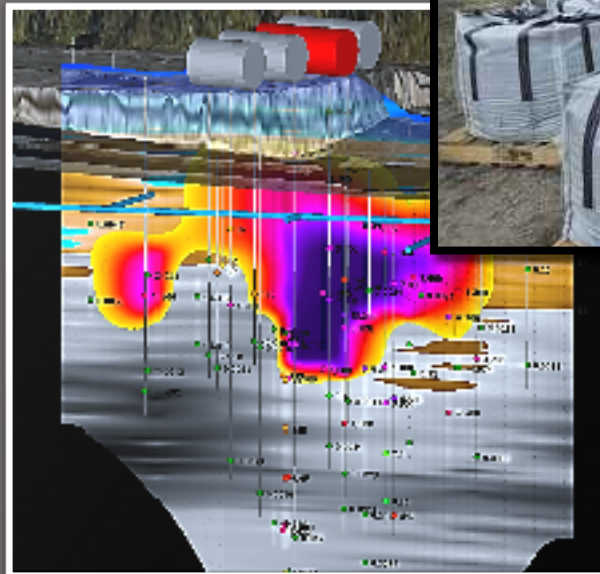
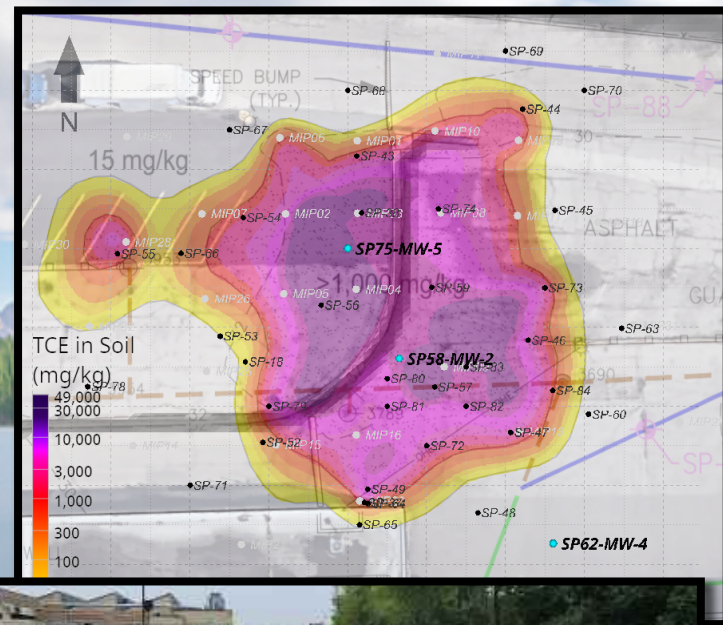


2024 Chlorinated Conference

June 2-6, 2024 | Denver, Colorado

battelle.org/chlorcon | #Chlorinated2024

**LESSONS LEARNED FROM
TREATING OVER 60,000
POUNDS OF TCE WITH 475
METRIC TONS OF ZVI IN
DENSE CLAY SOILS**



Jim Depa and Dave Kulczycki, PG



John Haselow, PhD and Kyle Clarke



Background: Manufacturing Operation (1940s to 1980s) – Chicago, Illinois

Geology:

0-3' Urban Fill

3-11' Silty Clay (*Lacustrine*)

11-25' Dense Clay Till (*Glacial*)

Hydrogeology:

Groundwater at 15' BGS

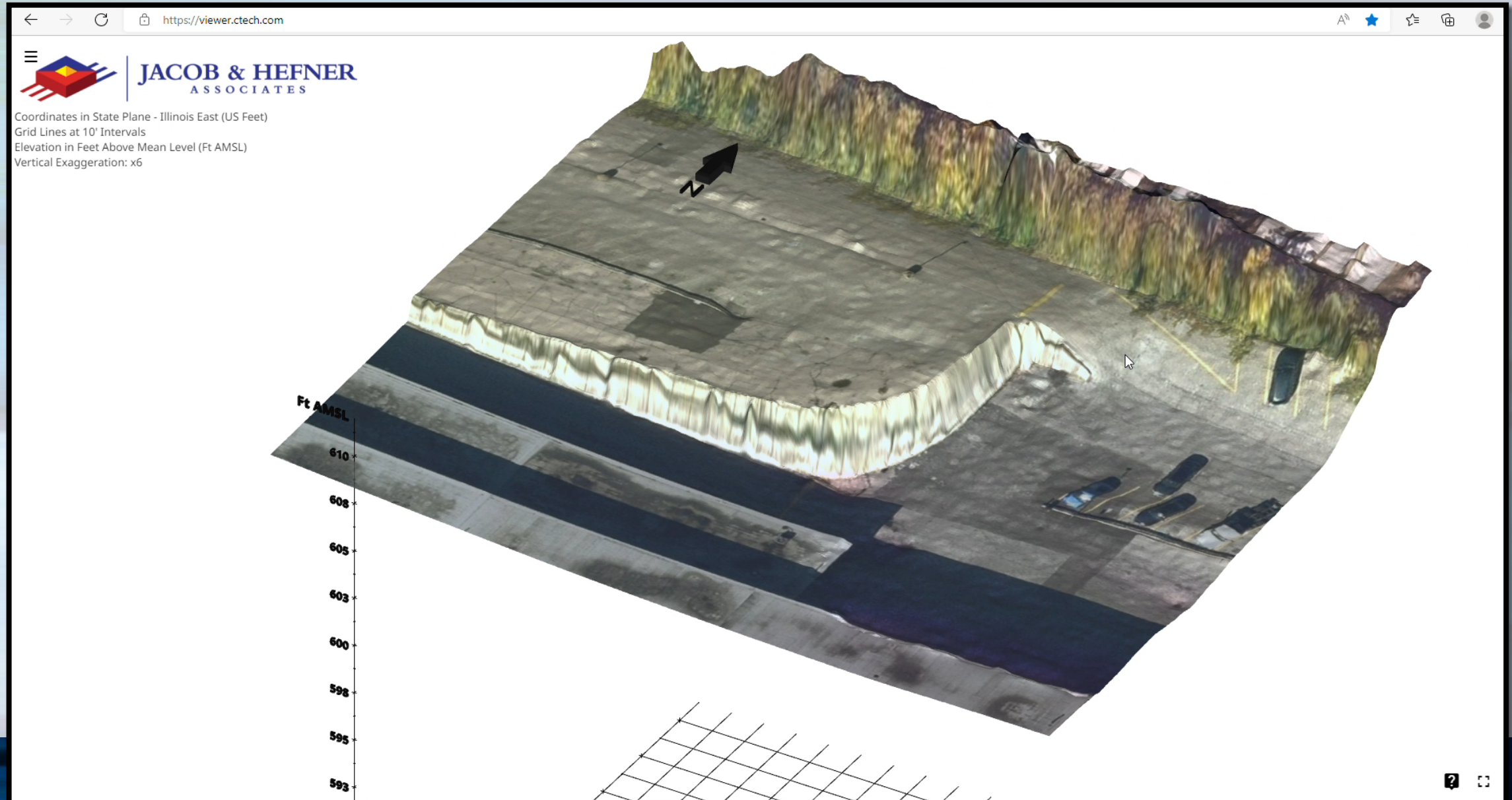
Flow to the South-Southeast

Investigations:

- 1) Limited Phase II (9 Borings)
- 2) MiHPT Investigation (32 Borings)
- 3) Soil Investigation (41 Borings)

