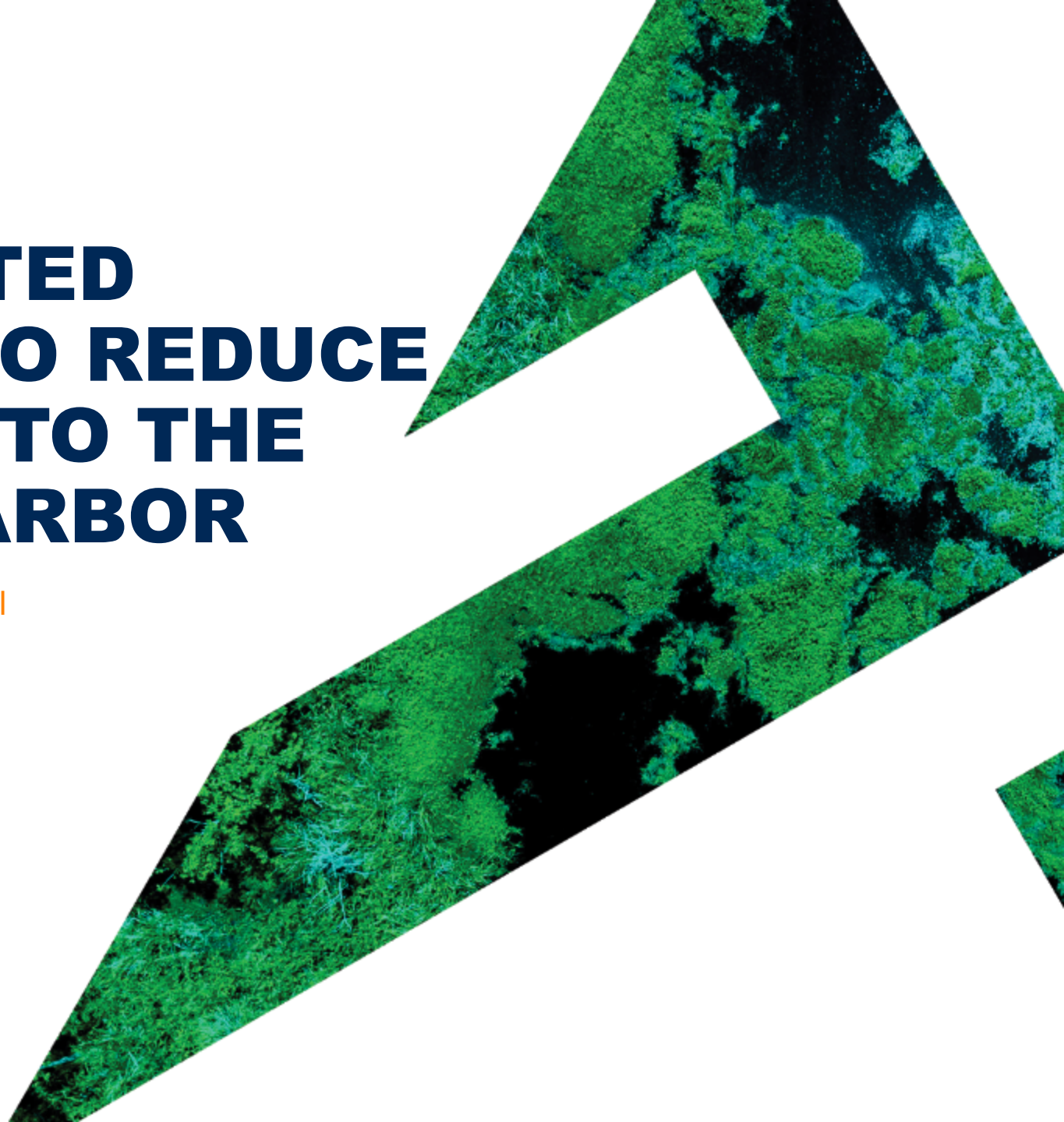
COLLOIDAL ACTIVATED CARBON BARRIER TO REDUCE PFAS MIGRATION INTO THE OAKLAND INNER HARBOR

Robert Mayer, Jr., Paul Hatzinger, Nels Johnson, Michael Lightner, Gary Cronk, Abram Eloskof, Craig Sandefur, and Dan Nunez



SITE OVERVIEW

Site Background

- Installation Restoration (IR) Site 14 (Site) is located on former Naval Air Station (NAS) Alameda.
- NAS Alameda served as an active Navy Base from 1940 to 1997.
- Site was developed by dredge and fill operations.

