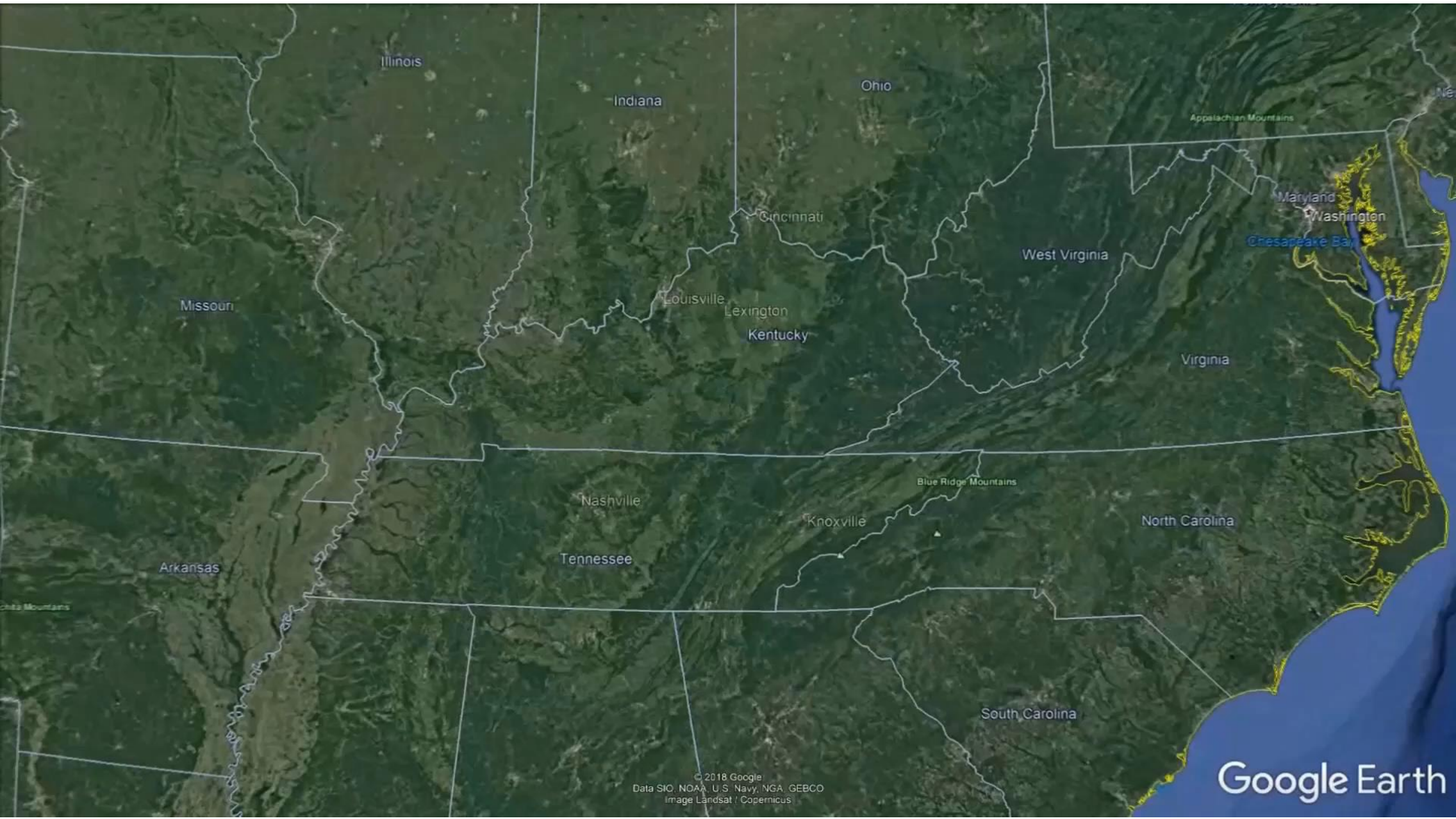
Illinois
Indiana
Ohio
Appalachian Mountains
Maryland
Washington
Chesapeake Bay
Cincinnati
West Virginia
Missouri
Louisville
Lexington
Kentucky
Virginia
Blue Ridge Mountains
Nashville
Knoxville
North Carolina
Tennessee
Arkansas
South Carolina
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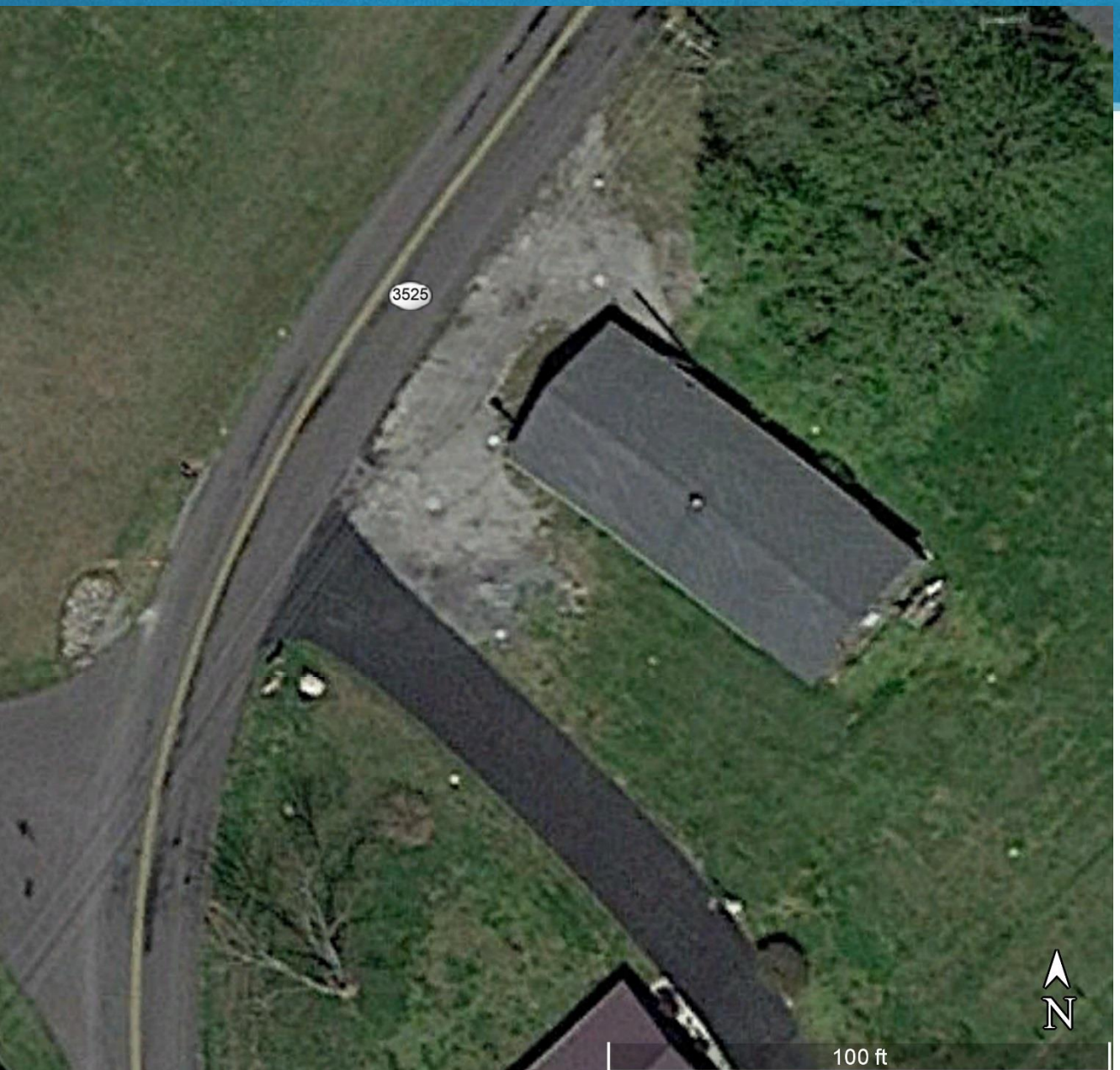
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth

Site History



Former UST Facility, Russell Springs, KY

- UST Closure 2000 and 2001 (in-place)
- Site Investigations 2002 thru 2013
- No previous remediation efforts, other than tank closure, prior to BOS 200® carbon injection.
- Benzene concentrations