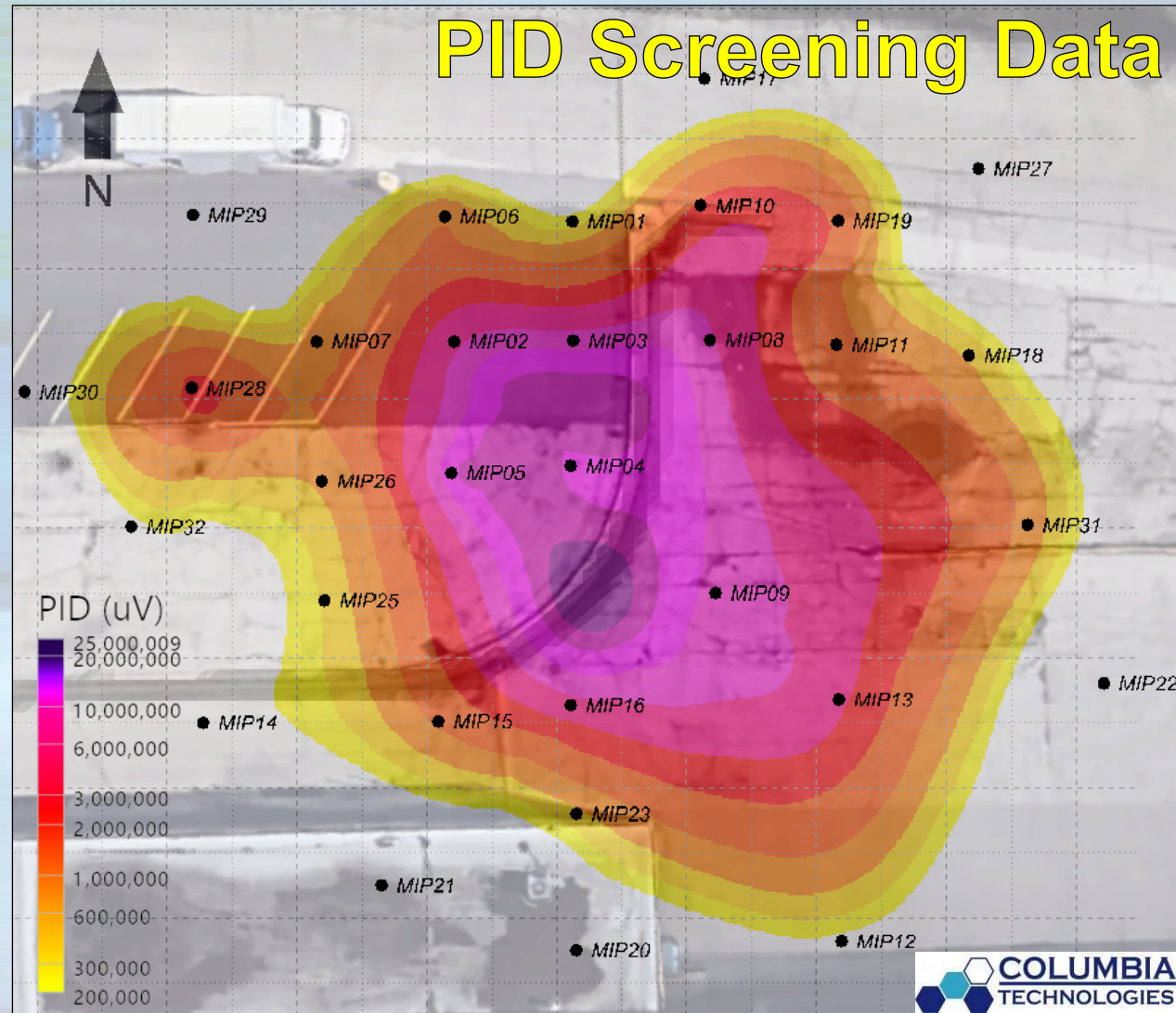


Conceptual Site Model: 3D Webscene Using Environmental Visualization Software

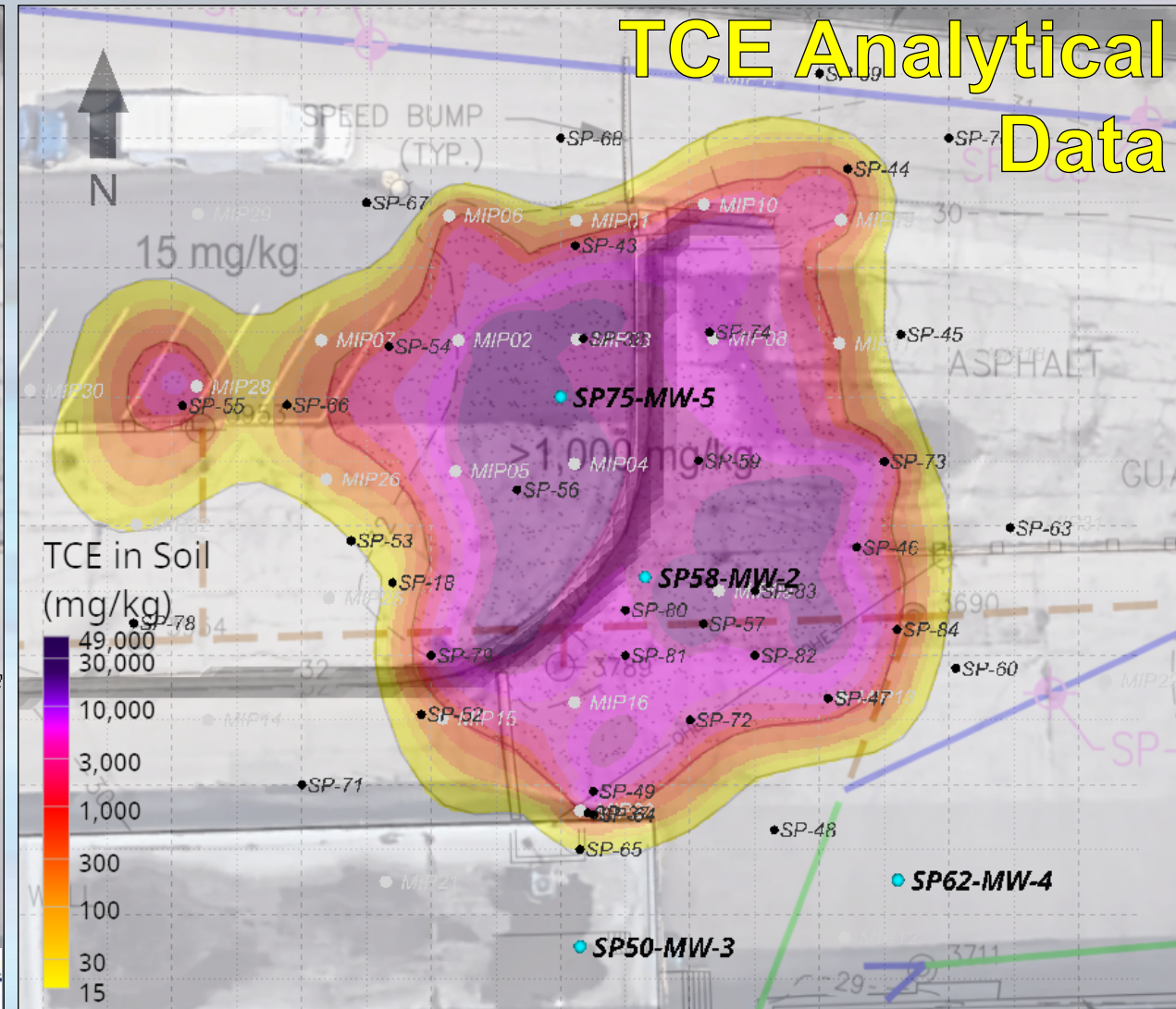


Lesson Learned #1: Utilize HRSC Tools

PID Screening Data



TCE Analytical Data

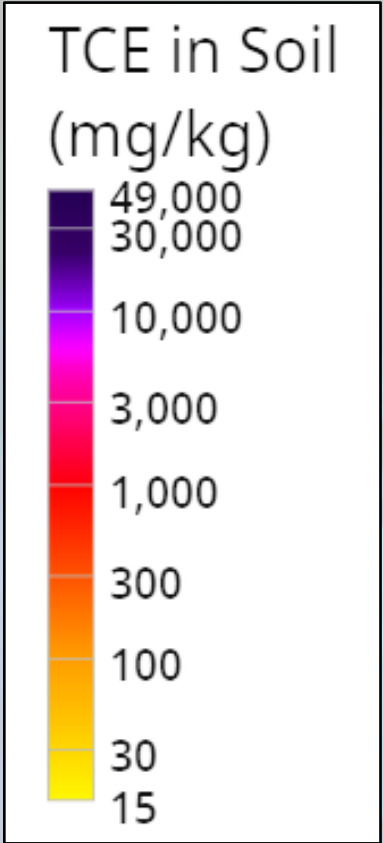
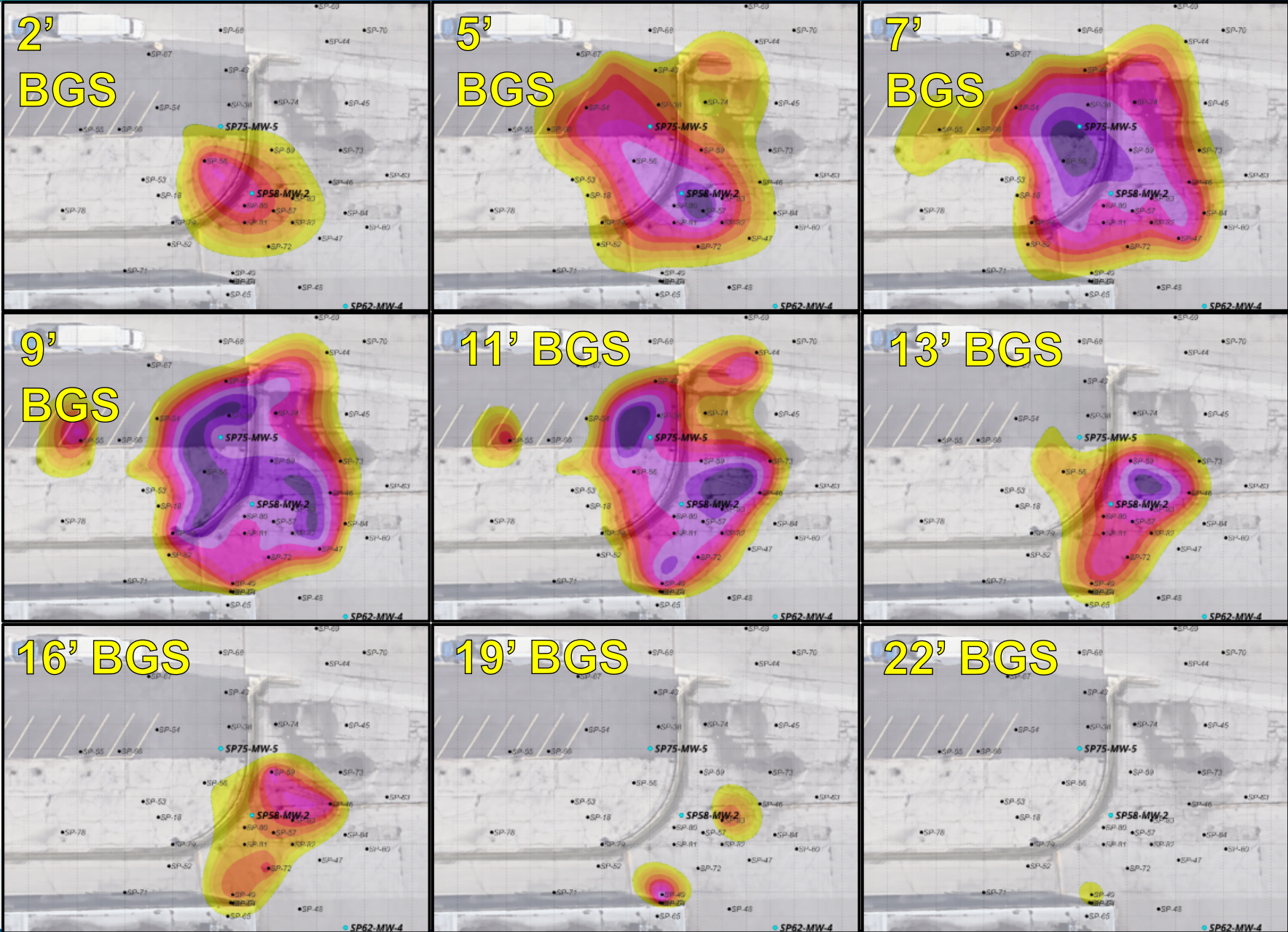


