

Rapid Assessment and Remediation of a Refined Product Release to Soil and Groundwater (Port Arthur, Texas)

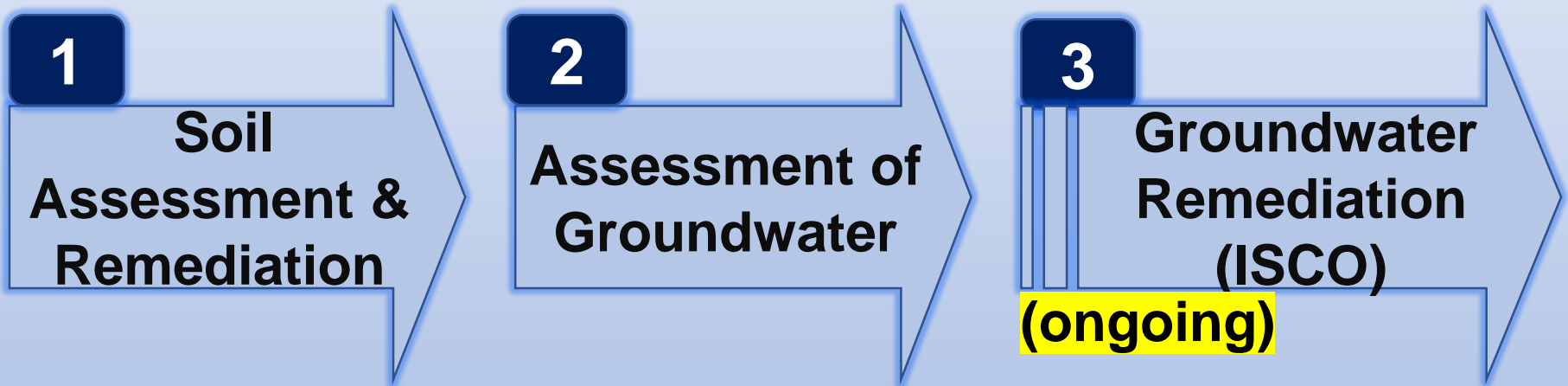


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Houston, Texas



Presentation Outline

- Measures taken to remediate soil and groundwater at a site following a pipeline release.



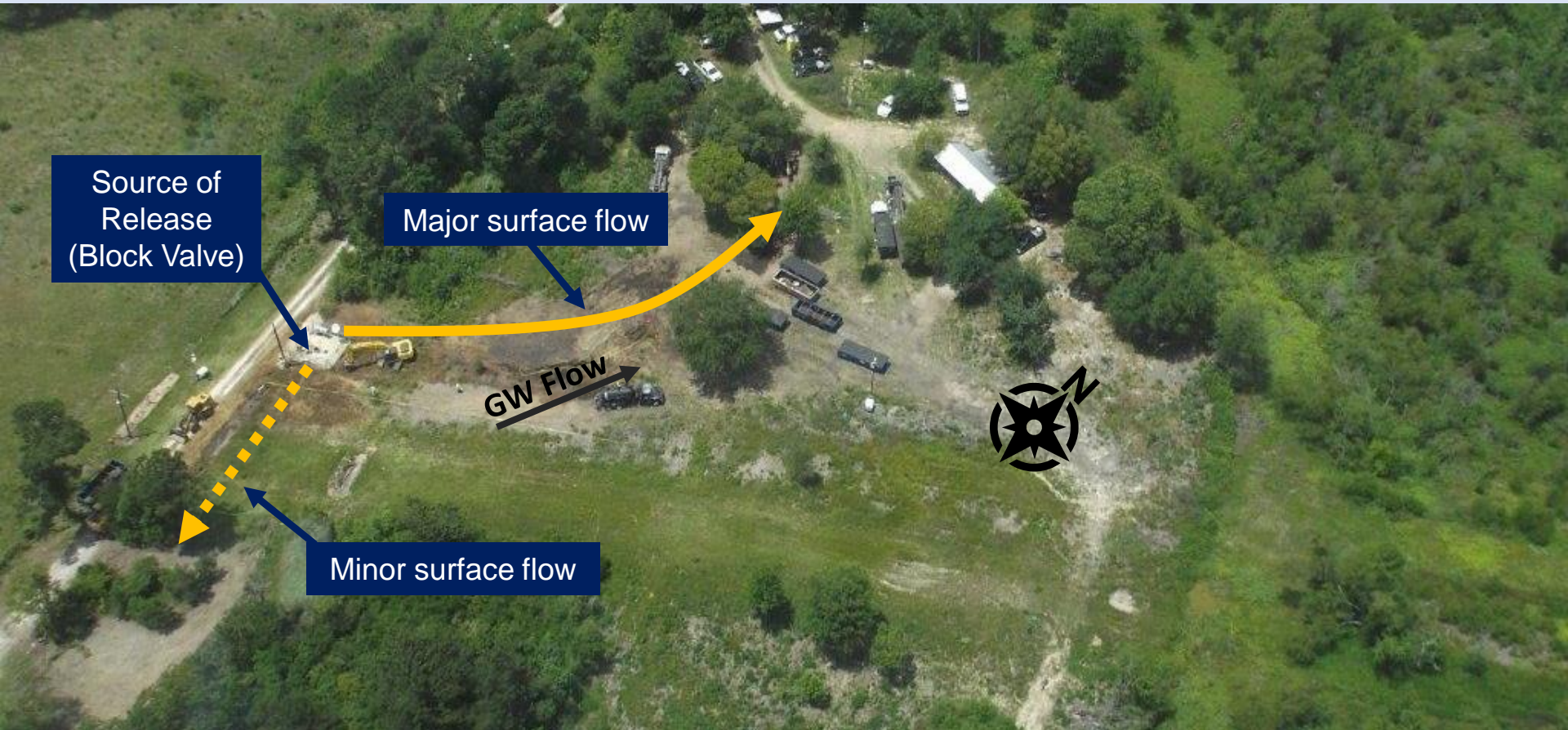
The Release Incident

- ❑ Gasoline and diesel-range hydrocarbons release discovered.
- ❑ Spill response/spill contained.
- ❑ Source identified as the block valve.
- ❑ Cleanup and assessment activities initiated.

Contaminants of Concern (COCs):
TPH, BTEX



Driver for risk assessment/evaluation:
Benzene



Soil Assessment & Remediation

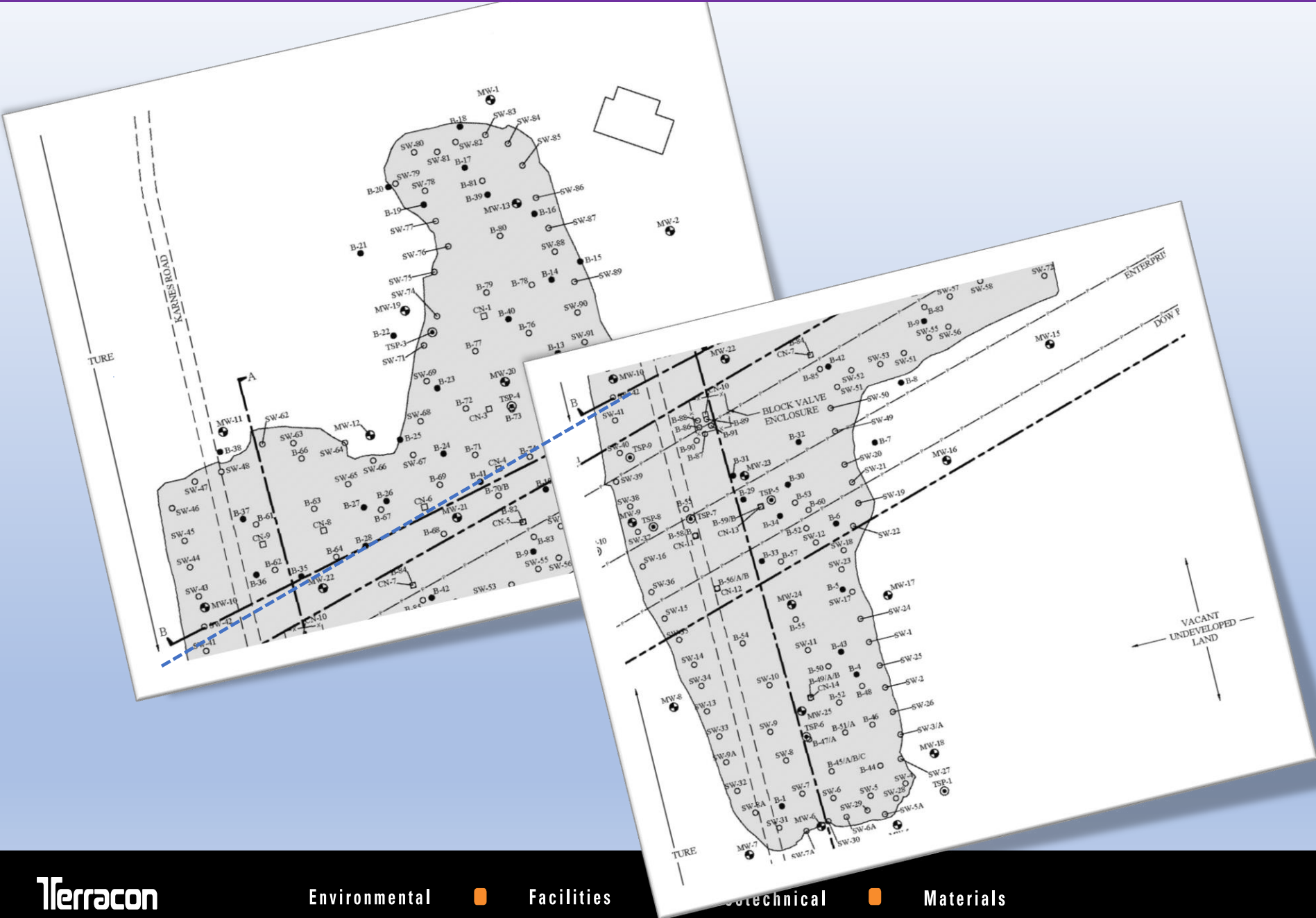
- **53 DPT borings (8-10 ft) for preliminary evaluation of lateral and vertical extent of impacted soil. Groundwater at ~12 feet bgs.**
- **PID used for screening soil cores. No analytical testing.**
- **Helped establish areas and depths of soil requiring excavation.**



