

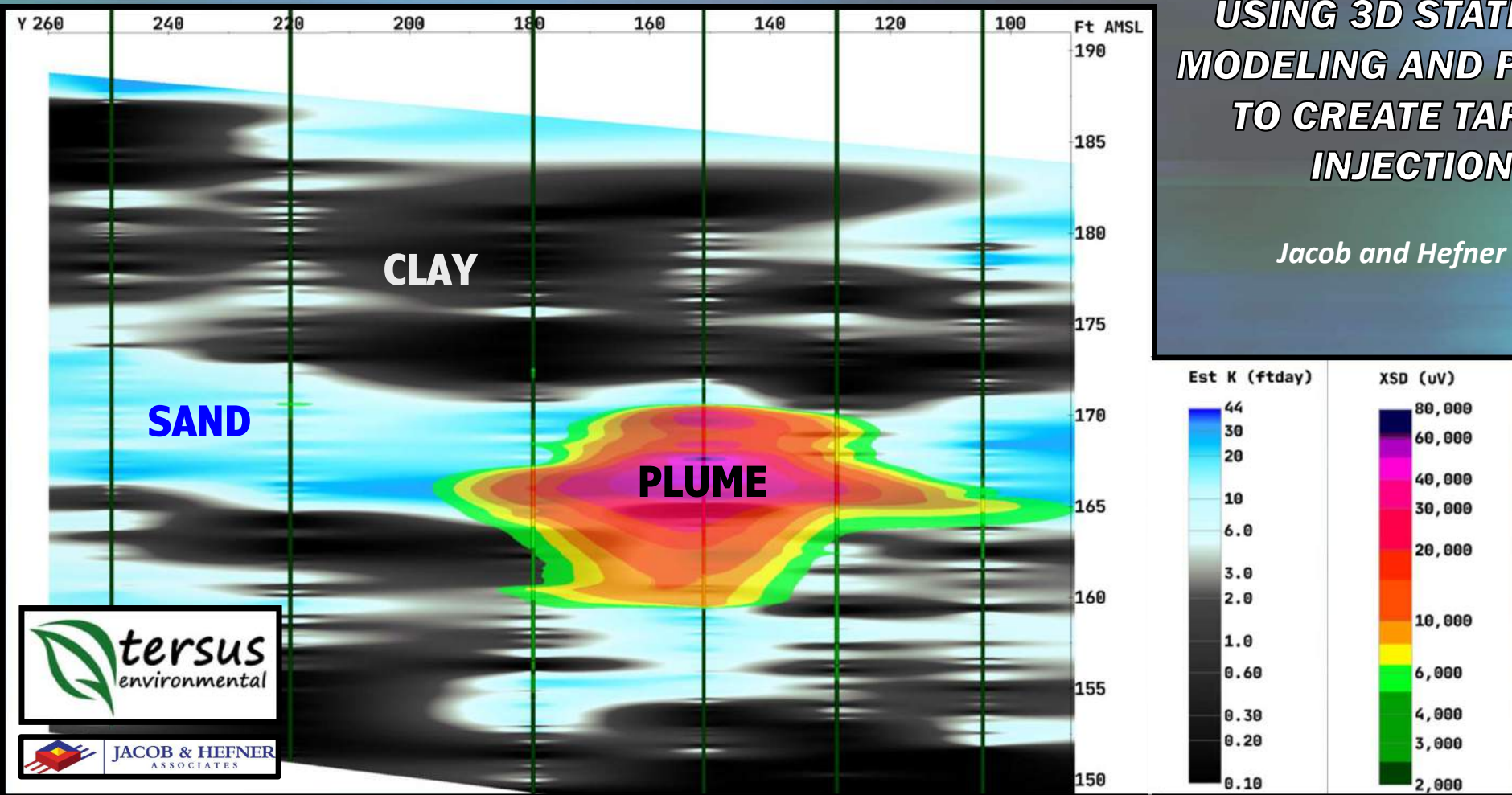
DON'T INJECT BLIND

June 7, 2023

**USING 3D STATISTICAL
MODELING AND PYTHON
TO CREATE TARGETED
INJECTION PLANS**

Jim Depa

Jacob and Hefner Associates



In Situ Treatment Remedies – What's the Trend?

Figure 5: Selection Trends for Decision Documents with Groundwater Remedies (FY 1981-2020)

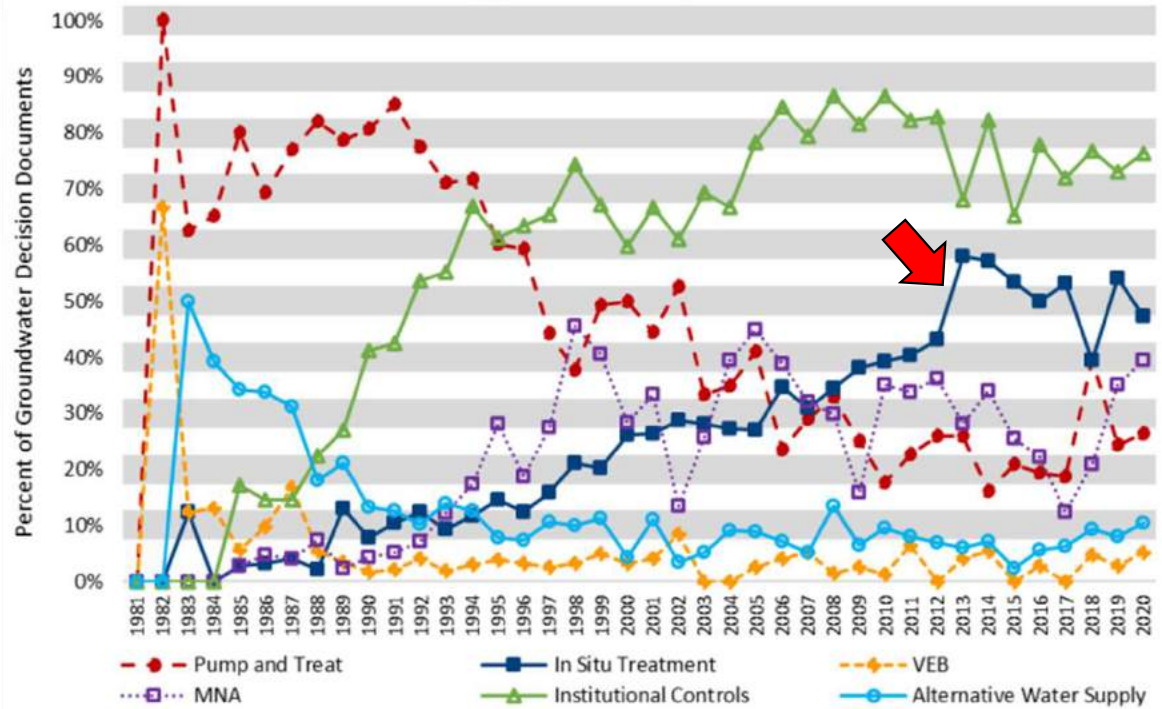


Table 6: Groundwater Remedies Selected Most Frequently in Recent Decision Documents (FY 2018-2020)

Selected Remedy	Number	Percent
Treatment	79	67%
In Situ Treatment	55	47%
Bioremediation	29	25%
Chemical Treatment	19	16%
Thermal Treatment	11	9%
Air Sparging	5	4%
Permeable Reactive Barrier	3	3%
Multi-phase Extraction	3	3%
Solidification/Stabilization	2	2%
Vapor Extraction	2	2%
Ex Situ Treatment (P&T)	36	31%
Vertical Engineered Barrier	5	4%
Monitored Natural Attenuation	37	31%
Institutional Controls	89	75%
Alternative Water Supply	11	9%
Other	6	5%

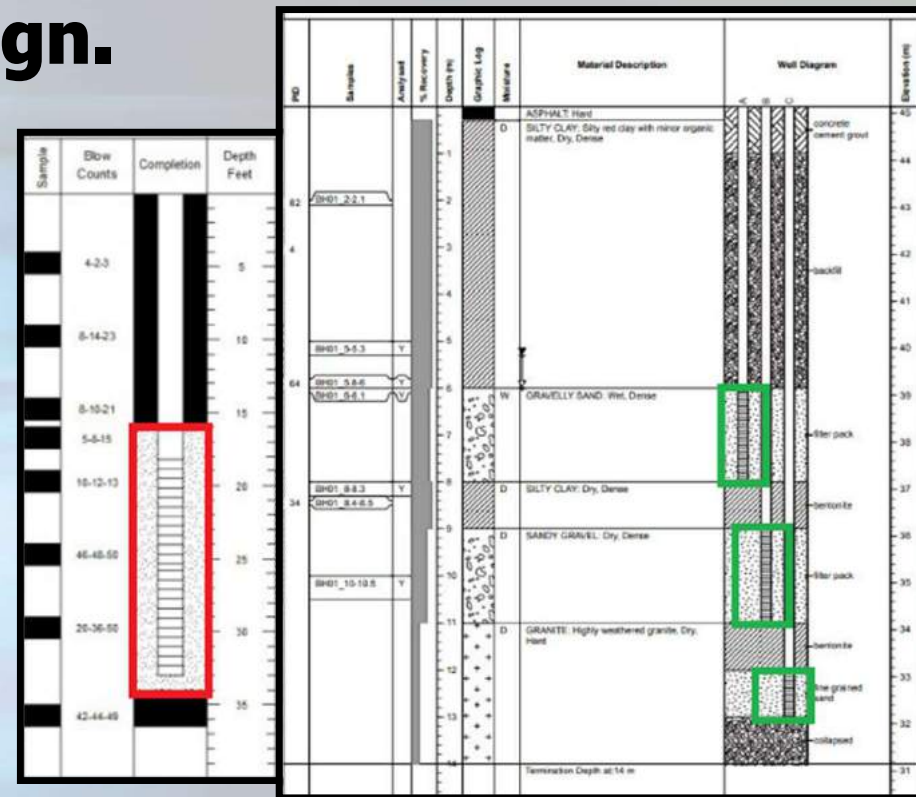
• Percentages based on 118 groundwater decision documents issued in FYs 2018 through 2020.

Source: Superfund Remedy Report, US EPA, January 2023

The PROBLEM

Many injection strategies often rely on monitoring well data for treatment design.

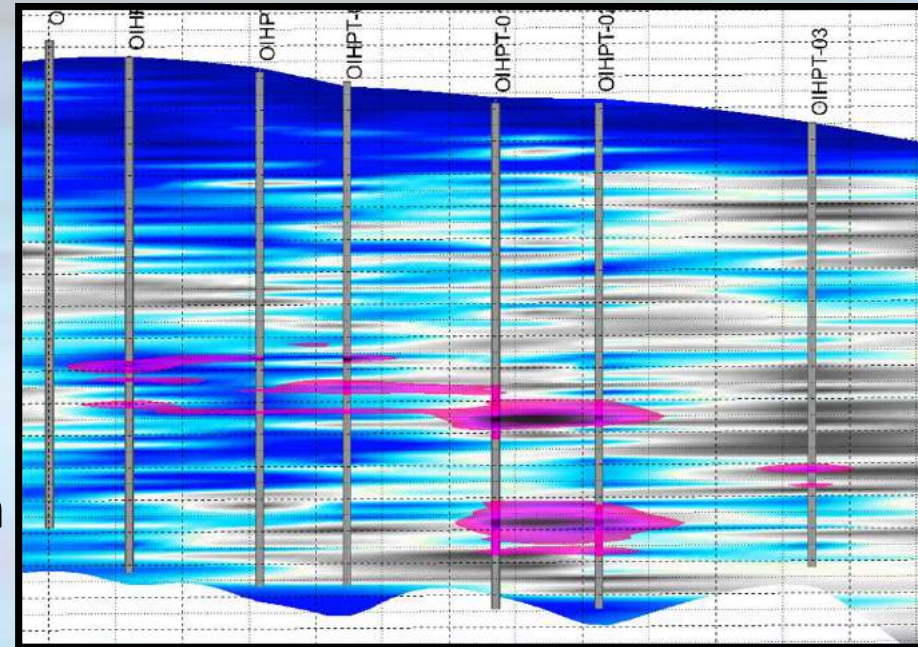
- Typically, limited data
- No verticality to the data (unless well nests exist)
- No geologic definition of impacts
- Injections can occur in **suboptimal** locations and at the **incorrect** depths



The SOLUTION

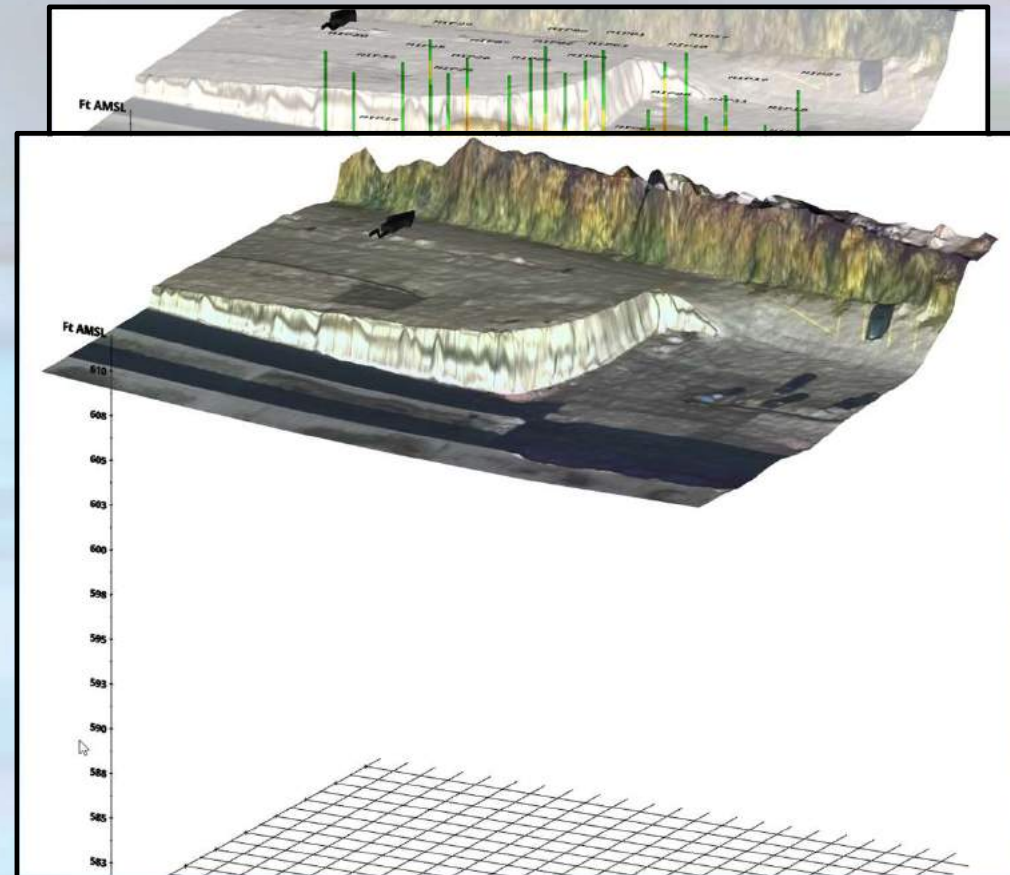
Create targeted injection plans by combining high resolution data and 3D statistical modeling technology

