

PFAS and CVOOC investigations

Flux based assessment of PFAS migration:
Industrial groundwater case (BE)



Making Groundwater Dynamics Manageable

By moving beyond estimates & simulations

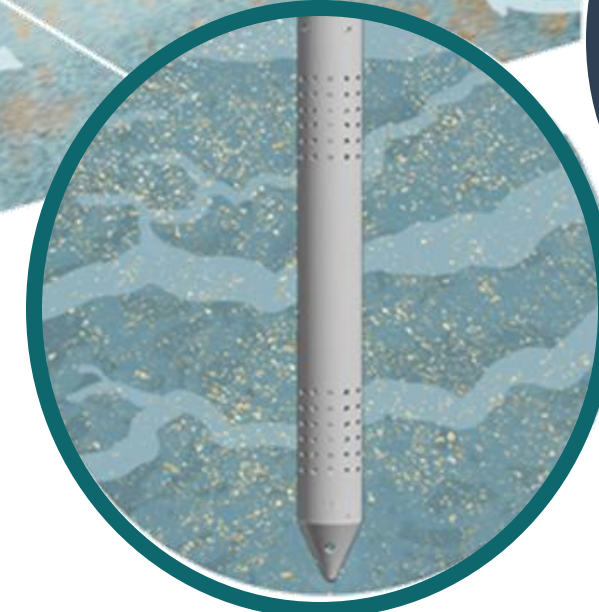
- ✓ Patented tech provides unique insights
- ✓ Holistic approach: full site surveillance
- ✓ Scalable service: DaaS + interpretation



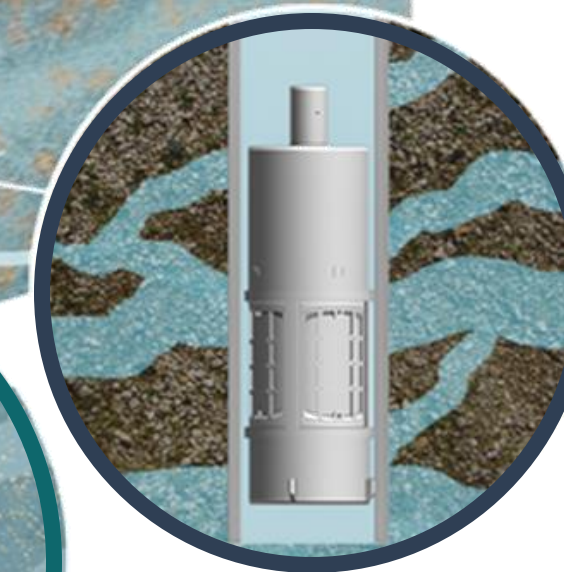
Meteo station



Flux Sampler
+ third party quality
or level sensor

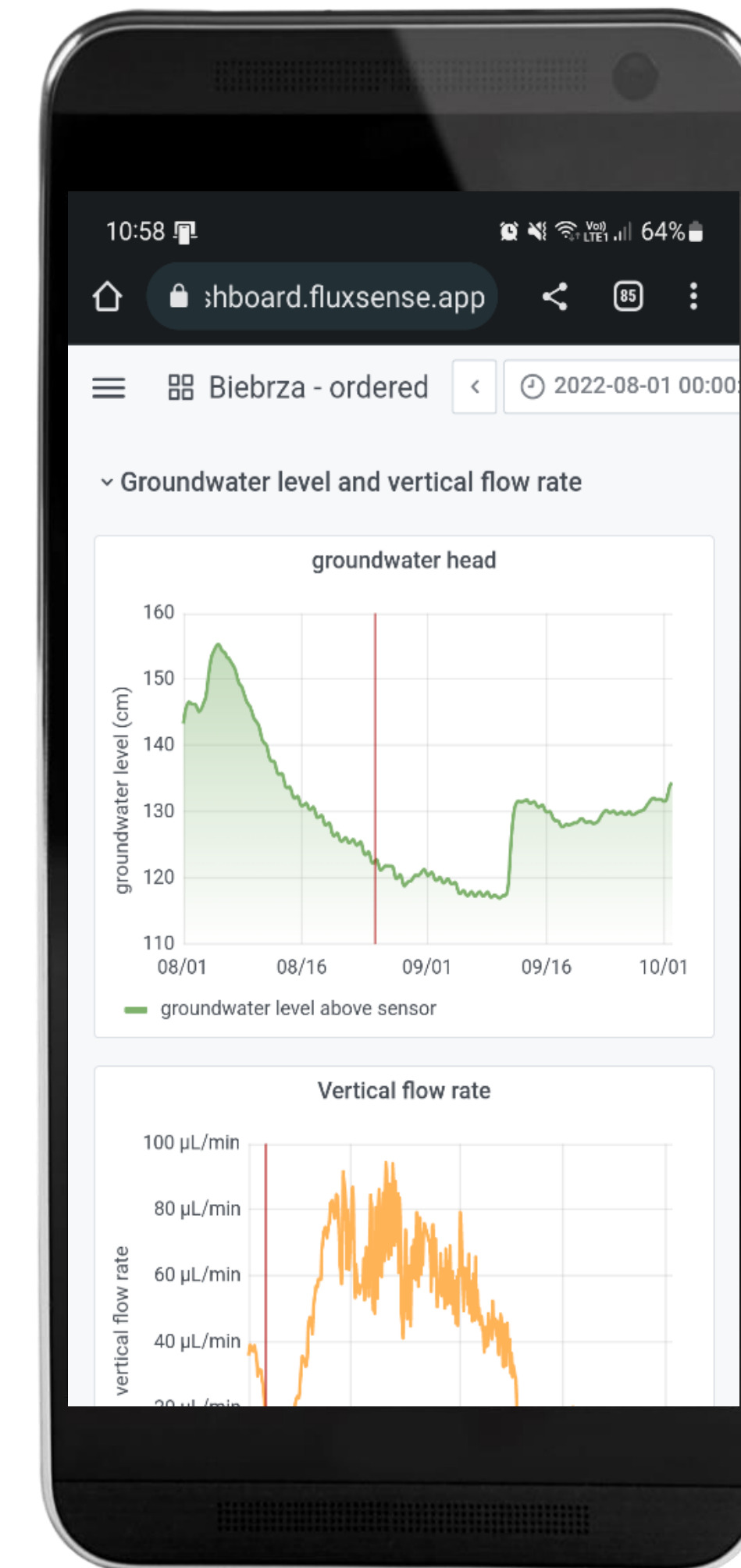


Vertical Flux
Sensor & Sampler



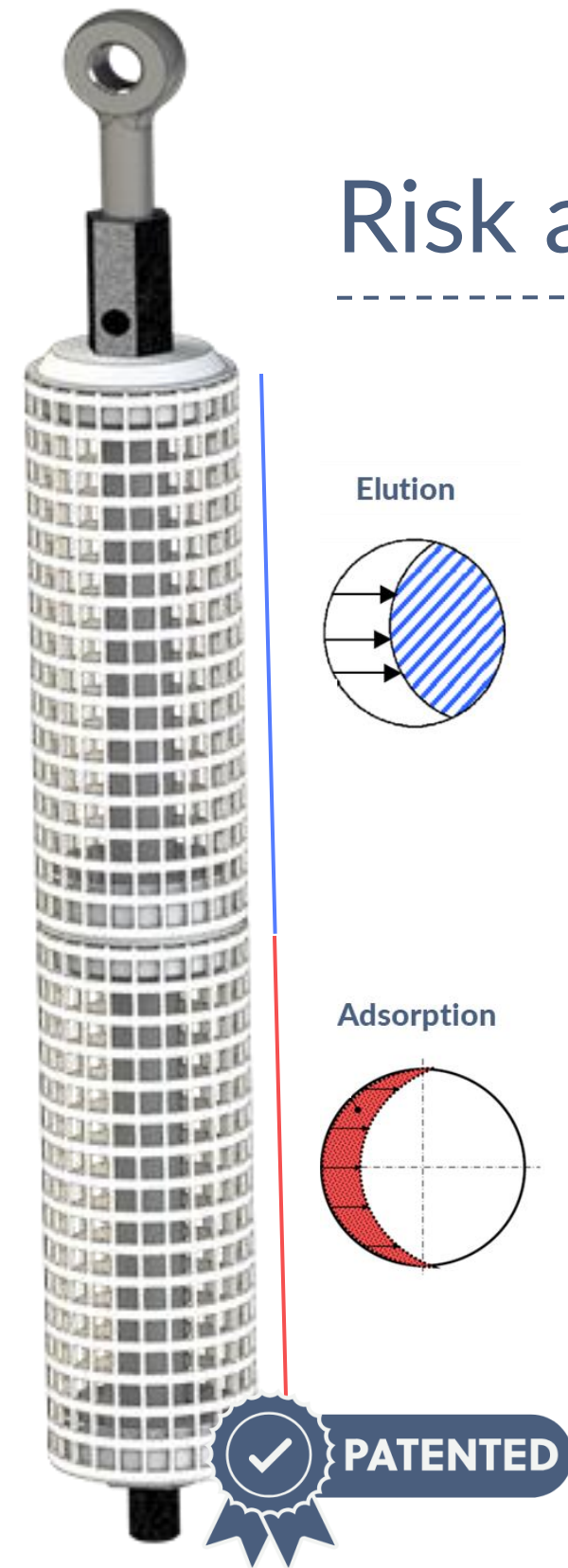
Horizontal
Flux Sensor

Real-time data 

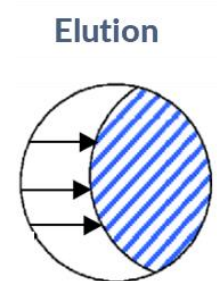


iFLUX Samplers – measuring groundwater & mass flux

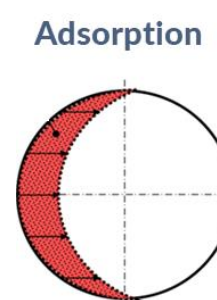
Risk assessment and targeted remediation to generate savings by avoiding ineffective actions