- ❑ **Excavation & confirmation samples collected to ensure adequate mass removal:**
 - ▶ **102 excavation sidewall samples.**
 - ▶ **61 excavation base samples.**
 - ▶ **regulatory samples ultimately submitted to make the case for soil closure.**



Soil Assessment & Remediation



Soil Assessment & Remediation

Before Excavation/Confirmation Sampling



Soil Assessment & Remediation

After Mass Removal and Disposal of 34K Tons of Impacted Soil



SOURCE FOR GROUDWATER IMPACT LARGELY REMOVED

Soil Assessment & Remediation



- ❑ Residual concentrations remained at the base: TPH-G up to 1,400 ppm, Benzene up to 1.8 ppm.
- ❑ Further excavation limited, to maintain pipeline integrity.

Soil Assessment & Remediation-Soil Treatment

- ❑ **Base of the excavation treated with RegenOx[®] & ORC Advanced[®].**
- ❑ **Excavation backfilled with select fill and compacted.**
- ❑ **Treated areas re-sampled after application to evaluate effectiveness.**



Chemical Oxidation



Soil Assessment & Remediation

Pre-Treatment

	C ₆₋₁₂	C ₁₂₋₂₈	B	T	E	X
B-56B	420	700	0.031 J	3.5	2.6	37
B-58B	1400	1200	0.49	28	15	94
B-59B	680	620	0.33	16	11	64
B-61	20 J	<19	0.7	16	8.3	45
B-62	83	81	0.39	6.9	3.5	19
B-63	<18	<18	0.062	2.2	0.71	11
B-64	330	260	0.49	21	12	61
B-67	180	71	<0.32	7	4	22
B-68	140	220	<0.34	3.7 J	1.8	12
B-69	23 J	82	0.34 J	4.5	1.9	12
B-70B	250	360	<0.0017	0.036	0.12	1
B-71	26 J	91	0.17	2.2	0.82	4.3
B-72	210	80	1.8	35	15	78
B-73	510	130	0.33	10	6.6	35
B-74	130	220	0.015 J	0.7	0.95	6.3
B-75	470	110	0.74	22	12	61
B-77	<18	<18	0.063	1.4	1.5	7.9
B-79	140	46 J	1.1	27	12	67
B-82	34 J	130	0.016	0.68	0.66	3.8
B-84	40 J	200	<0.0068	0.13	0.15	0.66
B-85	46 J	180	0.022	0.28	0.17	1
B-86	110	290	0.018	0.71	0.64	7.5
B-89	640	930	0.032 J	0.66	0.43	22
B-90	27 J	80	0.052	0.48	0.038	2.4
B-91	<15	<15	0.18	1.9	0.68	4.2

Post-Treatment

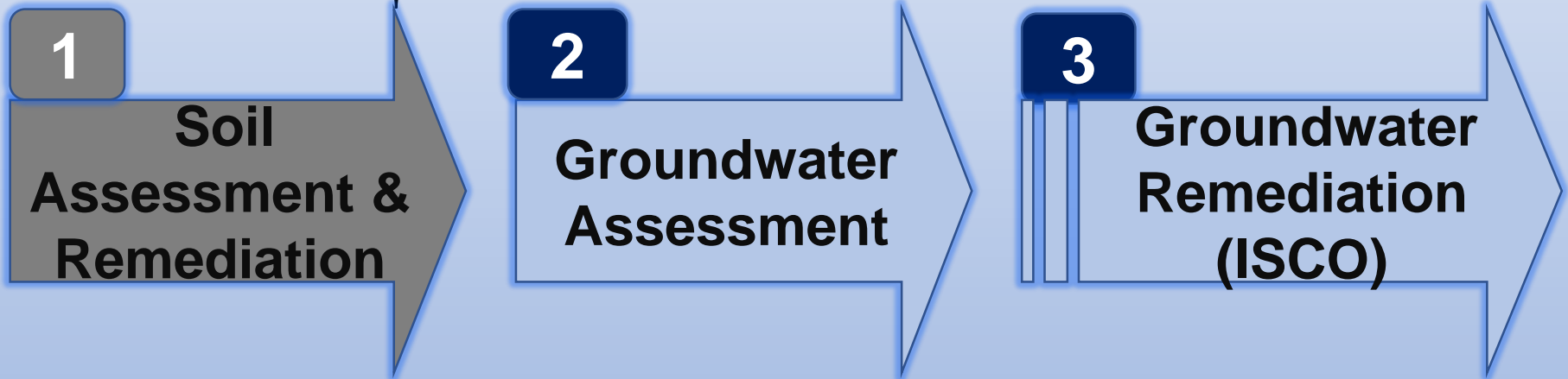
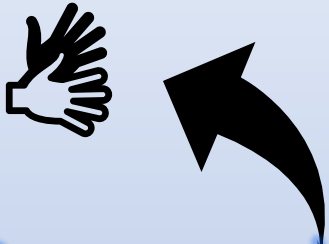
	C ₆₋₁₂	C ₁₂₋₂₈	B	T	E	X
B-77,B-79	<20	<20	<0.0019	<0.0030	<0.0020	<0.0048
B-75	<20	<20	<0.0018	<0.0029	<0.0020	<0.0046
B-72,B-73	<20	<20	<0.0018	<0.0029	<0.0020	<0.0046
B-70B,B-71,B-74	<19	<19	<0.0018	<0.0028	<0.0019	<0.0044
B-82	<18	<18	<0.0017	<0.0027	<0.0018	<0.0043
B-67,B-68,B-69	<18	<18	<0.0017	<0.0027	<0.0018	<0.0043
B-84,B-85	<21	<21	<0.0020	<0.0031	<0.0021	<0.0050
B-63,B-64	<20	<20	<0.0019	<0.0030	<0.0020	<0.0047
B-61,B-62	<19	<19	<0.0017	<0.0027	<0.0019	<0.0043
B-86,B-89,B-90,B-91	<23	<23	<0.0021	<0.0034	<0.0023	<0.0053
B-56B	<21	<21	<0.0019	<0.0030	<0.0021	<0.0048
B-58B	<21	<21	<0.0020	<0.0031	<0.0021	<0.0049
B-58B	<68	<68	<0.0068	<0.034	<0.0068	<0.020

Response Action Completion Report (RACR) for Soil Submitted to Texas Commission on Environmental Quality (TCEQ)



Regulatory Milestone

**TCEQ concurs
soil remediation
is completed**



Based on the TCEQ review of the RACR, Texas Risk Reduction Program (TRRP) Remedy Standard A Residential (PCLs) for soil has been achieved such that no institutional control or post-response action care is required. **No further action is required for soil** under 30 Texas

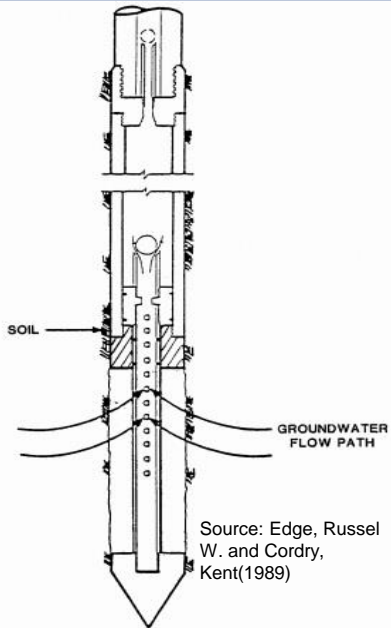


Rapid Assessment of Aerial Extent of GW Impact

TOOLS

Hydropunch™

- Stainless steel screen retracts at discrete depths
- FAST!



