

High-Resolution Design Optimization (HRDO) and Injection at Brookley AFB Mobile, Alabama

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Background



Background

- Refuse Burn Pits
- The majority of the site is located within the public Doyle Park
- Private residences are located across Rosedale Road to the south, and undeveloped commercial property is located to the west of the site.
- The favorable impact of the in-situ chemical reduction (ISCR) pilot injections at both shallow and intermediate depths, with gradual reduction in TCE from pre-injection concentration of 3,400 µg/L in September 2012 to none detected (ND) in August 2016. However rebound has occurred.
- Pre-Design Investigation 9.3.21

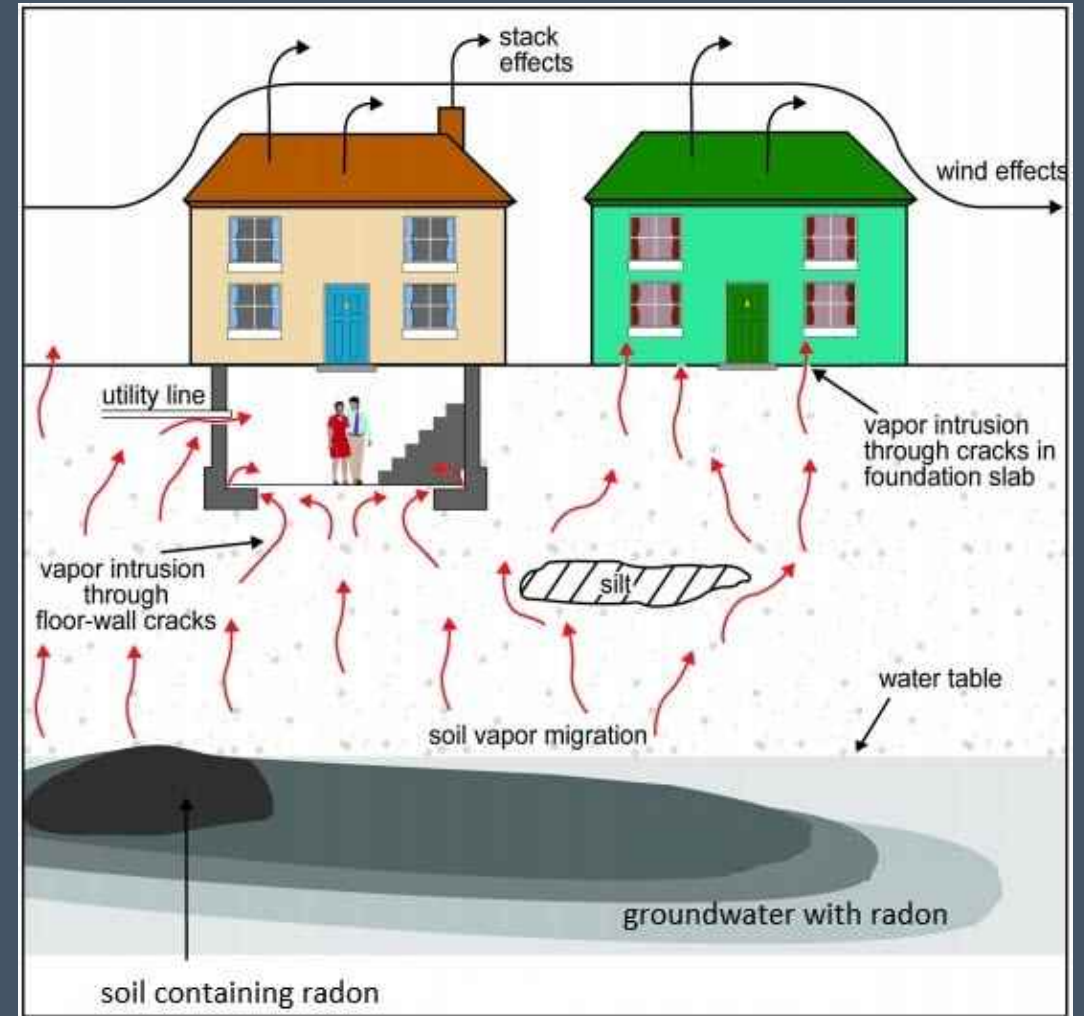


Background

- The major goal of the remedy is to implement a corrective action that will result in contaminants remaining on-site below levels that allow unlimited use and unrestricted exposure (UU/UE) within ten (10) years of the start of remedy implementation.

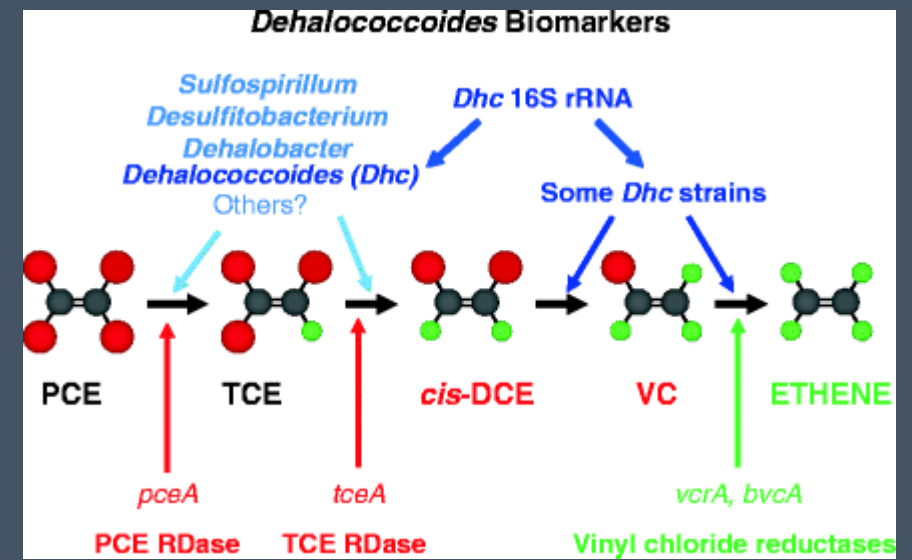
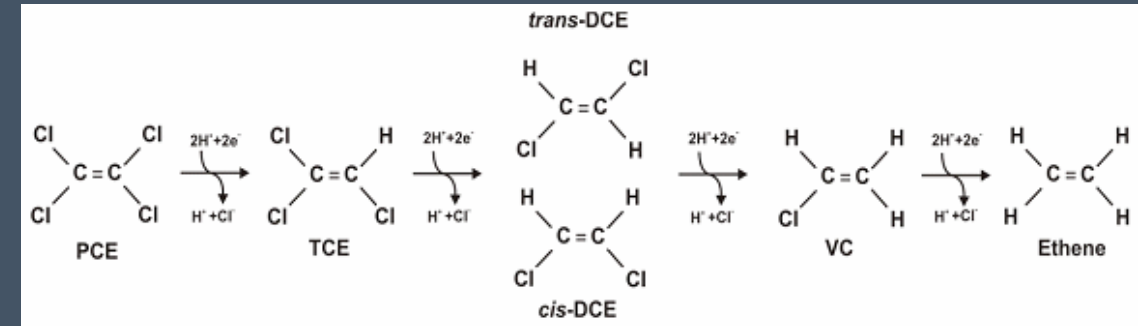
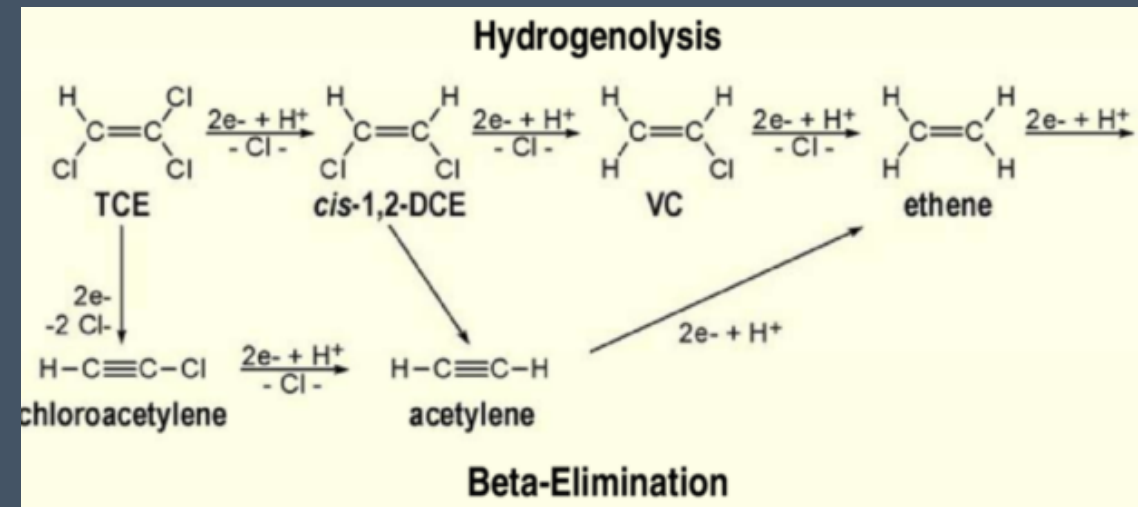
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- ARARS based on Maximum Contaminant Level (MCL) for the following Contaminants of Concern (COCs):
 - Trichloroethene: 5 µg/L
 - 1,2-Dichloroethane: 5 µg/L
 - cis-1,2-Dichloroethene: 70 µg/L
 - Vinyl Chloride: 2 µg/L
- Mitigate the potential future vapor intrusion risks



