Sustainable PFAS Remediation: Comparing the Environmental Impact of Enhanced Attenuation using Colloidal Activated Carbon to Pump and Treat

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E2 #244

Per- and Polyfluoroalkyl Substances

Widely used

- Commercial and domestic products/coatings

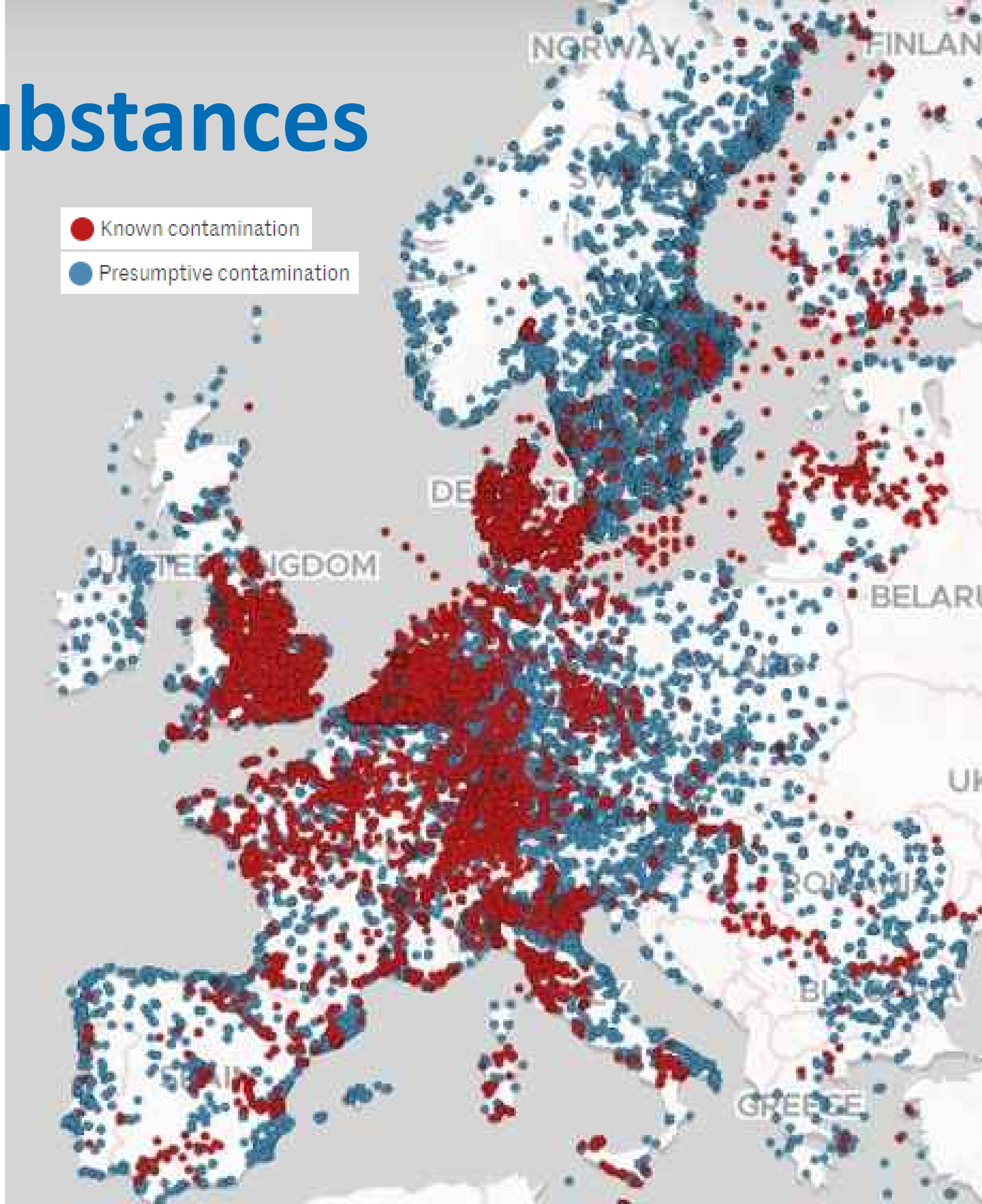
Regularly spilled

- Aqueous Film Forming Foams

Challenging contaminant behaviour

- Retained in soils for decades
- Very mobile once in groundwater
- Recalcitrant to degradation
- Toxic at low concentrations
- Large, very dilute plumes
- Impacting large areas

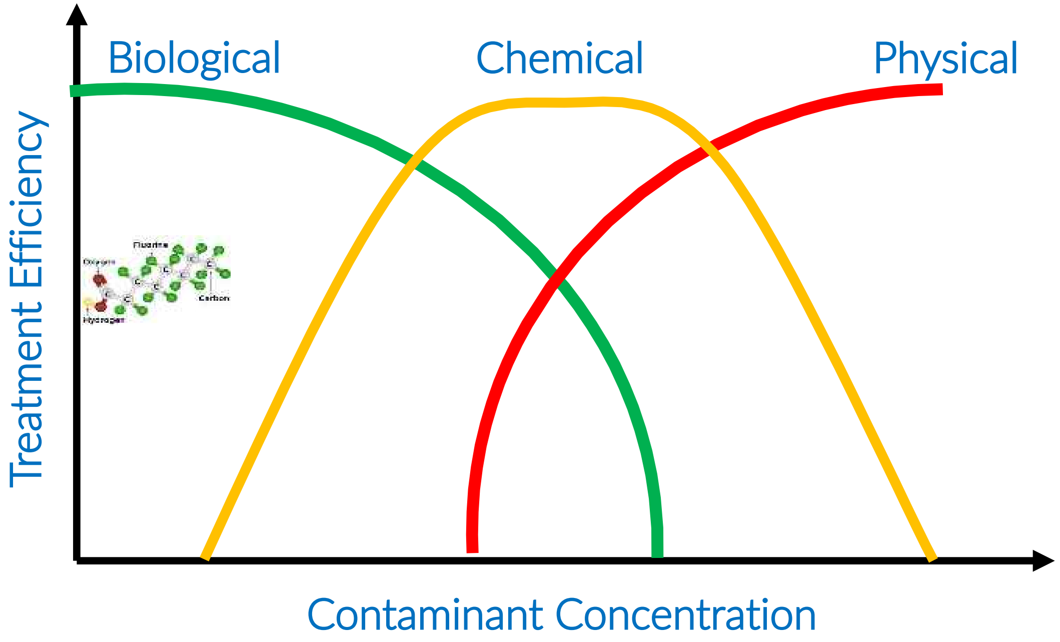
And so…PFAS are EVERYWHERE



https://www.lemonde.fr/en/les-decodeurs/article/2023/02/23/forever-pollution-explore-the-map-of-europe-s-pfas-contamination_6016905_8.html

How can we treat PFAS?

Removal and destruction, right?

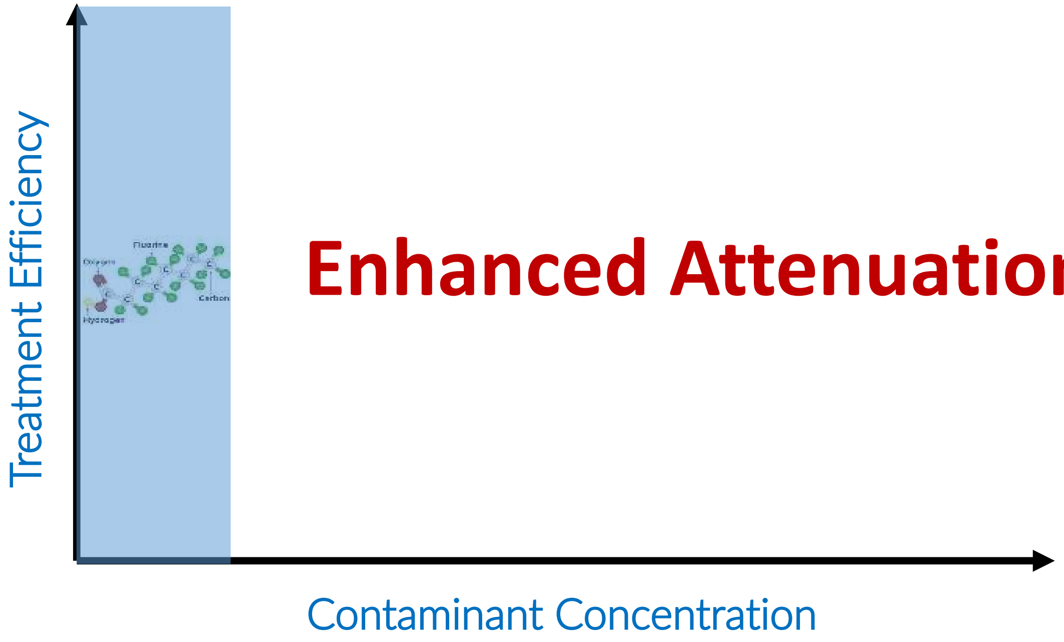


Pumping huge volumes, Landfill, Energy, Equipment, Transport, Cost

High ongoing carbon footprint

How should we treat PFAS?

