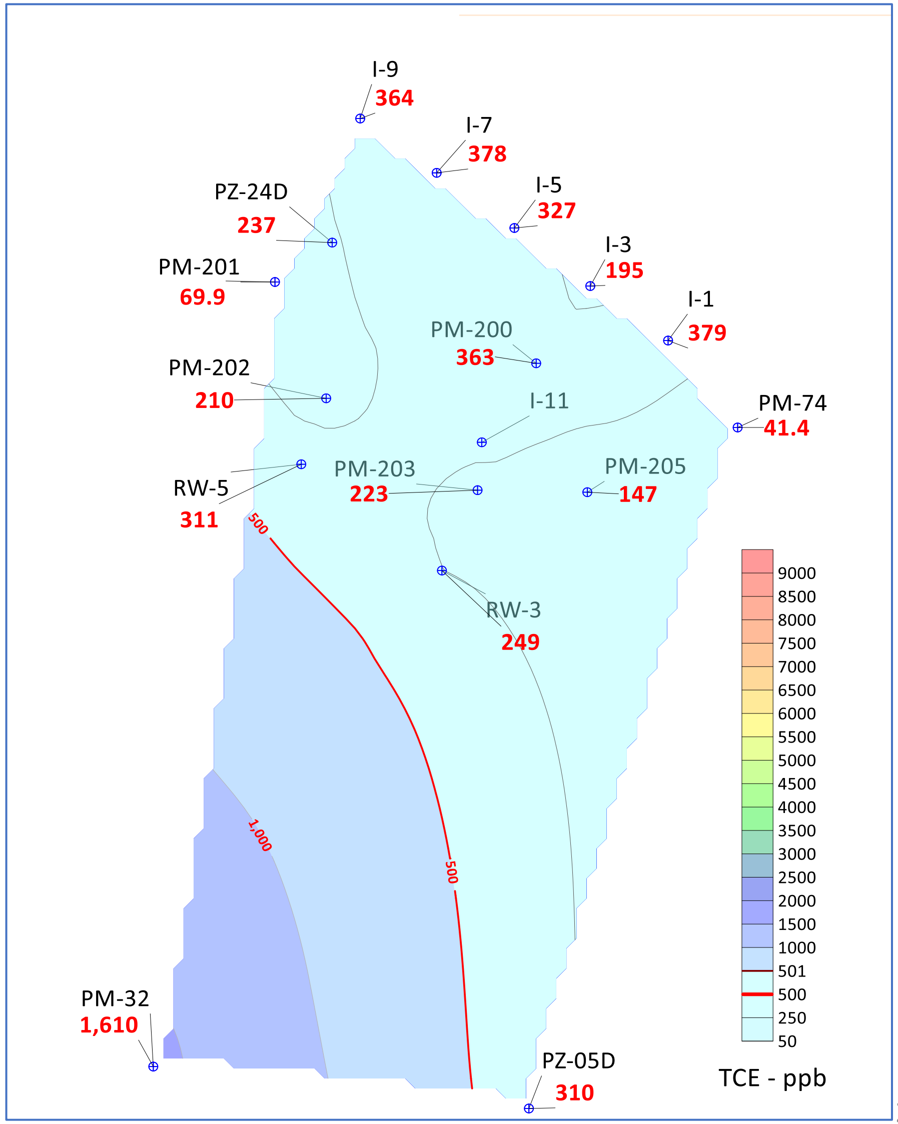


TCE Concentrations - Post-Recirculation (Deep Wells)

14 Months: Post-Injection Concentrations



26 Months: Post-Recirculation Concentrations



Hydraulic Changes as a result of Recirculation

Parameters	Baseline	Recirculation
Hydraulic Conductivity	2.5 ft/d	2.5 ft/d
Hydraulic Gradient	0.0175 ft/ft	0.33 ft/ft
Porosity	0.25	0.25
Seepage Velocity	0.18 ft/d (64 ft/yr)	3.3 ft/d (1,204 ft/yr)
100-foot Travel Time	570 days (19.0 months)	30 days (1.0 months)
Number of pore volumes per year	0.63 volumes	12 volumes
Total Volume – 24 months	525,000 gallons	6,000,000 gallons

Lessons Learned

A. Good site characterization is critical to any remedial action
   i. Look at non-target parameters (TOC, NOD, others)
   ii. Consider additional Remedial Design Characterization (RDC)