In Situ Objectives

- **Source Zone:** Injection of ISCR reagents within the elevated COC concentration plume beneath the residual source area soils.
- **Transition Zone:** Injection of ISCR reagents within the elevated COC concentration plume where TCE concentrations exceed 1,000 µg/L in the area surrounding the source area.
- **Plume:** Injection of Enhanced In Situ Bioremediation (EISB) reagents into the areas outside the elevated COC concentration plume where concentrations of the breakdown products of TCE that are undergoing sequential reductive dechlorination (cis-1,2-DCE and VC) exceed 1,000 µg/L .



Pilot Testing Before Pre-Design Investigation

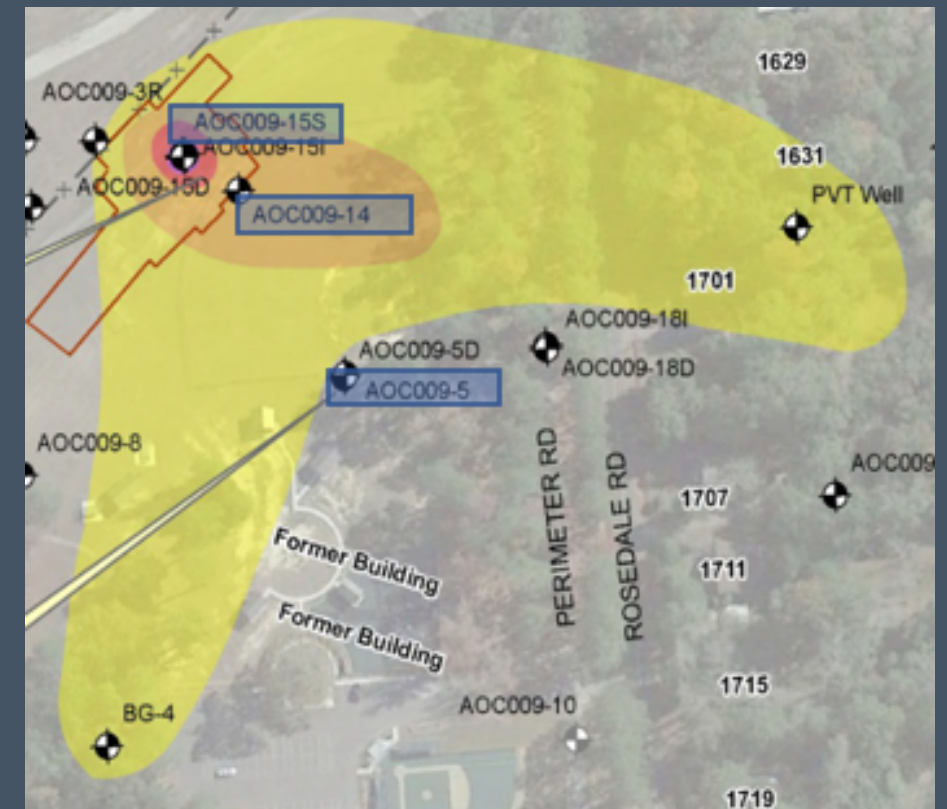
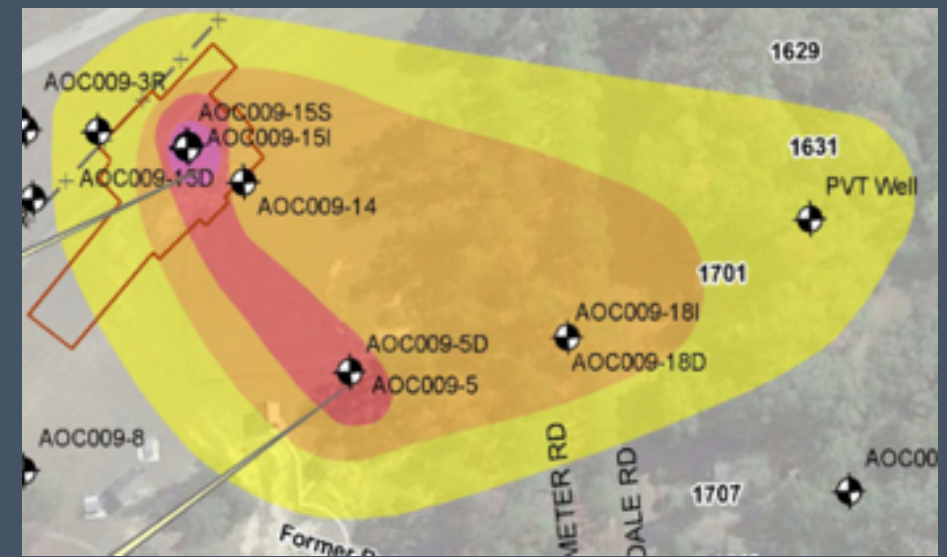
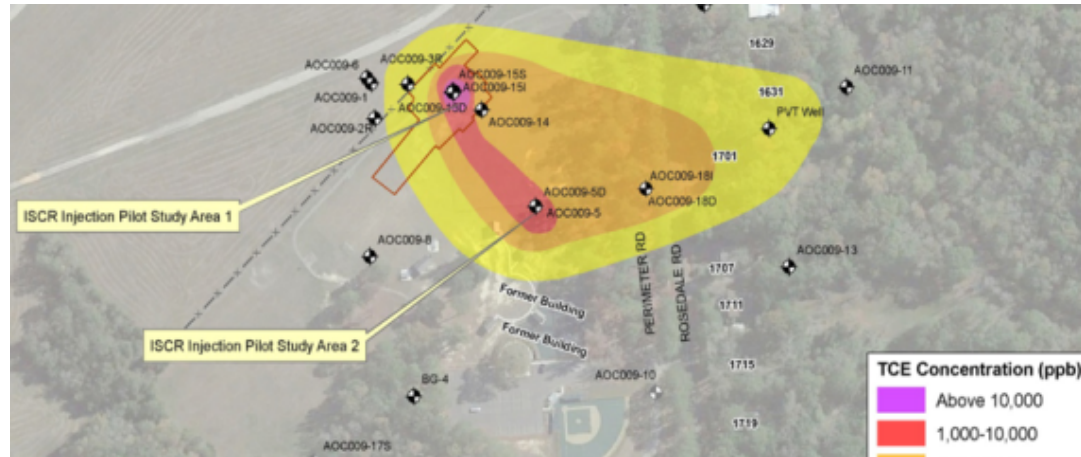
Well Locations



Pre (2012) & Post (2016) Pilot Test

January 2013: ISCR pilot study with 13,000 lbs of EHC.