  Soil concentration high ≈ 16 ppm

  Water concentration high ≈ 9 ppm
- Bedrock ≈ 550cm in treatment area

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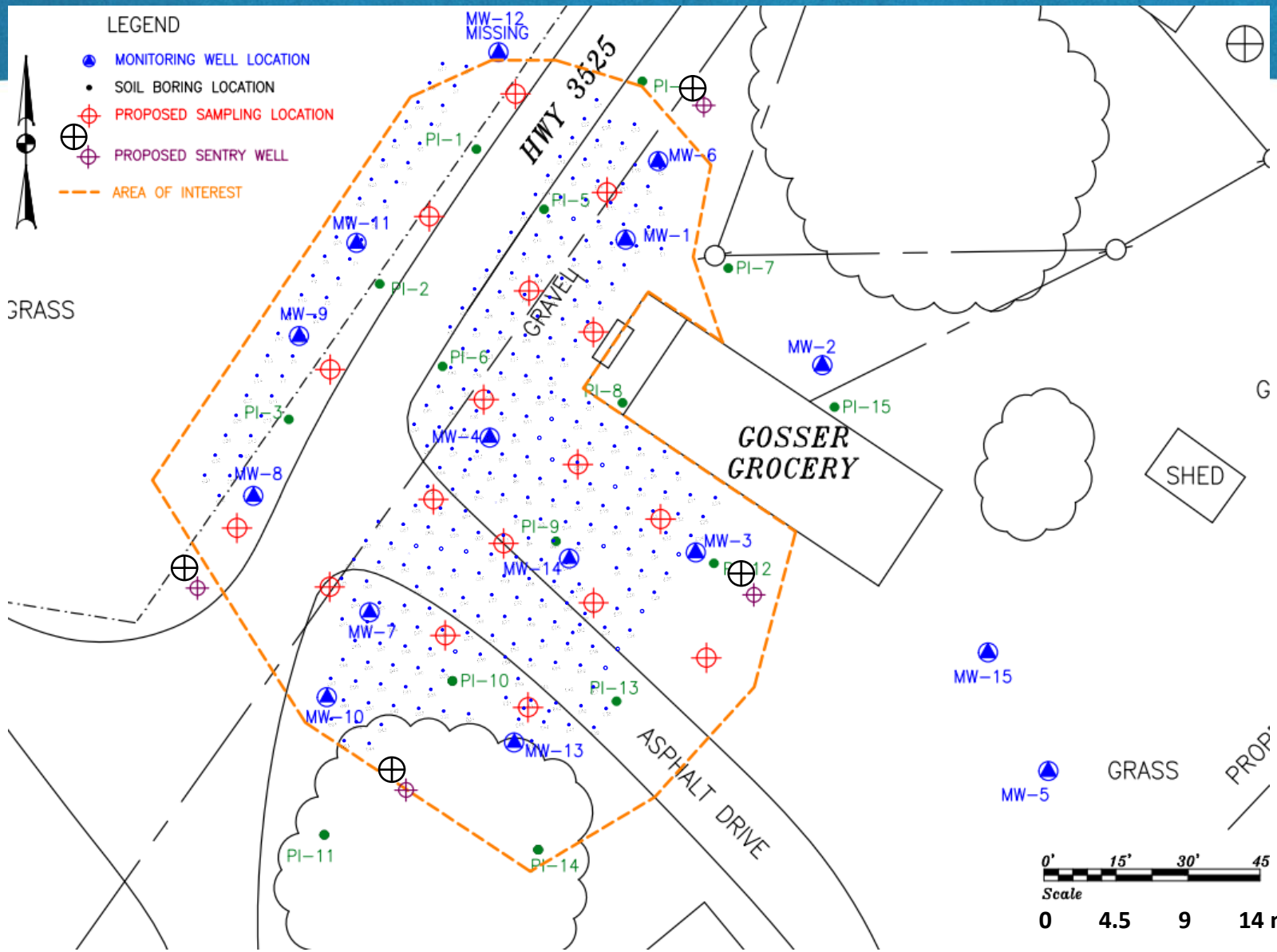
Soil and Groundwater Evaluation



- **11/7/16-11/8/16 Soil Sampling Work**
  - 32 locations (≥100 lab samples)
  - Installation of sentry wells (SW) (4)
- **6/12/17 Groundwater (GW) sampling** for 14 monitor wells (MW) & 4 SWs
- **6/14/17-7/17/17 BOS 200® Injections**
- **7/7/17, 8/14/17 Post-injection GW sampling**
- **8/30/17-9/7/17 BOS 200® injection analysis**
  - Soil cores collected and inspected for carbon distribution
  - Installation of PI nested wells (28)
- Soil and aquifer samples at 30 months

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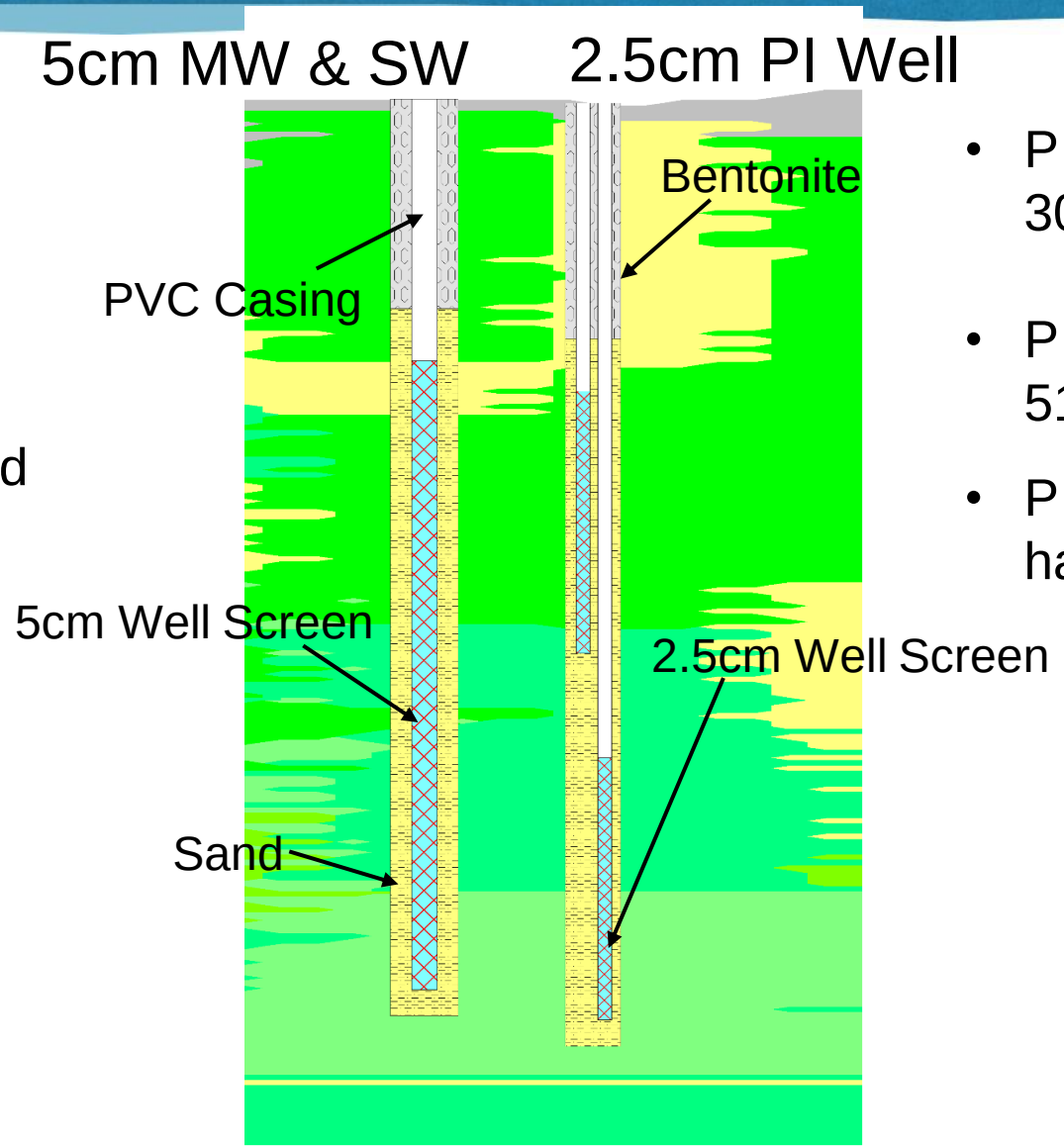
Well Construction

- 5cm Monitor Wells (MW) had 305cm screens.
- Total well depth to 550cm below ground surface
- 5cm Sentry Wells (SW) had 305cm screens with wells installed to 580cm below ground surface



- PI Shallow were installed to 305cm below ground surface
- PI Deep were installed to 518cm below ground surface
- PI Wells, shallow and deep, had 152cm screens.

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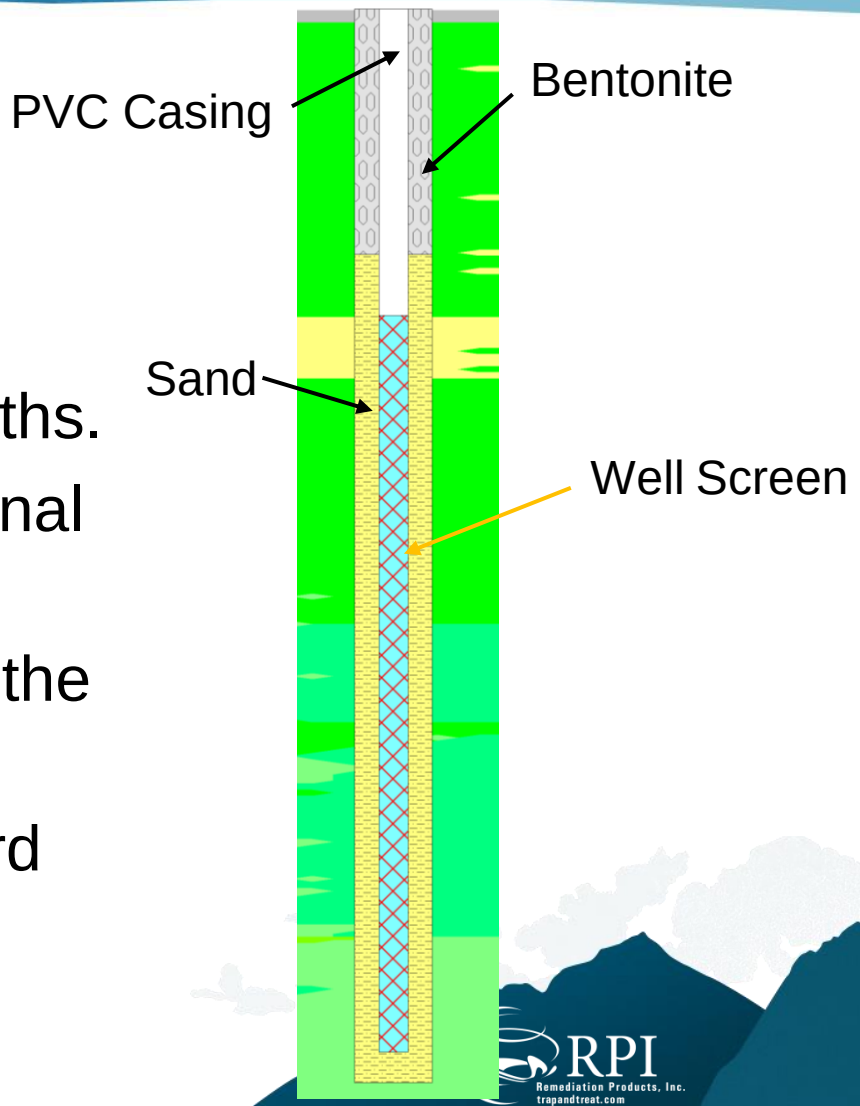
Monitoring or sentinel wells impacted by carbon were replaced

- Well replacement procedure
  - Drill to remove casing, screen, and sand pack.
  - New bore hole to the original depth.
  - Replacement with the same screen and riser lengths.
  - Sand and pack and bentonite seal match the original construction.
  - The replacement well is intended to be a clone of the original well.
  - Wells were developed and sampled using standard procedures.



