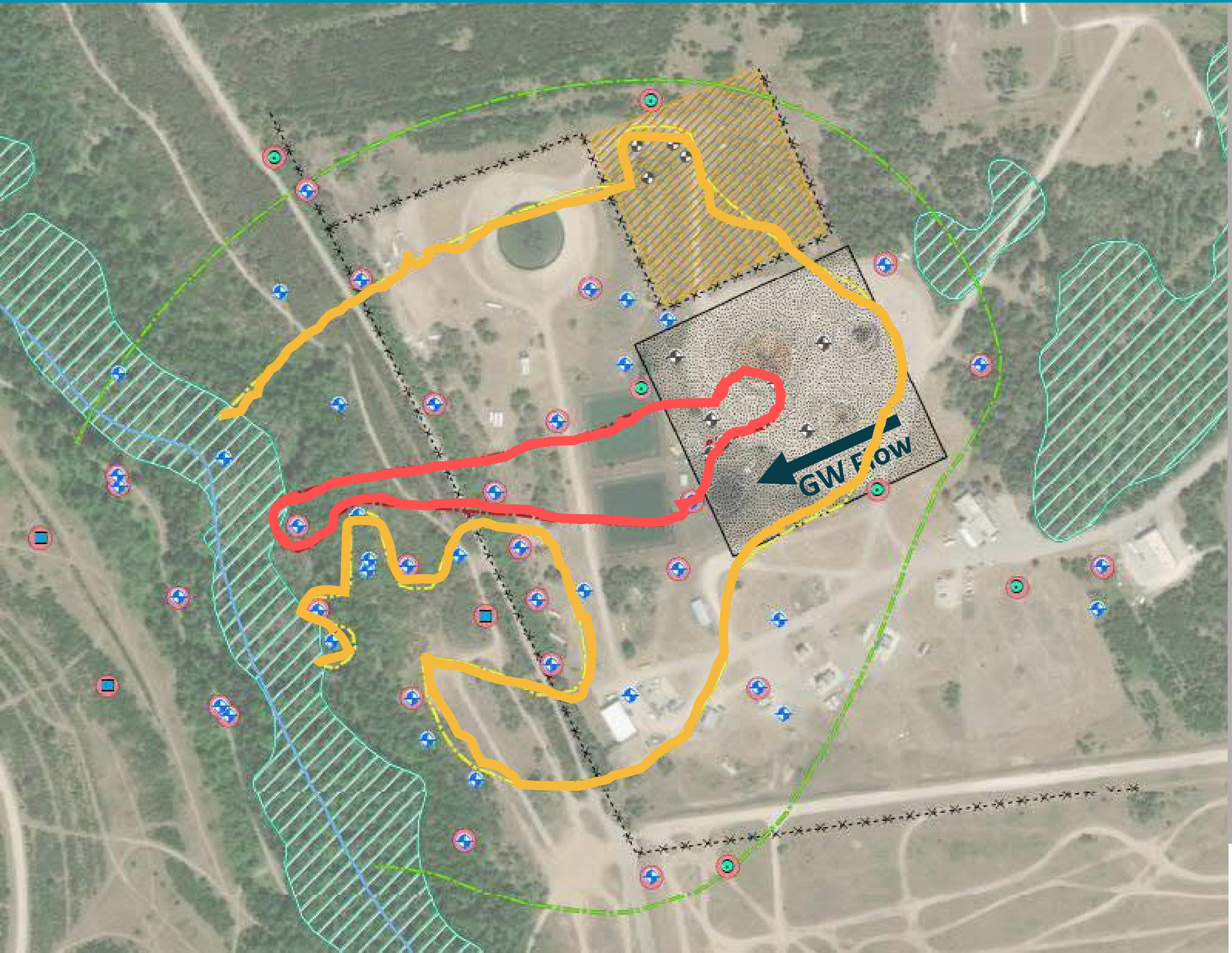
Lifecycle Cost-Effectiveness Analysis for PFAS Groundwater Remediation at CFB Borden

Andrew Thalheimer, P.Eng., *Dillon Consulting* (athalheimer@dillon.ca)
Paul Newman, PG, *ECT2* (panewman@ect2.com) *[in absentia; coming to the Dec 4 ESAA PFAS Symposium in Calgary]*

Site Characteristics / Nature and Extent of PFAS

Site Overview



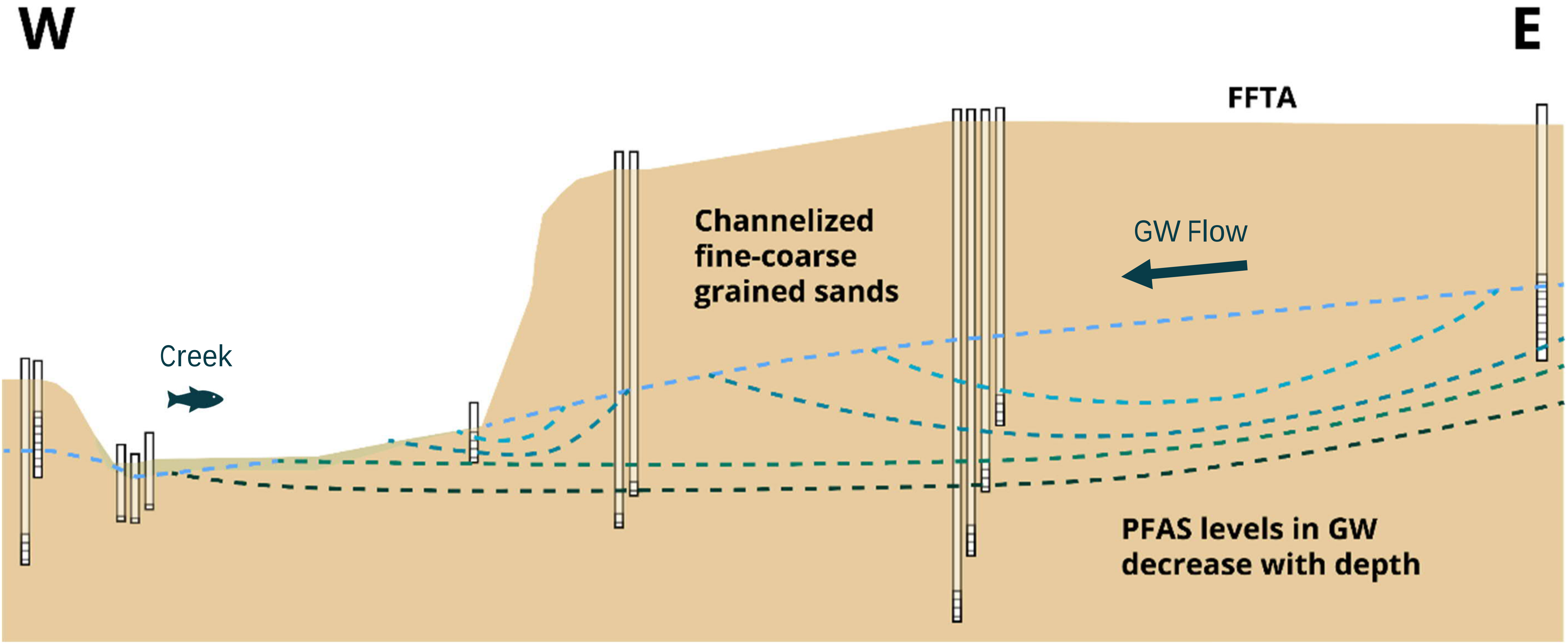
- FFTA – Used PFAS-containing AFFFs from 1950s to 2018
- COCs: PFAS, PHCs, VOCs/BTEX, PAHs and metals
- Impacted Media: soil, groundwater, and surface water