Risk assessments require quantifications of mobility



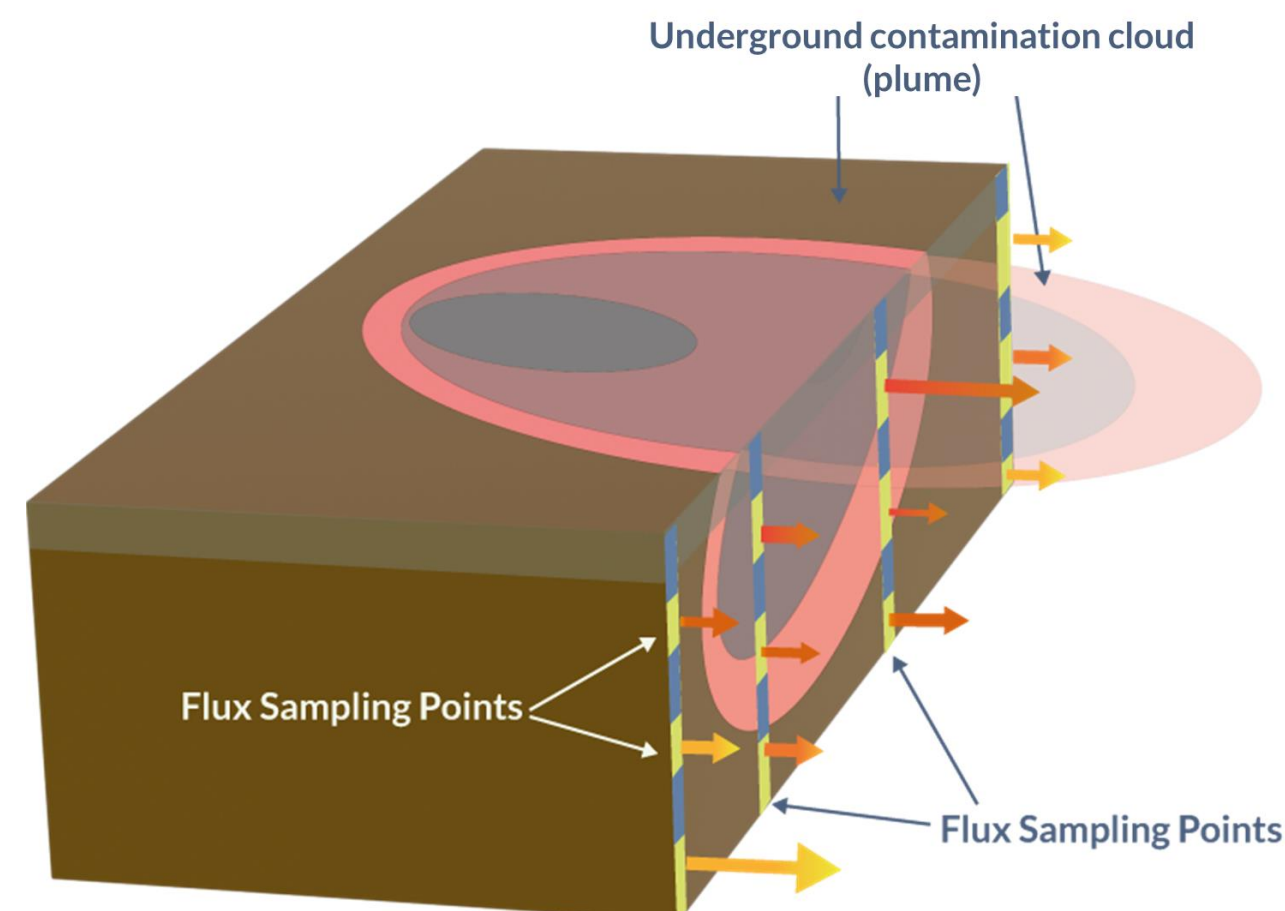
Water-flux tells us how much groundwater is moving



Mass-flux tells us how much contamination is moving with the groundwater

One measurement campaign to understand contaminant plume* evolution

*plume = underground contamination 'cloud'



- Avoid remediation by proving that contamination is not moving
⇒ Monitoring is 90% cheaper than remediation
- Targeted action **saves effort** and product
⇒ Reduce remediation costs by up to 50%
- **Avoid failed remediations** based on low-resolution assumptions
⇒ Avoid years of continued efforts and costs in the €100K's to € Millions
- **Quantify off-site contamination origins**
⇒ avoid or reduce remediation liabilities

Validated components

iFLUX Samplers - Contamination & Remediation



+160 Validated components, with 51 types de PFAS

Specific validations possible on demand

WATERFLUX Tracer alcohols	CHLOROTULUENES 2-Chlorotoluene 4-Chlorotoluene	VOLATILE ORGANIC COMPOUNDS SPECIFIC 1,1,1,2-Tetrachloroethane 1,1,2-Trichloro-1,2,2-trifluoroethane 1,1-Dichloroethene 1,1-Dichloropropane 1,1-Dichloropropene 1,2,3-Trichloropropane 1,2-Dibromoethane 1,2-Dichloropropane 1,3-Dichloropropane 2,2-Dichloropropane 2,3-Dichloropropene 2-Chloro-1,3-butadiene 2-Ethyltoluene 3-Chloro-1-propene (allylchloride) 3-Ethyltoluene 4-Ethyltoluene Bromobenzene Bromochloromethane Bromodichloromethane Bromomethane Chloroethane cis-1,3-Dichloropropene Cumene Dibromochloromethane Dibromomethane Diisopropylether ETBE (Ethyl tert-butyl ether) Ethylether Hexachlorobutadiene Iodomethane TAME (Tert-Amyl Methyl Ether) trans-1,3-Dichloropropene Tribromomethane (Bromoform) Trichloromonofluoromethane	HEAVY METALS Cadmium Chromium Copper Lead Nickel Zinc
BTEX-N-S-MTBE Benzene Toluene Ethylbenzene O-Xylene M,p-Xylenes Naphtalene Styrene MTBE	TRIMETHYBENZENES 1,2,3-trimethylbenzene 1,2,4-trimethylbenzene 1,3,5-trimethylbenzene		
MINERAL OILS Fraction C-10 – C-12 Fraction C-12 – C-20 Fraction C-20 – C-30 Fraction C-30 – C-40 Mineral oils (GC)	POLYAROMATIC HYDROCARBONS Napthalene Acenaphthylene Acenaphtene Fluorene Fenanthrene Anthracene Fluoranthene Pyrene Benzo(a)anthracene Chrysene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(a)pyrene Dibenzo(ah)anthracene Benzo(ghi)perylene Indeno(123cd)pyrene		METAL SPECIFIC Calcium Iron Potassium Magnesium Manganese Sodium
CHLORINATED SOLVENTS Dichloromethane 1,1-Dichloroethane 1,2-Dichloroethane Cis-1,2-dichloroethene Trans-1,2-dichloroethene Trichloromethane Trichloroethene 1,1,1-Trichloroethane 1,1,2-Trichloroethane Tetrachloromethane Tetrachloroethene Vinylchloride	POLYCHLORINATED BIPHENYLS PCB 28 PCB 138 PCB 52 PCB 153 PCB 101 PCB 180 PCB 118		NUTRIENT CATIONIC Ammonium - N
CHLOROBENZENES Monochlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene 1,2,3-Trichlorobenzene 1,2,4-Trichlorobenzene 1,3,5-Trichlorobenzene	CHLOROTULUENES 2-Chlorotoluene 4-Chlorotoluene		HEAVY METAL SPECIFIC Mercury Arsenic
			NUTRIENT ANIONIC Nitrate-N Sulfate
			DIOXANE 1,4-Dioxane