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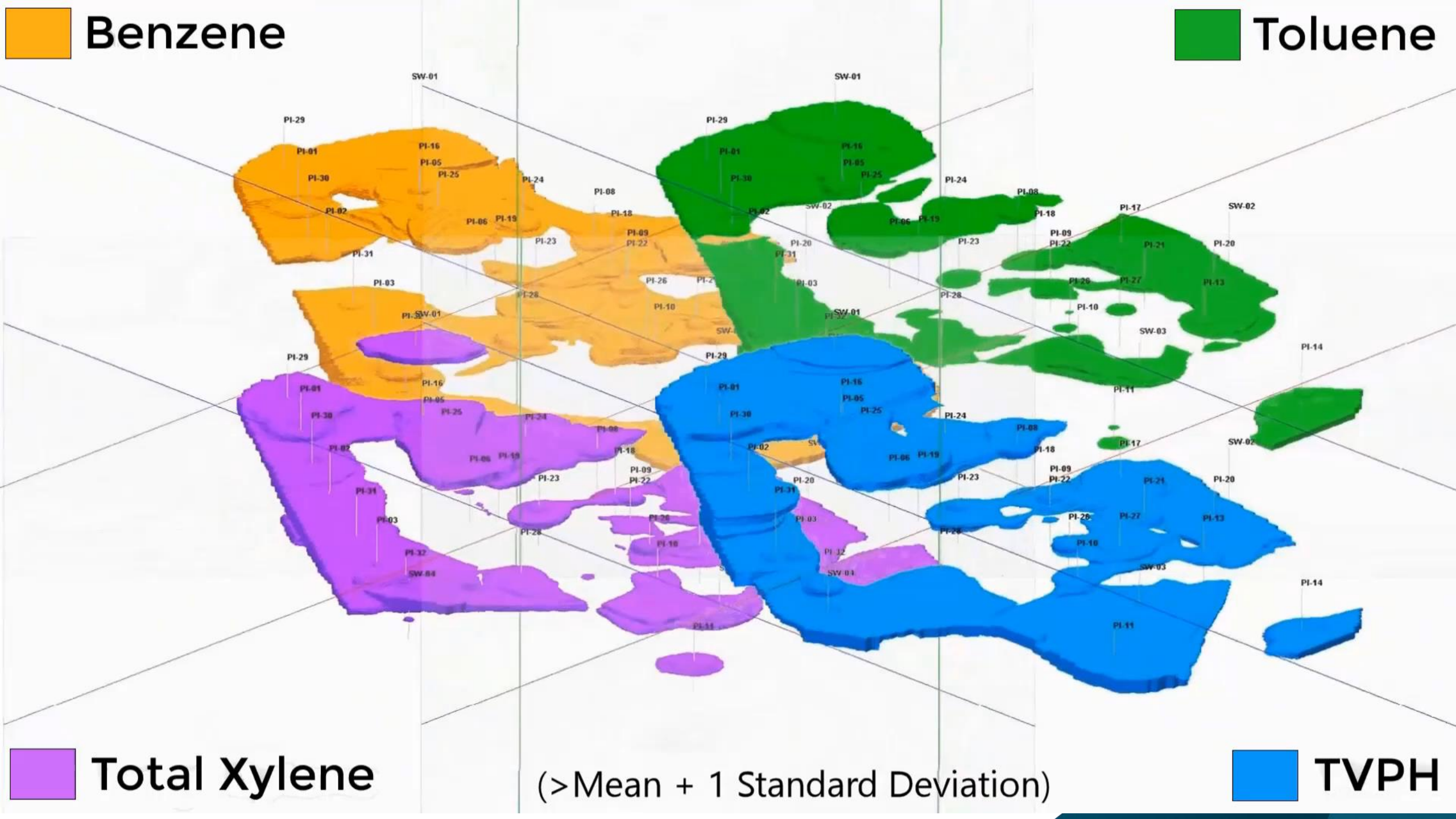
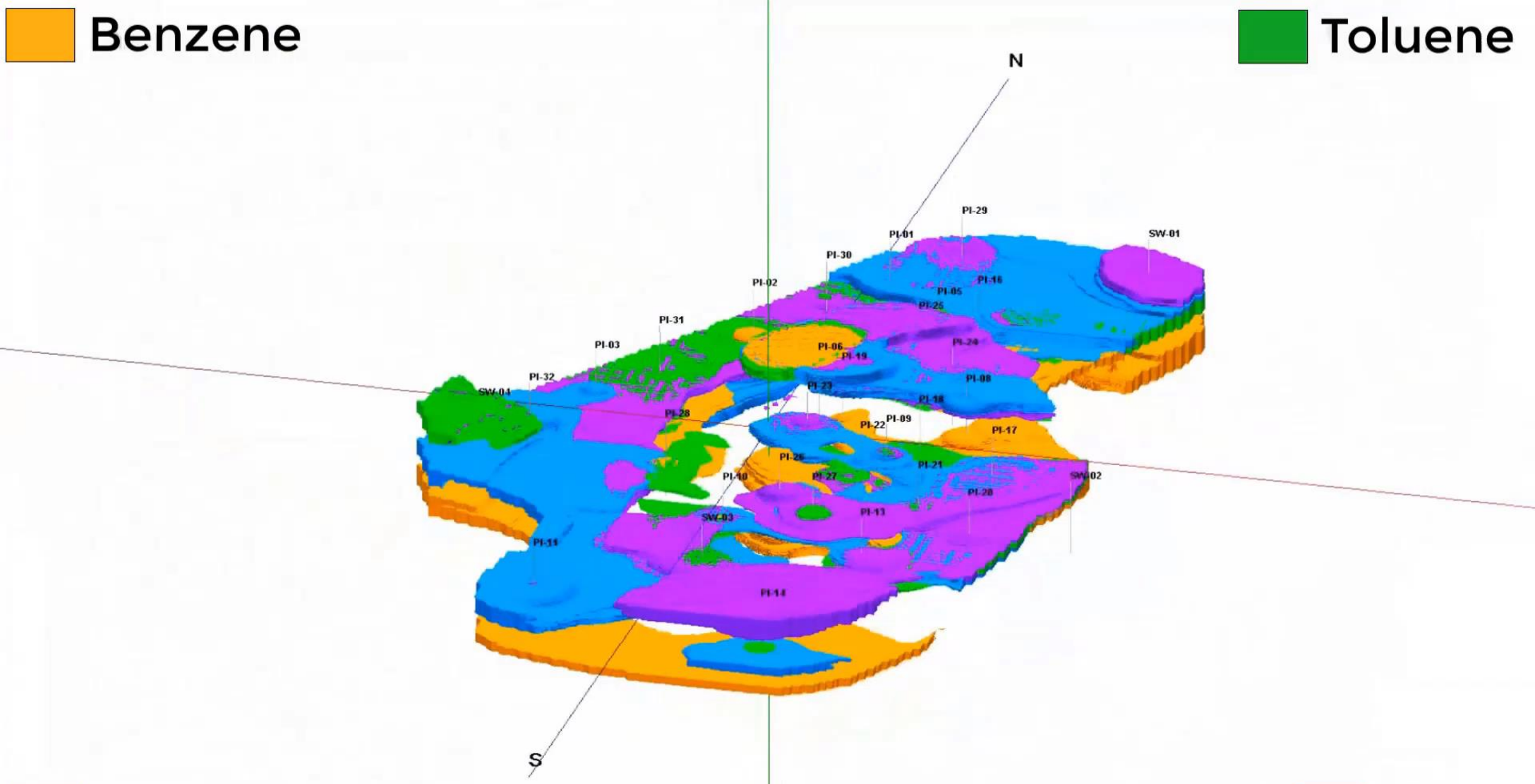
5,164,600
5,164,650
3,548,000
3,548,000
3,547,950
3,547,950
3,547,900
3,547,900
3,547,850
3,547,850
5,164,600
5,164,650
Google Earth