Department of Veterans Affairs Property Boundary

IR Site 14 Boundary

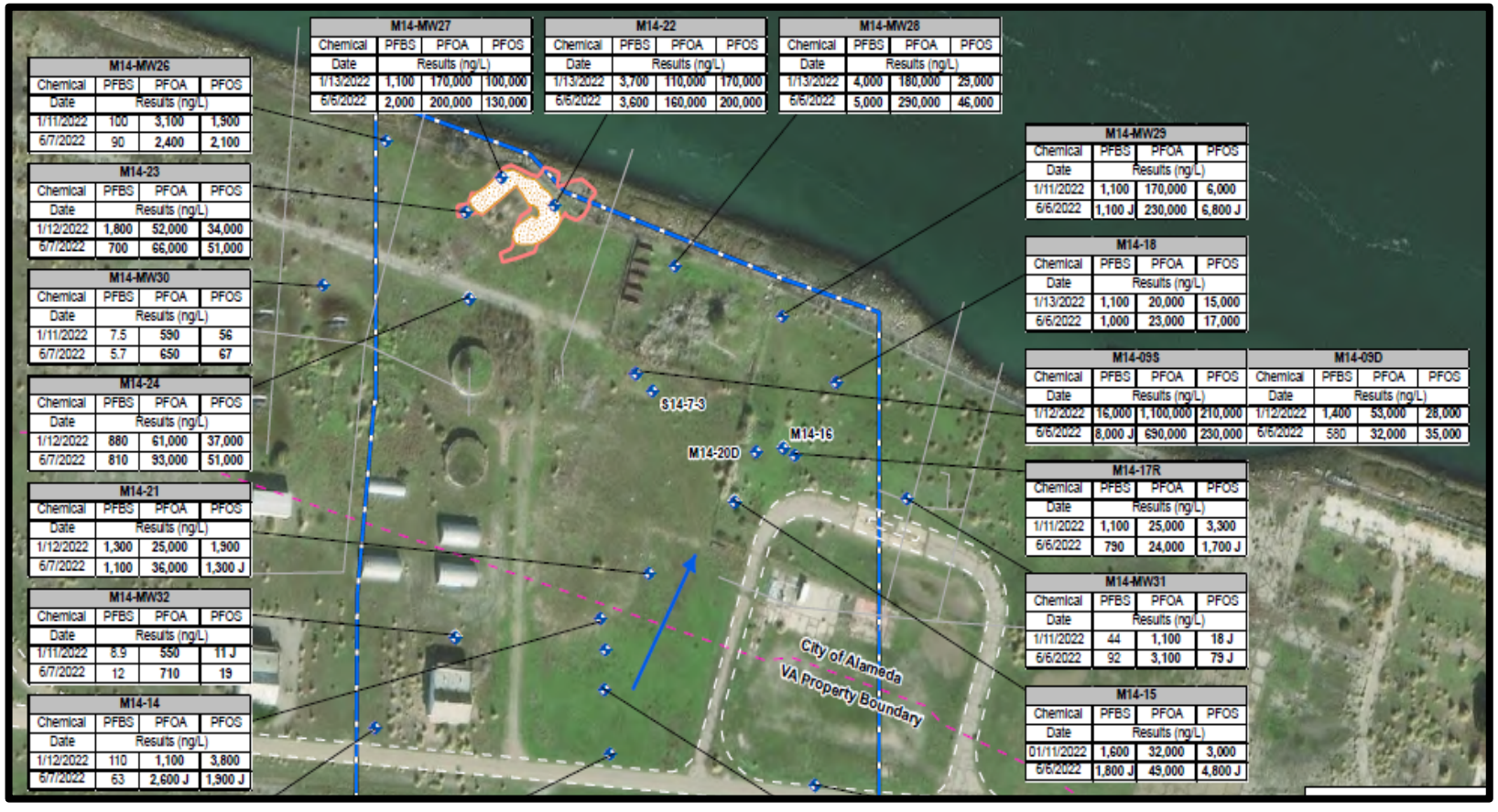
Alameda Point Boundary

SITE OVERVIEW

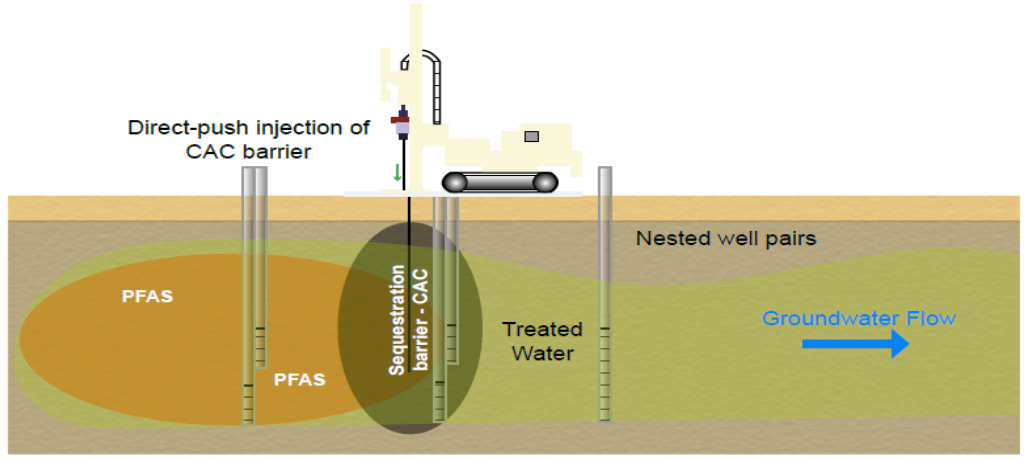
Per- and Polyfluoroalkyl Substances (PFAS) Concentrations

PFAS Source: Firefighting Foam used Historically during Firefighter Training.

- Initial Data Set
- Highest Levels
  - PFBS: 16,000 ng/L
  - PFOA: 1,100,000 ng/L
  - PFOS: 230,000 ng/L