PFAS Perfluorobutanoic acid (PFBA) Perfluorohexanoic acid (PFHxA) Perfluoroheptanoic acid (PFHpA) Perfluorooctanoic acid (PFOA) (linear) Perfluorooctanoic acid - sum (PFOATotal) Perfluorononoic acid (PFNA) Perfluorodecanoic acid (PFDA) Perfluoroundecanoic acid (PFUnDA) Perfluorododecanoic acid (PFDoDA) Perfluorohexadecanoic acid (PFHxDA) Perfluorohexadecanoic acid (PFHxS) Perfluorooctane sulfonic acid (PFOS) (linear) Perfluorooctane sulfonic acid - sum (PFOSTotal) Perfluorononane sulfonic acid (PFNS) Perfluorodecane sulfonic acid (PFDS) 4:2 Fluorotelomersulfonic acid (4:2 FTS) 6:2 Fluorotelomersulfonic acid (6:2 FTS) 8:2 Fluorotelomersulfonic acid (8:2 FTS) 10:2 Fluorotelomersulfonic acid (10:2 FTS) Perfluorooctane sulfonamide (PFOSA) (linear) Perfluorooctane sulfonamide - sum (PFOSA) (linear) N-ethylperfluorooctane sulfonamide (EtPFOSATotal) N-methylperfluorooctane-sulfonamidoacetic acid (MePFOSAA)	N-ethylperfluorooctanesulfonamidoacetic acid (EtPFOSAA) 8:2 Fluorotelomerphosphate diester (8:2 DiPAP) 2,3,3,3-tetrafluor-2-(heptafluoropropoxy)propanoic acid (HFPO-DA) Perfluorohexanesulfonamide (PFHxSA) Perfluorotridecanoic acid (PFTrDA) Perfluorooctadecanoic acid (PFODA) Perfluoroundecane sulfonic acid (PFUnDS) Perfluorododecane sulfonic acid (PFDoDS) Perfluorotridecane sulfonic acid (PFTrDS) 6:2 Fluorotelomerphosphate diester (6:2 DiPAP) 6:2/8:2 Fluorotelomerphosphatediester (6:2/8:2 DiPAP) 11-Chloroeicosafluoro-3-oxaundecane-1-sulfonate (11Cl-PF3OuDS) (F-53B Minor) 9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate (9Cl-PF3ONS) (F-53B Major) Perfluoropentanoic acid (PFPeA)* Perfluoropentane sulfonic acid (PFPeS)* N-methylperfluorooctanesulfonamide (MePFOSA) (linear)* N-methylperfluorooctanesulfonamide (MePFOSATotal)* 4,8-Dioxa-3H-perfluorononocacid (DONA)* Perfluoro-4-ethylcyclohexanesulfonic acid (PFECHS)* Perfluorobutanesulfonamide (PFBSA)* N-methylperfluorobutanesulfonamide (MePFBSA)* N-Methyl-perfluorobutane-sulfonylamidoacetate (MePFBSAA)* 2H-Perfluoro-2-decenoic acid (FOUEA / 8:2 FTUCA)*
	Indicative list
	For more details, please visit www.iFLUX.be Collaborative third-party labo
	SGS

Investigation 2024

Flux based decision making for remedial approach (Aecom, BE)

1. Context

2. Methodology

3. Results

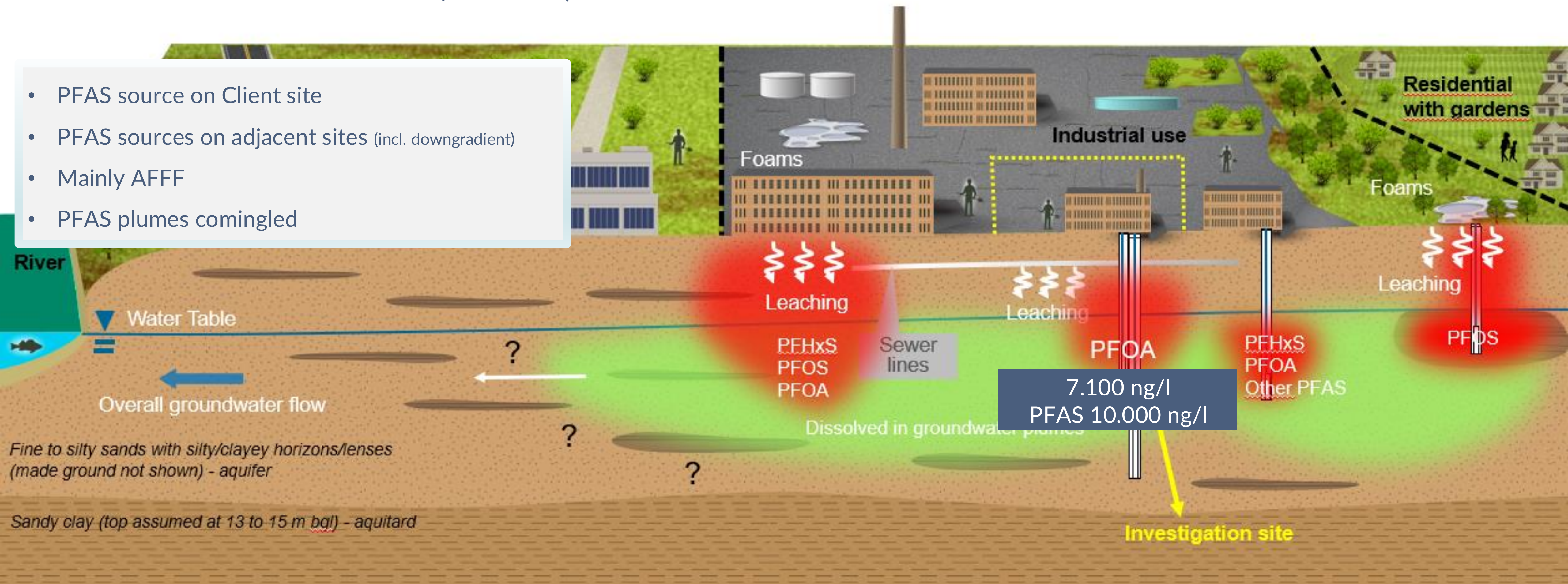
4. Conclusions



Flux based decision making for remedial approach (BE)

CONCEPTUEL site model (AECOM)

- PFAS source on Client site
- PFAS sources on adjacent sites (incl. downgradient)
- Mainly AFFF
- PFAS plumes comingled



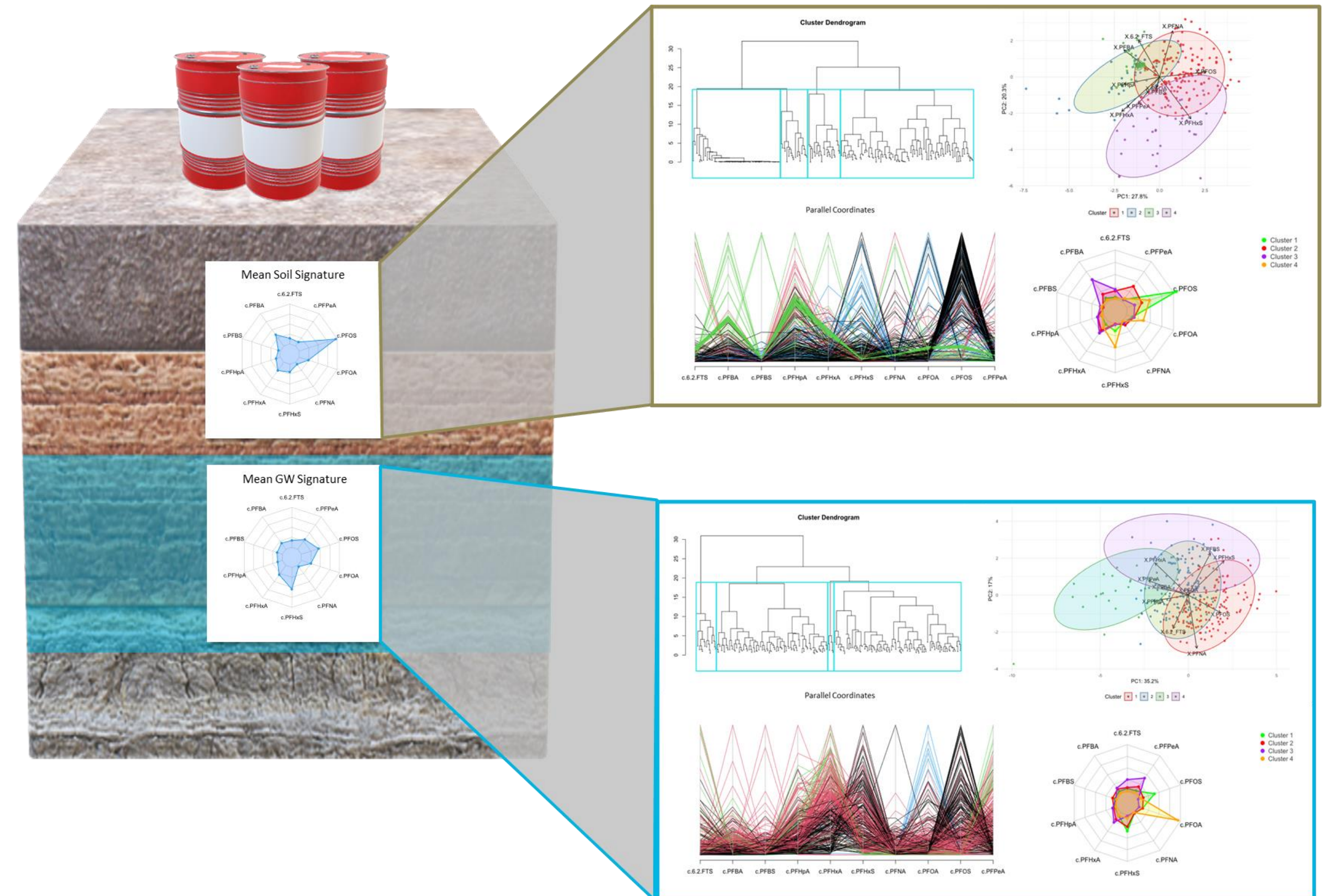
Source: AECOM

Flux based decision making for remedial approach (BE)

