Lessons Learned For Increasing PFAS Remediation Effectiveness

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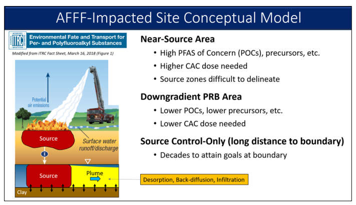
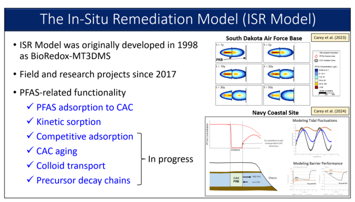
Introduction

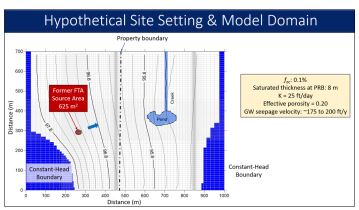
- Colloidal activated carbon (CAC) barriers are effective at sequestering PFAS in groundwater
- PFBS does not have an individual MCL, and thus may not need to be considered when designing CAC dose
- The relative additional costs and benefits for PFAS source control are not well understood for sites where a downgradient barrier is to be implemented

Methodology

1. Hypothetical site setting based on median PFAS at AFFF sites
2. Designed and costed a downgradient PlumeStop® PRB with target longevity of at least 30 years
3. Estimated costs for source control alternatives and modeled influence on longevity of downgradient PRB
   - Durable cover
   - Barrier wall around source area
   - In-Situ Soil Stabilization (ISS)

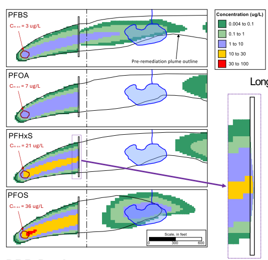






1 Design based on target longevity of at least 30 years

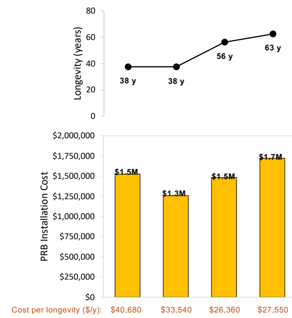
t=30 years after injection



PRB Design

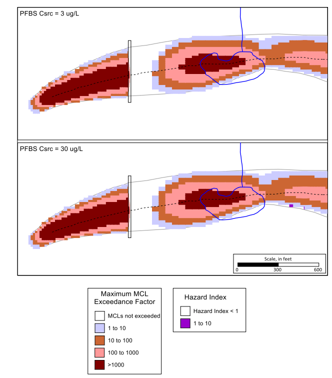
- 40 ft depth (27 ft below water table)
- 12 ft width
- f_{cac}=0.2%
- PFAS isotherms based on another site

2 Design conservatively when incremental cost is low

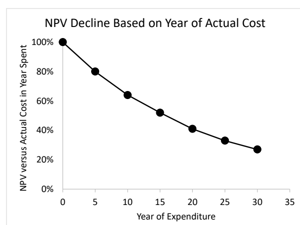


Design Parameter	Preliminary	Base Case	Conservative f_{cac}	Conservative Width
Plume Core				
f_{cac}	0.2%	0.2%	**0.3%**	0.2%
PRB width (ft)	12	12	12	**20**
Plume Fringes				
f_{cac}	0.2%	**0.1%**	0.1%	0.1%
PRB width (ft)	12	12	12	12

3 PFBS does not affect barrier performance



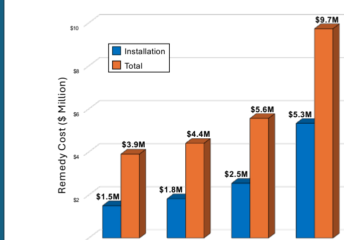
4 NPV Cost of CAC re-injection or treatment is low



Net present value (NPV) declines with year of expenditure.

Future CAC re-injection or treatment will have relatively low NPV compared to actual cost.

5 Little benefit from adding source control with a downgradient PRB in place



PRB CAC (%):	0.3 / 0.1	0.2 / 0.1	0.2 / 0.1	0.2 / 0.1
Source Control:	n/a	Cover	Wall + Cover	ISS
PRB Longevity (y):	56	43 to 57	>100	>100
Source Reduction:	n/a	20% to 50%	99%	99%

6 Models are needed for evaluating PFAS barrier design and cost

Model uses include:

- Predict CAC longevity
- Design CAC dose for PRB
- Evaluate integrated performance for multiple alternatives or implementation areas
- Assess performance at downgradient receptors

- PFAS-CAC batch tests with site groundwater may reduce longevity uncertainty.
  - SIREM offers this as a new service
- Plan for future CAC re-injection and/or treatment.
  - There are emerging technologies for potential in-situ treatment of spent CAC in the barrier, such as smoldering (see Savron ESTCP demonstration).

