



Site Cleanup Using In-Situ Activated Carbon Injection: A Case Study.

Lucy Flores, PMP, Environmental Specialist (SM).

David Sheehan, PE, Licensed Engineer (LP06 Engineer of Record).

Timothy Harman, PE, Licensed Engineer (Presenter).

OVERVIEW

Introduction.

- Site History.

Remediation Activities.

- History.
- Timeline.
- Sampling.

PetroFix Carbon Injections.

- Design.
- Implementation.
- Results.

Takeaways.

Closing Remarks.

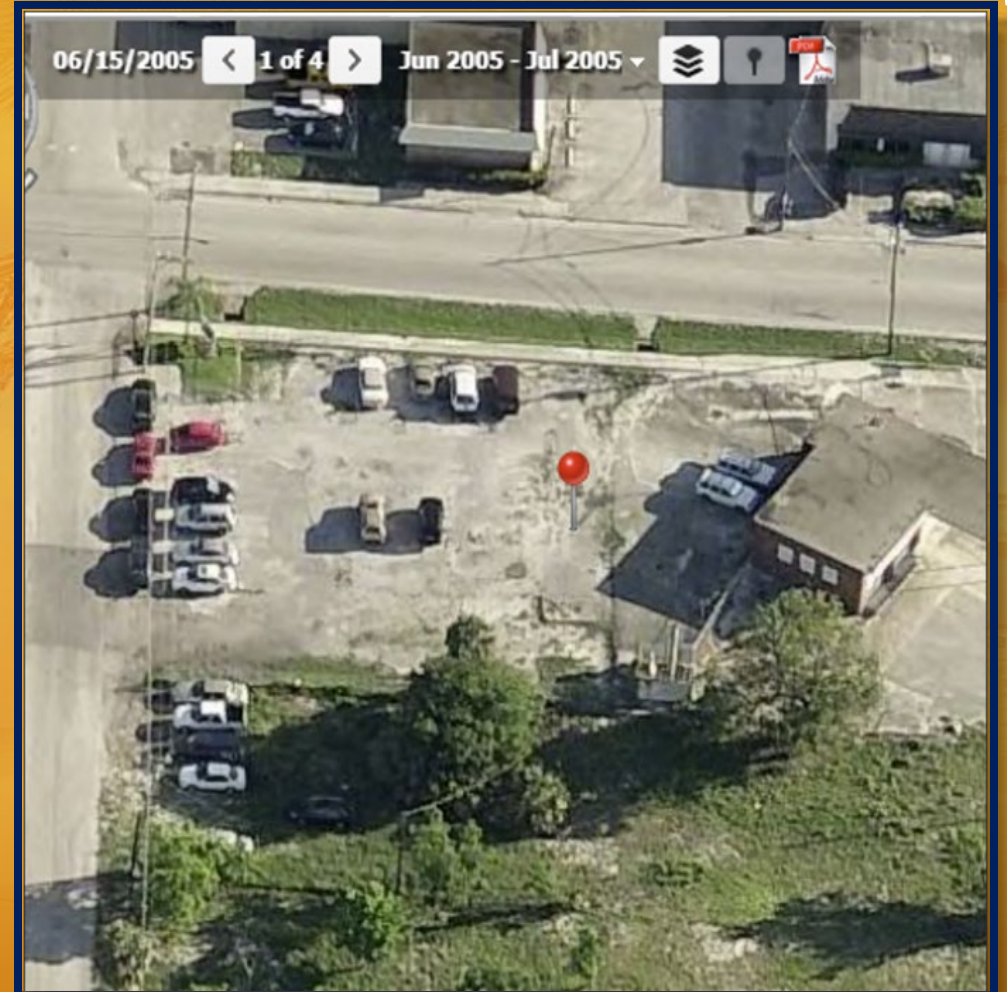


06 23 2020

SITE NAME: BP #24517
FAC ID: 069100407

- Former gas station.
- Three 6,000-gallon Underground Storage Tanks (USTs):
 - Super Unleaded;
 - Unleaded; and
 - regular grade gasolines.
- One 550-gallon waste oil tank.
- USTs reportedly removed in April 1986.

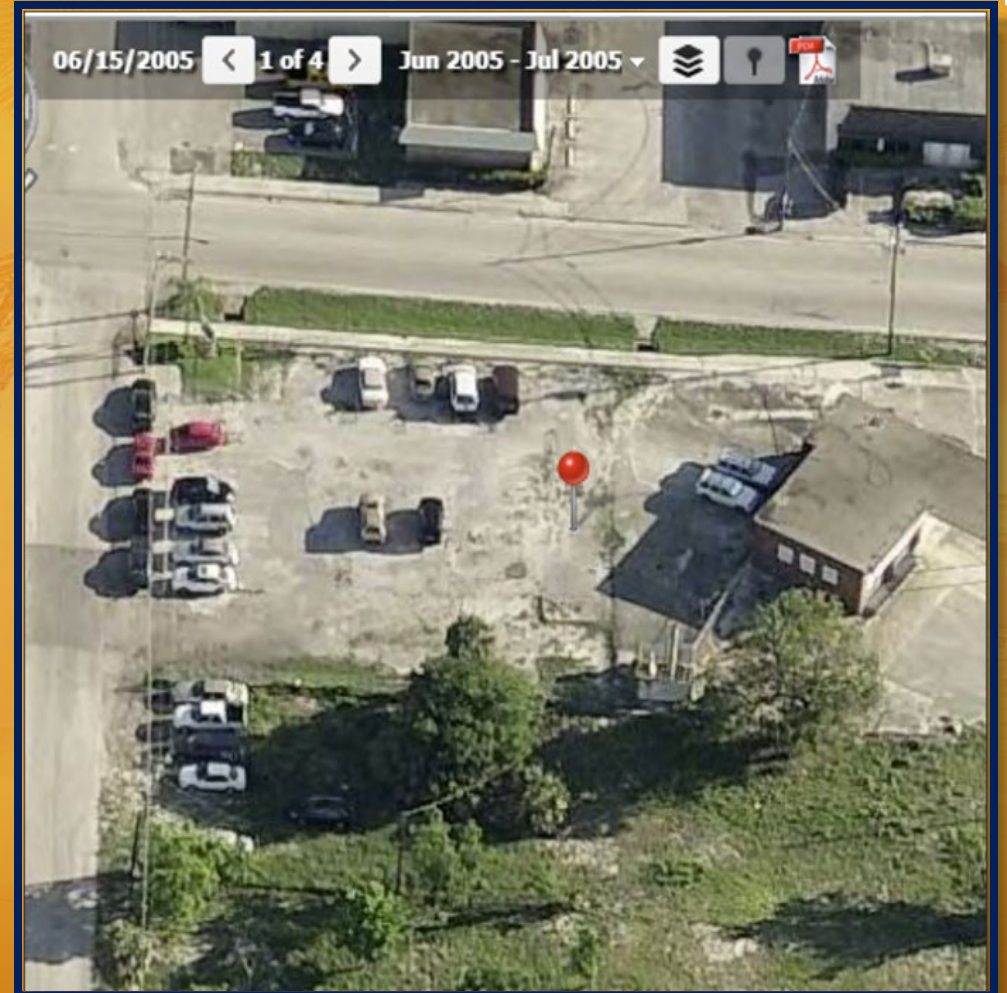
INTRODUCTION: Site History



SITE NAME: BP #24517
FAC ID: 069100407

INTRODUCTION - Site History

- Petroleum constituents
 - Above Groundwater Cleanup Target Levels (GCTLs):
 - Total Xylenes, 1-methylnaphthalene, and 2-methylnaphthalene
 - Above Natural Attenuation Default Concentrations (NADCs):
 - Ethylbenzene and Naphthalene

