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Monitoring the effects of a colloidal activated carbon barrier for stabilisation of PFAS: Insight into the development of AFFF contamination now and in the future

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SWEDISH GEOTECHNICAL INSTITUTE

MONITORING THE EFFECTS OF A COLLOIDAL ACTIVATED CARBON BARRIER FOR STABILISATION OF PFAS: INSIGHT INTO THE DEVELOPMENT OF AFFF CONTAMINATION NOW AND IN THE FUTURE

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Foto: SGI, Robert Earon

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INTRODUCTION AND BACKGROUND

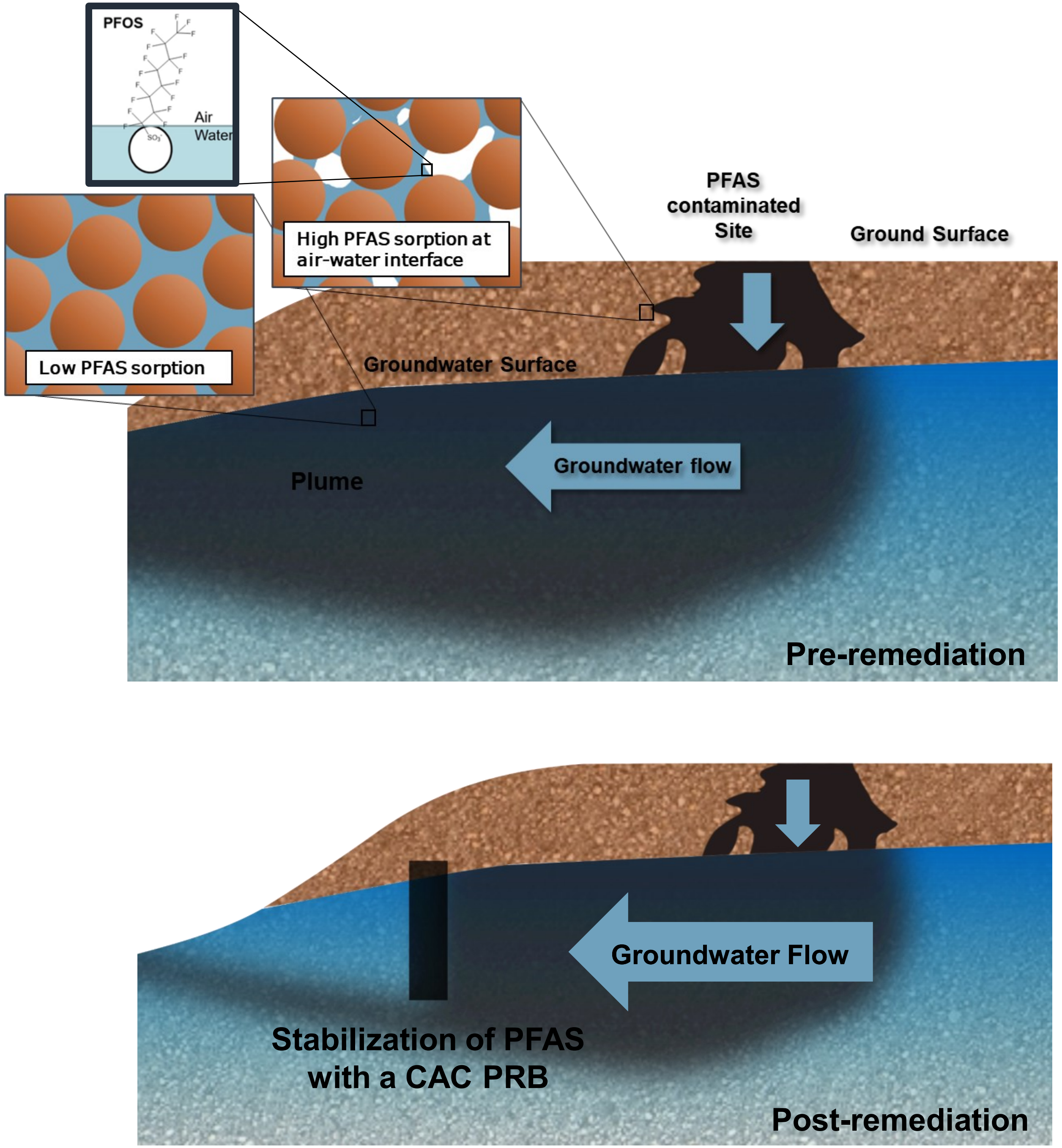
Transport in the vadose zone differs greatly from the saturated zone where air-water interface (AWI) interactions limit mobility.

Mass fluxes can often be a small portion of the total PFAS reservoir.

Composition of PFAS varies with depth, as different PFAS interact differently with the AWI.

Impacts likely to span decades.

SGI has an ongoing government assignment to develop/test remedial methods to increase the pace of remediation of PFAS-contaminated areas. Part of this assignment involves testing stabilization with activated carbon.