Conceptual site model - by AECOM

- Historical investigation
- Soil & groundwater sampling
- PFAS analysis (target analysis)
- Vertical delineation
- Horizontal delineation
- Chemometrics / Forensic Analysis

Group of contaminants	Regulatory framework
PFAS Total	500 ng/l
PFAS 20 EU DRWL	100 ng/l



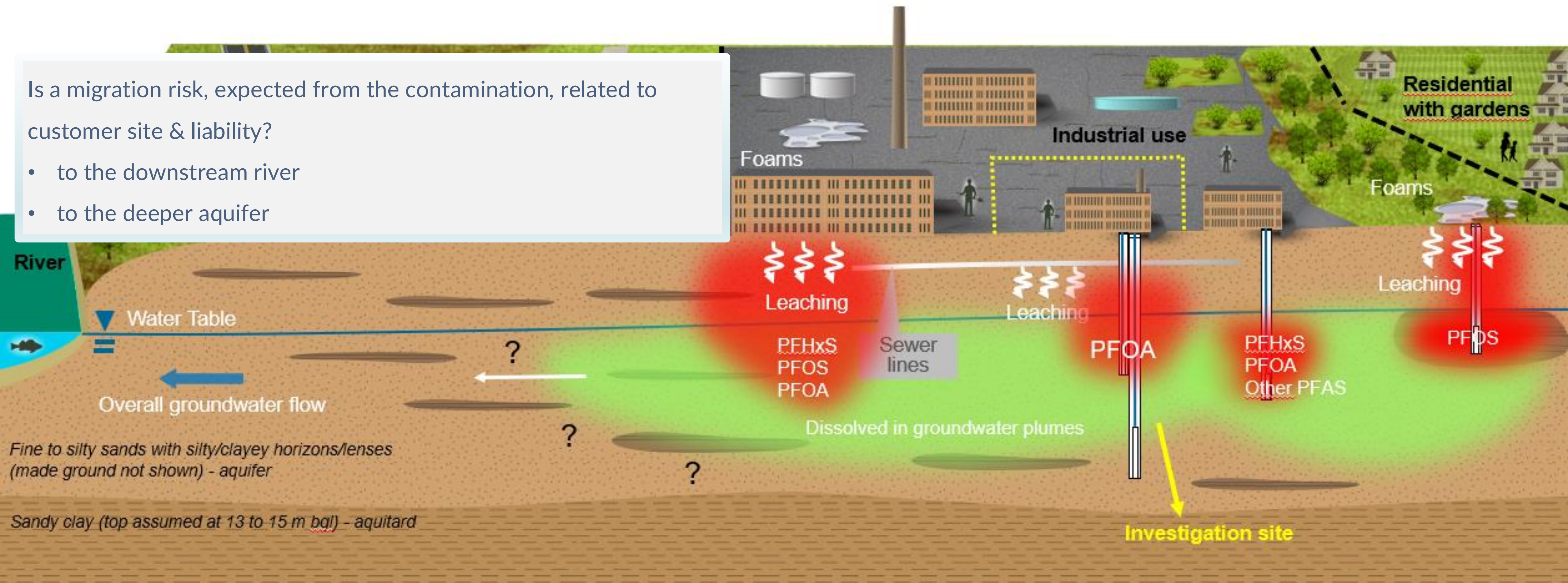
Source: AECOM

Flux based decision making for remedial approach (BE)

Questions for iFLUX

Is a migration risk, expected from the contamination, related to customer site & liability?

- to the downstream river
- to the deeper aquifer



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Migration Risk – additional lines of evidence?

What we already know

- Source zone(s)
- General groundwater characteristics (level, velocity & direction)
- Hydraulic conductivity based on grain size analysis
- Site specific soil structure & textures
- Risk receptors: deeper groundwater & river

What would help us to understand the migration risk

Detailed hydraulic conductivity along the vertical profile

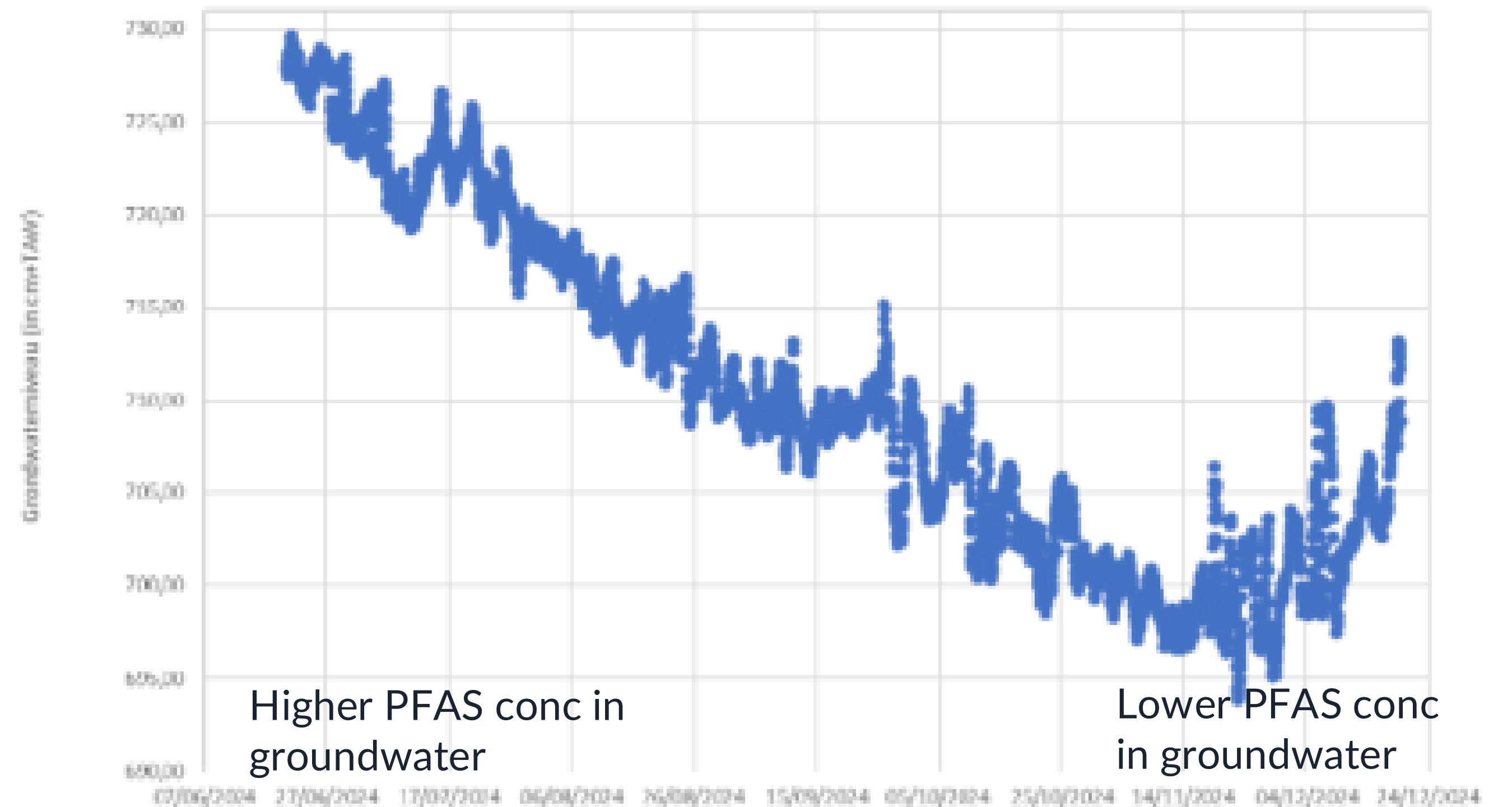
- Detailed groundwater & mass flux along the vertical profile
- Potential seasonal variation
- What's the mass flux to:
 - ✓ Downgradient off-site existing PFAS impacts
 - ✓ Downgradient risk receptor (river)
 - ✓ Deeper groundwater