- Past assessments conceptualized a pump and treatment design to capture and control future migration of PFAS-impacted groundwater.

Montrose Environmental Group

DILLON CONSULTING

Environmental Setting



Montrose Environmental Group

DILLON CONSULTING

Problem Statement

Objectives/Priorities

Project Objective

- RFP/SOW: "There is no specific target concentration for the future groundwater remediation, therefore the objective is to *achieve maximum treatment in relation to Health Canada Drinking Water Screening Value derivatives of PFAS*."

Priorities

- Provide Hydraulic Capture of the PFAS Plume to reduce migration of PFAS-impacted groundwater to Bear Creek.
- Remove PFAS Mass.

Purpose of the LCA

Why the LCA?

- To identify what PFAS Treatment Technology would be most cost-beneficial relative to percent mass removal of the PFAS groundwater plume.

LCA "Assumptions"

- Total Mass is approximate and based on TOF Concentrations
- Mass reduction is based on PFAS mass in groundwater
- Focused on Identifying Preferred Treatment Technology
- Relative Comparison
  - Technology Advantages and Limitations
  - Capital Costing
  - Operational Costing
  - Overall Effectiveness
  - Remediation Time Frame
- Influence of Recirculation Not Considered
- Treatment Technology had to be commercially available in the market.

ect2 Montrose Environmental Group
DILLON CONSULTING

Data Gaps

- Supplemental Site Investigation Activities
  - Site Characterization
  - Delineation
  - Pumping Tests
- Hydrogeological and Numerical Modelling
- Field Pilot Test
- Rapid Small-Scale Column Testing

Bench and Field Pilot Methodology and Results

Pilot Test Objectives

Six-week pilot test commenced Oct 2023

Foam Fractionation:

- Foamate generation rate
- Surfactant addition
- Removal efficiency by PFAS species

Media Testing:

- Water volume treated to breakthrough
- IX with pretreatment media
- GAC treatment

Montrose Environmental Group

DILLON CONSULTING

Pilot Study: Treatment Approaches Evaluated

	Ion Exchange Media	GAC Media	Foam Fractionation
Removal Efficiency Short-Chain PFAS Long-Chain PFAS	 High High	 Low High	 Low High
Contact time (min)	2-3	10-15	10-30
Footprint	Small	Large	Medium
Disposal Volumes (& Considerations)	Moderate (Incineration / LF)	Large (Incineration / LF / Reactivation)	Low (Foamate)
Key Advantages	High capacity, short-chain capabilities	Tried and True	Minimal pre-treatment
Off-Ramp for Destruction	No	No	Yes
Notable Disadvantages	Wastes generated, virgin media prices	Wastes generated, virgin media prices	Short-chain issues

Pilot Study: Foam Fractionation Results (µg/L)

	6:2 FTS	8:2 FTS	PFBS	PFBA	PFHpA	PFHxS	PFHxA	PFNA	PFOS	PFOA	PFPeA	**Total PFAS**
HCDWSV	0.2	0.2	15	30	0.2	0.6	0.2	0.02	0.2	0.6	0.2	
Influent	95	2.6	0.3	0.9	1.1	8.8	5.9	0.1	110	2.0	3.9	230
Effluent	0.8	0.04	0.08	0.96	0.04	0.11	1.6	0.02	1.41	0.03	3.6	8.7
% Removal	99.2	98.5	74.3	-2.1	96.5	98.7	72.7	100	98.7	98.6	7.6	96

Takeaways:

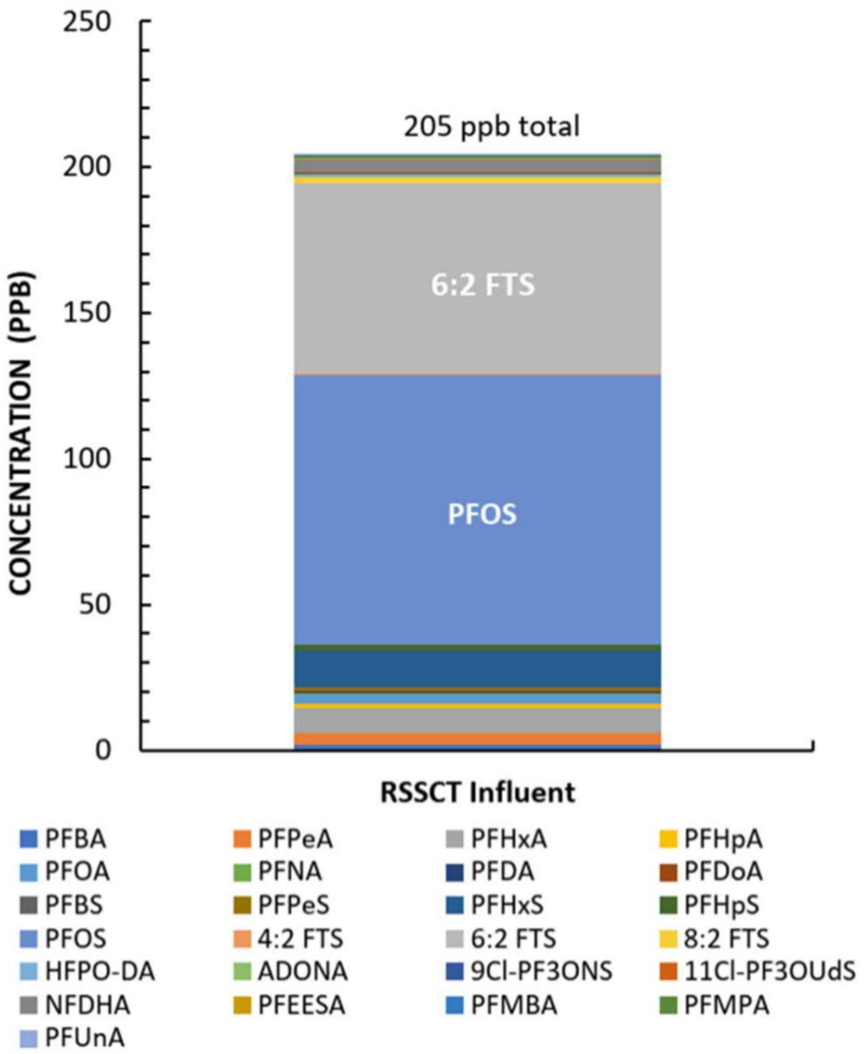
- Foam Fractionation can achieve excellent bulk PFAS removal (>96%)
- HC DWSV's reached for 7 of 11 screened species (8:2 FTS, PFBS, PFBA, PFHpA, PFHxS, PFNA, PFOA)
- Foam Fractionation did not measurably remove PFPeA

