A Case Study on the Importance of High-Resolution Site Characterization in Determining a Good Remediation Technology and Finding Target Zones for Remediation

Opelika Power and Light Facility
UST Incident 93-02-19

Presented to:
ADEM 27th Annual UST Assessment and Remediation Conference
Virtual Conference, June 16, 2021

Presented by:

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ENVIRONMENTAL
MATERIALS
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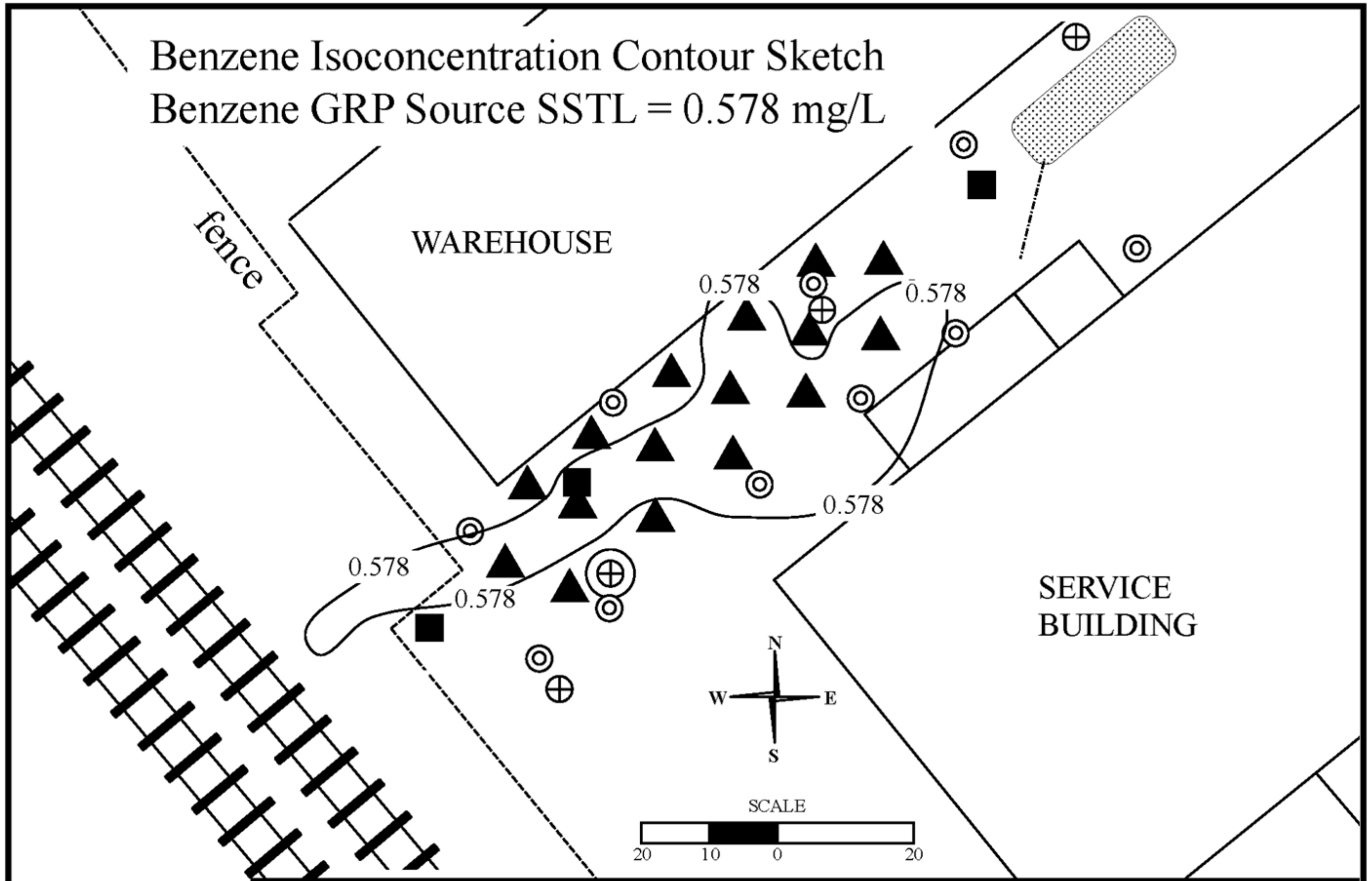
2027 Chestnut Street, Montgomery, Alabama 36106, 334-265-4000

Engineers • Geologists • Scientists

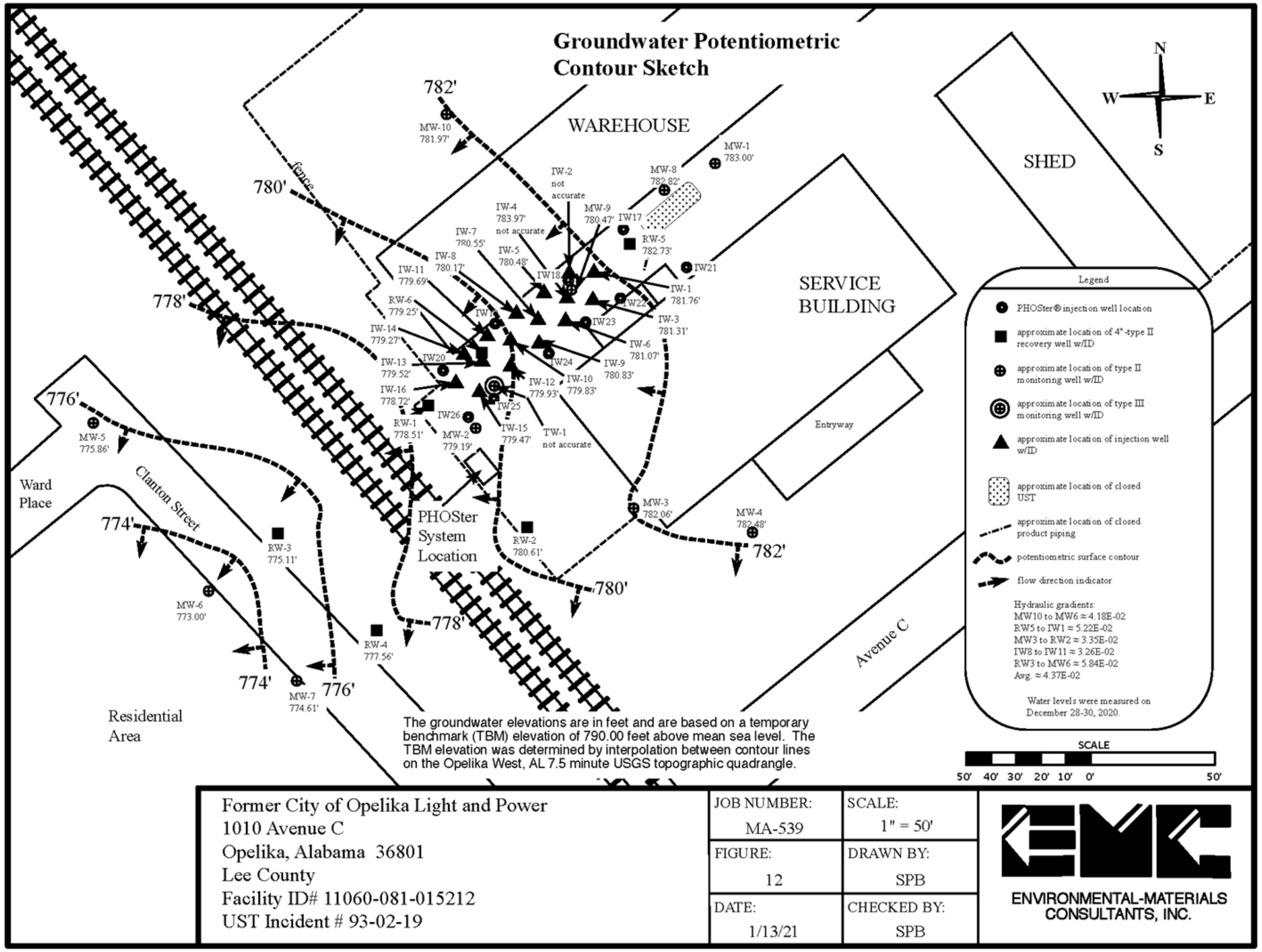
Site Introduction

- Location of site: Opelika, Alabama
- Gasoline release discovered in 1992 during UST closure
- Several investigations have been conducted including
  - Preliminary
  - Secondary
  - Data Acquisition
  - Groundwater Monitoring
- ARBCA - site-specific target levels were developed for the site

Benzene Isoconcentration Contour Sketch
Benzene GRP Source SSTL = 0.578 mg/L



Former City of Opelika Light and Power 1010 Avenue C Opelika, Alabama 36801 Lee County Facility ID# 11060-081-015212 UST Incident # 93-02-19	JOB NUMBER: MA-539	SCALE: 1" = 20'	ENVIRONMENTAL-MATERIALS CONSULTANTS, INC.
	FIGURE: 1	DRAWN BY: SPB	
	DATE: 5/24/21	CHECKED BY: SPB	



Groundwater Potentiometric Contour Sketch
WAREHOUSE
SERVICE BUILDING
SHED
Entryway
PHOSter System Location
Ward Place
Clanton Street
Avenue C
Residential Area
fence
N
S
E
W
782'
780'
778'
776'
774'
MW-10 781.97'
MW-1 783.00'
MW-8 782.82'
MW-9 780.47'
MW-2 779.19'
MW-3 782.06'
MW-4 782.48'
MW-5 775.86'
MW-6 773.00'
MW-7 774.61'
RW-1 778.51'
RW-2 780.61'
RW-3 775.11'
RW-4 777.56'
RW-5 782.73'
RW-6 779.25'
IW-1 781.76'
IW-2 not accurate
IW-3 781.31'
IW-4 783.97' not accurate
IW-5 780.48'
IW-6 781.07'
IW-7 780.55'
IW-8 780.17'
IW-9 780.83'
IW-10 779.83'
IW-11 779.69'
IW-12 779.93'
IW-13 779.52'
IW-14 779.27'
IW-15 779.47'
IW-16 778.72'
TW-1 not accurate
IW17
IW18
IW20
IW21
IW22
IW23
IW24
IW25
IW26
Legend
PHOSter® injection well location
approximate location of 4" -type II recovery well w/ID
approximate location of type II monitoring well w/ID
approximate location of type III monitoring well w/ID
approximate location of injection well w/ID
approximate location of closed UST
approximate location of closed product piping
potentiometric surface contour
flow direction indicator
Hydraulic gradients:
MW10 to MW6 ≈ 4.18E-02
RW5 to IW1 ≈ 5.22E-02
MW3 to RW2 ≈ 3.35E-02
IW8 to IW11 ≈ 3.26E-02
RW3 to MW6 ≈ 5.84E-02
Avg. ≈ 4.37E-02
Water levels were measured on December 28-30, 2020.
SCALE
50' 40' 30' 20' 10' 0' 50'
The groundwater elevations are in feet and are based on a temporary benchmark (TBM) elevation of 790.00 feet above mean sea level. The TBM elevation was determined by interpolation between contour lines on the Opelika West, AL 7.5 minute USGS topographic quadrangle.
Former City of Opelika Light and Power
1010 Avenue C
Opelika, Alabama 36801
Lee County
Facility ID# 11060-081-015212
UST Incident # 93-02-19
JOB NUMBER: MA-539
SCALE: 1" = 50'
FIGURE: 12
DRAWN BY: SPB
DATE: 1/13/21
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Subsurface at the Site

Soil

- Saprolite derived from metamorphic rocks of the Opelika Complex
  - Clay, silt, and sand layers
  - Low permeability, but not as impermeable as pure clay

Groundwater

- Benzene in several wells has commonly exceeded the source area target level (0.578 mg/L)
- Naphthalene has periodically exceeded the point-of-compliance target level in one downgradient well
- Other chemicals-of-concern have only rarely exceeded target levels

Remediation methods were tried

- Mobile Extraction Events
  - 34 were conducted
- In-Situ Chemical Oxidation (ISCO)
  - Several phases were conducted

Mobile Extraction Events

- 34 events were conducted from 2006 through 2016
- Most were 8-hour
- Most were conducted as part of the 2007 CAP implementation, but 3 were conducted just prior to ISCO events
- 20,000 gallons of liquids recovered
- 250 gallons of gasoline equivalent recovered (calculated from vapor emissions)

Benzene concentrations did not decrease in wells with the highest concentrations

- Benzene GRP Source SSTL = 0.578 mg/L
- RW6
  - 2008 average benzene concentration = 21.633 mg/L
  - 2014 average benzene concentration = 26.500 mg/L

Benzene concentrations did decrease in some wells with lower initial concentrations

- RW1
  - 2008 average benzene concentration was 0.232 mg/L
  - 2014 average benzene concentration was <0.001 mg/L (BDL)

In-Situ Chemical Oxidation (ISCO)

- Several phases were conducted:
  - August 2014 – 5 days of injection
  - November 2014 – 5 days of injection
  - April 2015 – 5 days of injection
  - November-December 2015 – 5 days of injection
  - March 2016 – 5 days of injection
  - August 2016 – 4 days of injection

ISCO Actual Totals vs Recommended

- <u>Total Injected:</u>
  5,270 pounds

- <u>Total Recommended:</u>
  8,370 pounds of chemical

Benzene decreased in some wells, but long-term averages showed little change

- MW9
  - 2013 average benzene was 3.413 mg/L
  - 2017 benzene was 3.900 mg/L

- RW6
  - 2013 average benzene was 26.433 mg/L
  - 2017 benzene was 25.400 mg/L

Factors that may have limited the effectiveness of the extraction events and ISCO events at this site

- Tightness of the soil
- ISCO recommended amount of chemicals was not applied
- Incorrect zones targeted vertically and horizontally
  - IW screens for ISCO were 15’ length and set 6’ - 21’ bgs
- Incorrect implementation
  - Maybe should have used direct-push instead of pre-installed IWs

We have a dilemma

We have tried a couple of remediation techniques that did not have the desired results

What do we do next?