Seasonal effects

Observations

- Groundwater concentrations vary with groundwater level fluctuations
- **Higher PFAS** concentrations when groundwater is high (leaching from soil impact)

Groundwater levels (6 months) : Δ 30 cm



Source: AECOM

Hydraulic conductivity profile

Regional

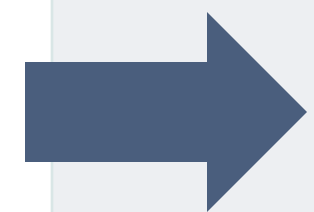
- ✓ (Quaternary) soil until $\pm 7,0$ m-gl: $K_h < 1$ m/day (1)
- ✓ Deeper (Tertiary) sandy soil: $K_h > 10$ m/day (2)
- ✓ Deeper sandy clay (~ Aquitard) (3)

PFAS
1.000-10.000 ng/l

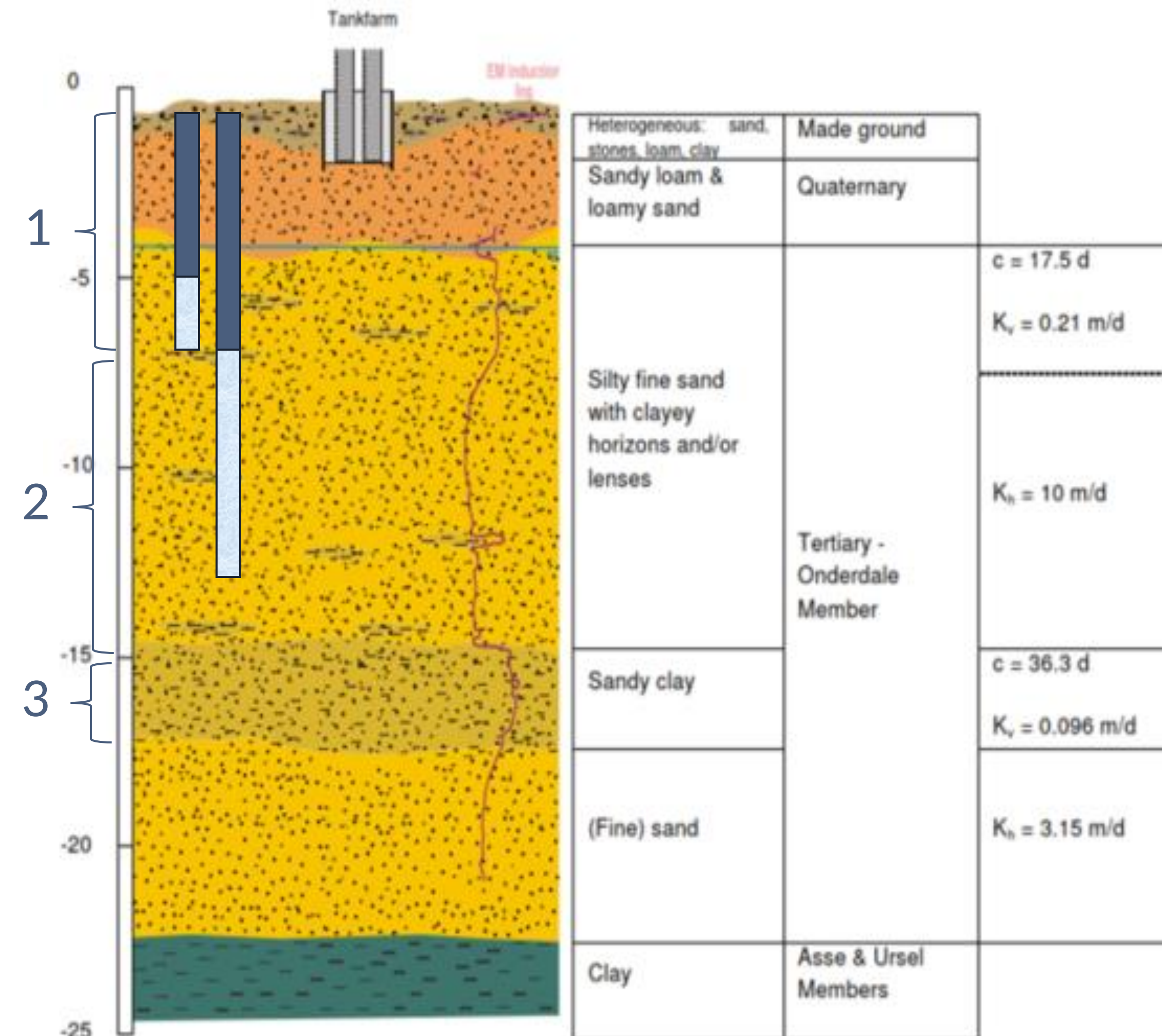
PFAS
100-500 ng/l

PFAS
< 100 ng/l

- Groundwater flow direction from east to west
- Detailed in-situ characterization on 2 locations



Based on HPT, 2 monitoring well clusters with optimized filter depths were installed to perform Flux measurements



Source: AECOM

iFLUX Campaign

5 depths in 2 wells

- 2 x PFAS flux : 5 to 7 m bgl
- 3 x PFAS flux : 7 to 13 m bgl

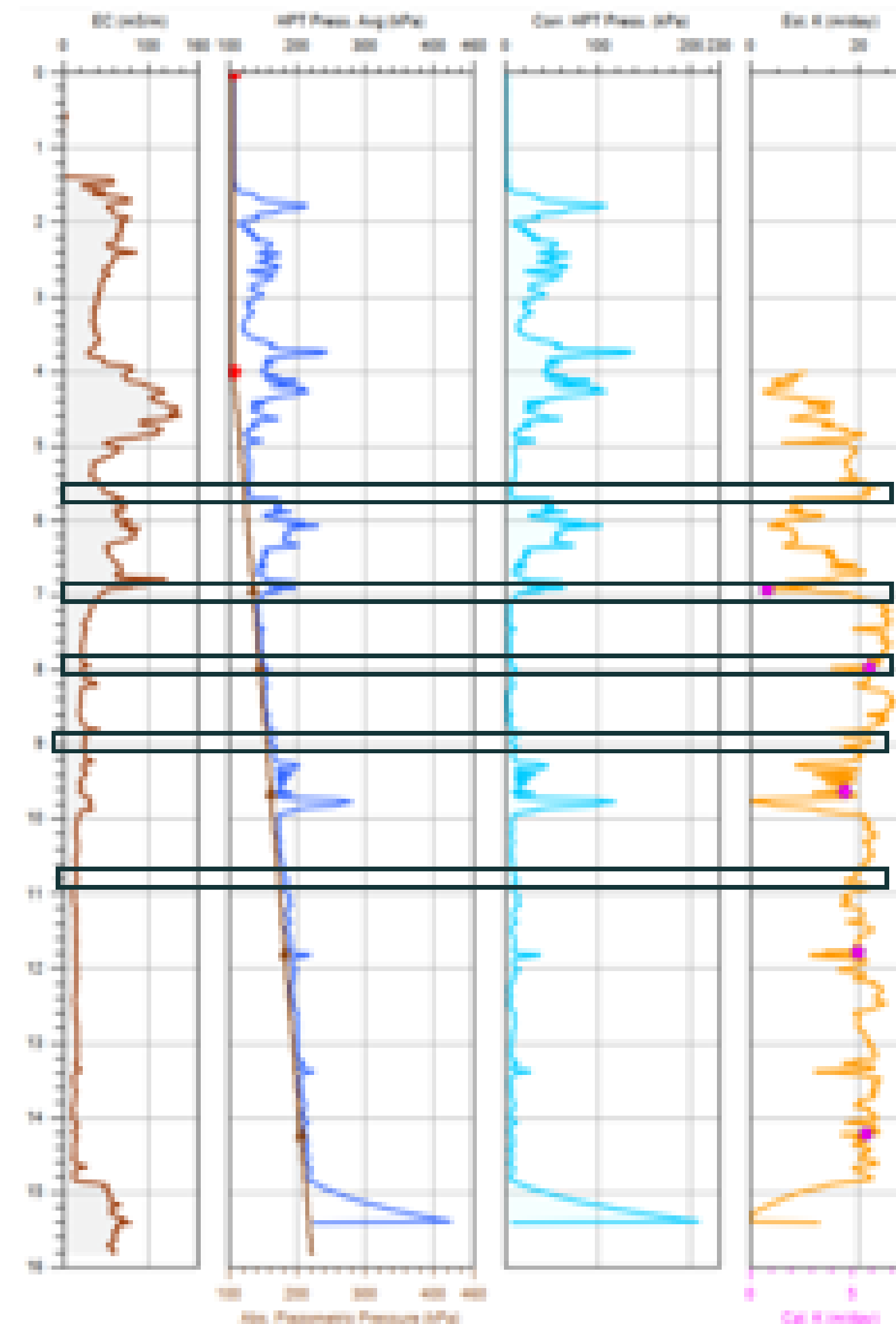
Exposure time

- ✓ Based on observed groundwater concentrations and estimated groundwater velocity
- ✓ ± 4 weeks to achieve sufficiently low detection values