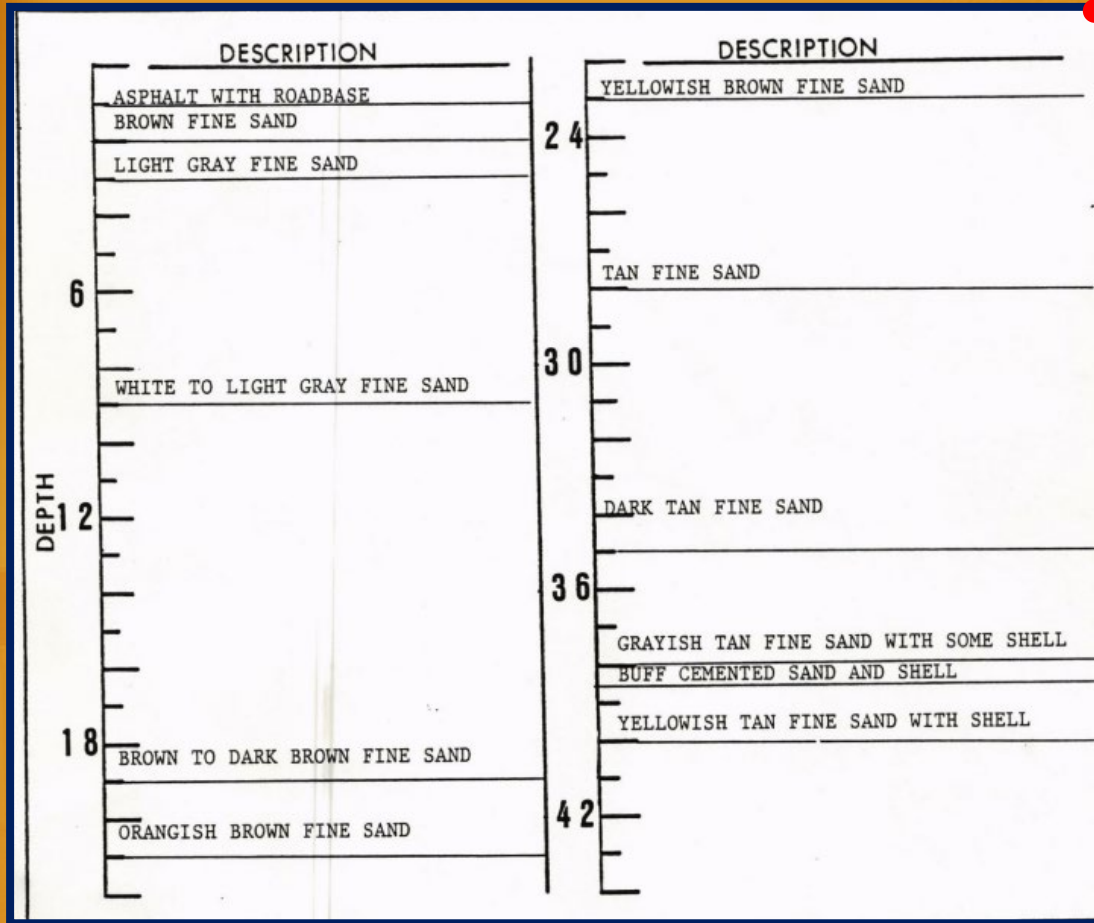


Site History

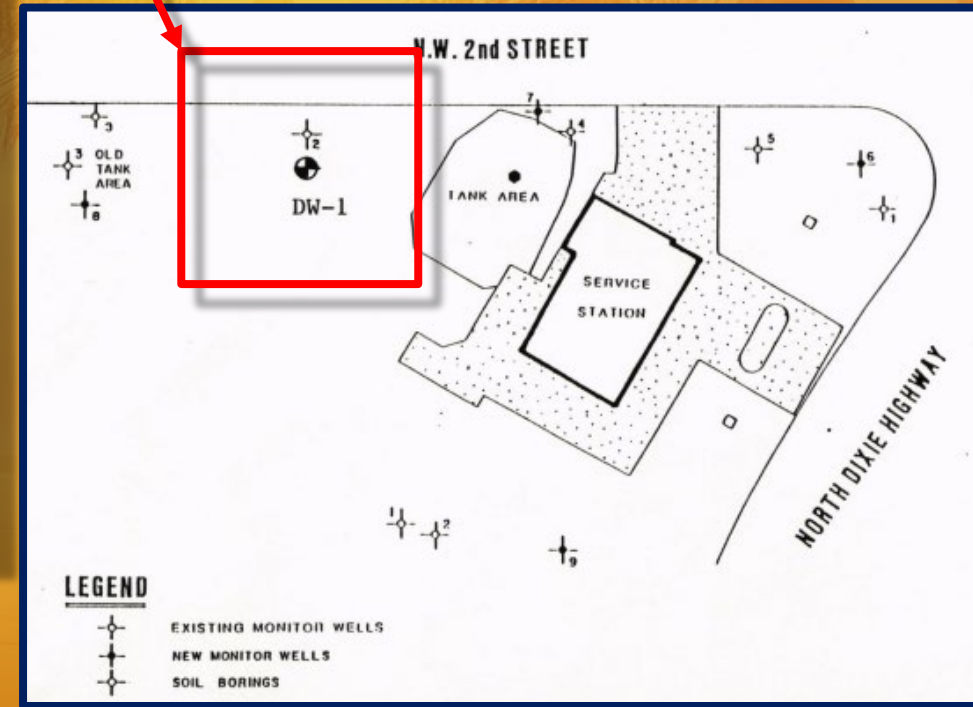


- Site is bordered by commercial properties to the North and West.
- North Dixie Highway, an overhead road, extends from the East of the property diagonally West to the South.

LITHOLOGY



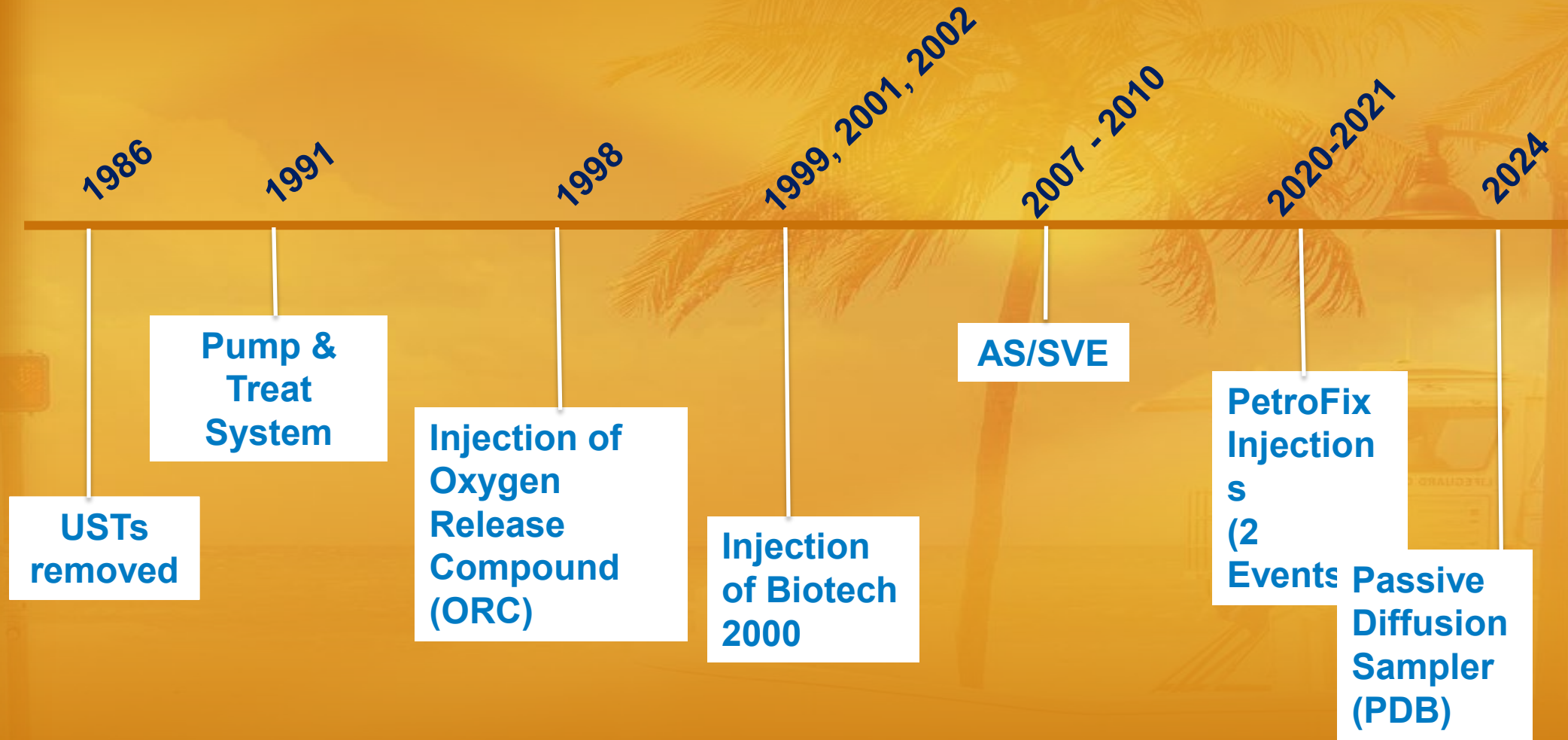
Vintage: 15 April 1988



REMEDIATION ACTIVITIES: History

- 1991 – Remedial Action Plan (RAP) Approval (Pump and Treat)
- 1993 to 1997 – 2.9 million gallons treated.
- 1998 – Oxygen Release Compound (ORC™) Injections
- 1999, 2001, and 2002 – Biotech 2000 injections
- 2007 to 2010 – Air Sparge (AS)/Soil Vapor Extraction (SVE)
- 2010 – FDOT roadway construction project (Dixie Flyover)
- 2019 – Limited Scope RAP
- 2020 - 2021– PetroFix Injections (2 events)
- 2022 – FDEP Sampling Protocol began (Carbon Injections)