Attachment 1

Groundwater Flow Input Parameters	
Minimimum spacing in x-direction (m):	0.25
Maximum spacing in x-direction (m):	25
Minimimum spacing in y-direction (m):	5
Maximum spacing in y-direction (m):	15

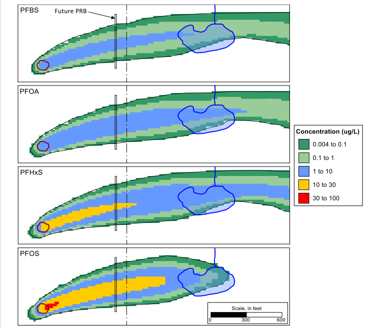
Groundwater Flow Input Parameters	
Hydraulic conductivity (m/day):	7.6
Hydraulic gradient at PRB (m/m):	0.0042
Effective Porosity (m^3/m^3):	0.20
Groundwater velocity at PRB (m/day):	0.16
Infiltration rate (mm/y):	50
Pond bed hydraulic conductivity (m/day):	0.003
Pond bed thickness (m):	1
Pond stage elevation (masl):	94
Streambed hydraulic conductivity (m/day):	0.1
Streambed thickness (m):	0.5
Stream stage elevation (masl):	94 to 95.5
Bottom elevation (masl):	80 to 95
Saturated Thickness at PRB (m):	8

Reactive Transport Input Parameters	
Longitudinal dispersivity (m):	4
Transverse dispersivity (m):	0.4
fraction of organic carbon, foc (g/g):	0.001
Soil dry bulk density (g/mL):	1.6

Solute	Koc (L/mg)	Kf $(mg/kg)(mg/L)^{-a}$	a (dim.)
PFBS	80	124	0.24
PFHxS	130	1240	0.24
PFOS	920	12000	0.33
PFOA	120	580	0.25

Attachment 2

Modeled pre-remediation plumes



Attachment 3

Basis of Cost Estimate (Scope and Assumptions) For PlumeStop to Treat PFAS in Groundwater:

Hypothetical Description: Downgradient in-situ zones amended with PlumeStop will be used to treat a PFAS plume.

Assume:
- CAC barrier is ~12 feet thick (3.6 m), injected with 0.2% fcac in core of plume and 0.1% in plume fringes
- CAC barrier saturated thickness is 8 meters; Length is 460 ft (140 m) in total (core=210 ft; total fringes=250 ft)
- Costs are relevant to 2023.

Other Assumptions Made:
- 18 Monitoring wells will be installed
- Quarterly monitoring for 1st 5 years, then annual monitoring. Assume Annual reporting each year.

Item	Qty	Unit	Unit Cost	Total
Construction Costs				
Well Installation: 18 Monitoring Wells				
Utility Locates	6	DAY	$1,500	$ 9,000
Hollow Stem Auger Mobilization	1	EA	$3,000	$ 3,000
Hollow Stem Well Install (Monitoring Wells, 2" PVC to 12 m bgs)	18	EA	$4,500	$ 81,000
Drilling Crew/Equipment	9	DAY	$2,600	$ 23,400
Drilling Oversight	9	DAY	$1,800	$ 16,200
Roll-Off Box/Rental	3	WEEK	$500	$ 1,500
Roll-Off Cuttings Disposal (Haz)	3	EA	$2,000	$ 6,000
Soil waste characterization - TCLP VOCs and metals	6	EA	$1,000	$ 6,000
Permits	1	EA	$5,000	$ 5,000
Well Install Subtotal				$ 151,100
Plumestop and Injection Cost f_{cac} = 0.2% (core) / 0.1% (fringes); L=12 ft				$ 1,258,000
Total Construction Costs				$ 1,409,100
Professional Services Costs				
Detailed Design, Work Plan, H&S Plan & Permitting	12%	of	$ 1,409,100	$ 169,092
Construction Management & As Built Report	8%	of	$ 1,409,100	$ 112,728
Health and Safety	2%	of	$ 1,409,100	$ 28,182
Project Management	6%	of	$ 1,409,100	$ 84,546
Professional Services Subtotal				$ 394,548
Contingency	30%	of	$ 1,803,648	$ 541,094
Construction Cost				**$ 2,340,000**
+50%				$ 3,510,000
-30%				$ 1,638,000
Annual Operations & Maintenance Costs				
Year 1-5:				
Quarterly Performance Monitoring - (Analytical for 18 MWs+QA/QC)	92	sample per year	$ 400	$ 36,800
Sampling Professional Time	28	day per year	$ 1,600	$ 45,400
Remedy Performance Data Analysis & Reporting	1	year	$ 50,000	$ 50,000
Annual O&M Subtotal (Year 1-5)				$ 132,200
Total O&M (Year 1-5)				$ 661,000
Year 6-30:				
Quarterly Performance Monitoring - (Analytical for 18 MWs+QA/QC)	23	sample per year	$ 400	$ 9,200
Sampling Professional Time	7	day per year	$ 1,600	$ 11,800
Remedy Performance Data Analysis & Reporting	1	year	$ 30,000	$ 30,000
Annual O&M Subtotal (Year 6-30)				$ 51,000
Total O&M (Year 6-30)				$ 1,275,000
Annual Cost (Year 1-5)				**$ 132,200**
+50%				$ 198,300
-30%				$ 92,540
Years	**5**			
Discount Rate	**4.5%**			
Annual Cost (Year 6-30)				**$ 51,000**
+50%				$ 76,500
-30%				$ 35,700
Years	**25**			
Discount Rate	**4.5%**			
Total O&M (30 years) no discounting				**$ 1,940,000**
+50%				$ 2,910,000
-30%				$ 1,358,000
Net Present Value (NPV) of Annual Costs over 30 Years				**$ 1,190,000**
+50%				$ 1,785,000
-30%				$ 833,000
Total Cost - Construction and Annual O&M				
Total: Construction + of Annual Costs over 30 Years				**$ 4,280,000**
+50%				$ 6,420,000
-30%				$ 2,996,000
Total: Construction + NPV of Annual Costs over 30 Years				**$ 3,530,000**
+50%				$ 5,295,000
-30%				$ 2,471,000

Costs are rough order of magnitude estimates, and assumed to represent the actual installed cost within a range of -30%/ +50% of the value indicated

EPA Guidance:
A GUIDE TO DEVELOPING AND DOCUMENTING COST ESTIMATES DURING THE FEASIBILITY STUDY--OSWER 9355.0-75, EPA 540-R-00-002