Adopt a sustainable remediation approach



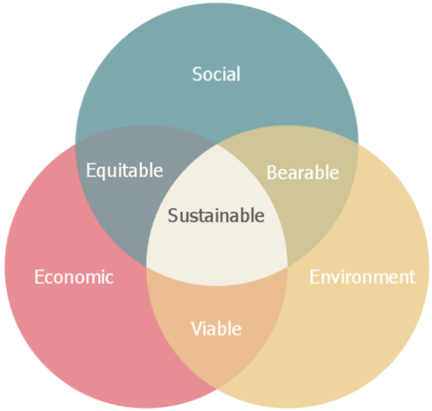
(ISO 18504:2017) definition:

Sustainable Remediation is the

*'elimination and/or **control** of unacceptable **risks** in a safe and timely manner **whilst***

optimizing the environmental, social and economic value

of the work.'



Pumping huge volumes, Landfill, Energy, Equipment, Transport, Cost

High ongoing carbon footprint

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Enhanced Attenuation of PFAS?!

But PFAS don't biodegrade?

Natural Attenuation ***doesn't*** just mean biological degradation:

- Diffusion
- Dispersion
- Volatilisation
- Sorption
- Chemical (abiotic) degradation

Increase the ability of the aquifer to sorb PFAS
'Retention'
=**Enhanced Attenuation** of the PFAS plume

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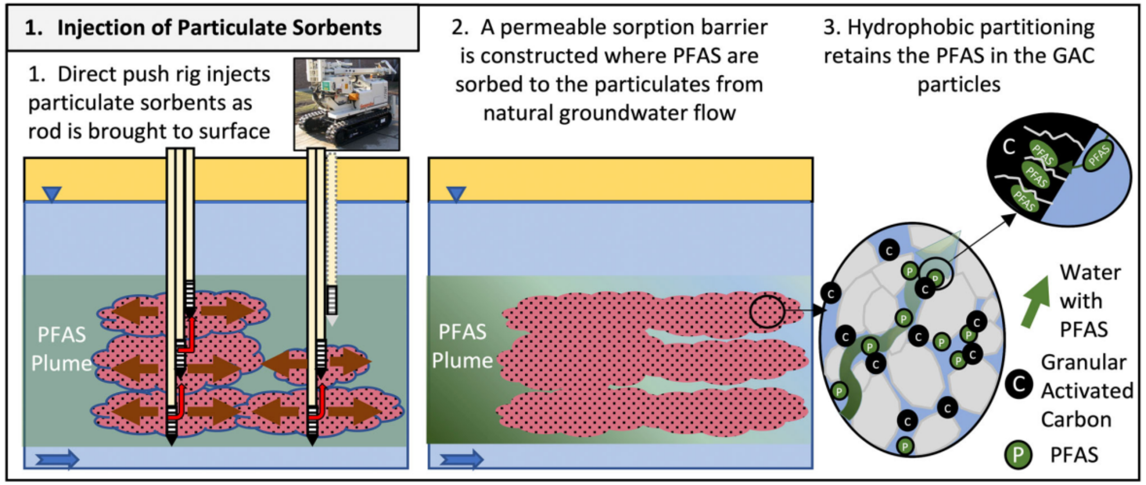
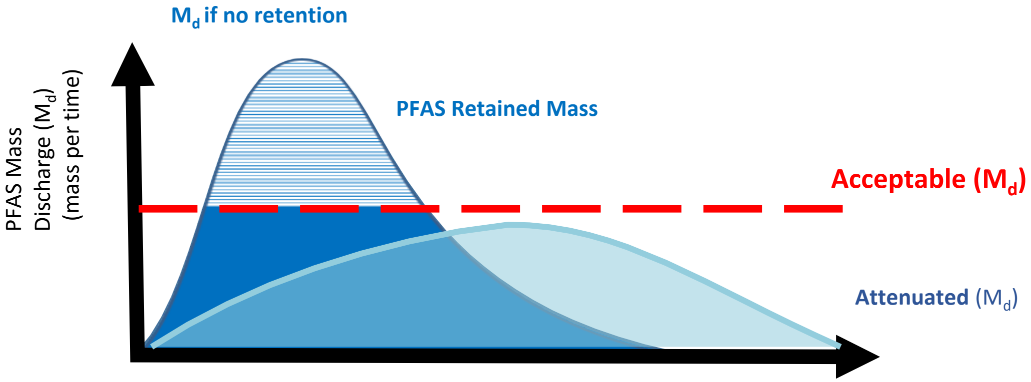
RESEARCH NOTE

WILEY

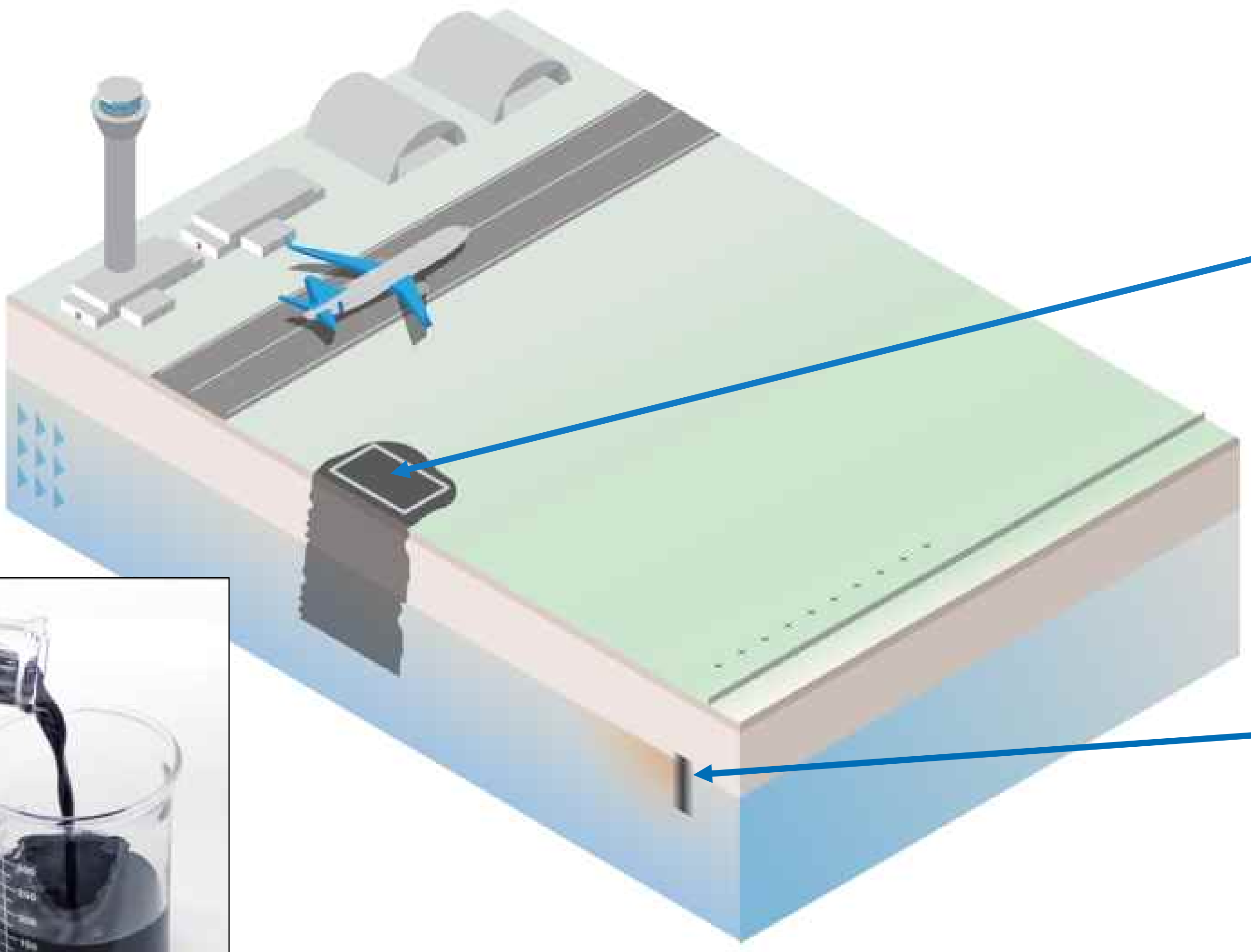
Enhanced attenuation (EA) to manage PFAS plumes in groundwater