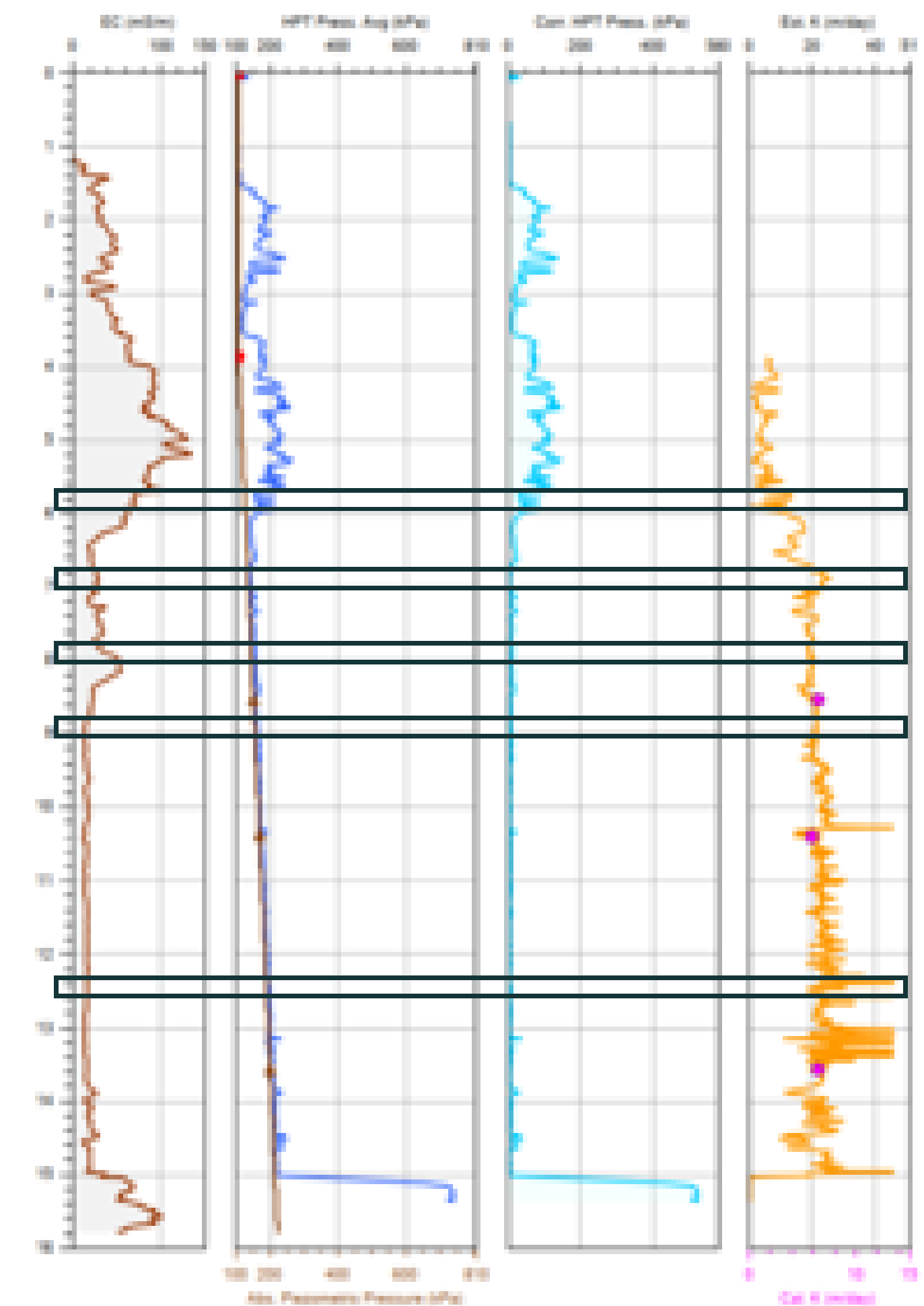
2 campaigns: Spring – Autumn 2024

- Campaign 1 : 11 PFAS components
- Campaign 2 : 41 PFAS components

Location 1 - N



Location 2 - S



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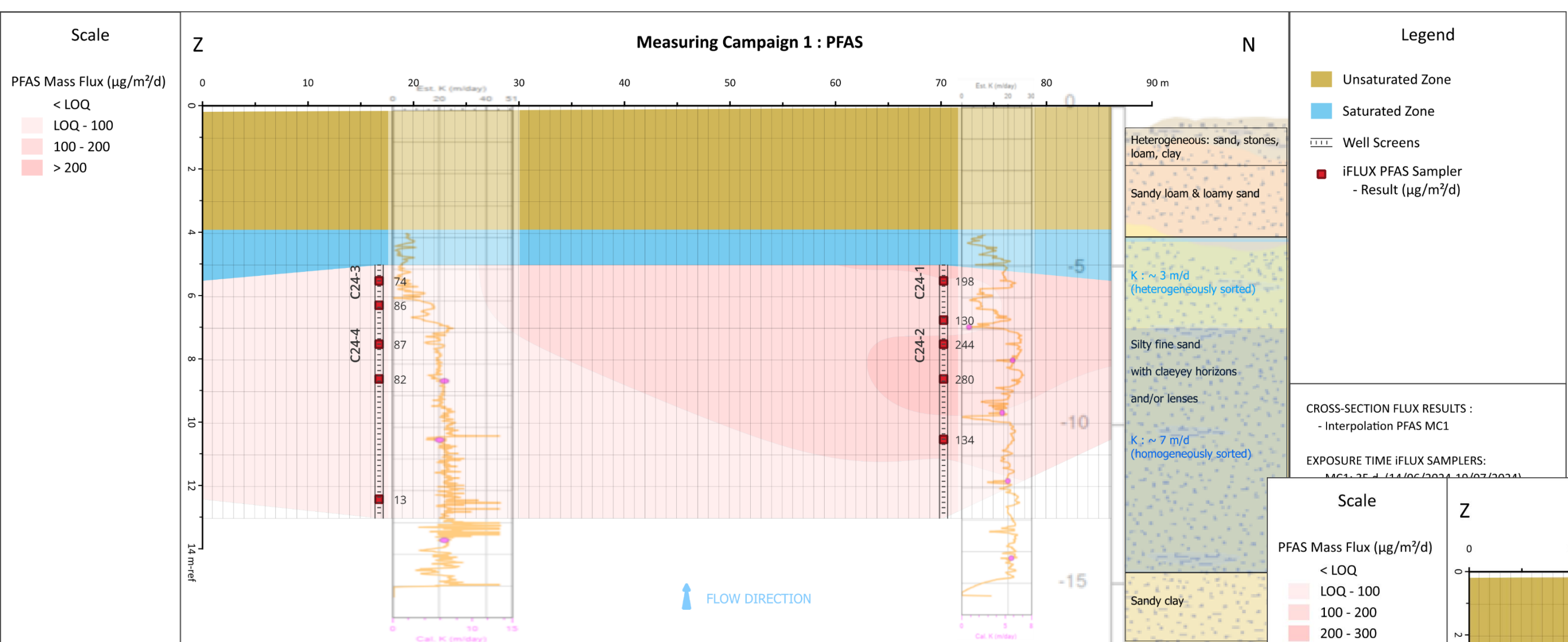
Flux based decision making for remedial approach (Aecom, BE)