Benzene
Toluene
Total Xylene
(>Mean + 1 Standard Deviation)
TVPH

Benzene

Toluene



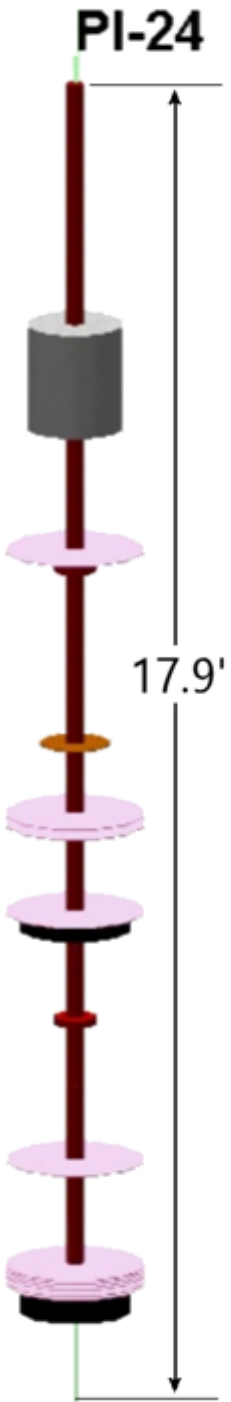
Total Xylene

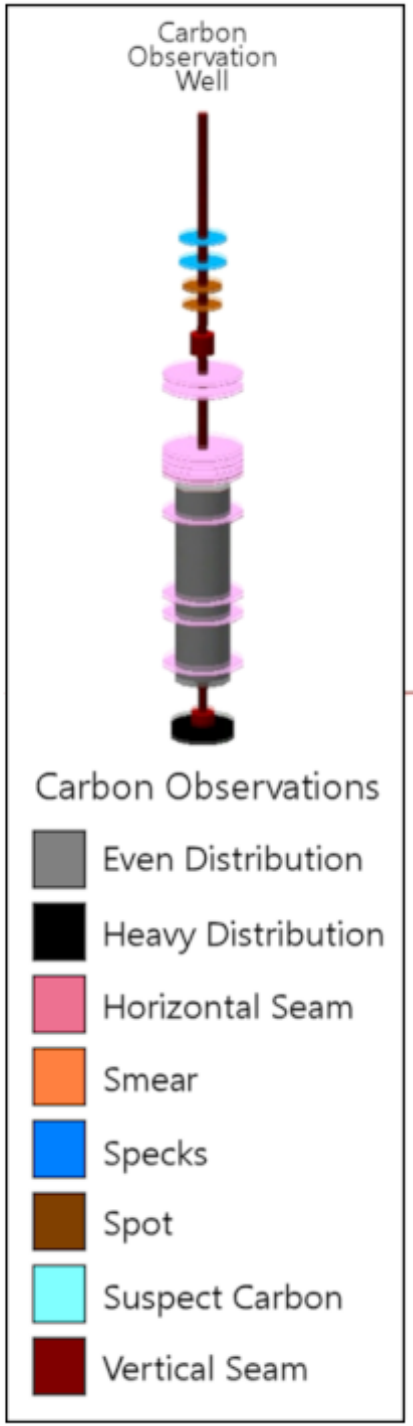
(>Mean + 1 Standard Deviation)

TVPH

Observed Carbon Types

- Suspect Carbon
- Specks
- Spots
- Smears
- Even Distribution
- Heavy Distribution
- Vertical Seams
- Horizontal Seams





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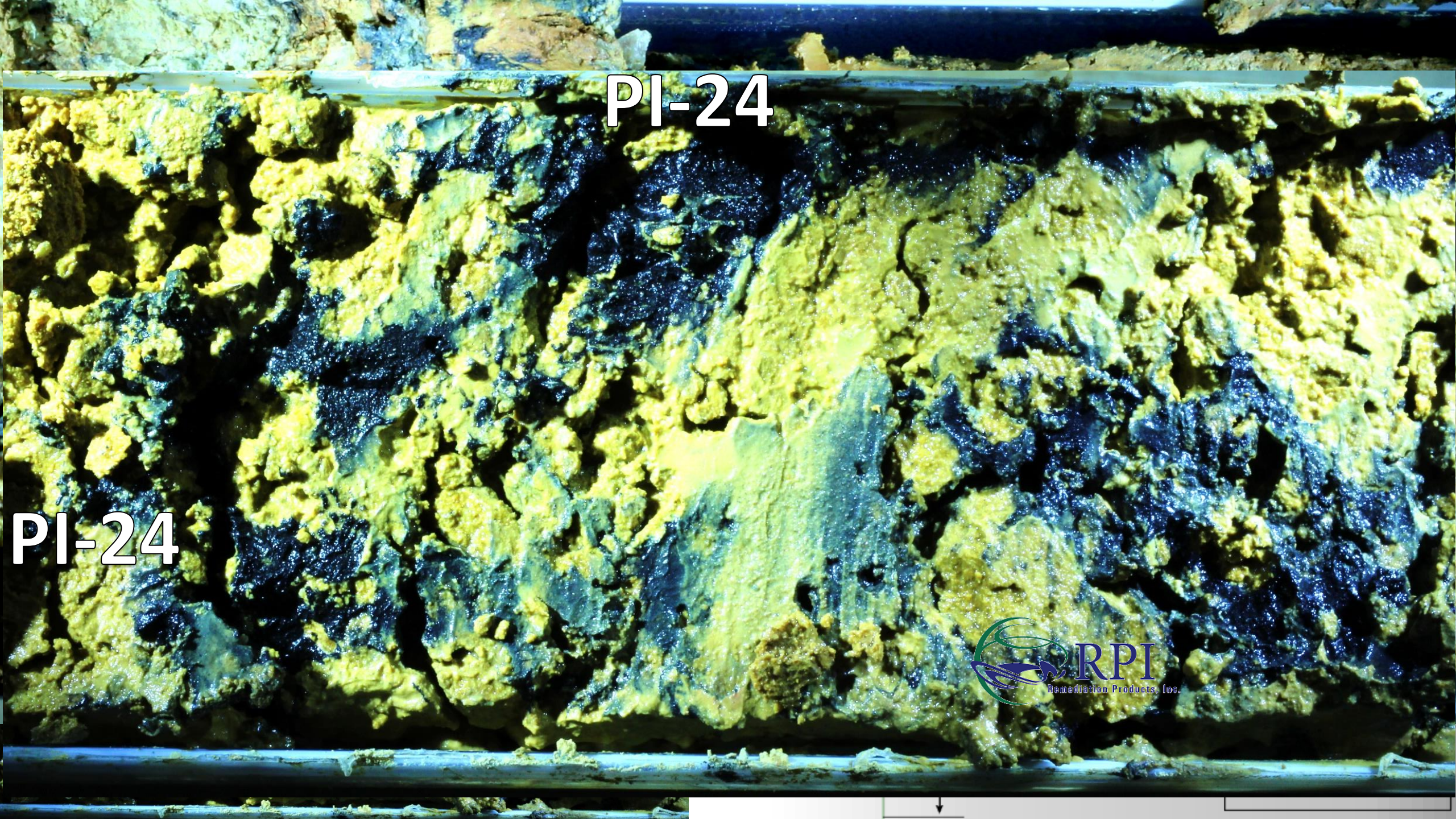
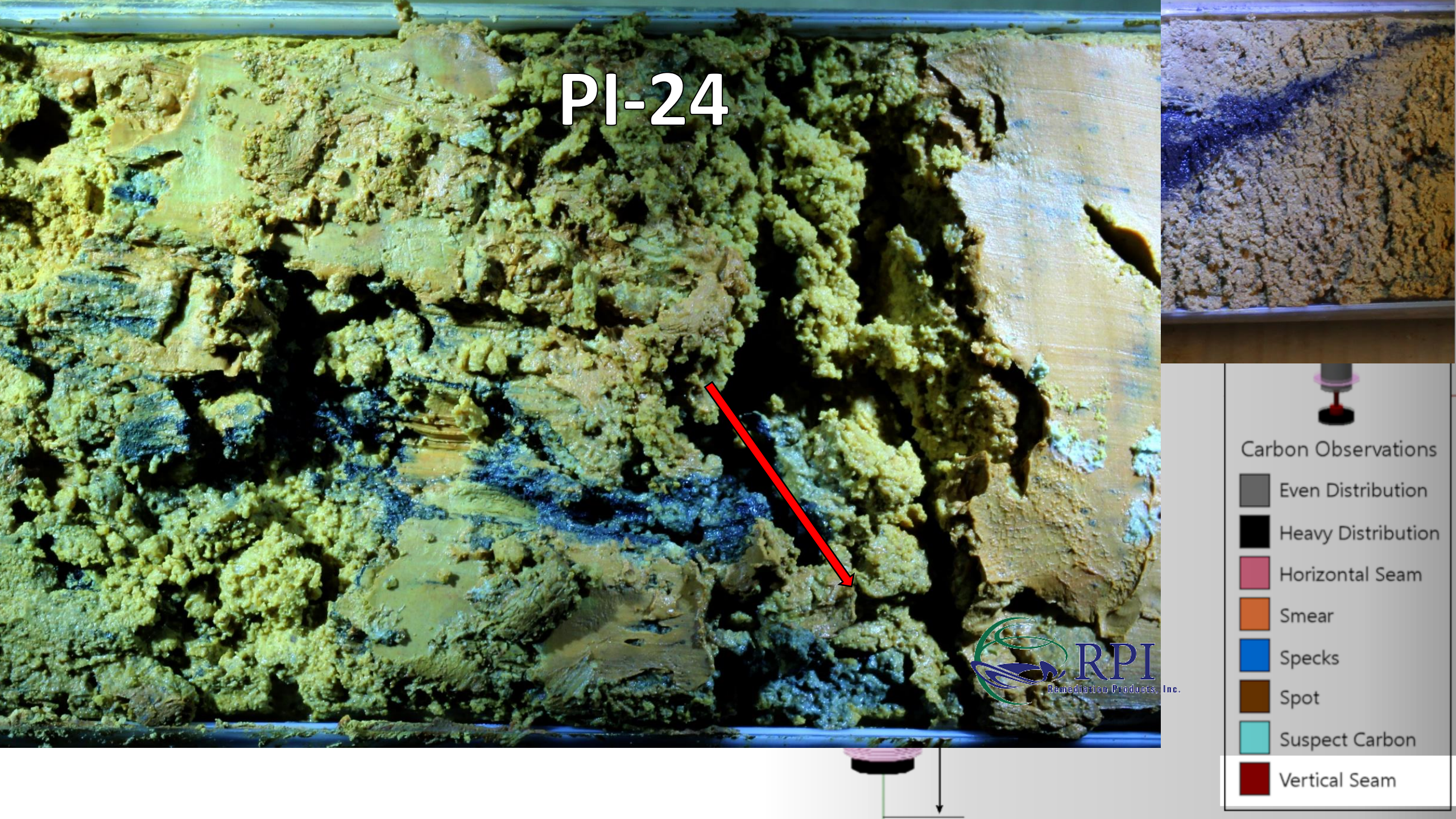
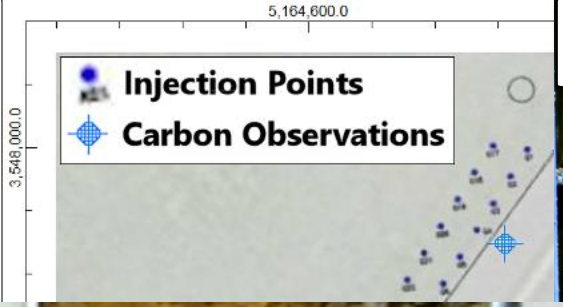

PI-24
PI-24
RPI
Remediation Products, Inc.