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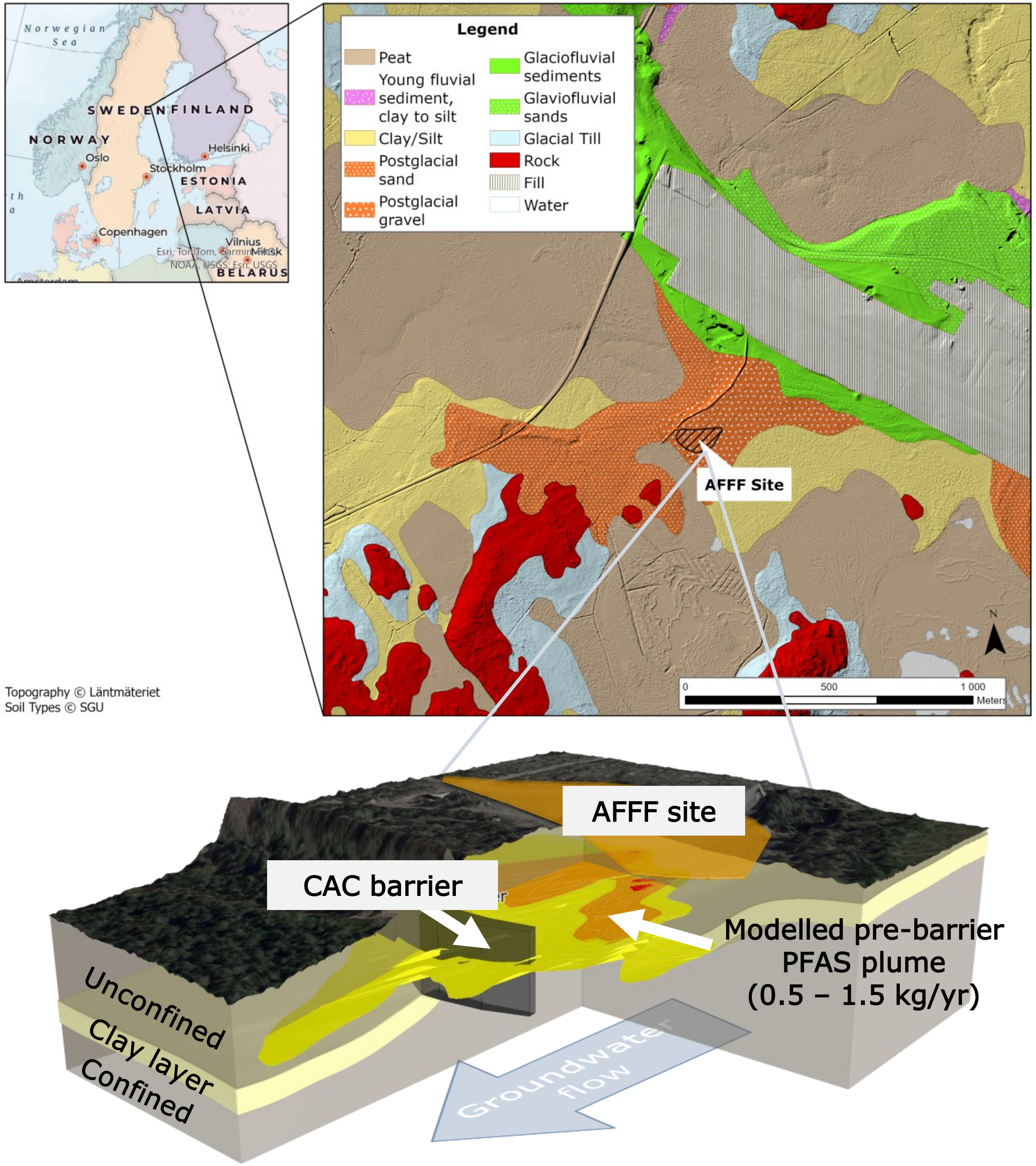
DESCRIPTION OF SITE

Active training site where AFFF foam containing PFAS used until late 2000's, PFAS from site linked with concentrations in surface water kilometers downstream.

Primary transport path of PFAS is through post glacial sand, overlying clay and glaciofluvial sediments.

Test site for SGI's pilot test for stabilization of PFAS with activated carbon.

Test site for research projects focused on developing practical models for transport of PFAS (Uppsala University/*Swedish EPA*) and linking remediation measures to soil health (PHISHES/*EU Mission Soil*)