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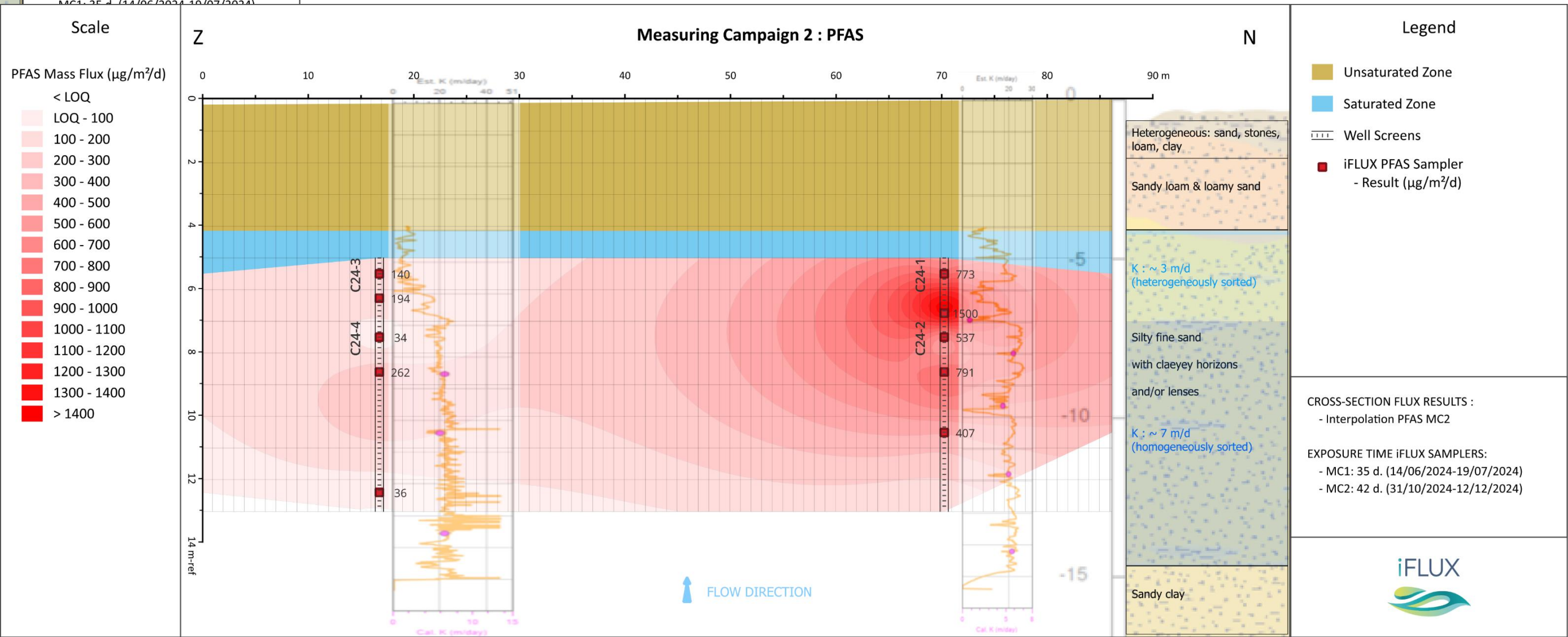
Observations and evaluation PFAS flux

Seasonal variation : Interpolation horizontal PFAS flux



Observations

- Seasonal variation, higher flux in autumn event
- Spatial variation, higher flux on one location



Observations and evaluation PFAS flux

Flux in shallow and deeper aquifer

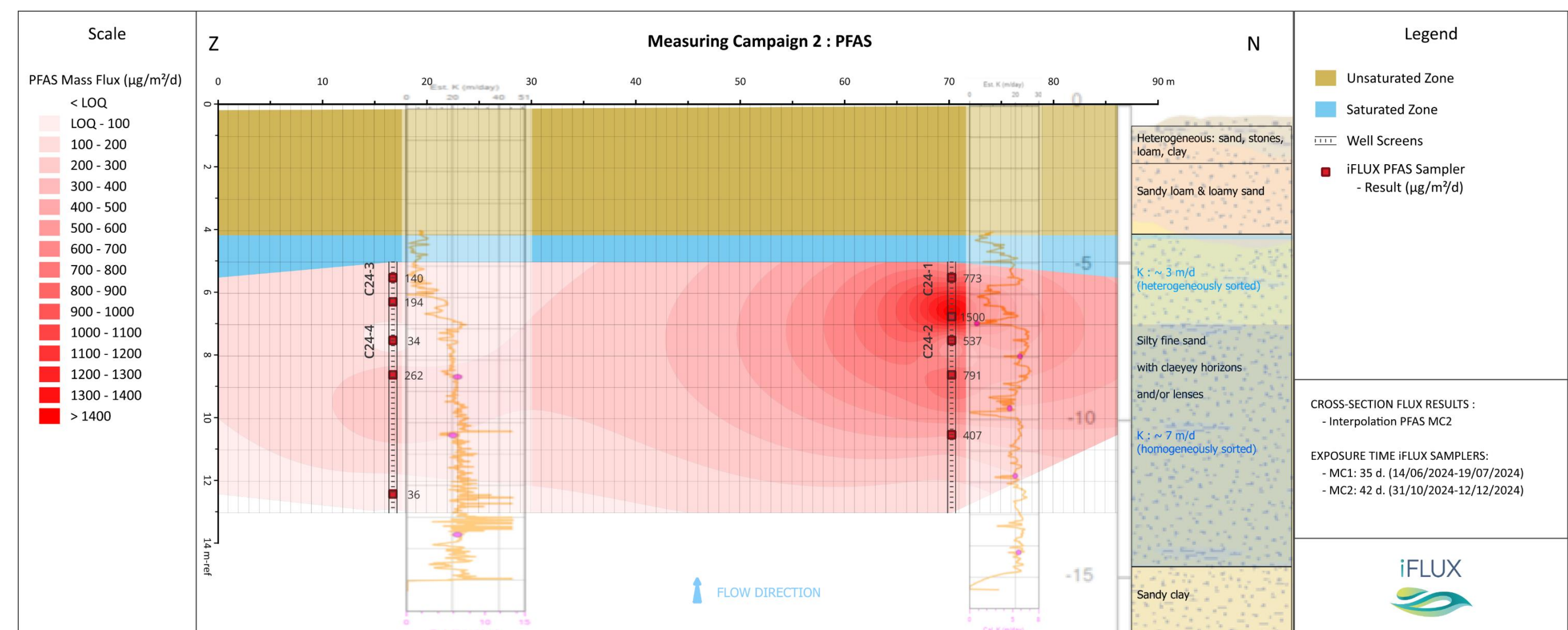
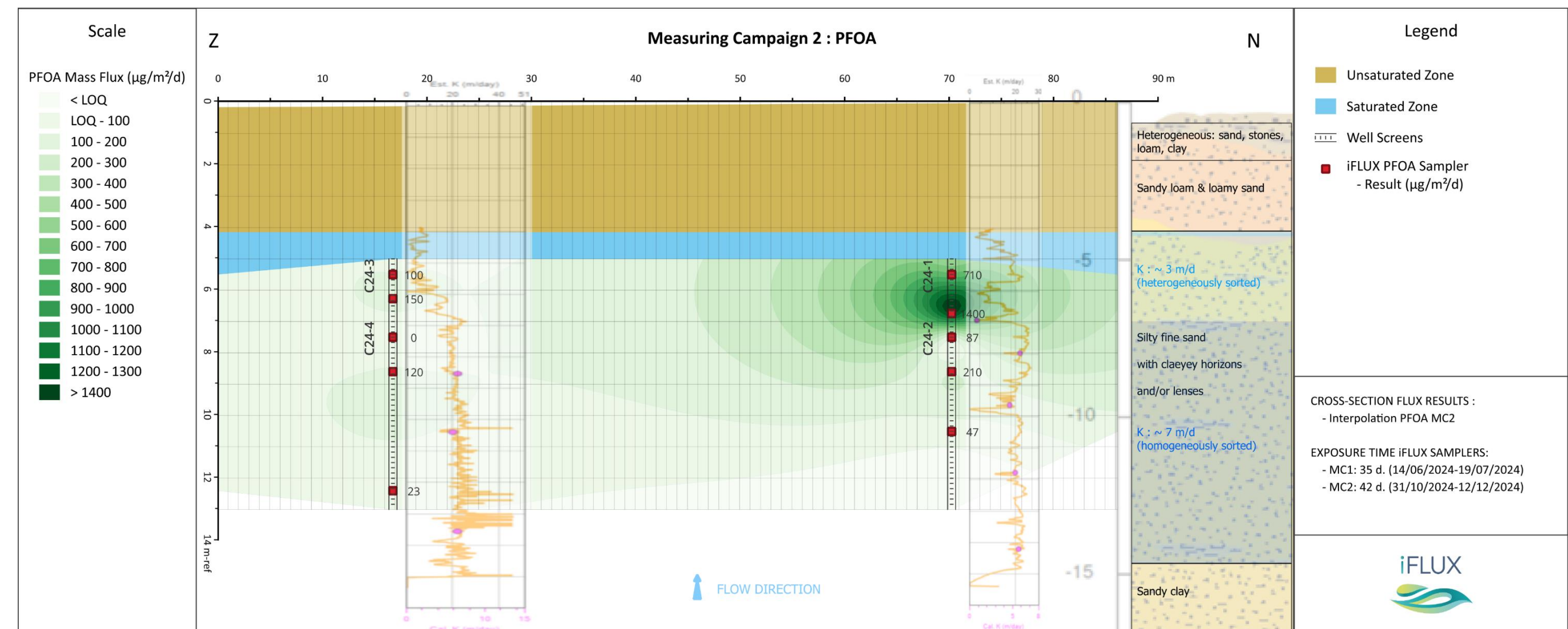
Evaluation