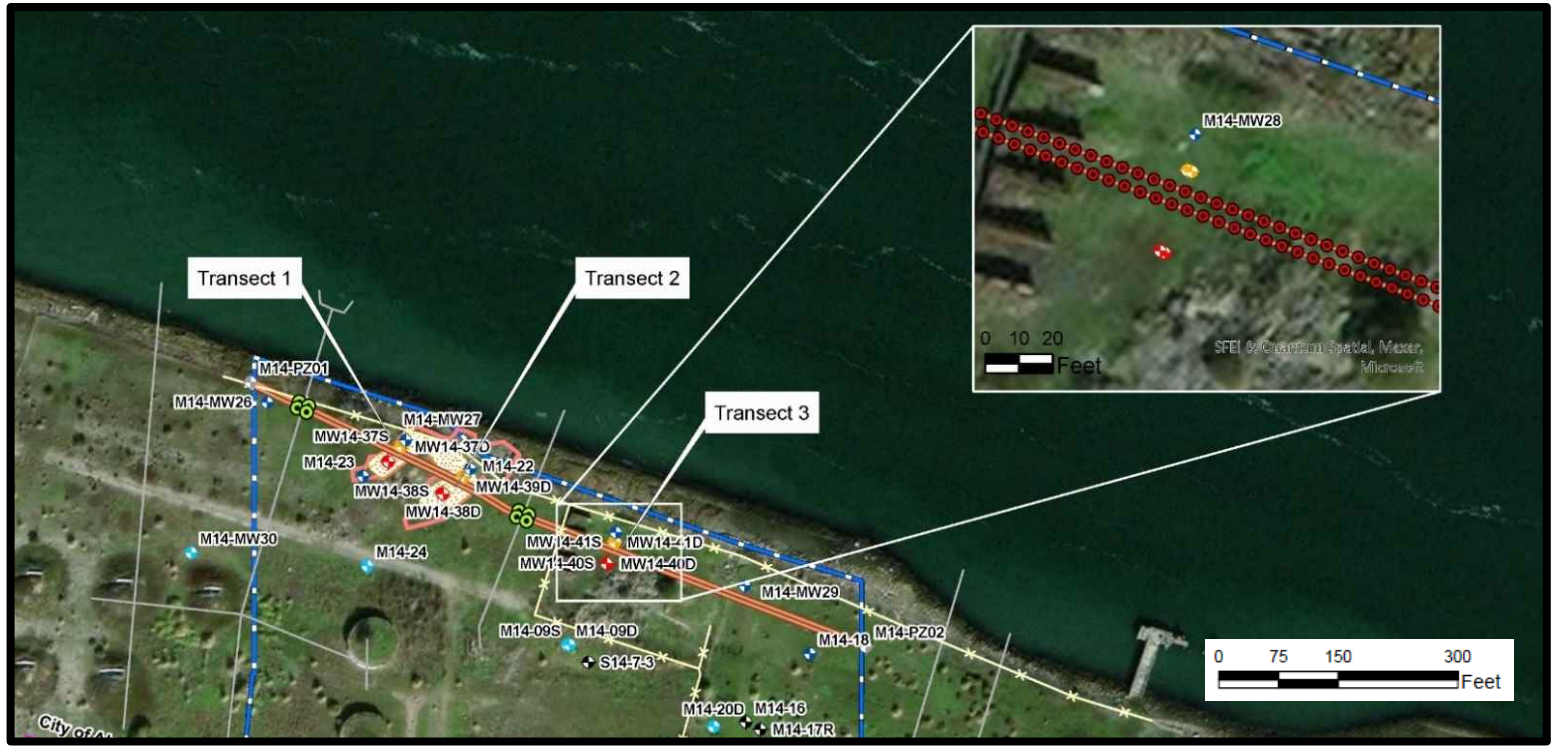
CONCEPTUAL DESIGN



Create a barrier to reduce the migration of PFAS in the groundwater.

- Injectable
- Permeable formation
- In-situ
- 720-feet long
- 288 direct push injection points

-NOT TO SCALE-

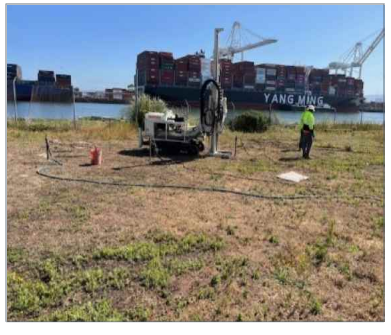


CONCEPTUAL DESIGN

Design Process

- Selection of amendment type
- Column study
- Soil and groundwater sampling
- Passive flux meters and well installation
- In-situ injections
- Sampling and evaluation

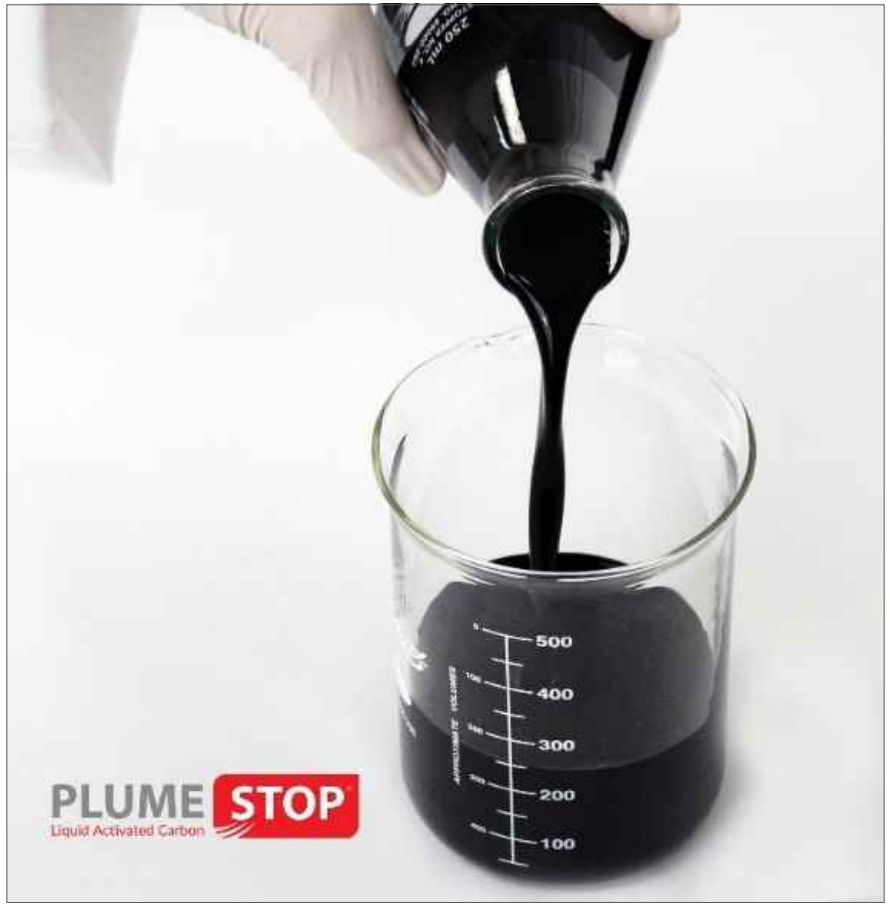
Courtesy: Regenesis



COLLOIDAL ACTIVATED CARBON (CAC) OVERVIEW

PlumeStop Attributes

- Carbon particle sizes 1–2 µm
- Suspends as a colloid in polymer solution
- Distributes easily under low pressure
- Creates an in-situ purifying filter within the saturated zone
- Reduces concentrations of target compounds in groundwater



COLUMN STUDY

Three Columns

- C1 = 0.0% CAC
- C2 = 0.5% CAC
- C3 = 2.0% CAC

Setup

- 12 inches in length
- 3.6 milliliters/hour flow rate
- 1-ft flow every 28 hours