The answer is:

- High-Resolution Site-Characterization

- Based on the HRSC data, we chose PHOSter as the remediation technology

COLUMBIA TECHNOLOGIES

Better Clarity Through Higher-Resolution

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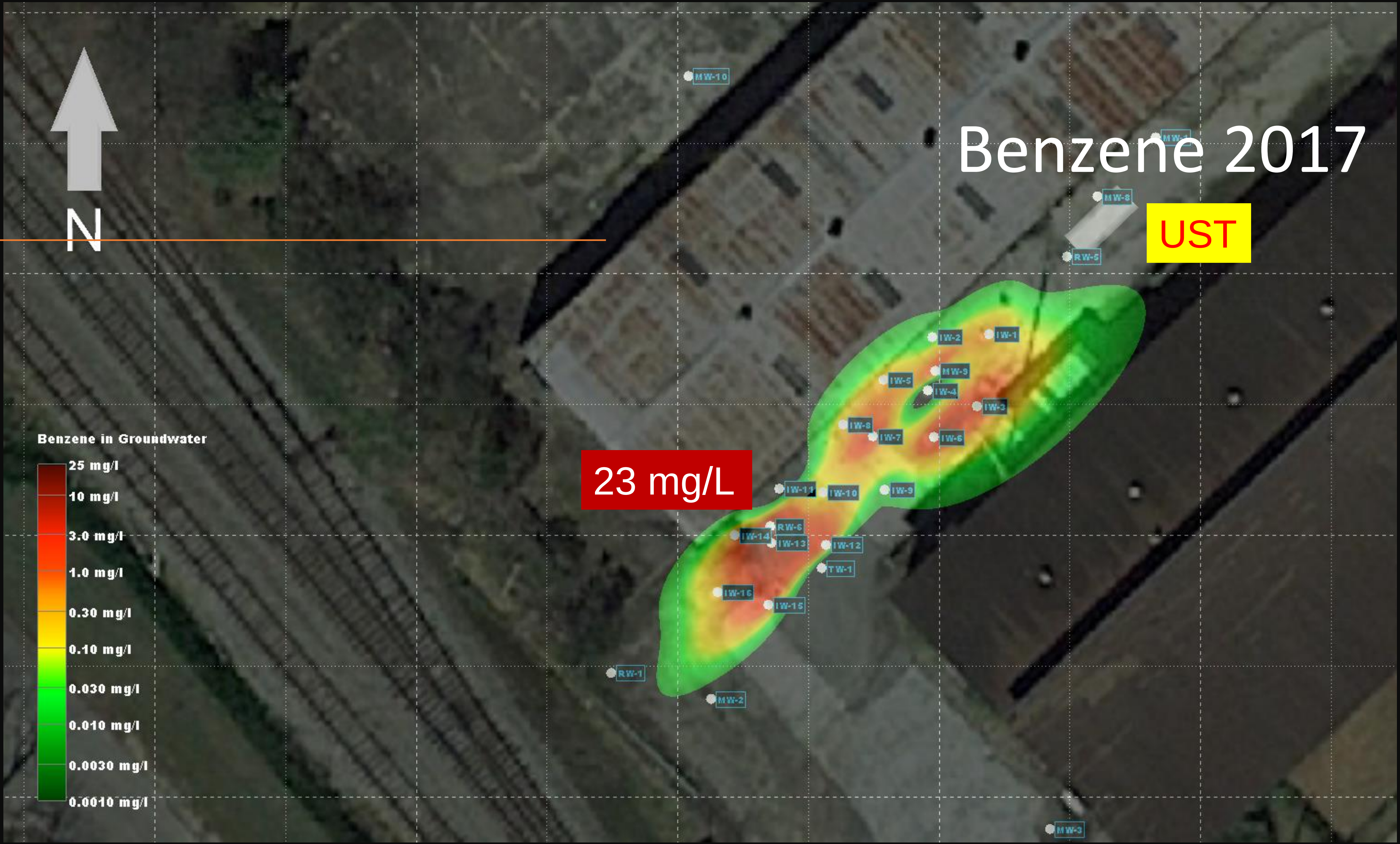
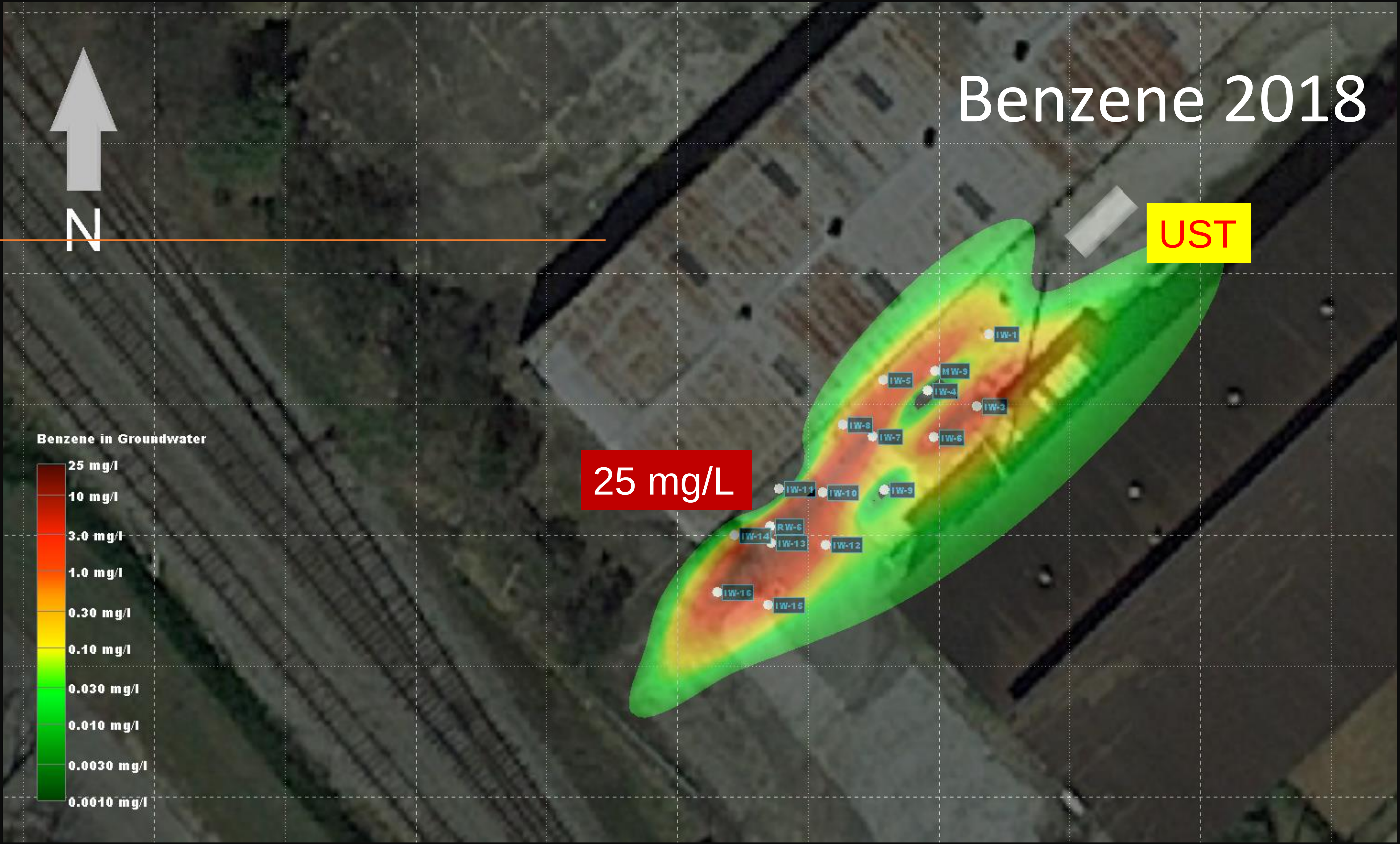

Benzene 2017
UST
23 mg/L
N
Benzene in Groundwater
25 mg/l
10 mg/l
3.0 mg/l
1.0 mg/l
0.30 mg/l
0.10 mg/l
0.030 mg/l
0.010 mg/l
0.0030 mg/l
0.0010 mg/l
MW-10
MW-8
RW-5
IW-2
IW-1
MW-9
IW-5
IW-4
IW-3
IW-8
IW-7
IW-6
IW-11
IW-10
IW-9
RW-6
IW-14
IW-13
IW-12
TW-1
IW-16
IW-15
RW-1
MW-2
MW-3

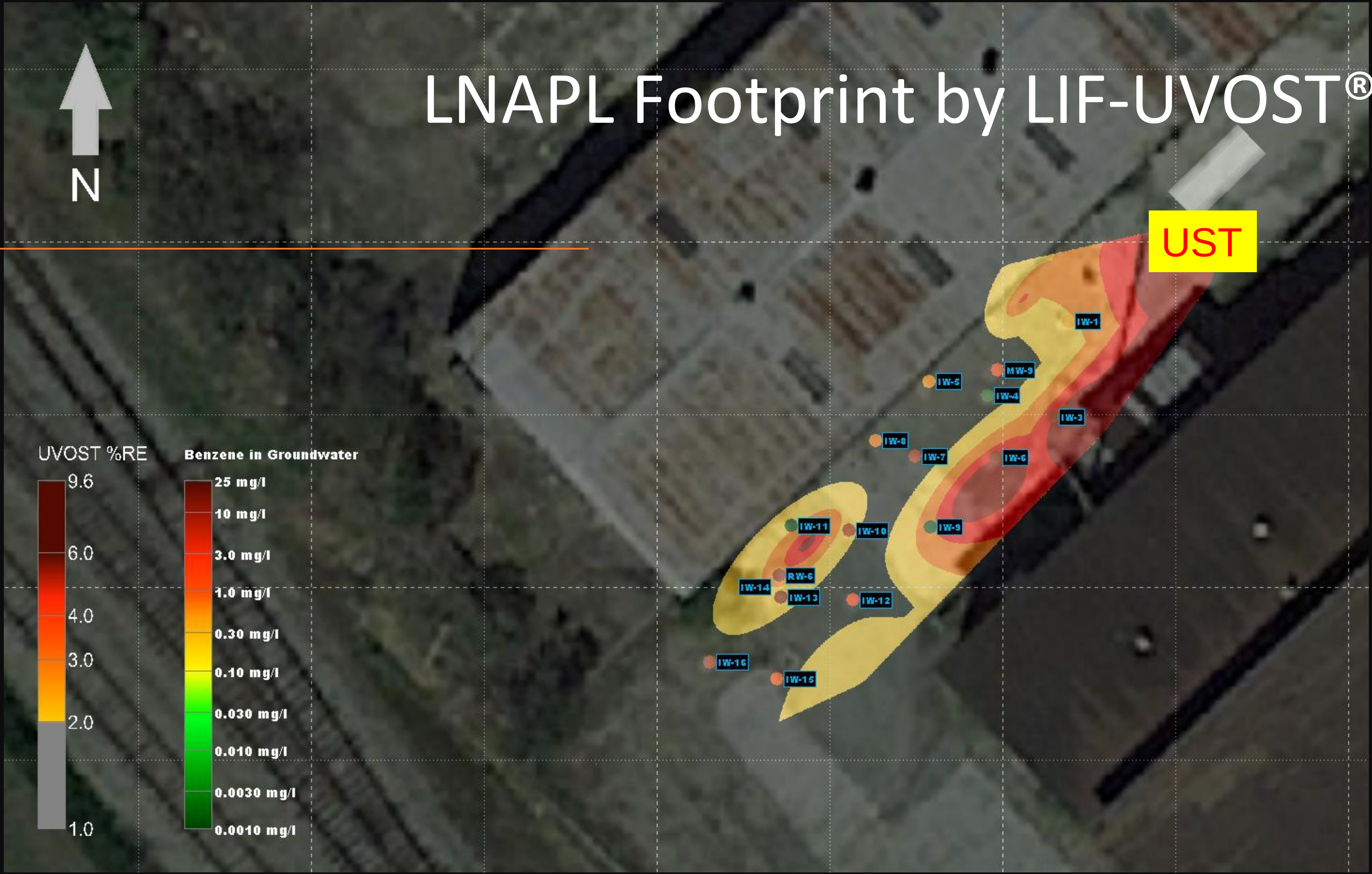


Benzene 2018
N
UST
25 mg/L
Benzene in Groundwater
25 mg/l
10 mg/l
3.0 mg/l
1.0 mg/l
0.30 mg/l
0.10 mg/l
0.030 mg/l
0.010 mg/l
0.0030 mg/l
0.0010 mg/l
IW-1
MW-3
IW-5
IW-4
IW-3
IW-8
IW-7
IW-6
IW-11
IW-10
IW-9
RW-6
IW-14
IW-13
IW-12
IW-16
IW-15

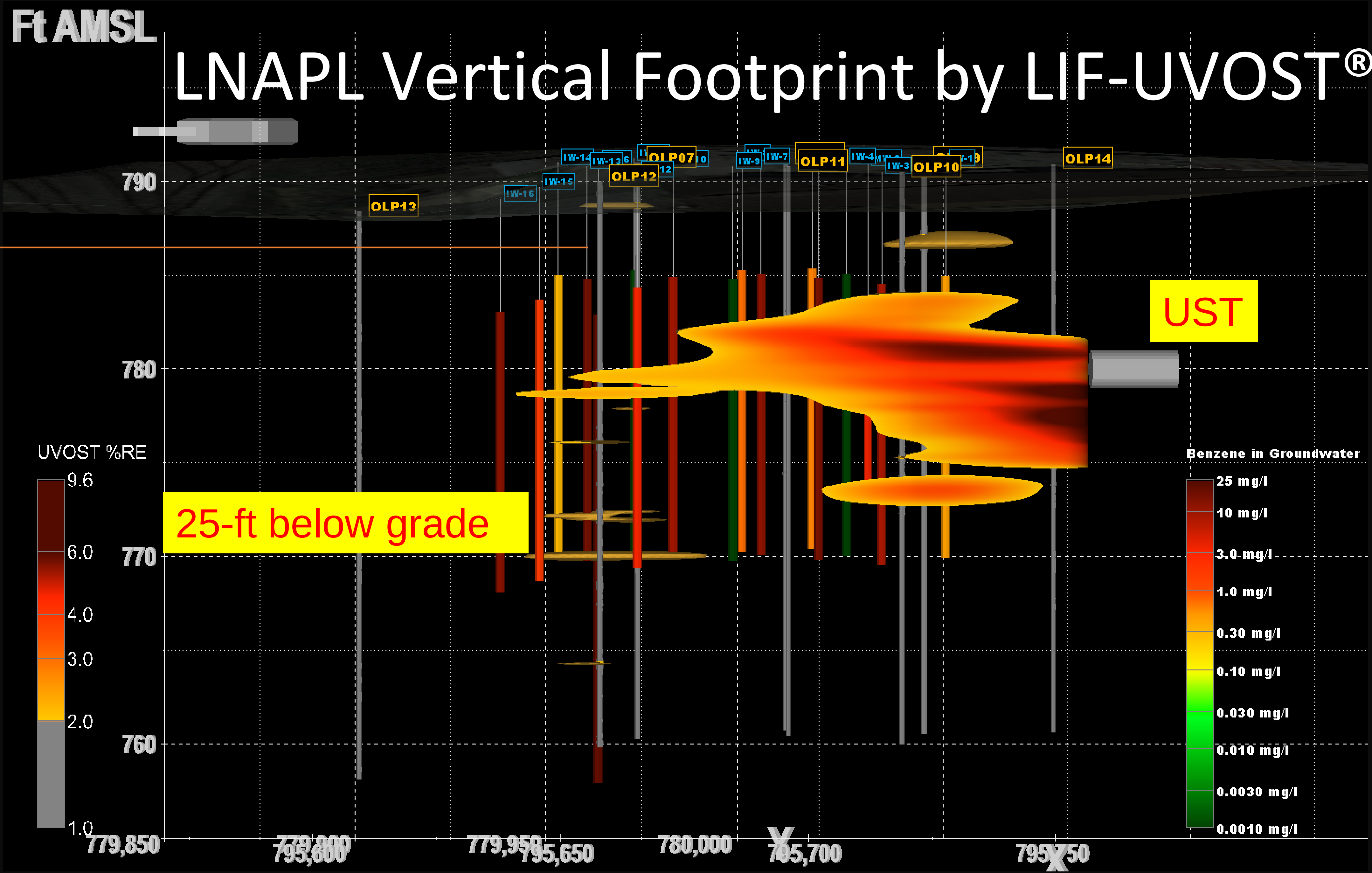
HRSC Approach

- WHERE IS THE RESIDUAL LNAPL?
  - Leverage the existing data
  - Map the residual LNAPL with OIP or LIF
- WHAT SOIL DOES THE LNAPL RESIDE IN?
  - Hydraulic Profiling Tool (HPT)
  - Storage – low permeability or Transport – generally NOT on older sites
- WHAT IS THE MASS & VOLUME OF THE RESIDUAL LNAPL?
  - Requires high-resolution *saturated* soil sampling
- WHAT IS THE EXTENT OF THE DISSOLVED PHASE PLUME?
  - MiHpt and Discrete GW Sampling
- REAL-TIME INFORMATION
  - Project Quality Control and Efficient Decision-Making