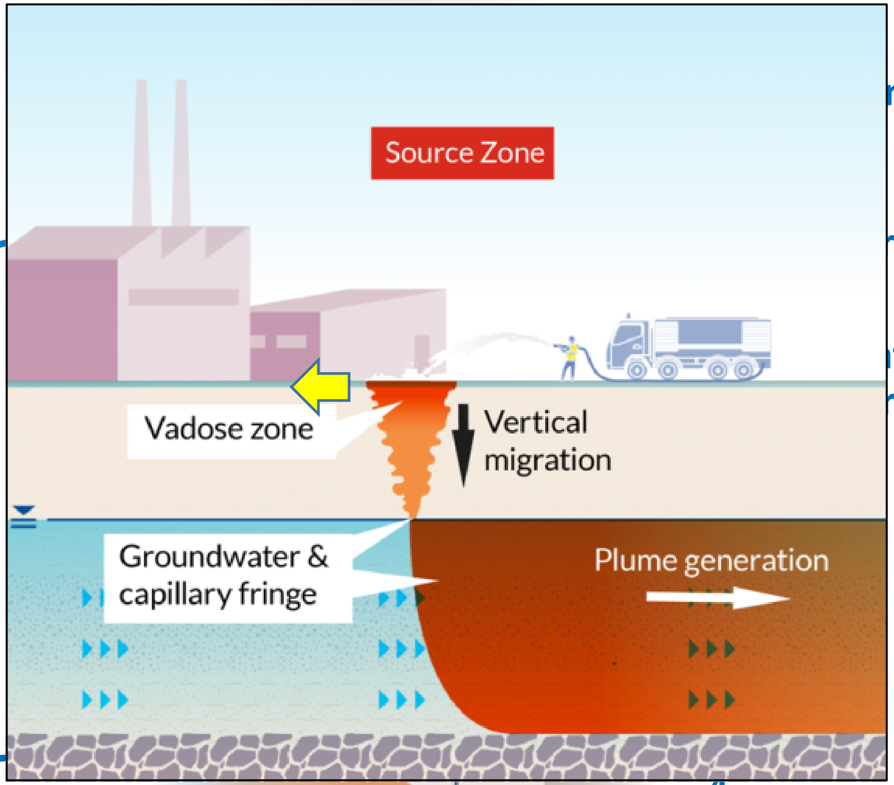
Charles J. Newell[1] | Hassan Javed[1] | Yue Li[1] | Nicholas W. Johnson[2] | Stephen D. Richardson[3] | John A. Connor[1] | David T. Adamson[1]





Considering the PFAS Source-Plume system





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4. Groundwater - Plume

Efficacy

Completed 40 sites so far

USA, Canada, UK, Sweden, Middle East, Australia

Third part study of 17 PFAS sites treated with PlumeStop

- Data available ranges 0.3-6 years
- 16 sites have data
    - 1 pilot site inappropriate for technology
    - 1 site 82 to >99% reduction (seasonal gw flow direction)
    - 14 sites >90% to >99% reduction

RESEARCH ARTICLE

WILEY

Longevity of colloidal activated carbon for in situ PFAS remediation at AFFF-contaminated airport sites

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Funding information
Porewater Solutions, Ontario Centers for Excellence, and Natural Sciences and Engineering Research Council

Abstract

A review of state per- and polyfluoroalkyl substances (PFAS) guidelines indicates that four long-chain PFAS (perfluorooctanesulfonic acid [PFOS] and perfluorooctanoic acid [PFOA] followed by perfluorohexanesulfonic acid [PFHxS] and perfluorononanoic acid [PFNA]) are the most frequently regulated PFAS compounds. Analysis of 17 field-scale studies of colloidal activated carbon (CAC) injection at PFAS sites indicates that in situ CAC injection has been generally successful for both short- and long-chain PFAS in the short-term (0.3–6 years), even in the presence of low levels of organic co-contaminants. Freundlich isotherms were determined under competitive sorption conditions using a groundwater sample from an aqueous film-forming foam (AFFF)-impacted site. The median concentrations for these PFAS of interest at 96 AFFF-impacted sites were used to estimate influent concentrations for a CAC longevity model sensitivity analysis. CAC longevity estimates were shown to be insensitive to a wide range of potential cleanup criteria based on modeled conditions. PFOS had the greatest longevity even though PFOS is present at higher concentrations than the other species because the CAC sorption affinity for PFOS is considerably higher than PFOA and PFHxS. Longevity estimates were directly proportional to the CAC fraction in soil and the Freundlich K_f, and were inversely proportional to the influent concentration and average groundwater velocity.

Efficacy

PFAS contaminated airport, UK

So, we know it works…

but how sustainable is it?

The theory:

- Low disruption
- Injection completed in weeks
- Low energy
- No equipment onsite
- No long-term energy use
- Low maintenance
- No equipment to replace
- Only validation sampling needed
- Fraction of site visits needed
- No waste produced

We need a third-party study!