- 28 x 28 ft around AOC009-15
- 20 x 20 ft around AOC009-5



Post Pilot Full-Scale Injection Design

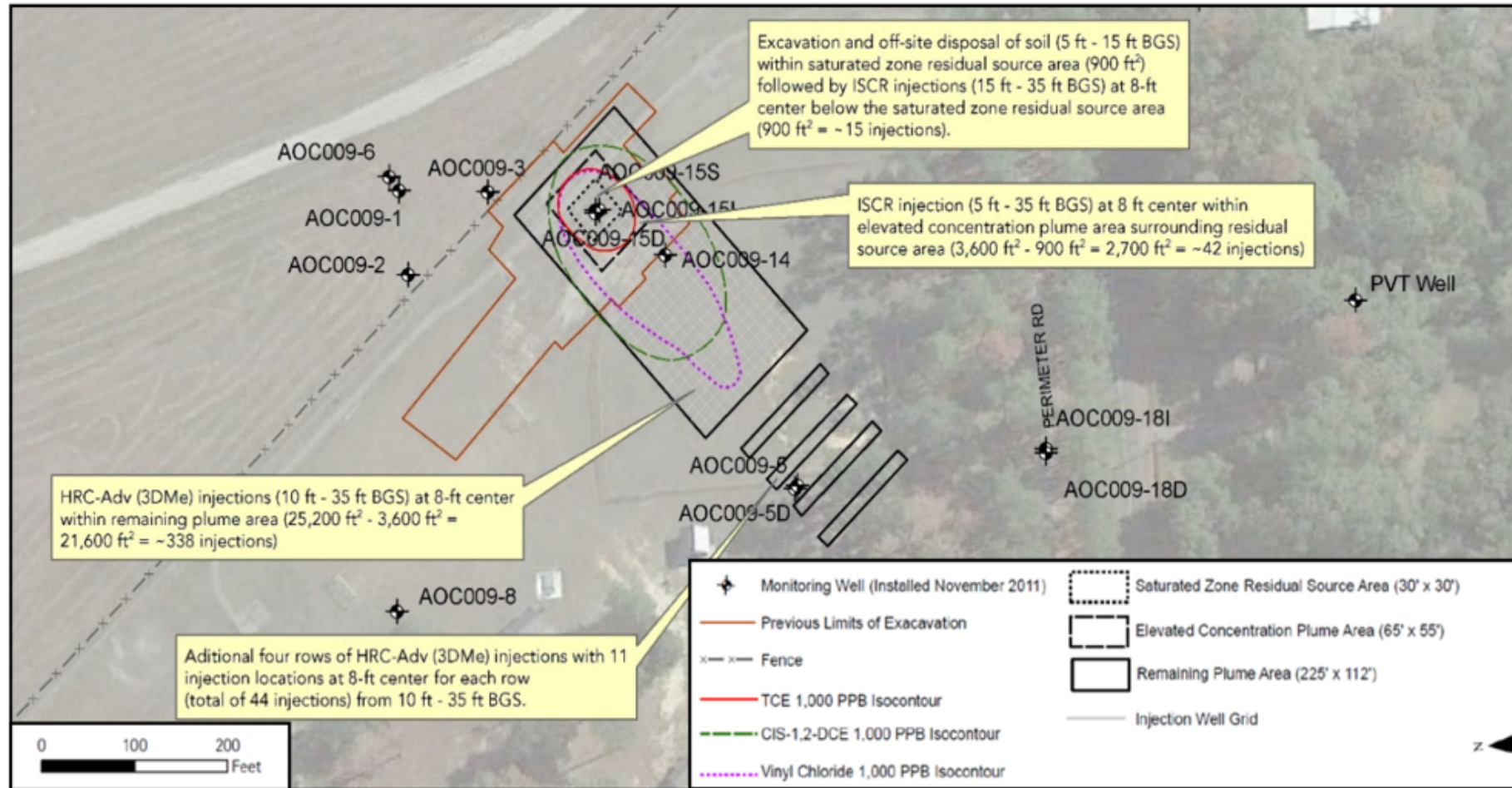


Figure 6 - Alternative 4 - Saturated Zone Residual Source Area Excavation with Off-Site Disposal, Elevated Concentration Plume Area ISCR Injections, and Plume Area EMNA (Plan View)

Pre-Design Investigation – MiHPT on Confirmation Sampling



Groundwater

TABLE 4

3843 - Brookley AFB

Pre-Design Investigation - GW Sample Results for COCs

8260D Volatile Organic Compounds (GC/MS)

CAS	Analyte (COGs)				Sample ID ¹ Result, ug/L							RAOs, ug/L
		15-S	15-D	15-I	14	5-D	5-D (dup)	5	18-D	18-I	18-I (dup)	
Depth of Sample Pump Intake from TOC (feet)		12	70	30	20	72	72	22	67	45	45	
107-06-2	1,2-Dichloroethane	47	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5
156-59-2	cis-1,2-Dichloroethene	97000	29	23	270	0.47	1	360	0.41	0.51	0.57	70
79-01-6	Trichloroethene	42000	28	23	59	1.3	1.2	2.9	0.65	0.56	0.53	5
75-01-4	Vinyl chloride	4300	4.3	1.9	230	0.5	0.5	210	0.5	0.5	0.5	2



DHC

TABLE 7

3843 - Brookley AFB

Pre-Design Investigation - GW Sample Results for Dechlorinating Bacteria Census

Dehalococcoides (DHC) Census

Sample Name	Parameter		Sample Result, cells/mL			
			15-D	15-I	18-D	18-I
Depth of Sample Pump Intake from TOC (feet)			70	33	67	45
15-D	Dehalococcoides	DHC	1.85E+04	1.61E+04	2.93E+01	1.60E+01
15-D	tceA Reductase	TCE	2.28E+03	1.85E+03	5.00E-01	5.00E-01
15-D	BAV1 Vinyl Chloride Reductase	BVC	5.00E-01	1.00E+00	5.00E-01	5.00E-01
15-D	Vinyl Chloride Reductase	VCR	1.09E+03	1.04E+03	5.00E-01	5.00E-01
15-D	Dehalobacter spp.	DHBt	3.40E+03	4.31E+03	2.09E+02	2.05E+01

Soil

TABLE 6

3843 - Brookley AFB

Pre-Design Investigation - Membrane Interface Probe and Hydraulic Profiling Tool (MiHPT)

Soil Sample Results for COCs in MiHPT Locations and Depth

8260D Volatile Organic Compounds (GC/MS)