- Tens of thousands of data points
- Excellent vertical data distribution
- Geologic definition of contamination (storage zones vs. transport zones)
- Injection locations, depths, and injection pressures can be **OPTIMIZED**

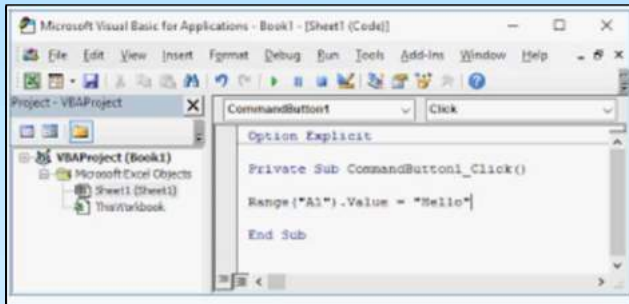


3D Visualization Technology – **What's Changed?**

	Older Technology	Recent Technology
Types of Deliverables	Static <i>(Screenshots)</i>	Interactive <i>(Animations & Web Scenes)</i>
Number of Data Points	Tens to Hundreds <i>(Analytical Data)</i>	Thousands to Millions <i>(HRSC & LiDAR)</i>
Modeling Run Times	Minutes to Hours <i>(Antiquated Hardware)</i>	Seconds to Minutes <i>(Moore's Law)</i>
Data Formatting Times	Days To Weeks <i>(Manual)</i>	Hours <i>(Automation)</i>

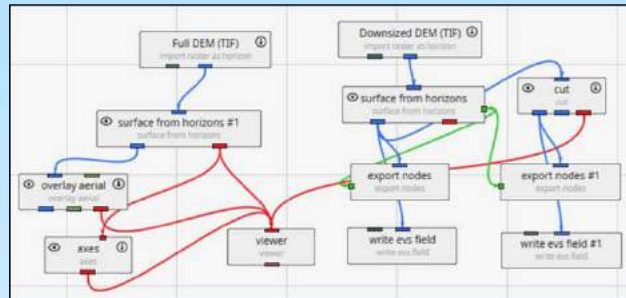


Automation Technology – What are the Programs?



Macros in Excel

*Compile Data and Build Input Files
Efficiently*



EVS by C-Tech

*Process and Visualize Datasets
Repeatably*

```
#Set for XSD  
#32 images  
#SET: 1) Ground - 2)Max Z (top of response) - 3) Interval (in feet)  
Ground=58.5  
zMax=55.5  
int=0.5  
  
evs.set_module('slice', 'Slice Settings', 'Z Position', zMax)  
Zposition = evs.get_module('slice', 'Slice Settings', 'Z Position')  
ZActual = Zposition  
titleString = "Slice Position: " + str(Zposition) + " ft AMSL"  
Depth=Ground-zMax  
titleStringb="Approx. " + str(Depth) + " ft in Depth"  
evs.set_module('titles', 'Properties', 'Title', titleString)  
evs.set_module('titles2', 'Properties', 'Title', titleStringb)  
evs.set_module('viewer', 'Export Image', 'Image Filename', 'C:\Users\jdepai\OneDrive - jacobandhefner.com\Desk
```



Python Scripting

*Create Data Deliverables
Automatically*



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Data Collection – What are the Drilling Tools?



**Membrane Interface Probe
(MIP)**



**Groundwater Profiling
Tool**



**Optical Image Profiler
(OIP)**

Hydraulic Profiling Data Can Be Collected Simultaneously

Scenario #1: Membrane Interface Probe (MIP)



**Membrane Interface Probe
(MIP)**

Description:

As the tool is advanced, a heater block volatilizes contaminants in both soil and groundwater. Contaminants pass through the membrane and are transported to the surface by an inert carrier gas to be analyzed by a series of detectors, typically a PID, FID, and XSD (halogen-specific detector).

Applications:

Chlorinated Solvents (TCE, PCE, Vinyl Chloride)

Hydrocarbons (Gasoline and Diesel)

Most Volatile Contaminants in Soil or Groundwater (500 ppb to 10,000 ppm)

Not For:

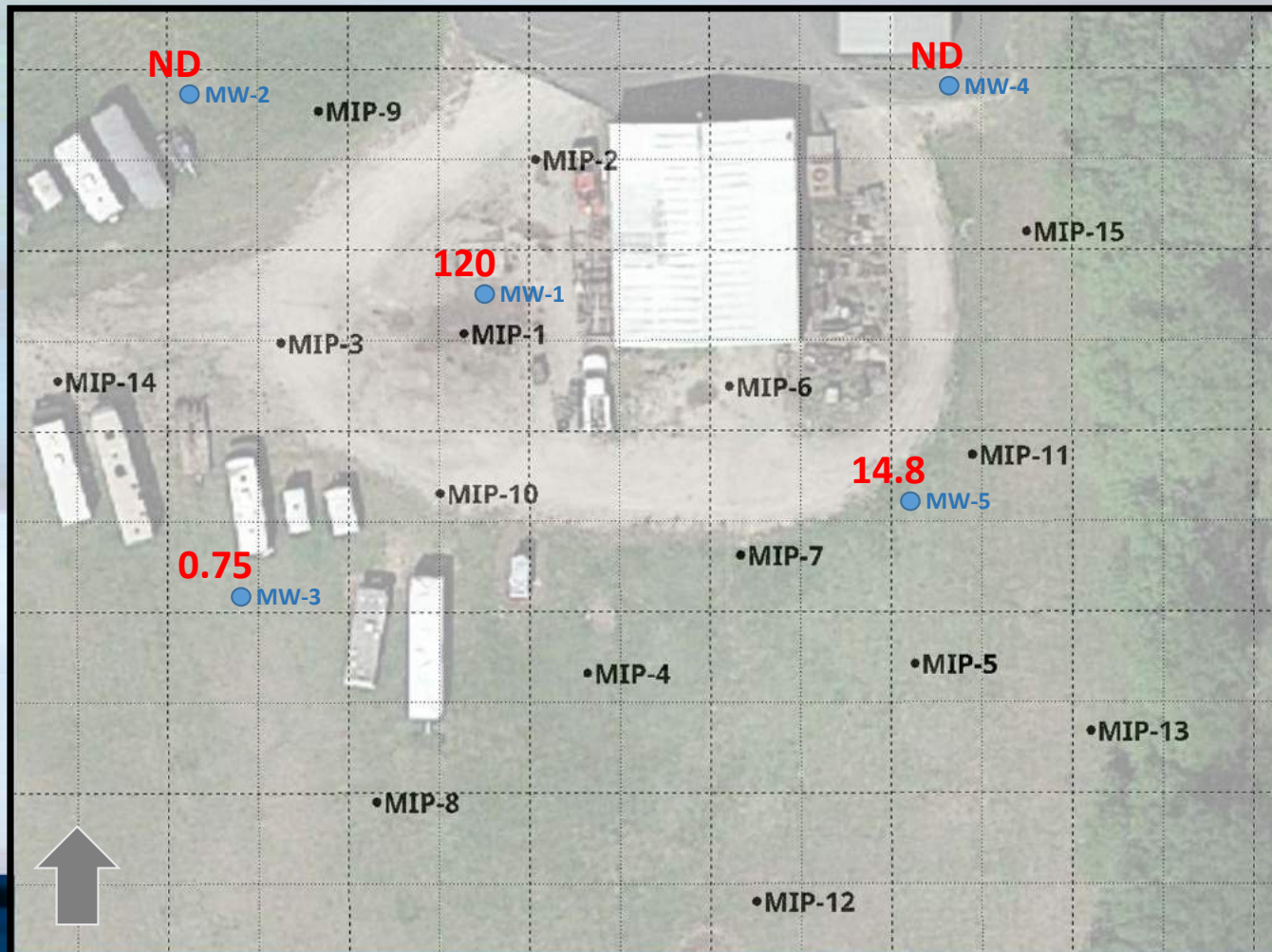
PFOA or PFOS

Metals or other Non-Volatile Contaminants

Free Product (with Caution)



Scenario #1: Membrane Interface Probe (MIP) Data



Drum Storage Facility

TCE in Groundwater

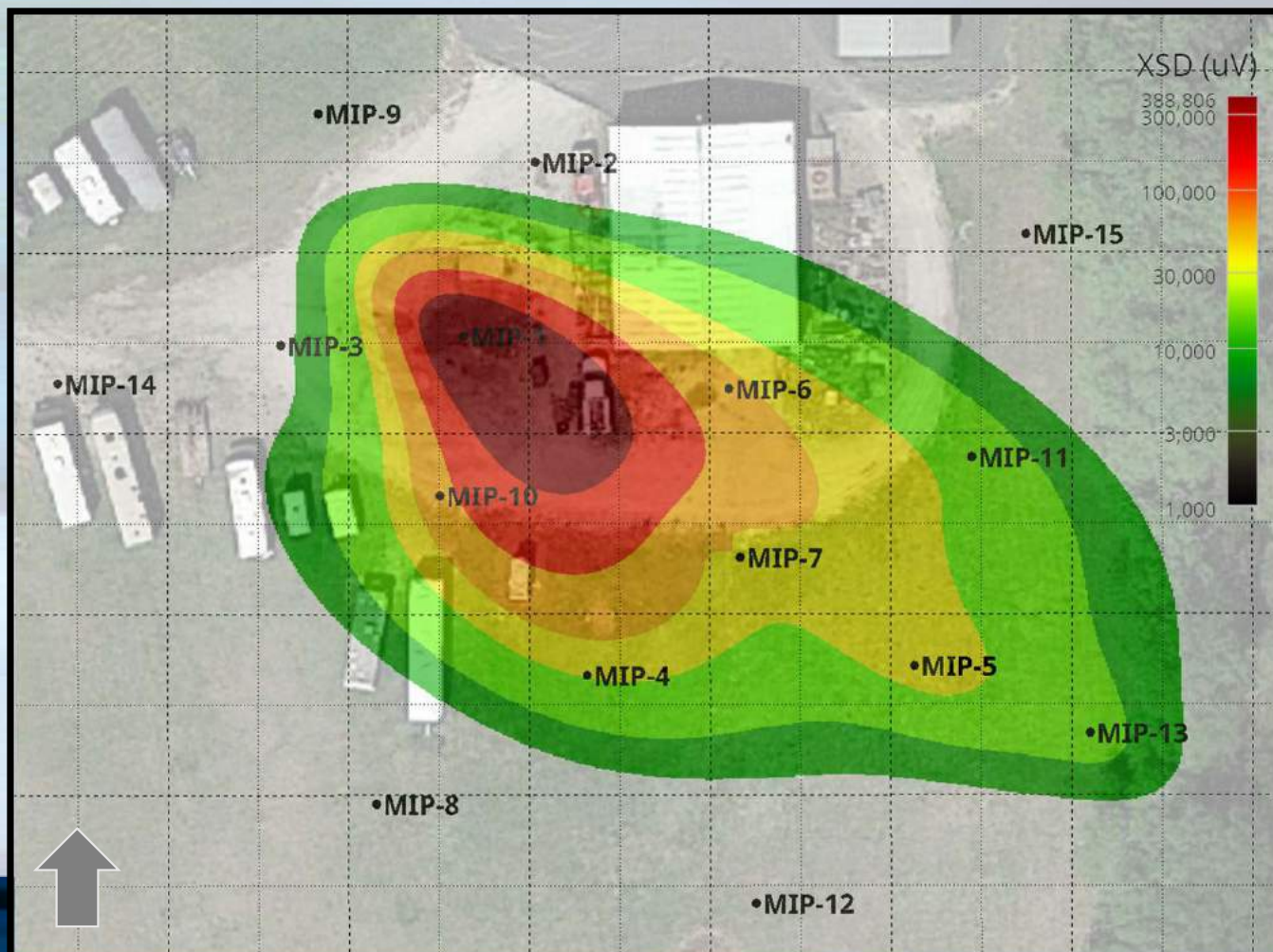
- Five (5) Groundwater Monitoring Wells
- Fifteen (15) Membrane Interface Probe (MIP) Borings