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Overview of Study

Ramboll

- Head of Circular Solutions and Climate Specialist team, Finland

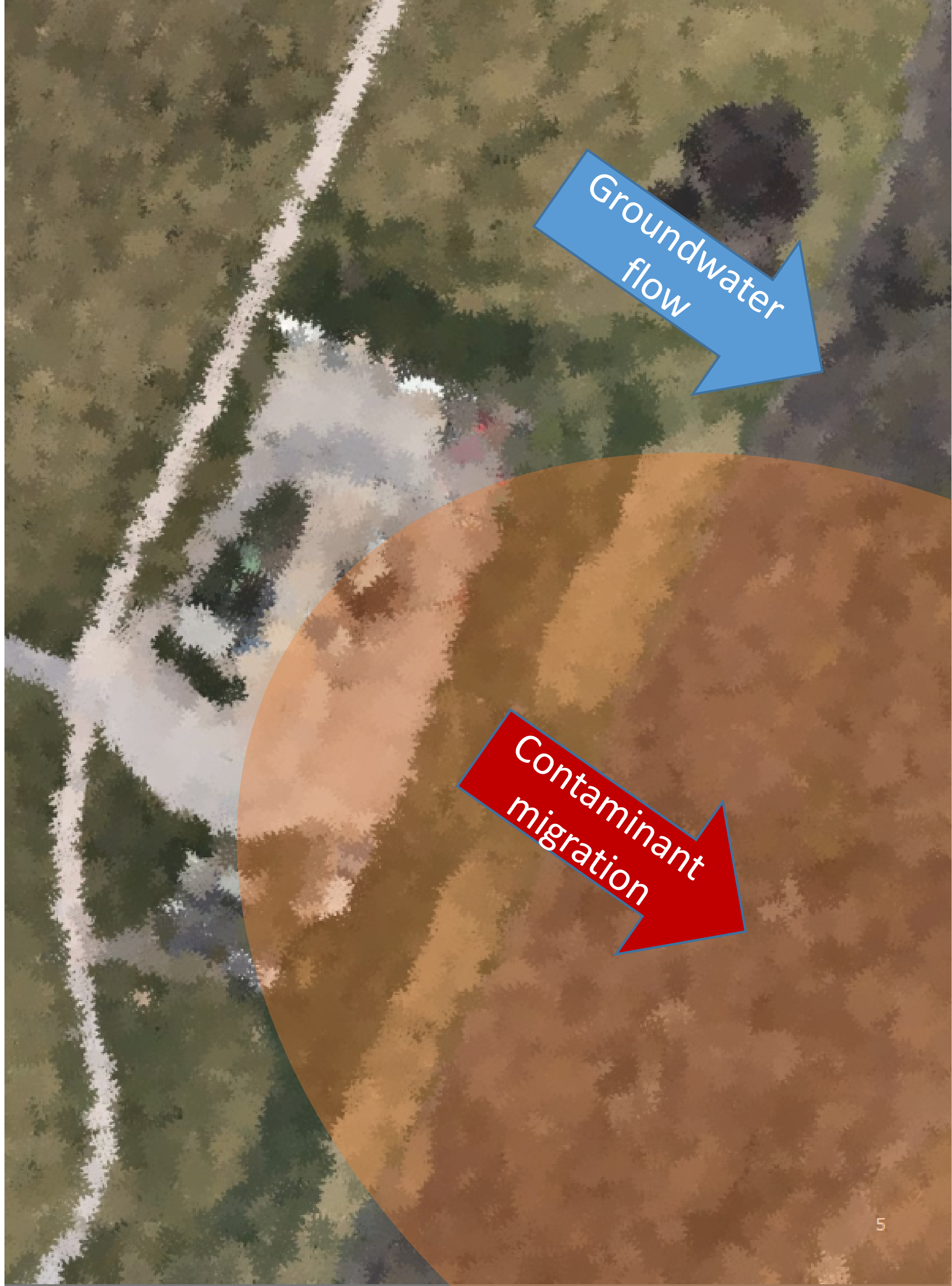
PFAS Contaminated Airport, UK

- Immediately prevent/reduce offsite PFAS migration
- Source treatment to follow

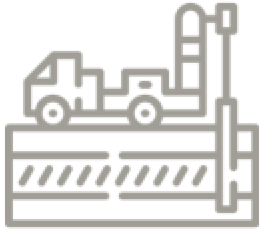
Compare the Life Cycle Analysis for:

- **In Situ Sorption and Retention Barrier**
  - Passive barrier of colloidal activated carbon (PlumeStop)
  - Recently implemented at the site

- **Ex Situ Pump and Treat**
  - Utilized granular activated carbon (GAC)
  - Theoretical, best-practice design

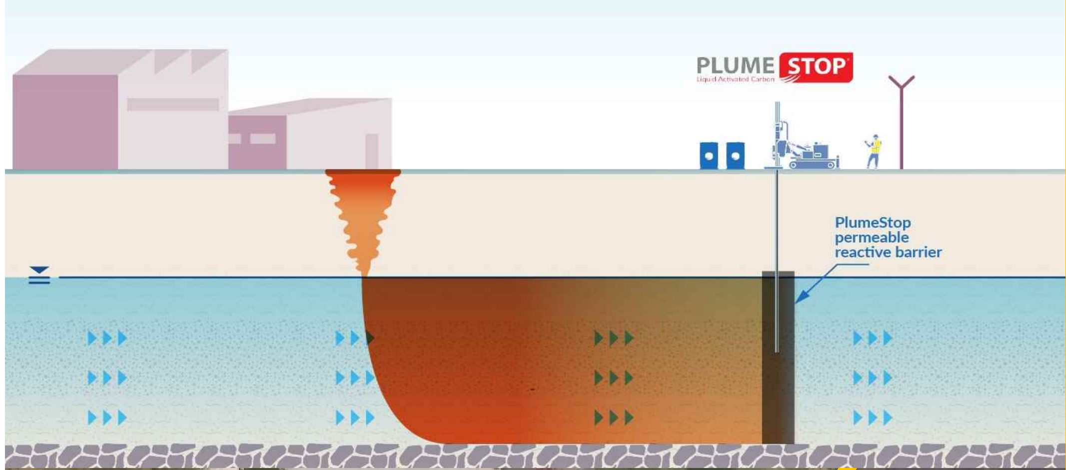


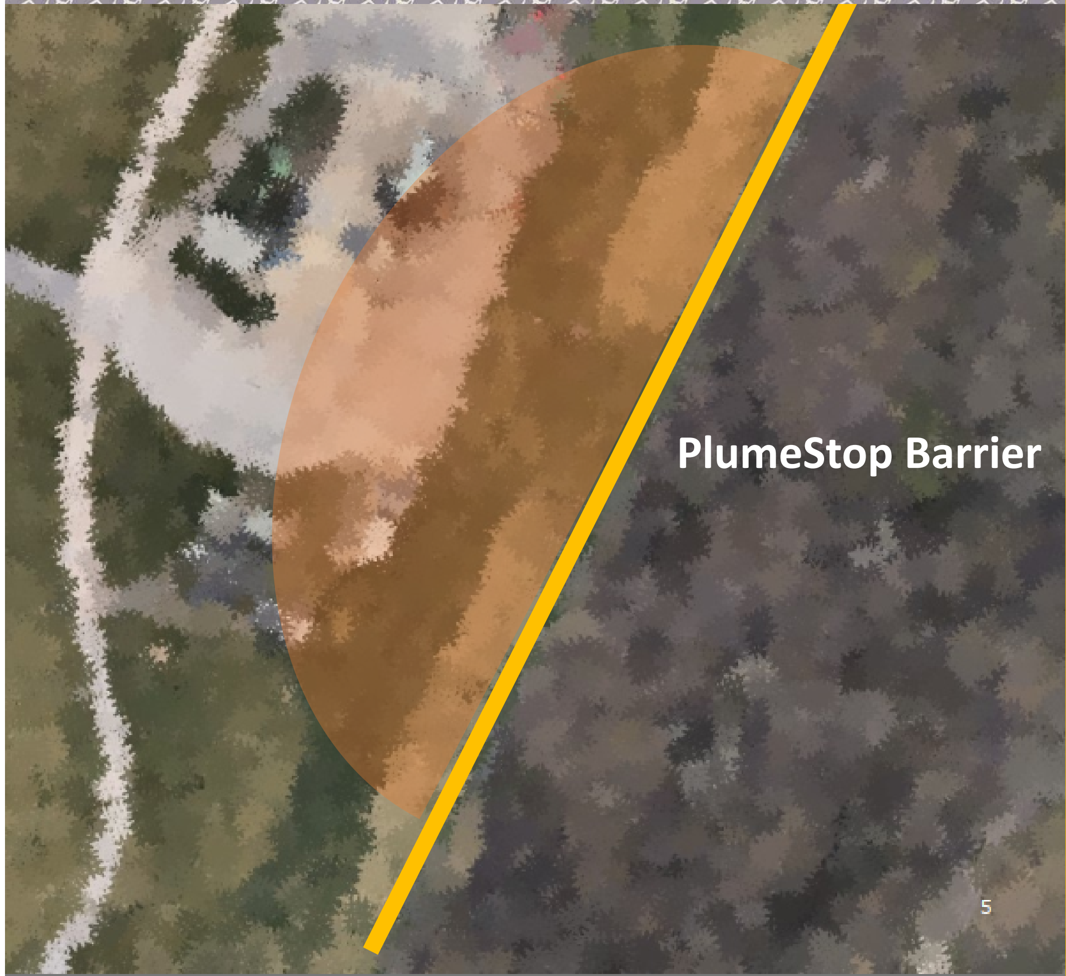
Life Cycle Inventory Analysis



Immobilization with PlumeStop ®

- Single injection round
- Designed for minimum 15 years of efficacy
- 102 injection points
- 120 yards long
- 74,000 lbs PlumeStop
- 420 gallons fuel used for injection
- 3 monitoring wells, 33 feet deep
- 2 times/yr, environmental monitoring