Containerized Pilot Unit

Foam Fractionation – 14 m3/hr

Media Columns – 29 m3/hr

Bench Study: Rapid Small-Scale Column Test (RSSCT)

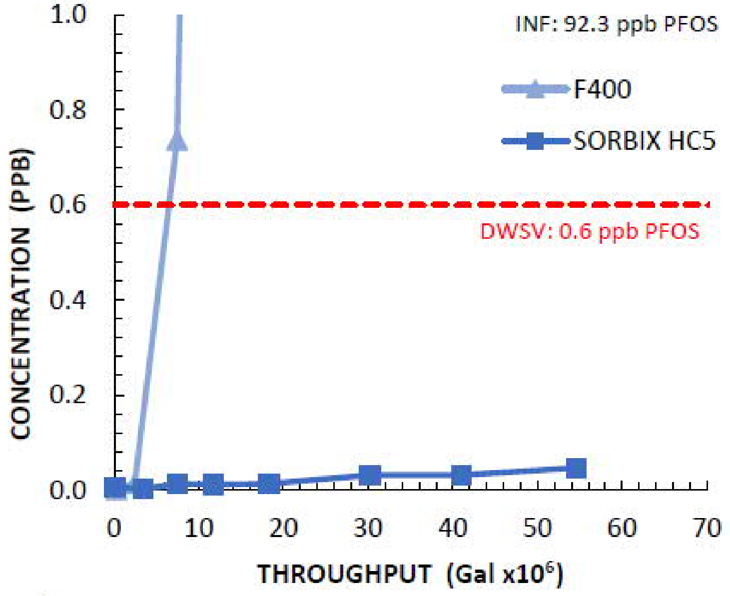


ect2 Montrose Environmental Group

DILLON CONSULTING

Bench Study: RSSCT Breakthrough Curves

PFOS

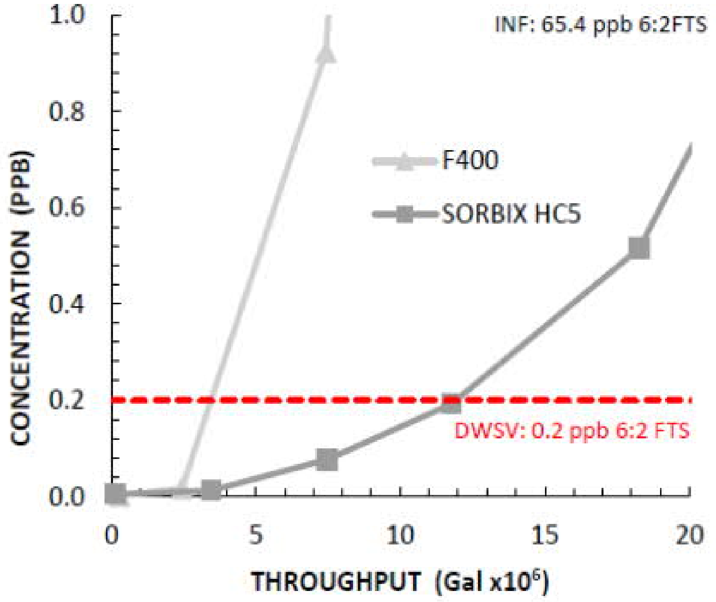


Breakthrough:

GAC: 4,986 BVs = 6.5 MG

IX: >140K BVs = > 55 MG

6:2 FTS

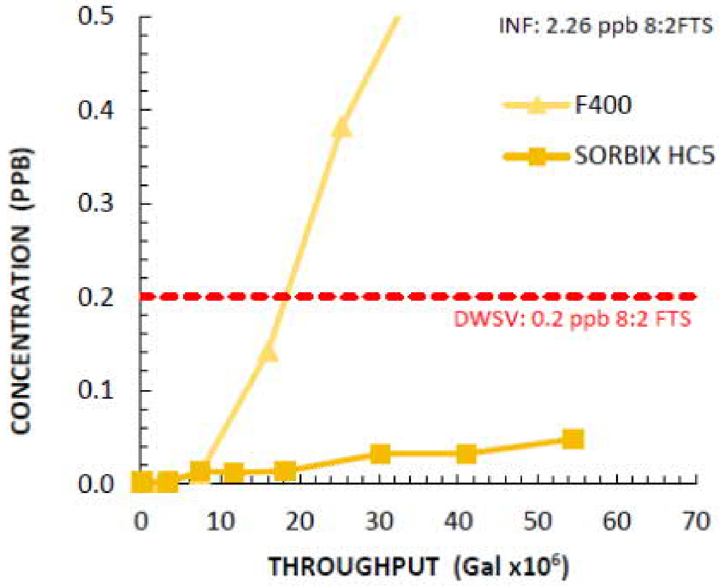


Breakthrough:

GAC: 2,656 BVs = 3.5 MG

IX: 30,608 BVs = 11.9 MG

8:2 FTS



Breakthrough:

GAC: 14,070 BVs = 18.3 MG

IX: > 139K BV = > 55 MG

Breakthrough = Exceedance of Health Canada DWSVs

Montrose Environmental Group

DILLON CONSULTING

Treatment Lifecycle Cost-effectiveness Analysis

Key Input Parameters

- Total PFAS Mass: 360 kg (based on TOF proxy)
- Average Influent Concentration: Initially 310 µg/L TOF (conservative, noting high variability). Accounts for changing concentrations over time using particle track analysis.