REMEDIATION ACTIVITIES: Timeline



REMEDIATION ACTIVITIES: Sampling Protocol

Cleanup Stage	Comments	Sampling
Prior to Injection for Pilot Test and Active Remediation (Baseline)	This should be the level of contamination in both matrices in equilibrium at that time. Include total organic carbon (TOC) in soil and CO ₂ and methane in groundwater for baseline sampling.	3-5 saturated soil and groundwater samples*
When Groundwater reaches Cleanup Target Levels and PARM begins	Not verifying that soils have reached any target but at this new equilibrium, it should show that whatever contamination remains on soil is not contributing to groundwater contamination because the groundwater concentrations are remaining steady or decreasing.	3-5 saturated soil and groundwater samples. Include TOC in soil and CO ₂ and methane in groundwater.
When Groundwater Maintains Cleanup Target Levels for 1 Year	Monitor GW for a year, and if it stays at or below cleanup target levels, the site can move forward with Risk Management Option I under 62-780, F.A.C., unless Soil levels exceed those at the beginning of PARM.	3-5 saturated soil and groundwater samples. Include TOC in soil and CO ₂ and methane in groundwater

* Saturated soil and groundwater samples should be collected in area of highest contamination based on pre-injection concentrations. This table only lists the additional sampling, contaminants of concern, Underground Injection Control parameters, and secondary drinking standards are still evaluated as with all other petroleum sites. Sample collection and analysis should follow standard protocols.

List of Accepted Innovative Technologies Subject to the Sampling Protocol for Petroleum Projects Utilizing In-Situ Activated Carbon Injections (as of July 19, 2022). This list may be amended or expanded as information on these or other technologies becomes available.

#	Technology Name	IT Acceptance # (linked to letter)	IT Acceptance Date
1.	Bioavailable Absorbent Media (BAM-C formulation)	1661	09/13/2019
2.	CarbonOx	1530	04/18/2016
3.	GR-320-IRC	1450	02/24/2014
4.	MetaFix (formulations I-3 and I-7A)	1487	10/20/2020
5.	Nutribind	1524	04/22/2016
6.	PetroFix with Electron Acceptor Blend – Regular and Nitrate Free	1833	05/14/2019
7.	PlumeStop Colloidal Biomatrix	1476	08/31/2015
8.	Trap & Treat BOS 100	1365	04/19/2007
9.	Trap & Treat BOS 200	1366	04/17/2007

Effective May 2022.

- Sampling Protocol for Petroleum Cleanup Projects Using In-Situ Activated Carbon Injections.



REMEDIATION ACTIVITIES: Baseline Sampling

May 2020 - Geosyntec collected GW samples from Monitoring Wells (MWs):

- IW- 4R, IW-7R, IW-12R, IW-21R, MW-25, MW-26, MW-27, MW-28, MW-29, MW-30, MW-31 and MW-32 to use as a baseline data prior to the implementation of remedial injection activities.



Baseline Sampling

- Analyzed for
 - Benzene-Toluene-Ethylbenzene-Total Xylenes/Methyl-tert-butyl ether
 - BTEX/MTBE.
 - Polynuclear Aromatic Hydrocarbons
 - PAHs.
 - Underground Injection Control
 - UIC parameters.
 - Total Dissolved Solids
 - TDS.
- No baseline saturated soil sampling.



PETROFIX CARBON INJECTION: Composition + Quantity

PetroFix Fluid Chemical Composition	Properties
Activated Carbon - CAS 7440-44-0 > 30% Calcium Sulfate Dihydrate - CAS 10101-41-4 < 10%	Appearance: Black Fluid Viscosity: 1500-3500 cP (corn syrup-like) pH: 8-10
PetroFix Electron Acceptor Powder Chemical Composition	Properties
OPTION 1 - EA Blend (preferred) Sodium Nitrate - CAS 7631-99-4, 50% Ammonium Sulfate - CAS 7783-20-2, 50%	Appearance: White Powder

2600	PetroFix Drums (400 lb) (RBP)	LBS	6000
2601	PetroFix EA Blend Pail (20 lb) (RBP)	LBS	300

ELECTRON ACCEPTOR SCIENCE

FIGURE 1 Oxidation Reduction Potentials for Electron Receptors	
AEROBIC BIODEGRADATION	<p>Aerobic Biodegradation ORP = 820 mV</p> $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}$
ANAEROBIC BIODEGRADATION	<p>Nitrate Reduction "Denitrification" ORP = 740 mV</p> $2\text{NO}_3 + 12\text{H}^+ + 10\text{e}^- \longrightarrow \text{N}_2 + 6\text{H}_2\text{O}$
	<p>Manganese Reduction ORP = 520 mV</p> $\text{MnO}_2 (\text{s}) + \text{HCO}_3 + 3\text{H}^+ + 2\text{e}^- \longrightarrow \text{MnCO}_3(\text{s}) + 2\text{H}_2\text{O}$
	<p>Iron Reduction ORP = -50 mV</p> $\text{FeOOH}(\text{s}) + \text{HCO}_2^- + 2\text{H}^+ + \text{e}^- \longrightarrow \text{FeCO}_3 + 2\text{H}_2\text{O}$
	<p>Sulfate Reduction ORP = -220 mV</p> $\text{SO}_4^{2-} + 9\text{H}^+ + 8\text{e}^- \longrightarrow \text{HS} + 4\text{H}_2\text{O}$
	<p>Carbon Dioxide Reduction "Methanogenesis" ORP = -240 mV</p> $\text{CO}_2 + 8\text{H}^+ + 8\text{e}^- \longrightarrow \text{CH}_4 + 2\text{H}_2\text{O}$

REFERENCE:

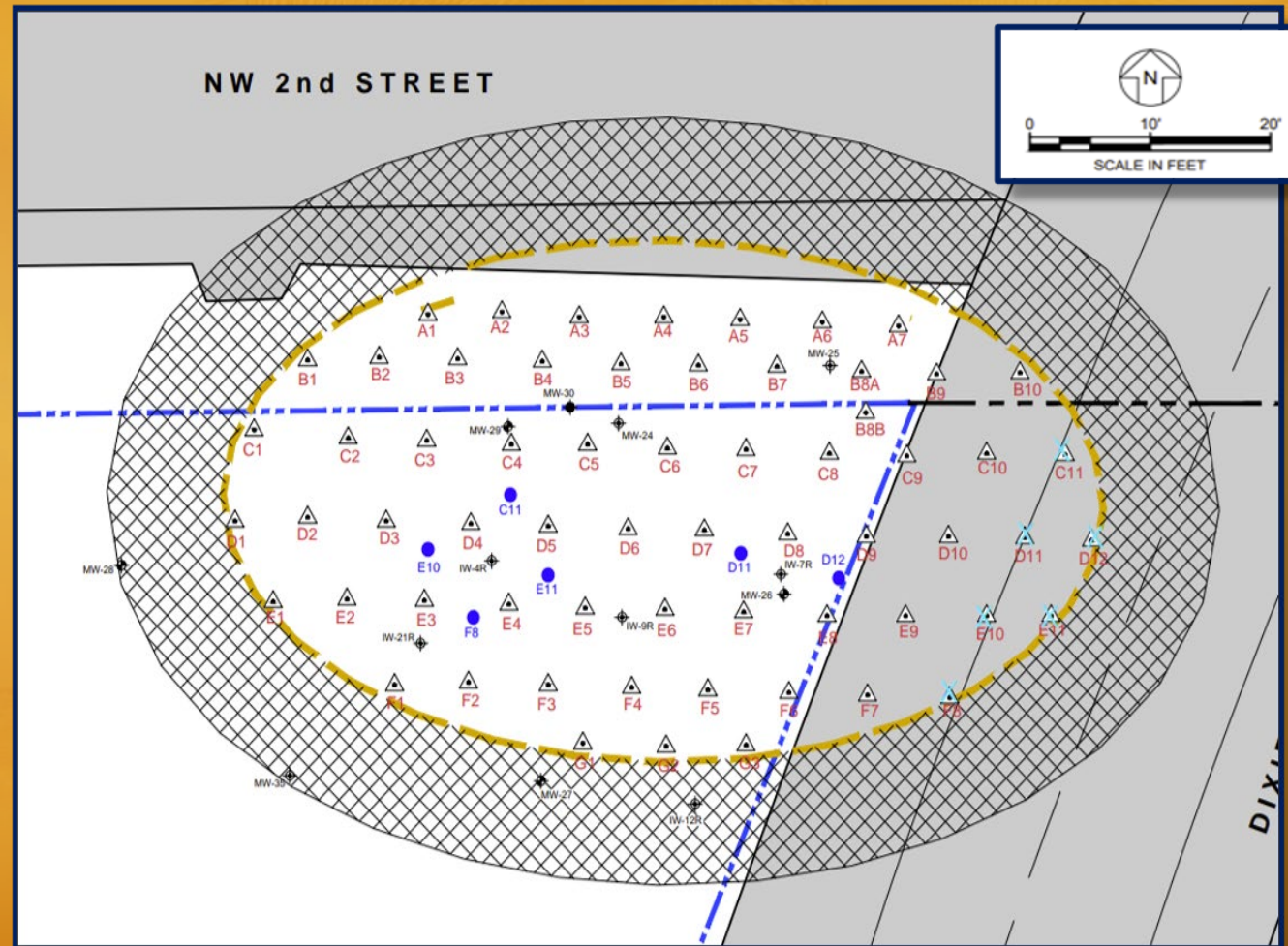
Technical Protocol for Evaluating Natural Attenuation Parameters
at Sites with Petroleum Contaminated Groundwater

Division of Waste Management
Petroleum Restoration Program

January 2018

PETROFIX CARBON INJECTION: (1st Event – Jun+Jul 2020)

- Delivered by means of Direct Push Technology (DPT).
- 62 boring locations. (injection event #1)
- Recommended spacing of 6.5 feet.
- 33,387 gallons (275:5) + 2 lbs Electron Acceptor (EA) Blend.
- Inj. Int.: 6 – 20 ft below ground surface (bgs).