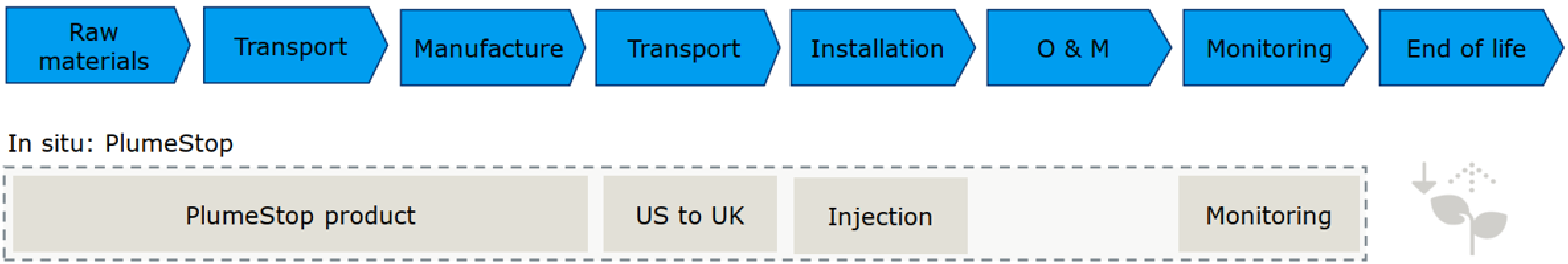


Scope of Assessment: Cradle to Grave

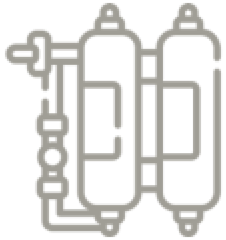
Methods/Software

- ISO 14040:2006, ISO 14044:2006, ISO 14067:2018, PCR for Basic Chemicals
- GaBi 10 Professional, Sphera, Ecoinvent 3.8

System boundary

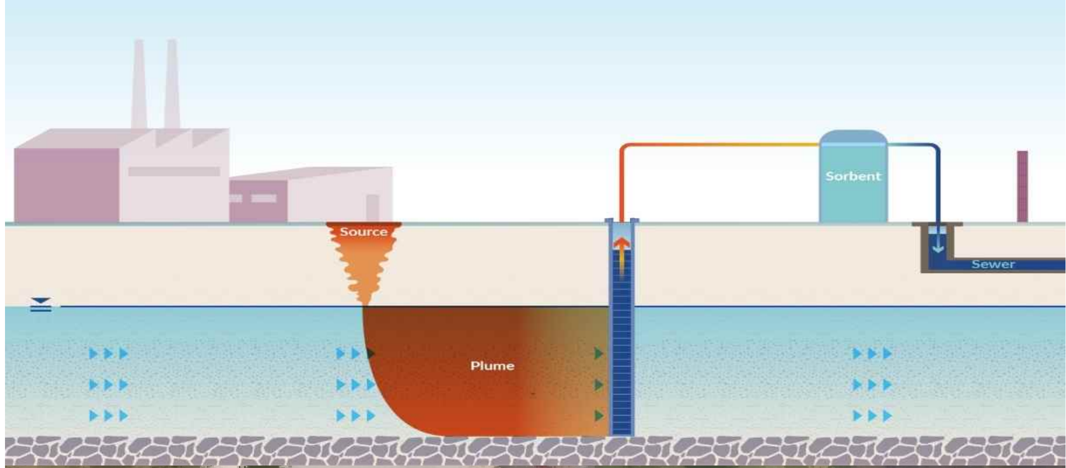


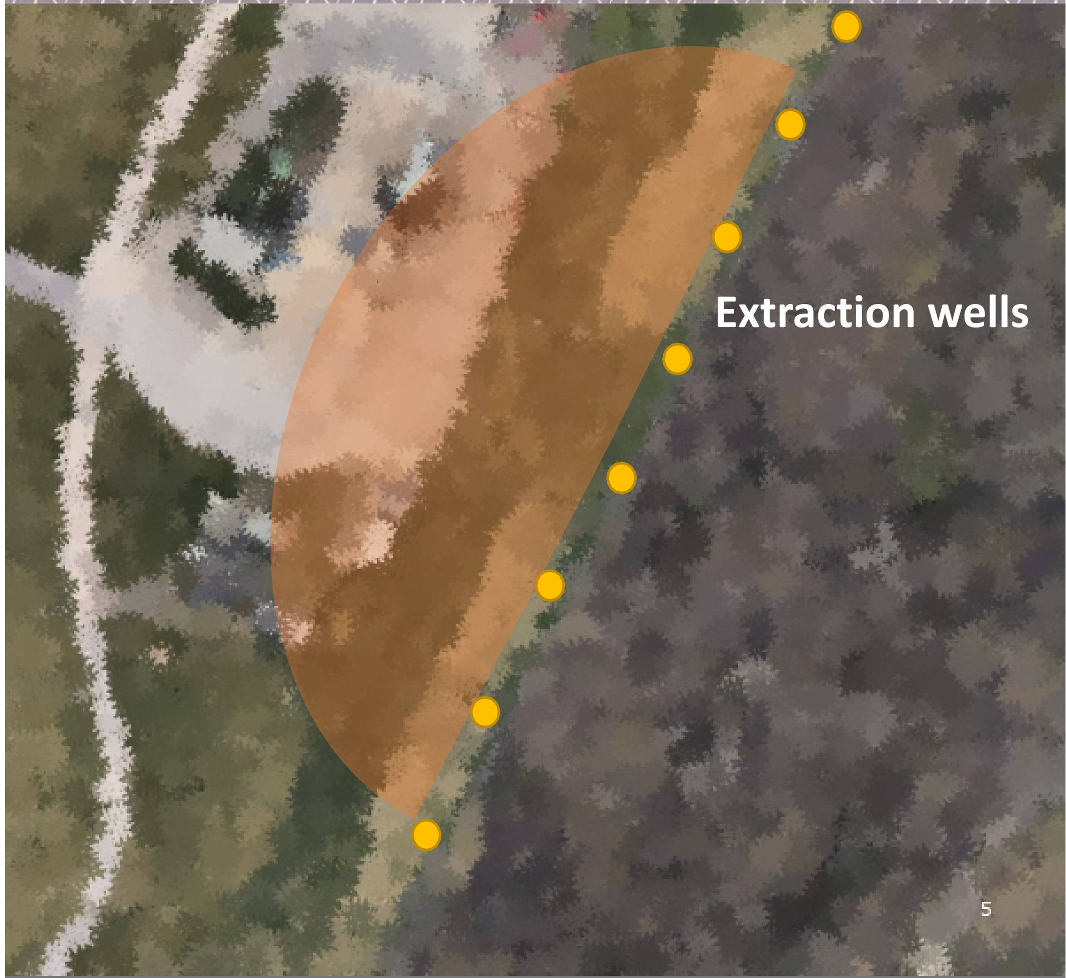
Life Cycle Inventory Analysis



Pump & Treat with
GAC filtration

- Based on consensus from 3 P&T designers
- Fixed equipment installation
- Continuous operation 15 years, 95% uptime
- 8 extraction wells, 25 feet deep
  - To avoid excess draw-down = vertical spread/smear
- 26 gal/min pumping rate
- 53,000 lbs GAC/yr usage rate
  - 100 mg/kg adsorption capacity
- 960 MWh/yr electricity consumption
- 4 times/yr O&M inspection from office
- 420 gallons fuel used for installation
- 3 monitoring wells, 33 feet deep
- 2 times/yr, environmental monitoring