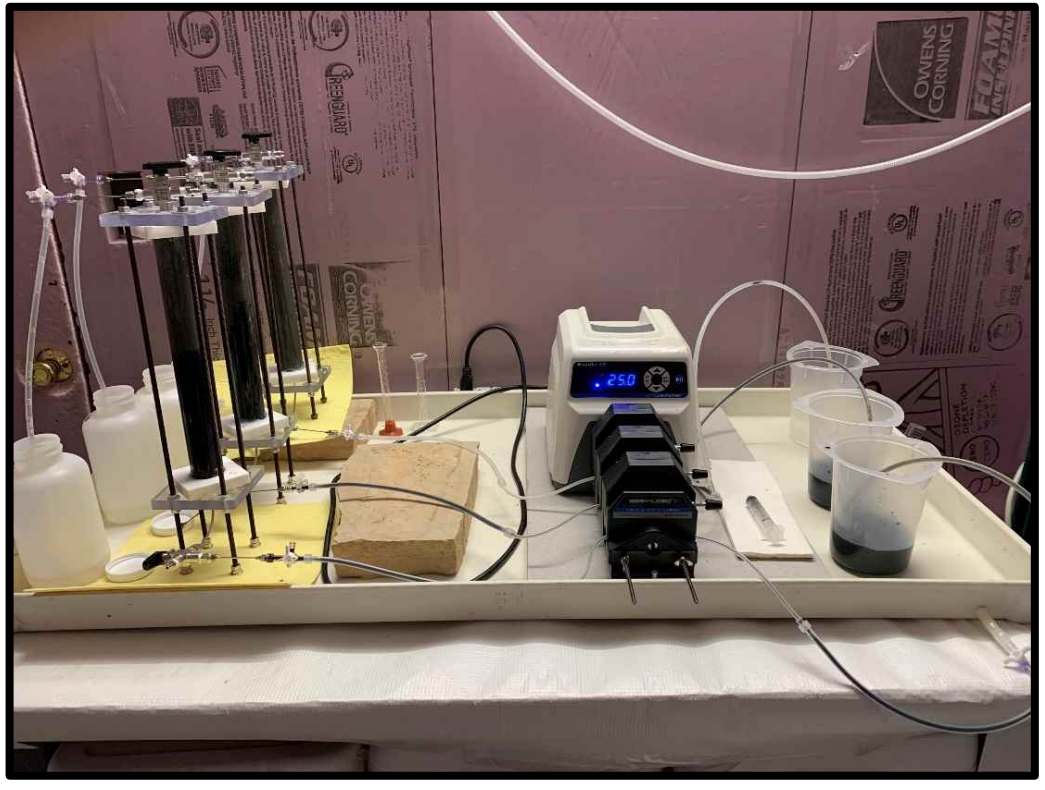
Operation

- Ran one month with site water, then added CAC
- Ran four months after CAC addition (9 liters water after CAC)
- Collected effluent into 1-L bottles
- Sampled soils and analyzed for PFAS and combustible carbon

COLUMN STUDY

Results

- C1 = 0.0% CAC
  - Little adsorption from the native aquifer soils observed
- C2 = 0.5% CAC
  - Reduced from 438,000 ng/L to 1,300 ng/L by Day 47
- C3 = 2.0% CAC
  - Reduced from 438,000 ng/L to less than 200 ng/L on Day 47 (slightly faster adsorption)
- Site groundwater that was collected to run the test had PFAS concentrations over 400,000 ng/L
- CAC can reduce groundwater PFAS concentration as expected
- Different concentrations of CAC can be matched to different PFAS concentrations along the barrier



PASSIVE FLUX METER (PFM) STUDY

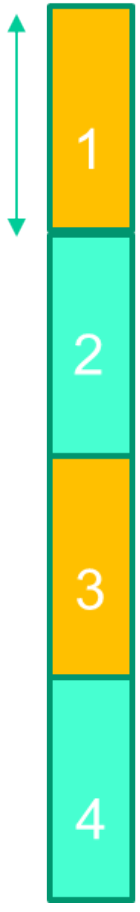
PFM Phases

- Phase 1: determine future well screen placement
- Phase 2: collect pre-injection data
- Phase 3: collect post-injection data (will be installed one year post-injection)

PFM DESIGN AND INSTALLATION

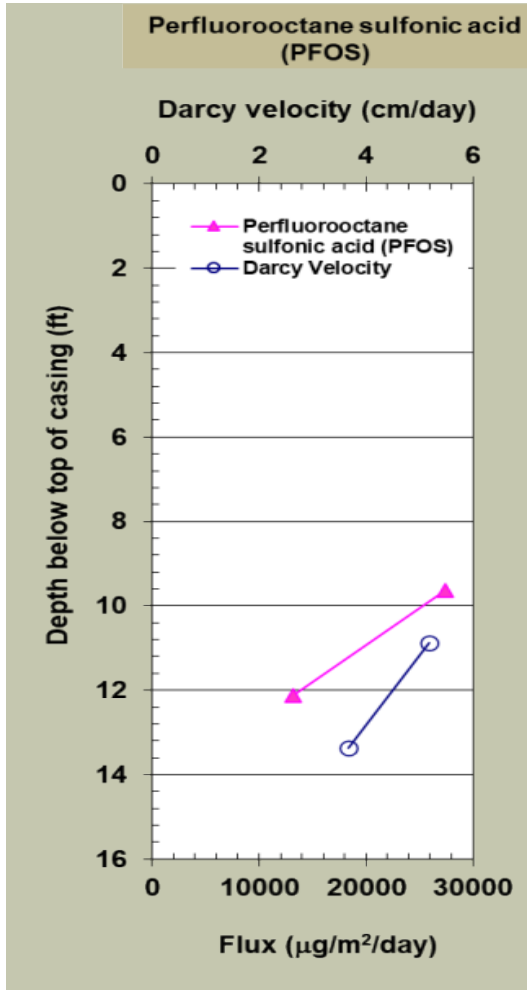
PFM Design

- Sections #1 and #3
  - Resin
- Sections #2 and #4
  - Granular Activated Carbon
- Each section is 1.25 ft (5 ft total)
- Placed into a well with a 5-ft screen