Approx. Correlation: 10,000 uV = 1 PPM
TCE

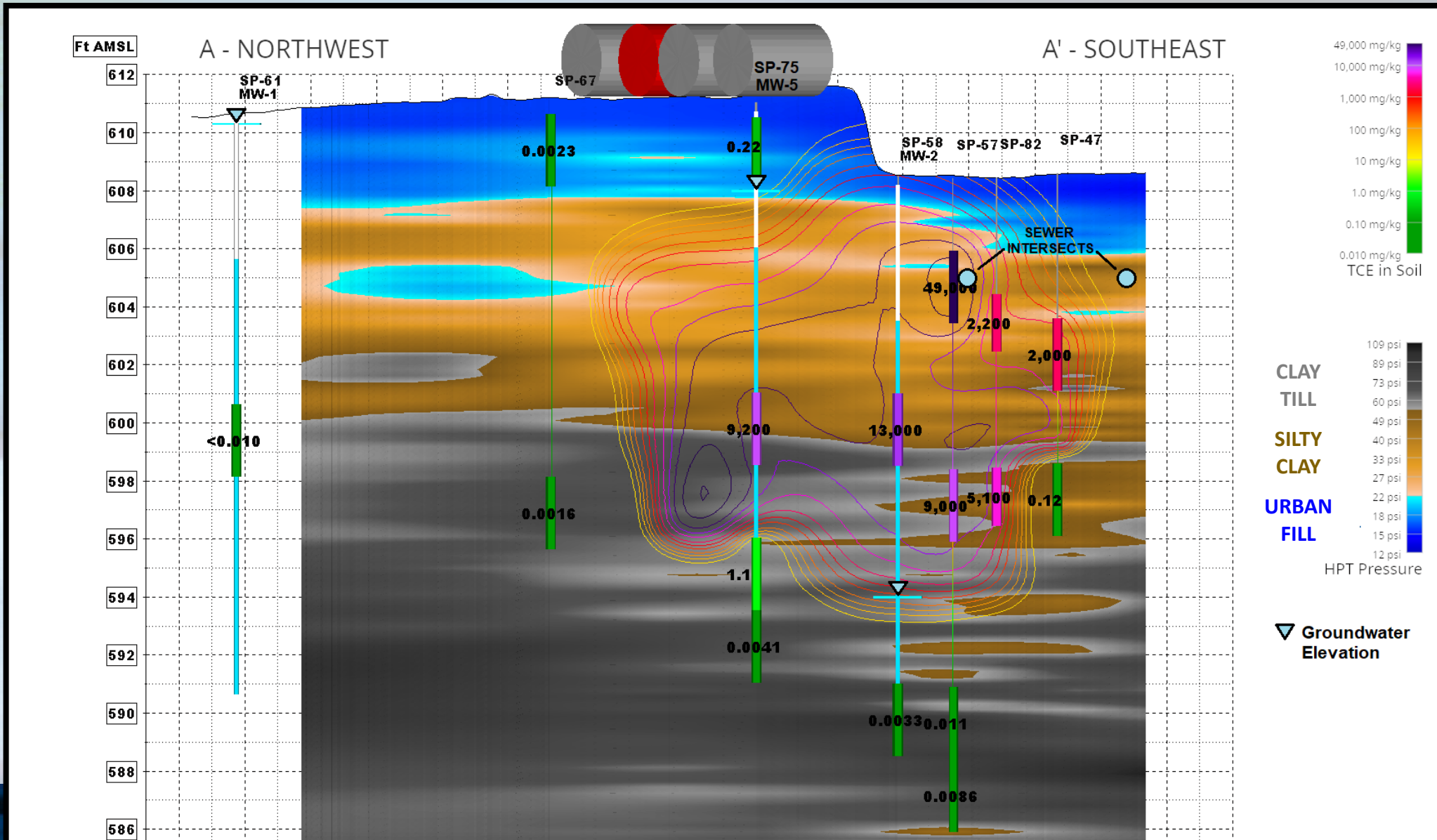


JACOB & HEFNER
ASSOCIATES

Plan View Maps by Depth

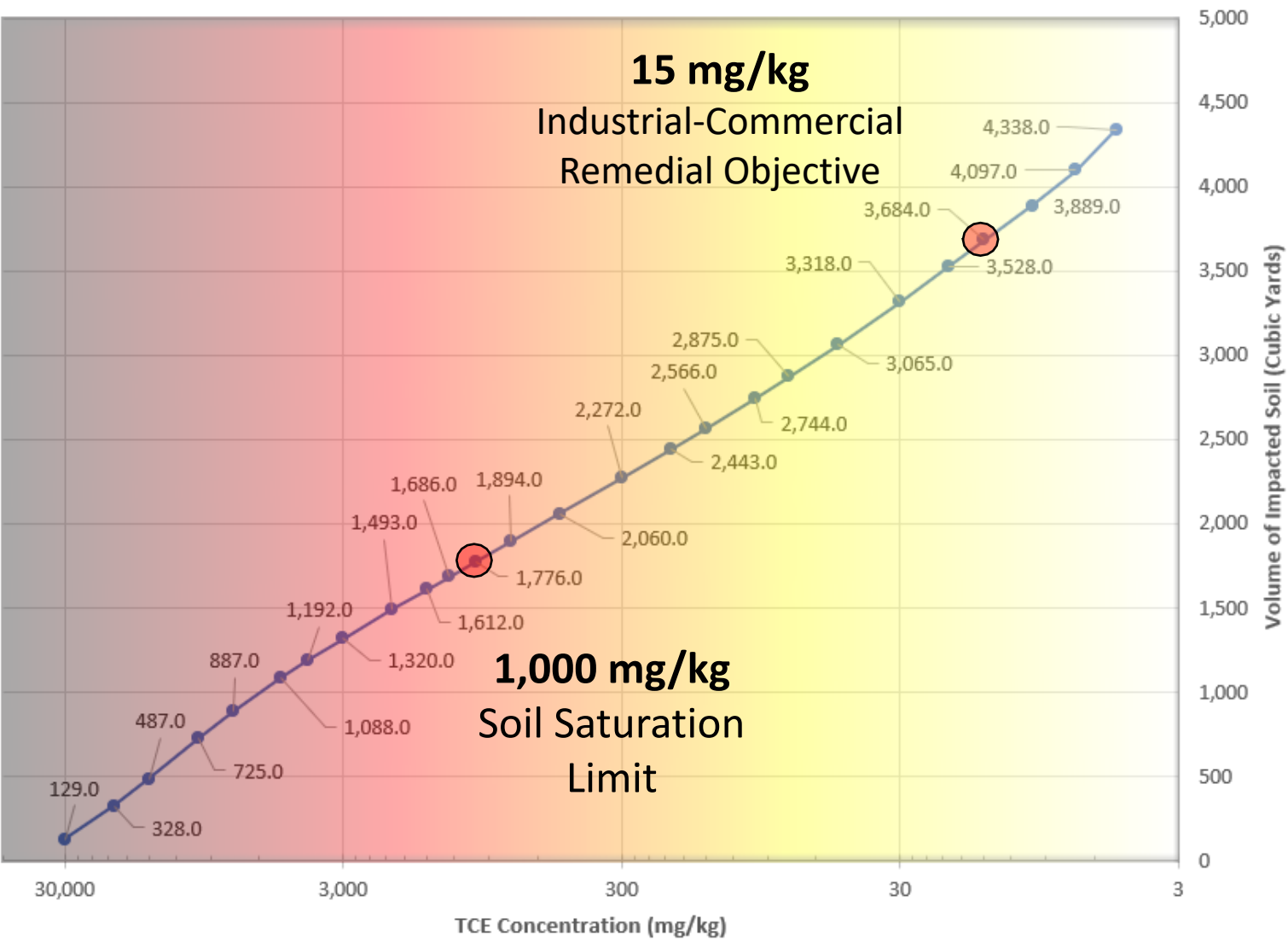


Cross-Section



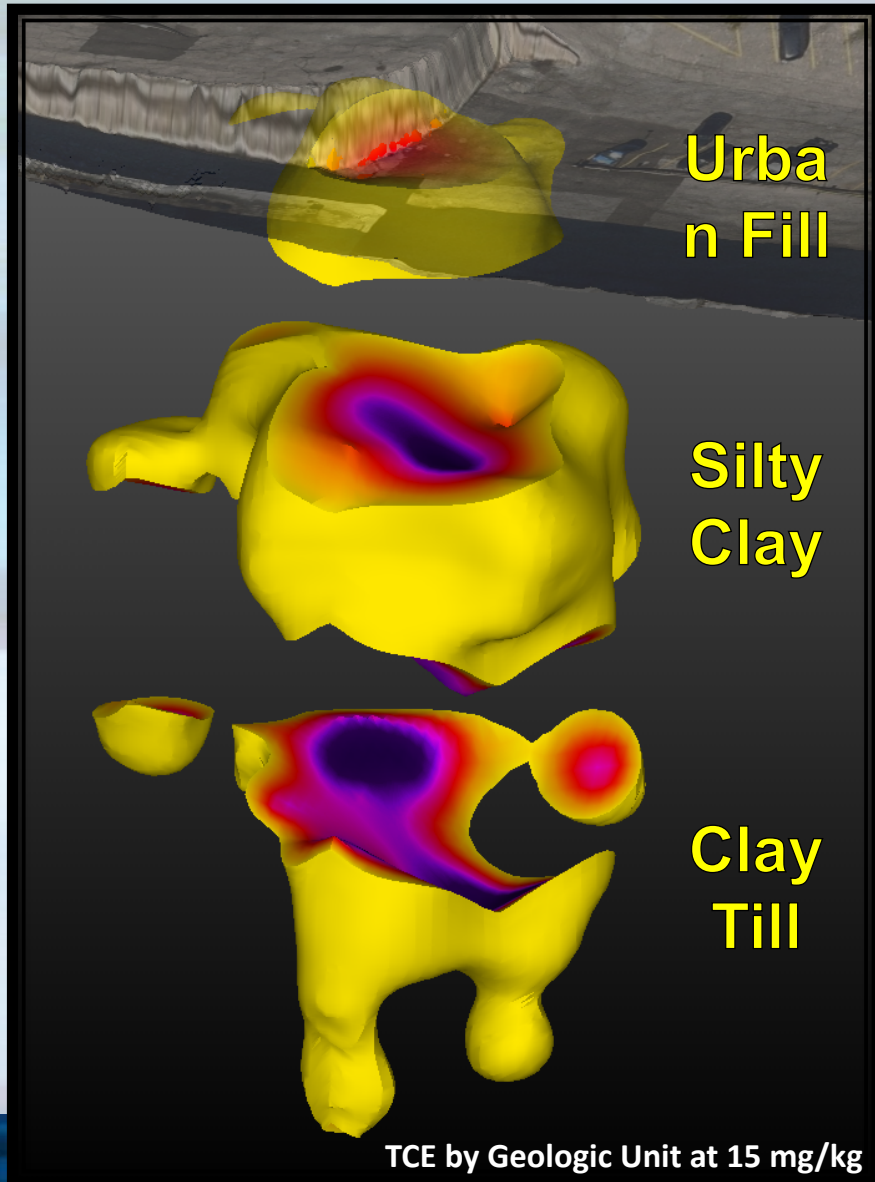
Volumes of Impacted Soil at Various Concentrations

Volumes of In-Situ Impacted Soil by TCE Concentration



TCE Conc. (mg/kg)	Volume of Soil (Cubic Yards)
5	4,338
7	4,097
10	3,889
15	3,684
20	3,528
30	3,318
50	3,065
75	2,875
100	2,744
150	2,566
200	2,443
300	2,272
500	2,060
750	1,894
1,000	1,776
1,250	1,686
1,500	1,612
2,000	1,493
3,000	1,320
4,000	1,192
5,000	1,088
7,500	887
10,000	725
15,000	487
20,000	328
30,000	129

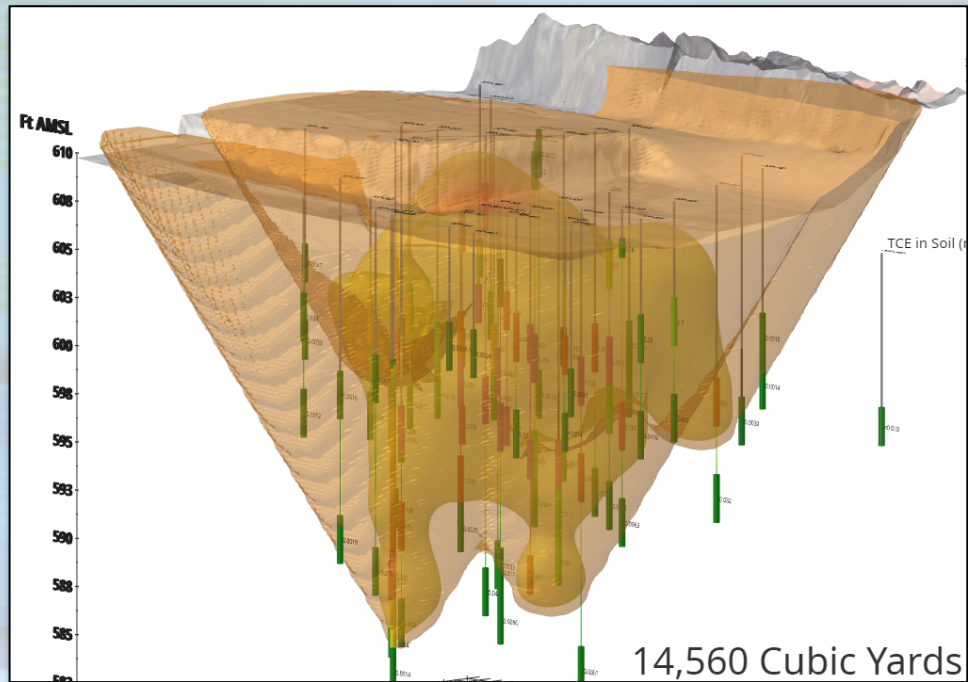
TCE Mass Calculation by Geologic Unit



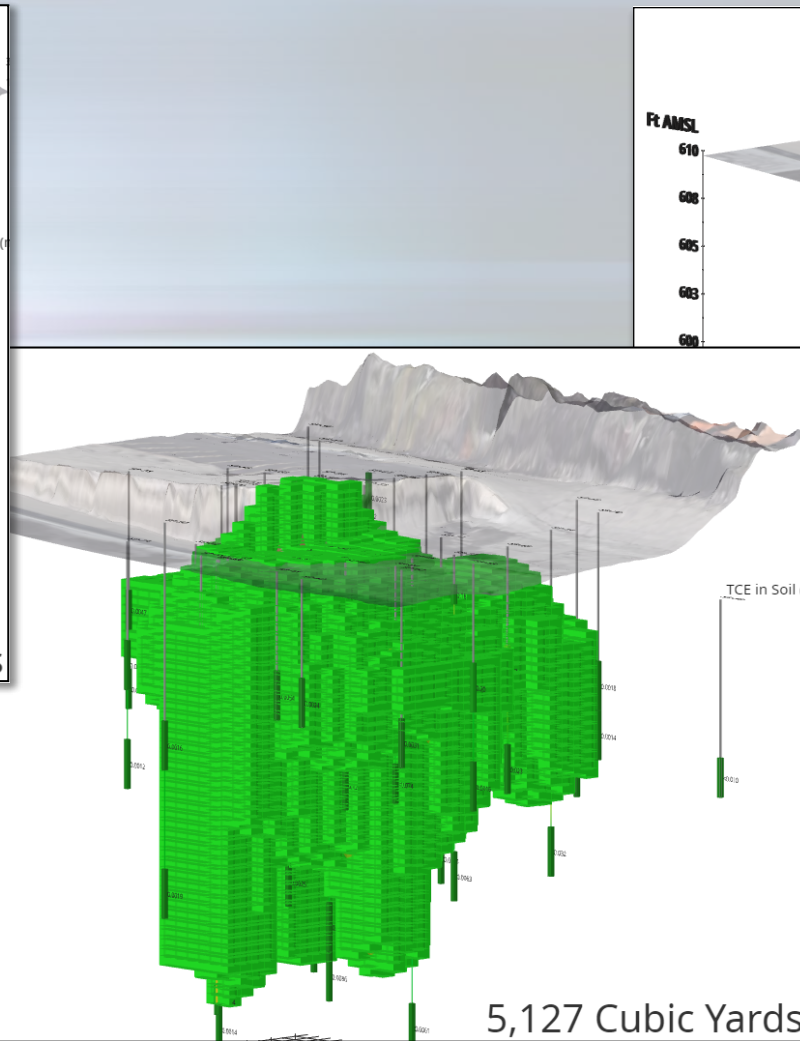
	Soil Density (g/cc)	TCE Mass (Pounds)
Urban Fill	1.60	1,971
Silty Clay	1.75	51,166
Clay Till	1.90	9,295
Total		62,432