Shallow (lower permeable) aquifer

- Non-negligible mass fluxes
- Impact analysis on down-stream receptor

Deeper (higher permeable) aquifer

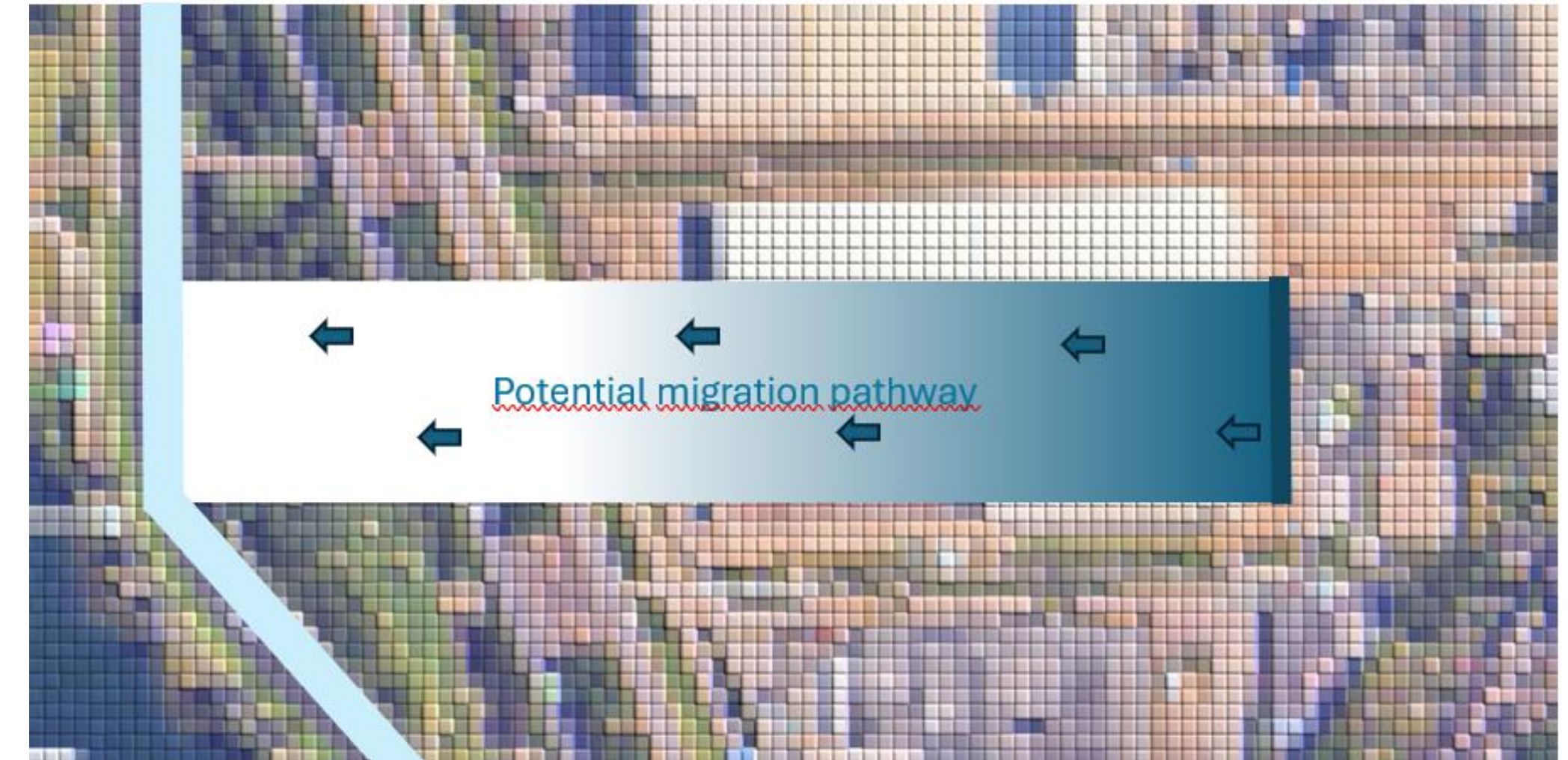
- Significantly lower (and more stable) flux in deeper aquifer
- Correlated with lower PFAS concentrations
- Migration PFOA to and via deeper sandy soil is negligible



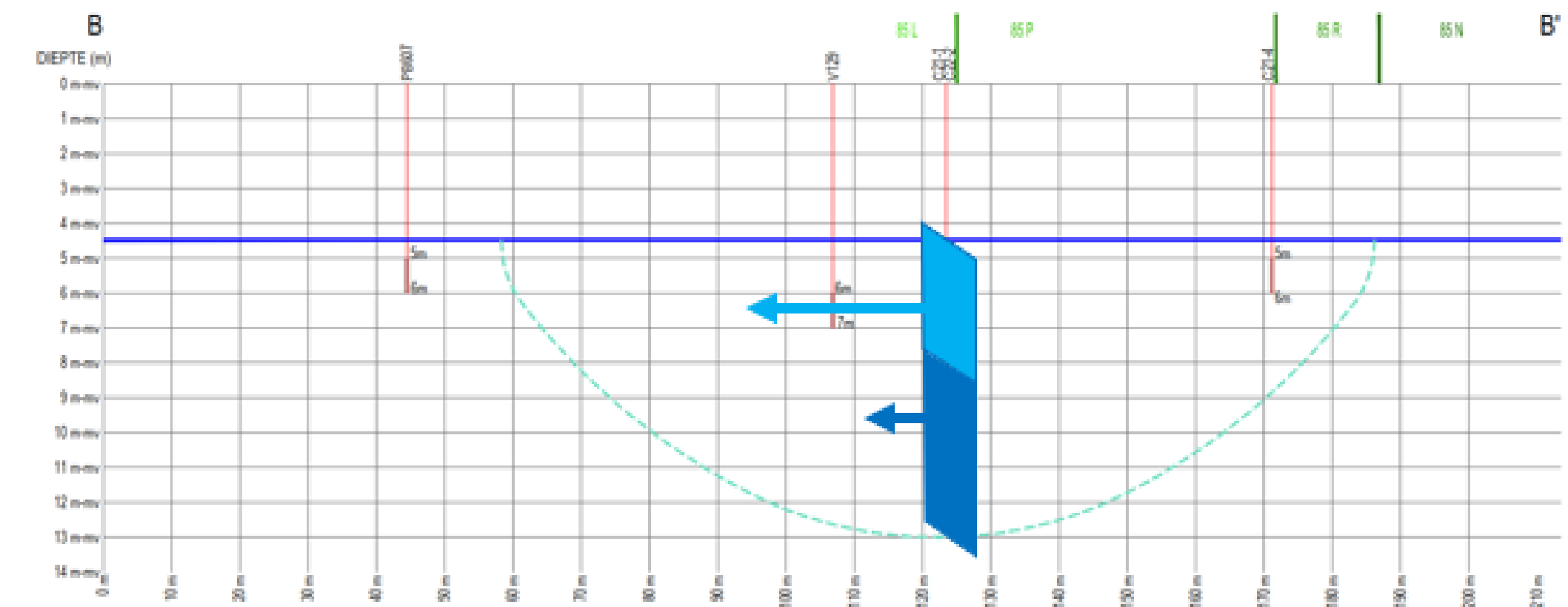
Flux – river as receptor

- Conservative theoretical flux & mass discharge
- Based on measured flux at site border
- Calculate surface water impact of PFAS
 - ✓ water velocity and distance to river: 80 – 220 year retardation (theoretical values ITRC)
mass flux & concentrations
 - ✓ Mass discharge and river volumes results theoretically:
< 0,5 ng/l PFAS
Lower than current reporting limits
Lower than current guideline and/or threshold values
 - ✓ Current average PFAS in the river 200 ng/l

→ No 'unacceptable risks' expected from site-specific PFAS impact



Geological transect B-B'



Investigation 2024

Flux based decision making for
remedial approach (Aecom, BE)

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4. Conclusions



Conclusions

Risk assessment

- PFAS discharge (128 à 203 g/year)
- Migration (flux) to and via the deeper aquifer is negligible
- No measurable impact on the downgradient river expected

No Further Action Required, Agreed by OVAM (environmental authority)

Flux based approach

Limits
uncertainty

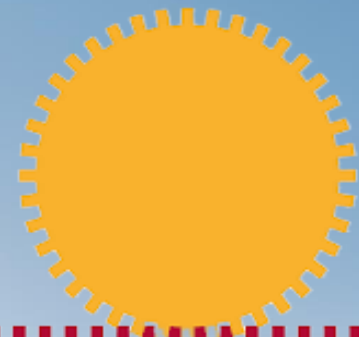
Identifying
mass flux
variabilities

Avoid
conservative
assumptions

Allows for a flux based remedial
approach (if applicable)

Aim on tackling
highest fluxes

Flux based
monitoring
during active
remediation



NORDROCS 2026

-Crossing borders



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