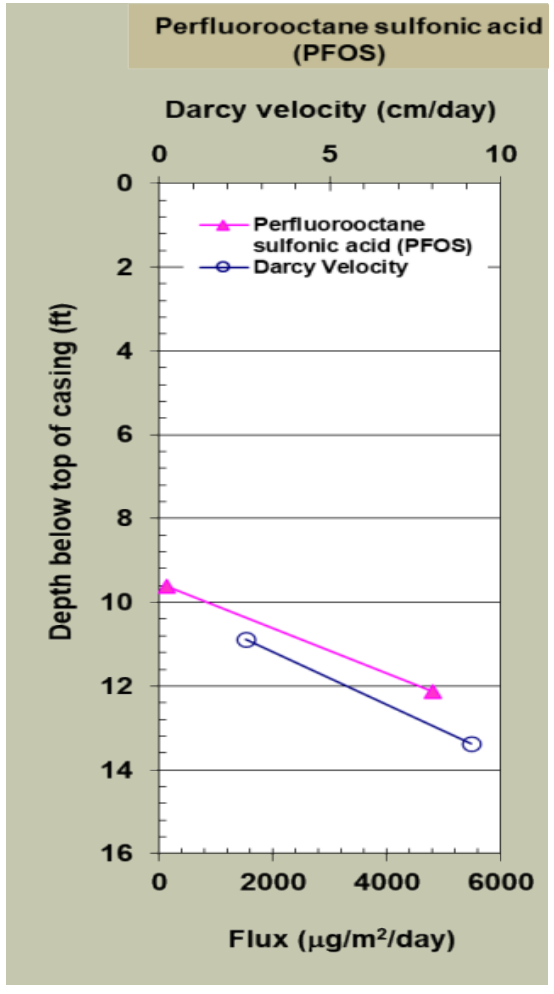


PHASE 1 OF PFM STUDY

M14–22



M14–28



MONITORING WELL TRANSECTS

Three Transects

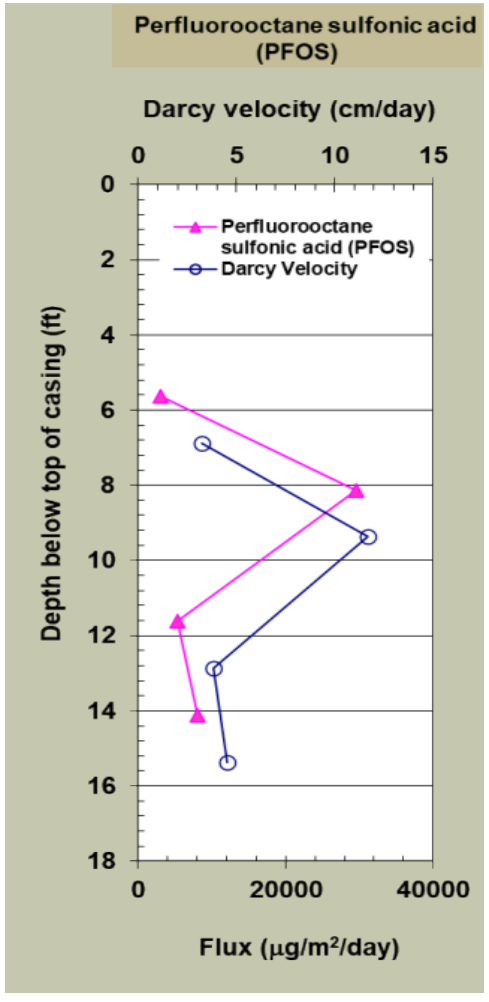
- West
- Middle
- East

Three Well Sets

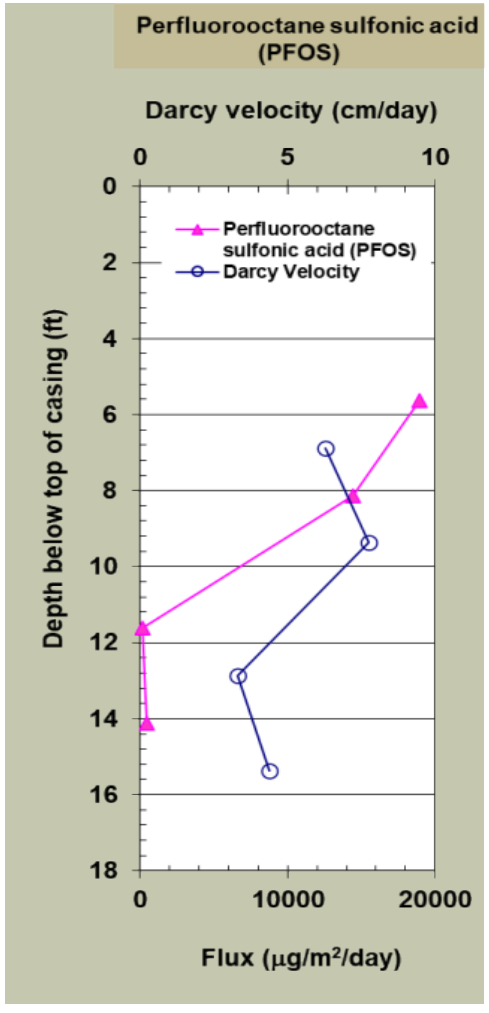
- Upgradient: paired shallow and deep wells
  - Shallow: 5–10 ft below ground surface (bgs)
  - Deep: 11–16 ft bgs
- In Barrier: paired shallow and deep wells
  - Shallow: 5–10 ft bgs
  - Deep: 11–16 ft bgs
- Downgradient: pre-existing shallow well
  - 9–14 ft bgs

PHASE 2 OF PFM STUDY

M14–37S/D



M14–41S/D



DESIGN OF CAC PERMEABLE BARRIER

Barrier Wall Overview

- 720-ft
- Two lines of injection borings parallel to the shoreline

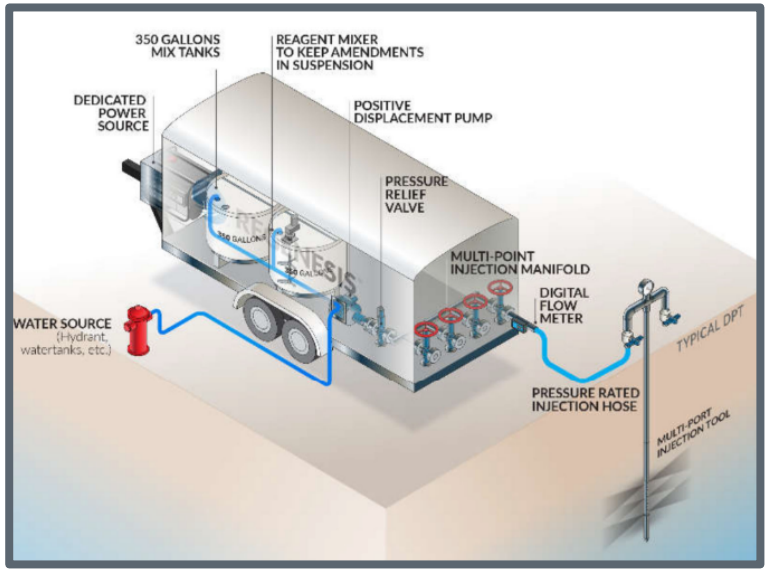
Injection Overview

- Target Zone: 1–16 ft bgs
- Varying doses of CAC injected into each boring, depending on PFAS levels (2.5%, 5.0%, and 7.5%)