Mobile GC Lab



- Stationed in Field (Van)
- Total TPH (Detection Limit 0.10 mg/L)
- BTEX (Detection Limit: 2ppb)
- ~40 mins per sample

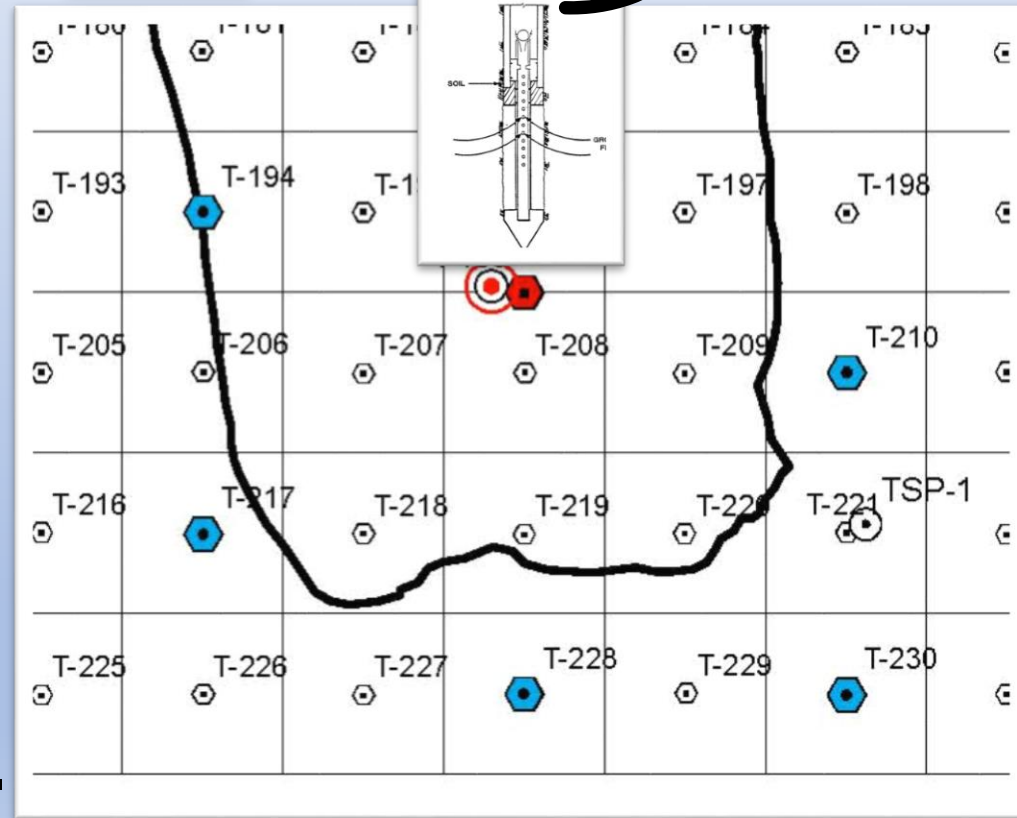
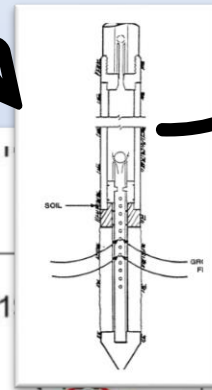
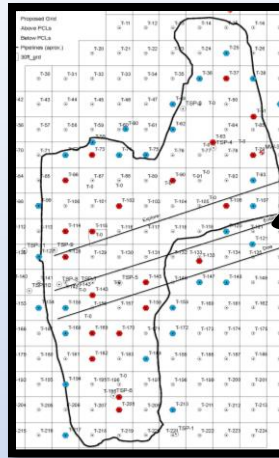
GPS



- Sub-meter accuracy
- Integrated with a GIS Map



Rapid Assessment of Aerial Extent of GW Impact



- ❑ 25-foot grid loaded in the Trimble unit.
- ❑ Labelled grids helped direct fieldwork from office/share progress with client.
- ❑ 58 Hydropunch™ borings in three days.



Rapid Assessment of Aerial Extent of GW Impact

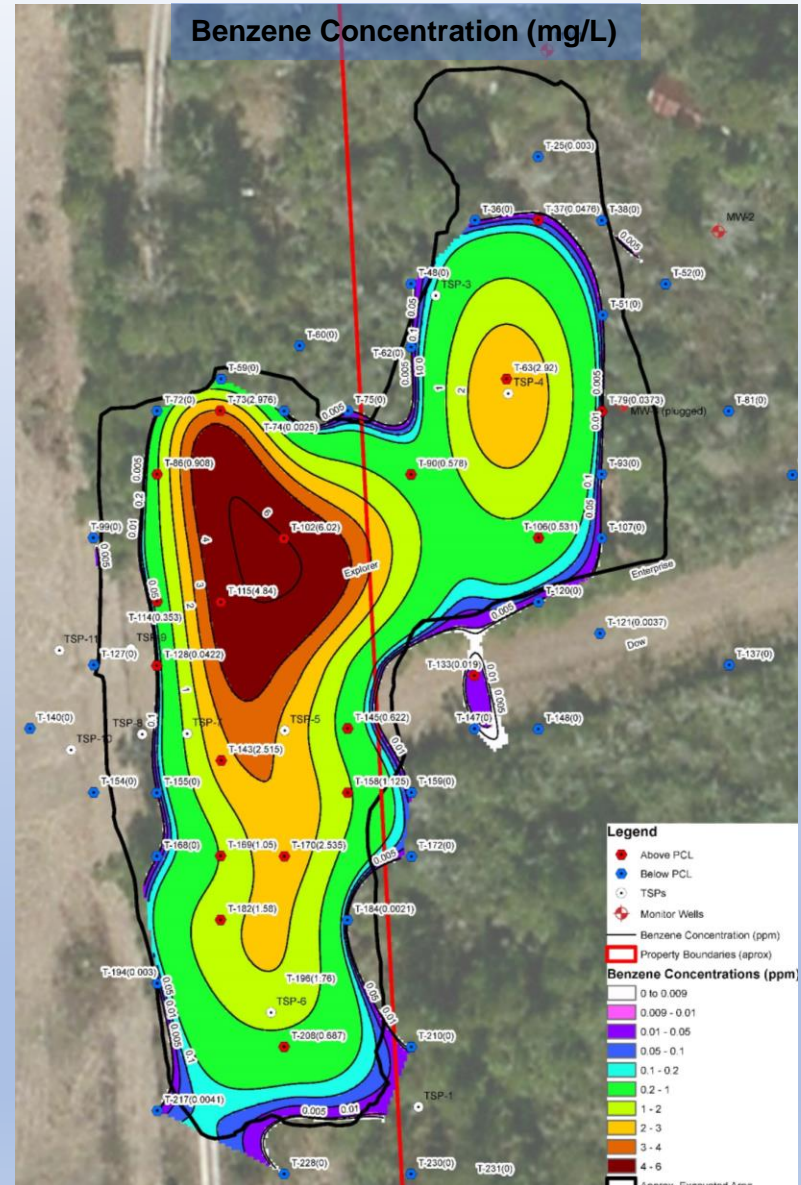
□ 58 groundwater data points for TPH/BTEX

Sample ID	Sample Date	B	T	E	X	Total TPH	Exceed PCL
		0.005	1	0.7	10	0.98	
T-25	11/6/2014	0.003	0.0174	0.0046	0.0068	0.02	No
T-36	11/5/2014	-	-	-	-	-	No
T-37	11/4/2014	0.0476	0.286	0.0334	0.13	0.59	Yes
T-38	11/6/2014	-	-	-	-	-	No
T-48	11/5/2014	-	-	-	-	-	No
T-51s	11/6/2014	-	-	-	-	-	No
T-52	11/4/2014	-	-	-	-	-	No
T-59S	11/5/2014	-	-	-	-	-	No
T-60E	11/5/2014	-	-	-	-	-	No
T-62	11/5/2014	-	-	-	-	-	No
T-63se	11/6/2014	2.92	8.39	0.555	2.11	15.4	Yes
T-72	11/5/2014	-	-	-	-	-	No
T-73	11/5/2014	2.979	4.74	1.2	3.25	14.6	Yes
T-74	11/6/2014	0.0025	0.0196	0.0066	0.0184	0.01	No
T-75	11/4/2014	-	-	-	-	-	No
T-79	11/6/2014	0.0373	0.249	0.075	0.255	0.74	Yes
T-81	11/4/2014	-	-	-	-	-	No
T-86	11/6/2014	0.908	1.73	0.28	0.699	0.91	Yes
T-90	11/6/2014	0.578	2.9	0.206	0.714	4.8	Yes
T-93	11/6/2014	-	-	-	-	-	No
T-96	11/4/2014	-	-	-	-	-	No
T-99	11/6/2014	-	-	-	-	-	No
T-102	11/5/2014	6.02	8.94	0.616	1.82	22.1	Yes
T-106	11/6/2014	0.531	2.69	0.485	1.77	6	Yes
T-107	11/6/2014	-	-	-	-	-	No
T-114	11/6/2014	0.353	0.0316	0.0385	0.0257	0.02	Yes
T-115	11/6/2014	4.84	8.37	4.83	1.7	23.7	Yes
T-120	11/6/2014	-	-	-	-	-	No
121S	11/5/2014	0.0037	0.0071	0.0038	0.0065	0.03	No
127	11/5/2014	-	-	-	-	-	No
T-128s	11/6/2014	0.0422	0.186	0.135	0.293	0.82	Yes
133-S	11/5/2014	0.019	0.148	0.0352	0.112	0.38	Yes
T-137	11/4/2014	-	-	-	-	-	No
140	11/5/2014	-	-	-	-	-	No
143-S	11/5/2014	2.515	6.035	1.375	4.155	17	Yes
T-145	11/5/2014	0.622	2.145	0.348	1.148	5.1	Yes
T-147	11/6/2014	-	-	-	-	-	No
T-148	11/6/2014	-	-	-	-	-	No