Influent Flow Rate(s):

- 725 m3/d [PFAS Mass Reduction]
- 75 m3/d [Capture and Control Future migration of PFAS-impacted groundwater]

Montrose Environmental Group

DILLON CONSULTING

Lifecycle Cost Inputs:

	Ion Exchange Media	GAC Media	Foam Fractionation
Capital Costs*			
Building	$350,000	$600,000	$2,150,000
Treatment System	$1,030,000	$1,160,000	$3,130,000
Site Works	$150,000	$150,000	$200,000
Total Capex (96% Removal – 725 m3/day)	$1,530,000	$1,910,000	$5,480,000
(90% Removal – 75 m3/day)	$918,000	$1,146,000	$3,288,000
Operational Costs (Annual)*			
Labour	$119,600	$119,600	$239,900
Power	$41,050	$41,050	$185,850
Media Replacement	$83,514	$167,846	$43,319
Media Disposal	$1,380	$7,600	$500
Total Opex (96% Removal – 725 m3/day)	$246,000	$337,000	$475,000
(90% Removal – 75 m3/day)	$49,200	$67,400	$95,000

** - Detail shown for 96% removal scenario*

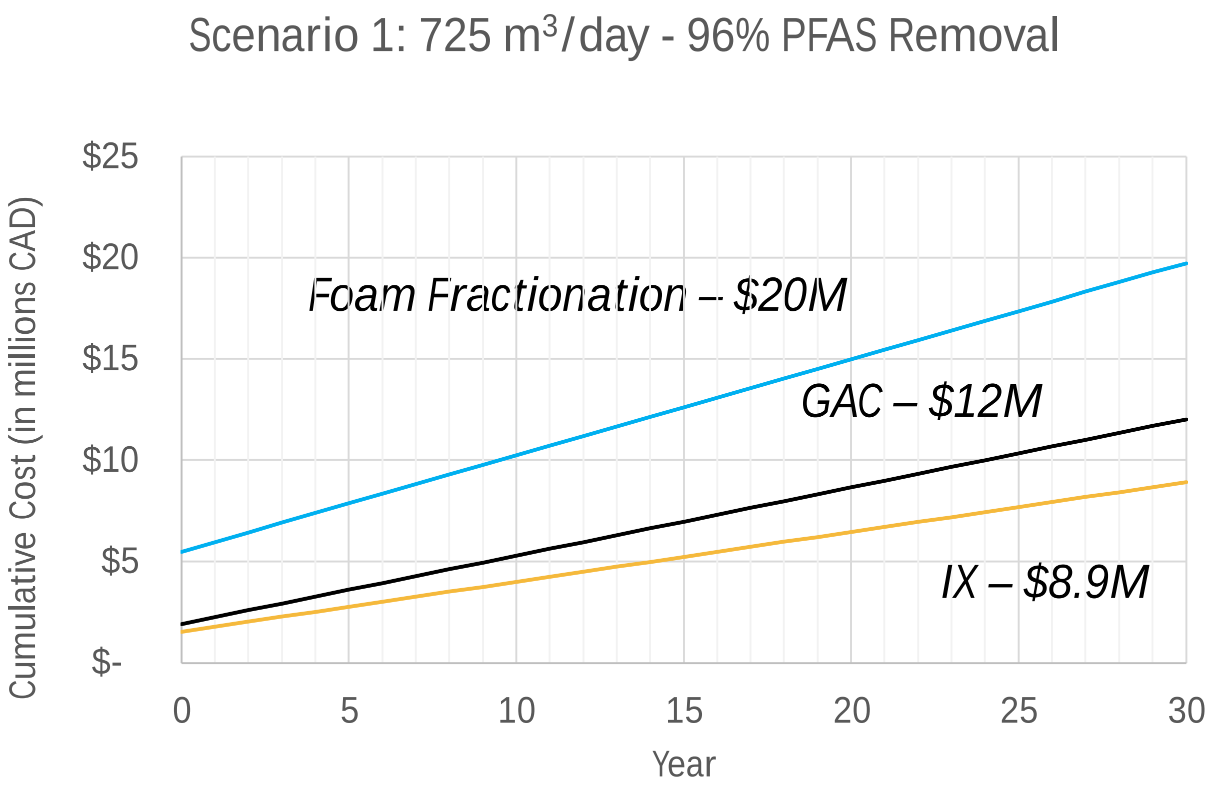
Lifecycle Cost Analysis: Full-Scale Treatment Approaches

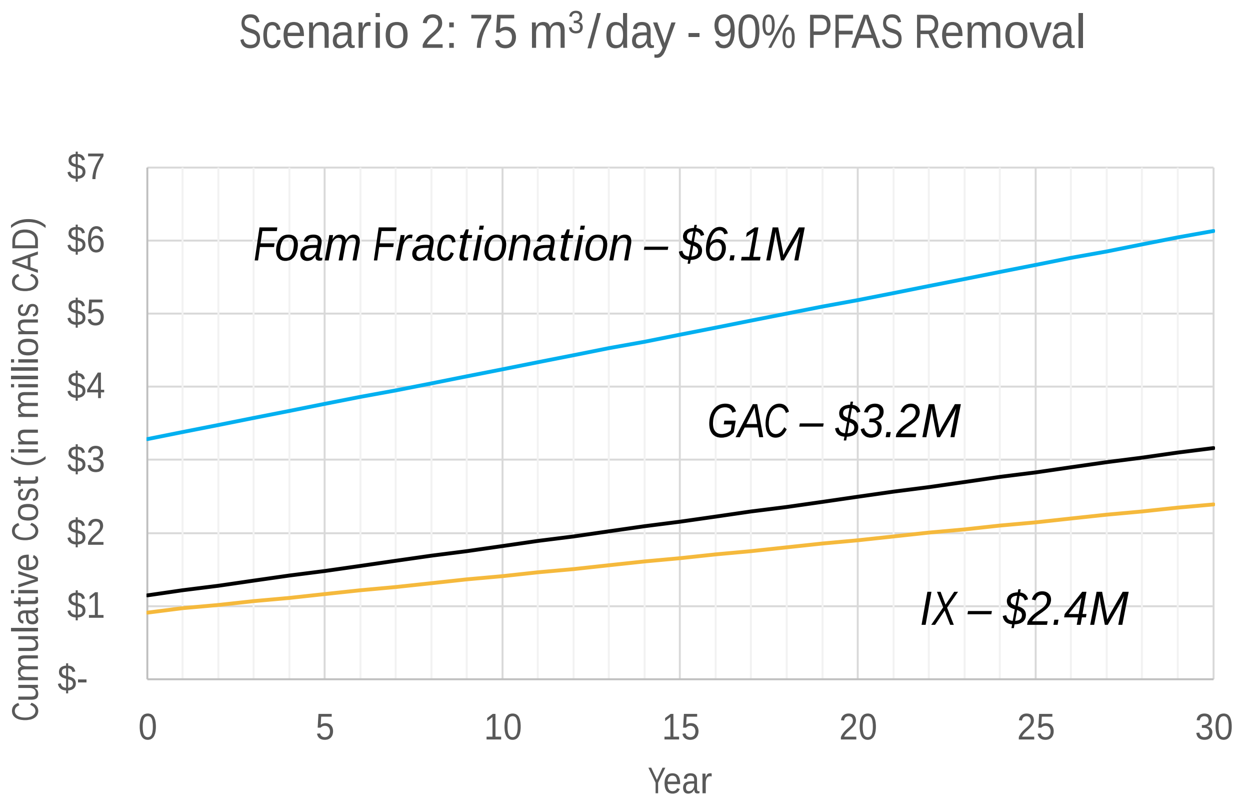
	Pretreatment	Treatment
IX Media	(3) 800L vessels in parallel	(2) 1,425L vessels in series – 3 min EBCT
GAC Media	(3) 800L vessels in parallel	(2) 7,000L vessels in series – 10 min EBCT
Foam Fractionation	(3) 800L vessels in parallel	(2) trains of (2) 8,000L 4 total vessels – 30 min HRT