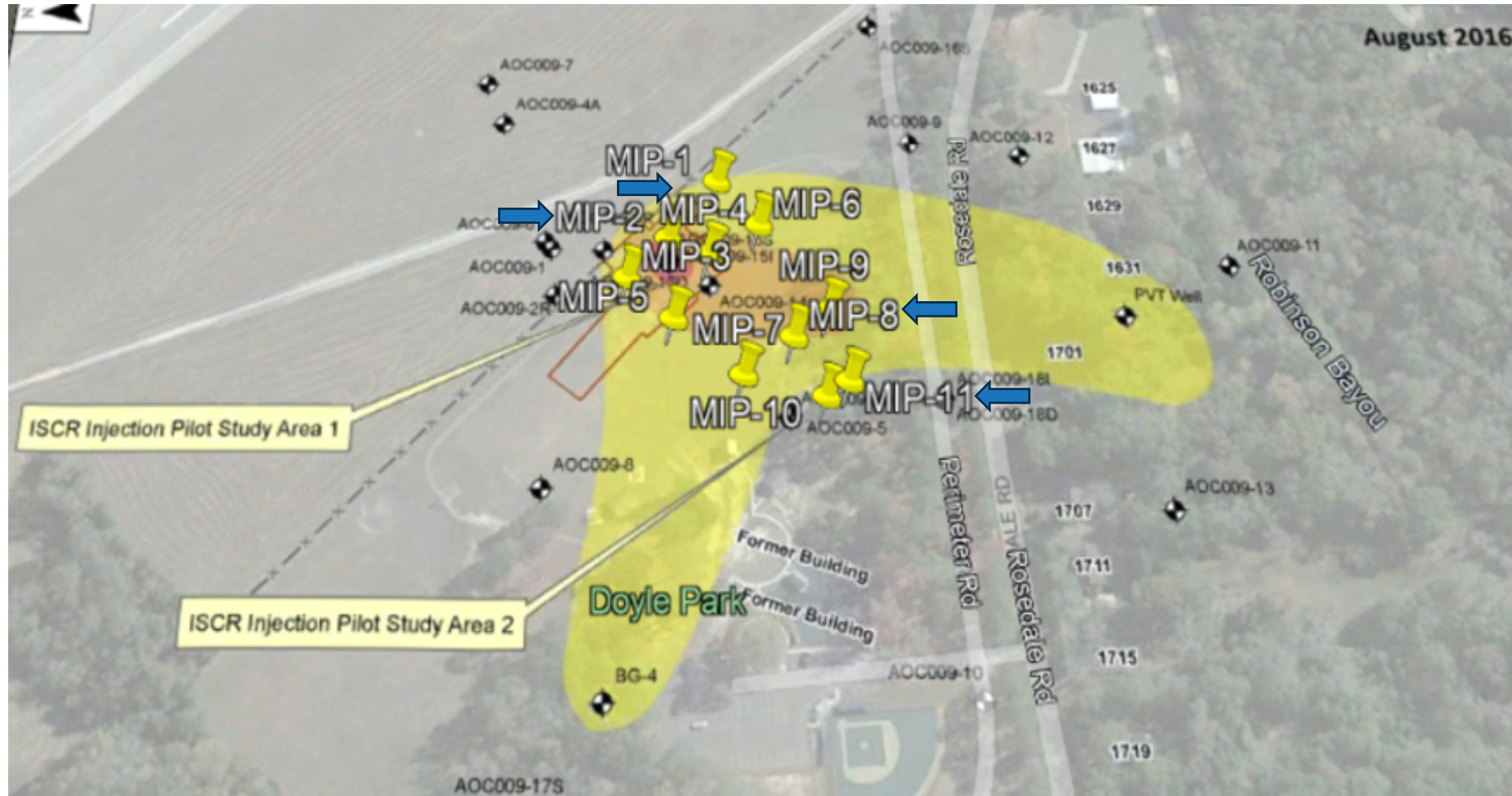
CAS	Analyte (COCs)	Sample ID ¹ Results, ug/Kg			
		MIP-02-16-18	MIP-04-30	MIP-08-17	MIP-11-10
107-06-2	1,2-Dichloroethane	180	42	49	0.93
156-59-2	cis-1,2-Dichloroethene	1700	390	1800	9
79-01-6	Trichloroethene	7400	1700	5100	110
75-01-4	Vinyl chloride	480	76	180	2.9
	Percent Moisture	42	19.9	24.2	18.7

Footnotes:

1	MIP-02-16-18	MiHPT location 02 at sample depth of 16 to 18 feet bgs
	MIP-04-30	MiHPT location 04 at sample depth of 30 feet bgs
	MIP-08-17	MiHPT location 08 at sample depth of 17 feet bgs
	MIP-11-10	MiHPT location 11 at sample depth of 10 feet bgs



MiHPT Injection Optimization Locations

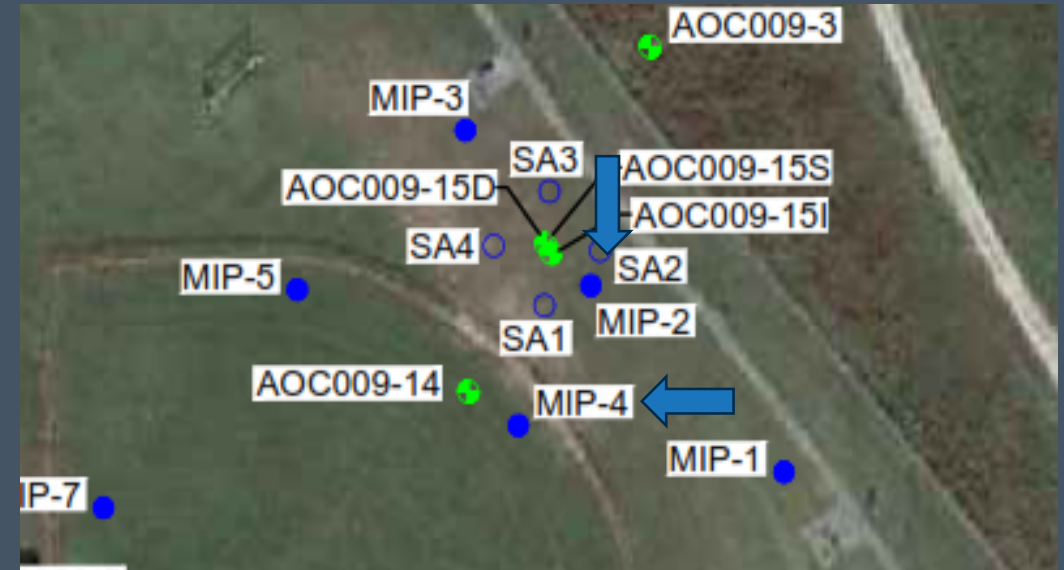
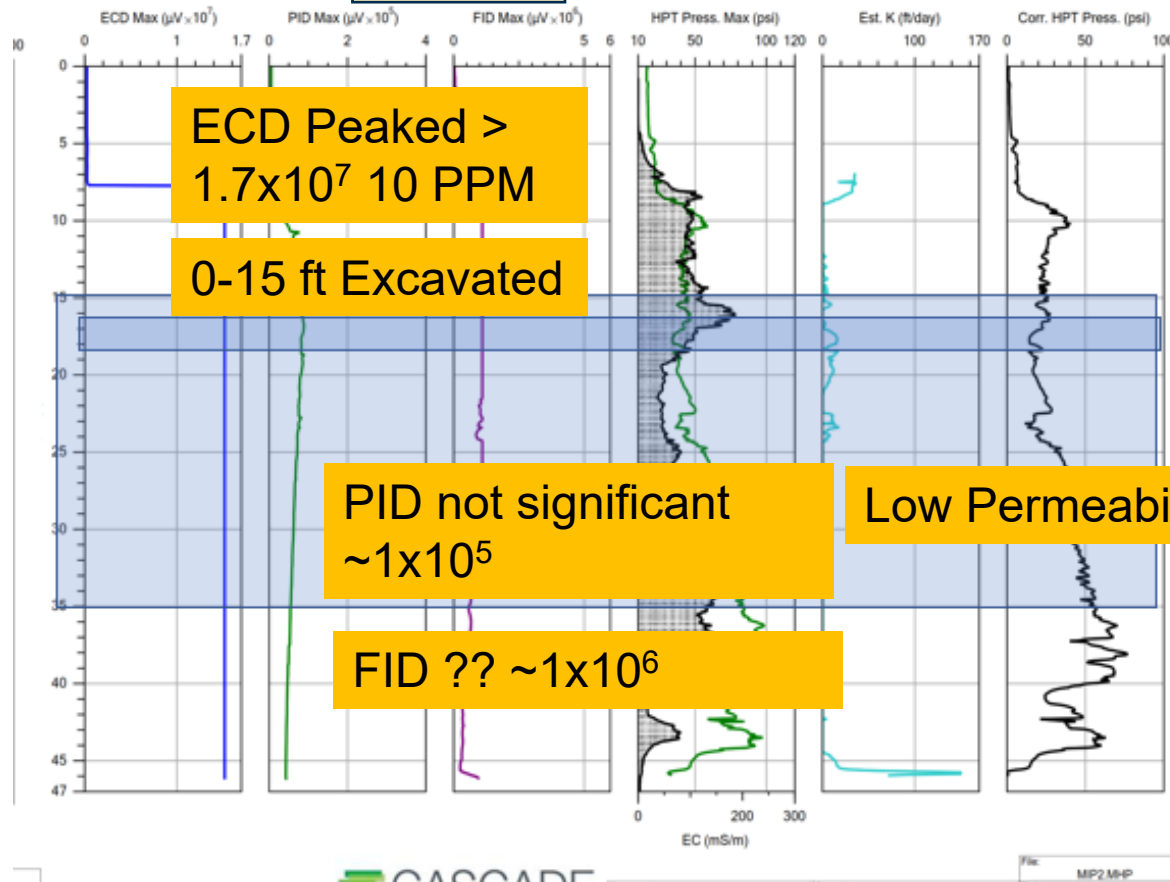