PETROFIX CARBON INJECTION: Implementation

BP 24517

LAST UPDATED
07.11.19

GW - EB Plume

SOURCE AREA
Application Summary

PROJECT LOCATION
10 Eller
Deerfield, FL, 33441
UNITED STATES

PetroFix Amount	6,000 lbs
Treatment Surface Area	2,600.0 ft ²
Delivery Points	62
Point Spacing	6.5 ft
Top of Treatment Interval	6.0 ft bgs
Bottom of Treatment Interval	20.0 ft bgs
Vertical Treatment Interval Thickness	14.0 ft
Treatment Volume	1,348 yd ³
PetroFix Dose	4.45 lb/yd ³

Total Volume	34,035 gal
Product Volume	614 gal
Water Volume	33,421 gal
Injection Volume/Point	549 gal
Inject Volume/Vertical ft	39 gal
Product/Point	9.9 gal
Water/Point	539.0 gal
Soil Type	>75% sand/gravel
Effective Pore Volume Fill %	50%

Mix Tank Volume	275 gal
Dilution Factor	55.42
PetroFix per Mix Tank	5 gal
Water per Mix Tank	270 gal
Electron Acceptor per Mix Tank	2 lb
Number of Batches Required	123.76

AREA NOTES

REPORTED

Ground Water Concentrations (µg/L)

Benzene	0
Toluene	0
Ethylbenzene	580
Xylenes	95
Trimethylbenzenes	0
Butylbenzene	0

NAPL Present?	No
Isopropylbenzene	0
Naphthalenes	528
MTBE	0
TPH-GRO	0
TPH-DRO	0
Sum of Dissolved Concentrations:	1,203



PETROFIX CARBON INJECTION: Results

POST INJECTIONS

- 4 quarters of groundwater monitoring.
- PetroFix solution *did not* distribute as designed in the vicinity of MW-26.
 - Ethylbenzene and Total Xylenes exceeded GCTLs.
 - Proposed based on results (to be detailed later):
 - Focused treatment in the vicinity of MW-26.
 - Injection of Petrofix solution into 10 boring locations.

TABLE 3A: GROUNDWATER MONITORING WELL ANALYTICAL SUMMARY - VOCs

Facility ID#: 06-9100407 Facility Name: BP 24517; 199 N Dixie Hwy, Deerfield Bch, FL See notes at end of table.

Sample		Benzene	Toluene	Ethylbenzene	Total Xylenes	Total BTEX	MTBE
Location	Date	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
MW-26	4/19/2017	16 U	15 U	828	4570	5298	11 U
MW-26	03/26/2019	0.25 U	0.24 U	110	95	205	0.44 U
MW-26	05/26/2020	0.25 U	0.24 U	5.3	0.89 I	6.19	0.44 U
MW-26	10/20/2020	0.25 U	0.24 U	71	62	133	0.44 U
MW-26	1/21/2021	0.25 U	0.24 U	98	160	258	0.44 U
MW-26	4/22/2021	0.25 U	0.24 U	69	55	124	0.44 U
MW-26	7/23/2021	0.25 U	0.24 U	110	66	176	0.44 U
MW-26	3/21/2022	0.25 U	0.24 U	9.4	12	21.4	0.44 U
MW-26	6/22/2022	0.38 I	0.43 I	73	56	130	0.44 U
MW-26	9/28/2023	0.71 U	0.72 U	0.69 U	1.3 U	0.72 U	0.60 U
MW-26	5/3/2024	0.71 U	0.72 U	1.2	1.3 U	1	0.60 U
MW-27	4/20/2017	0.31 U	0.30 U	0.36 U	0.72 U	0.72 U	0.23 U
MW-27	03/26/2019	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-27	05/26/2020	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-28	4/20/2017	0.31 U	0.30 U	0.36 U	0.72 U	0.72 U	0.23 U
MW-28	03/26/2019	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-28	05/26/2020	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-29	4/20/2017	1.6 U	1.5 U	323	3.6 U	323	1.1 U
MW-29	03/25/2019	0.50 U	0.48 U	580	2.4 I	582.4	0.88 U
MW-29	05/26/2020	0.25 U	0.24 U	260	5.3	265.3	0.44 U
MW-29	10/20/2020	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-29	1/21/2021	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-29	4/22/2021	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-29	7/23/2021	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-30	4/20/2017	0.31 U	0.33 I	10.9	0.72 U	11.23	0.23 U
MW-30	03/25/2019	0.25 U	0.30 I	0.27 U	0.50 U	0.3	0.44 U
MW-30	05/27/2020	0.25 U	0.37 I	0.42 I	0.50 U	0.79	0.44 U
MW-31	11/3/2017	0.10 U	0.50 U	0.50 U	1.5 U	1.5 U	0.50 U
MW-31	05/27/2020	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-31	7/23/2021	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-32	11/3/2017	0.10 U	0.50 U	0.50 U	1.5 U	1.5 U	0.50 U
MW-32	05/27/2020	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-32	7/23/2021	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
MW-33	11/7/2017	0.10 U	0.50 U	0.50 U	1.5 U	1.5 U	0.50 U
MW-34	11/3/2017	0.10 U	0.50 U	0.50 U	1.5 U	1.5 U	0.50 U
MW-35	5/30/2019	0.25 U	0.24 U	0.27 U	0.50 U	0.50 U	0.44 U
GCTLs		1	40	30	20	NA	20
NADCs		100	400	300	200	NA	200

PETROFIX CARBON INJECTION: Results

April 2024

- Geosyntec mobilized to the Site to deploy a passive diffusion sampler (PDB) into MW-26.
- The Passive diffusion bag (PDB) bag was allowed to remain in the well for a minimum of 2 weeks.

May 2024

- Collected groundwater samples from monitoring wells MW-26 and MW-29.

Detection Summary									
Client: Geosyntec Consultants Inc								Job ID: 670-39250-1	
Project/Site: BP #24517 Deerfield Beach FL									
Client Sample ID: MW-26					Lab Sample ID: 670-39250-1				
Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Ethylbenzene	1.2		1.0	0.09	ug/L	1		8280D	Total/NA
Client Sample ID: MW-29					Lab Sample ID: 670-39250-2				
Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Fluoride	0.10		0.20	0.032	mg/L	1		9056A	Total/NA
Sulfate	2.6	I	5.0	0.066	mg/L	1		9056A	Total/NA
Aluminum	190		44	3.8	ug/L	1		6020B	Total Recoverable
Chromium	1.8	I	2.2	0.43	ug/L	1		6020B	Total Recoverable
Sodium	13		0.11	0.069	mg/L	1		6020B	Total Recoverable
Lead	0.73	I	2.2	0.27	ug/L	1		6020B	Dissolved
Ammonia (as N)	2.3		0.20	0.14	mg/L	10		350.1	Total/NA
Total Dissolved Solids	190		5.0	5.0	mg/L	1		SM 2540C	Total/NA
Field pH	6.57				SU	1		Field Sampling	Total/NA
Field Temperature	26.66				Celsius	1		Field Sampling	Total/NA
Oxygen, Dissolved	0.18				mg/L	1		Field Sampling	Total/NA
Specific Conductance	421				umhos/cm	1		Field Sampling	Total/NA
Turbidity	45.2				NTU	1		Field Sampling	Total/NA