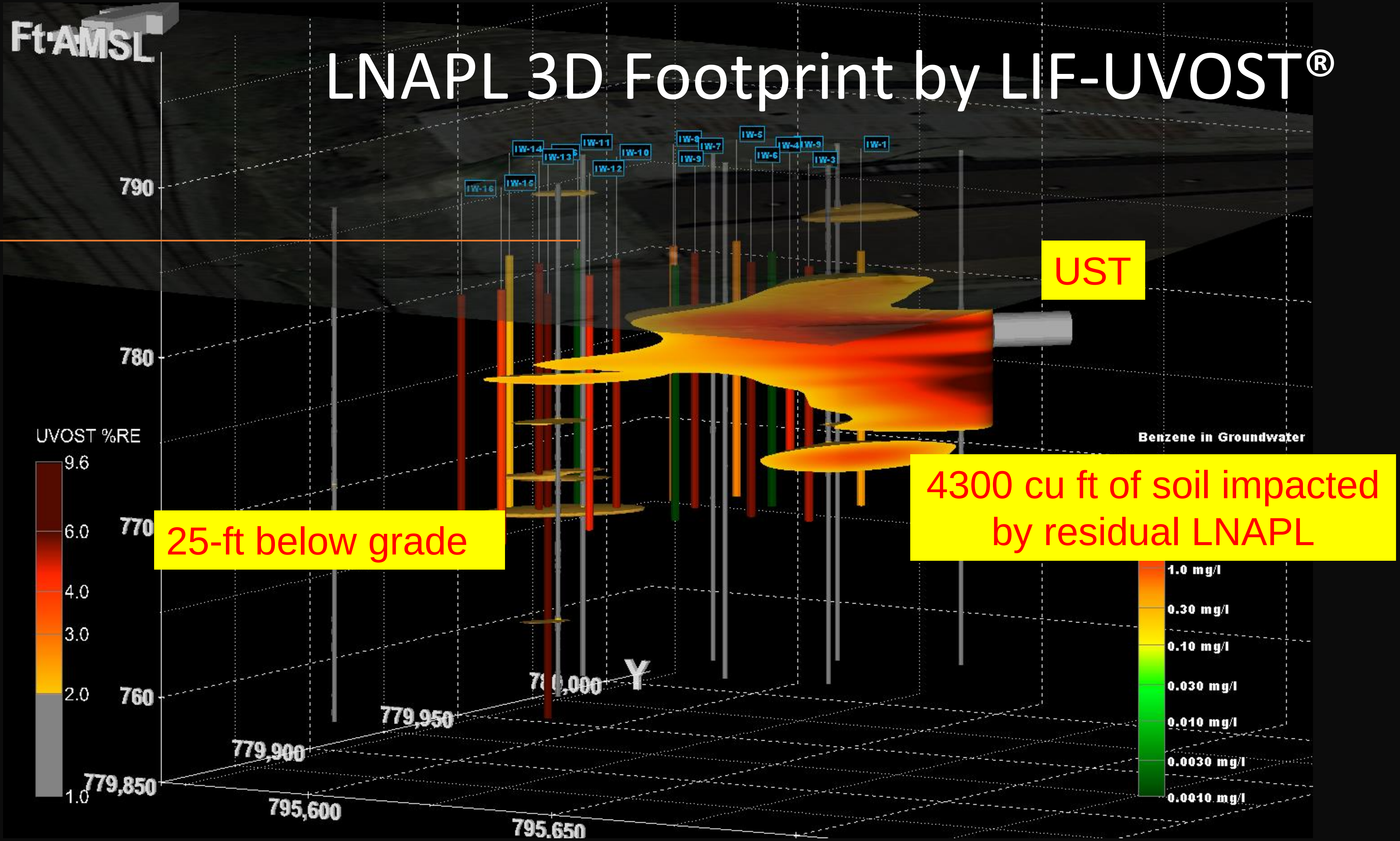
LNAPL Footprint by LIF-UVOST®



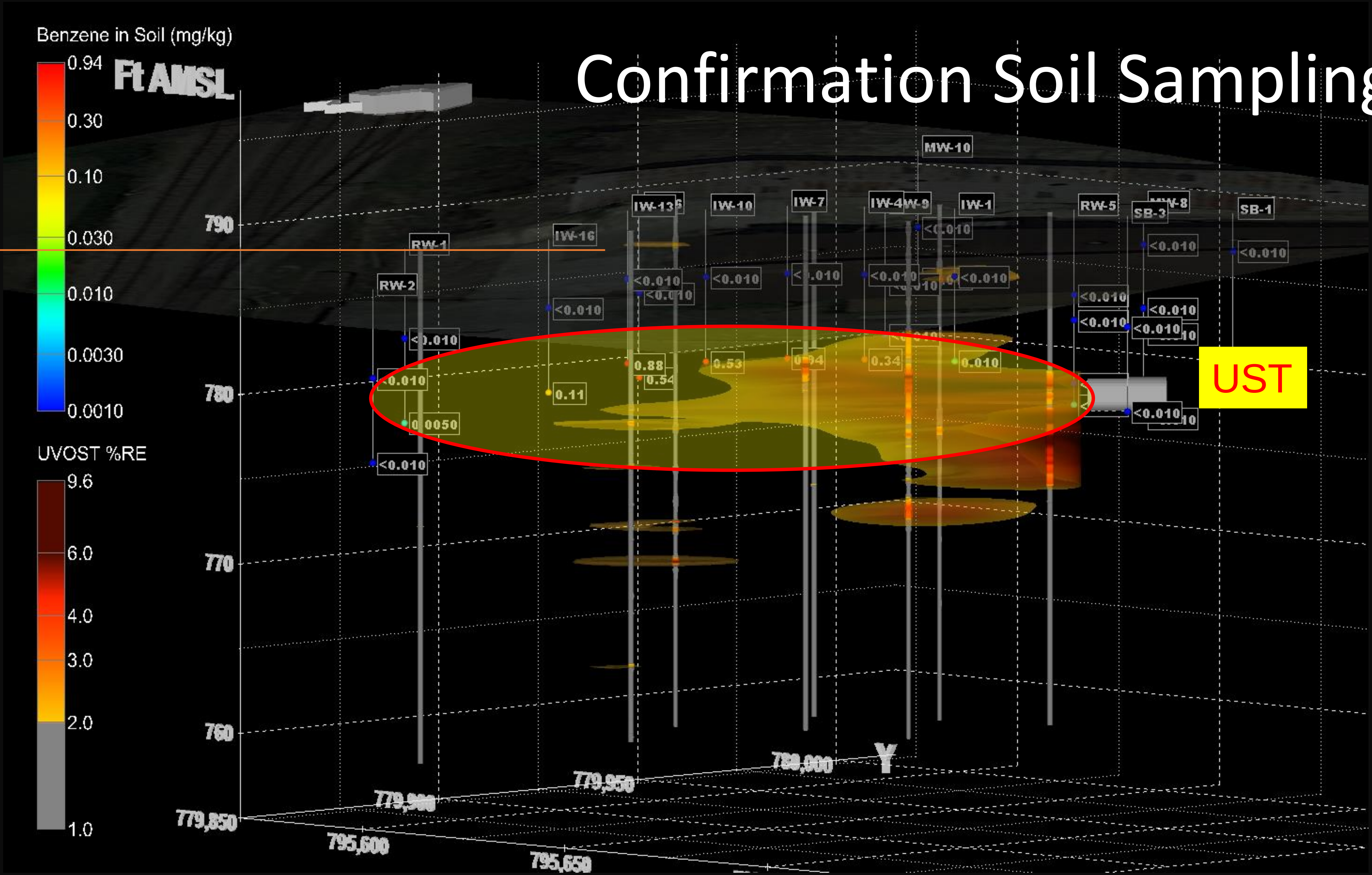
LNAPL Vertical Footprint by LIF-UVOST®



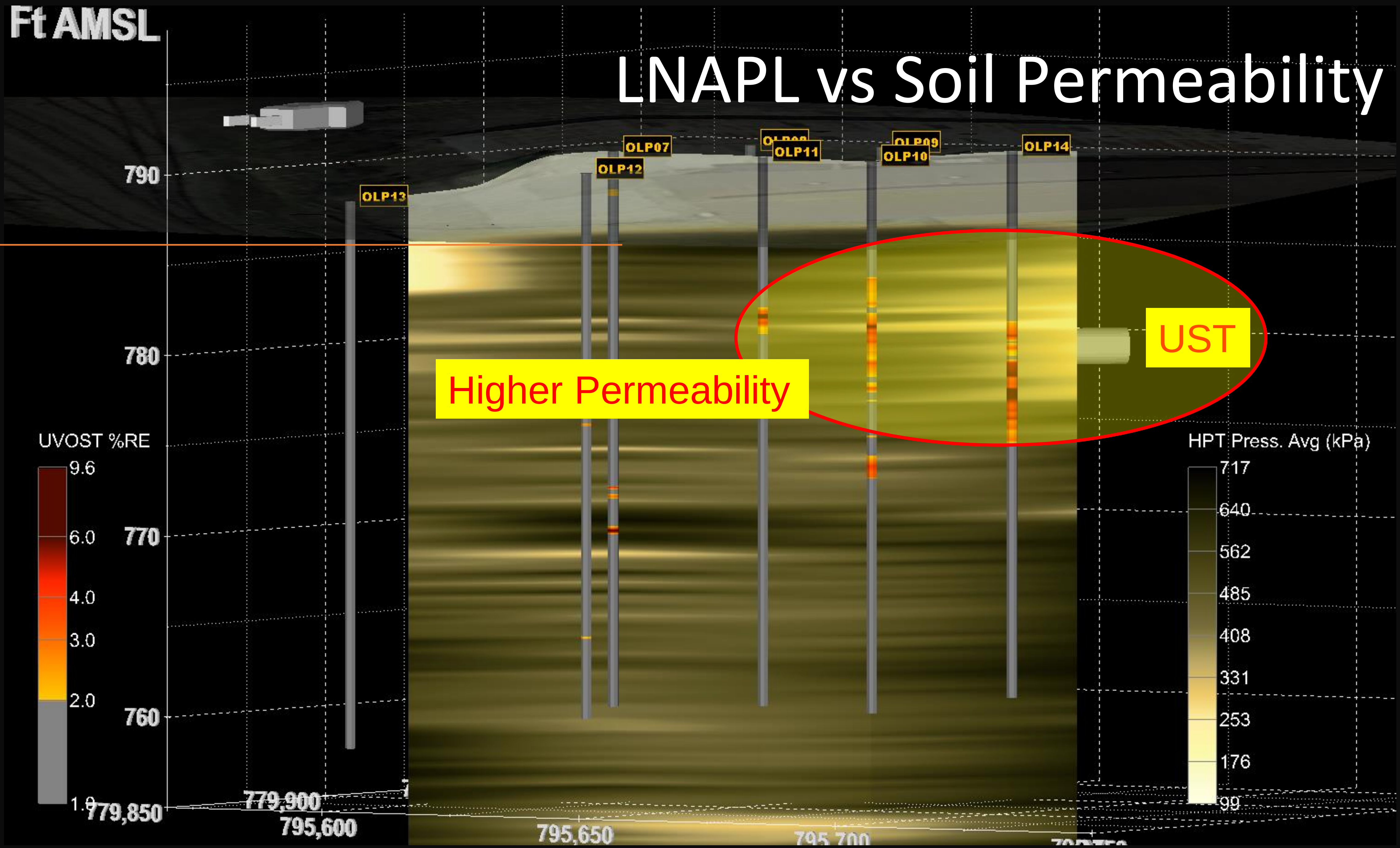
LNAPL 3D Footprint by LIF-UVOST®

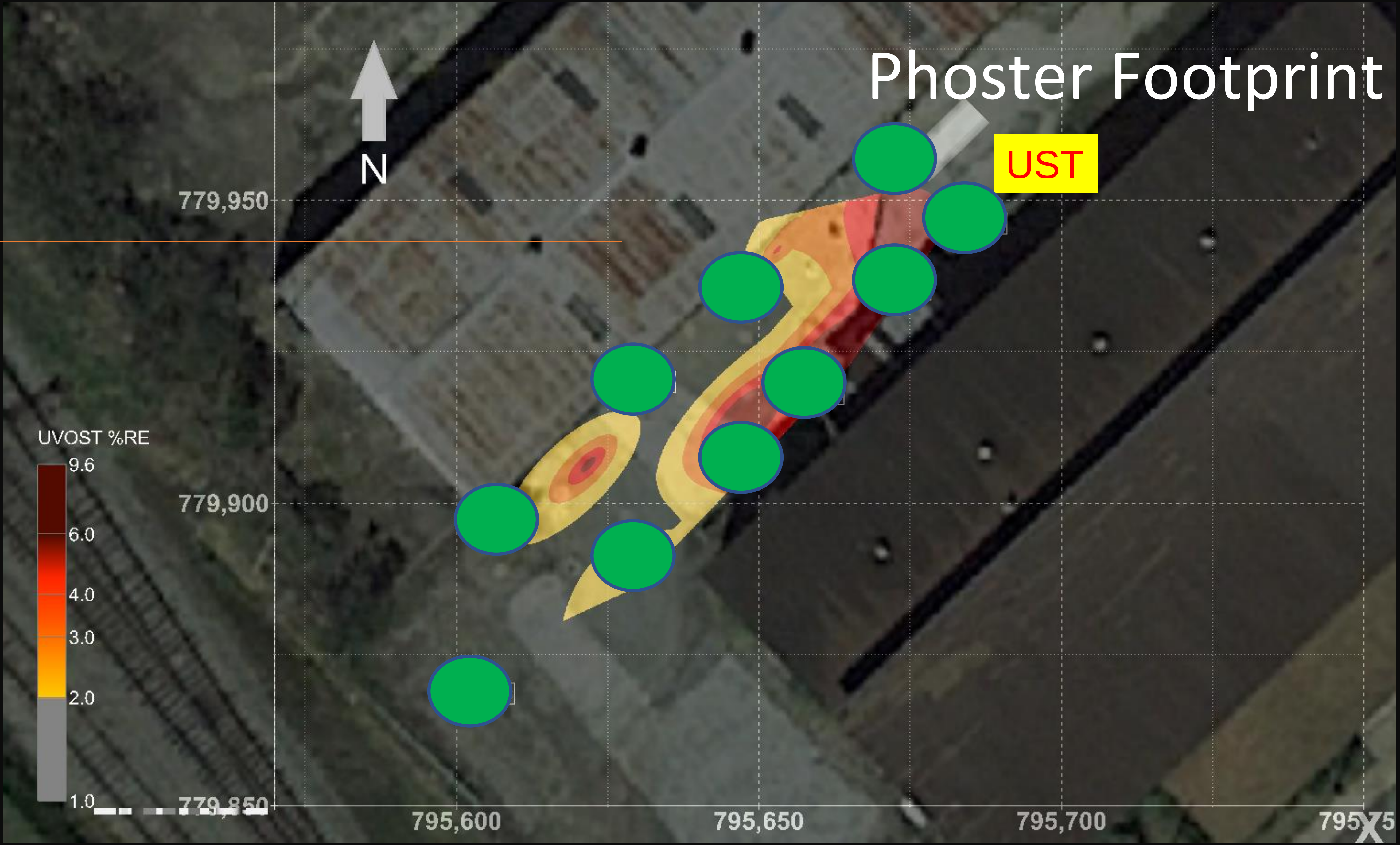


Confirmation Soil Sampling

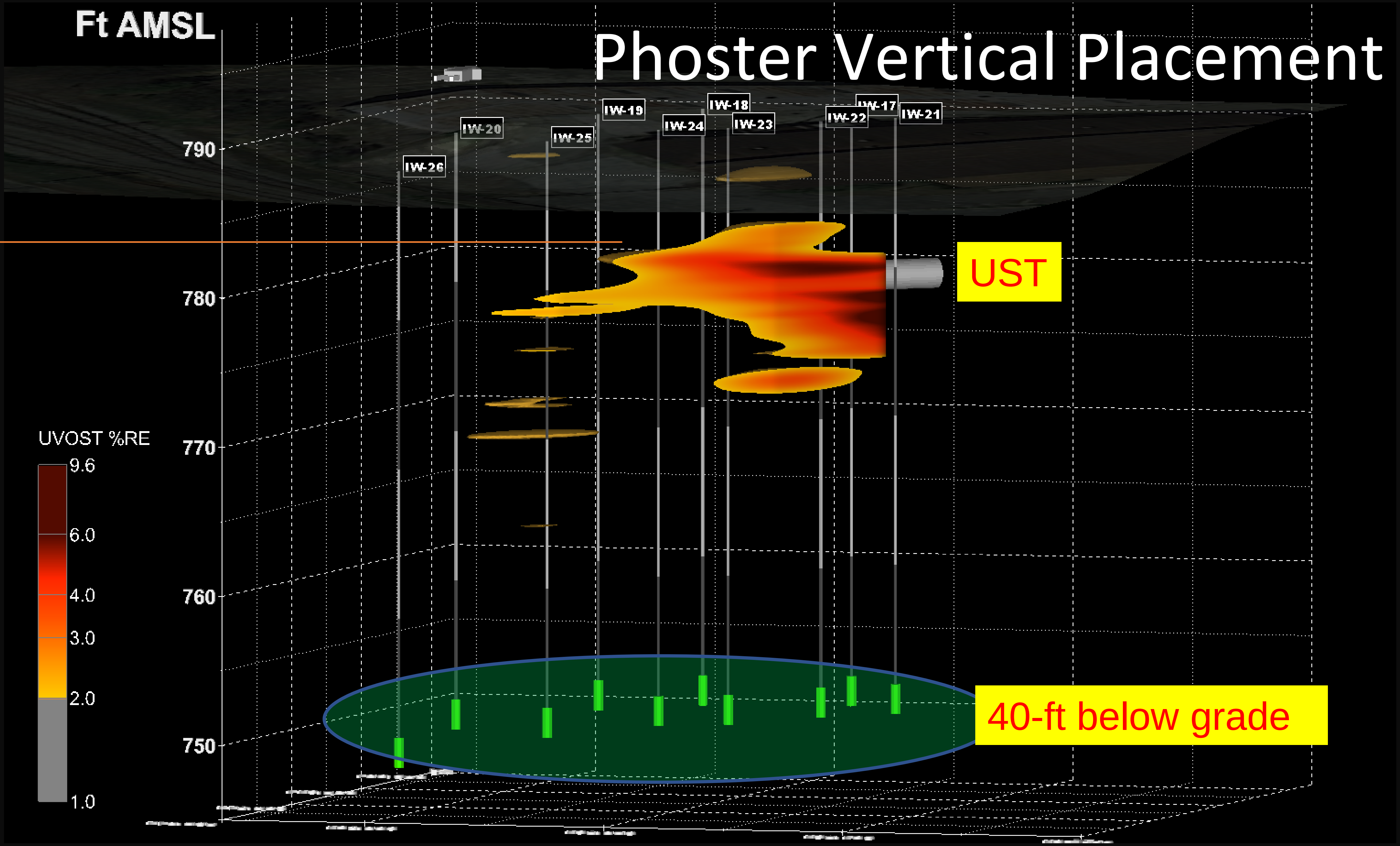


LNAPL vs Soil Permeability



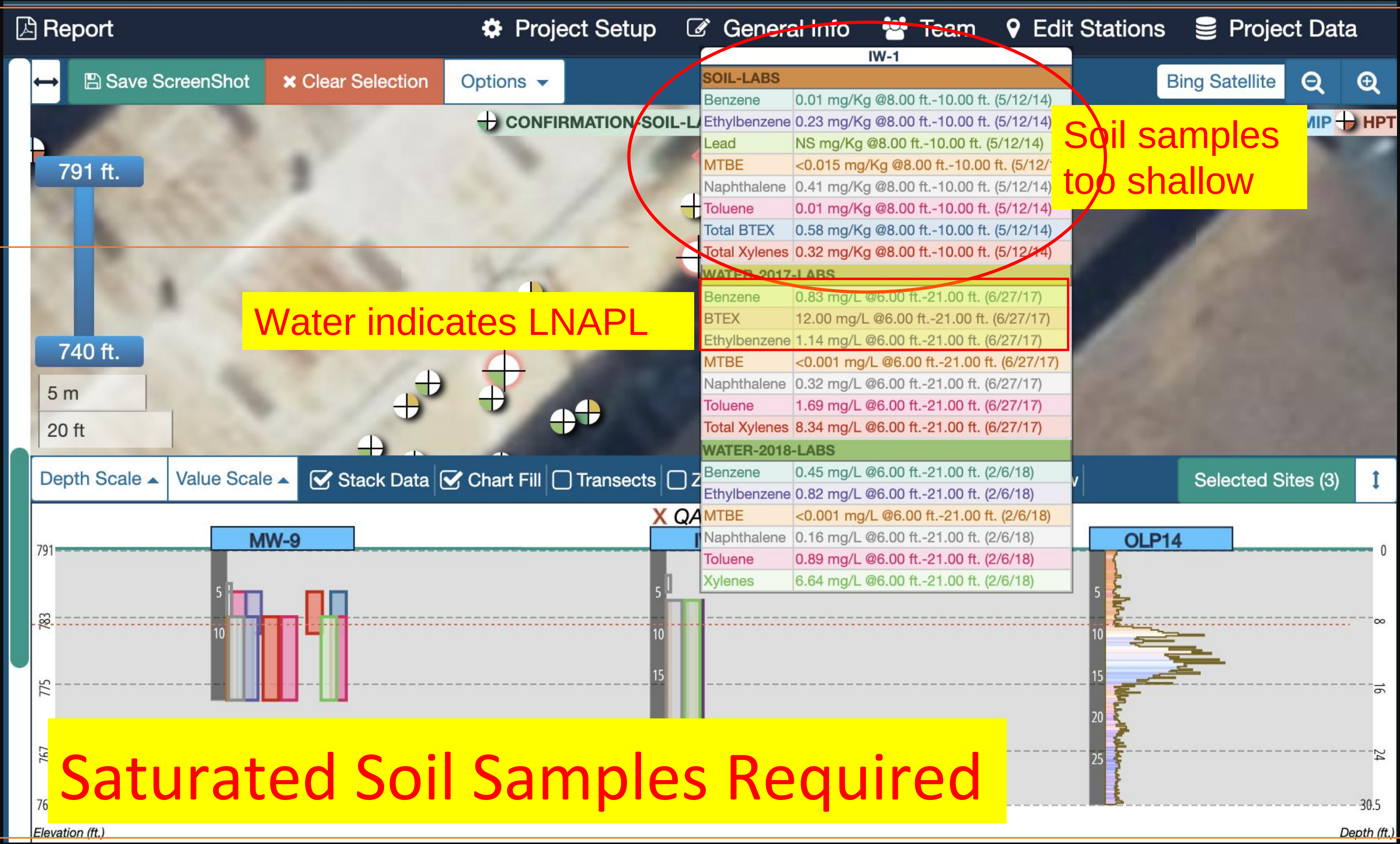

Phoster Footprint
UST
N
UVOST %RE
9.6
6.0
4.0
3.0
2.0
1.0
779,950
779,900
779,850
795,600
795,650
795,700

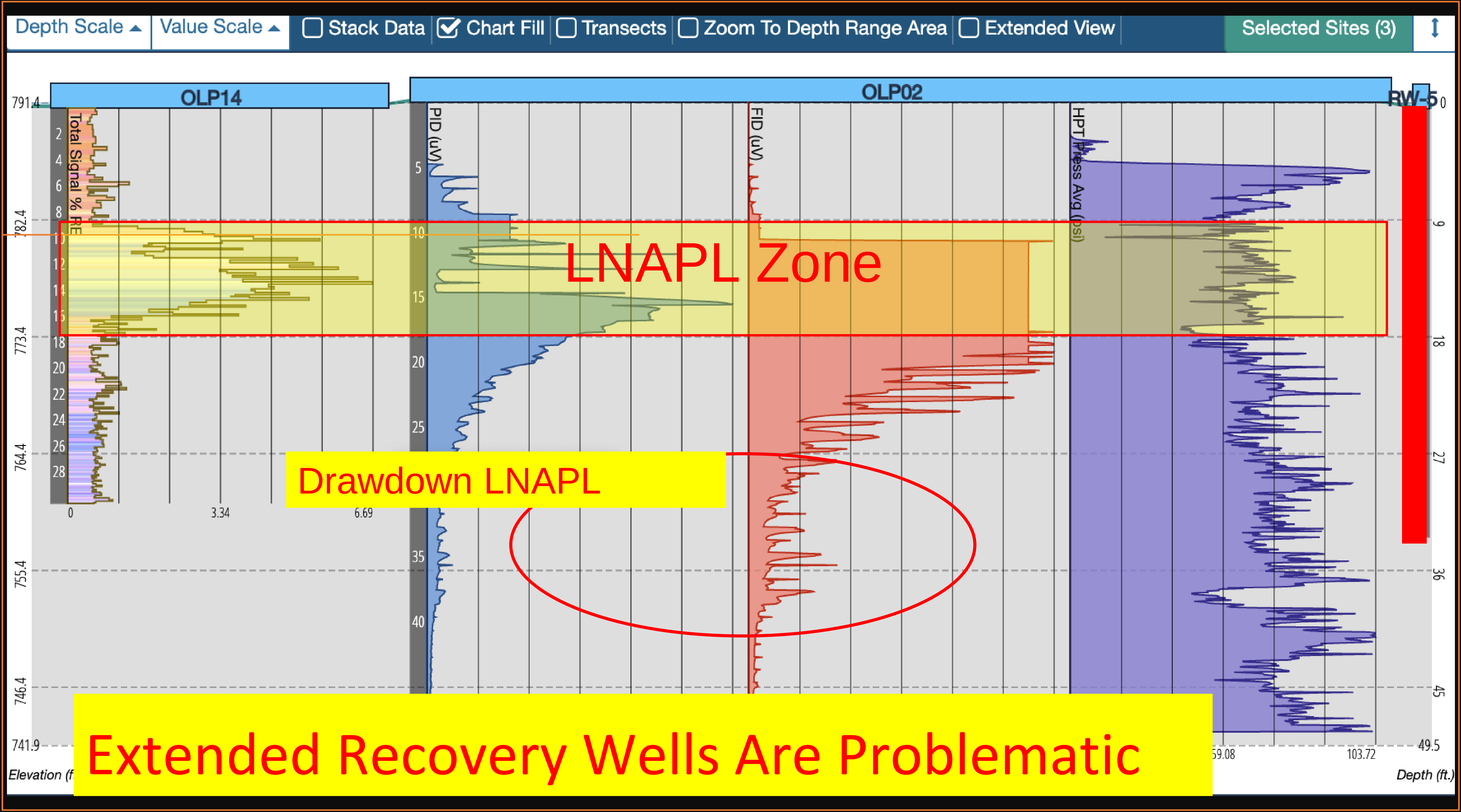
Phoster Vertical Placement



Challenges to MEME / ISCO Approach

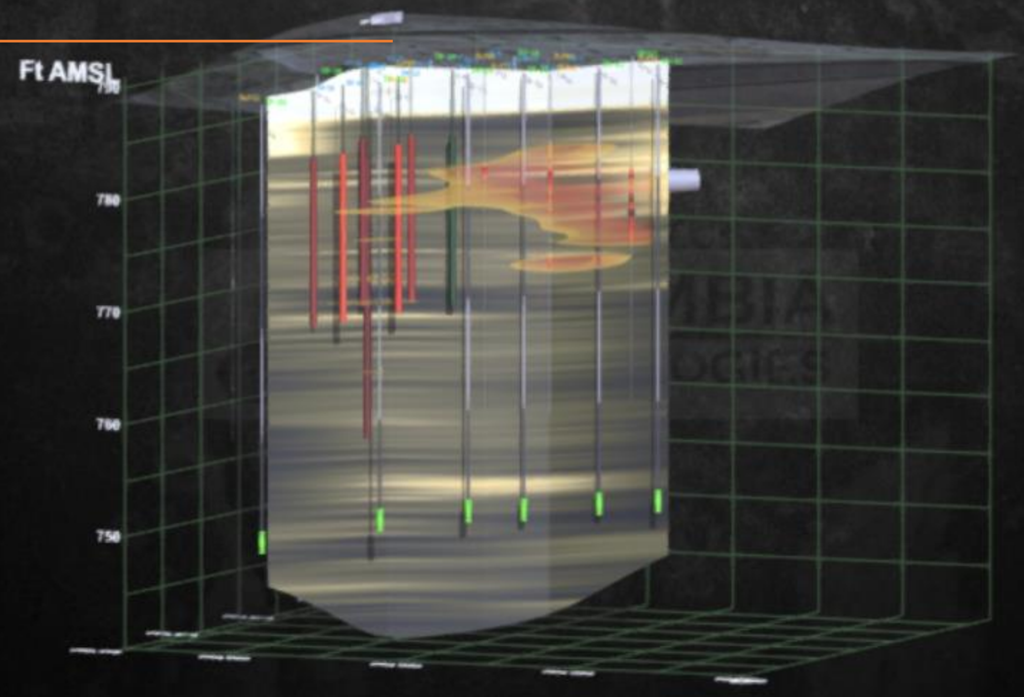
- Inaccurate measurement of total hydrocarbon mass – *requires saturated soil samples and TPH*
- LNAPL trapped in low permeability soils – *difficult for MEME or gravity feed of ISCO*
- Extended screen interval on recovery wells – *ineffective vacuum extraction, draw down water table, extends smear zone of hydrocarbons*


Report
Project Setup
General Info
Team
Edit Stations
Project Data
Save ScreenShot
Clear Selection
Options
Bing Satellite
CONFIRMATION-SOIL-L
MIP
HPT
791 ft.
740 ft.
5 m
20 ft
IW-1
SOIL-LABS
Benzene 0.01 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