TCE in Groundwater
mg/L

Membrane Interface Probe (MIP) Data – 3D Animation



Membrane Interface Probe (MIP) Data

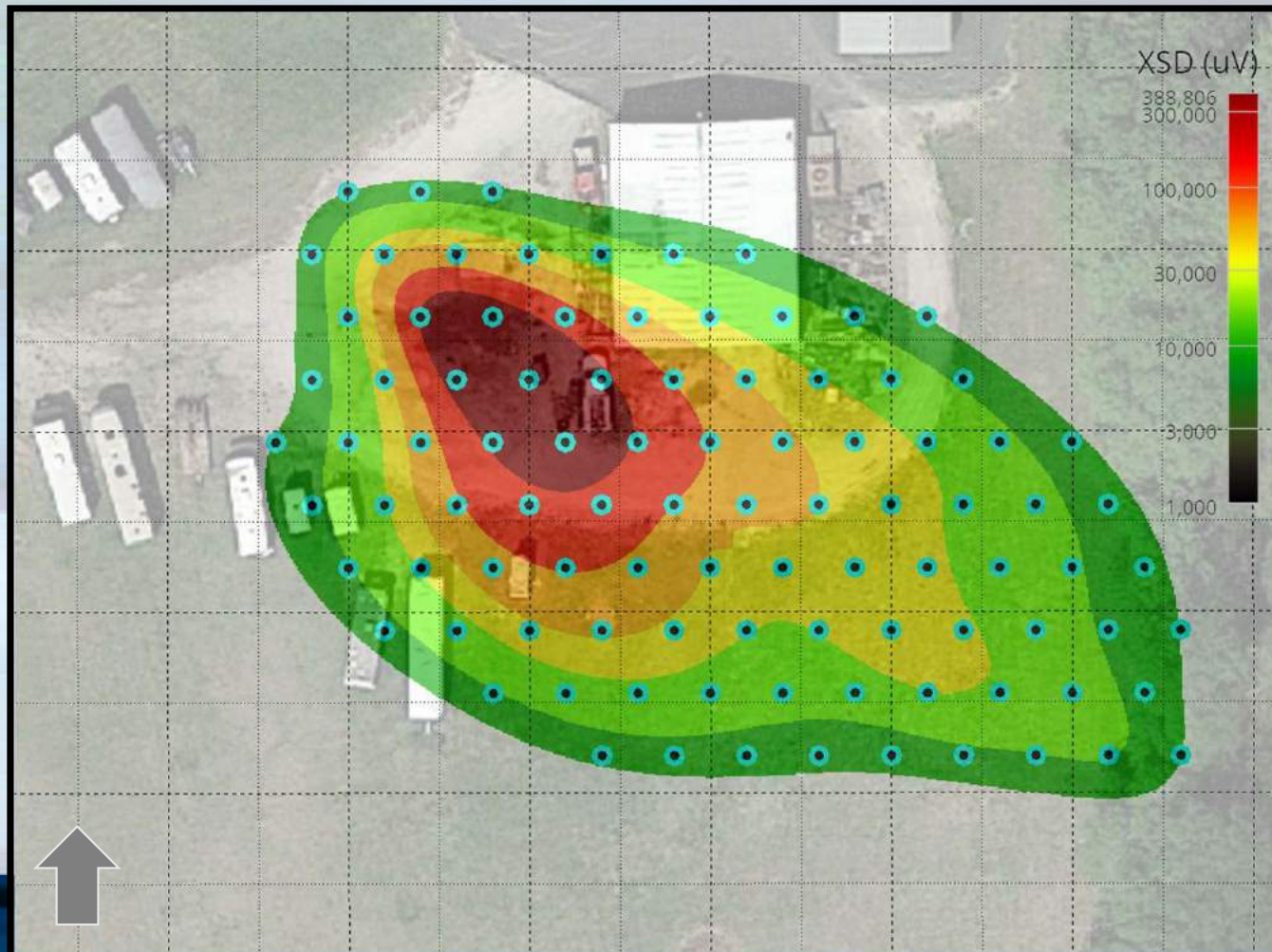


Footprint from the Halogen-Specific Detector (XSD)

Approx. Correlation:
10,000 uV = 1 mg/L Total
CVOCs

Color	XSD Result (uV)	Approx. TCE Conc. (mg/L)
Dark Green	6,000	0.6
Green	10,000	1
Yellow	25,000	2.5
Orange	50,000	5
Red	75,000	7.5
Dark Red	150,000	15

Membrane Interface Probe (MIP) Data



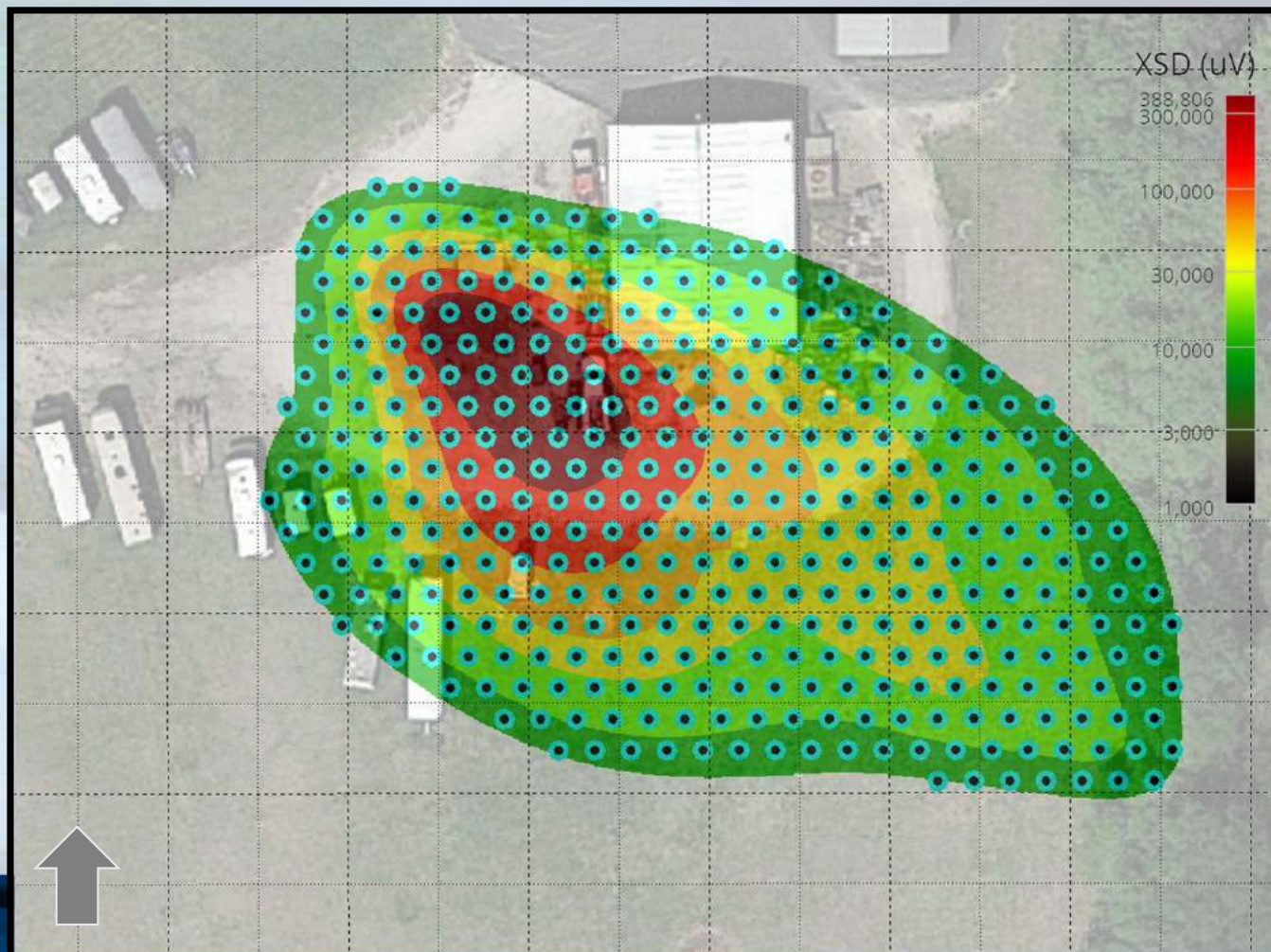
Option #1

Target: 6,000 uV
(Approx. 0.6 mg/L of TCE)

Spacing: 20'

Injection Pts: 96

Membrane Interface Probe (MIP) Data



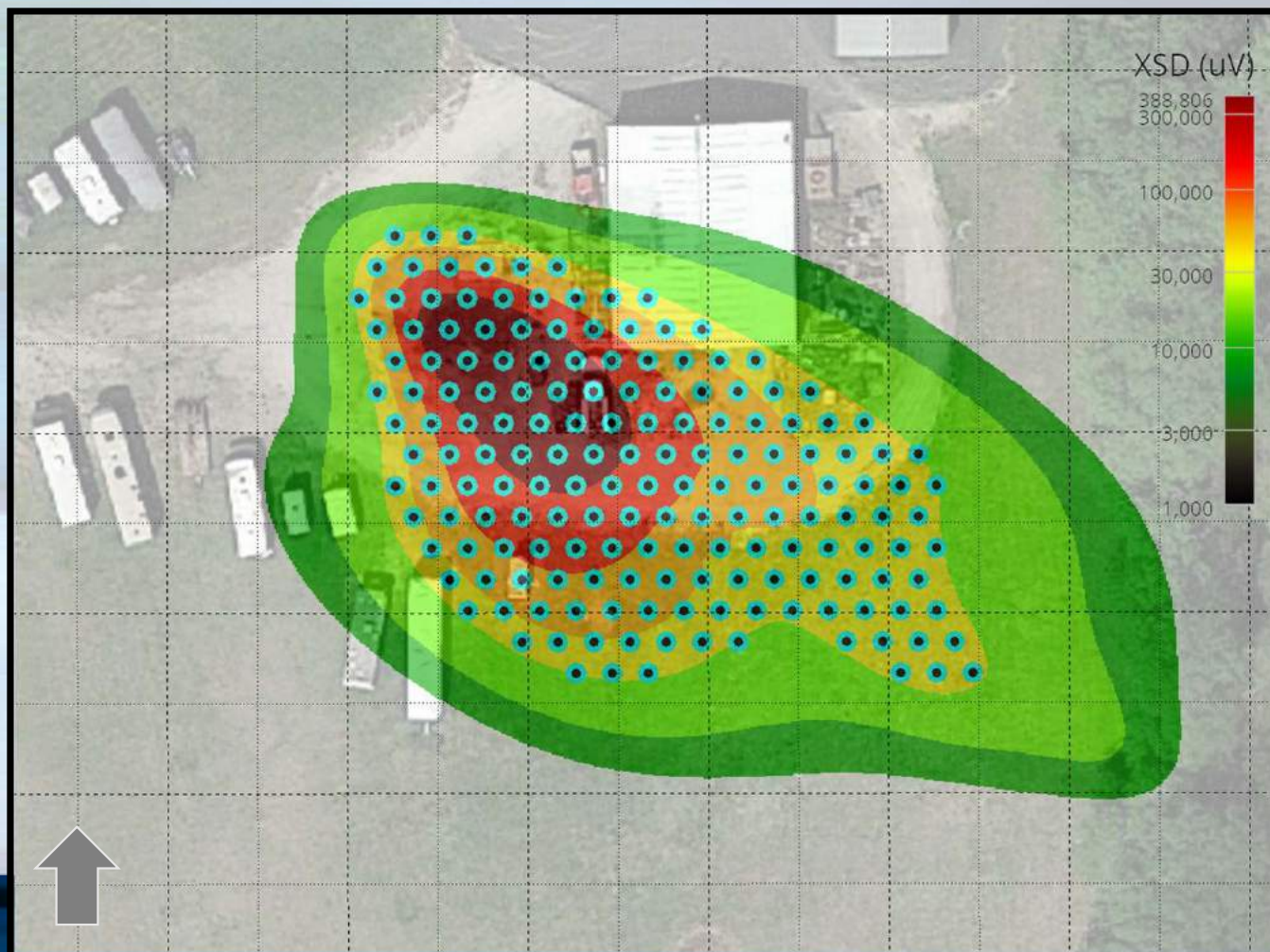
Option #2

Target: 6,000 uV
(Approx. 0.6 mg/L of TCE)

Spacing: 10'

Injection Pts: 371

Membrane Interface Probe (MIP) Data



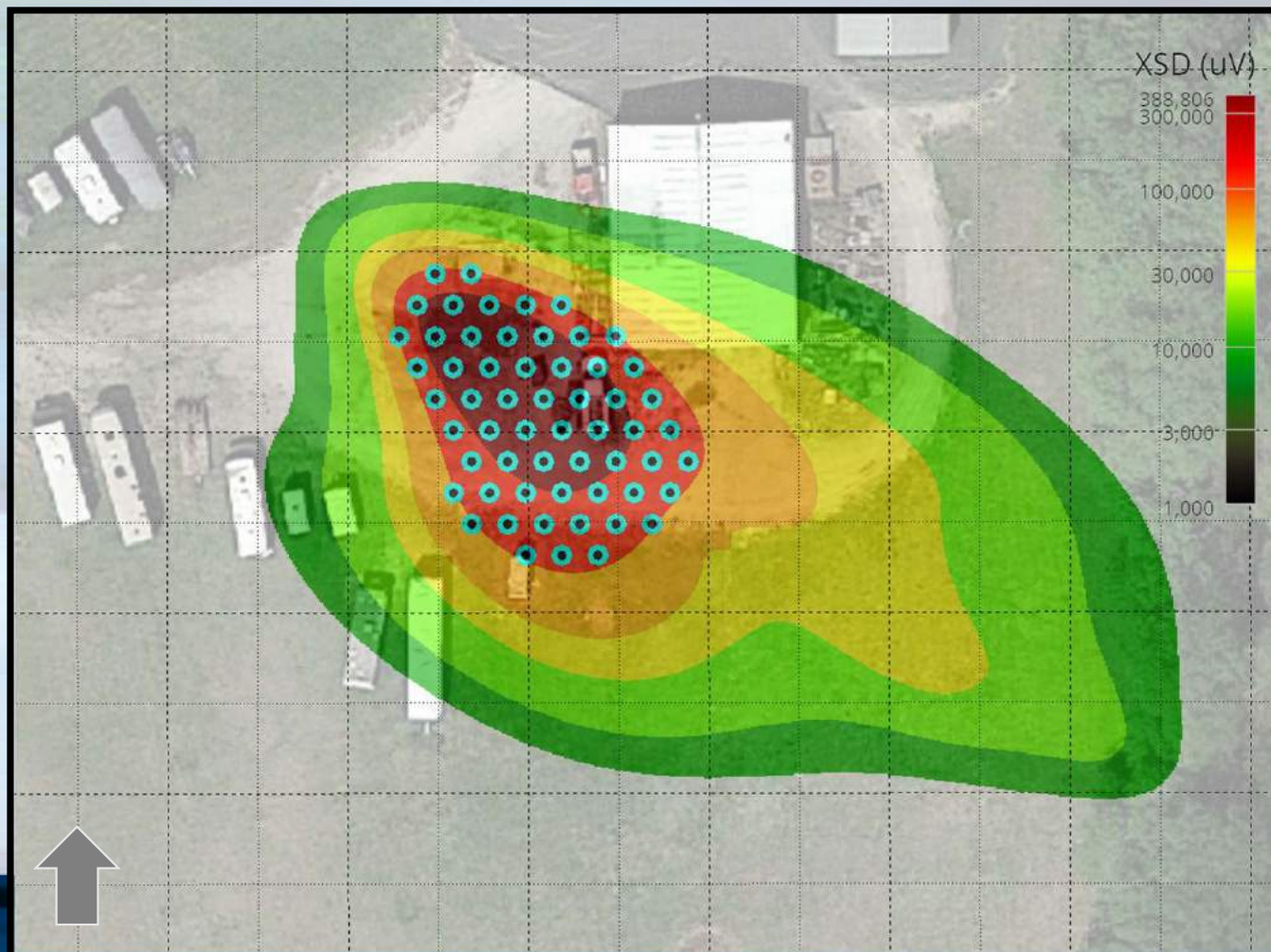
Option #3

Target: 25,000 μV
(Approx. 2.5 mg/L of TCE)