PASSIVE DIFFUSION BAG

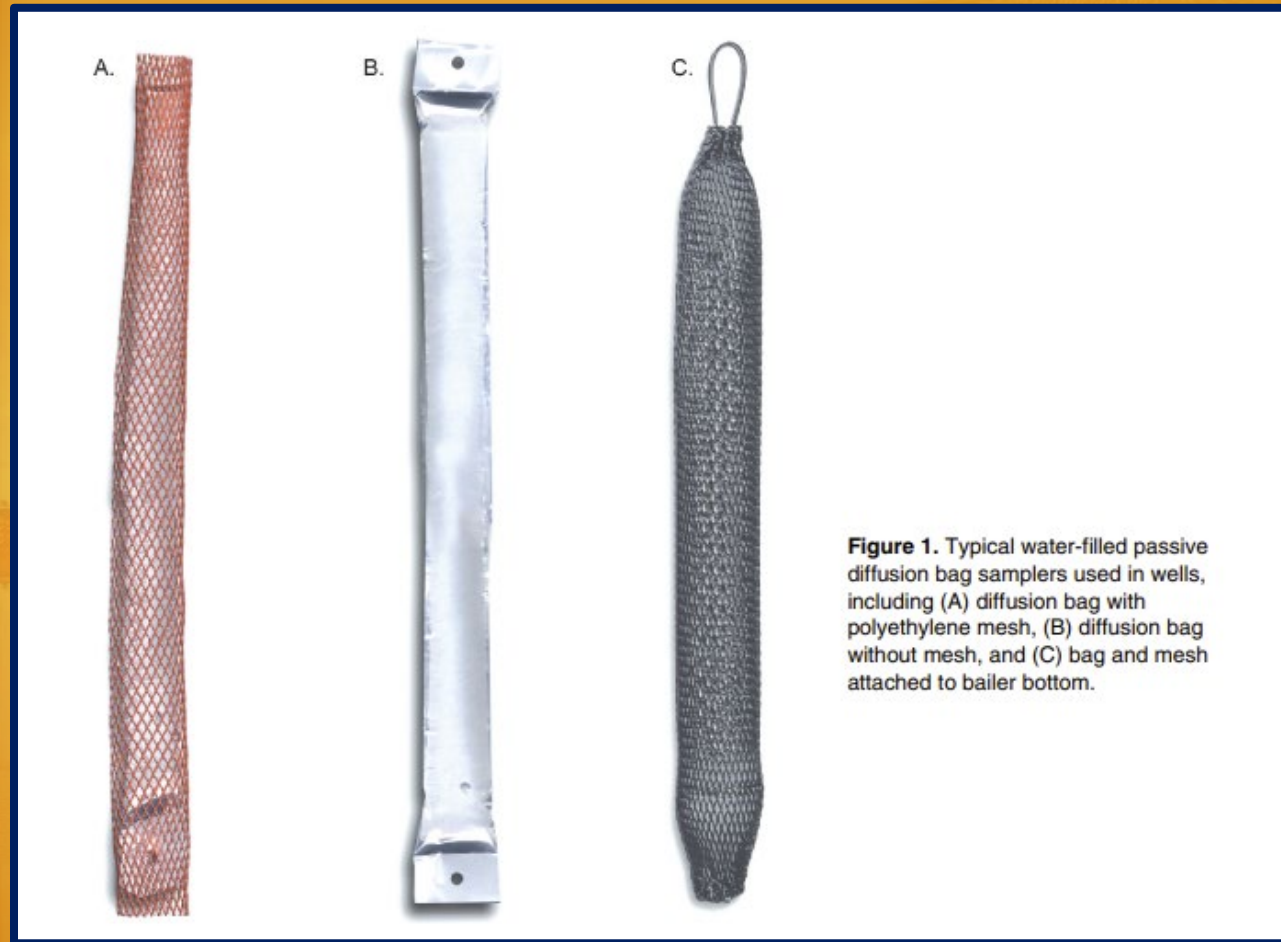


Figure 1. Typical water-filled passive diffusion bag samplers used in wells, including (A) diffusion bag with polyethylene mesh, (B) diffusion bag without mesh, and (C) bag and mesh attached to bailer bottom.

REFERENCE:



USER'S GUIDE FOR POLYETHYLENE-BASED PASSIVE DIFFUSION BAG SAMPLERS TO OBTAIN VOLATILE ORGANIC COMPOUND CONCENTRATIONS IN WELLS

**PART 1:
DEPLOYMENT, RECOVERY, DATA INTERPRETATION,
AND QUALITY CONTROL AND ASSURANCE**

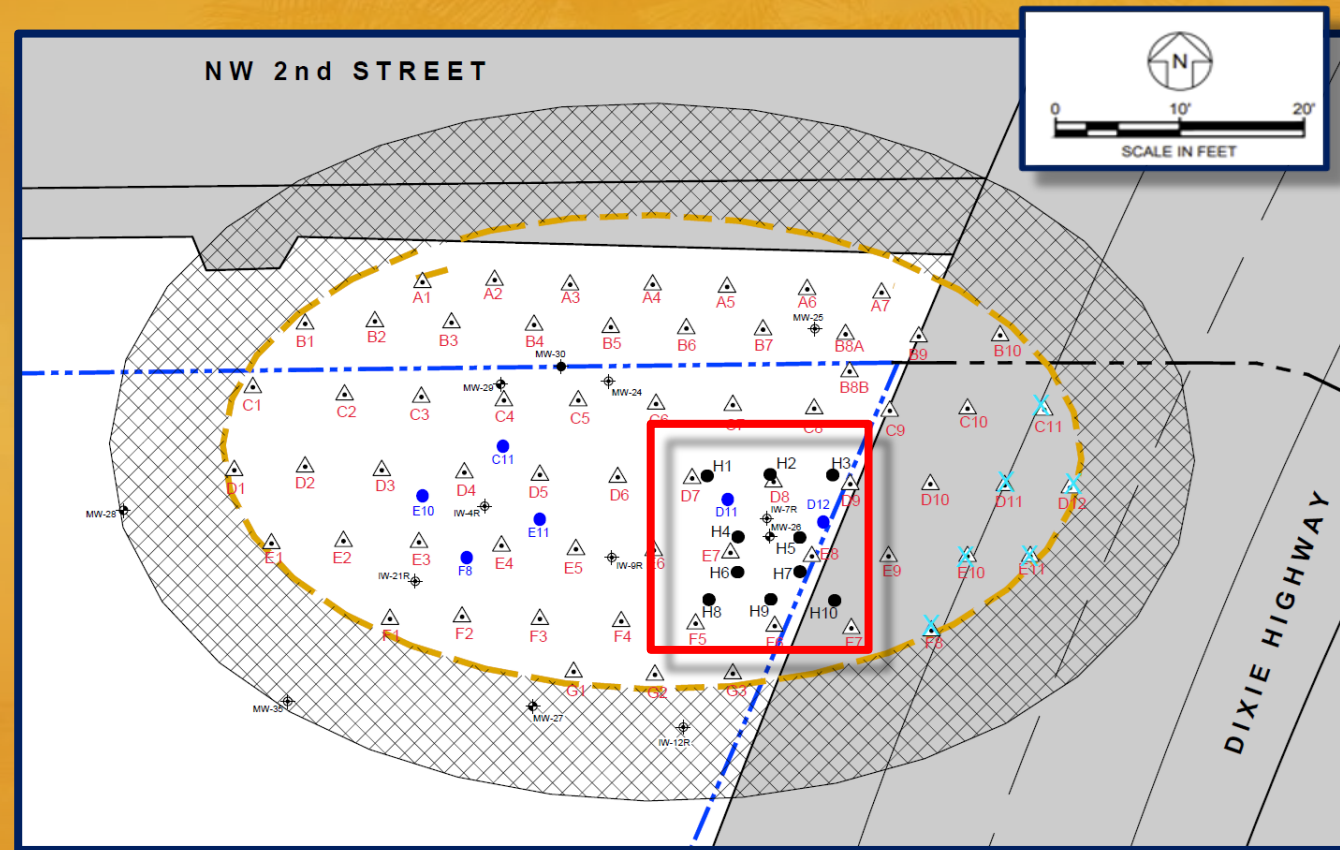
Water-Resources Investigations Report 01-4060

**PART 2:
FIELD TESTS**


Water-Resources Investigations Report 01-4061


PETROFIX CARBON INJECTION: (2nd Event – DEC 2021)