Rapid Assessment of Aerial Extent of GW Impact

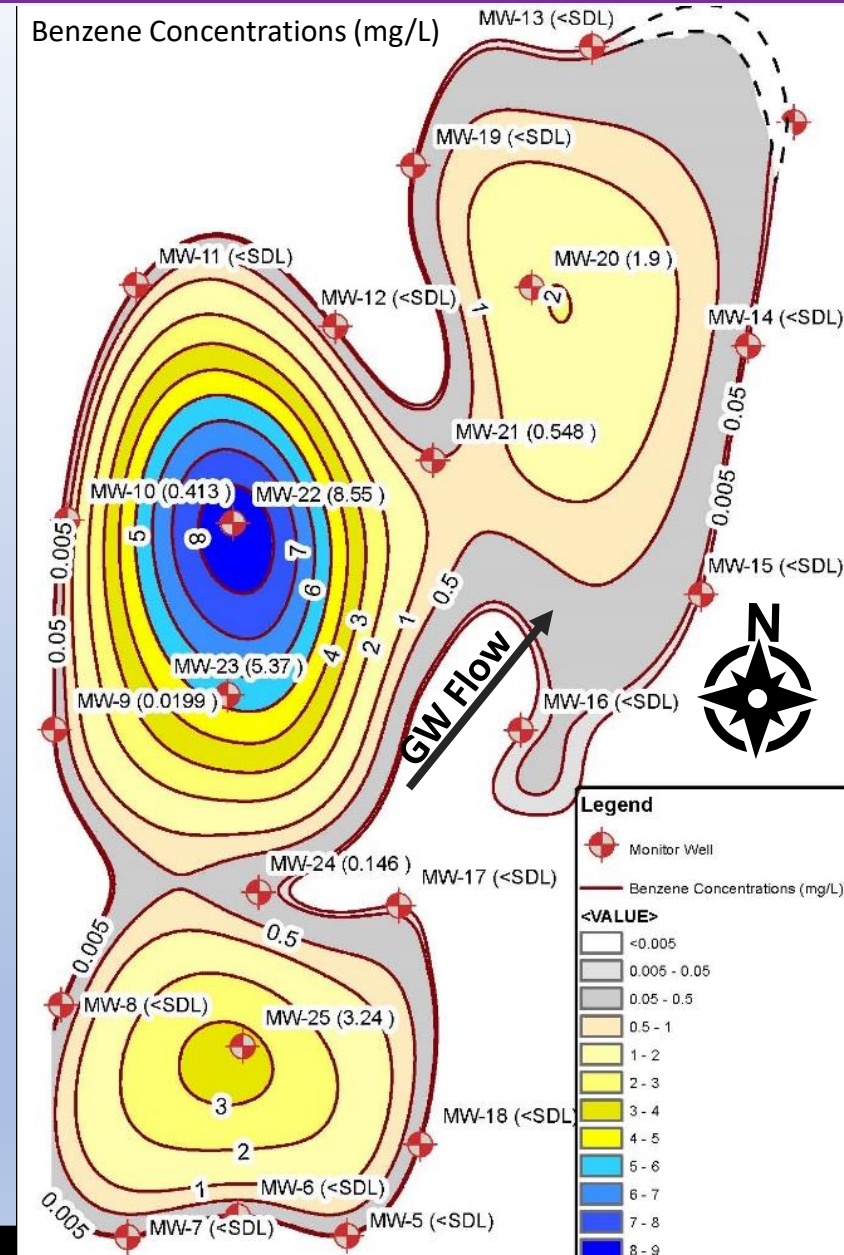
- ❑ Determined the rough extent of affected groundwater using the 58 Hydropunch™ borings.
- ❑ Completed in three days!



Rapid Assessment of Aerial Extent of GW Impact

- Installed 25 monitoring wells to complete groundwater investigation in accordance with the Texas Risk Reduction Program (TRRP.)

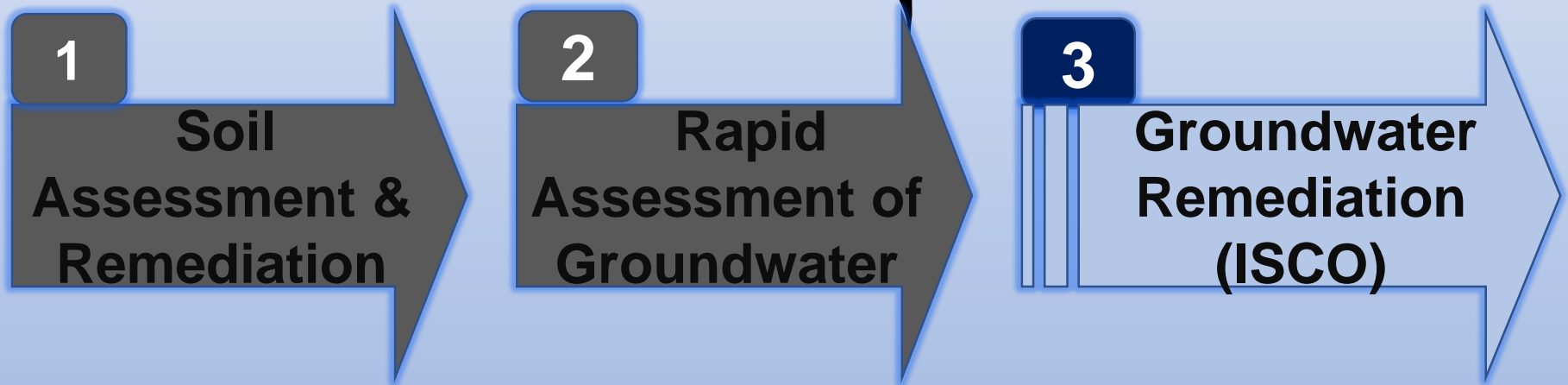
- Affected Property Assessment Report (APAR) submitted to the TCEQ.



Regulatory Milestone



**TCEQ concurrence
on completion of
groundwater
assessment**



Based on our review of the APAR for the [REDACTED] Road site, the TCEQ concurs that investigation has been completed in accordance with 30 Texas Administrative C



- ❑ **TPH-G up to 52 mg/L. Benzene up to 8.5 mg/L in source area.**
- ❑ **Groundwater flow towards the northeast: off-site impact concerns. Monitoring events indicted plume was stable but not decreasing.**
- ❑ **Based on high concentrations in groundwater, In-Situ Chemical Oxidation (ISCO) was the preferred remedy option.**



Groundwater Remediation: Choice of Oxidant

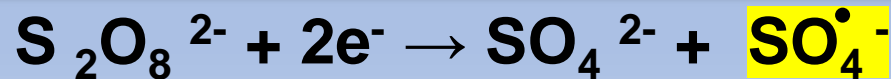


- ❑ Sodium Persulfate ($\text{Na}_2\text{S}_2\text{O}_8$)
- ❑ High solubility (73%) → can be delivered to subsurface at high concentrations.
- ❑ Denser than H_2O → amenable to gravity-driven delivery.
- ❑ Persists for weeks.
- ❑ Strong oxidizer when activated
 ✓ Choice of Activator: NaOH

Formula	Standard Reduction Potential (V)
OH^\cdot	+2.8
$\text{SO}_4^{\cdot-}$	+2.6
O_3	+2.1
$\text{S}_2\text{O}_8^{2-}$	+2.1
H_2O_2	+1.77
MnO_4^-	+1.7
HO_2^\cdot	+1.7
O_2	+1.23
HO_2^-	-0.88
$\text{O}_2^{\cdot-}$	-2.4

From Suthersan (2017)