MiHPT vs. Well Locations



MIP-02 / AOC009-15 Source -EHC

Analyte (COCs)	MIP-02-16-18	Sample ID ¹ Results, ug/Kg			
		MIP-04-30	MIP-08-17	MIP-11-10	
1,2-Dichloroethane	180	42	49	0.93	
cis-1,2-Dichloroethene	1700	390	1800	9	
Trichloroethene	7400	1700	5100	110	
Vinyl chloride	480	76	180	2.9	



Source Zone Characterization: MIHPT Expert Rules

HIGH SORBED MASS TO DNAPL

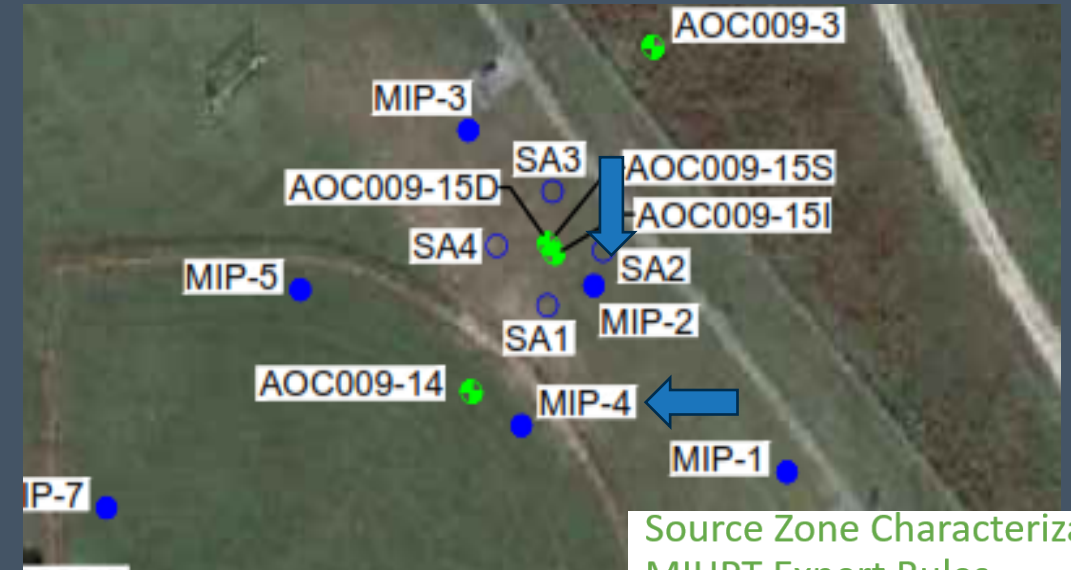
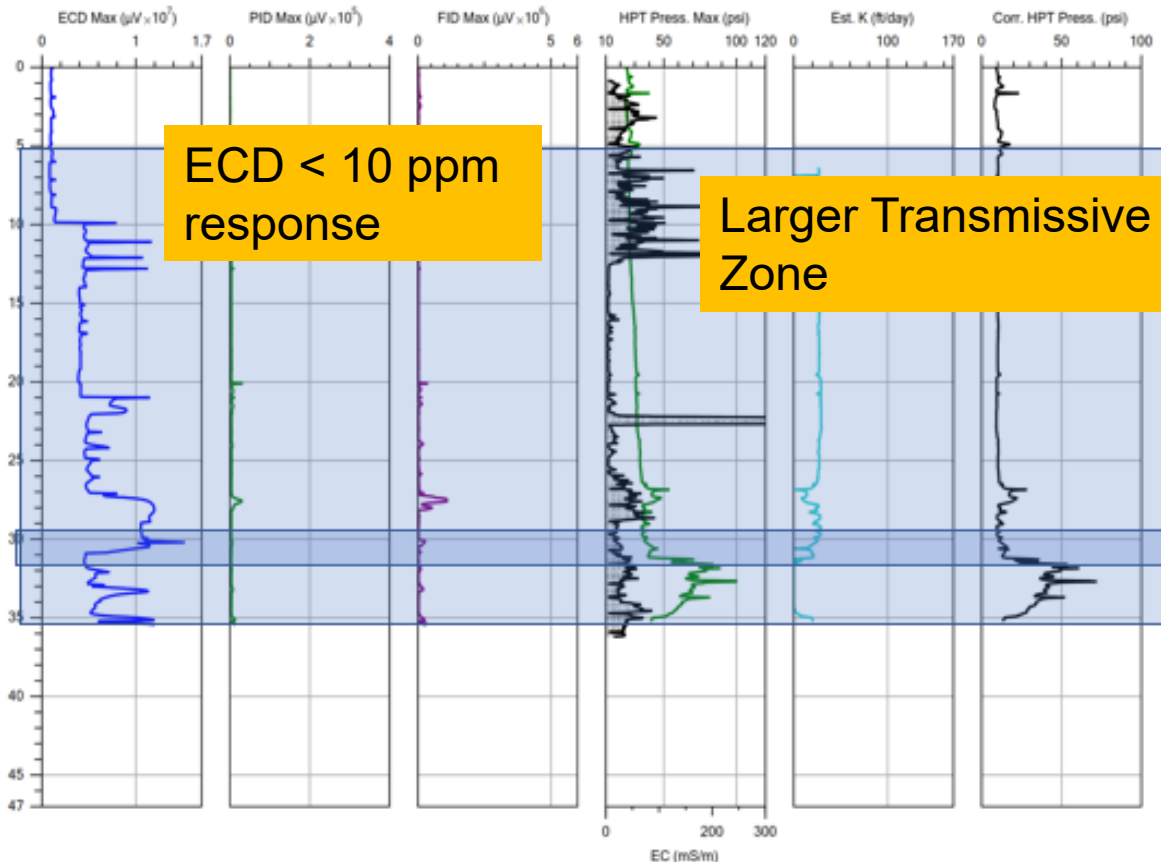
- $XSD > 5 \times 10^{+5} uv$
- $PID > 1 \times 10^{+6} uv$
- $FID > 1 \times 10^{+6} uv$
- $ECD > 1.4 \times 10^{+7} uv$

INJECTION Vs. Fracturing

- $EC > 50$ ms/m
- HPT Pressure > 50 to 75 PSI

MIP-04 / AOC009-14 Transition Zone - EHC

Analyte (COCs)	Sample ID' Results, ug/Kg			
	MIP-02-16-18	MIP-04-30	MIP-08-17	MIP-11-10
1,2-Dichloroethane	180	42	49	0.93
cis-1,2-Dichloroethene	1700	390	1800	9
Trichloroethene	7400	1700	5100	110
Vinyl chloride	480	76	180	2.9