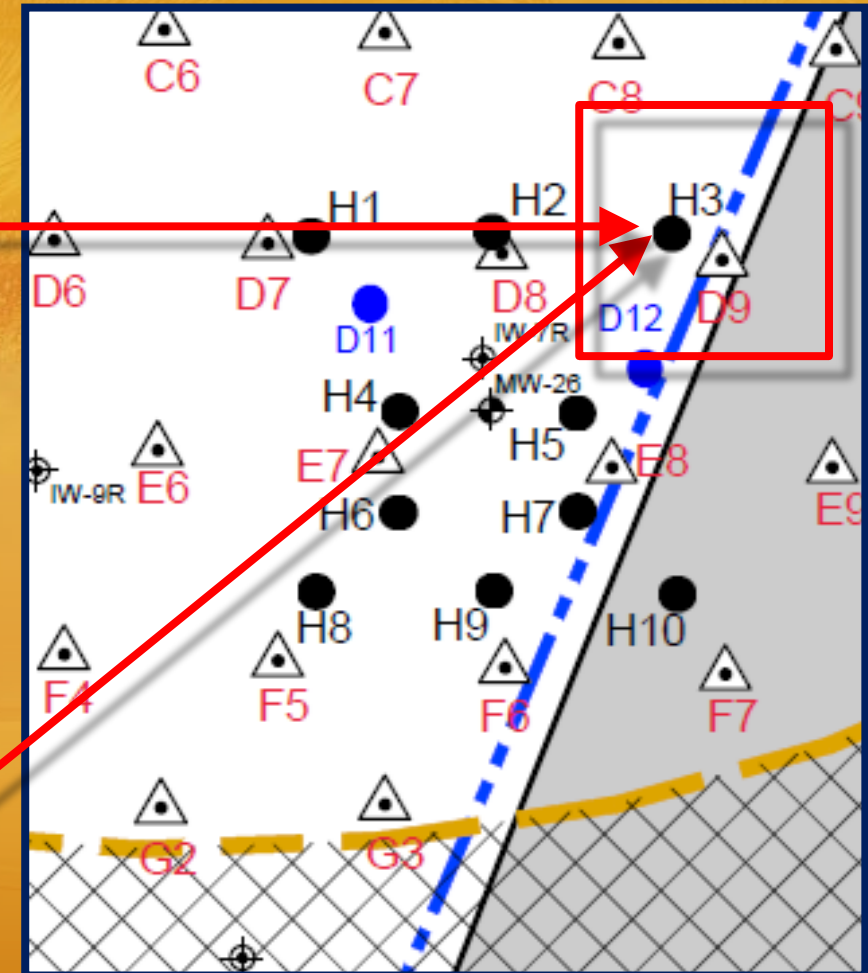
- Targeted PetroFix delivered by means of Direct Push Technology (DPT).
- 10 boring locations (injection event #2).
- 2,880 Gallons (267:77) +3.8 lbs EA Blend.
- Inj. Interval: 14 – 22 ft bgs.



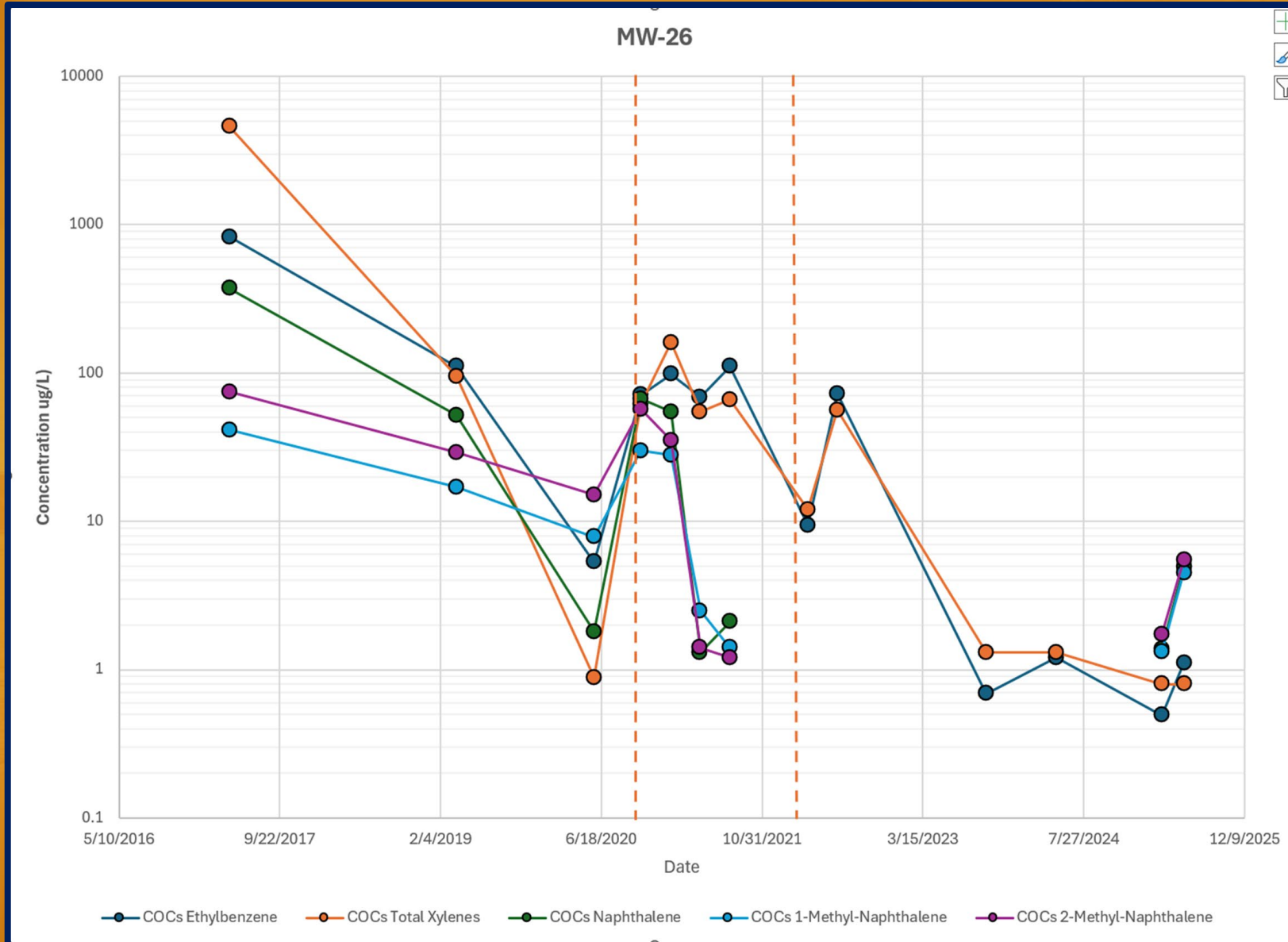
(2nd Event – DEC 2021)

Photograph #10	
Date: 12/16/2021	
Comments: View of soil lithology after injecting in injection location H3. Soil appear to display adsorption of remedial product to its surface.	

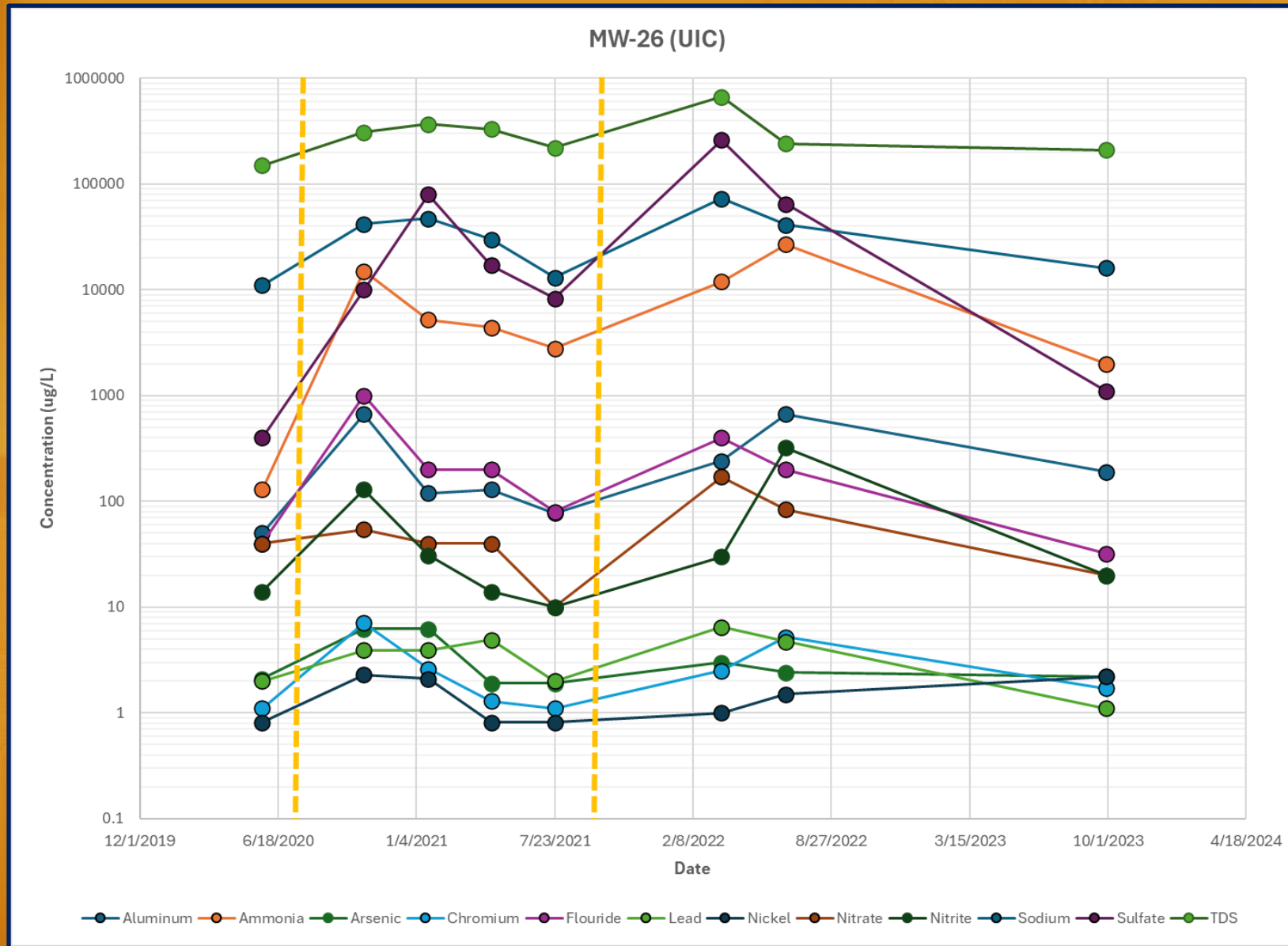
Photograph #11	
Date: 12/16/2021	
Comments: Close-up view of coating of remedial product on the soil adjacent to injection location H3.	