Radical Oxidation (with activator)-Fast



Sulfate Radical

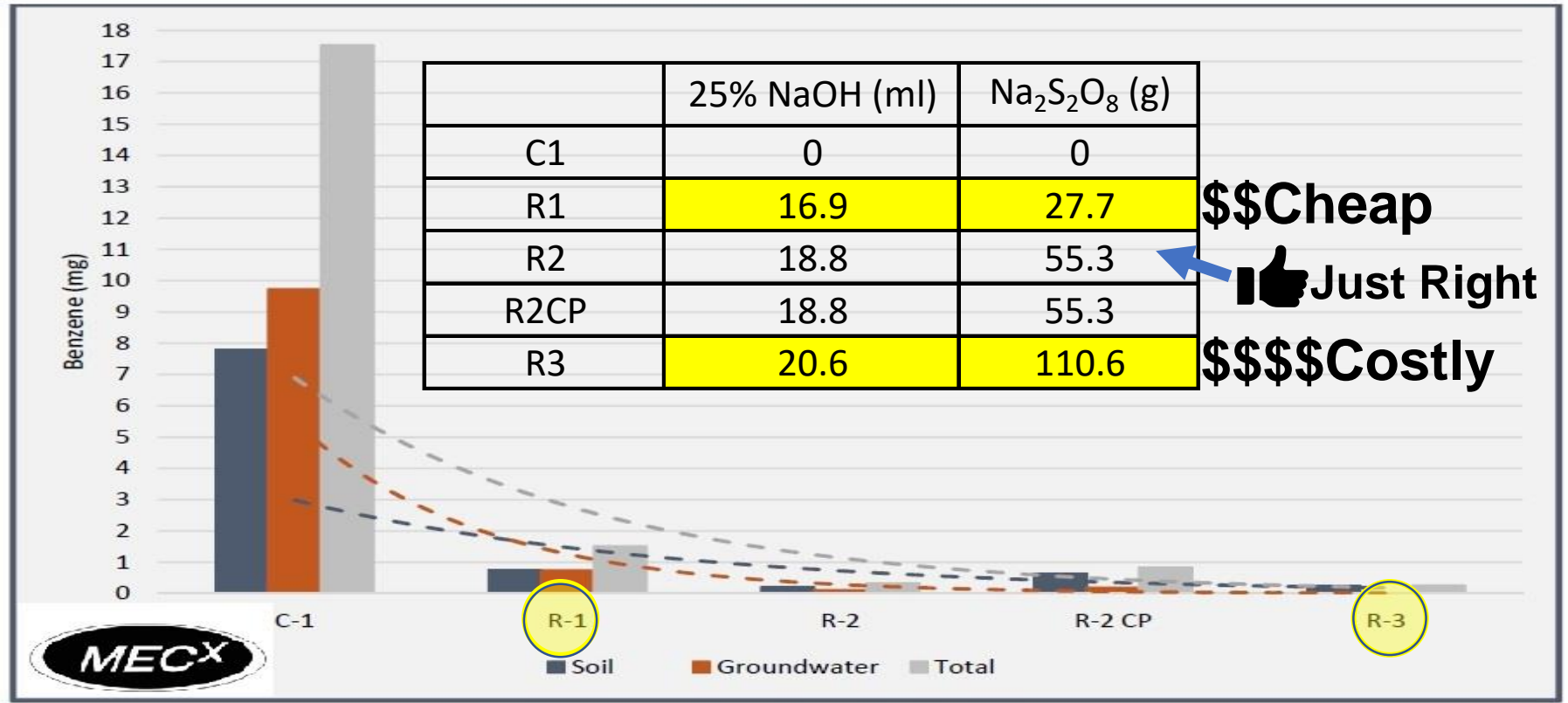
Groundwater Remediation: Bench-Scale Test

- ❑ **Why bench-scale prior to field-scale?**
 1. ***Basic feasibility of the oxidant (does it work?)***
 2. ***Oxidant scavenging (how much is lost to non-target demands of organic matter, soil matrix etc.)-helps with dosing.***
 3. ***Optimal mix of oxidant/activator that is cost effective.***
- ❑ **Saturated soil and groundwater submitted to MEC^x lab in Houston.**
- ❑ **Test run for ~21 days by MEC^x.**



Groundwater Remediation: Bench-Scale Test

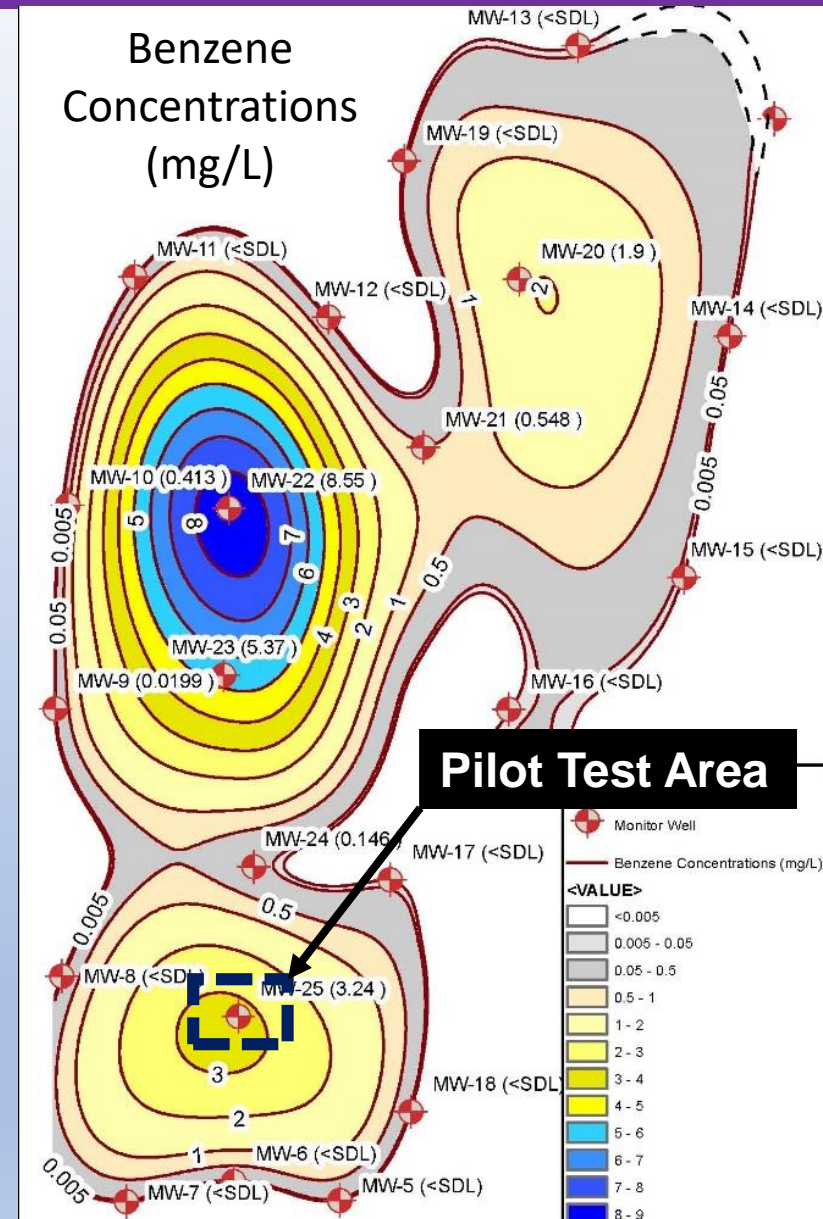
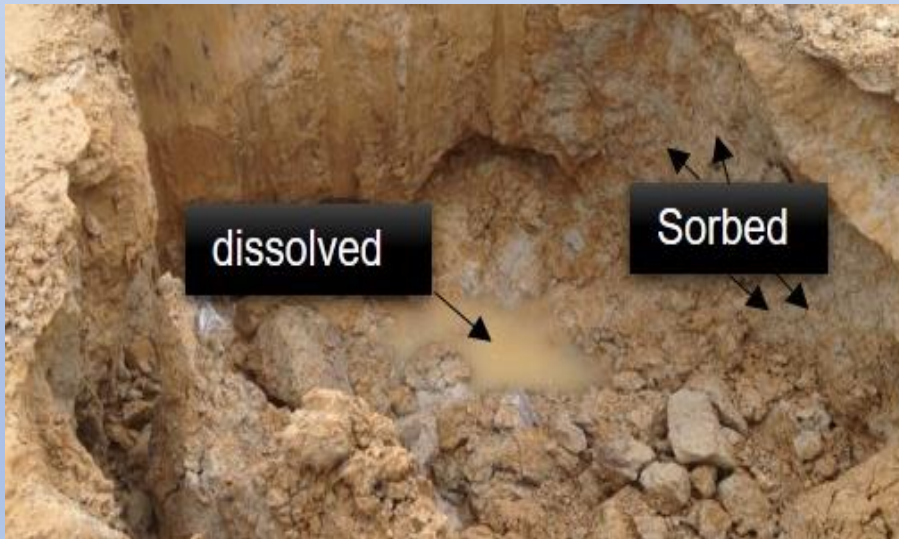
Graph 3 – DPE Benzene Destruction



- ❑ Formulation: (between R3 and R1).
- ❑ Dose: 75 gal NaOH, 530 pounds Na₂S₂O₈ per injection well. (~1-2 %)

Groundwater Remediation: Pilot Test

- Why field scale before full-scale?
 - Can reagents be delivered easily to the target formation?
 - What's the radius of influence (ROI)?
 - Helps design full-scale