ect2 Montrose Environmental Group

DILLON CONSULTING

Lifecycle Cost Analysis Results: 30-Year Basis

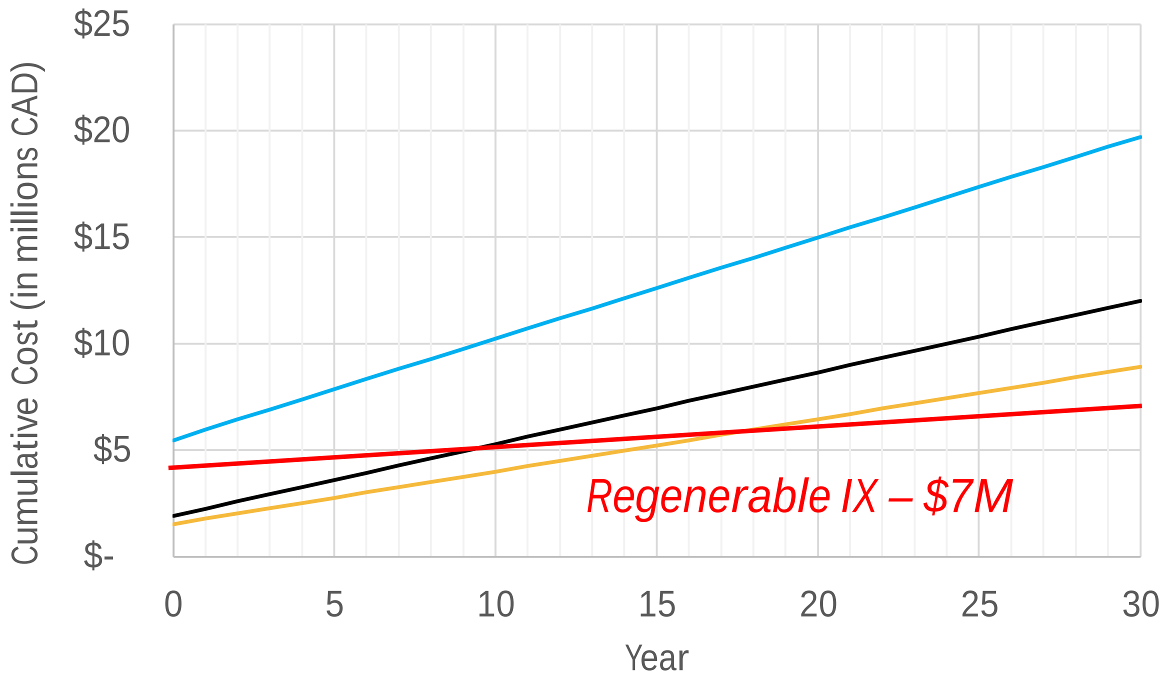




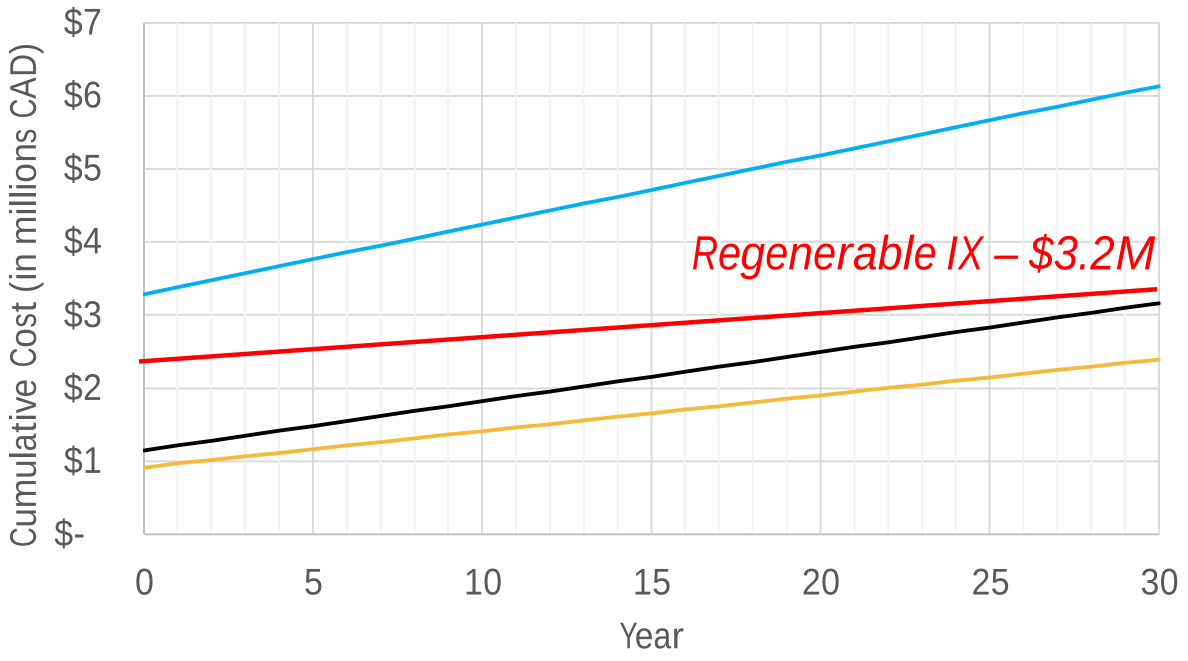
IX media treatment – lowest LCA

Lifecycle Cost Analysis Results: 30-Year Basis

Scenario 1: 725 m^3/day - 96% PFAS Removal



Scenario 2: 75 m^3/day - 90% PFAS Removal



Consider regenerable IX when:

- Stricter treatment targets (short-chain PFAS) increase media changeout frequency
- Destruction of waste desired
- Capital cost of regen plant can be defrayed over multiple sites

Holistic Lifecycle Cost-effectiveness Analysis Results

Scenarios Evaluated

Scenario 1: PFAS Mass Reduction Priority (High Flow)

- ◦ Objective: Maximize PFAS mass removal.
- ◦ Influent Flow Rate: 725 m^3/day
  (modeled cumulative flow from 6 wells, consistent with pilot study).
- ◦ Assumptions: Capital and operational costs sized for mass removal.