- **3.2%** in the Urban Fill
- **81.9%** in the Silty Clay
- **14.9%** in the Clay Till

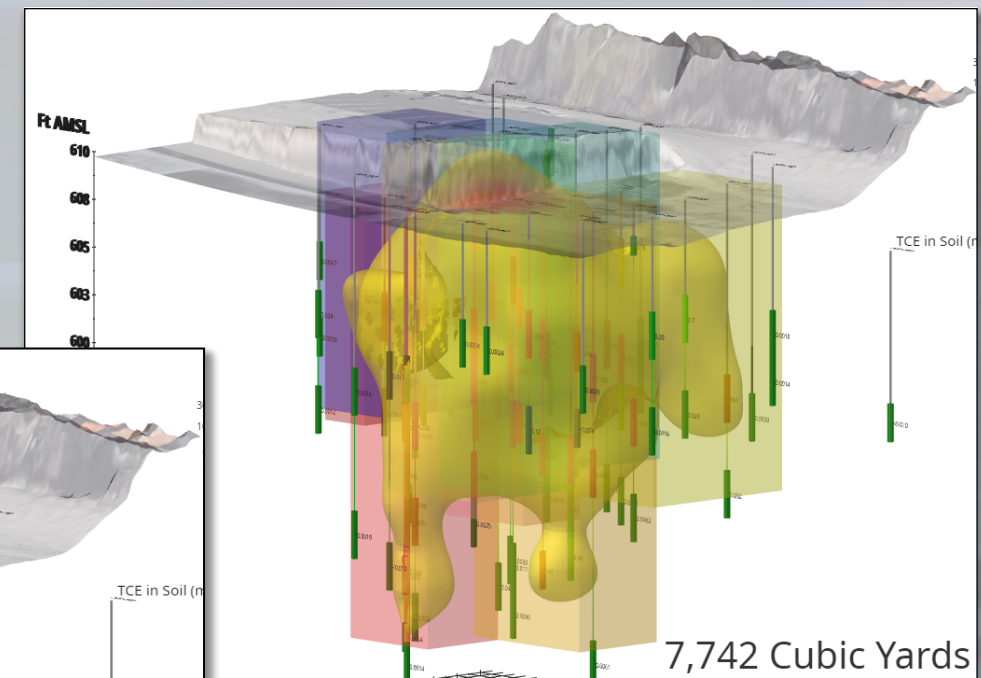
Lesson Learned #2: The 3D Model Was More Than a Visualization Tool



Excavation

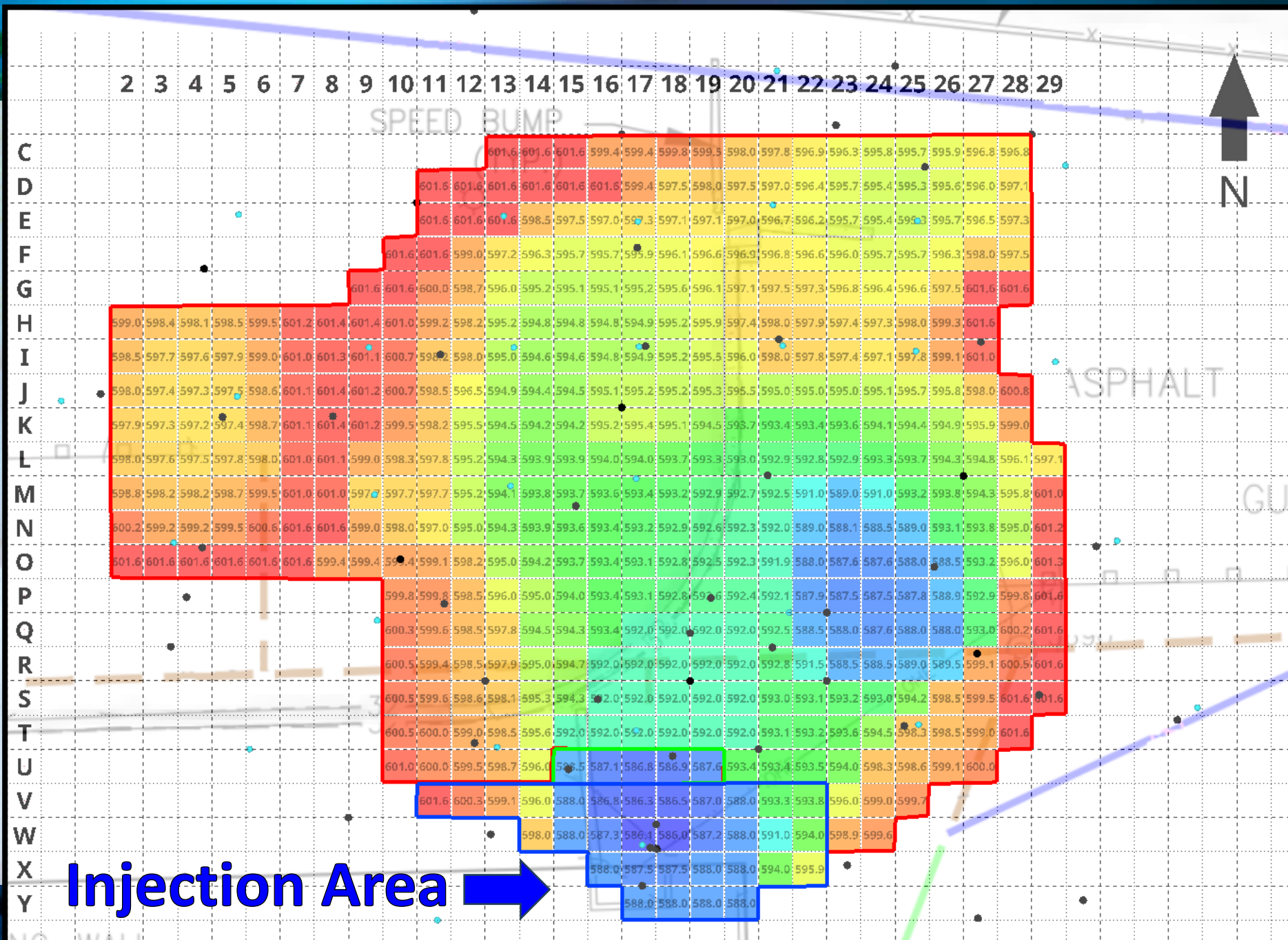


Soil Mixing



Thermal





**Bottom Elevation
Of Treatment
Area
(Ft AMSL)
5x5' Grid**

Other Maps:
Top Elevation
Top & Bottom Depth
Thickness



**JACOB & HEFNER
ASSOCIATES**

Lesson Learned #3: Always Perform a Bench Study

Table 2. Permanganate TOD (48 hour) Results.

Sample	Dosage g/kg	TOD g/kg
TS-1 (1'-10')	34.74	21.0
TS-1 (10'-15')	10.47	9.29
TS-2 (0'-10')	34.83	24.8
TS-2 (10'-15')	34.71	27.6

Total Oxidant Demand (TOD)
>20 g/kg in 3 of 4 Samples

Overcoming TOD of Native Soils was
Cost Prohibitive for ISCO as Sole
Remedial Chemistry

Alternative:

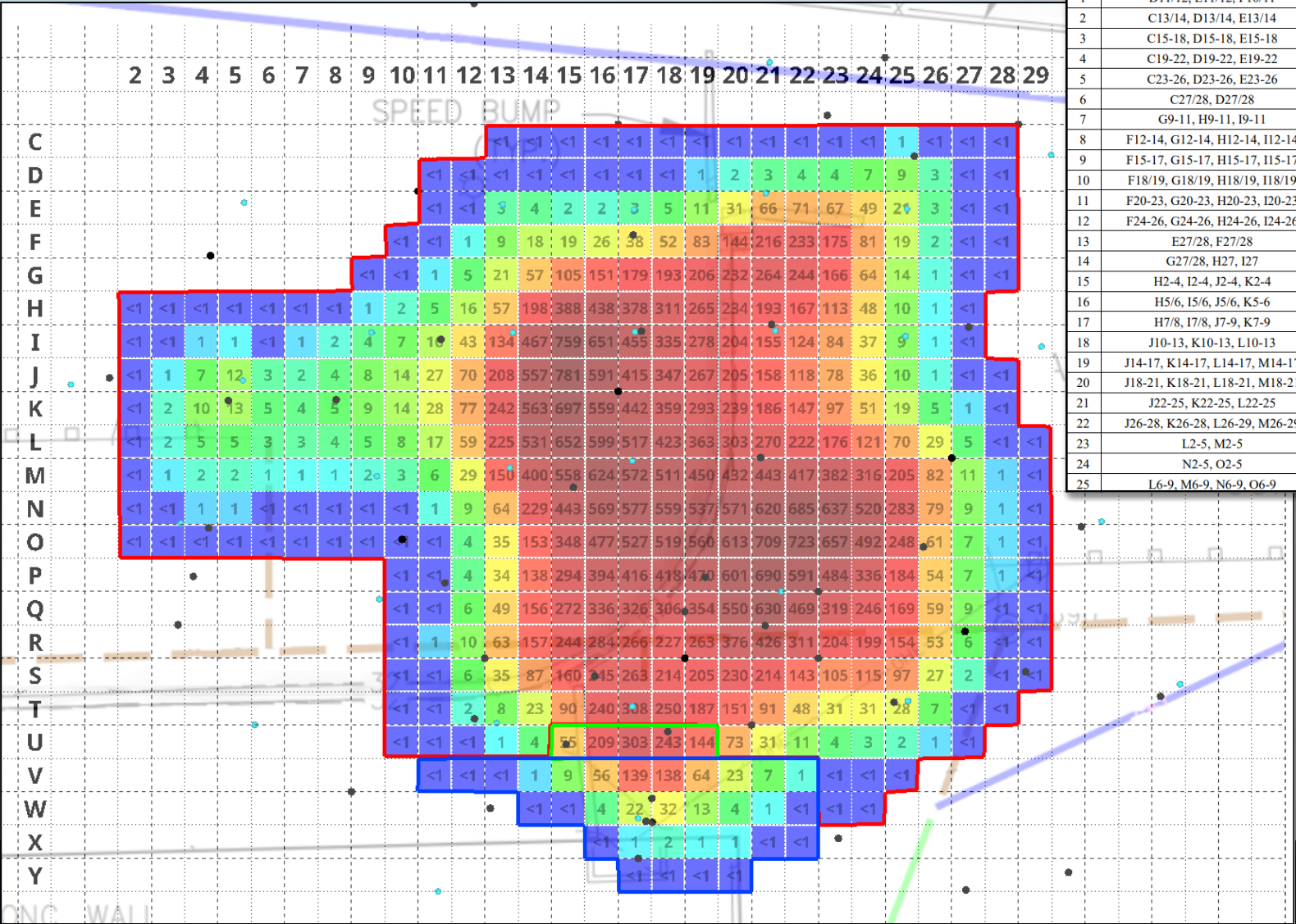
In-Situ Chemical Reduction (ISCR) Using
Zero Valent Iron (ZVI)