Ethylbenzene 0.23 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
Lead NS mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
MTBE <0.015 mg/Kg @8.00 ft.-10.00 ft. (5/12/
Naphthalene 0.41 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
Toluene 0.01 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
Total BTEX 0.58 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
Total Xylenes 0.32 mg/Kg @8.00 ft.-10.00 ft. (5/12/14)
WATER-2017-LABS
Benzene 0.83 mg/L @6.00 ft.-21.00 ft. (6/27/17)
BTEX 12.00 mg/L @6.00 ft.-21.00 ft. (6/27/17)
Ethylbenzene 1.14 mg/L @6.00 ft.-21.00 ft. (6/27/17)
MTBE <0.001 mg/L @6.00 ft.-21.00 ft. (6/27/17)
Naphthalene 0.32 mg/L @6.00 ft.-21.00 ft. (6/27/17)
Toluene 1.69 mg/L @6.00 ft.-21.00 ft. (6/27/17)
Total Xylenes 8.34 mg/L @6.00 ft.-21.00 ft. (6/27/17)
WATER-2018-LABS
Benzene 0.45 mg/L @6.00 ft.-21.00 ft. (2/6/18)
Ethylbenzene 0.82 mg/L @6.00 ft.-21.00 ft. (2/6/18)
MTBE <0.001 mg/L @6.00 ft.-21.00 ft. (2/6/18)
Naphthalene 0.16 mg/L @6.00 ft.-21.00 ft. (2/6/18)
Toluene 0.89 mg/L @6.00 ft.-21.00 ft. (2/6/18)
Xylenes 6.64 mg/L @6.00 ft.-21.00 ft. (2/6/18)
Soil samples too shallow
Water indicates LNAPL
Depth Scale
Value Scale
Stack Data
Chart Fill
Transects
Selected Sites (3)
MW-9
OLP14
Elevation (ft.)
Depth (ft.)
Saturated Soil Samples Required