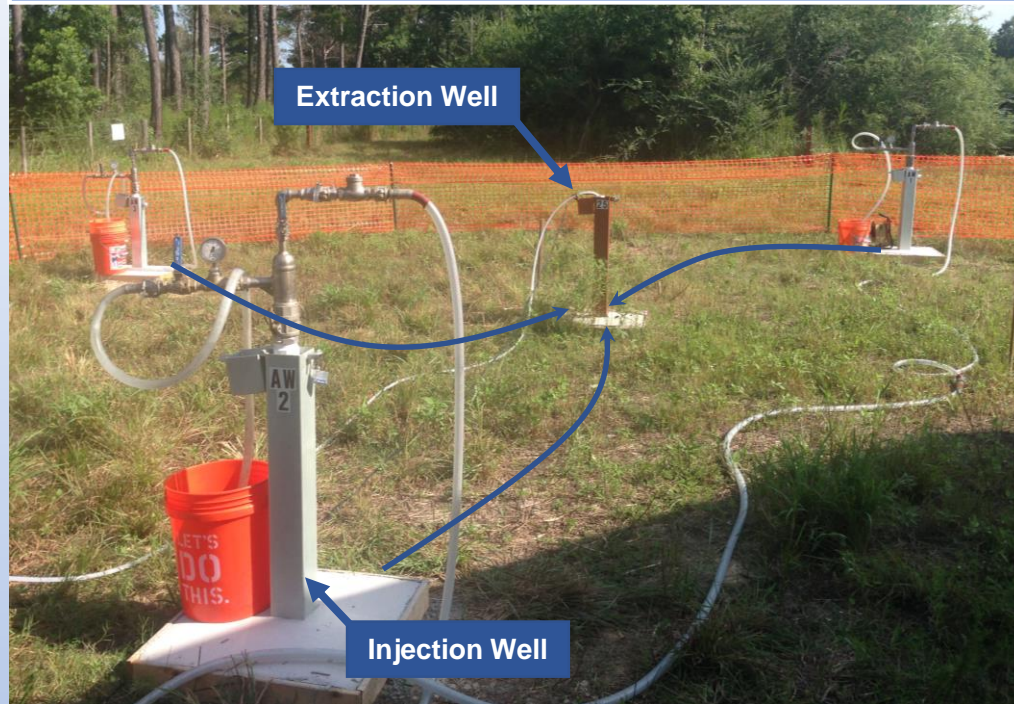


- **Results/Lessons from the Pilot Test:**
 1. **83% reduction in total contaminant mass (free+sorbed+dissolved phases) [based on pre- and post-pilot sample comparison of in-situ saturated soil and groundwater].**
 2. **Radius of Influence (ROI) 10 feet.**
 3. **Desired extraction rate (1 gpm) could not be achieved. Full-scale ISCO was planned accordingly, with arrangements for make-up water for injection.**



Groundwater Remediation: Pilot Test

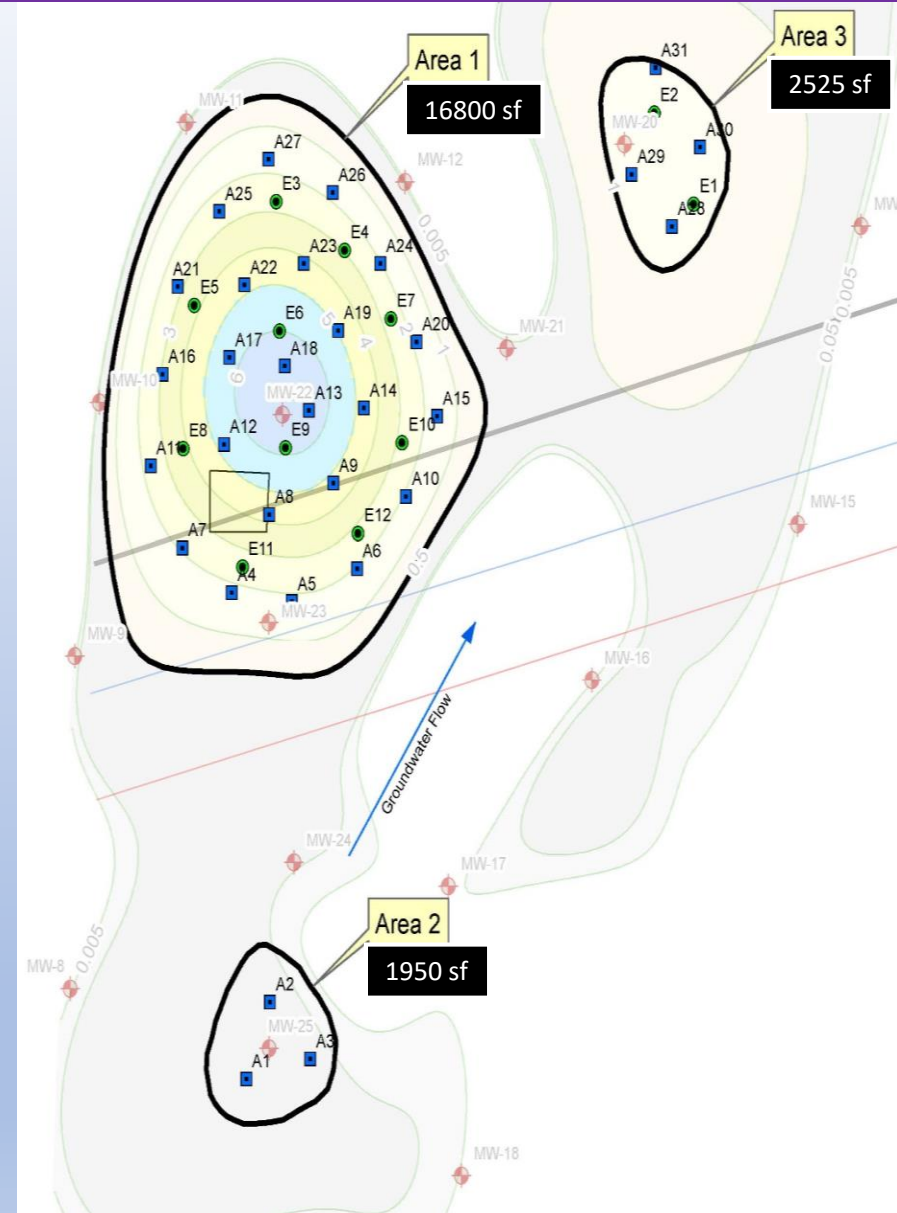
Pilot Test Setup (four well cluster)



- ❑ **Injection-Recirculation delivery system:**
 - ✓ **Maintains hydraulic control.**
 - ✓ **No mounding (reduced surfacing of reagents)**
 - ✓ **Better delivery/contact.**

Groundwater Remediation: Full Scale ISCO Design

- ❑ Three (3) Target Areas.
- ❑ Thirty-one (31) Injection Wells.
- ❑ Thirteen (13) Extraction Wells.
- ❑ No injection pressure applied. (injecting under compacted fill)



Groundwater Remediation: Full-Scale ISCO

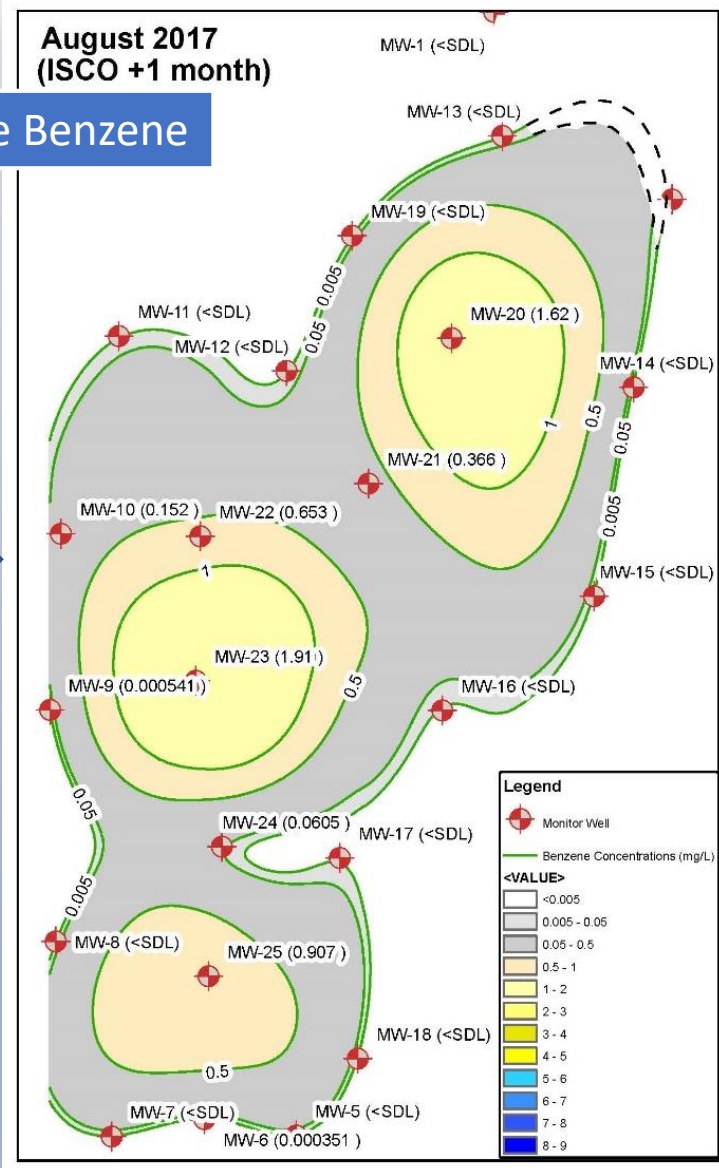
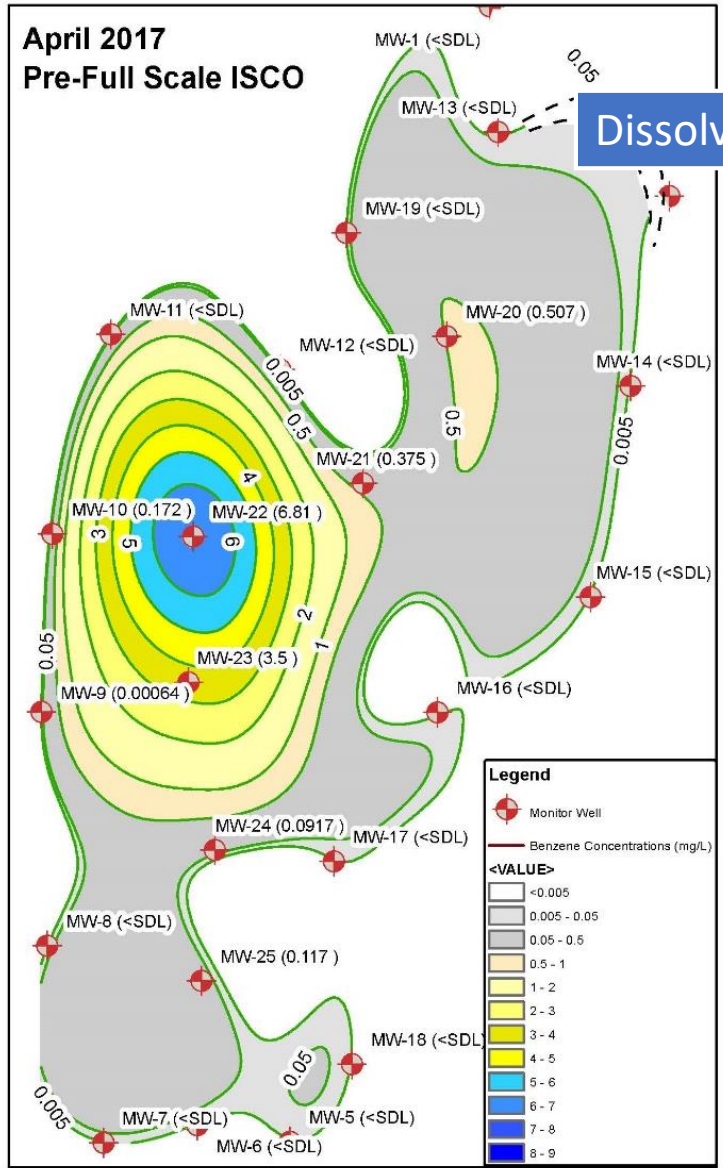