- Scenario 2: Contaminant Containment Priority (Low Flow)

- Objective: Capture and control future migration of PFAS-impacted groundwater.
- Influent Flow Rate: 75 m^3/day (conservative sustainable cumulative flow from 5 wells).
- Assumptions: Capital costs roughly 60% of Scenario 1; operational costs roughly 20% of Scenario 1 (due to less flow, reduced media changeouts, etc.).

Scenario 1: PFAS Mass Removal Priority

Scenario 1 (725 m³/d, PFAS Mass Removal Priority)

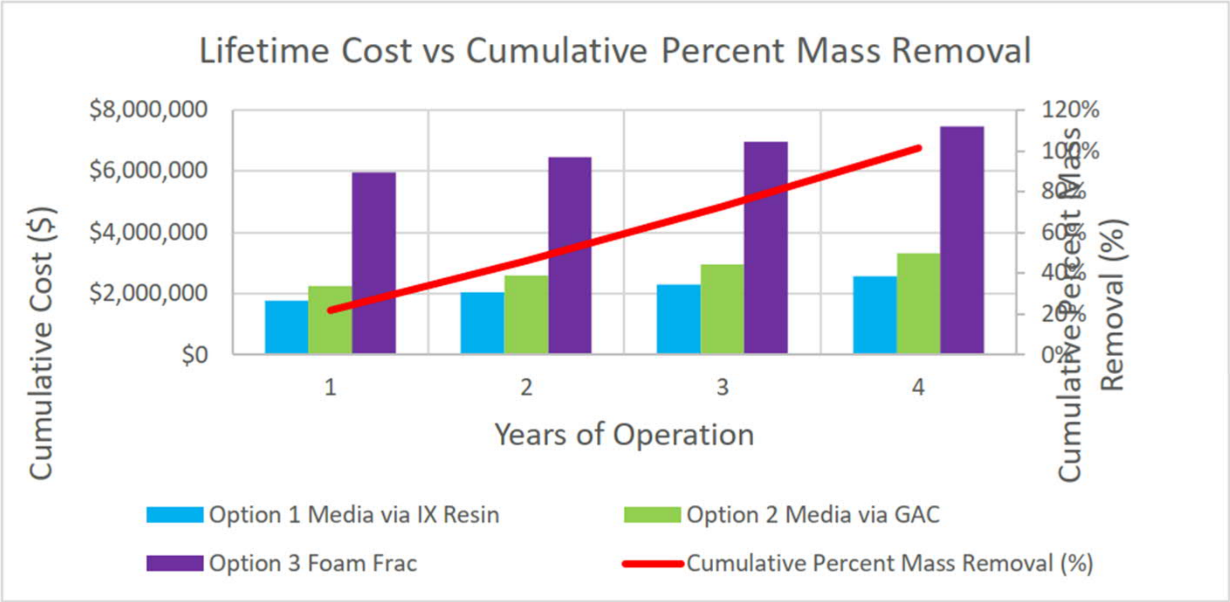


Figure 1 Lifetime Cost vs Cumulative Percent Mass Removal for all Options under Flow Scenario 1

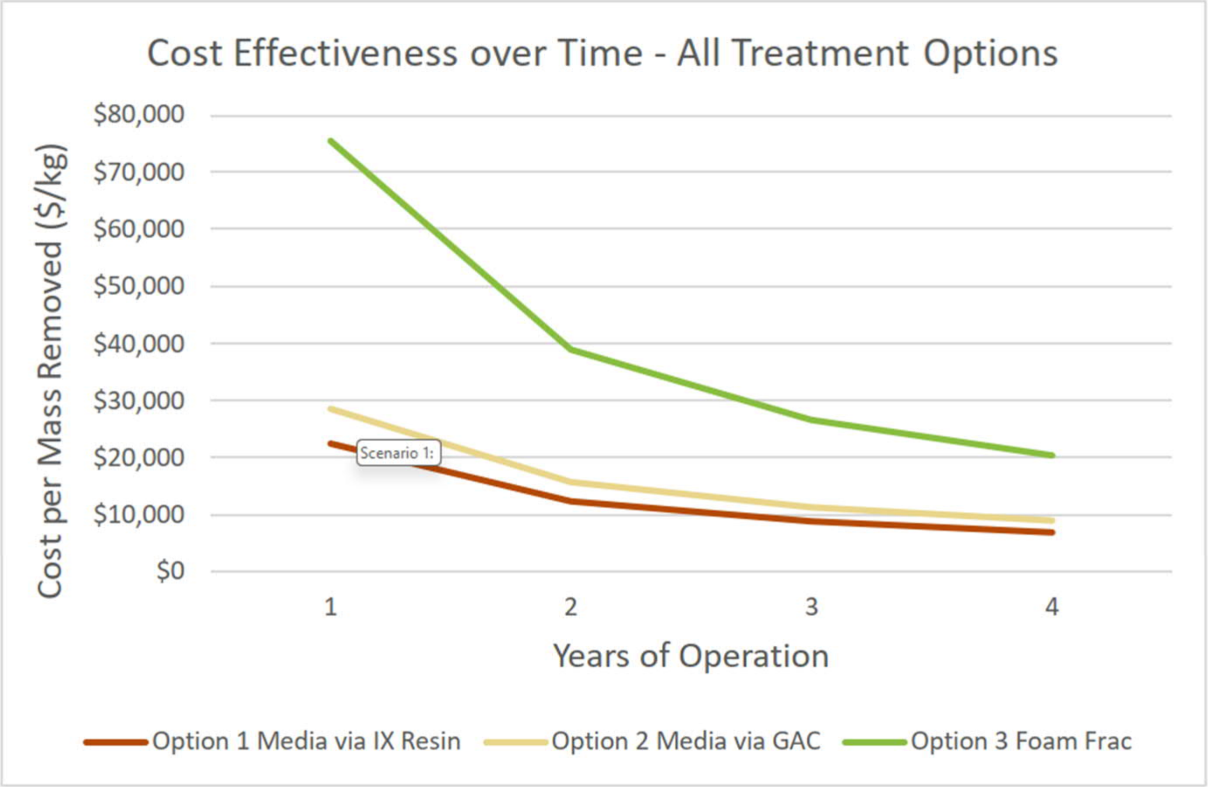


Figure 2 Cost Effectiveness over Time for all Options under Flow Scenario 1

Montrose Environmental Group

DILLON CONSULTING

Scenario 2: Capture and Migration Control

Scenario 2 (75 m³/d, Contaminant Containment Priority)