Figure 1. Sample Containers after a TOD Test with Permanganate

Lesson Learned #4: Statistical Modeling Assisted with ZVI Dosing

Estimated Pounds of TCE



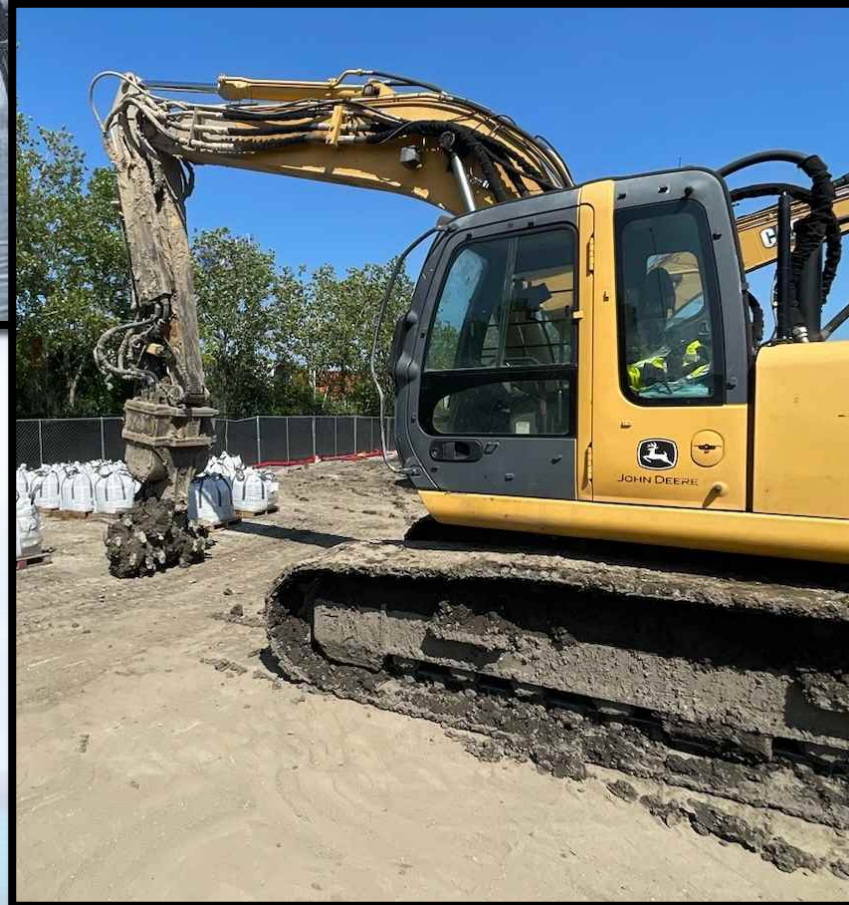
Cell ID	Associated 5ft by 5ft Block from JHA Figure 4	Dimensions (ft x ft)	Area (ft²)	Depth (ft bgs)	Volume (cy)	Est. Average Mass TCE (lbs)	Est. Low Mass TCE (lbs)	Est. High Mass TCE (lbs)	Target Weight Percent ZVI	Exact Weight Percent ZVI	ZVI Required (lbs)	Super Sacks
1	D11/12, E11/12, F10/11	Figure	150	5-10	27.78	<1	<1	<1	1	2.49	2,205	1
2	C13/14, D13/14, E13/14	10 x 15	150	5-10	27.78	<8	<6	<8	2	2.49	2,205	1
3	C15-18, D15-18, E15-18	20 x 15	300	5-14.5	105.56	<13	<10	<14	2	1.98	6,615	3
4	C19-22, D19-22, E19-22	20 x 15	300	3-14	122.22	189	158	214	4	4.44	17,640	8
5	C23-26, D23-26, E23-26	20 x 15	300	2.5-14.5	133.33	164	140	190	4	4.09	17,640	8
6	C27/28, D27/28	10 x 10	100	6-13.5	27.78	<1	<1	<1	1	2.49	2,205	1
7	G9-11, H9-11, I9-11	15 x 15	225	3-13	83.33	36	30	42	2	2.49	6,615	3
8	F12-14, G12-14, H12-14, I12-14	15 x 20	300	3-17	155.56	1026	841	1214	7	7.20	37,485	17
9	F15-17, G15-17, H15-17, I15-17	15 x 20	300	3-17	155.56	3587	2935	4239	8	8.37	44,100	20
10	F18/19, G18/19, H18/19, I18/19	10 x 20	200	4-16.5	92.59	1723	1391	2058	8	8.43	26,460	12
11	F20-23, G20-23, H20-23, I20-23	20 x 20	400	2-13.5	170.37	2948	2390	3500	8	8.40	48,510	22
12	F24-26, G24-26, H24-26, I24-26	15 x 20	300	2-13.5	127.78	287	234	342	5	5.26	22,050	10
13	E27/28, F27/28	10 x 10	100	4-13	33.33	<1	<1	<1	1	2.09	2,205	1
14	G27/28, H27, I27	Figure	100	4-8	14.81	<1	<1	<1	1	4.58	2,205	1
15	H2-4, I2-4, J2-4, K2-4	15 x 20	300	4-14	111.11	21	18	24	2	2.49	8,820	4
16	H5/6, I5/6, J5/6, K5-6	10 x 20	200	3.5-13.5	74.07	34	30	38	2	2.80	6,615	3
17	H7/8, I7/8, J7-9, K7-9	Figure	250	2.5-10	69.44	35	32	41	2	2.00	4,410	2
18	J10-13, K10-13, L10-13	20 x 15	300	2.5-17	161.11	989	813	1164	7	6.97	37,485	17
19	J14-17, K14-17, L14-17, M14-17	20 x 20	400	0.5-18.5	266.67	9058	7333	10772	8	8.08	72,765	33
20	J18-21, K18-21, L18-21, M18-21	20 x 20	400	0-19	281.48	5249	4065	6432	8	7.90	74,970	34
21	J22-25, K22-25, L22-25	20 x 15	300	0-16	177.78	1145	910	1400	7	7.05	41,895	19
22	J26-28, K26-28, L26-29, M26-29	Figure	350	3.5-15	149.07	135	111	156	3	3.23	15,435	7
23	L2-5, M2-5	20 x 10	200	4-13.5	70.37	17	13	19	2	1.98	4,410	2
24	N2-5, O2-5	20 x 10	200	5-12	51.85	2	<1	2	2	2.67	4,410	2
25	L6-9, M6-9, N6-9, O6-9	20 x 20	400	3-13.5	155.56	20	16	23	2	2.23	11,025	5

Treatment Plan





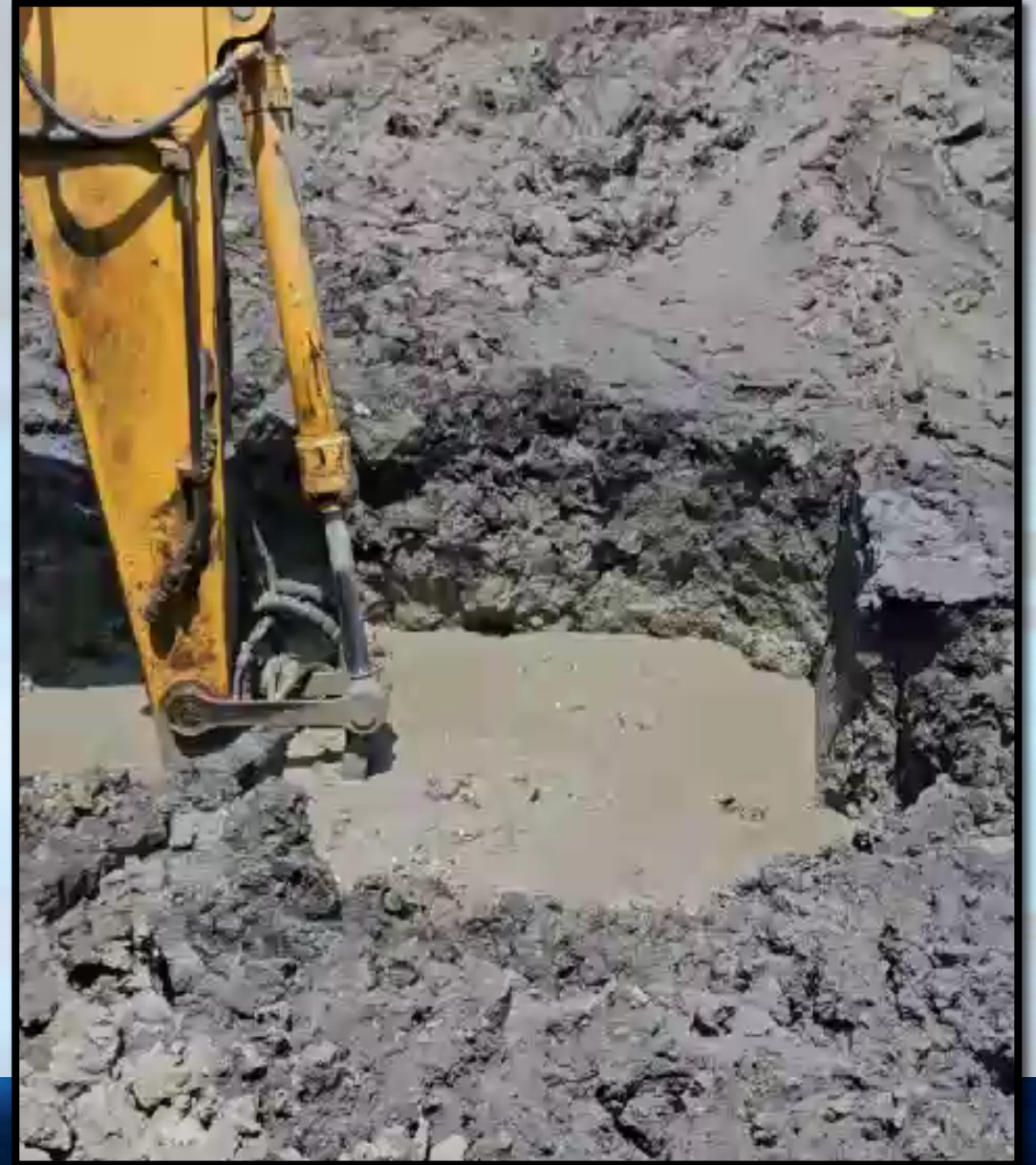
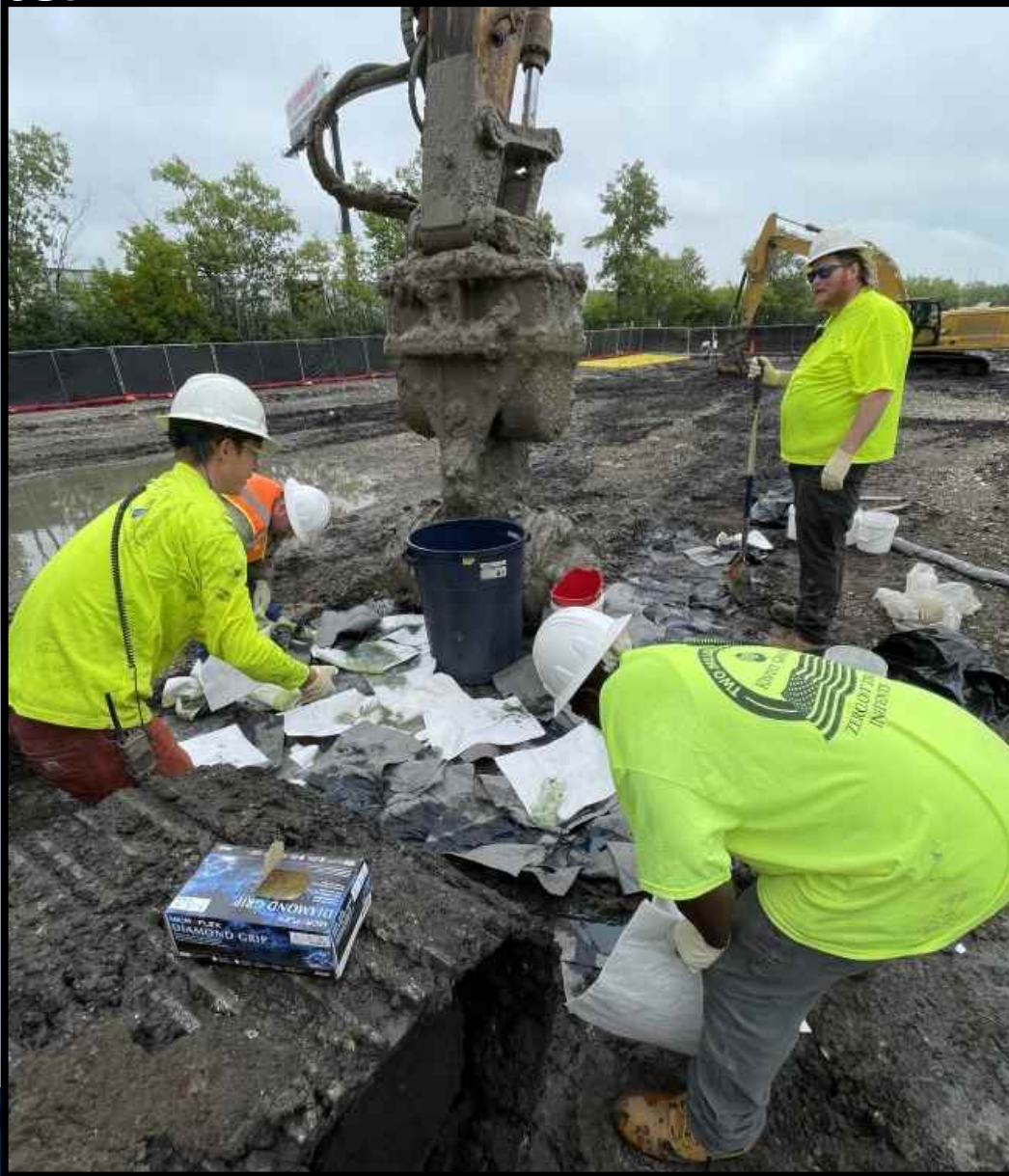
**475 Tons of Zero Valent
Iron (ZVI)**