Spacing: 10'

Injection Pts: 172

Membrane Interface Probe (MIP) Data



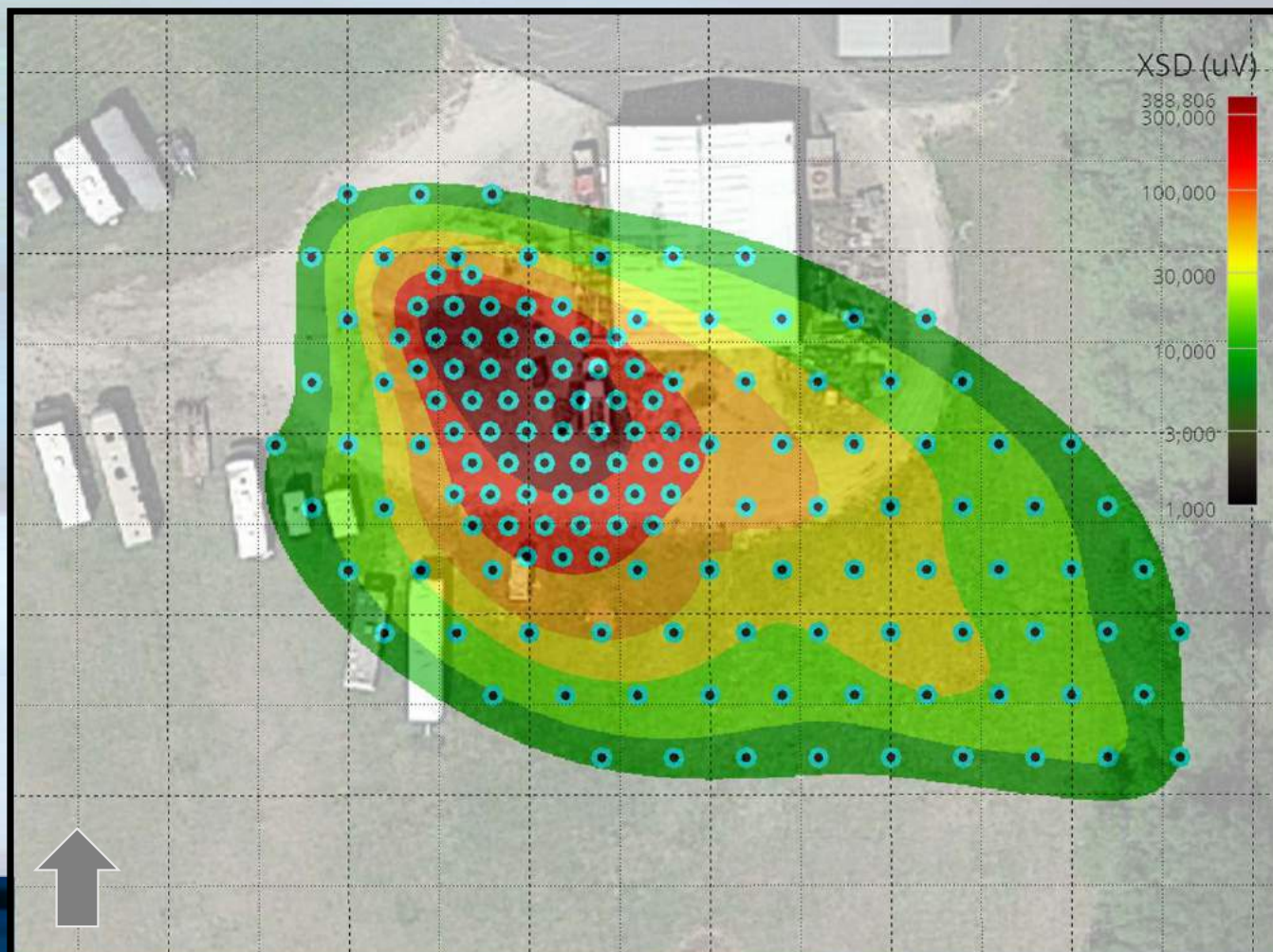
Option #4

Target: 75,000 μV
(Approx. 7.5 mg/L of TCE)

Spacing: 10'

Injection Pts: 58

Membrane Interface Probe (MIP) Data



Option #5

Targets: 6,000 and 75,000 μV
(Approx. 0.6 and 7.5 mg/L of TCE)

Spacing: 10' and 20'

Injection Pts: 140

Membrane Interface Probe (MIP) Data – 3D Animation of Injection Options



Scenario #1: Injection Plan for Implementation in the Field

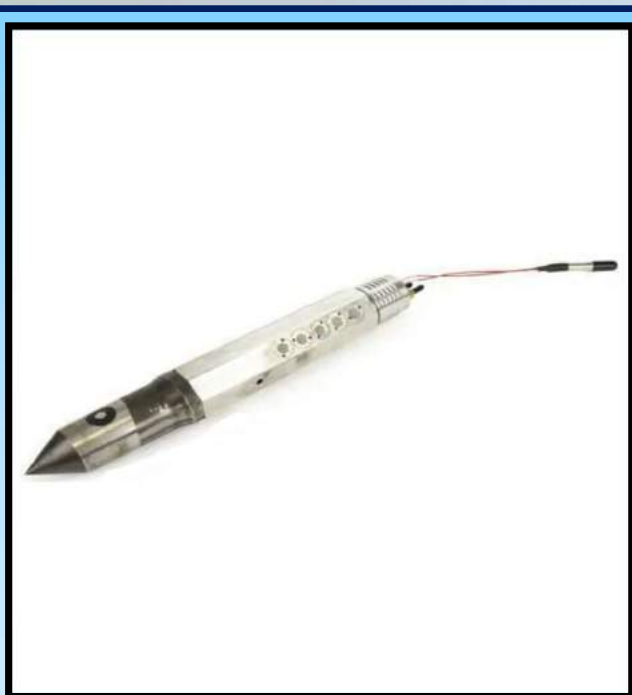
Well ID	X (Easting)	Y (Northing)	Est. Ground (ft MSL)	Treatment Depth (ft MSL)		Treatment Elev (ft MSL)		Treatment Thickness (ft)
				Top	Bottom	Top	Bottom	
406	570339.5	947604.608	611	4	8	607	603	4
407	570343.5	947604.608	611	3	9	608	602	6
408	570347.5	947604.608	611	2	11	609	600	9
409	570351.5	947604.608	611	2	14	609	597	12
410	570355.5	947604.608	611	1	14	610	597	13
411	570359.5	947604.608	611	1	14	610	597	13
412	570363.5	947604.608	610	0	13	610	597	13
413	570367.5	947604.608	610	0	13	610	597	13
414	570371.5	947604.608	610	0	14	610	596	14
415	570375.5	947604.608	610	1	14	609	596	13
416	570379.5	947604.608	610	3	14	607	596	11
506	570337.5	947601.144	611	3	9	608	602	6
507	570341.5	947601.144	611	2	11	609	600	9
508	570345.5	947601.144	611	2	13	609	598	11
509	570349.5	947601.144	611	1	15	610	596	14
510	570353.5	947601.144	611	1	16	610	595	15
511	570357.5	947601.144	611	0	15	611	596	15
512	570361.5	947601.144	611	0	15	611	596	15
513	570365.5	947601.144	611	1	15	610	596	14
514	570369.5	947601.144	611	1	15	610	596	14
515	570373.5	947601.144	611	1	15	610	596	14
516	570377.5	947601.144	611	2	15	609	596	13
601	570319.5	947597.679	611	8	12	603	599	4
602	570323.5	947597.679	611	8	12	603	599	4
605	570335.5	947597.679	611	2	10	609	601	8
606	570339.5	947597.679	611	2	11	609	600	9
607	570343.5	947597.679	611	2	12	609	599	10
608	570347.5	947597.679	611	1	17	610	594	16

Includes:

- Injection Well ID
- Injection Well Coordinates
- Ground Surface Elevation
- Injection Depths
- Injection Elevations
- Treatment Thickness



Scenario #2: Groundwater Profiling Tool



**Groundwater Profiling
Tool**

Description:

As the tool is advanced, a small amount of deionized water is continuously injected into the formation while injection pressure values are continuously recorded. Below the water table, flow can be stopped and groundwater samples can be collected for laboratory analysis.

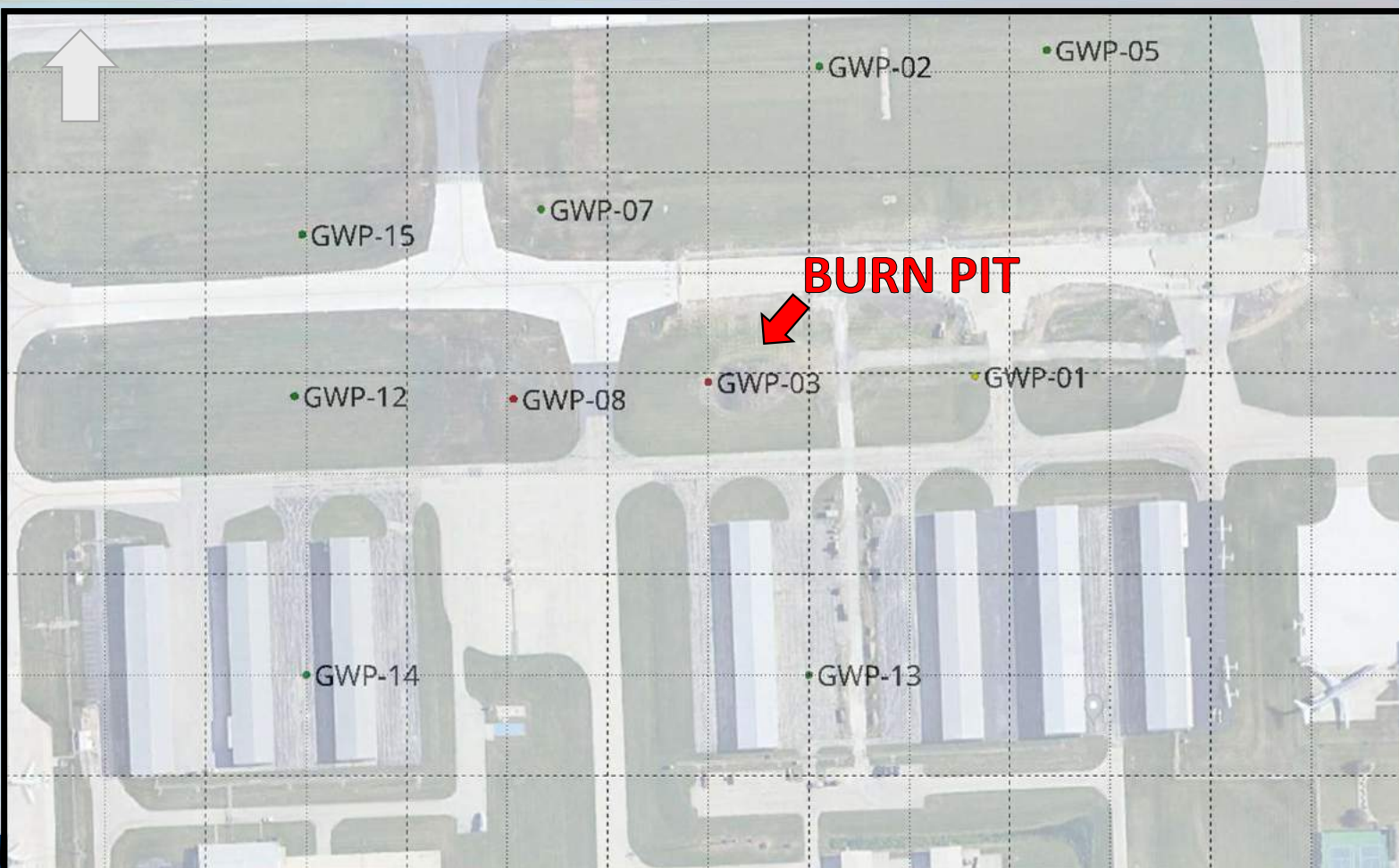
Applications:

PFOA or PFOS
Metals Contamination
Any Contaminant in Groundwater

Not For:

Free Product

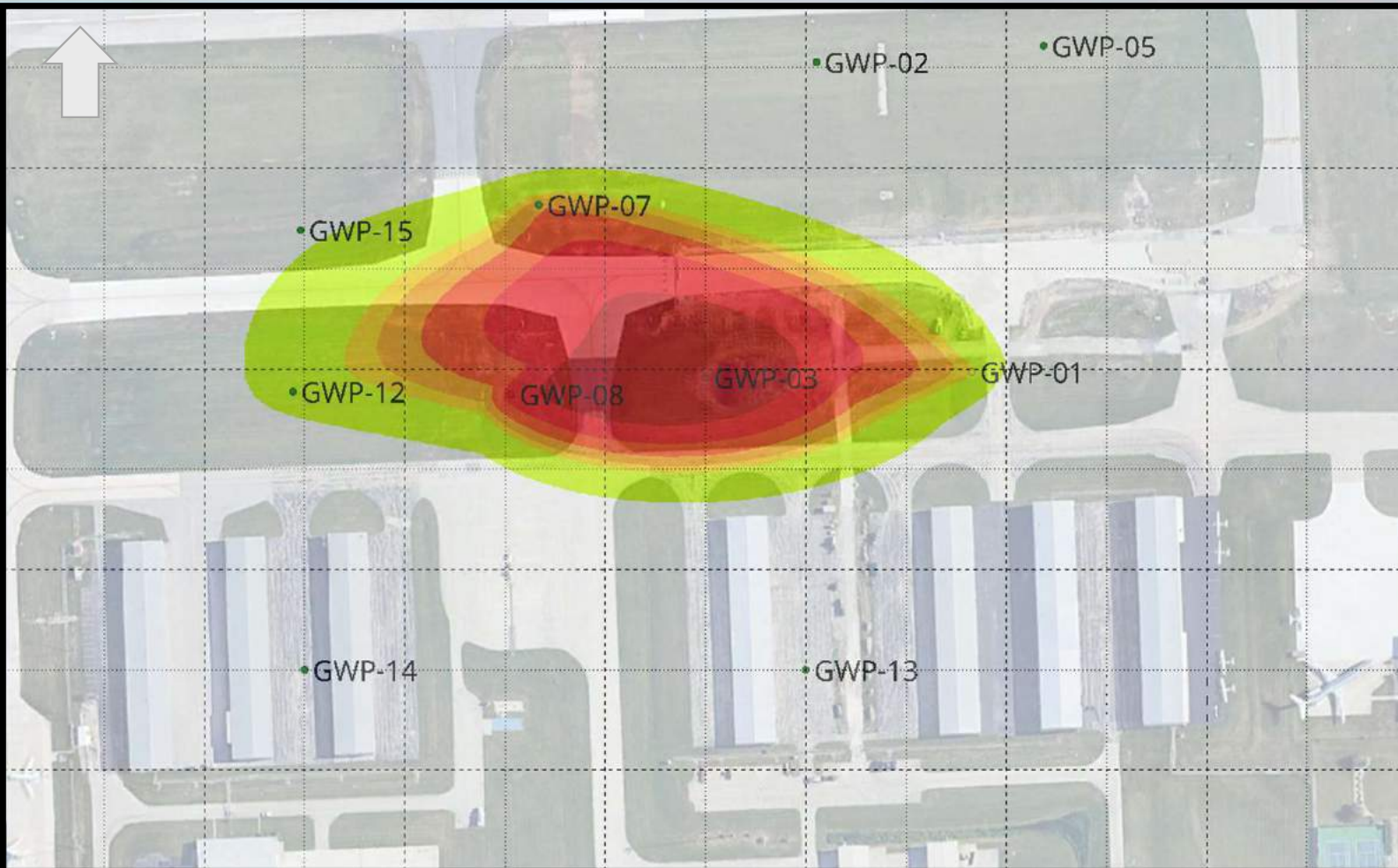
Scenario #2: Groundwater Profiling Tool



Burn Pit at Airport PFOS in Groundwater

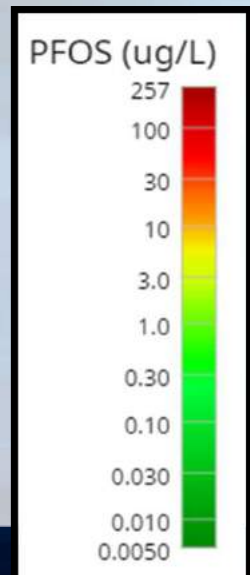
- Ten (10) Groundwater Profiler Borings with Hydraulic Profiling Data
- Twenty-Five (25) Groundwater Samples