Source Zone Characterization:
MIHPT Expert Rules

HIGH SORBED MASS TO DNAPL

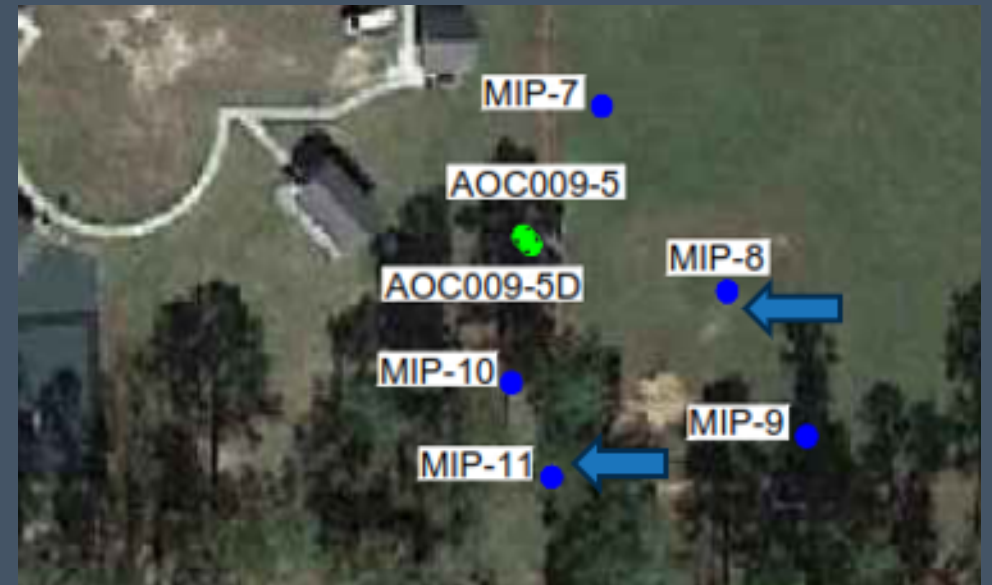
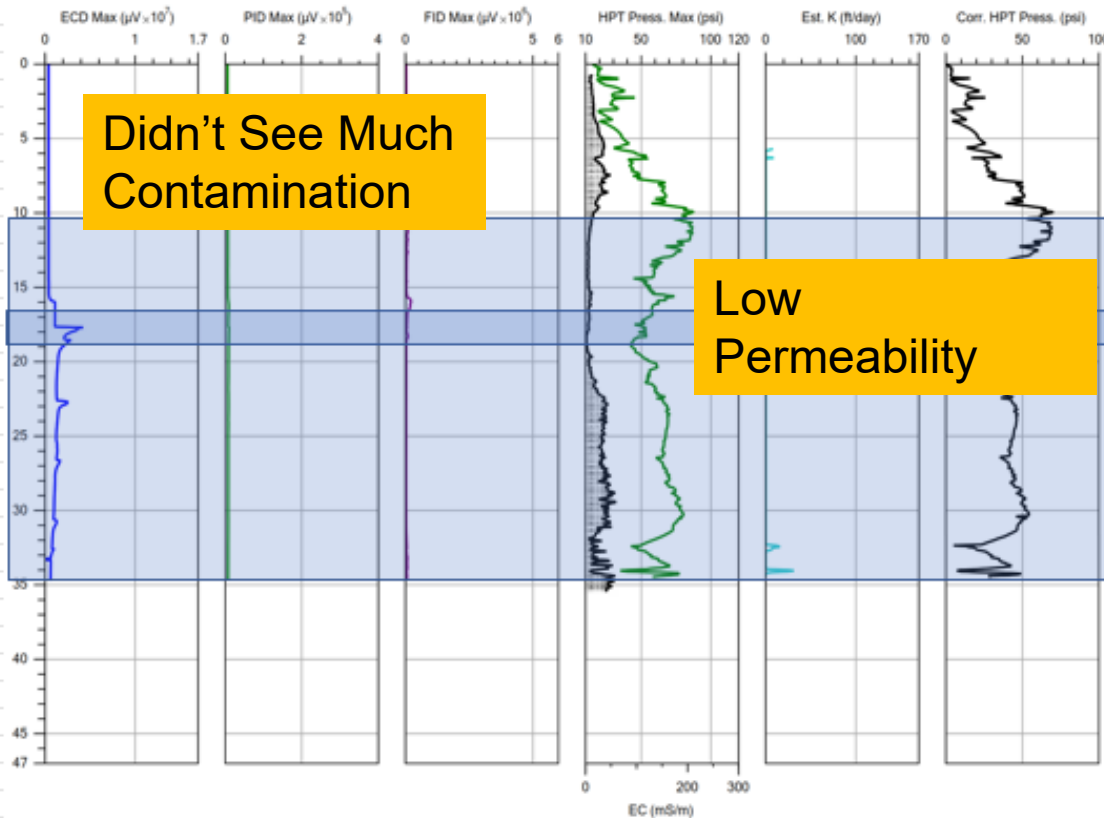
- XSD > $5 \times 10^{+5} \mu v$
- PID > $1 \times 10^{+6} \mu v$
- FID > $1 \times 10^{+6} \mu v$
- ECD > $1.4 \times 10^{+7} \mu v$

INJECTION Vs. Fracturing

- EC > 50 ms/m
- HPT Pressure > 50 to 75 PSI

MIP-08 / AOC009-5 Plume - ELS

Analyte (COCs)	Sample ID ¹ Results, ug/Kg			
	MIP-02-16-18	MIP-04-30	MIP-08-17	MIP-11-10
1,2-Dichloroethane	180	42	49	0.93
cis-1,2-Dichloroethene	1700	390	1800	9
Trichloroethene	7400	1700	5100	110
Vinyl chloride	480	76	180	2.9



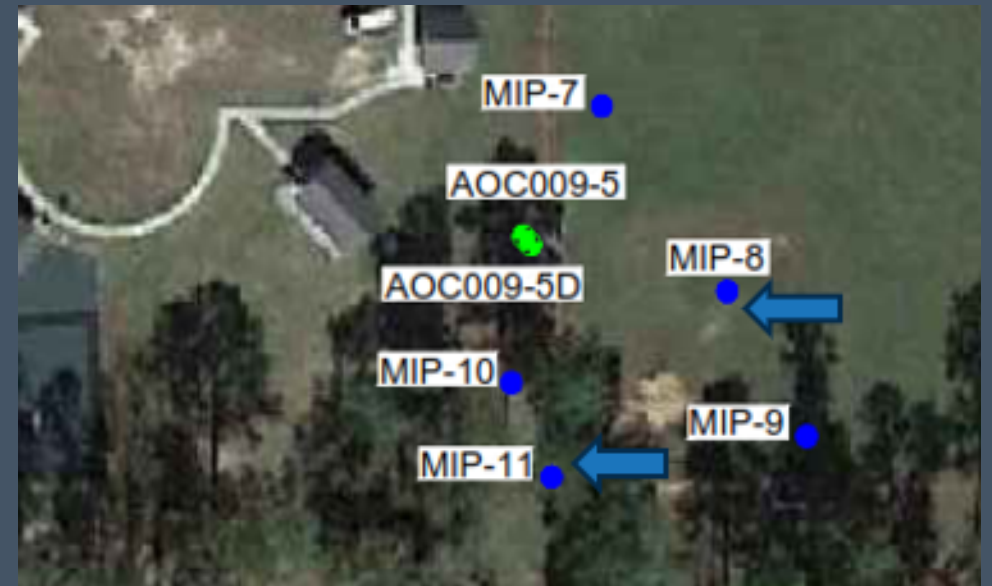
MIP-11

MP-11 / AOC009-5 Plume - ELS

Analyte (COCs)	Sample ID ¹ Results, ug/Kg			
	MIP-02-16-18	MIP-04-30	MIP-08-17	MIP-11-10
1,2-Dichloroethane	180	42	49	0.93
cis-1,2-Dichloroethene	1700	390	1800	9
Trichloroethene	7400	1700	5100	110
Vinyl chloride	480	76	180	2.9

Didn't See Much
Contamination

Low Permeability



PDI Shallow Well TCE Isopleth



New GW Well AOC009-19

New GW Well AOC009-20

ISCR Area 2: EHC Injections for ISCR.
42 injections at 8 ft centers (from 15 ft to 35 ft bgs) in the elevated concentration plume area surrounding the residual source area (60 ft by 60 ft = 3,600 SF - 900 SF = 2,700 SF).