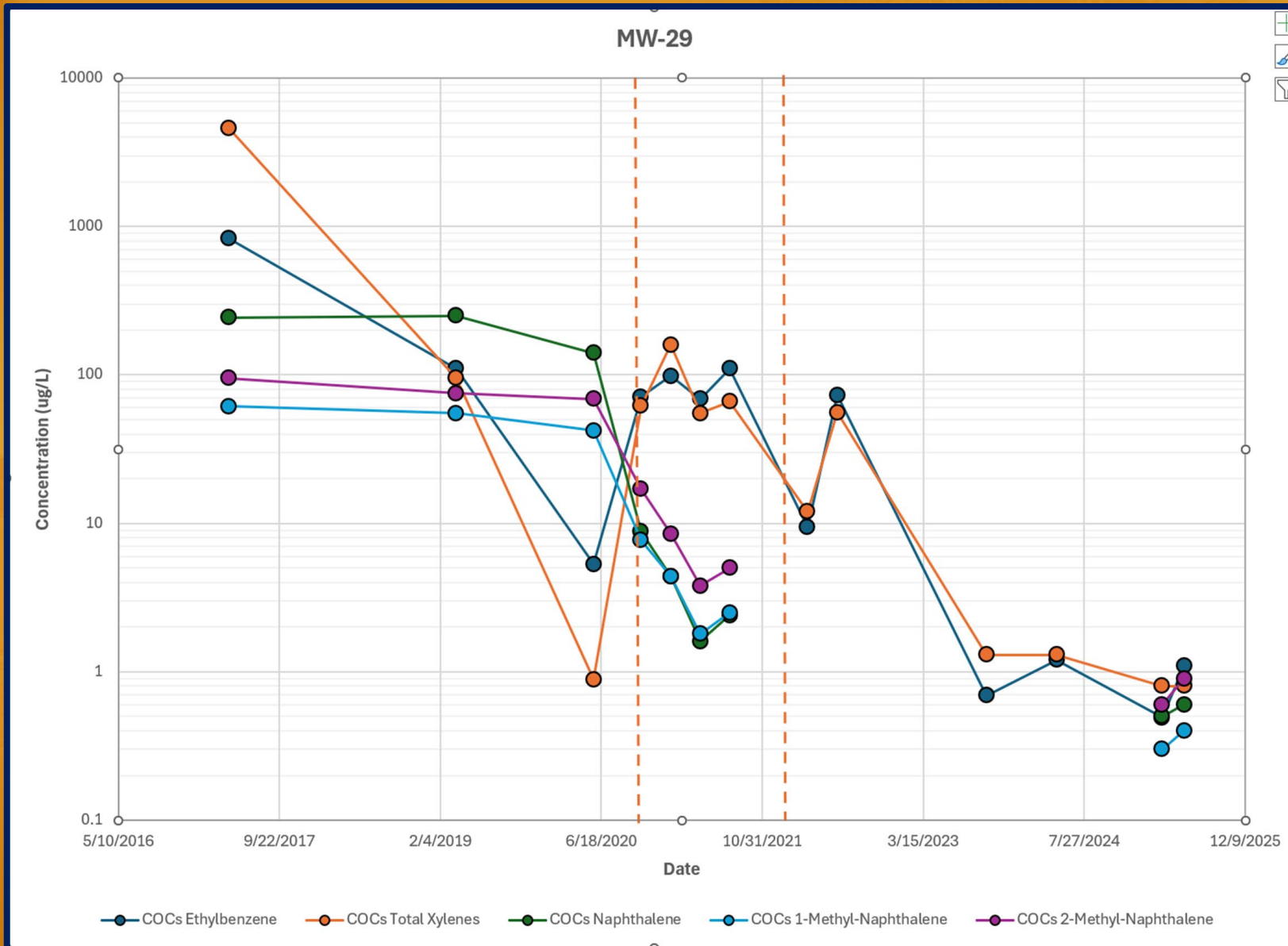
PETROFIX CARBON INJECTION: Results

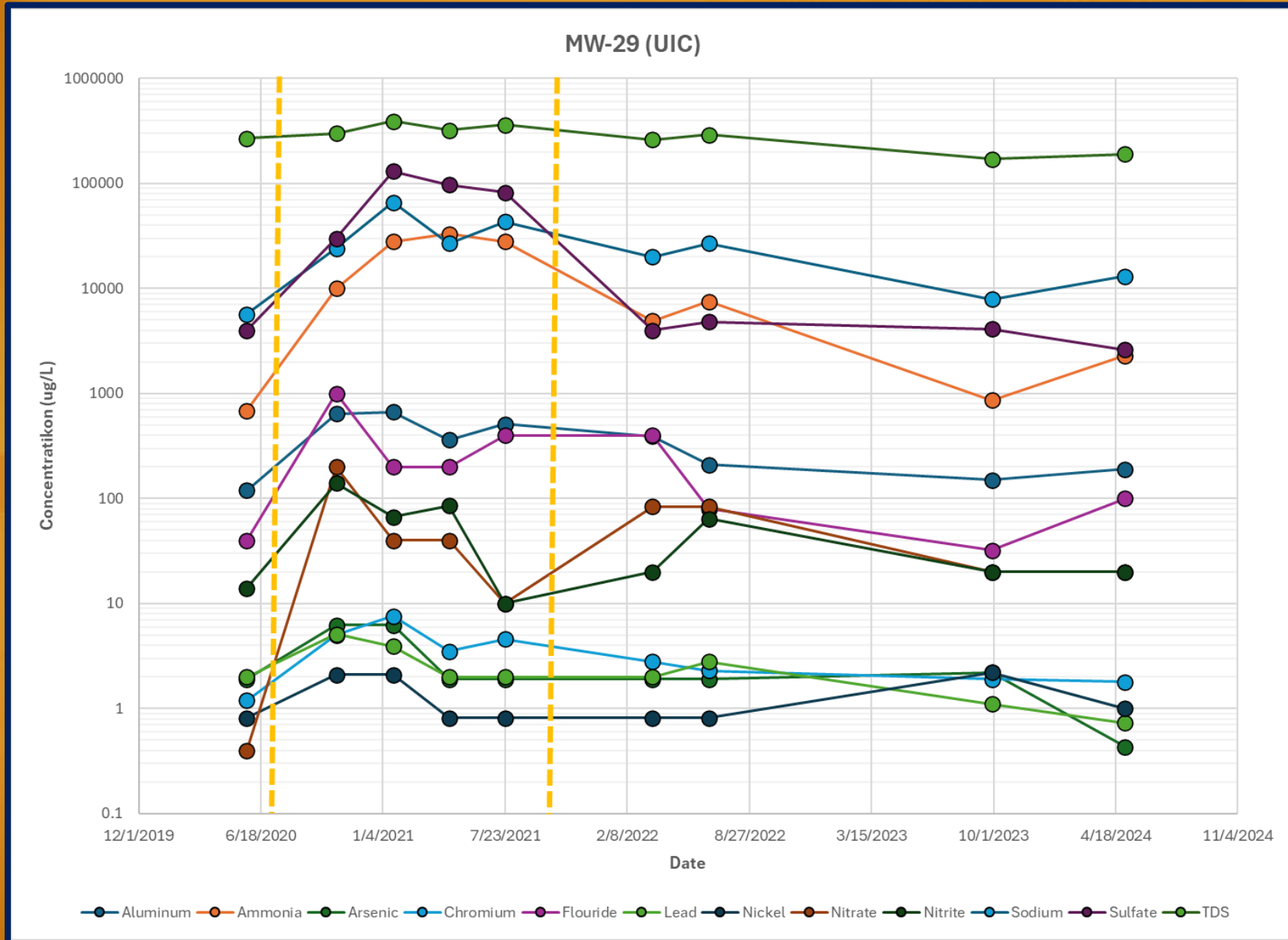


PETROFIX Results



PETROFIX: Results





POST ACTIVE REMEDIATION MONITORING

PARM Approval Order issued October 31, 2024.