Groundwater Profiling Tool – Footprint Map



Plume at 4 ug/L

**Max Concentration
273 ug/L
(GWP-03 @ 17.5')**

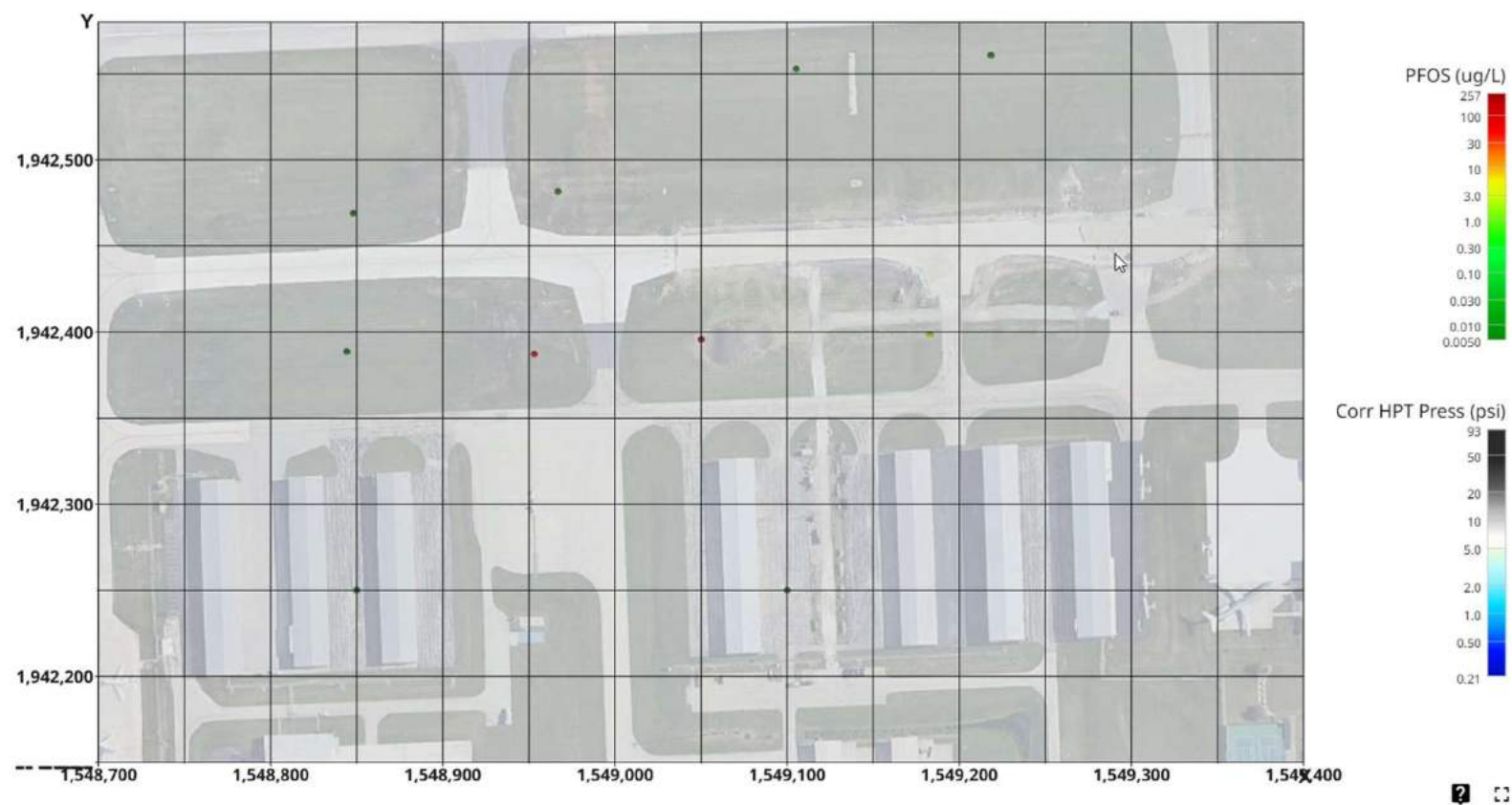


Groundwater Profiling Tool - 3D Animation



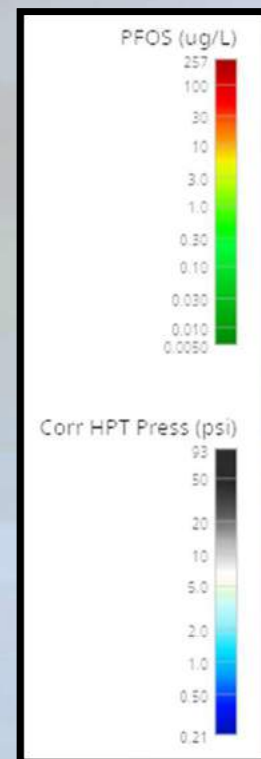
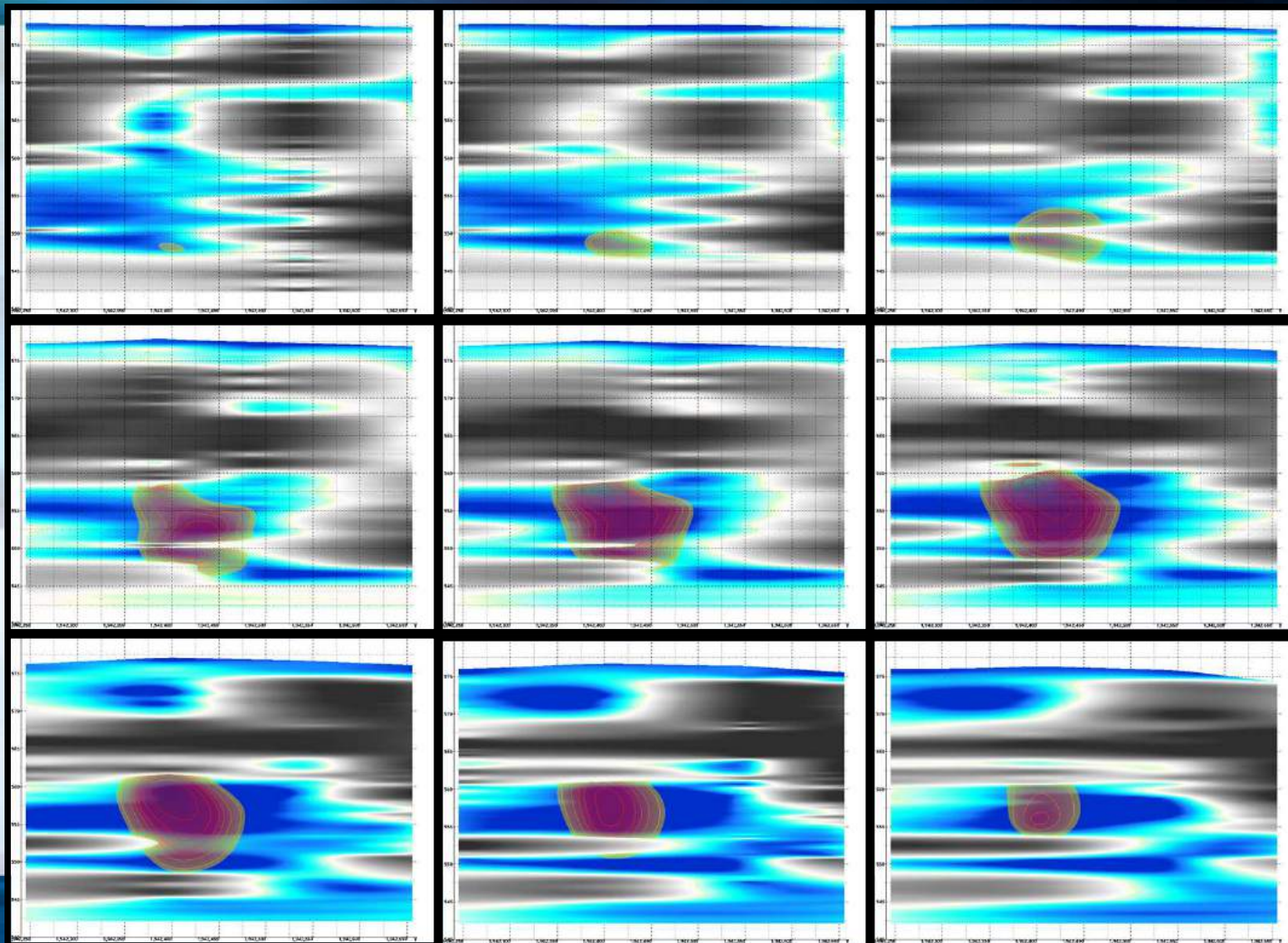
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Vertical Exaggeration: x8
Elevation in Feet Above Mean Sea Level (Ft AMSL)
Coordinates in State Plane (US Feet)



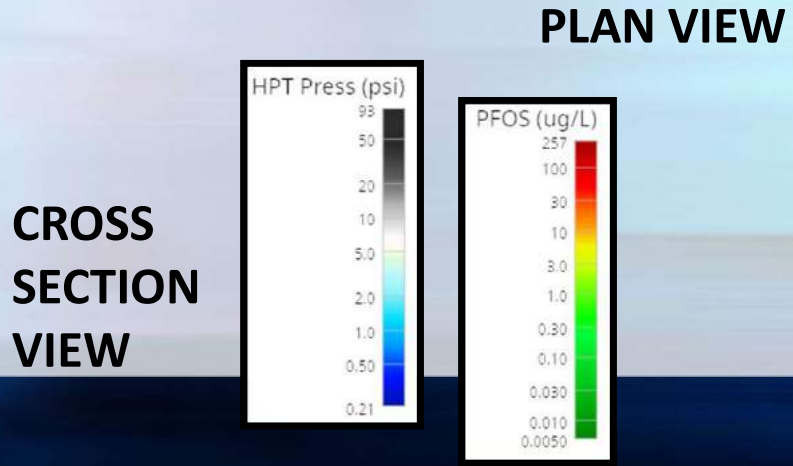
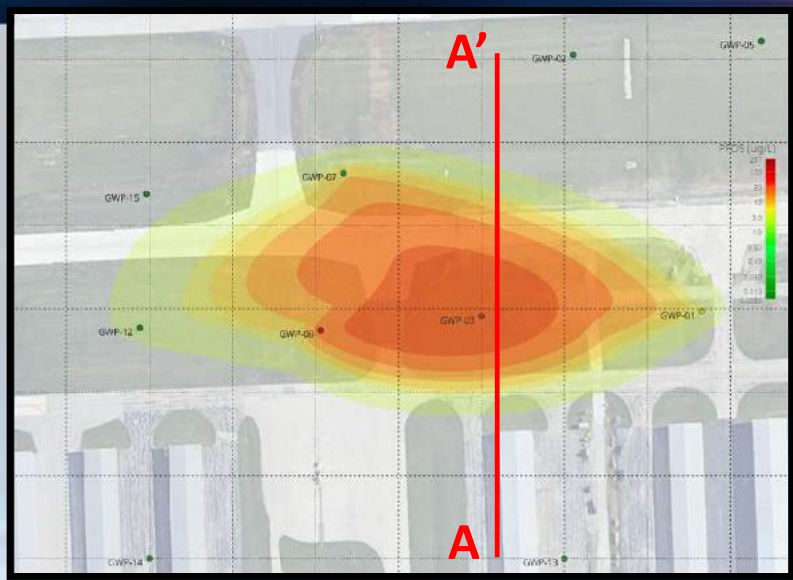
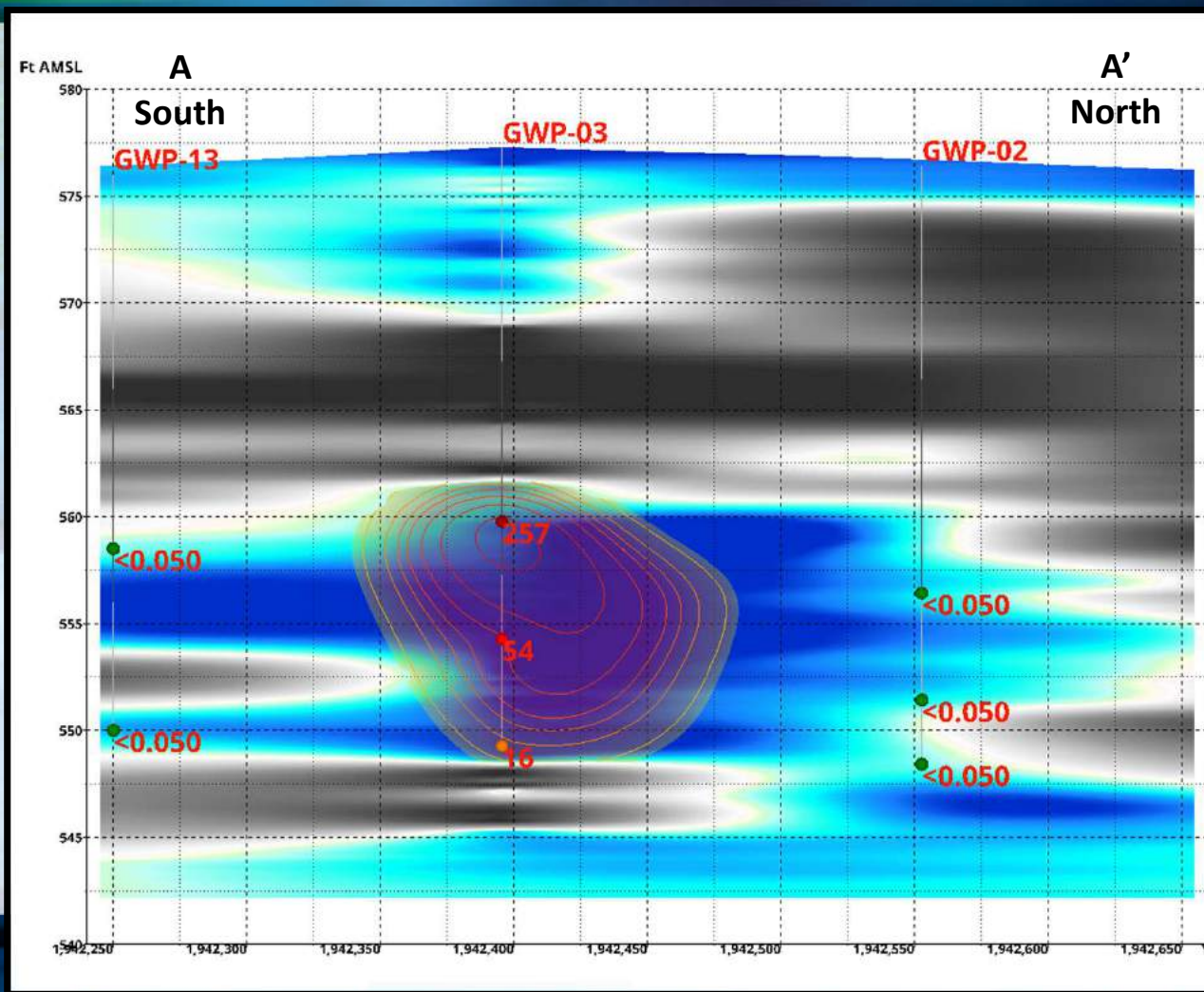
Groundwater Profiling Tool – Cross Section Maps Using Python