Scope of Assessment: Cradle to Grave

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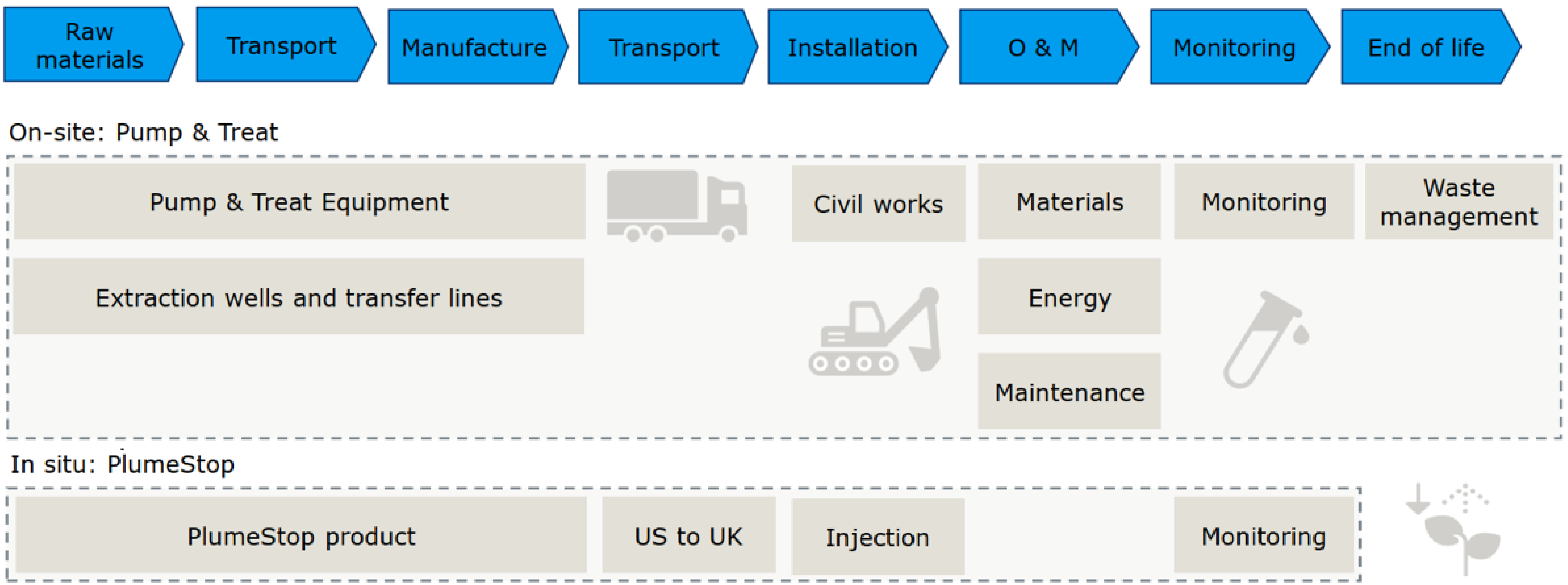
System boundary



Methods/Software

- ISO 14040:2006, ISO 14044:2006, ISO 14067:2018, PCR for Basic Chemicals
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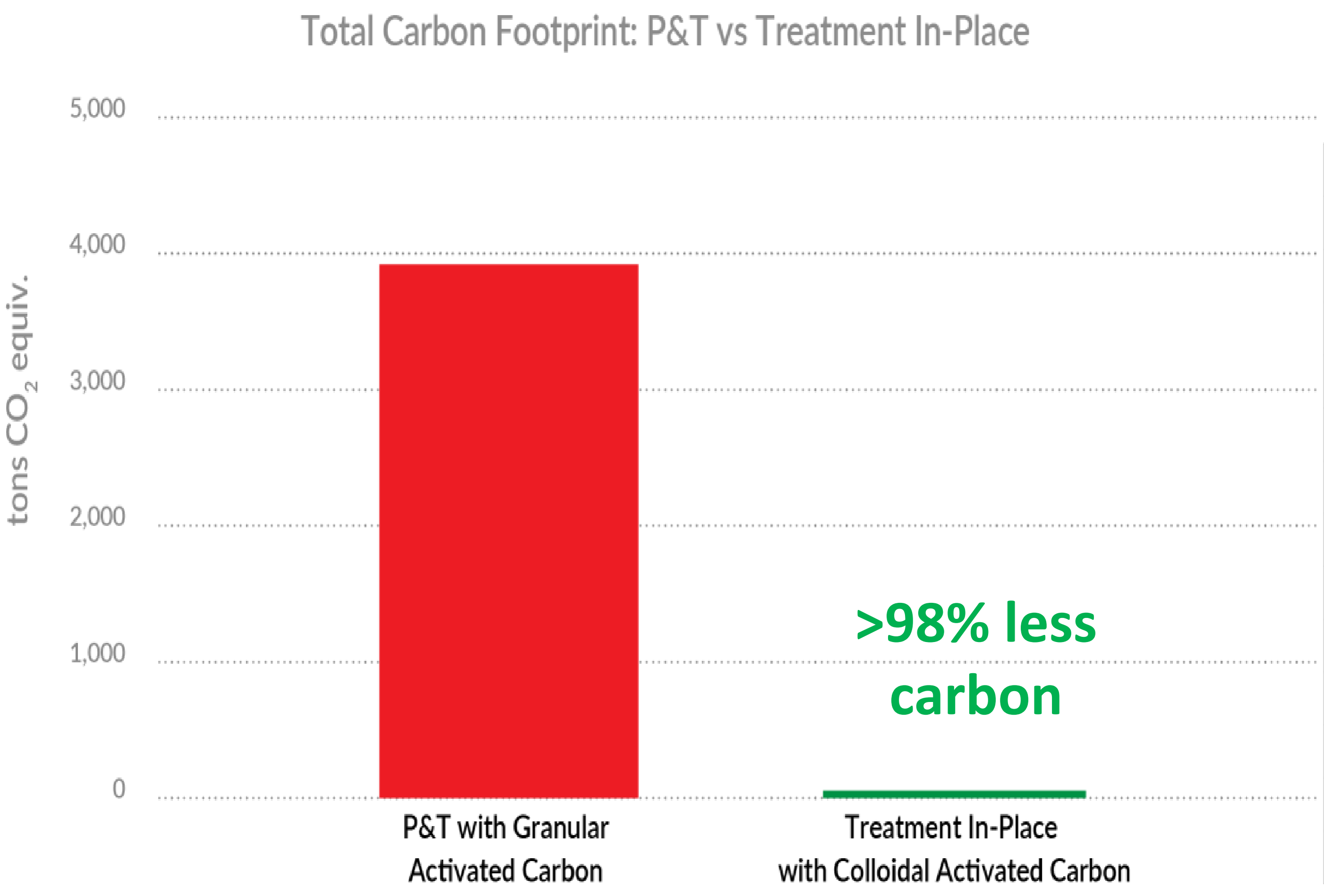
Carbon Footprint



carbon footprint = 70 x smaller

	PlumeStop	P&T w/ GAC
Remediation equipment		15,2
Civil works		
Fixed installations	0,05	0,9
Machinery	1,0	1,3
Remediation and operations		
PlumeStop / GAC	50,5	2 860
Electricity		281
Maintenance		3,6
Monitoring	4,0	4,0
Waste management		
Hazardous waste		112
Wastewater treatment		644
Total carbon footprint	**56**	**3 922**

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Carbon Footprint

- GAC footprint most significant impact
- Assumes landfill
  - Incineration in future
  - Will increase impact
- Options to reduce or remove GAC?