GPS Readout in Cab

**Soil Blending
Equipment**

Lesson Learned #5: Mixing Dense & Plastic Clays Can Require Additional Water



Other Challenges



Site Flooding



Excavated Bone



Lead Contaminated Soil



Other Challenges

- A portion of the Overburden was impacted with Hazardous Lead – Required On-Site Stabilization Prior to Disposal
- Additional Water Effected the Geotechnical Stability of the Soils
- Incorporation of Portland Cement was Required in the Upper 3'
- Portland Cement Halts the ZVI Reaction

Lesson Learned #6: Have a Flexible Site Restoration Plan

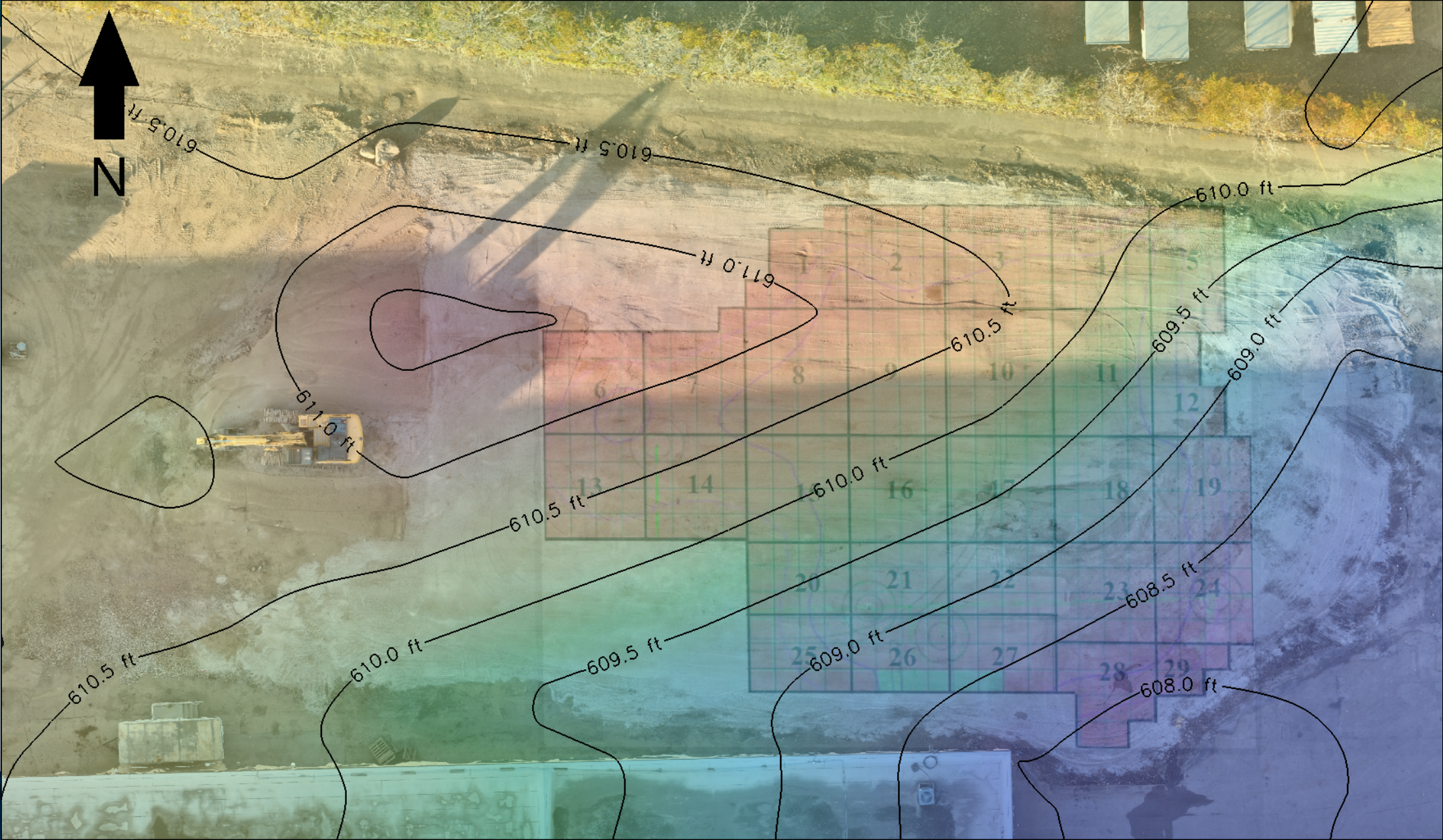


Treating the Top 3 Feet of Soil with Potassium Permanganate

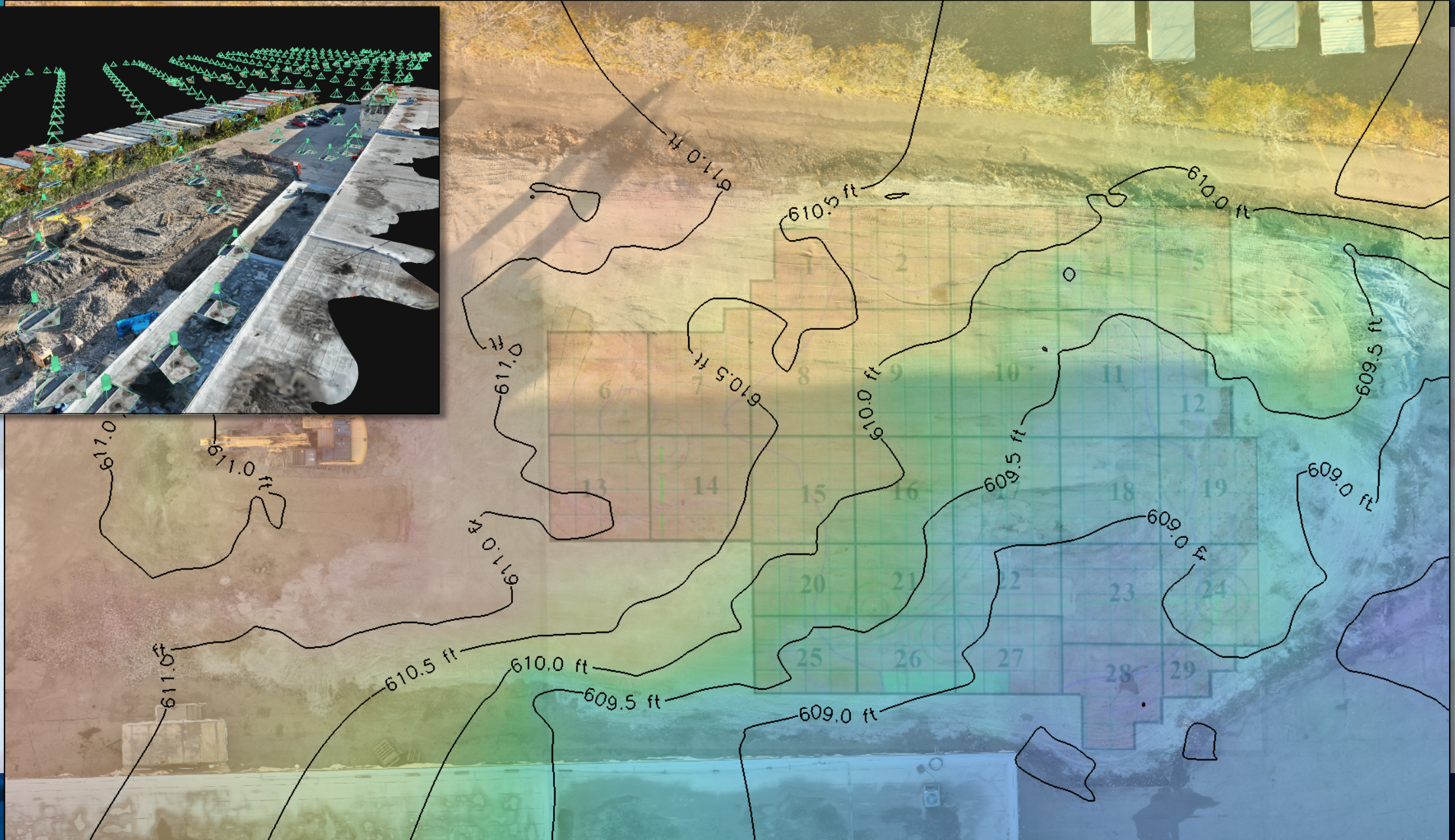
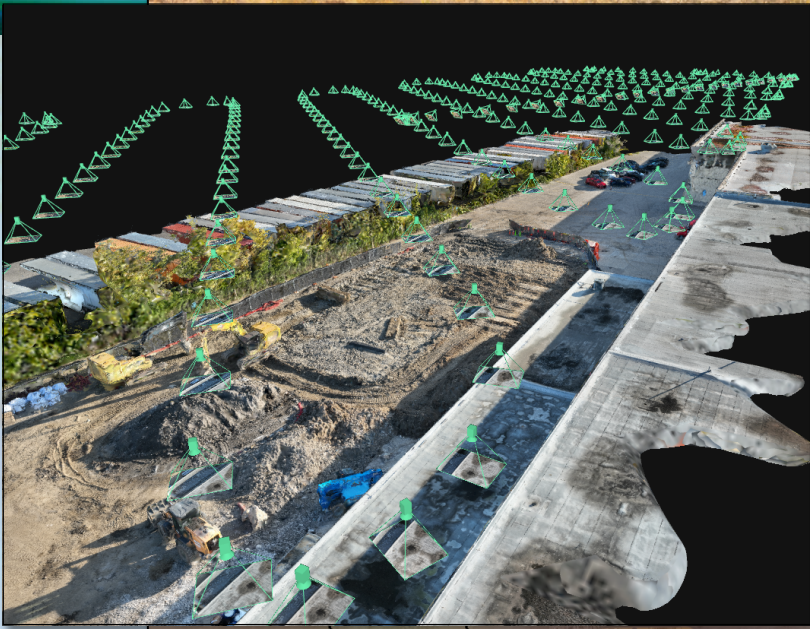