Depth Scale
Value Scale
Stack Data
Chart Fill
Transects
Zoom To Depth Range Area
Extended View
Selected Sites (3)
OLP14
OLP02
RW-5
Total Signal % RE
PID (uV)
FID (uV)
HPT Press Avg (psi)
LNAPL Zone
Drawdown LNAPL
791.4
782.4
773.4
764.4
755.4
746.4
741.9
0
3.34
6.69
59.08
103.72
49.5
Elevation (f
Depth (ft.)
Extended Recovery Wells Are Problematic

3D Conceptual Site Model



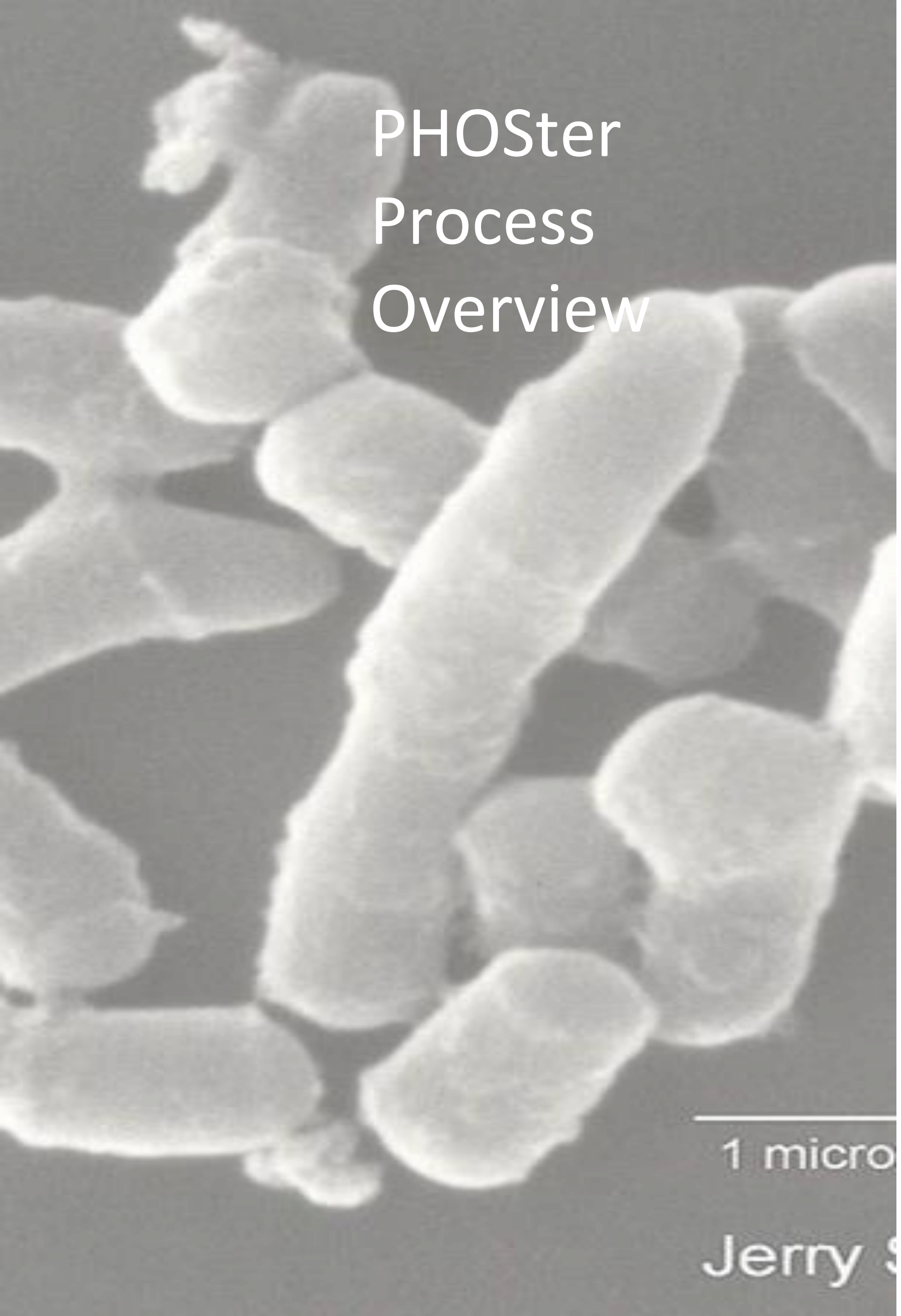
HRSC Conclusions

- 4300 cu-ft of residual LNAPL mass identified (mass under the building not yet determined)
- LNAP was further “upgradient” than recognized
- LNAPL was present as deep as 33-ft
- LNAPL was trapped in low permeability soils

How should we measure performance?

- Benzene concentration
- Dissolved oxygen
- Oxygen or nutrient consumption
- Microbial populations
- Mass removal vs time or $$
- Sustainability metrics *(energy use, water, waste, carbon – travel)*

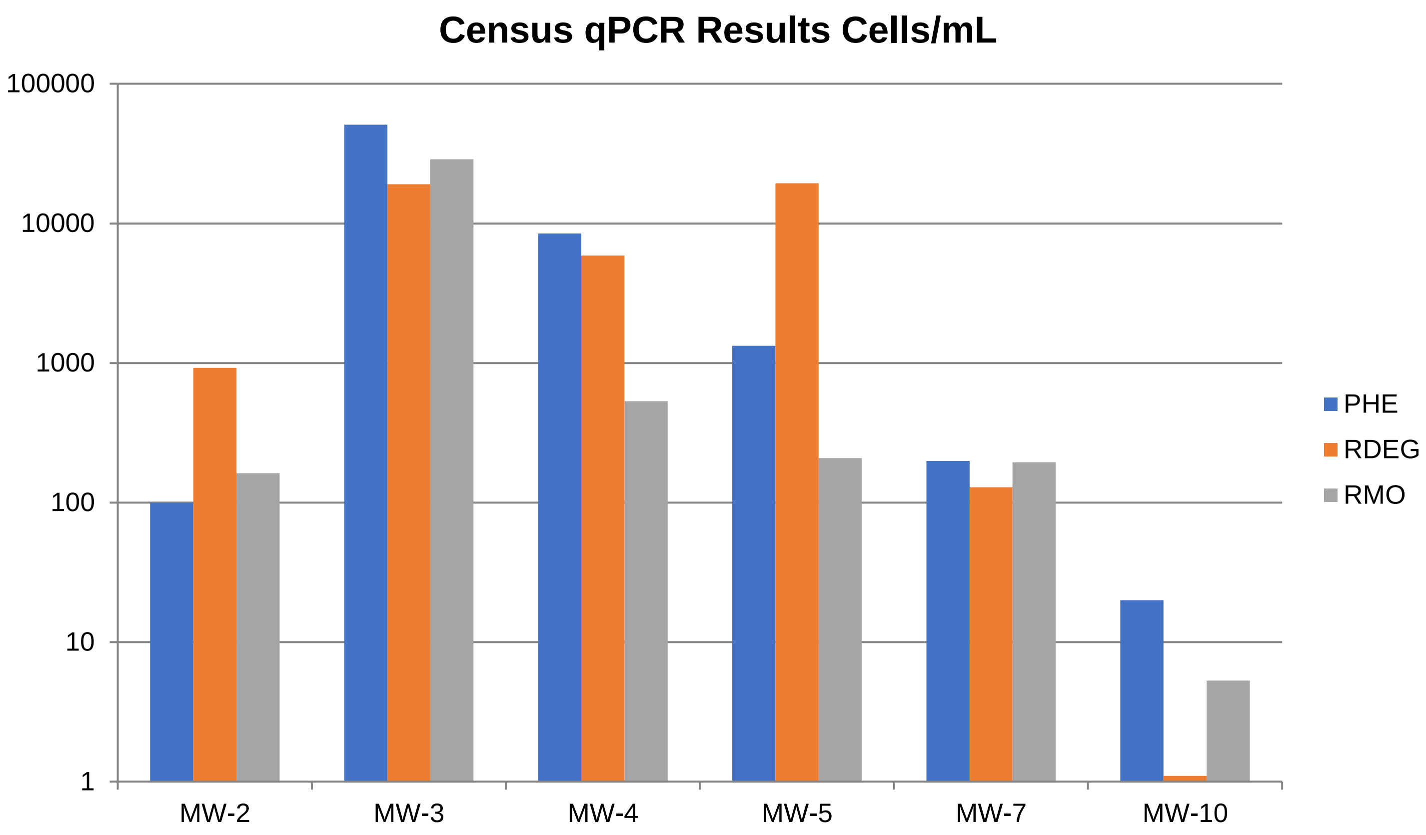
PHOSter Process Overview



- Gas-phase nutrient injection to stimulate indigenous bacteria cell division and metabolism.
- Independently controlled, pulsed air sparge. Flows from 0.5 to 2.0 cfm per injector.
- PLC controlled dosage:
  - Air/Oxygen
  - Nitrous Oxide
  - Triethyl-phosphate
  - Methane/Propane/Butane

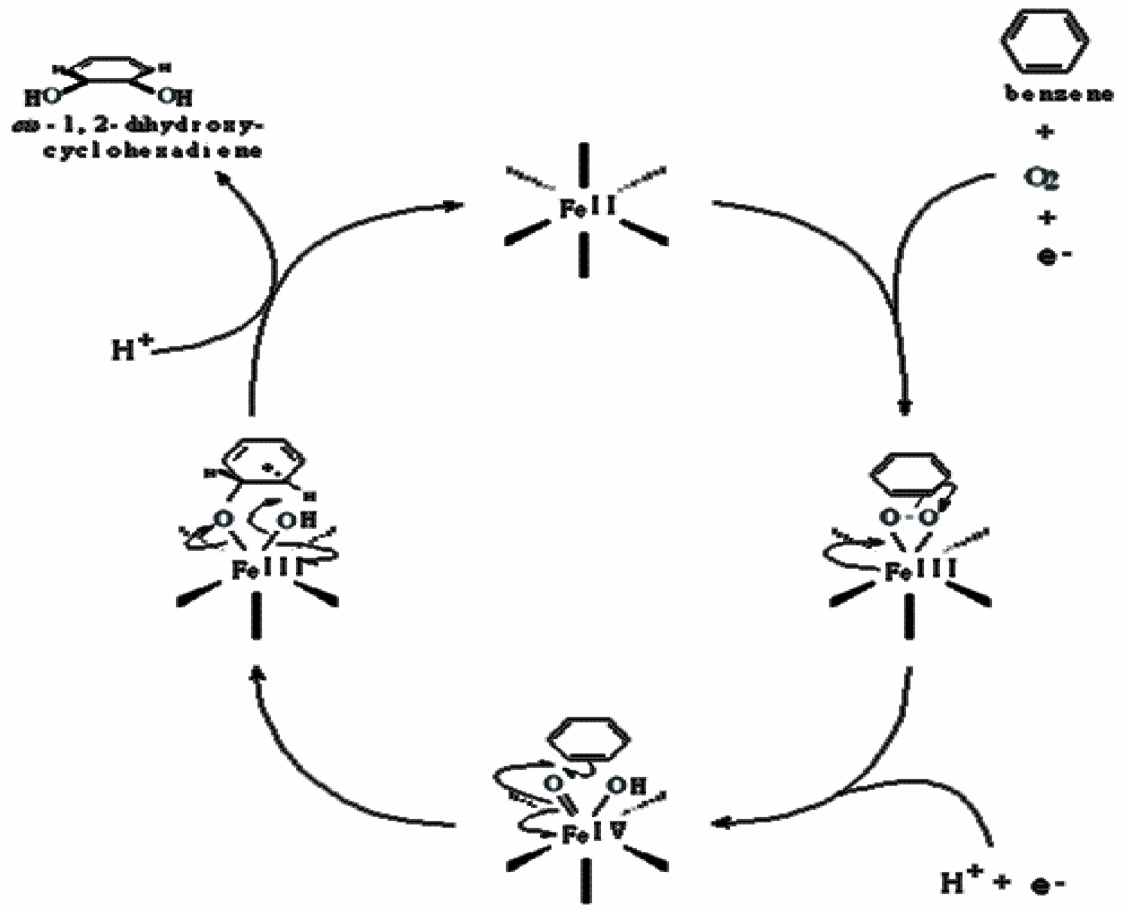
Building a Population

- Bacteria Nutrient Molar Ratio: $C_{64}H_{85}O_{23}N_{13}P$
- Addition of Nitrous Oxide and TEP slow dose/low dose.
- Establish Cell Counts of more than 10^4 cells/mL.
- Build Aerobic Population until Respiration Rates are Maximized. Establish an Oxygen Demand.
- Cease nutrient addition when active sparge zone DO≈2 mg/L.



Support of Aerobic Respiration

- $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O + \Delta G$
- Adjustable Intermittent Sparge Well Operation.
- Average Delivery of 120-150 Pounds of O_2 per Month per Well (based on 10’ submergence).
- Design Treatment Rate of 10 # O_2 / # BTEX.



Graphic by: Matt D Wolfe
Based on data from:
Ballou, D.P., and D.P. Batie (1988) Oxidases and related redox systems. Progress in Clinical and Biological Research 274, 211-226.

How Much of What?

Stoichiometry: $C_{64}N_{13}P$ Assuming Target Cell Mass 100 mg/L.