WEST

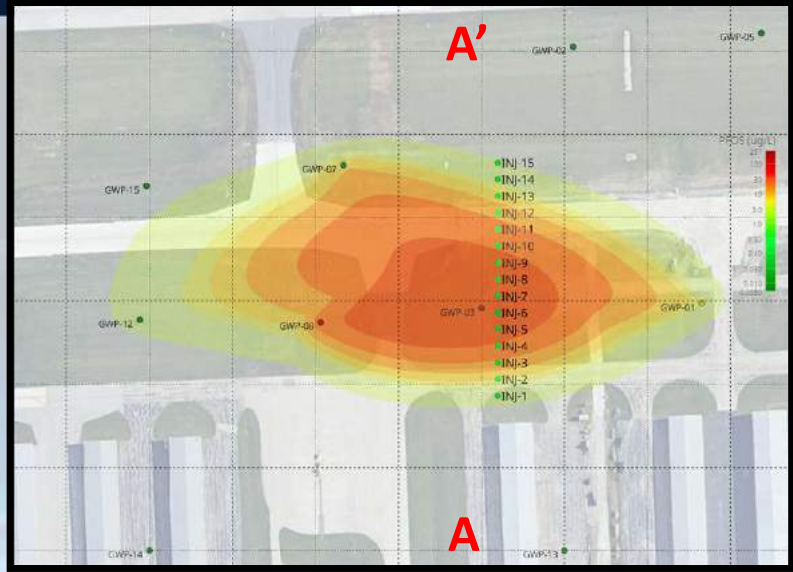
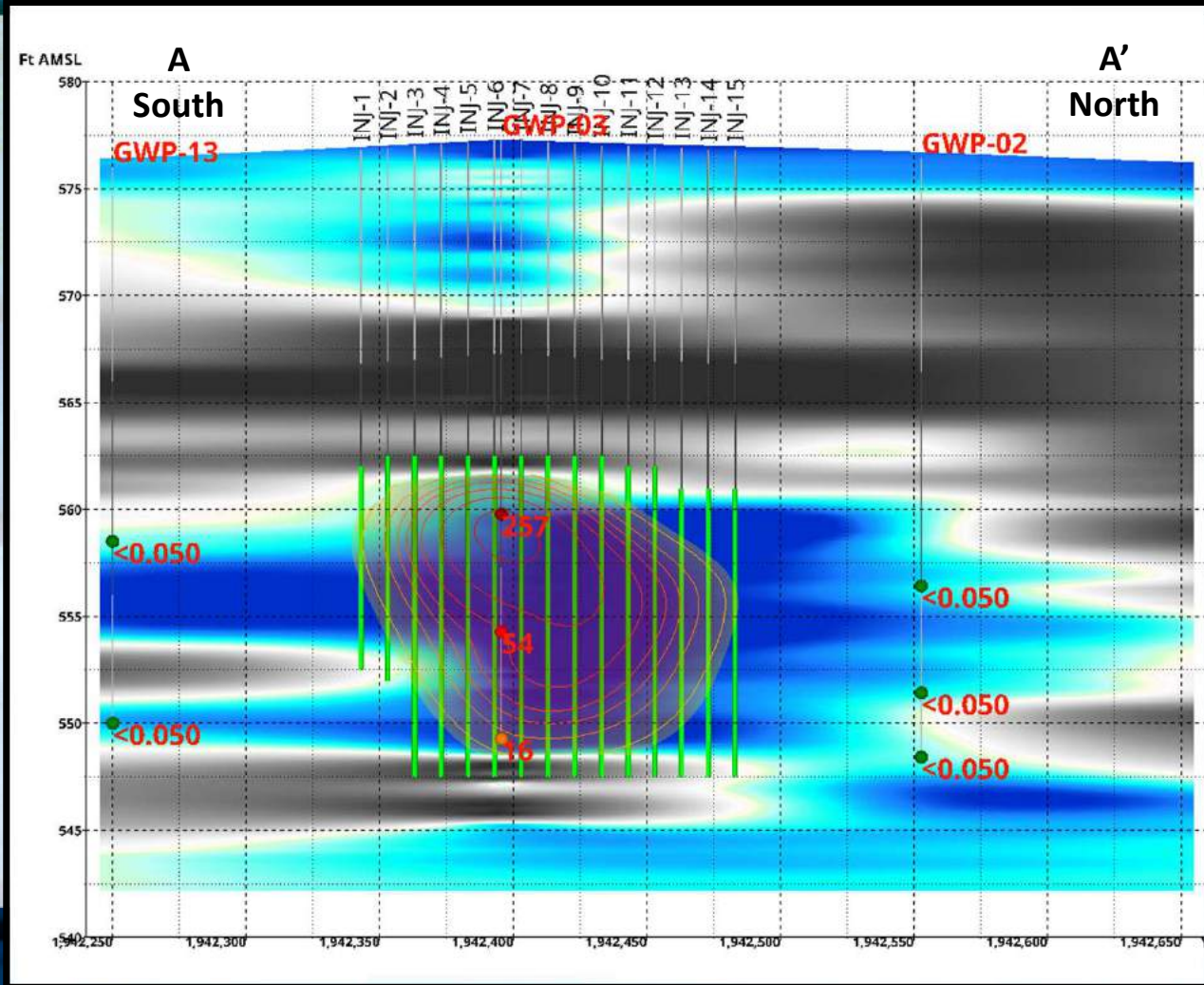


EAST

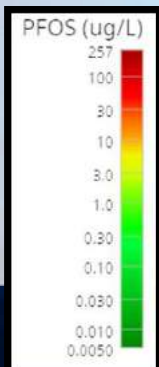
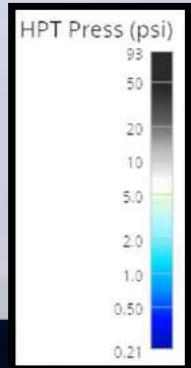
Groundwater Profiling Tool – Injection Plan Cross Section



Groundwater Profiling Tool – Injection Plan Cross Section



CROSS SECTION VIEW



Scenario #2: Injection Plan for Implementation in the Field

Well ID	Ground Surface Elevation	X	Y	Top Elevation of Injection	Bottom Elevation of Injection	Top Depth of Injection	Bottom Depth of Injection
	(Ft AMSL)			State Plane (US Feet)		(Ft AMSL)	(Ft AMSL)
INJ-1	576.8	1549060	1942343	562	552.5	14.8	24.3
INJ-2	576.9	1549060	1942353	562.5	552	14.4	24.9
INJ-3	577	1549060	1942363	562.5	547.5	14.5	29.5
INJ-4	577.1	1549060	1942373	562.5	547.5	14.6	29.6
INJ-5	577.2	1549060	1942383	562.5	547.5	14.7	29.7
INJ-6	577.3	1549060	1942393	562.5	547.5	14.8	29.8
INJ-7	577.3	1549060	1942403	562.5	547.5	14.8	29.8
INJ-8	577.2	1549060	1942413	562.5	547.5	14.7	29.7
INJ-9	577.1	1549060	1942423	562.5	547.5	14.6	29.6
INJ-10	577	1549060	1942433	562.5	547.5	14.5	29.5
INJ-11	577	1549060	1942443	562	547.5	15	29.5
INJ-12	576.9	1549060	1942453	562	547.5	14.9	29.4
INJ-13	576.9	1549060	1942463	561	547.5	15.9	29.4
INJ-14	576.8	1549060	1942473	561	547.5	15.8	29.3
INJ-15	576.8	1549060	1942483	561	547.5	15.8	29.3
AMSL: Above Mean Sea Level							
BGS : Below Ground Surface							



Scenario #3: Optical Image Profiler (OIP)



**Optical Image Profiler
(OIP)**

Description:

As the tool is advanced, an Ultra-Violet (UV) light induces fluorescence of the Polycyclic Aromatic Hydrocarbons (PAHs) found in hydrocarbons. This fluorescence is captured by an onboard camera and recorded in high resolution (every 0.05' of advancement).

Applications:

Free Product - Light and Mid Range Hydrocarbons
Hydrogeologic Classification (Hydraulic Profiling Tool)

Not For:

Free Product from Heavier Hydrocarbons (OIP-G)
Dissolved or Sorbed Contamination



Scenario #3: Optical Image Profiler (OIP)



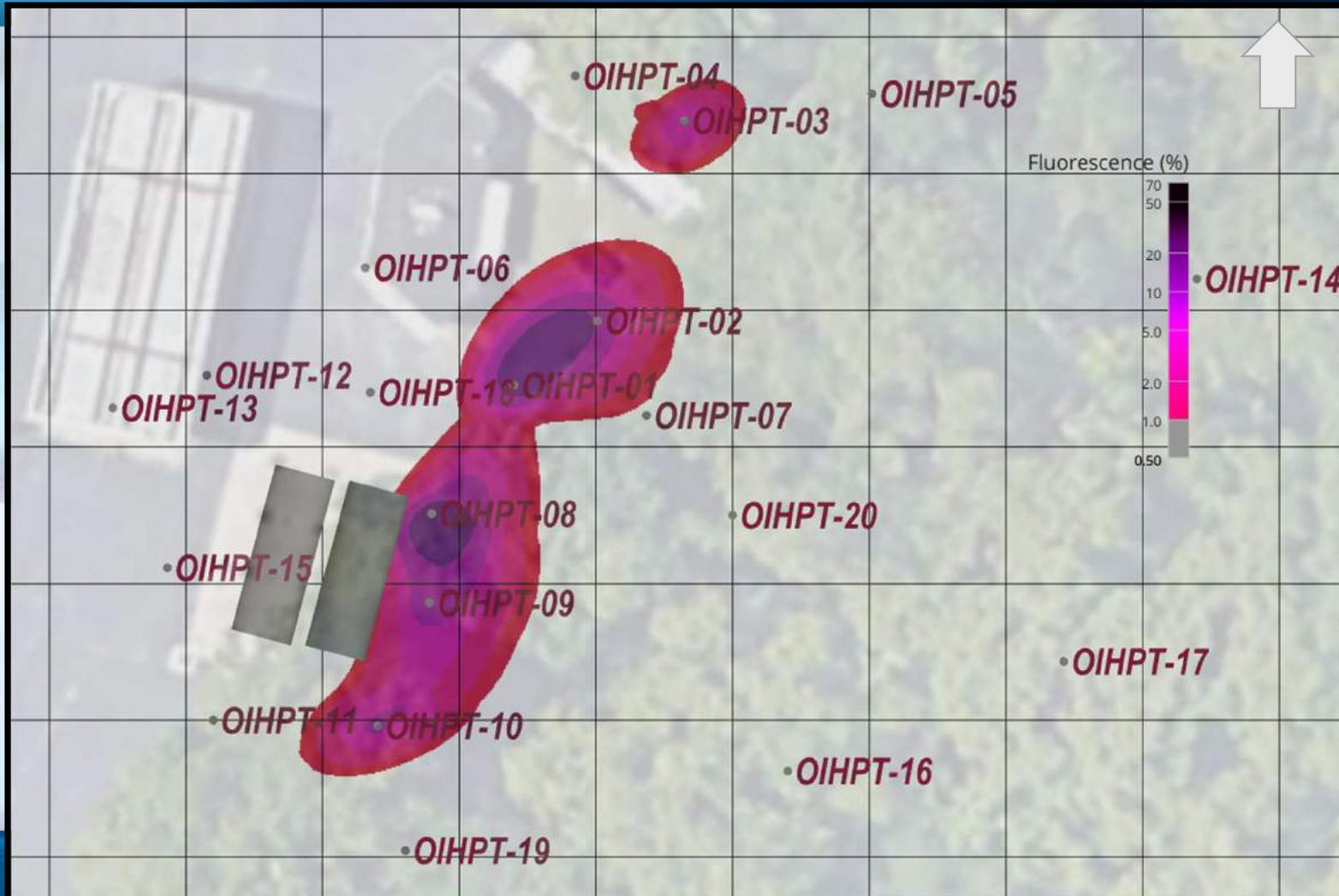
Gas Station with Free Product

- **Two (2)** Former USTs
- **Twenty (20)** Optical Image Profiler / Hydraulic Profiling Tool (OIHPT) Borings