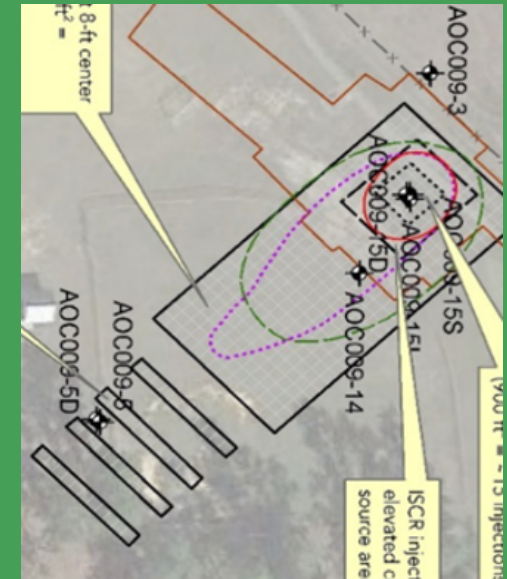
ISCR Area 1: EHC Injections for ISCR.
Prior to excavation and offsite disposal of soils within the saturated zone residual source area (from 5 ft to 15 ft bgs), 15 injections at 8 ft centers (from 15 ft to 35 ft bgs) below the saturated zone residual source area (30 ft by 30 ft = 900 SF). Replace Well Cluster 15 after excavation and backfill of saturated zone residual source area is complete.

EISB Area 3: ELS Injections for EISB.
178 injections at 8 ft centers over the remaining plume area from 10 to 35 feet bgs. (150 ft by 100 ft = 15,000 SF - 3,600 SF = 11,400 SF).

EISB Area 4: Additional thirteen (13) rows of ELS Injections for EISB.
11 injections per row at 8 ft centers per row for a total of 143 injections from 10 to 35 feet bgs.

Monitoring points labeled on map: AOC009-8, AOC009-2, AOC009-6, AOC009-1, AOC009-3, AOC009-15S, AOC009-15I, AOC009-14, AOC009-5, AOC009-5D, AOC009-18D, AOC009-18I, AOC009-9, AOC009-10, AOC009-12, AOC009-16S, BG-4, MIP-1, MIP-2, MIP-3, MIP-4, MIP-5, MIP-6, MIP-7, MIP-8, MIP-9, MIP-10, MIP-11, SA1, SA2, SA3, SA4.

Roads: Perimeter Rd, Rosedale Rd.



Full-Scale Injection

Amendment Dosing

Source Excavation: 3,200 lbs EHC

Source Injection: 5,400 lbs EHC

Transition Injection: 24,500 lbs EHC

Plume Injection: 37,600 lbs Emulsified Lecithin Substrate (ELS) 100%
Concentrate

All: Buffering with Magnesium Hydroxide and DHC Bioaugmentation



Source Below Excavation EHC Demand

Application type: Source Zone Treatment

	<u>Value</u>	<u>Unit</u>
Minimum EHC application rate to meet H2 demand	0.01	% by soil mass
Minimum recommended dosing for application type*	0.272	% by soil mass
Recommended EHC application rate	0.27	% by soil mass



Injection Logs - EHC

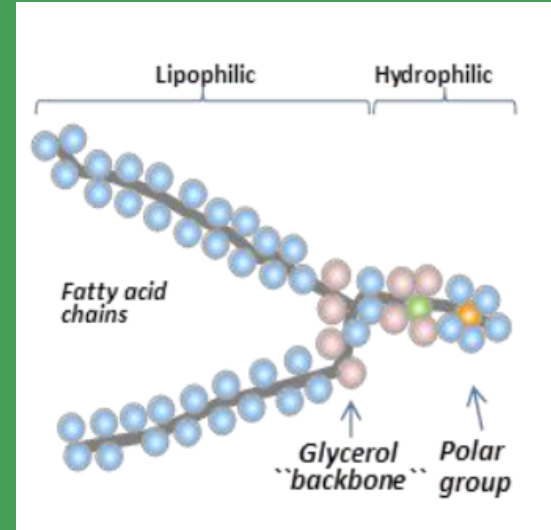
PROJECT NUMBER/NAME: DELMONICO BROOKLEY AFB MOBILE/206211033

Injection Point ID	Start Date	Start Time	End Time	Injection Interval (Feet bgs)	Initial Pressure (PSI)	Sustained Pressure (PSI)	Average Flow Rate (GPM)	EHC® ISCR Solution			EHC® ISCR Solution Injected (Gallons)	DHC/Bugs SDC-9 Injected (Liters)	Total Injected (Gallons)	Day Lighting (X)
								EHC® Carbon/ZVI (Pounds)	Mg(OH)2 Buffer (Pounds)	Anaerobic Mix Water (Gallons)				
A1-11	7/28/2022	1:58 PM	2:00 PM	33 - 35	90	60	9.5	40	6.0	15.9	19	0.05	19	
	7/28/2022	2:01 PM	2:03 PM	31 - 33	90	80	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	2:04 PM	2:06 PM	29 - 31	70	50	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	2:07 PM	2:09 PM	27 - 29	90	70	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	2:10 PM	2:12 PM	25 - 27	90	70	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	3:00 PM	3:02 PM	23 - 25	90	70	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	3:04 PM	3:06 PM	21 - 23	90	70	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	3:08 PM	3:10 PM	19 - 21	90	70	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	3:12 PM	3:14 PM	17 - 19	80	60	9.5	40	6.0	16	19	0.05	19	
	7/28/2022	3:15 PM	3:17 PM	15 - 17	80	60	9.5	40	6.0	16	19	0.05	19	
TOTALS								397	60.0	159	190	0.5	190	

Area 1 Plume ELS Demand

Application type: Plume Treatment

	<u>Value</u>	<u>Unit</u>
Specific H2 capacity of ELS (100% concentrate)	349.2	g H2/Kg
Concentration ELS in GW to meet H2 demand	29.4	mg/L
Recommended minimum conc. lecithin in pore water*	3,180	mg/L
Recommended conc. of ELS in pore water	3,180	mg/L



Post Injection Results – 1st and 2nd Quarter

RAOs, ug/L		5			70			5			2		
CAS		107-06-2			156-59-2			79-01-6			75-01-4		
Analyte (COCs)		1,2-Dichloroethane			cis-1,2-Dichloroethene			Trichloroethene			Vinyl Chloride		
Sampling Event		Baseline	1st Qtr 2023	2nd Qtr 2023	Baseline	1st Qtr 2023	2nd Qtr 2023	Baseline	1st Qtr 2023	2nd Qtr 2023	Baseline	1st Qtr 2023	2nd Qtr 2023
Sample ID ¹ Result, ug/L	1	0.9	NS	NS	1.3	NS	NS	ND	NS	NS	ND	NS	NS
	2	6.1	0.58 J	3.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
	3	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	3DUP	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	5D	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	5	ND	ND	ND	410	10	5.7	2.2	2	ND	410	41	51
	9	ND	ND	ND	73	95	130	7.4	7.7	6.7	ND	ND	ND
	11	ND	NS	ND	ND	NS	ND	ND	NS	ND	ND	NS	ND
	12	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	14	1.3	ND	ND	310	8.4	170	78	0.26 J	ND	310	27	130
	15S	NS	5	5.0 U	NS	3900	500	NS	98	16 J	NS	2000	1200
	15I	ND	5	ND	0.43	1900	3800	ND	4	ND	2	140	1800
	15D	ND	5	5.0 U	ND	34000	12000	ND	4	4.0 U	2.8	650	2300
	16	NS	ND	ND	NS	0.42	ND	NS	ND	ND	NS	ND	ND
	18I	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	18I-DUP	ND	NS	NS	0.32	NS	NS	ND	NS	NS	ND	NS	NS
	18D	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS
	19S	ND	ND	ND	10	3.5	2.9	4.5	4.2	2.8	ND	ND	ND
	19I	ND	ND	ND	4.4	ND	ND	1.7	ND	ND	ND	ND	ND
	20S	25	ND	ND	2400	1000	1500	140	100	58	40	ND	ND
	20I	ND	ND	ND	2800	2200	3100	260	320	160	15	ND	ND
	21S	ND	ND	ND	7	ND	0.3	0.54	ND	ND	1.3	ND	ND
	21I	ND	ND	ND	0.66	ND	0.45	ND	ND	ND	ND	ND	ND
	21I-DUP	ND	NS	NS	0.63	NS	NS	0.2	NS	NS	ND	NS	NS
	22S	2.5	ND	ND	240	57	360	4.4	1.2	8.3	15	1.8 J	29
	22I	ND	ND	ND	280	19	47	11	3.2	3.5	27	0.61 J	1.0 J
	PVT	ND	ND	ND	210	360	250	67	75	53	ND	2.0 U	2.0 U