Groundwater Remediation: ISCO Full-Scale

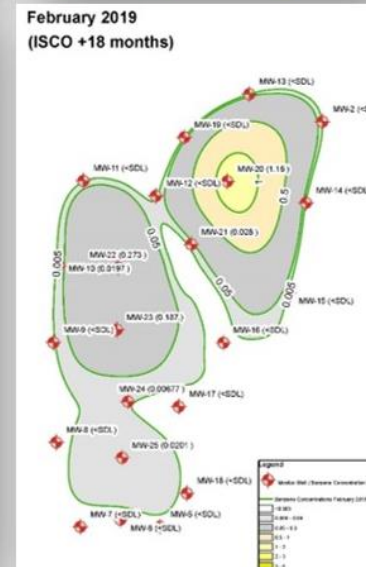
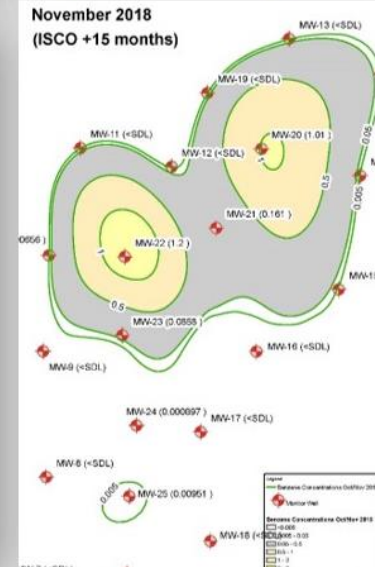
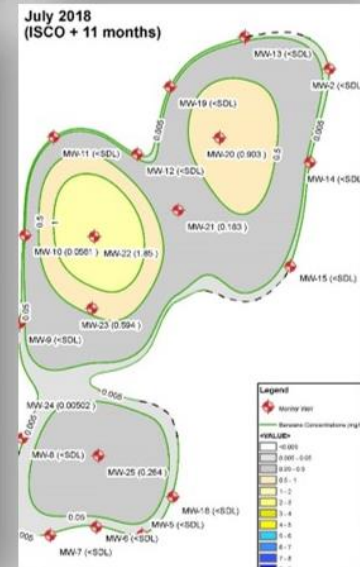
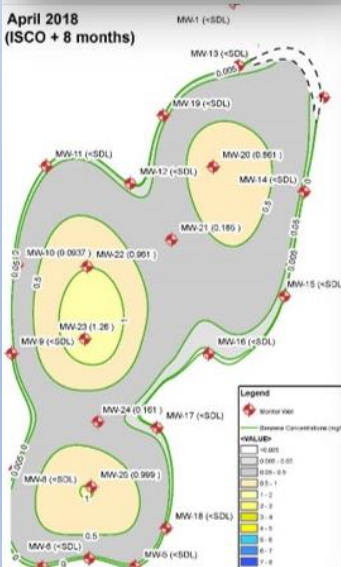
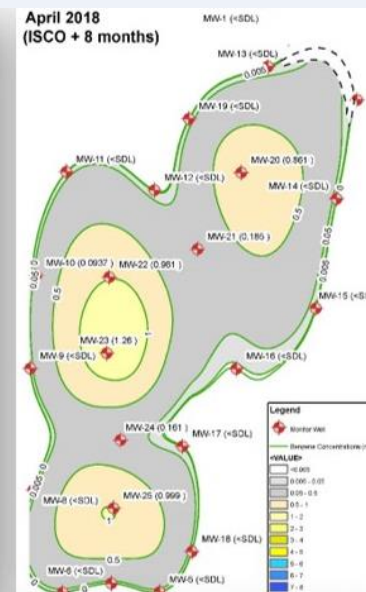
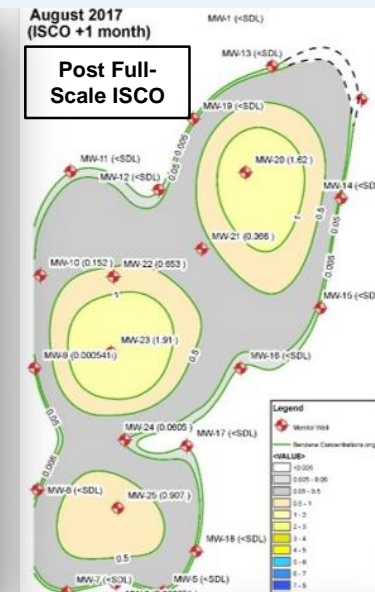
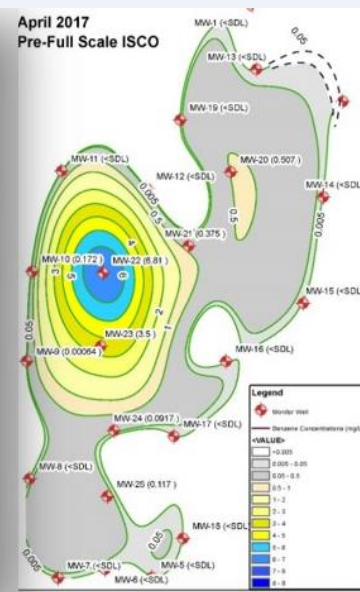
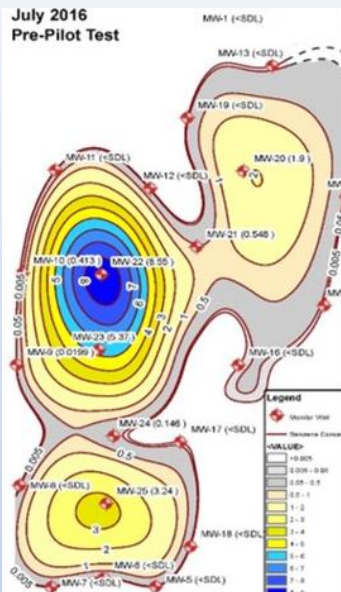
April 2017
Pre-Full Scale ISCO

August 2017
(ISCO +1 month)