11 # Nitrous Oxide per Well

3.6 # TEP per Well

$2C_{10}H_{22} + 31O_2 \rightarrow 20CO_2 + 22H_2O$ Decane Oxidation

3.5 # O_2/# Hydrocarbon

Real-Life:

128 # Nitrous Oxide

2 Gallons TEP

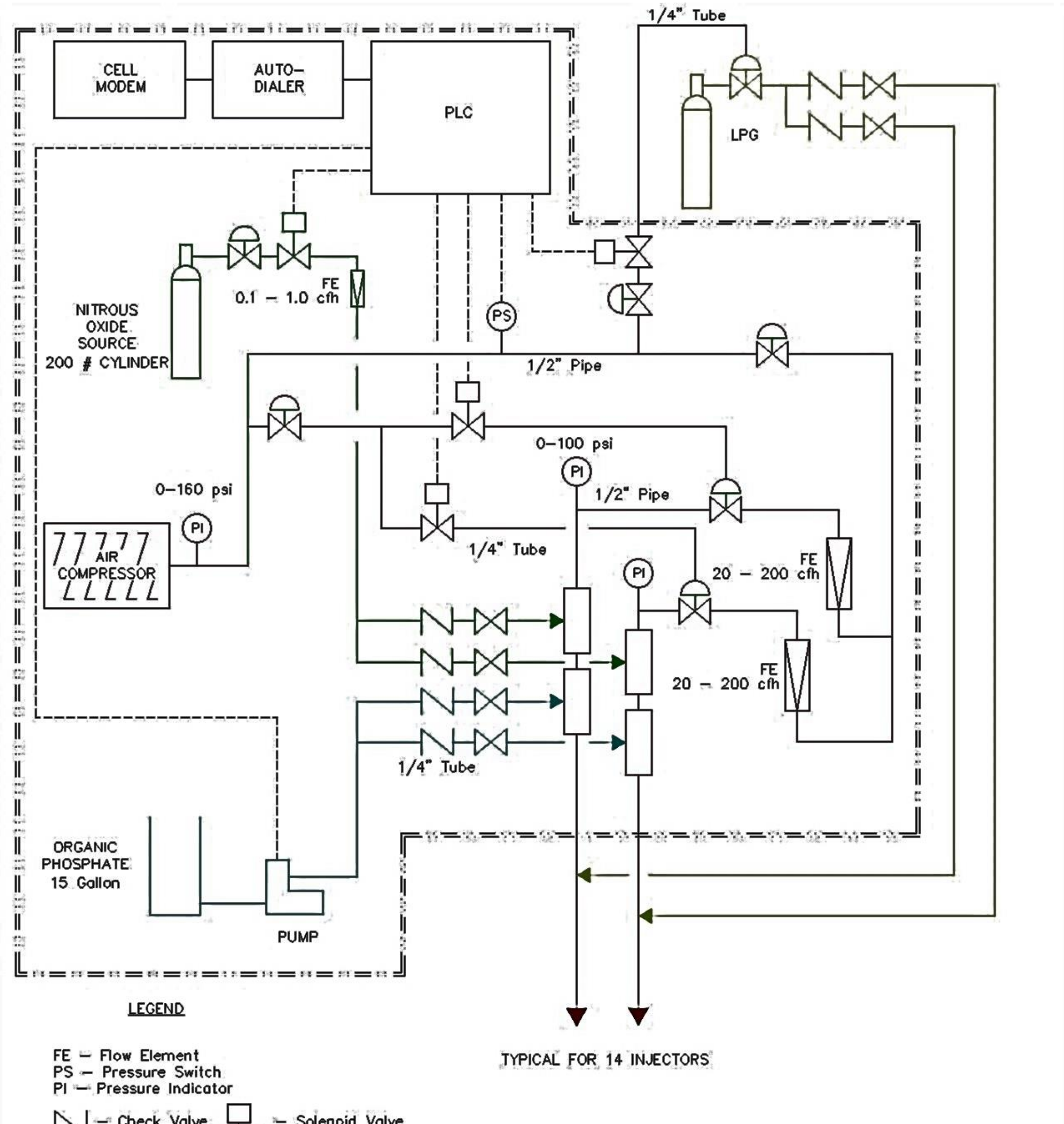
50,000 # O_2

40,000 kWh

$5,200 Total Power Cost

P&ID

- PLC Controlled.
- Independent gas flow regulation.
- Isolatable nutrient and co-metabolite delivery.
- Cellular comm. to/from auto-dialer.



Injection Well

- Install to 10’ below historical low water level (min.).
- Use 1” or 2” PVC.
- Supply tubing is ½” LLDPE.
- Can be installed via Geoprobe.

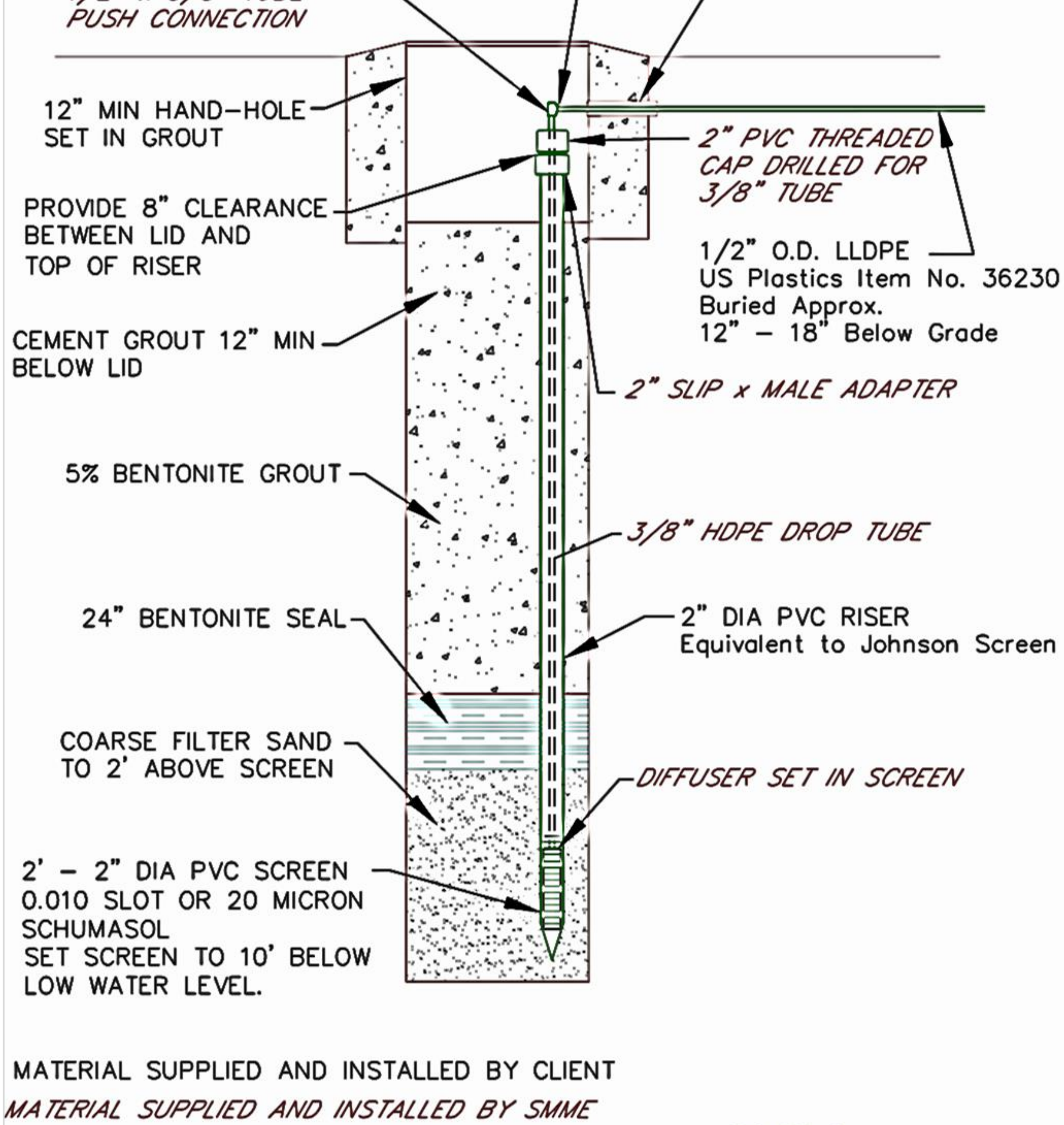
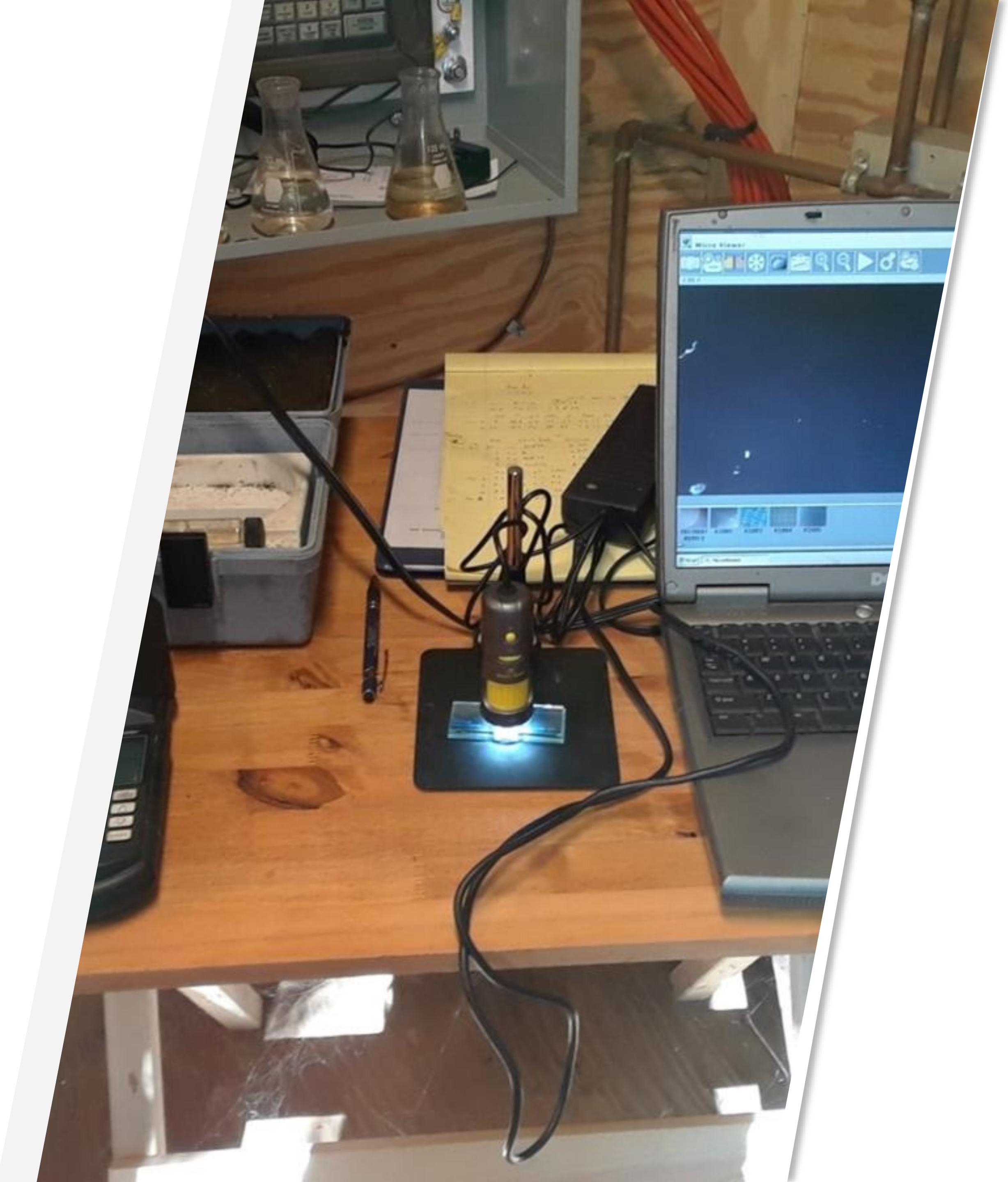


FIGURE 2

INJECTION WELL DETAIL

Process Control Testing

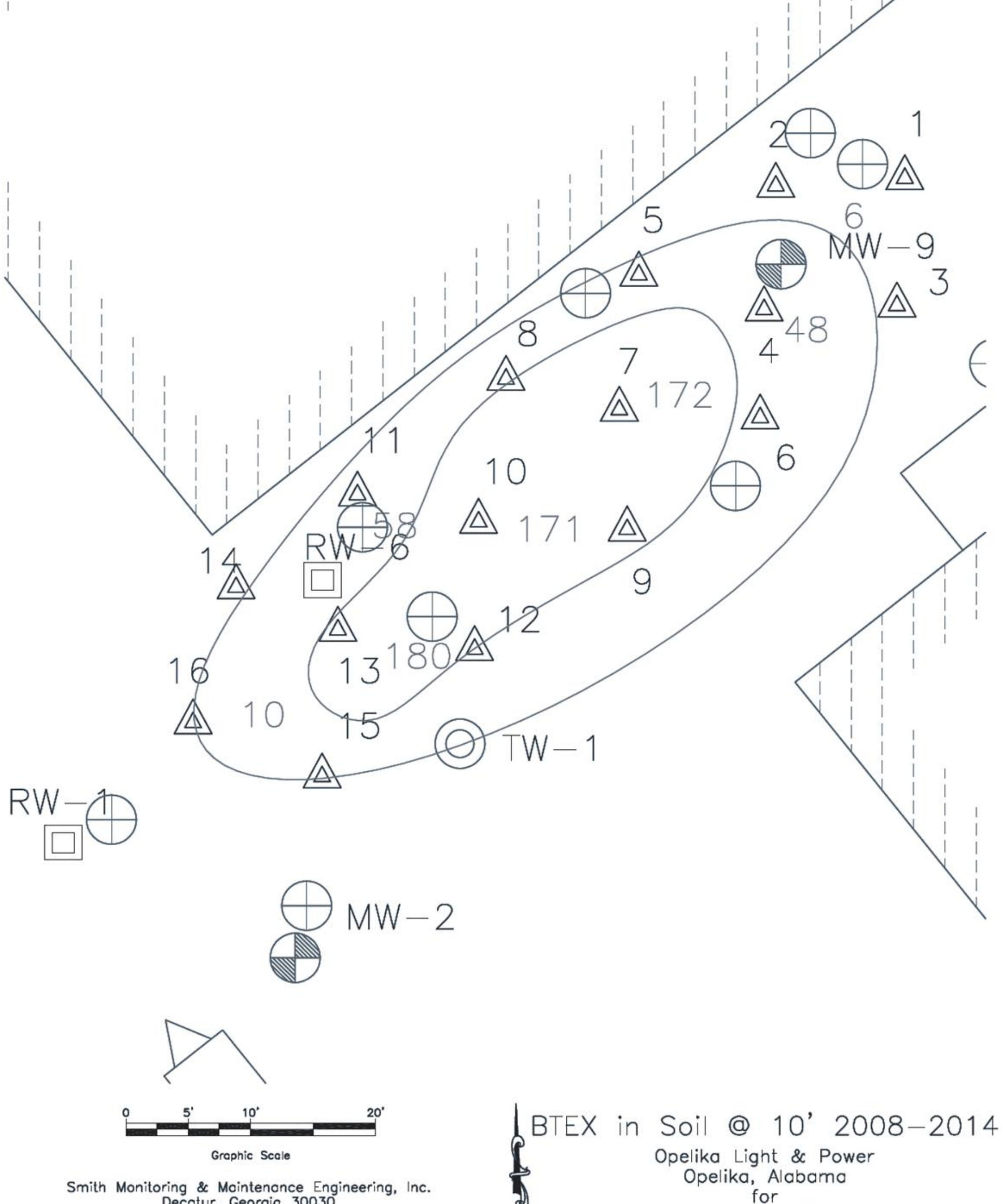
- Recommend monthly field analysis of DO, pH and nutrients for process control.
- Can include qPCR to confirm target bacteria populations are forming.