INJECTION EQUIPMENT

Injection Equipment

- Two injection trailers and two direct push rigs to optimize time in the field
- Two 300-gallon mixing tanks per injection trailer
- Injection hoses
- Flow meters
- Electronic pressure gauges



CAC INJECTIONS

Equipment

- Two direct push rigs
- Advance rods to 16-ft depth
- 3-ft perforated injection tool

Injection Technique

- Bottom-up technique
- Five 3-ft injection intervals per boring

Injection Production

- Completed up to 12 injection points per day
- Injected on average, 3,500–4,500 gallons each day

REAL TIME INJECTION EVALUATION

Soil Cores

- Collected cores to 16 ft bgs
- Darker colors correspond to higher CAC concentrations

Groundwater Parameters

- Conductivity
- Oxidation reduction potential

SITE MANAGEMENT

Totes

- 170 totes of CAC used
- Each tote holds 222 gallons (2,000 pounds)
- Full-time effort to constantly relocate totes using forklift

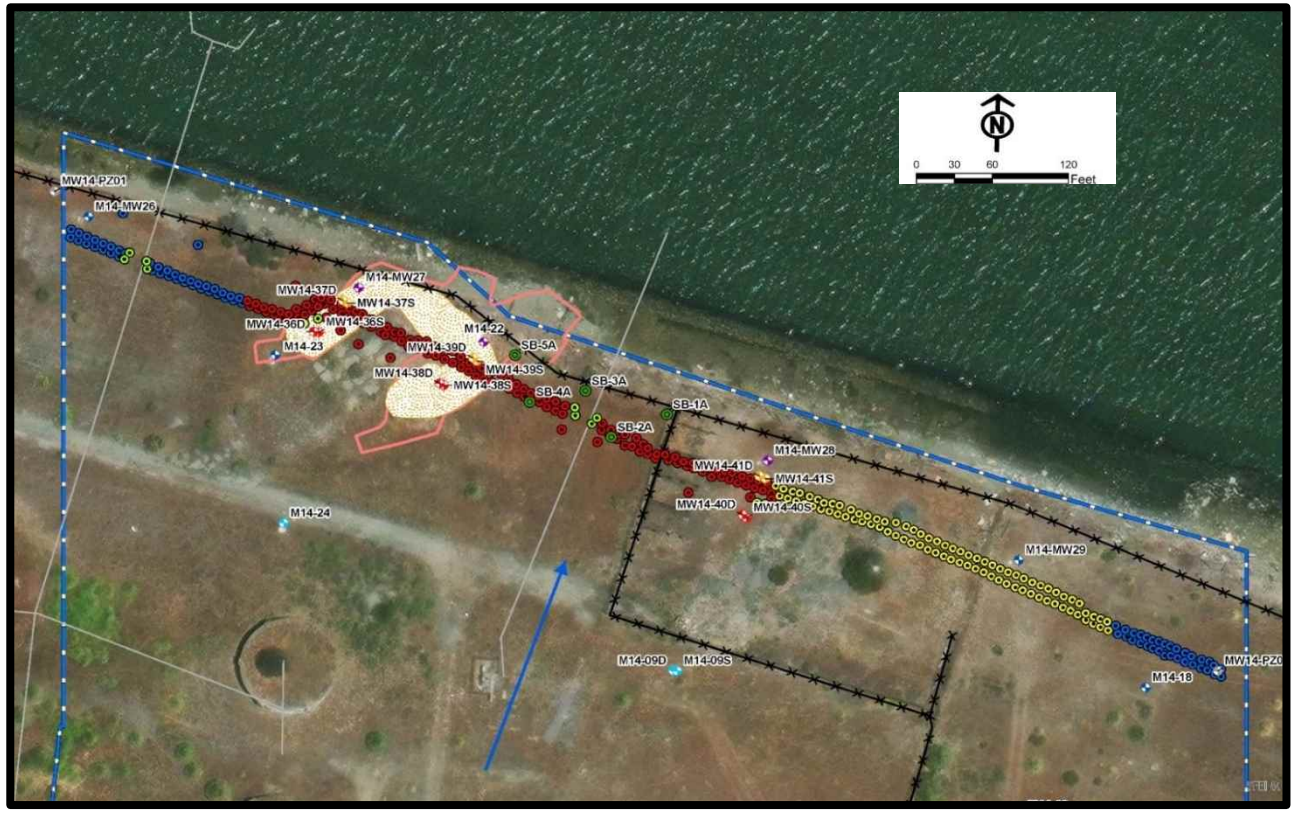
CAC Surfacing

- Surfacing was observed at some injection points
- Conducted shoreline monitoring to verify CAC did not discharge into Oakland Inner Harbor from the injection points or the stormwater outfall
- No CAC was discharged to the Harbor

FINAL CAC BARRIER LOCATION

CAC Barrier Details

- Injected on average, 3,500–4,500 gallons per day
- 720 foot long barrier
- 278 direct push borings
- Two parallel rows of injections
- Used calcium chloride to break the colloid and prevent CAC from entering the existing sewer lines