	PlumeStop	P&T w/ GAC
Remediation equipment		15,2
Civil works		
Fixed installations	0,05	0,9
Machinery	1,0	1,3
Remediation and operations		
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Maintenance		3,6
Monitoring	4,0	4,0
Waste management		
Hazardous waste		112
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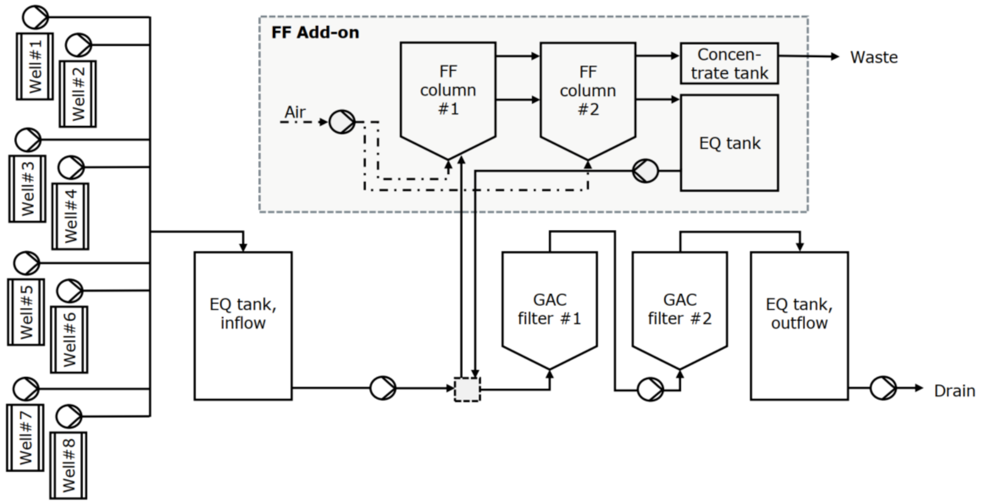
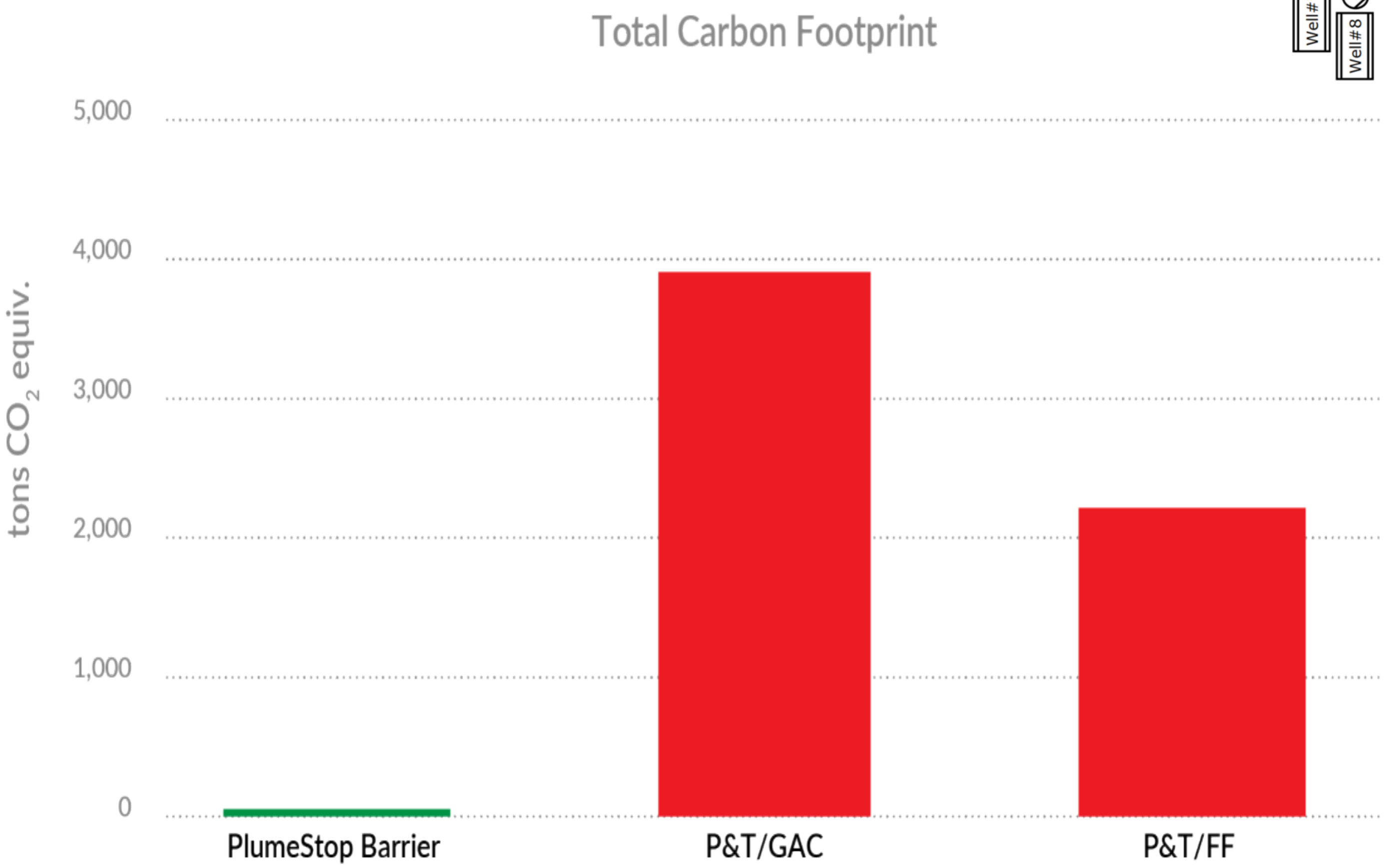
Total carbon footprint	**56**	**3 922**

Carbon Footprint

We also modelled Foam Fractionation (FF):

- Bubble/skim off PFAS
- Reducing GAC
- Increasing equipment/electricity





- In situ retention still 97.5% lower (carbon footprint = 40 x smaller)

- Changing treatment ≠ significant reduction
- Pumping alone = 1-2 Orders Of Magnitude increase in Carbon Footprint
- ANY filtration or destructive treatment technique only adds to this

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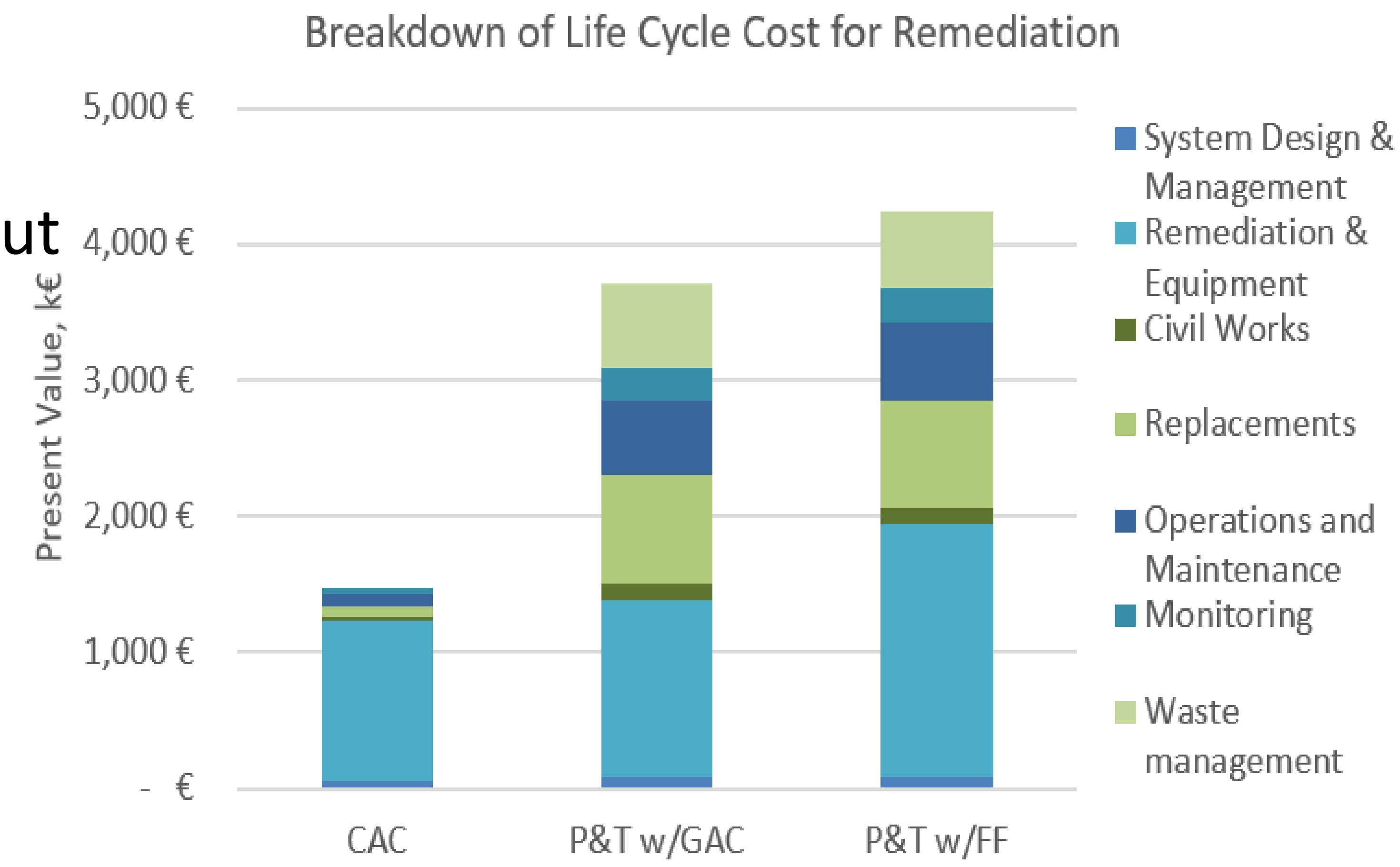
Life Cycle Cost Analysis