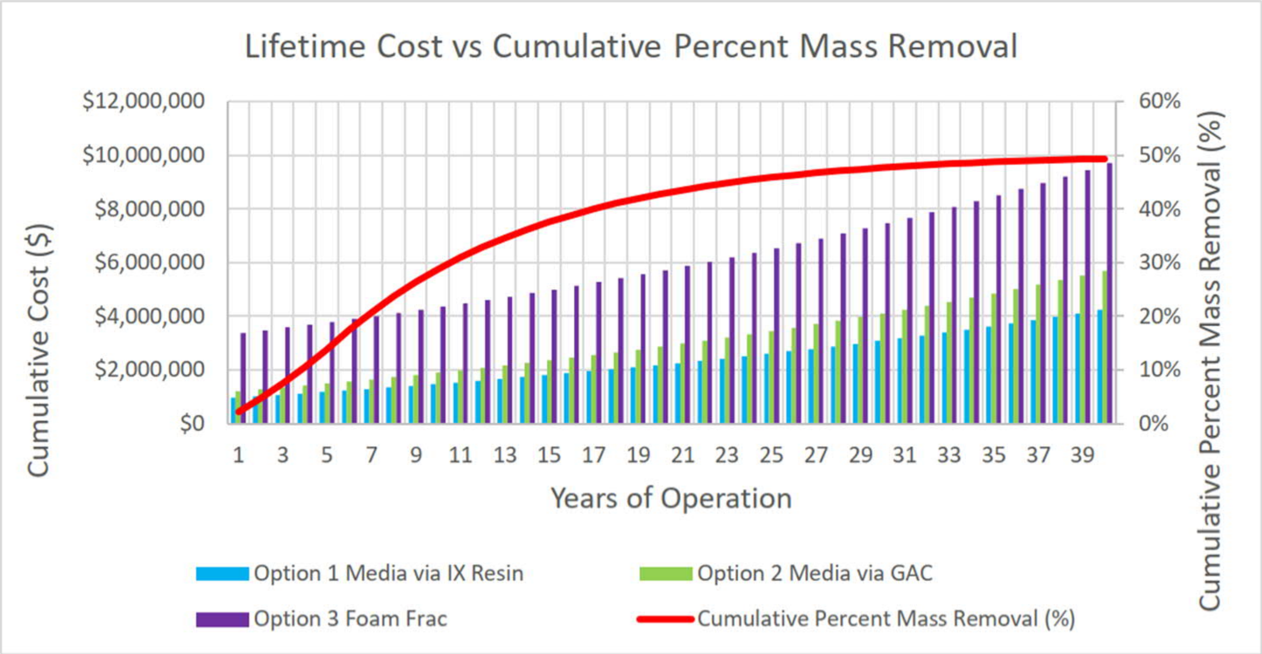


Figure 3 Lifetime Cost vs Cumulative Percent Mass Removal for all Options under Flow Scenario 2

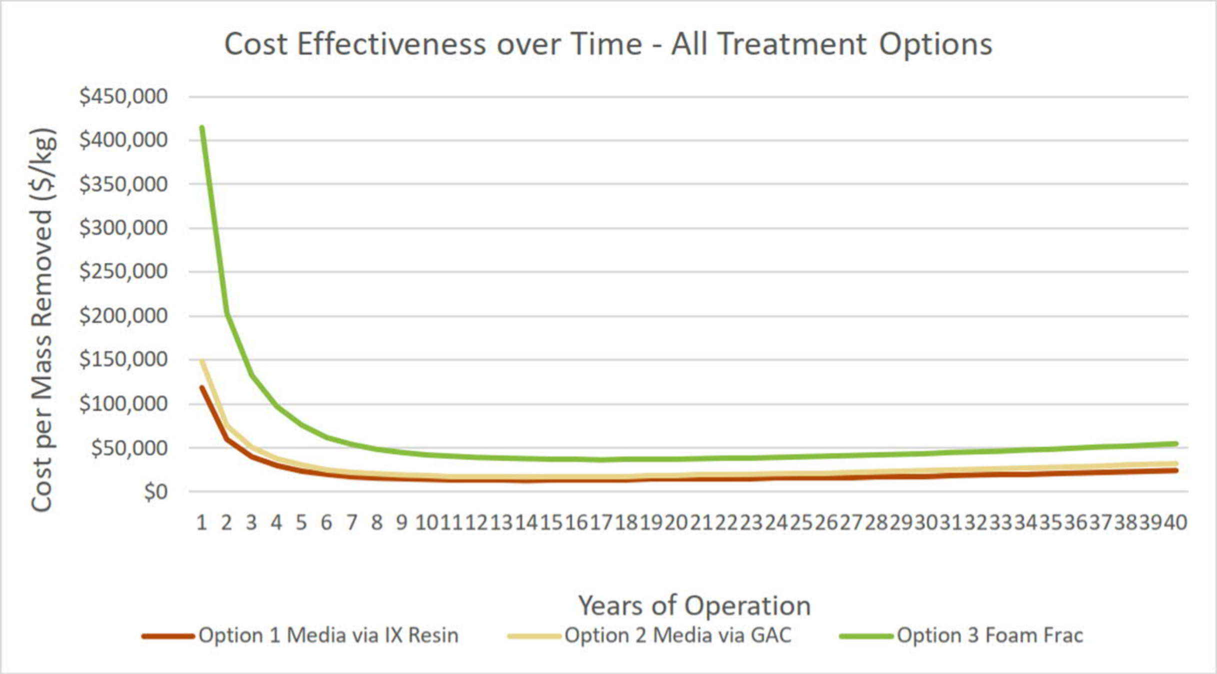


Figure 4 Cost Effectiveness over Time for all Options under Flow Scenario 1

Overall LCA Results: Cost-Effectiveness Summary

- Ion exchange resin is, relatively, the most cost-effective remedial treatment approach over time, regardless of the influent flow rate.
- Presuming sufficient and sustainable groundwater extraction (Scenario 1), greater than 90 percent mass reduction (of PFAS mass in groundwater) could be removed in 4 years.
- Under a conservative cumulative groundwater extraction rate (Scenario2), mass reduction will be limited over time, achieving no more than 50% reduction.
- Under Scenario 2, return on investment levels off after Year 6 (only after 20 percent of the mass has been removed).