Dissolved Phase Benzene



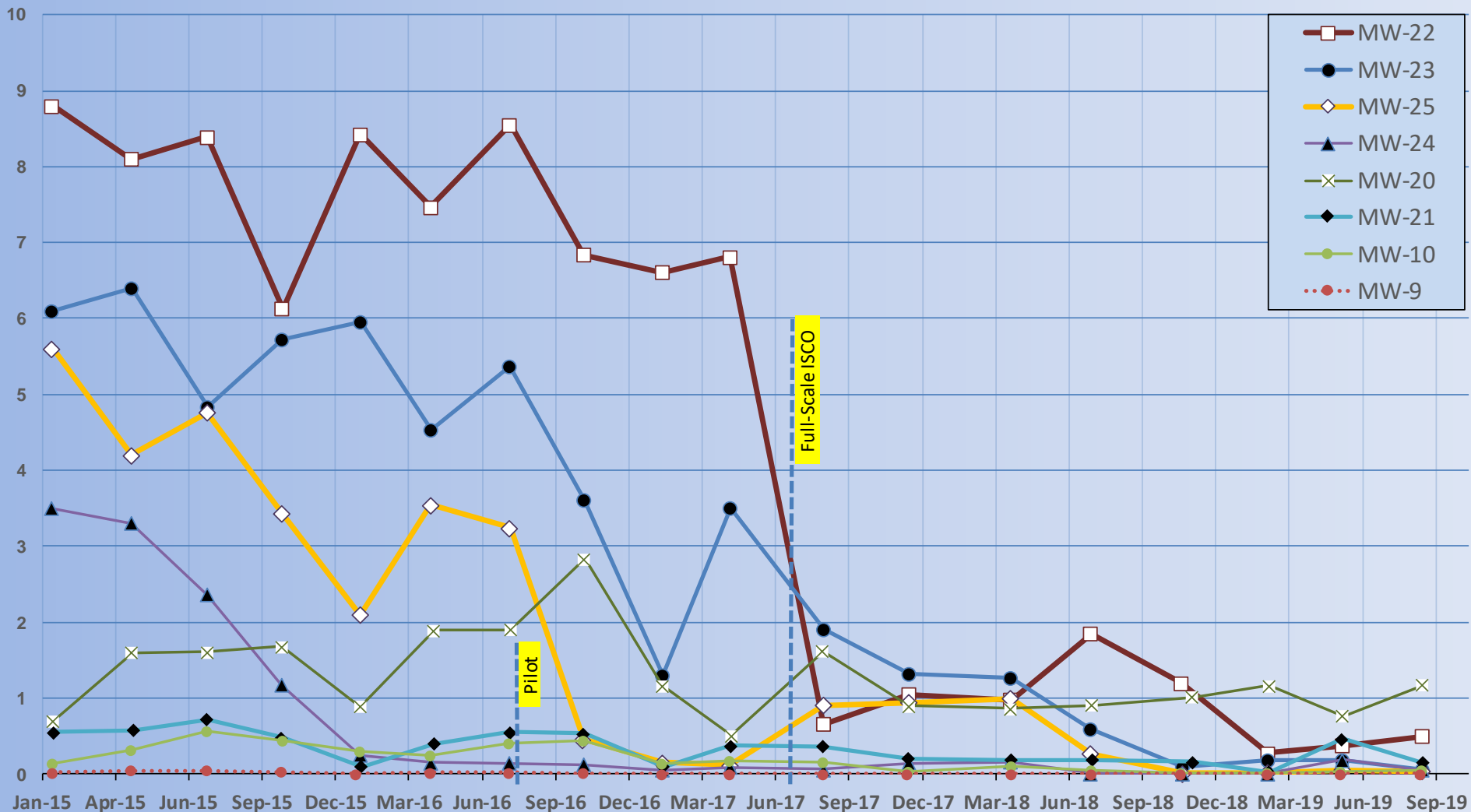
Groundwater Remediation: Full Scale ISCO



Dissolved Phase Benzene

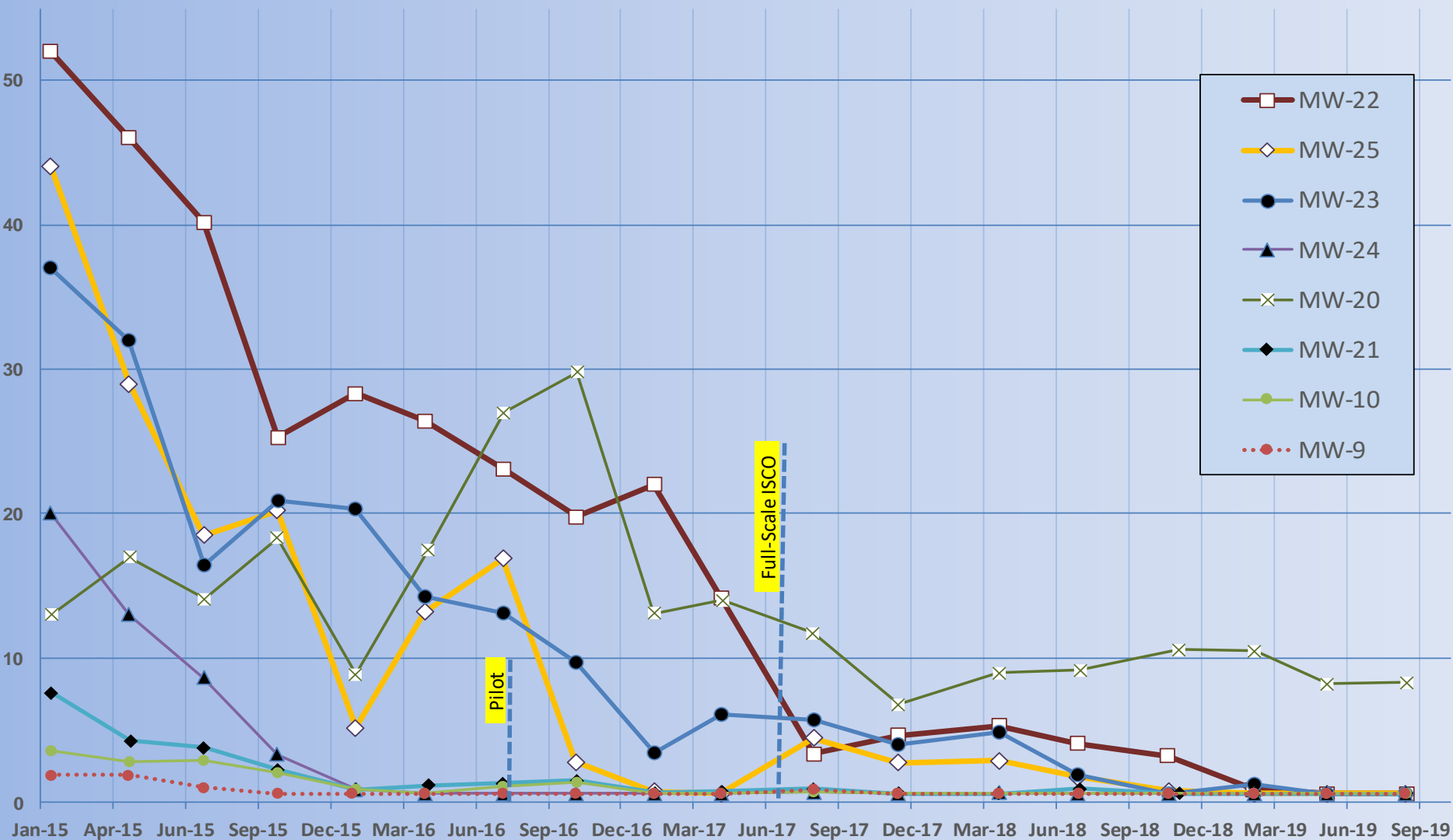
Groundwater Remediation: Full Scale ISCO

BENZENE CONCENTRATIONS IN CRITICAL WELLS (mg/L)



Groundwater Remediation: Full Scale ISCO

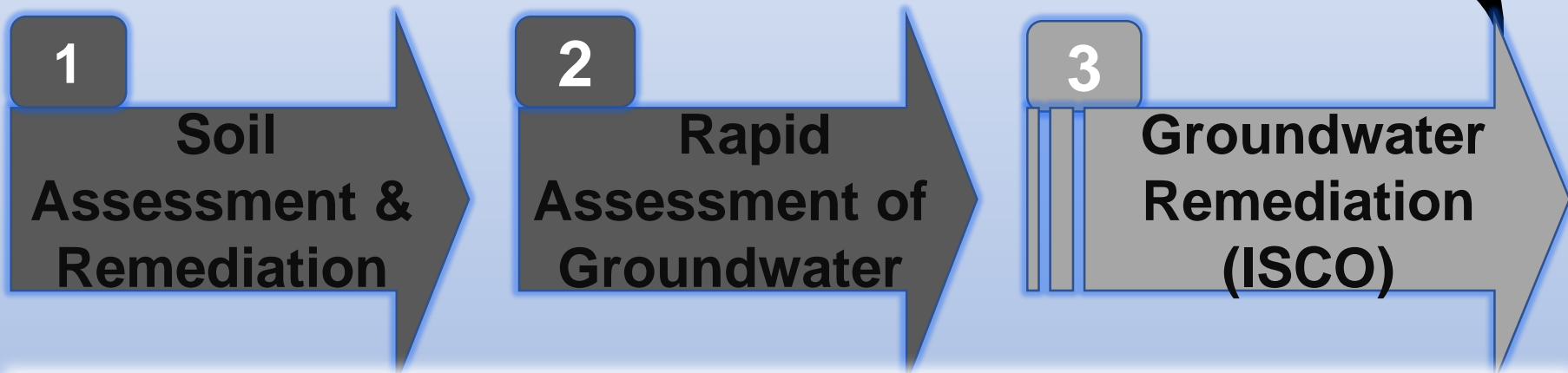
TPH (C₆-C₁₂) CONCENTRATIONS IN CRITICAL WELLS (mg/L)



Regulatory Milestone



TCEQ approval of
Response Action
Effectiveness Report
(RAER)



results from the response action documents that total petroleum hydrocarbons, benzene, toluene, ethylbenzene, and xylene concentrations in ground water have decreased significantly but remain above the critical PCLs. [redacted] proposes additional groundwater monitoring for three quarters to evaluate plume stability before implementing additional response actions. Based on our review, the TCEQ approves the RAER which fulfills the requirements of 30 Texas



Groundwater Remediation: Next Steps

- Natural attenuation via natural source zone depletion (NSZD) and/or enhanced biostimulation/bioaugmentation to address remaining concentrations.



View of the site