- Pricing analysis by Ramboll
- Based on a 15-year treatment
- Costs at different times throughout
- Net Present Value:

CAC retention barrier = $1.608M

P&T with GAC = $4.039M

P&T with FF = $4.623M



61-65% less

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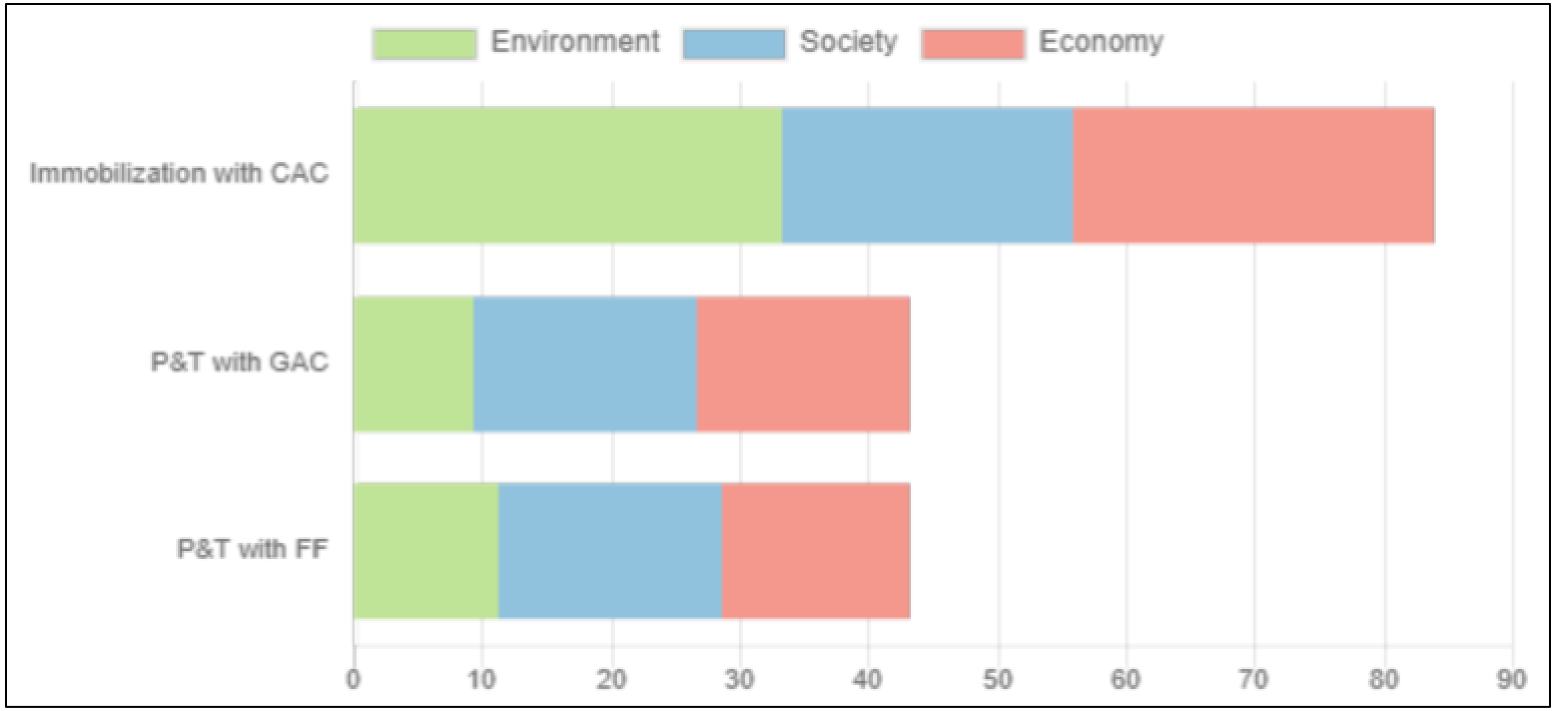
Reviewing other impact factors

- A 'Tier 2' sustainability assessment was completed by using SURE by Ramboll (SURE).
- SURE is based on standards from ISO and ASTM, and aligned with the Sustainable Remediation Forum (UK) guidance.
- Linear-additive multi-criteria analysis (MCA) method and is designed to incorporate both qualitative and quantitative information.
- 15 sustainability indicators encompassing each sustainability domain weighted and scored
- Comparison remedial options



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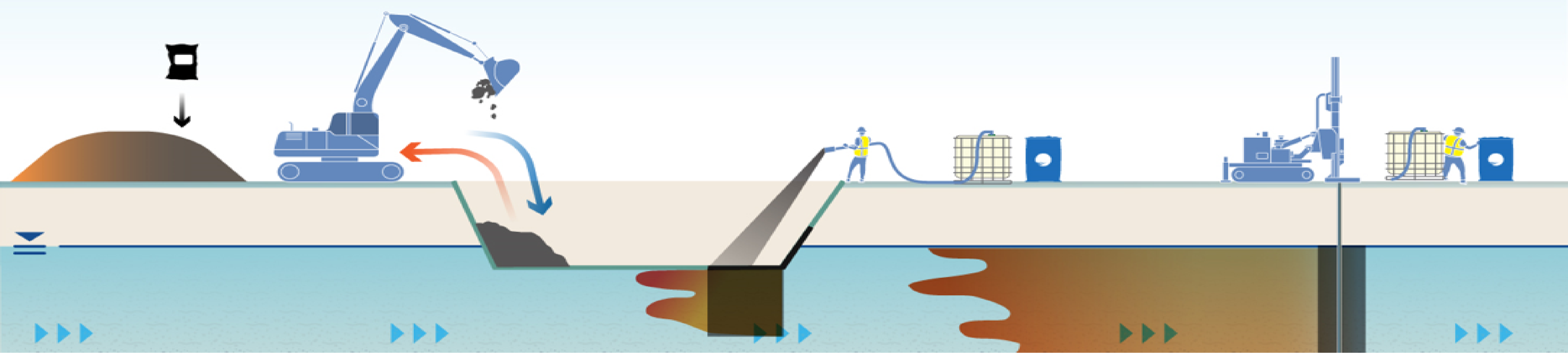
Conclusion

- Remediation of a PFAS site should consider sustainability
  - A way of ensuring the site is not managed in isolation
- Pump & Treatment has a carbon footprint for both components
  - Pumping alone has a MUCH higher impact than in situ treatment
  - ANY ex-situ Treatment will add to that impact
- Enhanced attenuation of PFAS through retention by CAC injection
  - Effective and Sustainable approach to address a <u>global pollution issue</u>



Thank You!

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