PI-24
RPI
Remediation Products, Inc.
Carbon Observations
Even Distribution
Heavy Distribution
Horizontal Seam
Smear
Specks
Spot
Suspect Carbon
Vertical Seam

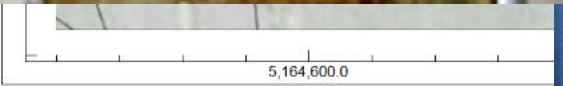
Carbon Observation Well

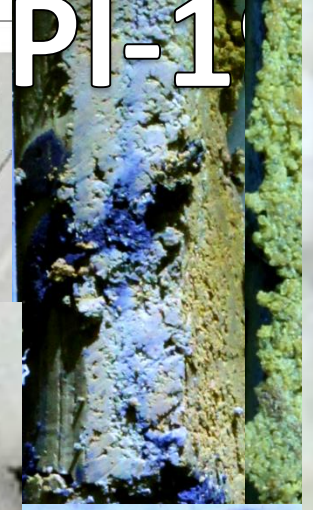
on Observations
Even Distribution
Heavy Distribution
Horizontal Seam
Smear
Specks
Spot
Suspect Carbon
Vertical Seam

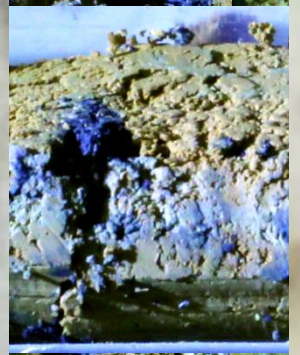

Injection Points
Carbon Observations
5,164,600.0
5,164,650.0
3,548,000.0
3,547,950.0
3,547,900.0
3,547,850.0