15S– TCE ug/l	15S– DCE ug/l	15S – VC ug/l
Baseline - NS	Baseline - NS	Baseline - NS
98	3,900	2,000
16J	500	1,200

20I – TCE ug/l	20I – DCE ug/l	20I – VC ug/l
Baseline - 260	Baseline – 2,800	Baseline – 40
320	2,200	ND
160	3,100	ND

1st Quarter

- Remained the same at 14 of 17 wells
- 3 wells had increases
- Source Well 15, but physical disturbance during excavation and potentially mobilizing DNAPL
- Conversion TCE to DCE and VC.
- ISCR conditions slowly getting established and should last for years.

2nd Quarter

- The same at 14 of 17 wells
- Source Well 15 – TCE ND, DCE increased, VC transient.
- Conversion TCE to DCE and VC.
- ISCR conditions slowly

Post Injection Results 1st and 2nd Quarter

<u>Well</u> <u>15S&I</u>	Iron mg/l	pH	Sulfate mg/l	TOC mg/l	Ethane ug/l	Ethene ug/l	Methane ug/l	ORP
Baseline	NS / 72	NS / 6.4	NS / 0.8	NS / 6.9	NS / 69	NS / 910	NS / 21000	NS / 37
1 st Quarter	200 / 820	6.1 / 6.3	4 / 4	290 / 690	1300 / 1	4900 / 390	6300 / 20000	36 / -56
2 nd Quarter	600 / 160	6 / 6.3	1.3 / 0.97	930 / 180	440 / 47	1900 / 980	10,000 / 17,000	37 / 66

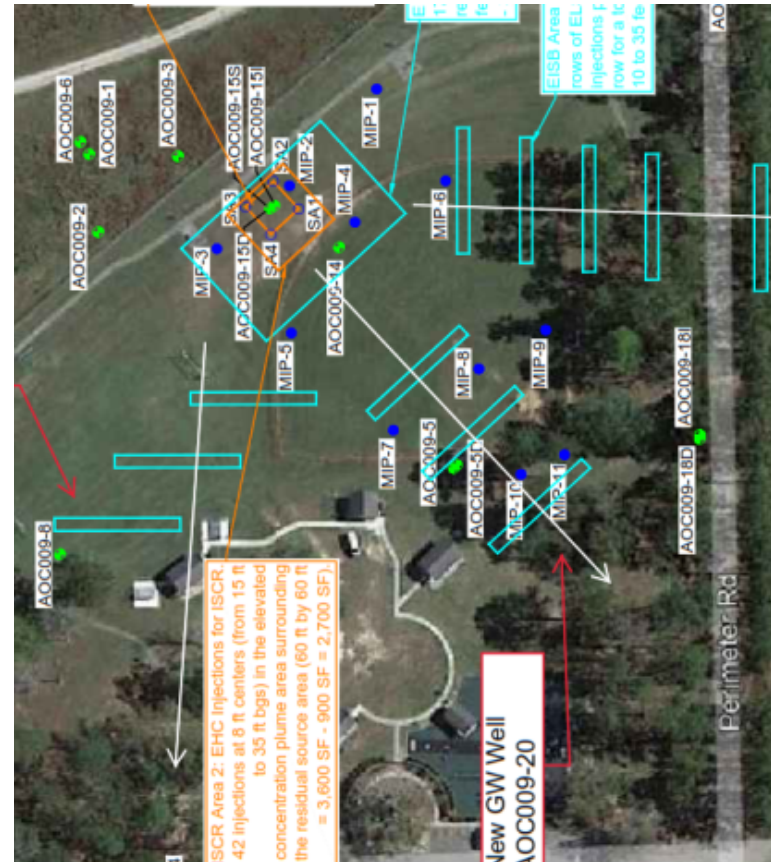
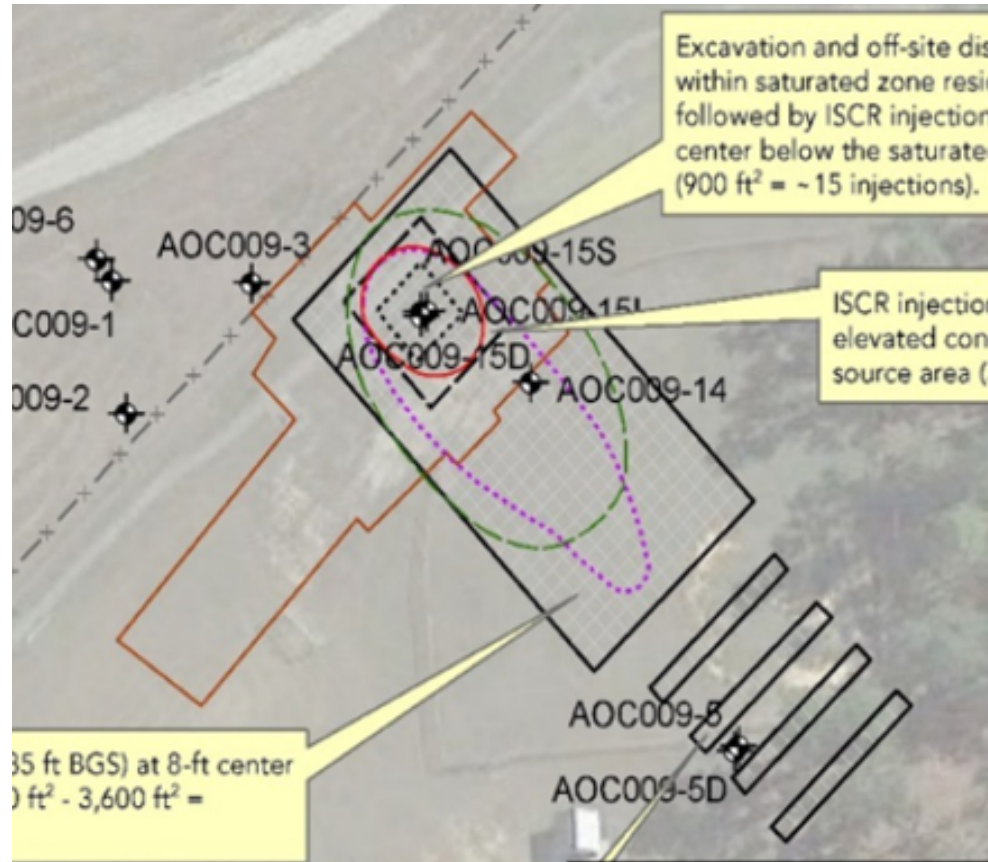
1st Quarter

- Well 15 – TOC, ethane, ethene, and methane
- Generation of reduction by products effective distribution of ISCR and EISB in treatment zone

2nd Quarter

- Remediation still in state of trans
- High TOC, sulfate, iron and ethane, ethene, and methane in Well 15 are all favorable.

Key Take Away



- HRDO provides better understanding of contaminant distribution versus the original Feasibility Report.
- Which provided for new target areas in the plume to meet ARARs.



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