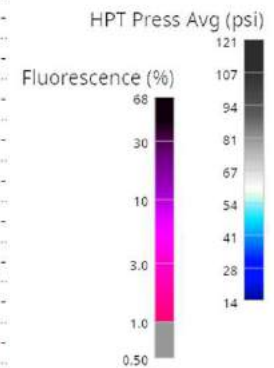
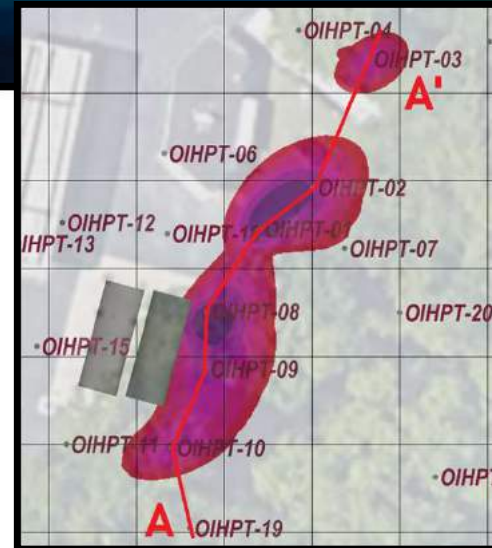
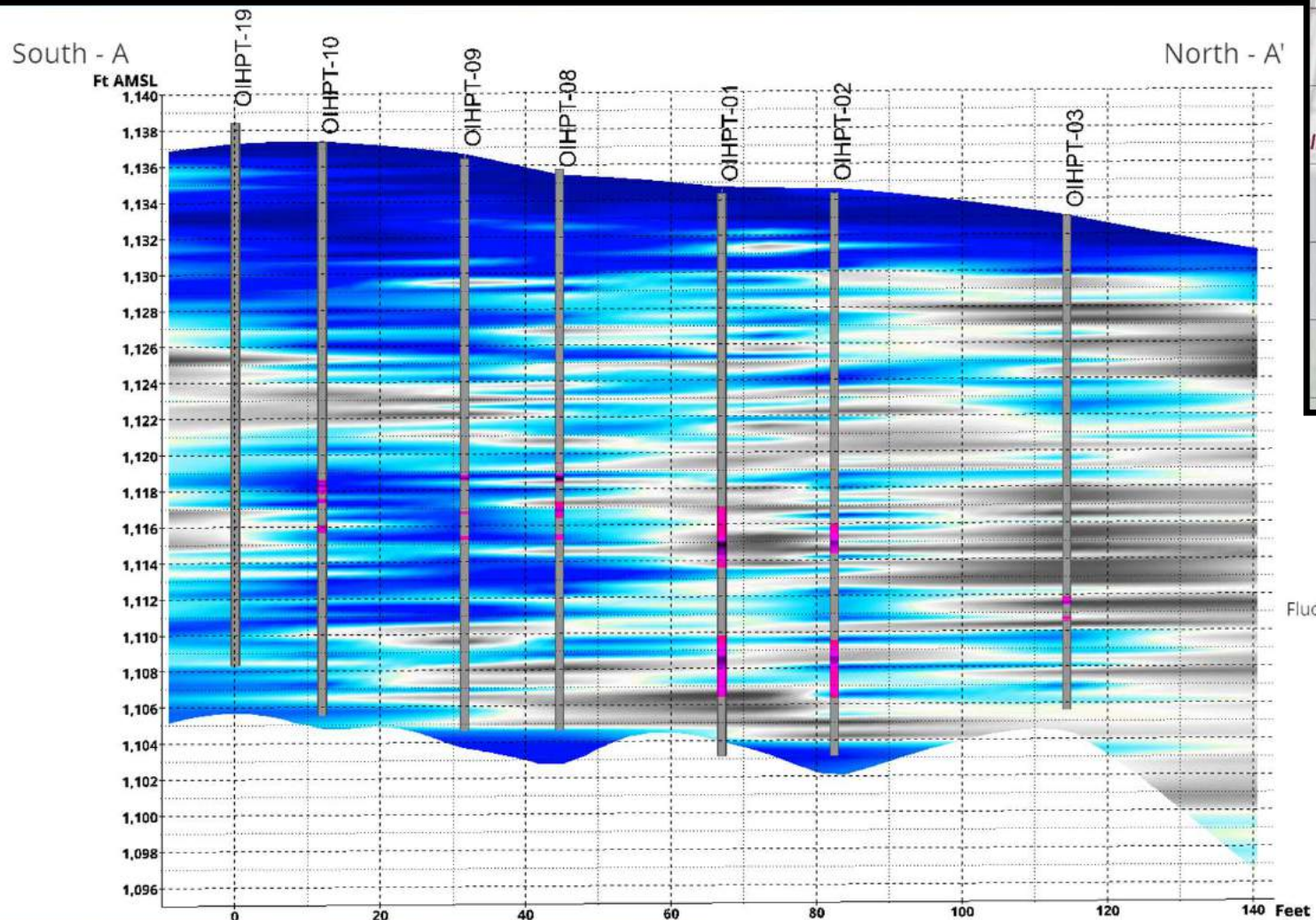
Optical Image Profiler (OIP) – 3D Animation



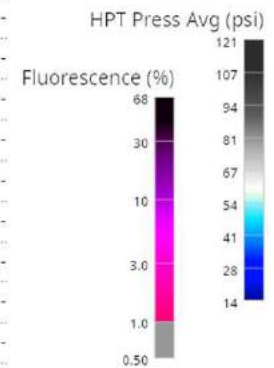
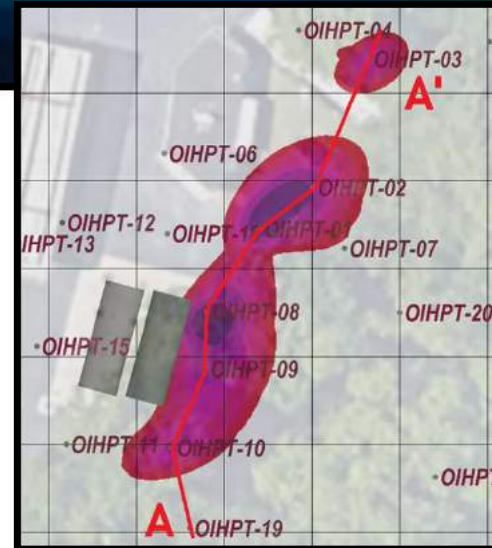
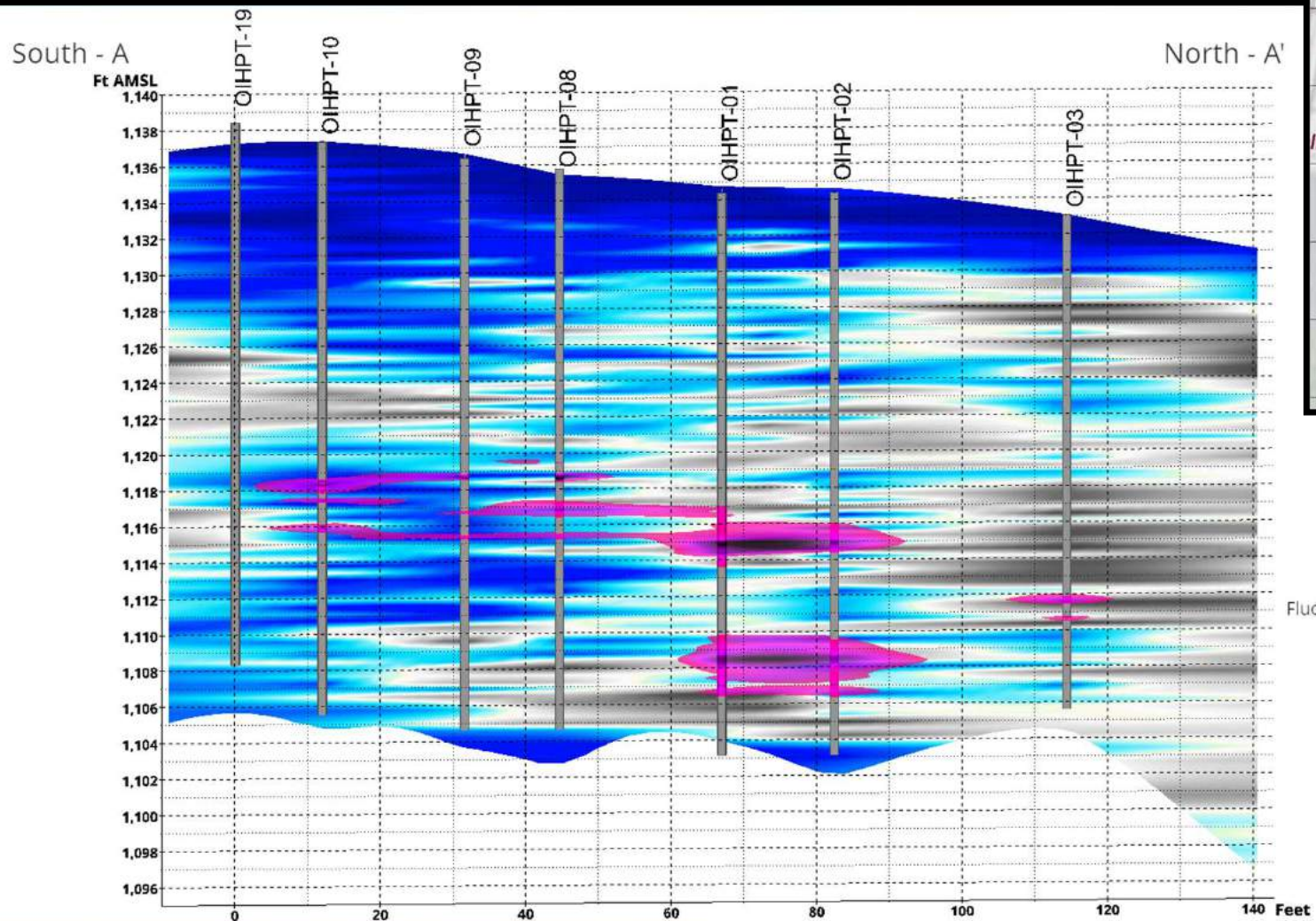
Optical Image Profiler (OIP) – Footprint Map



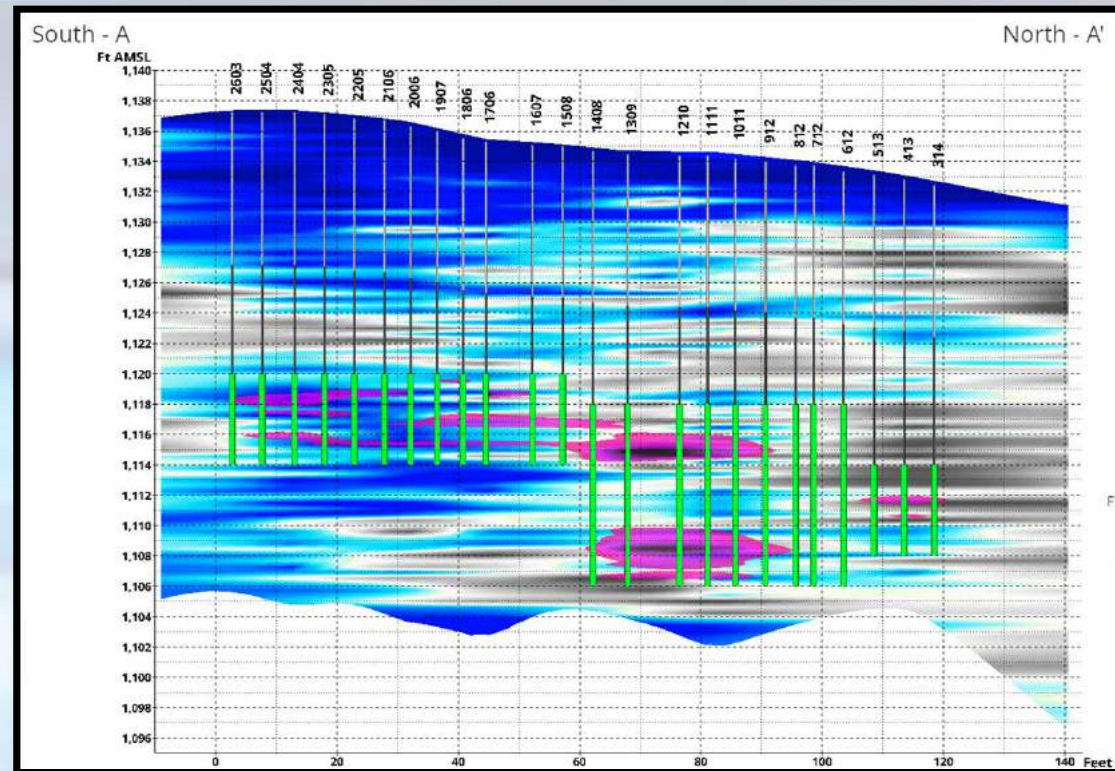
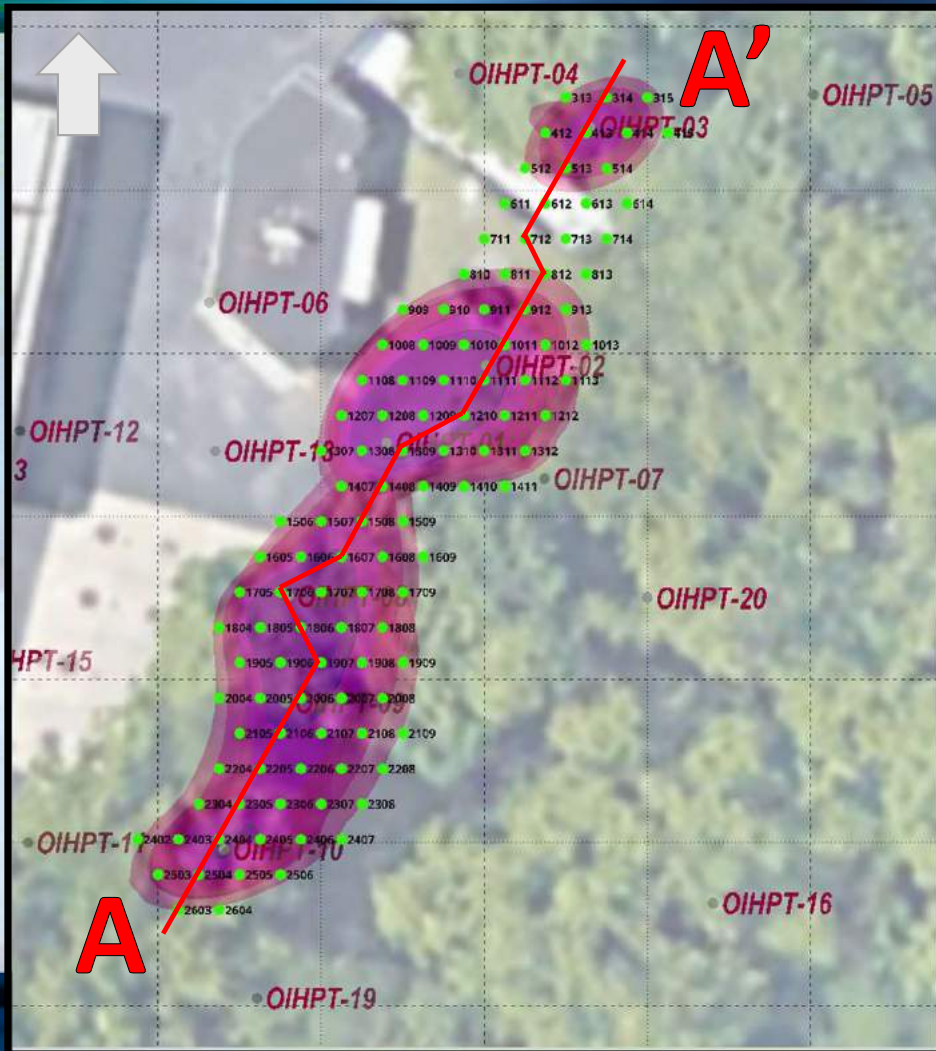
Optical Image Profiler (OIP) – Cross Section