5,164,600.0
3,548,000.0
Injection Points
Carbon Observations

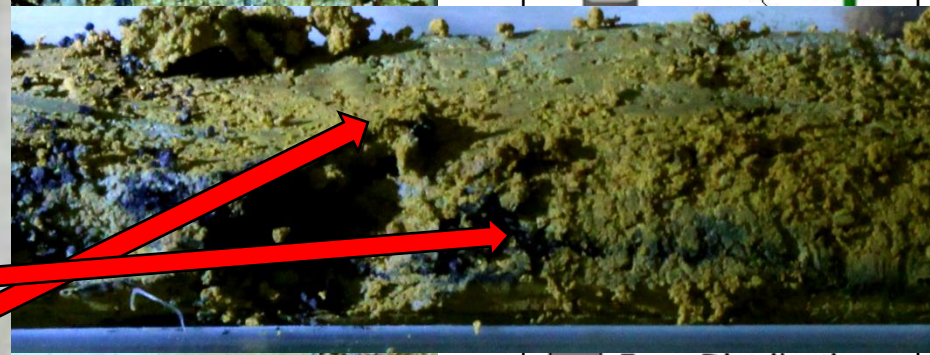

MW-04

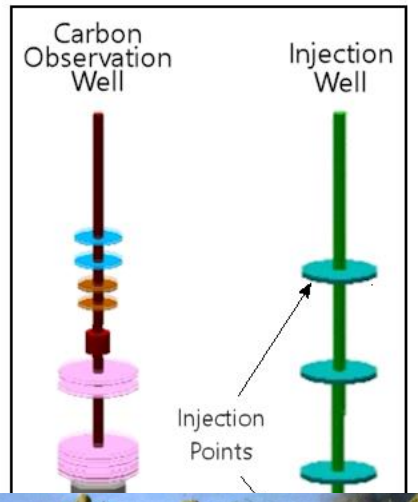

5,164,600.0

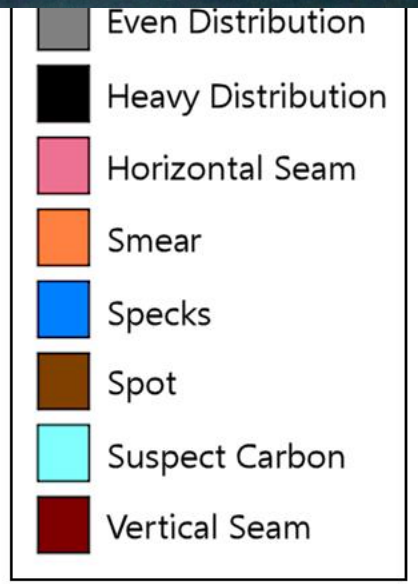

PT-1




MW-04

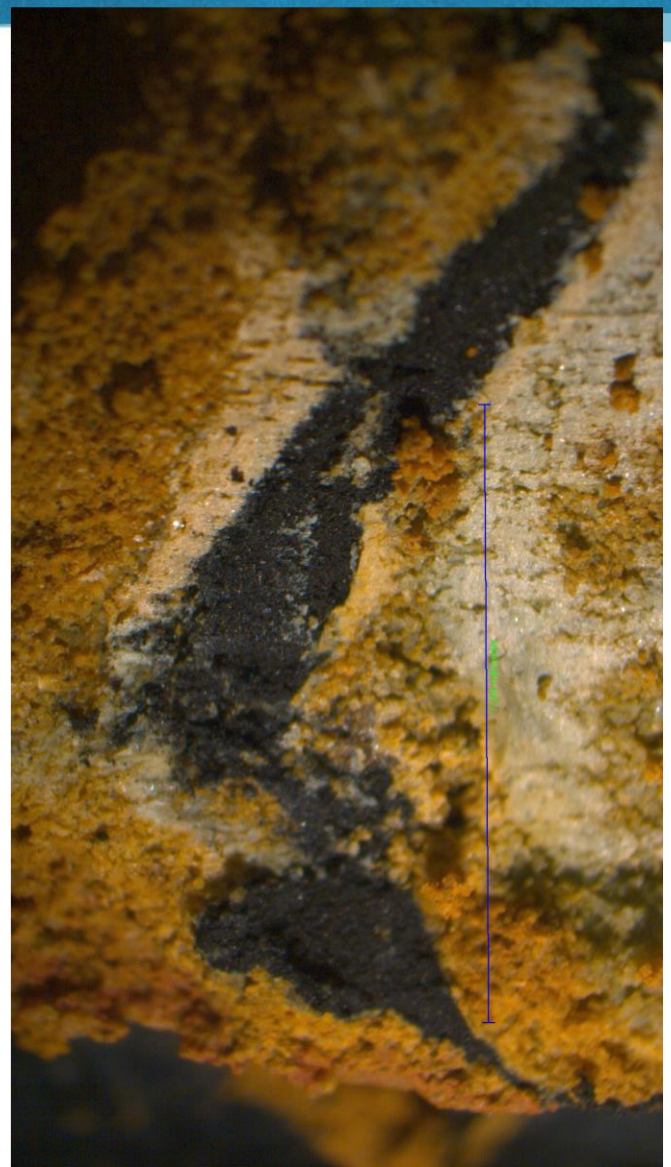


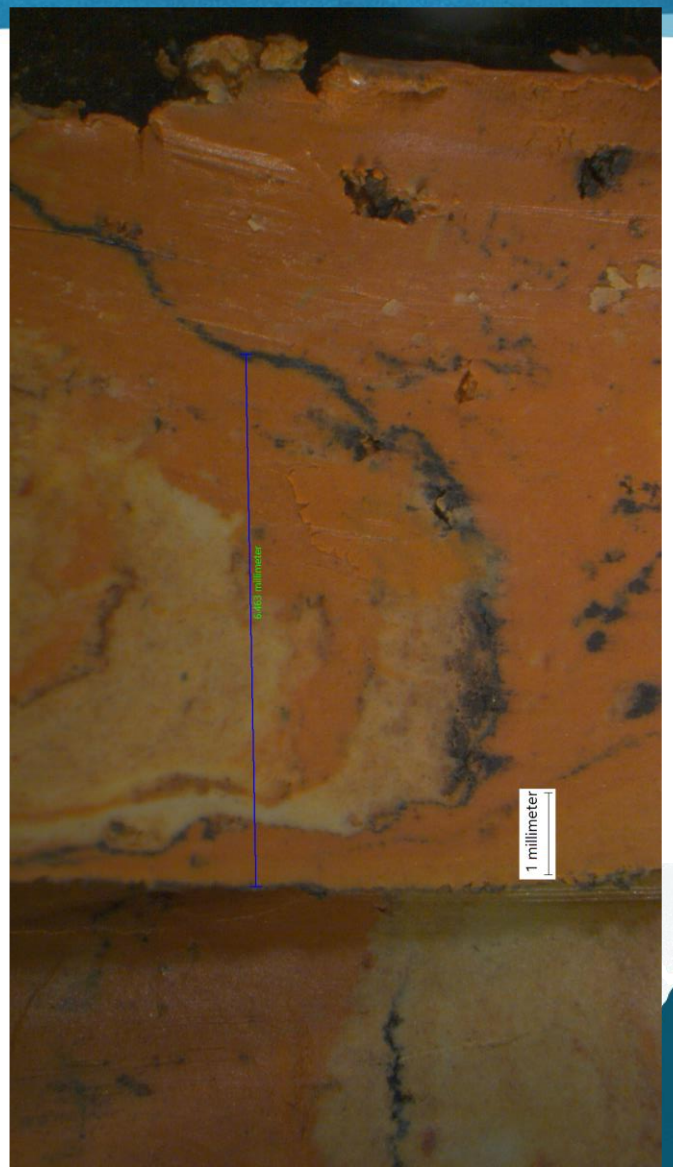

Carbon Observation Well
Injection Well
Injection Points

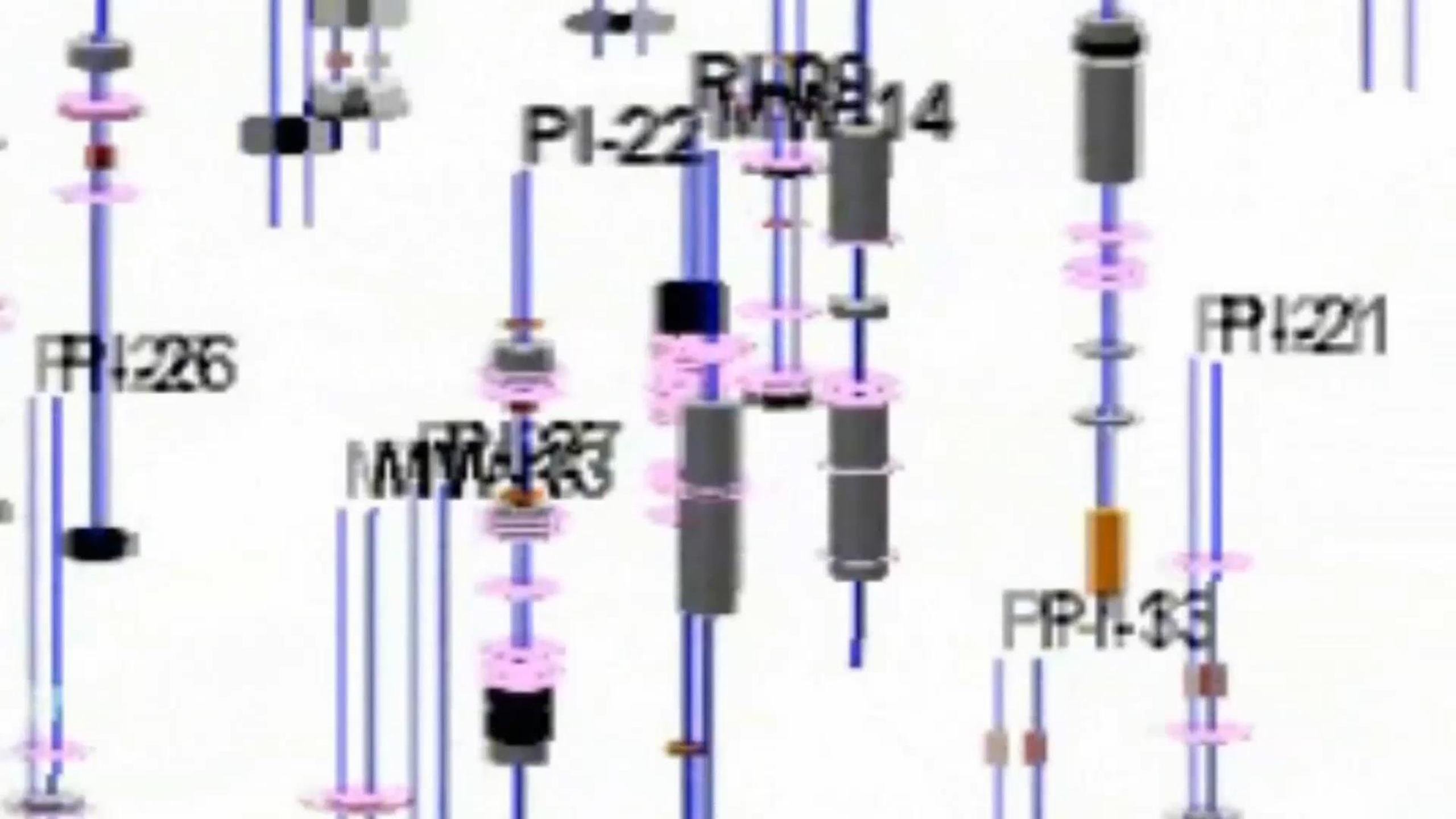

Even Distribution
Heavy Distribution
Horizontal Seam
Smear
Specks
Spot
Suspect Carbon
Vertical Seam

PI-19

Carbon often tracks the interface between soil textures






PI-22
PP-I-221
PP-I-13

Quantification of Carbon Sightings

183-244cm 244-305cm 305-366cm 366-427cm 427-488cm

X=1

X=2

X=3

X=4

X≥5

Carbon Count by # of Inclusion within 40 Cores by Depth		6-8 FT	8-10 FT	10-12 FT	12-14 FT	14-16 FT	Sum of Inclusions per Category	Percent of Total Sightings
Carbon Present	X≥1	32	32	31	26	29	150	55%
% by Interval	%	80%	80%	77.50%	65%	72.50%		
	X≥2	14	20	15	7	18	74	27%
	%	35%	50%	37.50%	17.50%	45%		
	X≥3	4	9	5	3	11	32	12%
	%	10%	22.50%	12.50%	7.50%	27.50%		
	X≥4	2	3	1	0	4	10	3%
	%	5%	7.50%	2.50%	0	10%		
	X≥5	1	1	1	0	1	4	1%
	%	2.50%	2.50%	2.50%	0	2.50%		

Visual Carbon: Sum of Cores		6-8 FT	8-10 FT	10-12 FT	12-14 FT	14-16 FT	Total	
TOTAL Sightings per depth for all cores:		53	65	53	36	65	272	
% OF TOTAL:		19%	24%	19%	13%	24%		

- Top Chart Summary
  - Each core had between 65 to 80% probability of visually demonstrating carbon (Row data)
  - 55% of all inclusions were single inclusions
- Bottom Chart Summary
  - Each of the 5, ~60cm intervals demonstrated between 13 to 24% of the total carbon identified (20% would be equity)