Opelika Power & Light

UST 93-02-19

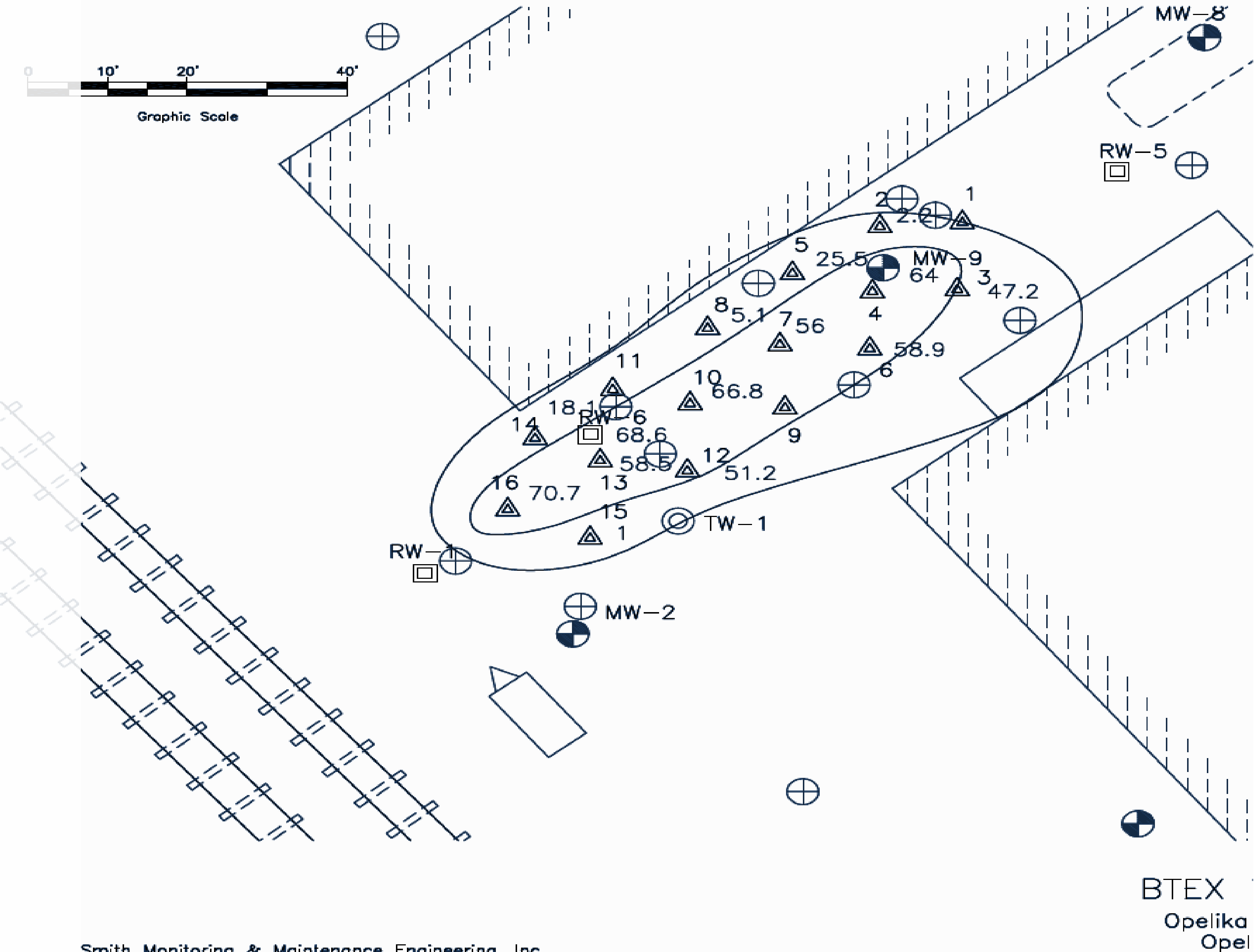
Soil Sampling Data from RW and ChemOx IW Install



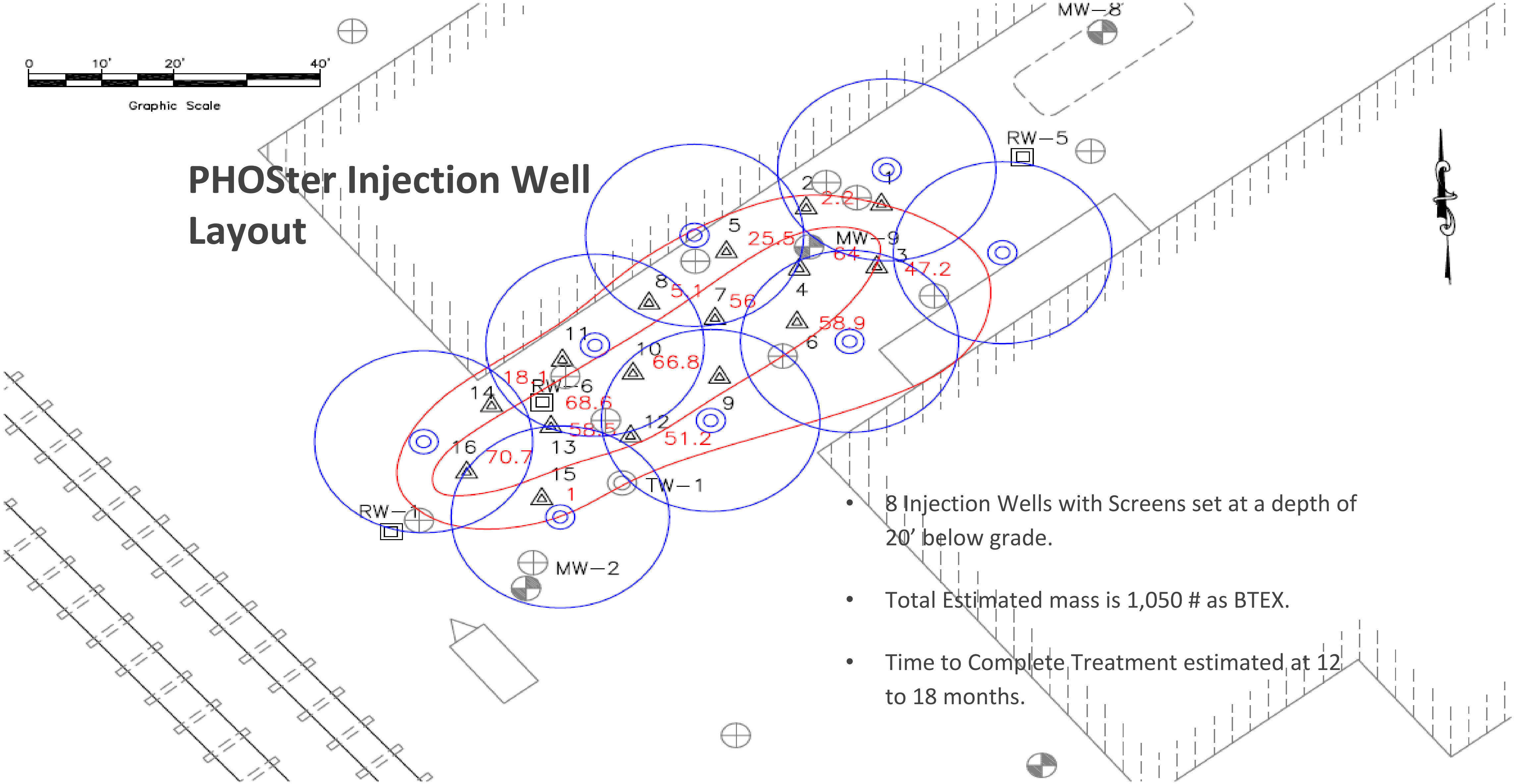
- Smear zone sampling at 8’ to 11’.
- Estimated less than 1000 # as BTEX (based on 3’ thick impacted zone).

BTEX in Groundwater 2018

- Assuming 10’ of impacted aquifer thickness total mass in water estimated at 45#.



PHOSter Injection Well Layout



- 8 Injection Wells with Screens set at a depth of 20' below grade.
- Total Estimated mass is 1,050 # as BTEX.
- Time to Complete Treatment estimated at 12 to 18 months.

PHOSter IW Layout 8 Points
Opelika Light & Power
Opelika, Alabama
for
Environmental-Materials Consultants, Inc.

Smith Monitoring & Maintenance Engineering, Inc.
Decatur, Georgia 30030
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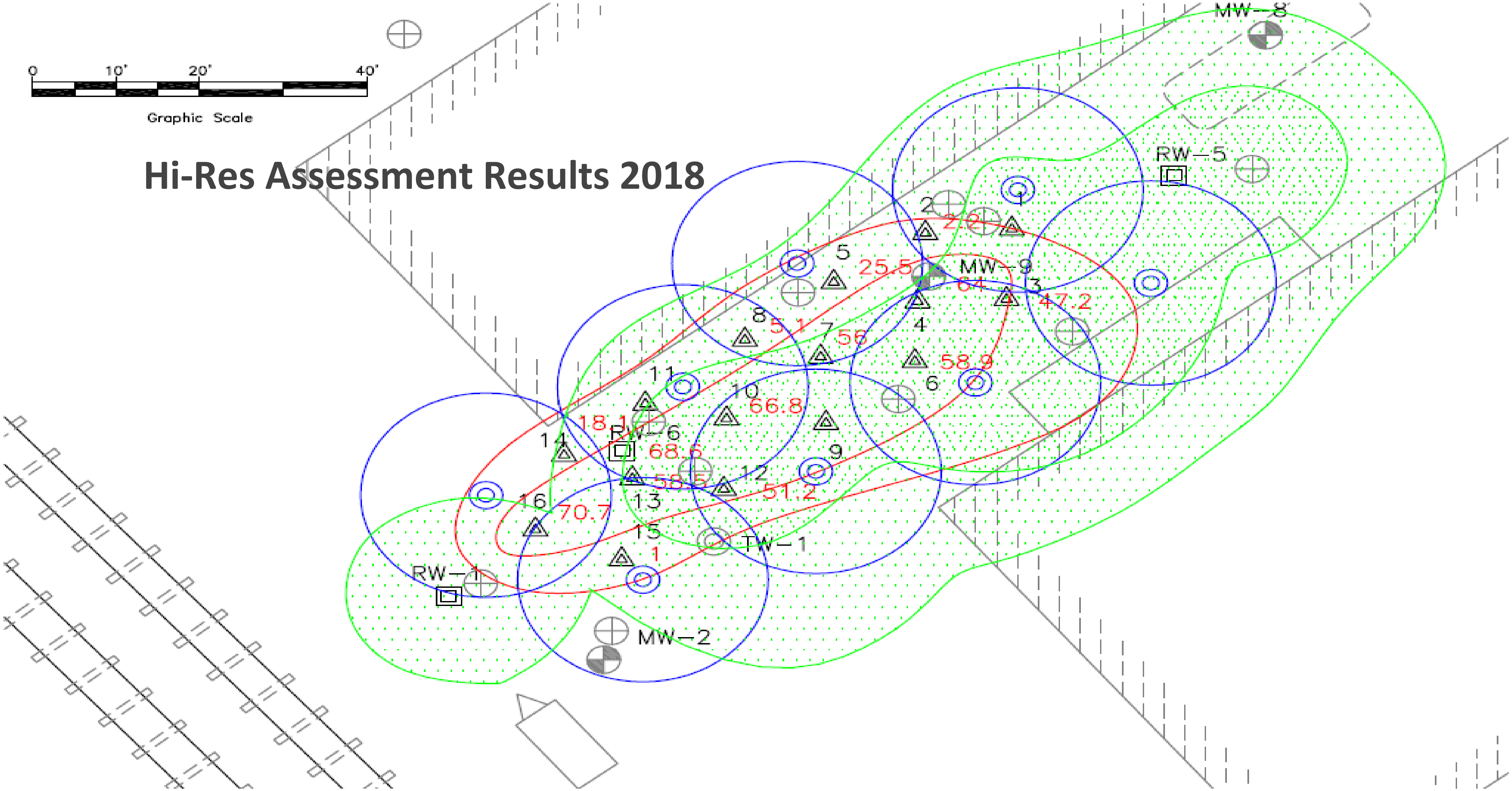
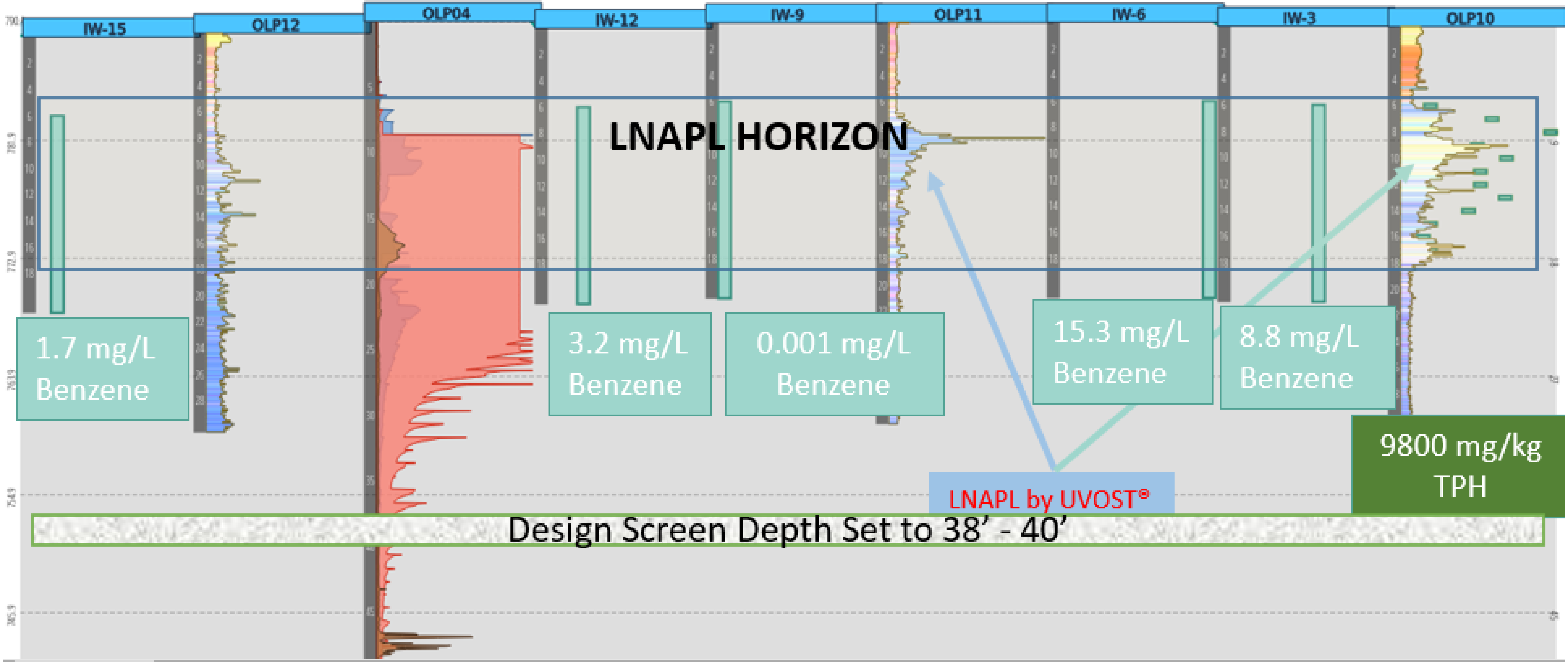
Hi-Res Assessment Results 2018