October 31, 2024

Sent via email only to addressee at AASmith@Geosyntec.com

Mr. Adrian Smith, P.E.
Geosyntec Consultants, Inc.
900 Broken Sound Parkway NW, Suite 200
Boca Raton, Florida 33487

Subject: **Post Active Remediation Monitoring Plan Approval**
BP #24517
199 North Dixie Highway
Deerfield Beach, Broward County
FDEP Facility ID# 069100407
Discharge Date: February 26, 1987 (EDI)
Score: 60

Dear Mr. Smith:

The Broward County Environmental Permitting Division (Division), on behalf of the Florida Department of Environmental Protection (FDEP), has reviewed the Post Active Remediation Monitoring (PARM) Plan, dated June 5, 2024 (received June 7, 2024), submitted for the petroleum product discharge referenced above. Pursuant to Paragraph 62-780.750(2)(a), Florida Administrative Code (F.A.C.), the Division approves the PARM Plan.

Water-level measurements must be made immediately prior to each sampling event. The analytical results (laboratory report), chain of custody record form, cumulative summary tables as required by Subparagraph 62-780.600(8)(a)27, F.A.C. (updated as applicable), site map(s) that illustrate the most recent analytical results, including plume delineation(s), and the water-level elevation information (cumulative summary table and most recent flow interpretation map), must be submitted to the Division according to the time frame established in an executed purchase order.

The monitoring wells to be sampled, the sampling parameters, and the sampling frequency for the first year are as follows:

Monitoring Wells	Contaminants of Concern	Frequency
IW-4R, IW-7R, MW-29 and MW-26	BTEX, MTBE, PAHs	Quarterly

If concentrations of contaminants of concern in any of the designated wells increase above the action levels listed below, a Rush Request for Change should be submitted to the Division so the

Mr. Adrian Smith, P.E.
FDEP Facility ID# 069100407
Page 2
October 31, 2024

well or wells can be resampled no later than 30 days after the initial positive results are known. If the results of the resampling confirm the initial sampling results, then the monitoring report referenced in Paragraph 62-780.750(4)(d), F.A.C., must be signed and sealed by an appropriate registered professional pursuant to Rule 62-780.400, F.A.C., and must include a recommendation as described in Paragraph 62-780.750(4)(e), F.A.C.

ACTION LEVELS

	Benzene	Ethylbenzene	Naphthalene	1-Methylnaphthalene
IW-4R	1 µg/L	30 µg/L	14 µg/L	28 µg/L
IW-7R	1 µg/L	30 µg/L	14 µg/L	28 µg/L
MW-29	1 µg/L	30 µg/L	14 µg/L	28 µg/L
MW-26	100 µg/L	300 µg/L	140 µg/L	280 µg/L

If the applicable No Further Action criteria of Rule 62-780.680, F.A.C., are met at the end of the monitoring period (for at least the last two sampling events), a Site Rehabilitation Completion Report with a No Further Action Proposal, that summarizes the monitoring program and contains documentation to support the opinion that the cleanup objectives have been achieved, must be submitted to the Division as required in Subsection 62-780.750(6), F.A.C. The Site Rehabilitation Completion Report must include a summary of analytical results obtained for groundwater, soil, surface water and sediment, as applicable, to support the recommendation that the site qualifies for No Further Action in all media. If the applicable No Further Action criteria of Rule 62-780.680, F.A.C., are not met following one year of monitoring, then the monitoring report must include a recommendation as described in Paragraph 62-780.750(4)(e), F.A.C.

The FDEP Facility Number for this facility is 069100407. Please use this identification on all future correspondence with the Division. If you should have any questions concerning the review, please contact me at (954) 519-1279 or luciflores@broward.org

Sincerely,

ENVIRONMENTAL PERMITTING DIVISION

Lucy Flores
Lucy Flores, Contract Manager
Environmental Specialist

Engineering Aspects Reviewed By:
David J. Sheehan
David J. Sheehan, P.E.
Professional Engineer #63418
Date: 10/31/2024

cc: Torie Tompkins, Geosyntec Consultants Inc., torie.tompkins@geosyntec.com
Thomas Roegiers, MWI Pump Corporation, TomR@mwiumps.com
Gigliola Barrasso, BC Real Estate Officer, gbarrasso@broward.org
File

March 2025

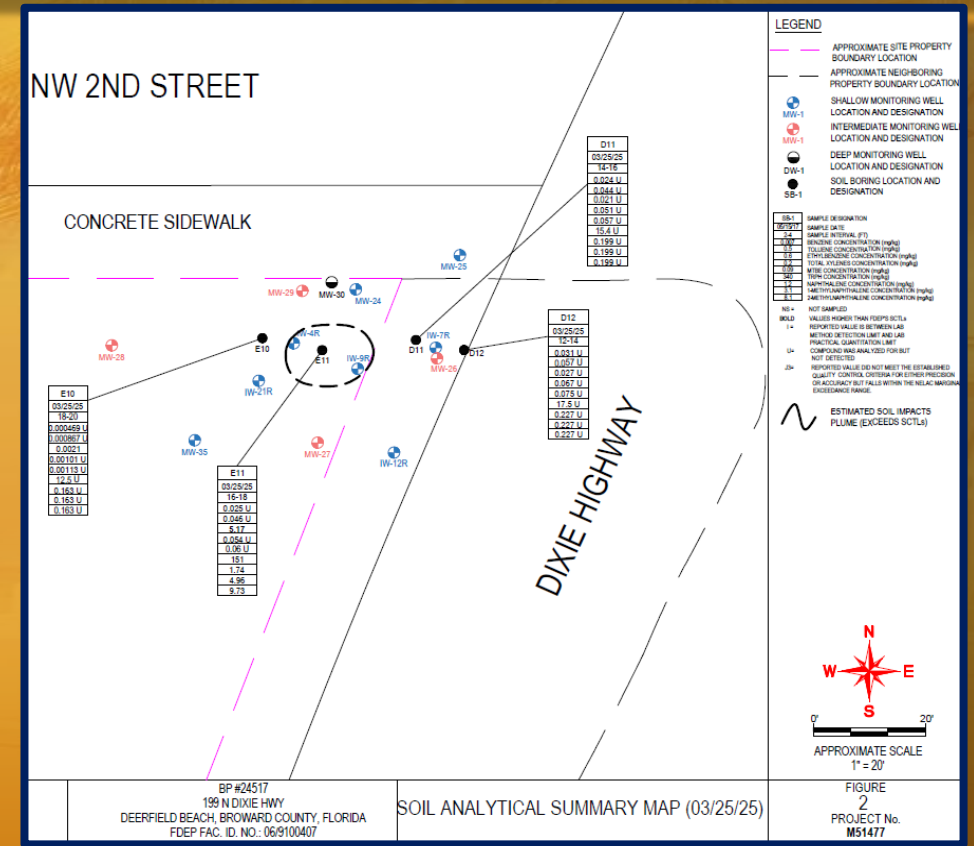
- Soil samples collected
 - D-11, 14-16 ft. below land surface (bls.)
 - D-12, 12-14 ft. bls.
 - E-10, 18-20 ft. bls.
 - E-11, 16-18 ft. bls.

- No detection of Benzene.

- E-11, 16-18 ft. bls.
 - Detected concentrations above Soil Cleanup Target Level (SCTLs):
 - Ethylbenzene;
 - Naphthalene;
 - 1-Methyl-naphthalene;
 - 2-Methyl-naphthalene.

SOIL SAMPLING

When Groundwater reaches Cleanup Target Levels and PARM begins	Not verifying that soils have reached any target but at this new equilibrium, it should show that whatever contamination remains on soil is not contributing to groundwater contamination because the groundwater concentrations are remaining steady or decreasing.	3-5 saturated soil and groundwater samples. Include TOC in soil and CO ₂ and methane in groundwater.
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POST REMEDIATION SOIL CORES



GROUNDWATER RESULTS

March 2025

- Groundwater samples of IW-7R, MW-26, and MW-29.
 - IW-4R blocked by root intrusion.
- No exceeding GCTLs in IW-7R and MW-29.
- MW-26 exceeding GCTLs for TDS.
- Continuing with PARM activities.
 - IW-4R and IW-7R in process of redeveloping and/or re-installing.



CLOSING REMARKS

Thank You!

FOR MORE INFORMATION:

Lucy Flores (Site Manager) – LUCFLORES@broward.org

David Sheehan, PE (LP06 EOR) – DSHEEHAN@broward.org

FDEP MAP DIRECT or OCULUS (FAC ID # 069100407)

ENVIROS (SF-1142) - - <https://dpep.broward.org/Enviros/>

Broward County Contaminated Sites Locator Map:

<https://www.broward.org/Environment/CONTAMINATEDSITES/Pages/SiteLocations.aspx>