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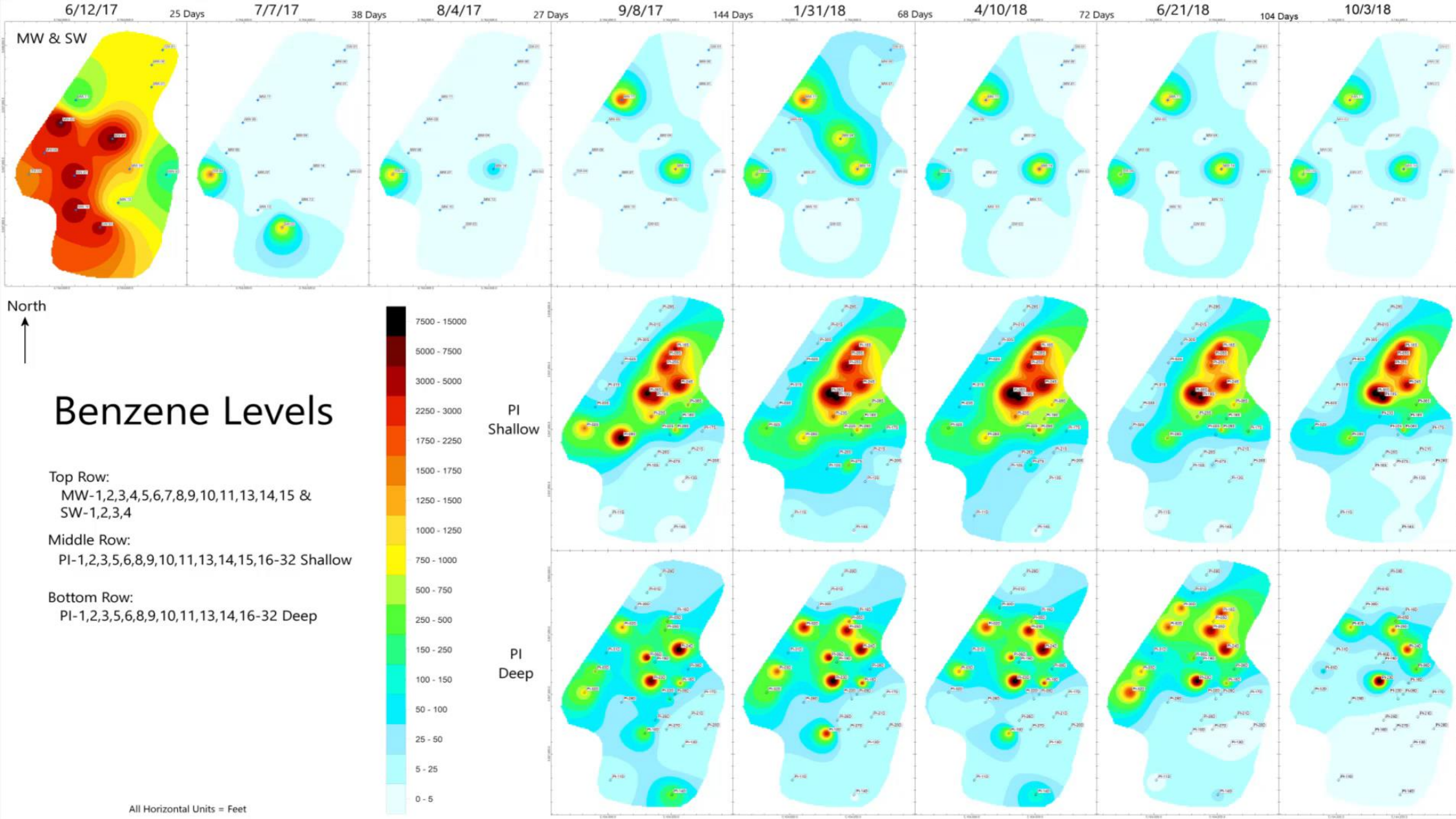
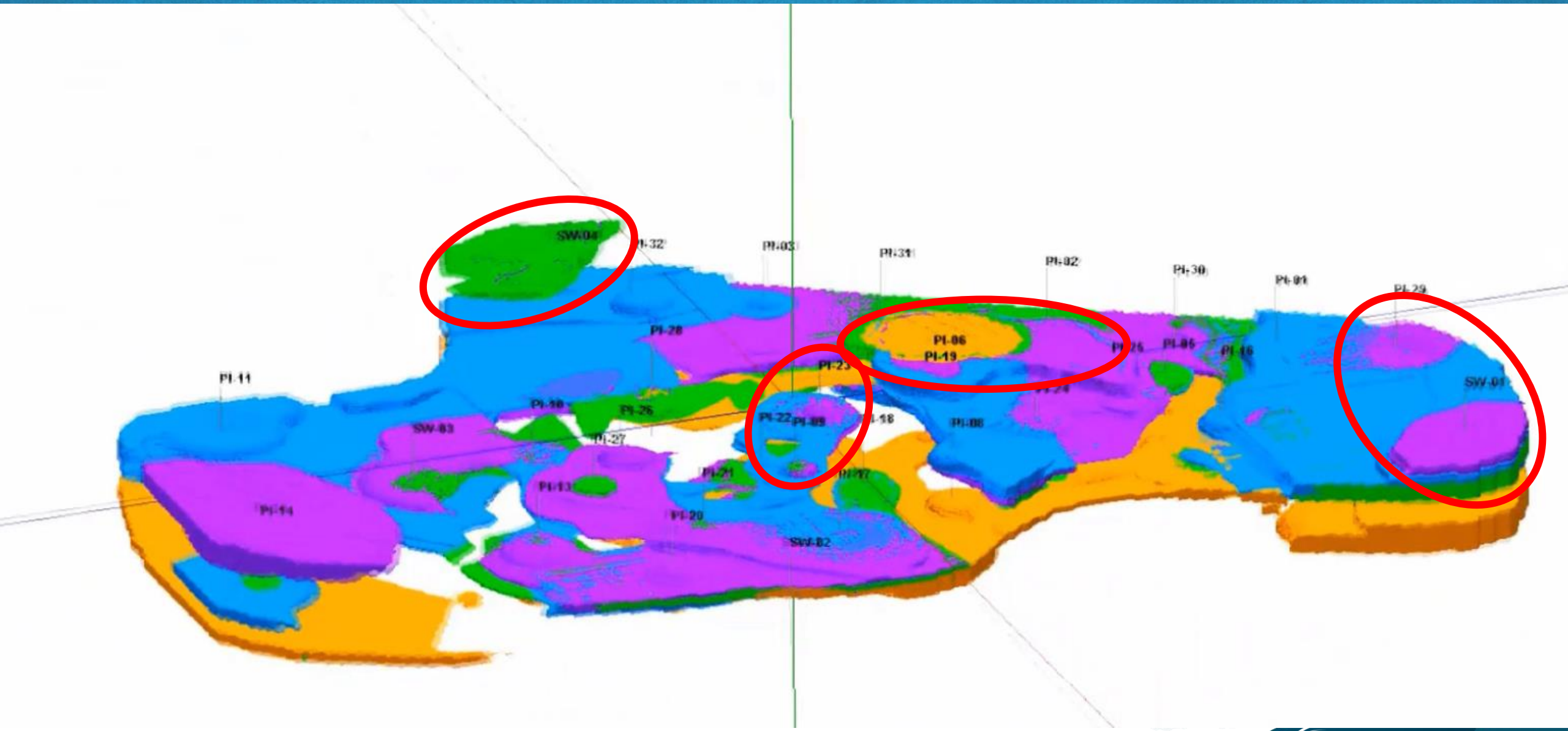

6/12/17
25 Days
7/7/17
38 Days
8/4/17
27 Days
9/8/17
144 Days
1/31/18
68 Days
4/10/18
72 Days
6/21/18
104 Days
10/3/18
MW & SW
North
Benzene Levels
Top Row:
MW-1,2,3,4,5,6,7,8,9,10,11,13,14,15 &
SW-1,2,3,4
Middle Row:
PI-1,2,3,5,6,8,9,10,11,13,14,15,16-32 Shallow
Bottom Row:
PI-1,2,3,5,6,8,9,10,11,13,14,16-32 Deep
7500 - 15000
5000 - 7500
3000 - 5000
2250 - 3000
1750 - 2250
1500 - 1750
1250 - 1500
1000 - 1250
750 - 1000
500 - 750
250 - 500
150 - 250
100 - 150
50 - 100
25 - 50
5 - 25
0 - 5
PI
Shallow
PI
Deep
All Horizontal Units = Feet

Contamination in top 183cm was purposely not treated



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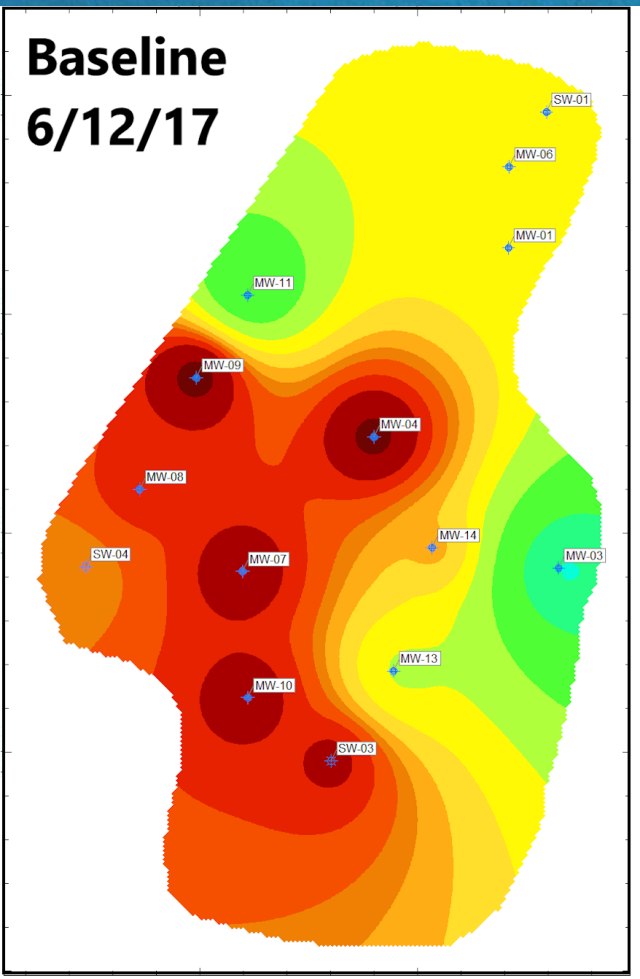
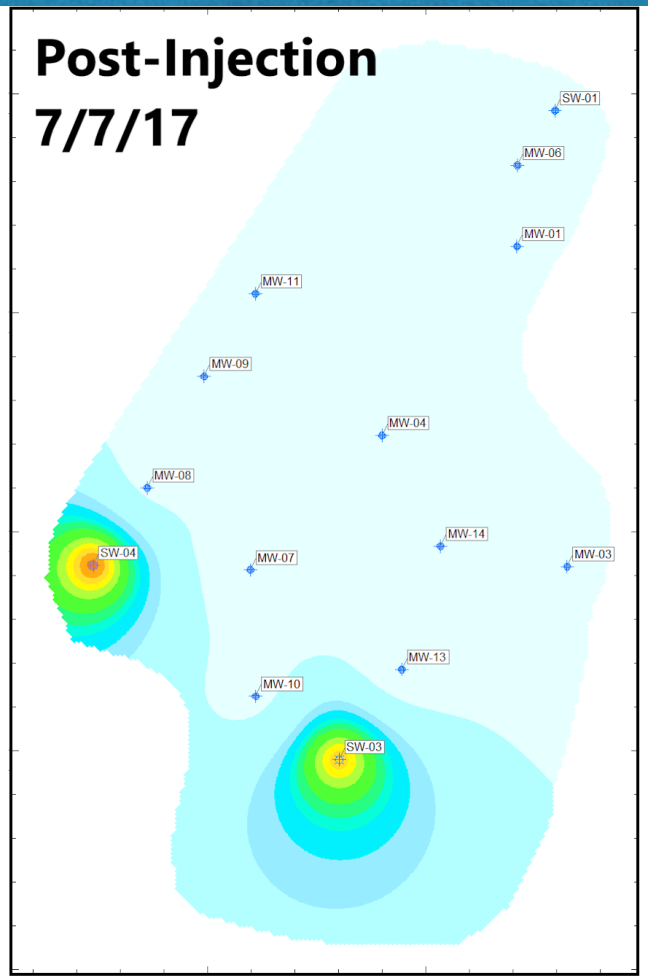
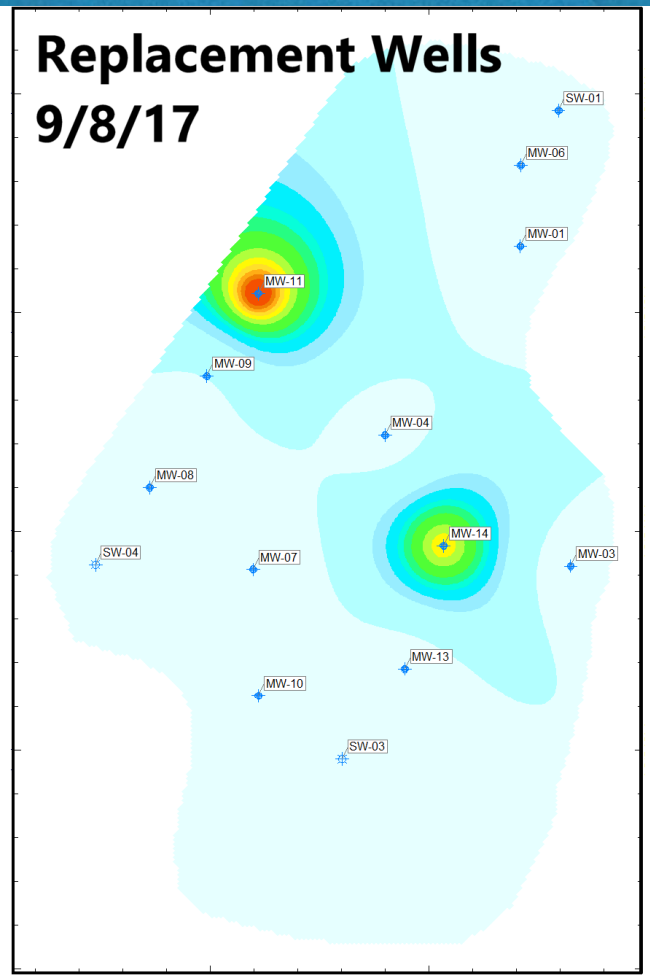
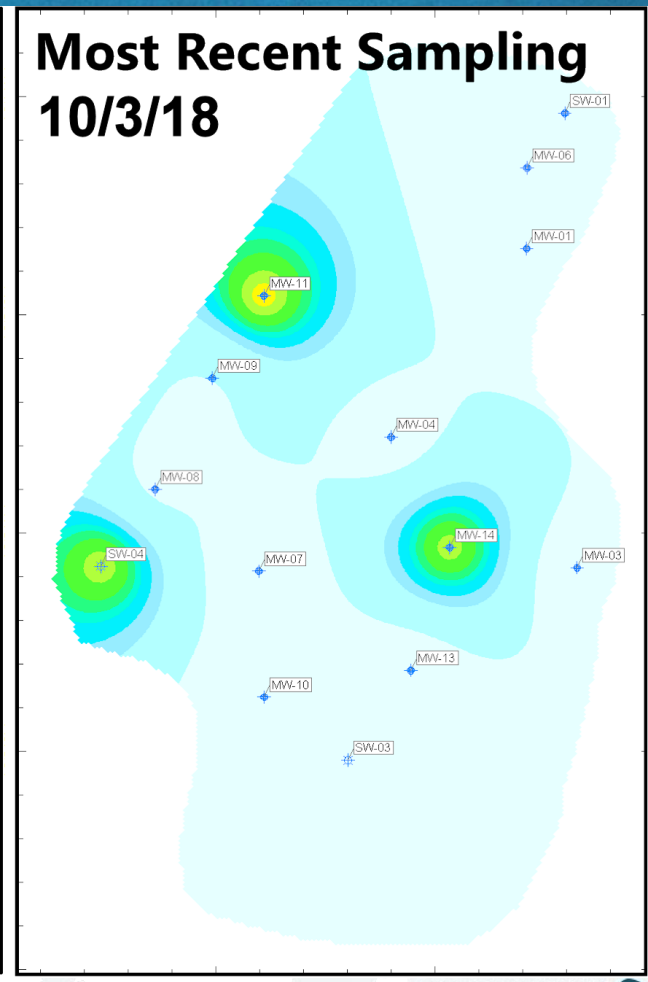
Benzene Comparison