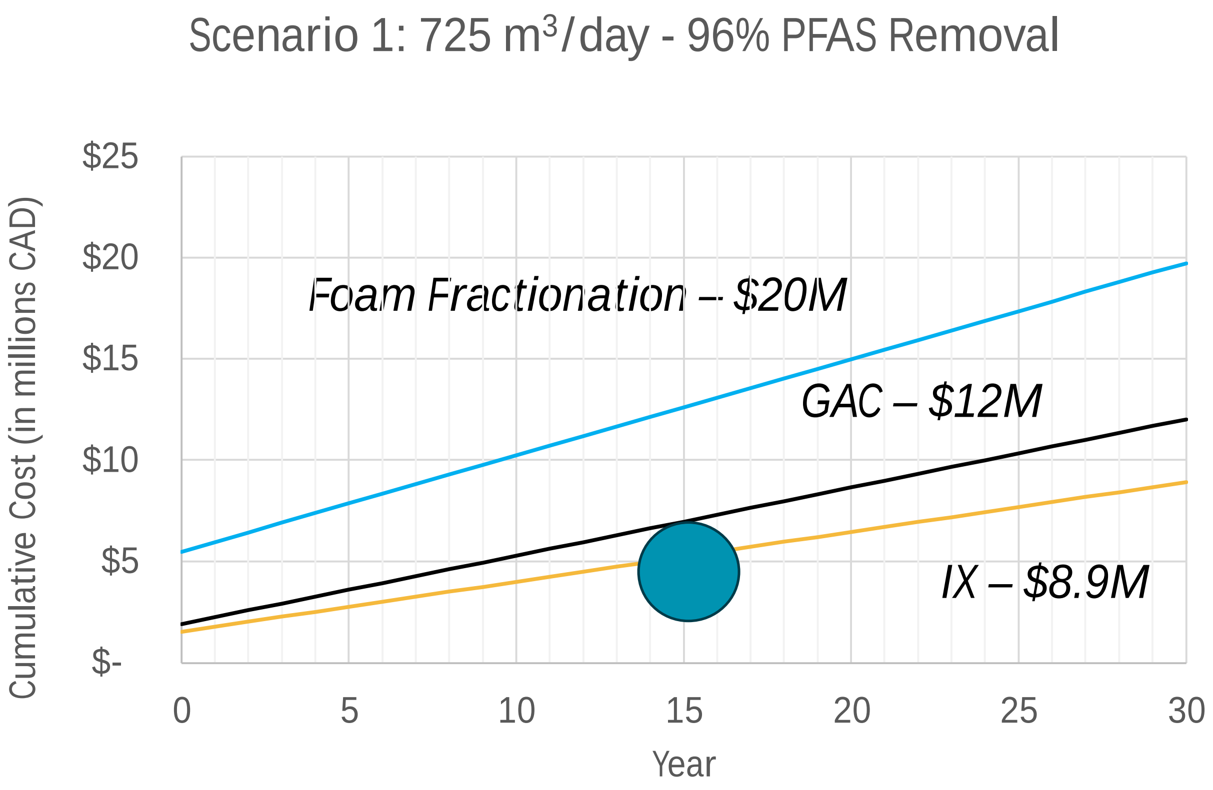
Implications for Full-Scale Treatment Design and Implementation

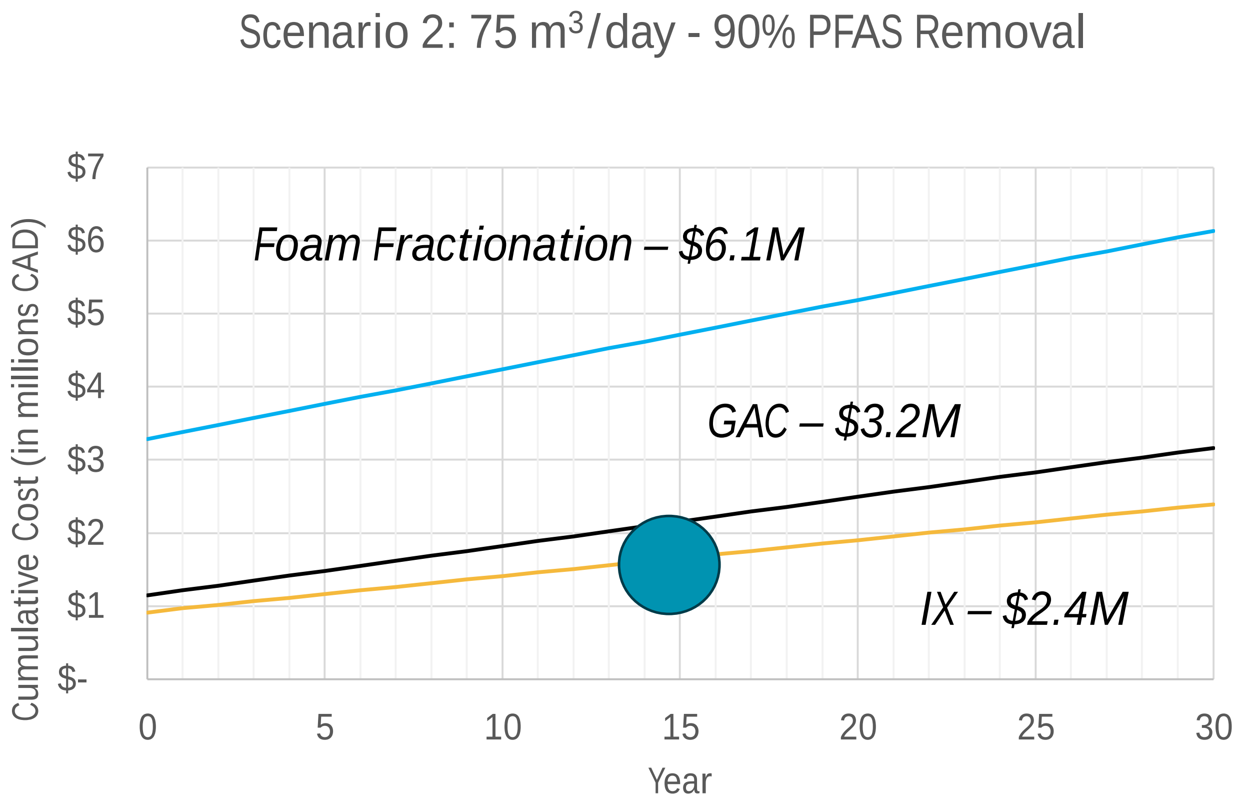
Full-Scale Treatment Design and Implementation Considerations

- Commercially Available Treatment Technology that can treat the groundwater
- Ion Exchange is the most cost-effective remediation approach.
- Cost-Effectiveness Driven by Extraction Flow Rate
- Benefit of Capital Investment in Groundwater Extraction System

DILLON CONSULTING

ROI





Cost Saving Overtime re Capital Investment for Extraction System

ect2 Montrose Environmental Group
DILLON CONSULTING

Thank you!!

Andrew H Thalheimer, P.Eng. MBA
Partner, Contaminated Site Management Leader
Dillon Consulting Limited
athalheimer@dillon.ca
902.476.5590