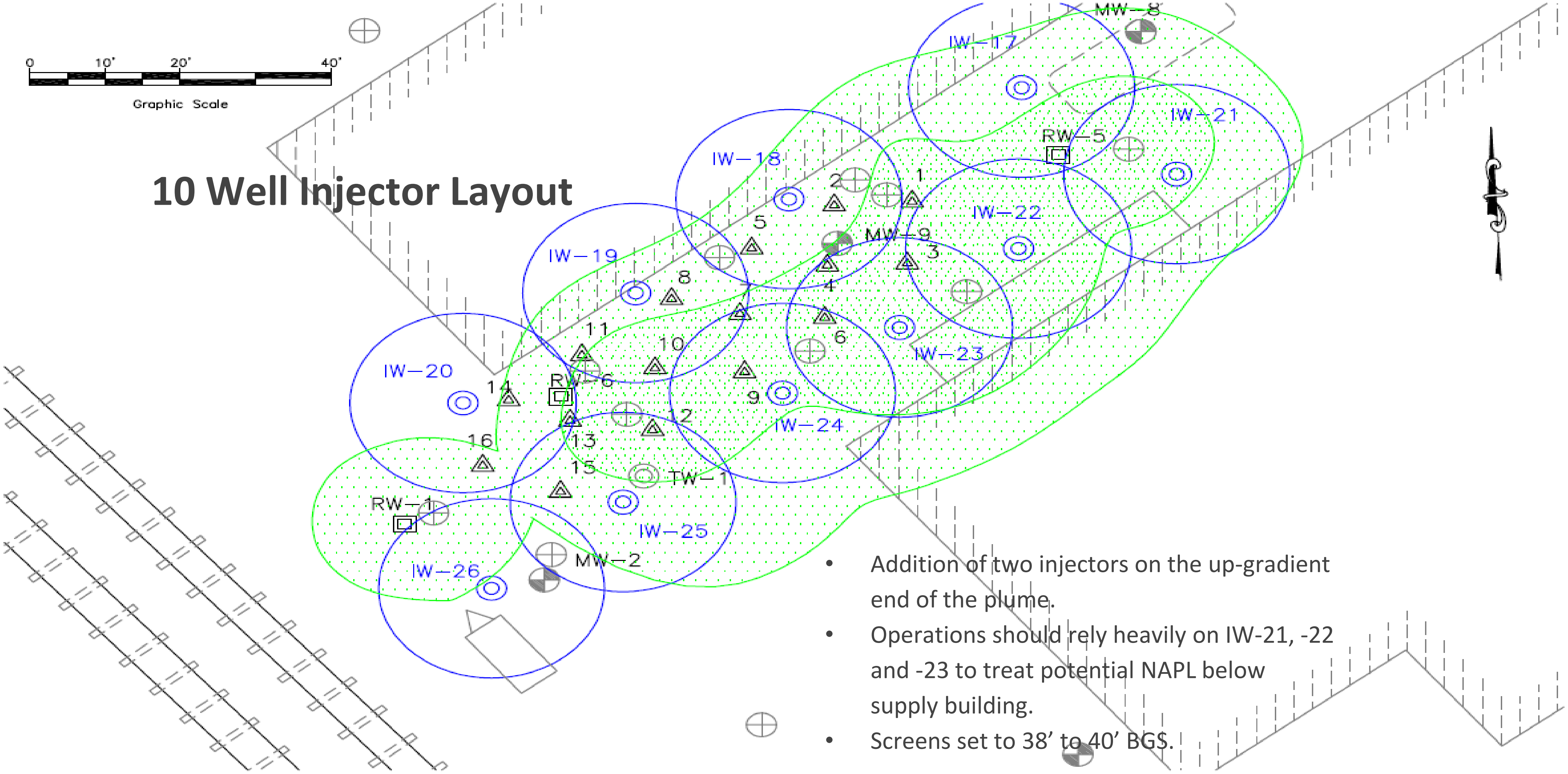
- Assessment showed an upgradient area of NAPL around OLP-14.
- Slight NAPL down-gradient and potential migration below the supply building.

Hi-Res Assessment Results 2018



- LNAPL detected from 6' to 18' below grade.
- Extended PHOSter IW design depth to 40' below grade.

10 Well Injector Layout



- Addition of two injectors on the up-gradient end of the plume.
- Operations should rely heavily on IW-21, -22 and -23 to treat potential NAPL below supply building.
- Screens set to 38' to 40' BGS.

PHOSter IW Layout 10 Points
Opelika Light & Power
Opelika, Alabama
for
Environmental—Materials Consultants, Inc.
November 2019

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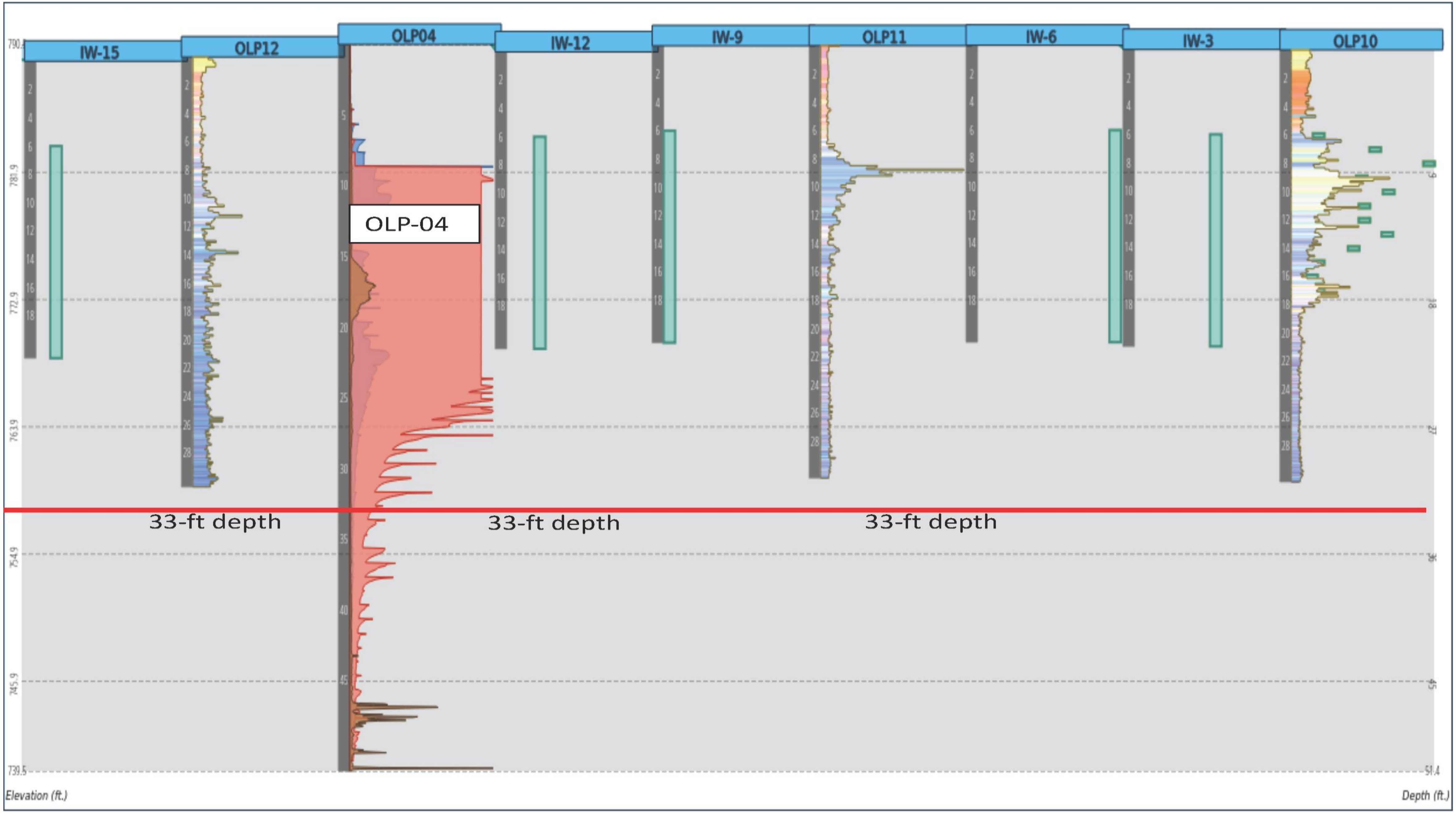


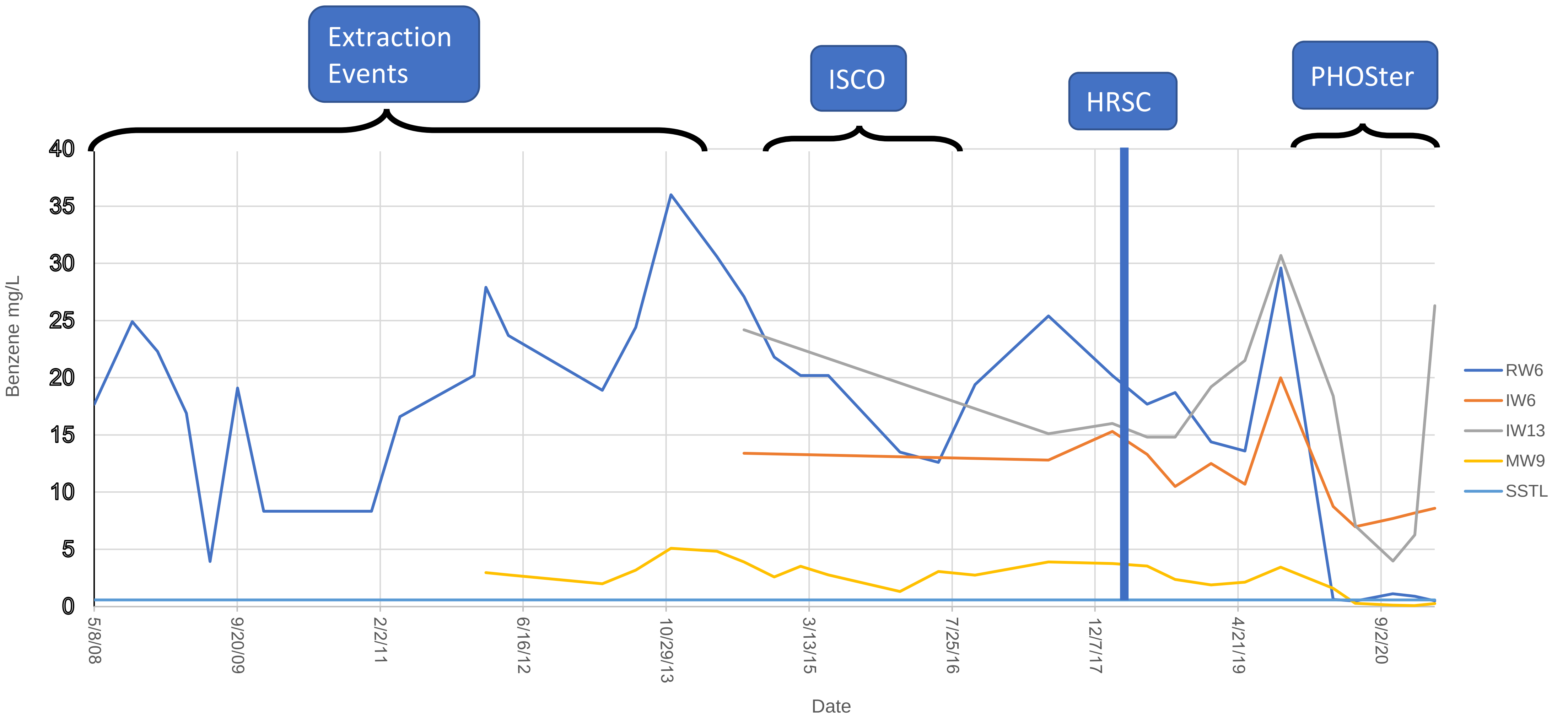
IW-15
OLP12
OLP04
IW-12
IW-9
OLP11
IW-6
IW-3
OLP10
OLP-04
33-ft depth
33-ft depth
33-ft depth
Elevation (ft.)
Depth (ft.)

We are currently at about 18 months into using PHOSter

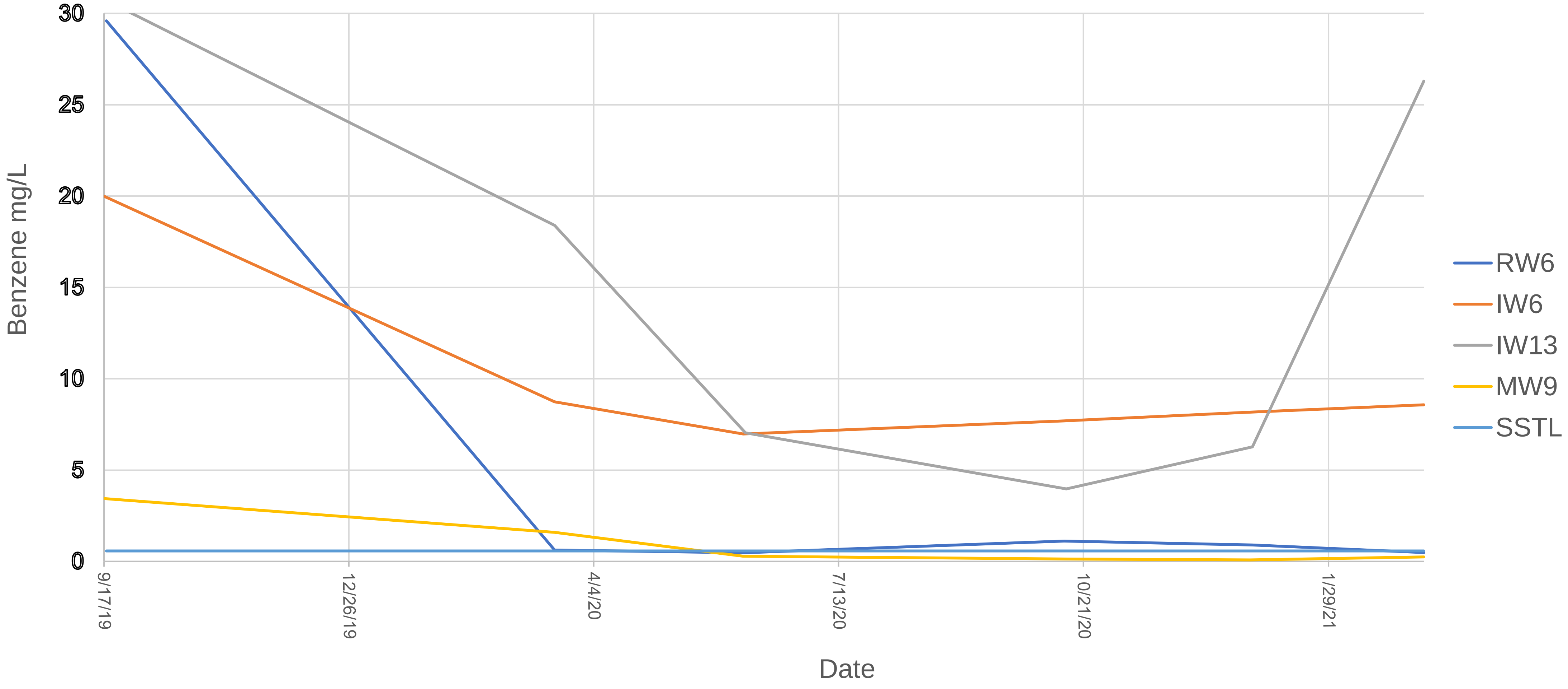
- Most wells have shown decreases in benzene concentrations
  - RW6's benzene concentration dropped from 19.200 mg/L average for 2019 to 0.835 mg/L average for most recent three samplings.
- Some wells have shown decreases, but not as pronounced
  - IW6's benzene concentration was 14.400 mg/L average for 2019 and was 8.150 mg/L average for most recent three samplings.
- Some wells have shown some fluctuations in benzene concentrations
  - IW13's benzene concentration was 23.800 mg/L average for 2019, had a substantial decrease, but was 26.300 mg/L for the most recent sampling.

DO vs Time (since starting PHOSter)

Benzene vs Time



Benzene vs Time (since starting PHOSter)



Cumulative Costs vs Time