Stabilizing the Top 3 Feet of Soil with Portland Cement

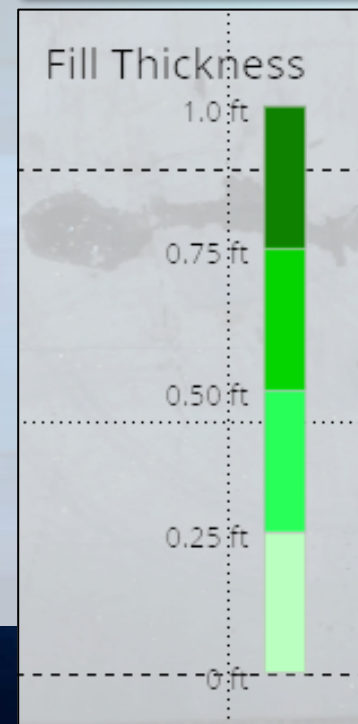
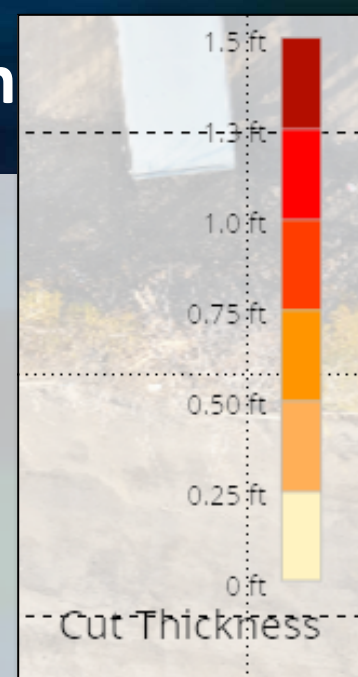
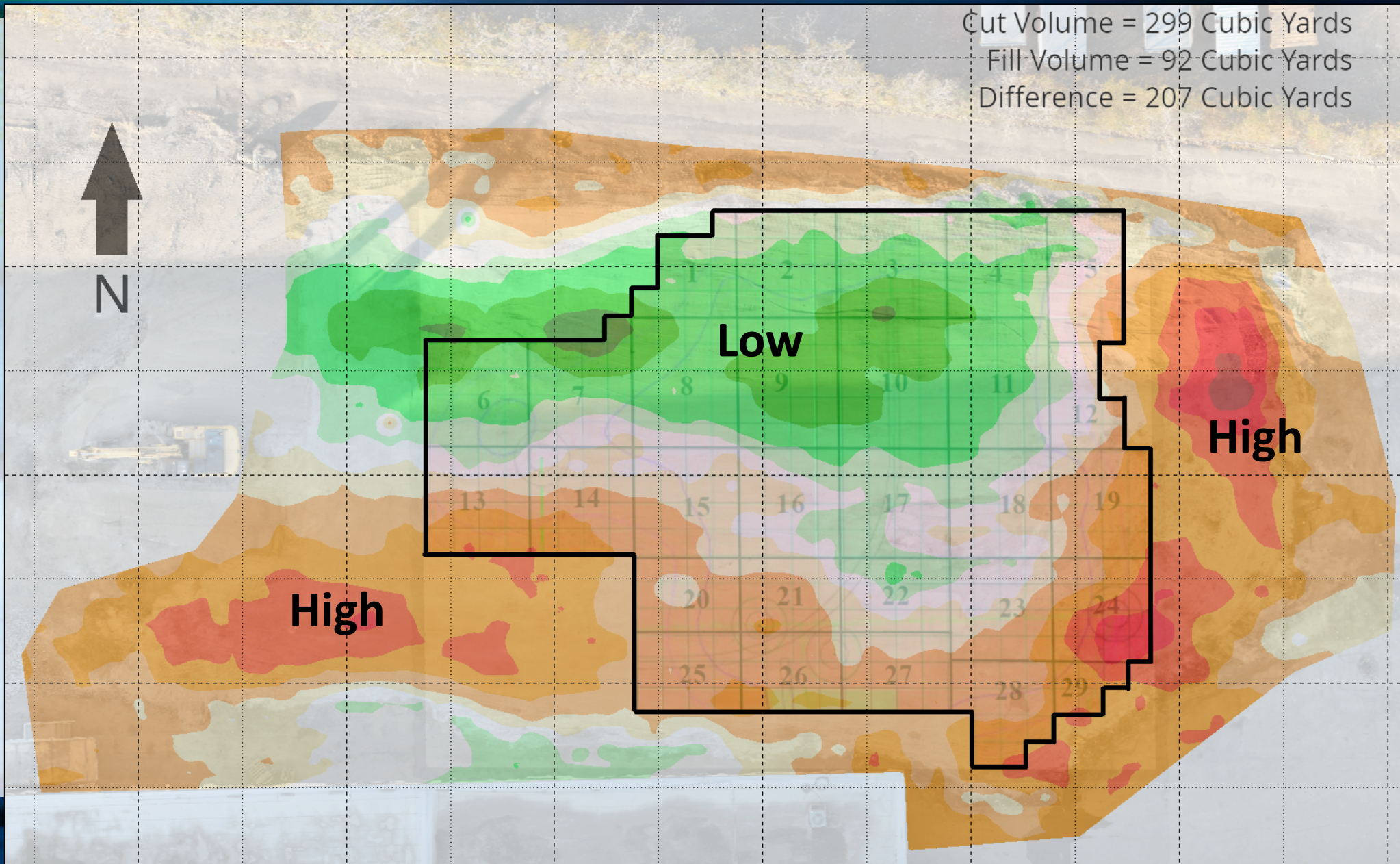
Proposed Grade of the Site