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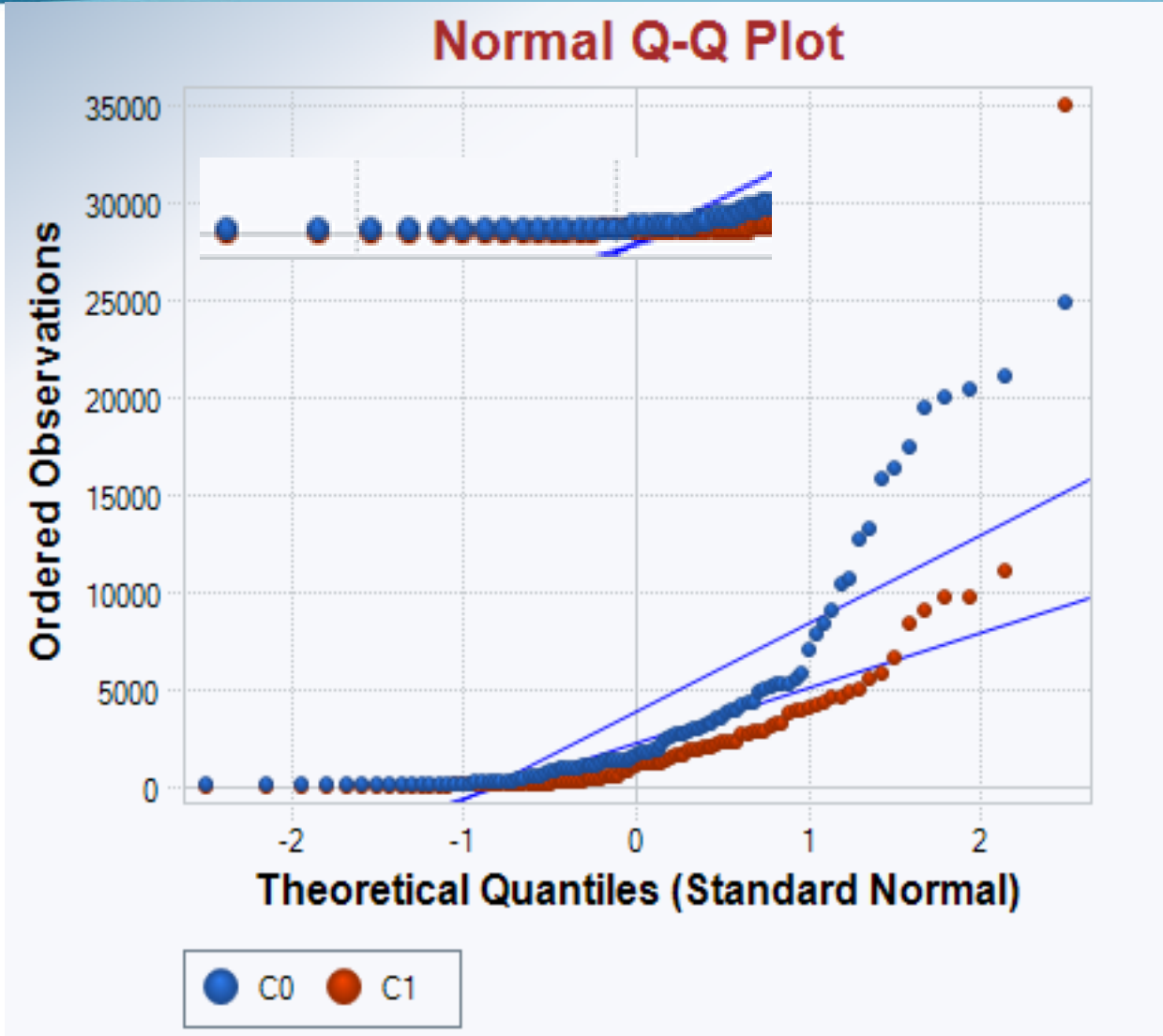
Naphthalene ug/Kg in aquifer soil at 30 months



Wilcoxon-Mann-Whitney Test

Co, site initial, C1, site post-emplacement

Raw Statistics		Pre-emplacement	Post-emplacement
Number of Valid Observations		**99**	**99**
Number of Missing Observations		1	1
Number of Distinct Observations		95	93
Minimum		39.2	0.25
Maximum		24900	35000
Mean		**3806**	**2148**
Median		**1550**	**1010**
SD		5481	4114
SE of Mean		550.9	413.5
H0: Mean/Median of Pre-emplacement <= Mean/Median of Post-emplacement			
Sample 1 Rank Sum W-Stat		11027	
Standardized WMW U-Stat		2.916	
Mean (U)		4901	
SD(U) - Adj ties		403.2	
Approximate U-Stat Critical Value (0.05)		1.645	
P-Value (Adjusted for Ties)		**0.00177**	
Conclusion with Alpha = 0.05			
Reject H0, Conclude Pre-emplacement > Post-emplacement			

BTEX plus at 30 months post-emplacement

Constituent	Median Difference	p value	1/2-life in years
Benzene	3.6-fold lower	0.0009	0.48
Toluene	1.5-fold lower	0.0018	1.16
Ethylbenzene	4.0-fold lower	0.00089	0.43
m/p Xylene	2.2-fold lower	0.0091	0.79
o-Xylene	2.5-fold lower	0.019	0.69
1,2,4-TMB	1.2-fold lower	0.0289	1.44
Naphthalene	3.5-fold lower	0.0018	0.50

½-life in soil cores post- BOS200 emplacement

Constituent	1/2-life in years Post-BOS200	Kentucky estimate using groundwater	California estimate using groundwater
Benzene	0.48	3.2	3.8
Toluene	1.16		3.2
Ethylbenzene	0.43		4.6
m/p Xylene	0.79		3.8
o-Xylene	0.69		3.8
1,2,4-TMB	1.44		
Naphthalene	0.50		8.7
BTEX		3.9	
TPHGRO			5.3

Summary

- Carbon inclusions are predictable, but inclusion types vary.
- Carbon often tracks the interface between different soil textures
- Monitoring well results
  - Results vary by well type, i.e., 5cm, 305cm screened vs 2.5cm, 152cm screened Shallow & Deep
  - The remaining contamination impacts both well types (Positive Control)
- At 30 months the aquifer/soil BTEX mass is significantly improved
- Degradation ½-life decreased 3 to 15-fold.
- One BOS200® injection was the sole remedy used on the site.
- Site received regulatory closure in 2022.

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