$CaCl_2$ Injection Location

2.5% CAC Injection Location

5.0% CAC Injection Location

7.5% CAC Injection Location

GROUNDWATER SAMPLING

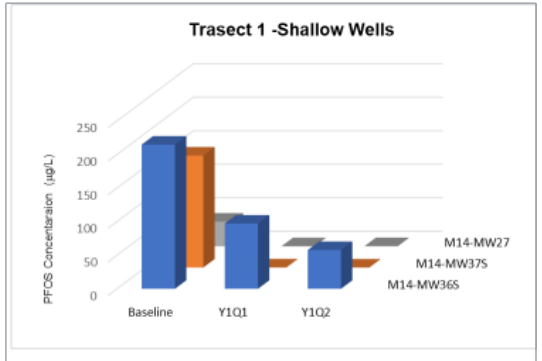
Quarterly Sampling

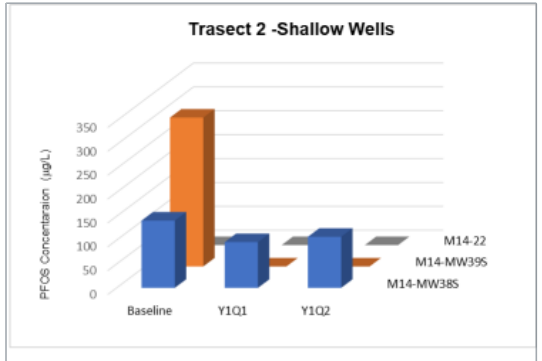
- Sampling 18 wells
- All transect wells
- Cross gradient wells

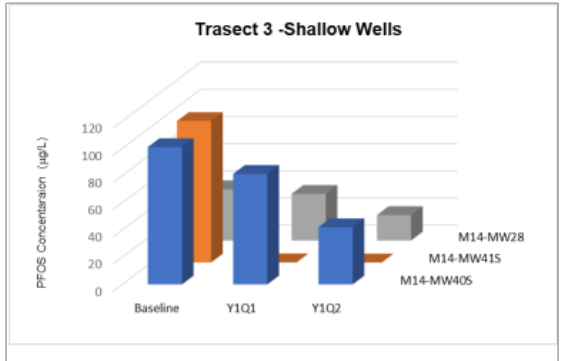
CAC Observed in Samples

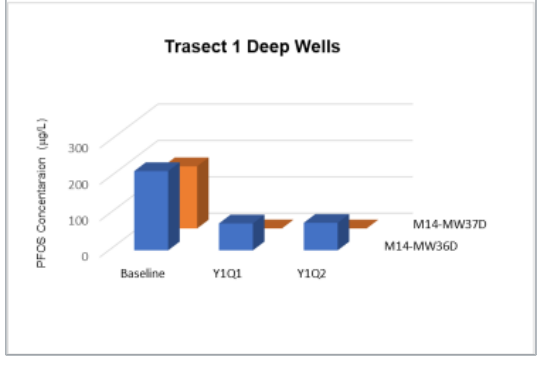
- Primarily in-barrier wells
- CAC was not observed in downgradient wells
- Samples were centrifuged in analytical laboratory

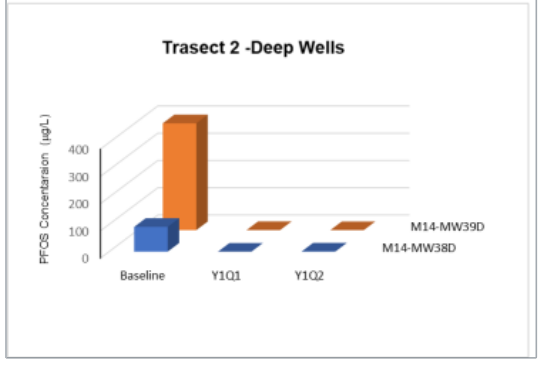
PFOS REDUCTIONS

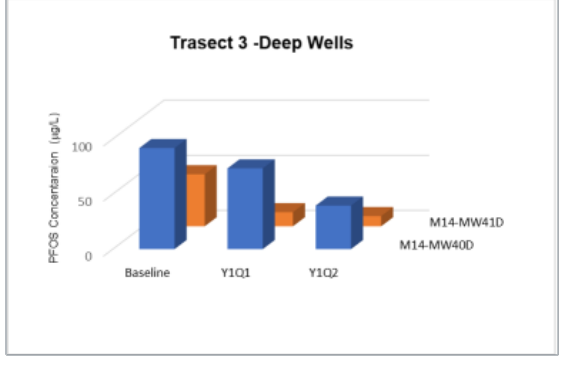












POST-TREATMENT ANALYTICAL RESULTS: TRANSECT 1

Transect 1																
	Location	Upgradient - Shallow					Mid Barrier - Shallow					Downgradient				
		M14-MW36S					M14-MW37S					M14-MW27				
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	04/20/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)
	Event	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2		
PFPES	µg/L	2.86	1.25	0.669	56.3	76.6	4.37	0.2	0.04	95.4	99.1	6.52	0.0165	0.0705	99.7	98.9
PFBS	µg/L	1.68	0.738	0.495	56.1	70.5	2.41	0.1	0.02	95.9	99.2	5.93	0.245	0.438	95.9	92.6
PFBA	µg/L	1.57	0.976	0.737	37.8	53.1	1.89	0.344	0.191	81.8	89.9	3.84	2.44	1.96	36.5	49.0
PFOSA	µg/L	6.37	1.74	1.69	72.7	73.5	5.39	0.1	0.02	98.1	99.6	4.62	0.015	0.02	99.7	99.6
PFOS	µg/L	215	97.3	57.9	54.7	73.1	167	0.14	0.0091	99.9	100.0	36.7	0.015	0.186	100.0	99.5
PFOA	µg/L	73.5	26.2	17.3	64.4	76.5	99.7	0.0873	0.01	99.9	100.0	247	0.0445	0.491	100.0	99.8
PFPA	µg/L	5.13	2.44	1.72	52.4	66.5	6.43	0.1	0.0337	98.4	99.5	9.48	4.41	5.35	53.5	43.6
	Location	Upgradient - Deep					Mid Barrier - Deep									
		M14-MW36D					M14-MW37D									
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)					
	Evemt	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2							
PFPES	µg/L	2.94	2.44	1.78	17.0	39.5	3.73	0.2	0.04	94.6	98.9					
PFBS	µg/L	1.49	1.09	1.02	26.8	31.5	2.67	0.1	0.0083	96.3	99.7					
PFBA	µg/L	1.58	1.49	1.45	5.7	8.2	1.99	0.726	0.714	63.5	64.1					
PFOSA	µg/L	6.31	0.754	1.05	88.1	83.4	4.8	0.1	0.0089	97.9	99.8					
PFOS	µg/L	218	74.1	75.8	66.0	65.2	171	0.417	0.0255	99.8	100.0					
PFOA	µg/L	77.4	59.1	70.8	23.6	8.5	123	0.118	0.01	99.9	100.0					
PFPA	µg/L	5.33	5.34	5.65	0.2	6.0	6.89	0.445	0.342	93.5	95.0					

*Green shading indicates a reduction in concentration greater than 90%.