B. Cost and benefits of various alternative

C. Know the limitation of various (toolbox) remedial approaches

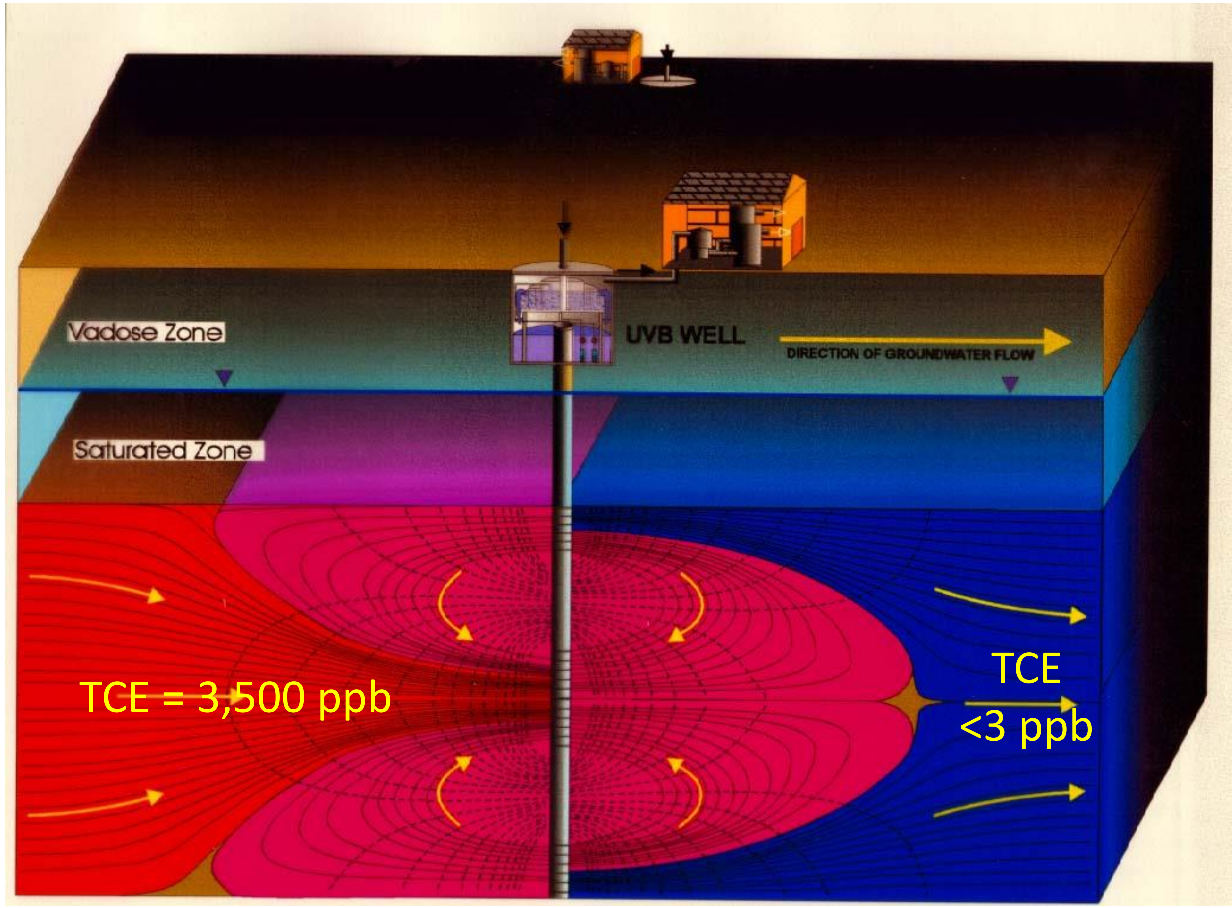
D. Collect sufficient data during the remediation – changes might be required
   i. During the injection (field design changes many be required)
   ii. During the recirculation (vary injection and extraction flow rates)

E. Field Hach kits are valuable for inexpensively field validation tools

F. Monitor performance
   i. Amendment distribution
   ii. Groundwater flow

Questions

GEOTECHNICAL ENVIRONMENTAL ECOLOGICAL WATER CONSTRUCTION MANAGEMENT



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Benjamin Rach
GZA GeoEnvironmental, Inc.

Glastonbury, CT

Richard.Desrosiers@gza.com
860-965-1117 (cell)