Optical Image Profiler (OIP) – Cross Section



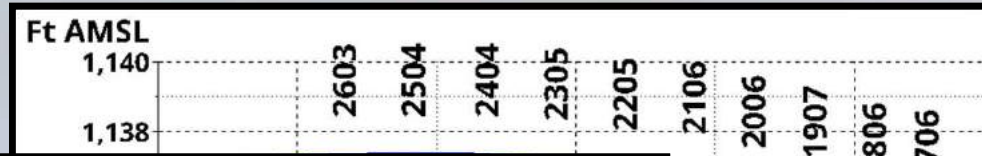
Optical Image Profiler (OIP) – Injection Well Plan



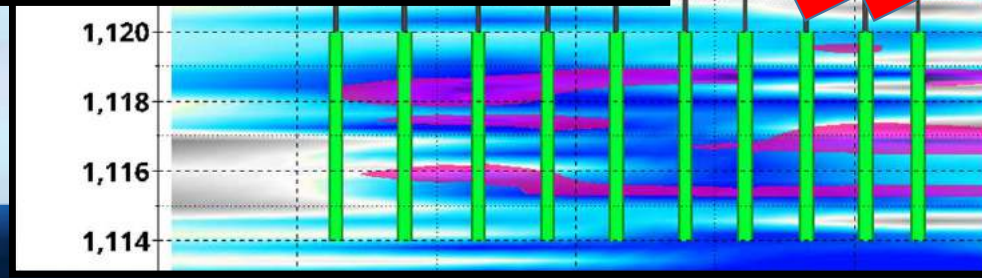
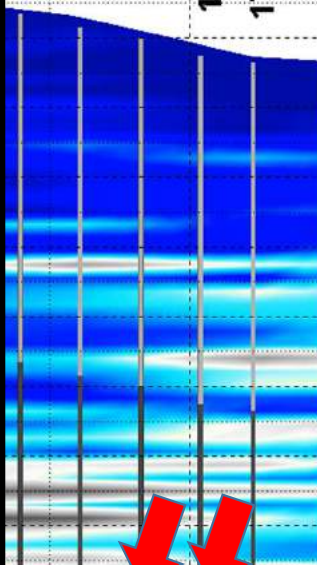
CROSS SECTION VIEW

PLAN VIEW

Scenario #3: Detailed Injection Plan for Implementation in the Field

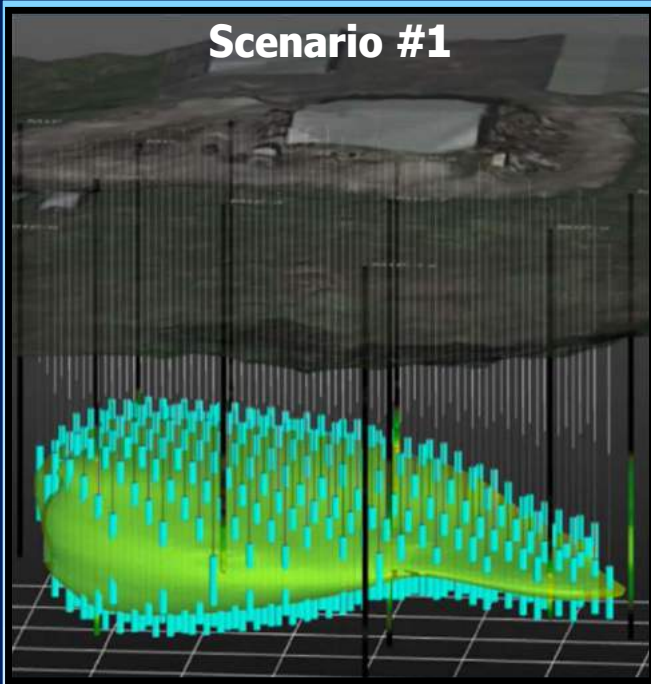


Injection Well ID	X	Y	Inj. Top Elevation (Ft AMSL)	Inj. Btm Elevation (Ft AMSL)	Inj. Top Depth (Ft BGS)	Inj. Btm Depth (Ft BGS)	Injection Interval (Ft BGS)	Est. OIP Response (%)	Est. HPT Pressure (PSI)	Ground Surface (Ft AMSL)
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	15.5	1.5	44	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	16.5	0	15	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	17.5	0	25	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	18.5	1.5	72	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	19.5	4	50	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	20.5	0	81	1135.5
1806	1104147.5	1583496.39	1120	1114	15.5	21.5	21.5	1.3	19	1135.5
1907	1104150	1583492.06	1120	1114	16	22	16	0.9	44	1136
1907	1104150	1583492.06	1120	1114	16	22	17	0	15	1136
1907	1104150	1583492.06	1120	1114	16	22	18	0	25	1136
1907	1104150	1583492.06	1120	1114	16	22	19	1.1	59	1136
1907	1104150	1583492.06	1120	1114	16	22	20	3.2	48	1136
1907	1104150	1583492.06	1120	1114	16	22	21	0	63	1136
1907	1104150	1583492.06	1120	1114	16	22	22	1.2	19	1136



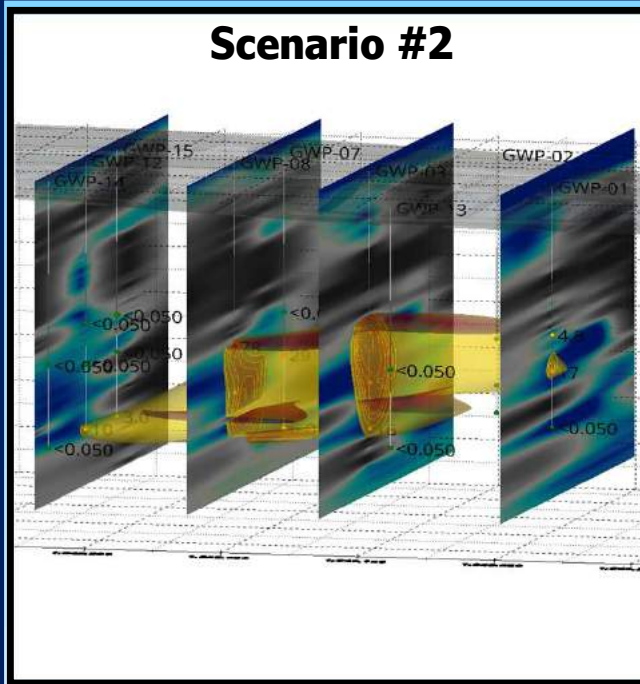
Advantages of Targeted Injection Plans

Scenario #1



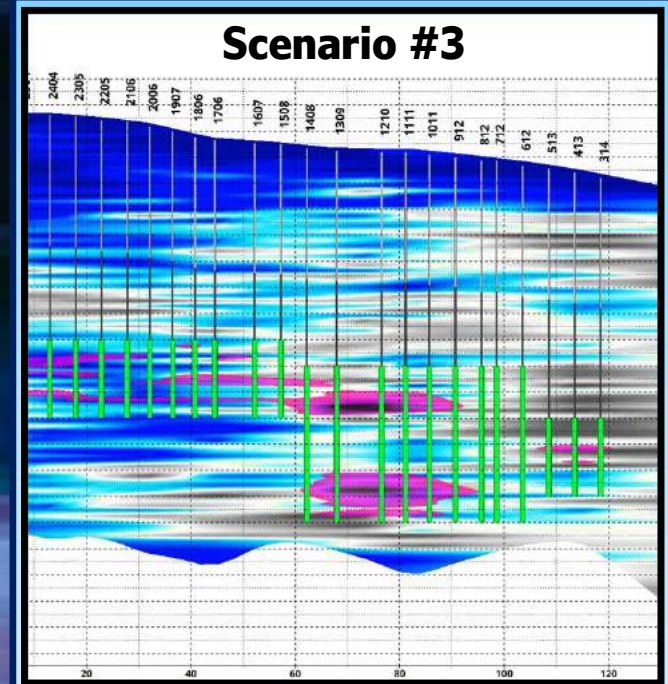
FLEXIBLE

Scenario #2



LIMITED DATA

Scenario #3



DETAILED

EFFICIENTLY AND ECONOMICALLY PRODUCED

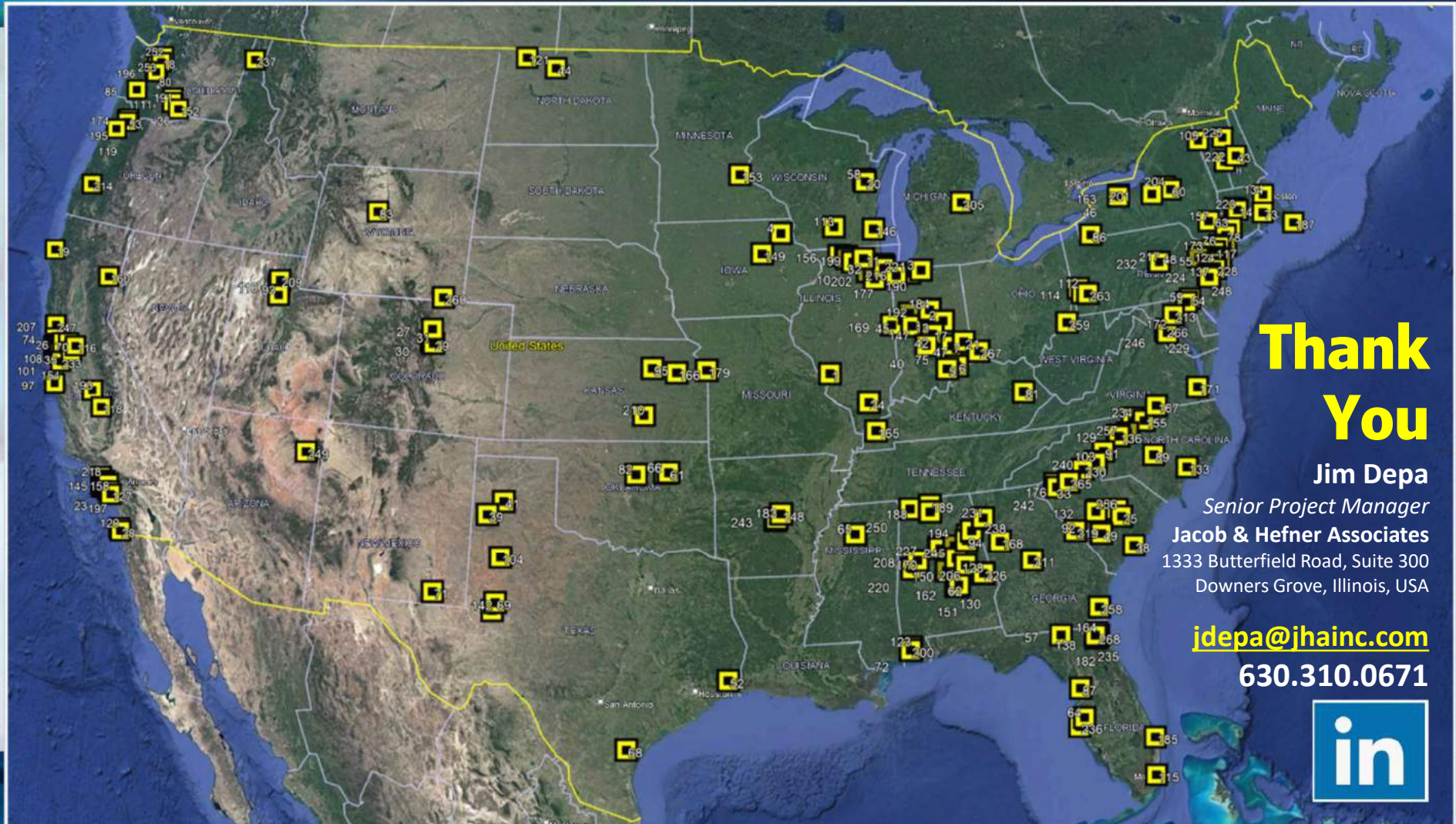
Limitations and Considerations

- Correlation of MIP Response to Analytical Data
- Effect of Carry-Over During MIP Drilling
- Trip Times for Different Contaminants
- Over-Reliance on the Statistical Interpolation

3D Deliverable or Injection Plan: 270 Projects



JACOB & HEFNER
ASSOCIATES



Thank You

Jim Depa

Senior Project Manager
Jacob & Hefner Associates
1333 Butterfield Road, Suite 300
Downers Grove, Illinois, USA

jdepa@jhainc.com

630.310.0671