Lesson Learned #7: Utilize a LiDAR Drone for Surveying



Lesson Learned #8: Utilize 3D Software for Cut-Fill Optimization

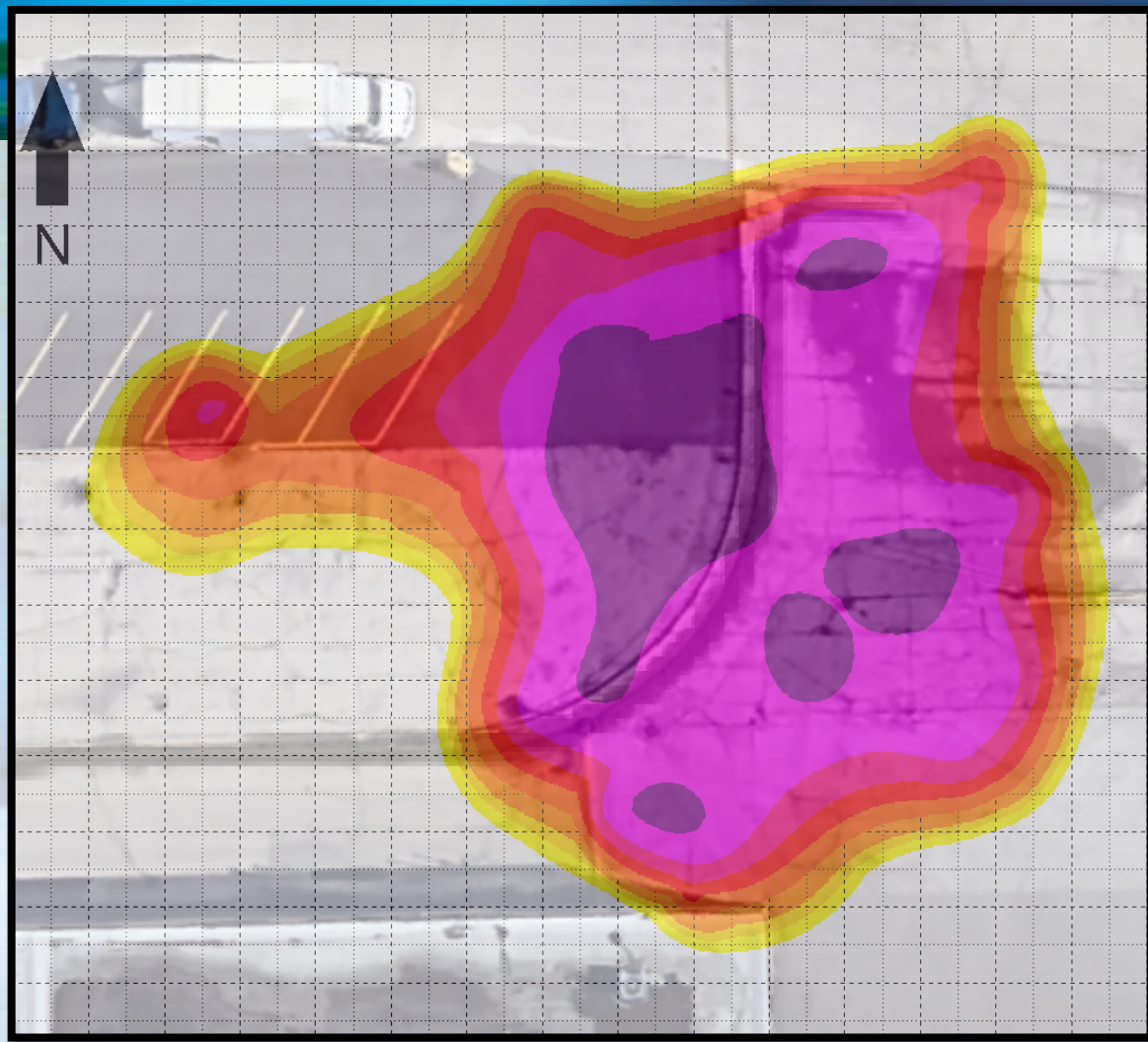


Regraded Site

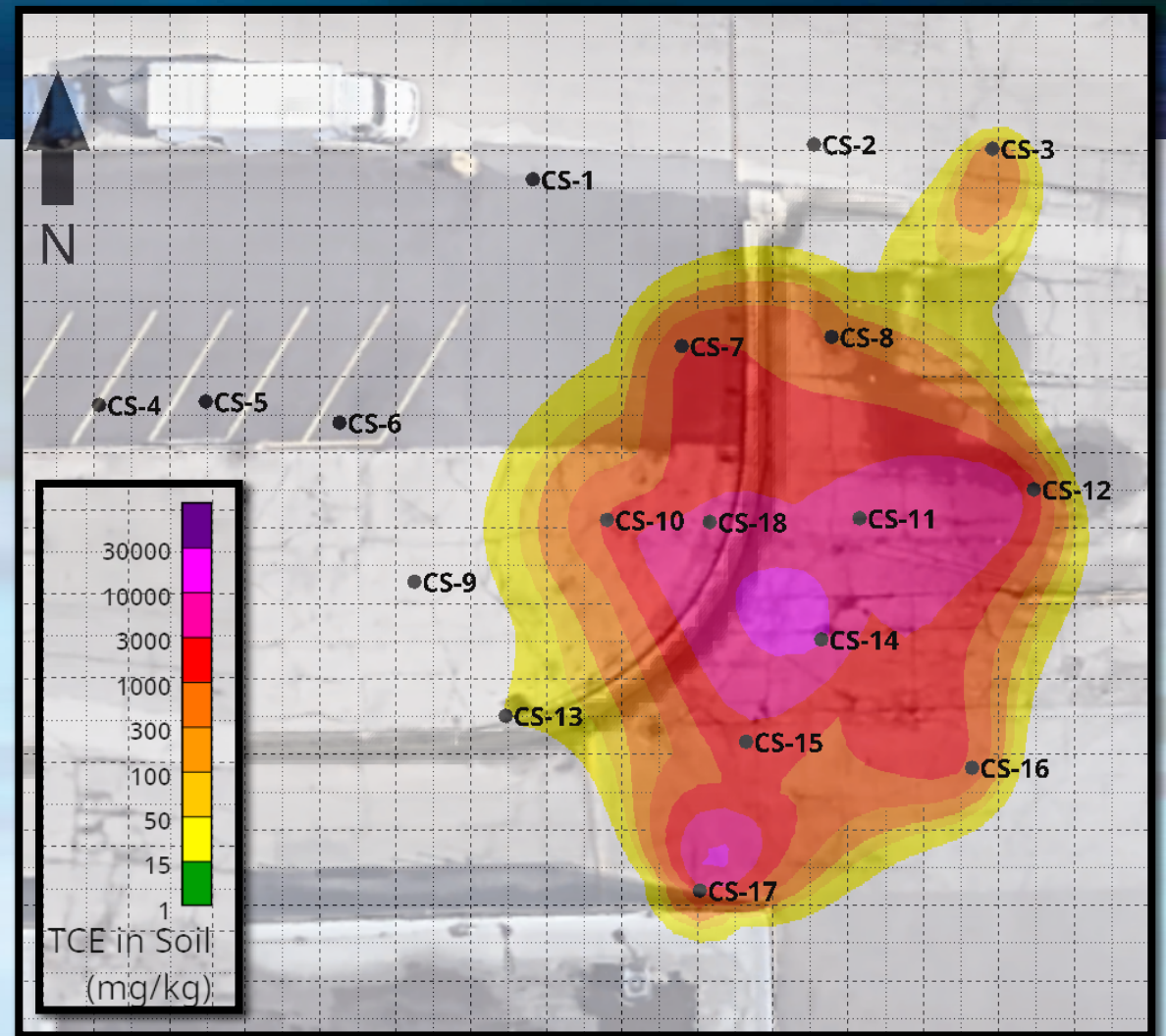
Looking West



JACOB & HEFNER
ASSOCIATES



Initial



Six Months After Treatment

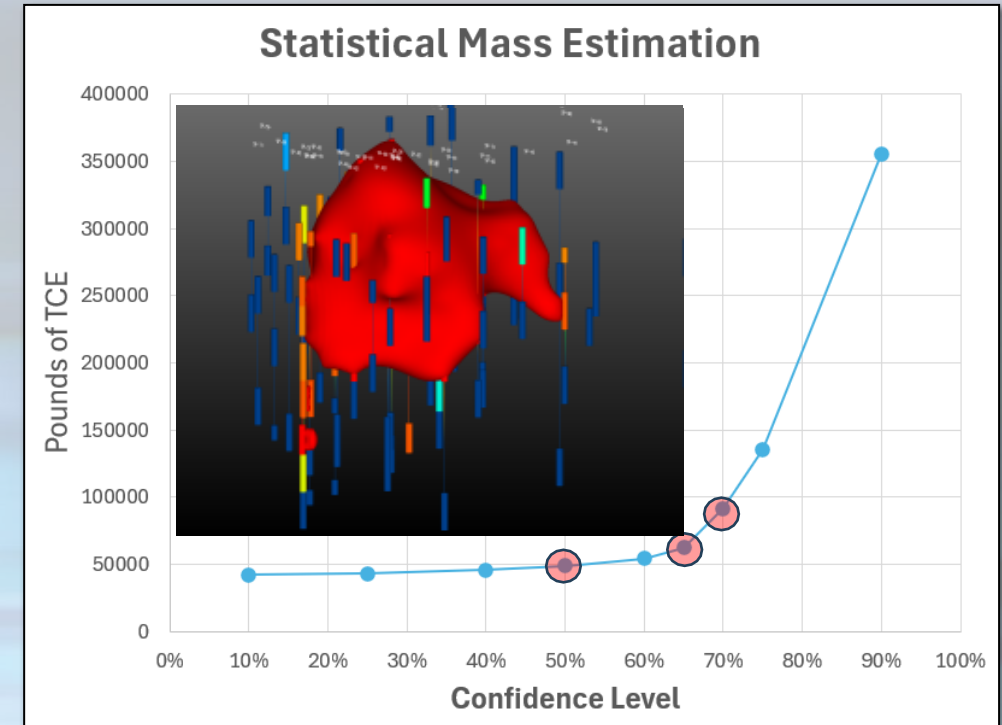
50% Reduction in Impacted Soil Volume
80% Reduction in TCE Mass



JACOB & HEFNER
ASSOCIATES

Lesson Learned #9: Estimate the Mass Conservatively

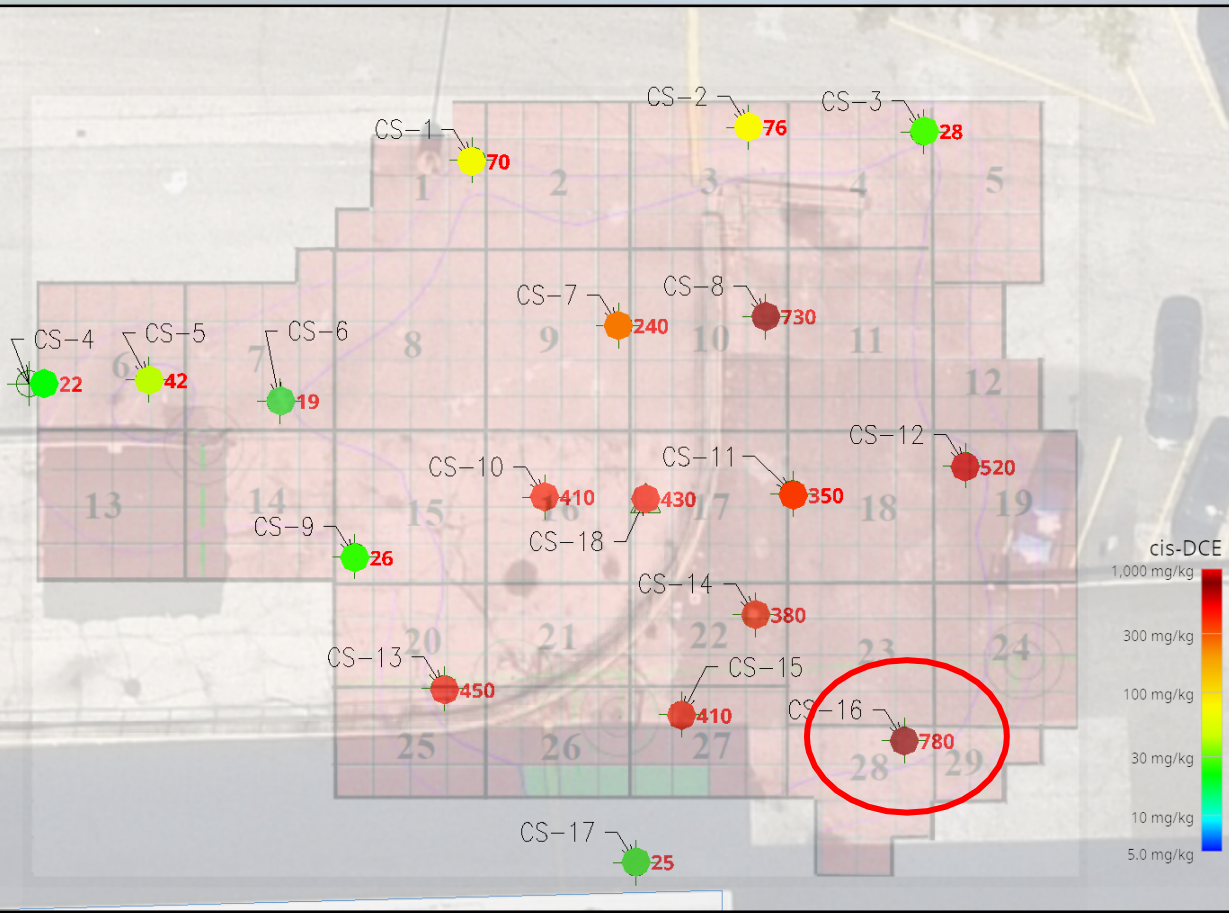
- Statistically Model the Analytical Data at Multiple Confidence Levels
- Visually Inspect the Modeling Results
- Use Other Calculation Methods
- Add a Buffer / Round Up the Amendment Dosage



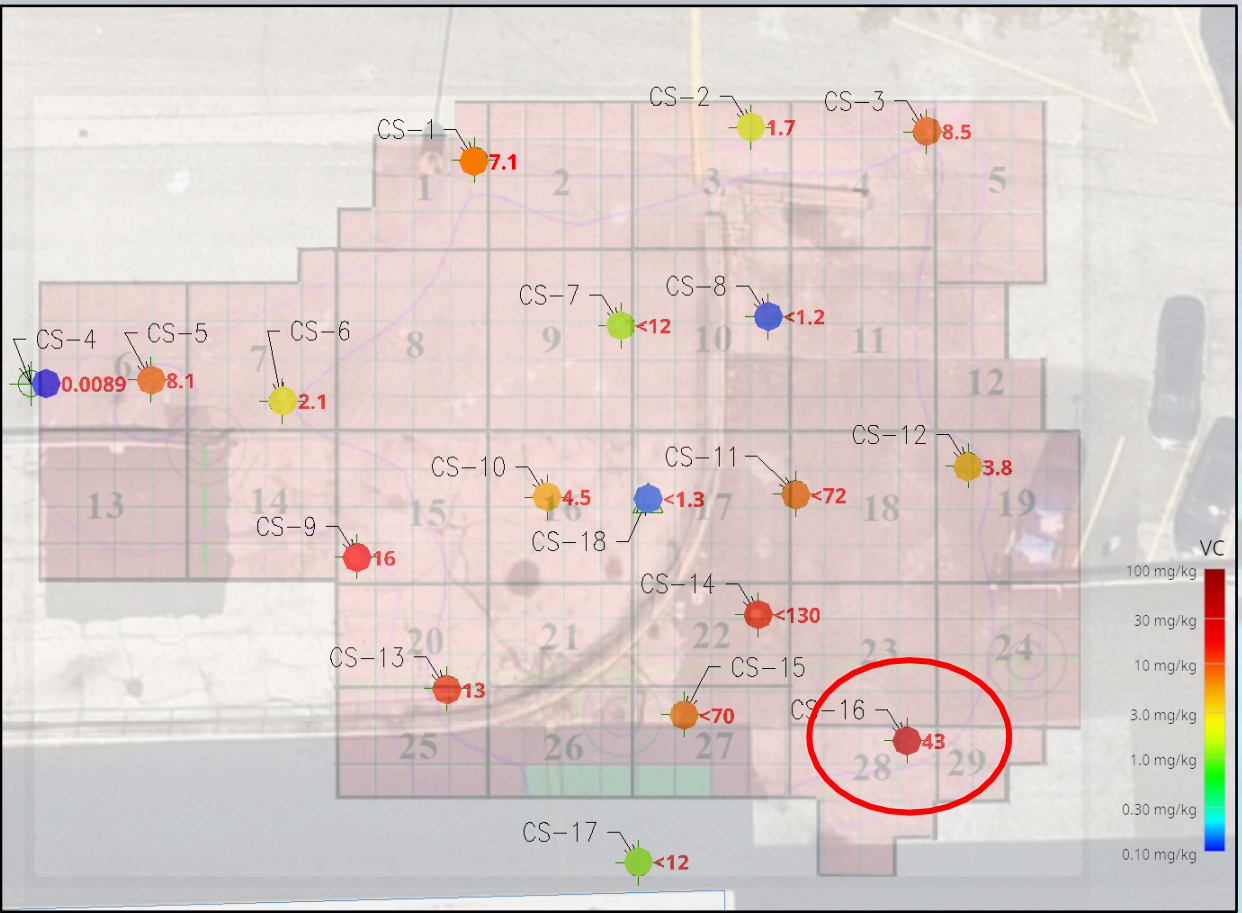
Ave. Conc.	x	Volume	x	Density
2,800	x	138,000	x	49.55
mg/kg		cu. feet		kg/cu. ft
19,150,000,000 mg				
42,000 pounds				



Lesson Learned #10: Daughter Products Can Initially be Generated using ZVI



cis-DCE in Soil – Maximum: 780 mg/kg



Vinyl Chloride in Soil – Maximum: 43 mg/kg

Next Steps:

- 1) Wait Another Month (1 Year Total)
- 2) Resample 12 of 18 Confirmation Sampling Locations
- 3) Injections in Recalcitrant Areas, Add & Mix Additional ZVI (if Needed)
- 4) Resampling of CS Locations Not Meeting 15 mg/kg, and Repeat

Note: Remediation goal of 15 mg/kg for TCE was guaranteed by contractor within the mixing area and 1,000 mg/kg within the injection area

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



JACOB & HEFNER
ASSOCIATES