POST-TREATMENT ANALYTICAL RESULTS: TRANSECT 2

Transect 2																
	Location	Upgradient - Shallow					Mid Barrier - Shallow					Downgradient				
		M14-MW38S					M14-MW39S					M14-22				
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	04/21/23	10/23/23	01/23/24	Percent Difference (Quarter)	Percent Difference (Quarter 2)
	Event	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2		
PFPES	µg/L	2.94	2.37	2.01	19.4	31.6	4.86	0.2	0.043	95.9	99.1	5.86	3.87	1.34	34.0	77.1
PFBS	µg/L	1.81	1.29	1.1	28.7	39.2	3.12	0.1	0.021	96.8	99.3	3.6	2.53	1.24	29.7	65.6
PFBA	µg/L	5.31	3.6	2.29	32.2	56.9	3.7	0.478	0.502	87.1	86.4	3.4	3.04	1.83	10.6	46.2
PFOSA	µg/L	5.97	1.02	1.71	82.9	71.4	4.29	0.1	0.0127	97.7	99.7	3.73	3.68	2.7	1.3	27.6
PFOS	µg/L	141	95.9	107	32.0	24.1	312	0.0543	0.0255	100.0	100.0	153	195	108	27.5	29.4
PFOA	µg/L	126	91.4	95.5	27.5	24.2	282	0.0306	0.0153	100.0	100.0	152	139	38.7	8.6	74.5
PFPA	µg/L	23.2	13.6	9.41	41.4	59.4	15.4	0.0688	0.106	99.6	99.3	12.3	10.4	4.15	15.4	66.3
	Location	Upgradient - Deep					Mid Barrier - Deep									
		M14-MW38D					M14-MW39D									
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)					
	Evemt	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2							
PFPES	µg/L	3.13	0.067	0.122	97.9	96.1	5.07	0.2	0.042	96.1	99.2					
PFBS	µg/L	1.71	0.033	0.24	98.1	86.0	2.97	0.1	0.0113	96.6	99.6					
PFBA	µg/L	3.04	1.66	1.02	45.4	66.4	3.91	0.867	0.812	77.8	79.2					
PFOSA	µg/L	1.17	0.033	0.02	97.2	98.3	4.57	0.1	0.0243	97.8	99.5					
PFOS	µg/L	90.9	0.0183	0.761	100.0	99.2	392	0.232	0.049	99.9	100.0					
PFOA	µg/L	143	0.031	2.71	100.0	98.1	260	0.129	0.0183	100.0	100.0					
PFPA	µg/L	12.9	1.02	3.57	92.1	72.3	15.5	0.0984	0.638	99.4	95.9					

*Green shading indicates a reduction in concentration greater than 90%.

POST-TREATMENT ANALYTICAL RESULTS: TRANSECT 3

Transect 3																
	Location	Upgradient - Shallow					Mid Barrier - Shallow					Downgradient				
		M14-MW40S					M14-MW41S					M14-MW28				
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	04/20/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)
	Event	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2		
PFPES	µg/L	3.69	5.18	1.5	40.4	59.3	5.38	0.2	0.043	96.3	99.2	6.82	4.9	0.562	28.2	91.8
PFBS	µg/L	2.84	2.96	1.17	4.2	58.8	4.32	0.1	0.021	97.7	99.5	5.98	3.41	0.54	43.0	91.0
PFBA	µg/L	1.74	2.54	0.836	46.0	52.0	2.24	0.2	0.115	91.1	94.9	3.93	2.46	0.401	37.4	89.8
PFOSA	µg/L	7.97	5.09	4.74	36.1	40.5	5.83	0.1	0.021	98.3	99.6	4.83	2.63	1.5	45.5	68.9
PFOS	µg/L	101	81.3	42.1	19.5	58.3	104	0.1	0.021	99.9	100.0	37.7	34.3	18.7	9.0	50.4
PFOA	µg/L	230	169	67.6	26.5	70.6	307	0.162	0.0323	99.9	100.0	252	168	27.4	33.3	89.1
PFPA	µg/L	4.63	6.61	2.27	42.8	51.0	6.95	0.1	0.0125	98.6	99.8	9.82	6	0.914	38.9	90.7
	Location	Upgradient - Deep					Mid Barrier - Deep									
		M14-MW40D					M14-MW41D									
Analyte	Date	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)	06/05/23	10/23/23	01/23/24	Percent Difference (Quarter 1)	Percent Difference (Quarter 2)					
	Evemt	Baseline	Year 1 Quarter 1	Year 1 Quarter 2			Baseline	Year 1 Quarter 1	Year 1 Quarter 2							
PFPES	µg/L	5.44	6.57	1.97	20.8	63.8	6.26	3.7	1.86	40.9	70.3					
PFBS	µg/L	4.44	3.68	1.63	17.1	63.3	6.21	4.2	2.06	32.4	66.8					
PFBA	µg/L	2.71	2.87	1.22	5.9	55.0	3.6	3.12	1.73	13.3	51.9					
PFOSA	µg/L	22.3	9.43	6.5	57.7	70.9	3.36	0.594	0.727	82.3	78.4					
PFOS	µg/L	91.7	73.3	39.5	20.1	56.9	47.2	12.8	9.26	72.9	80.4					
PFOA	µg/L	230	227	90.4	1.3	60.7	301	115	69.3	61.8	77.0					
PFPA	µg/L	6.21	7.2	3.05	15.9	50.9	9.82	7.3	3.53	25.7	64.1					

*Green shading indicates a reduction in concentration greater than 90%.

UPCOMING POST-INJECTION ACTIVITIES

Conduct Groundwater Sampling

- July 2024: Year 1, Quarter 4
- October 2024: Year 2, Quarter 1

Install Phase 3 Passive Flux Meters

- October 2024: One Year Post-Injection

PROJECT TEAM

Aptim Federal Services

- Nels Johnson
- Paul Hatzinger
- Michael Lightner

Bayside Engineering Construction

- Abram Eloskof
- Sridhar Palakur
- Gary Cronk

Regenesis

- Craig Sandefur
- Daniel Nuñez

In Pursuit of Better.