DESCRIPTION OF SITE

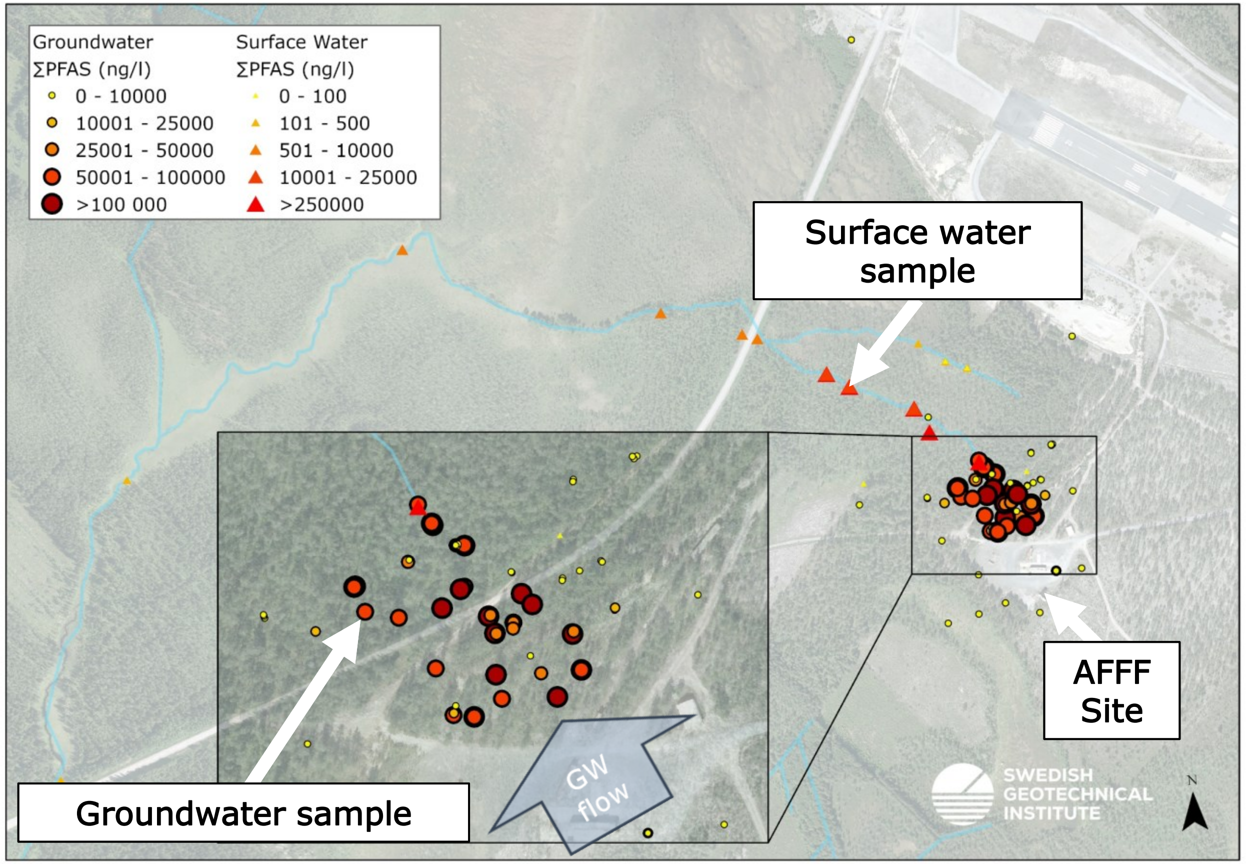
Extensive monitoring programme initiated during 2023 involving depth-specific and monthly groundwater sampling, snow sampling, measurements of the groundwater surface, passive measurements, soil samples, etc.

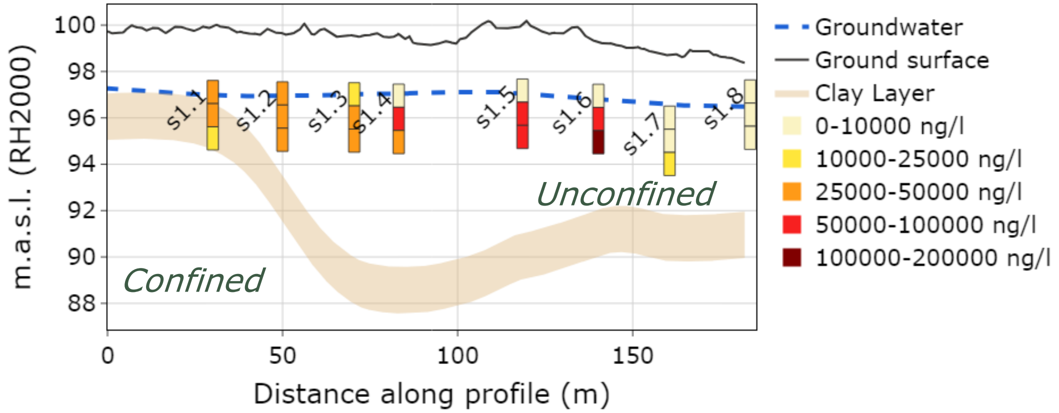
Concentrations of PFAS-32 in the groundwater of more than 200 000 ng/l. Seasonal variations prominent due to snow melt.

Channeling clear despite homogeneous geological conditions.

Discharge area to non-seasonal spring (roughly 0.6 to 1.6 kg/yr ΣPFAS-32).

Evidence of non-target precursors.





Cross section of aquifer with depth-specific samples.

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INSTALLATION OF CAC BARRIER

Permeable reactive barrier installed as a pilot test.

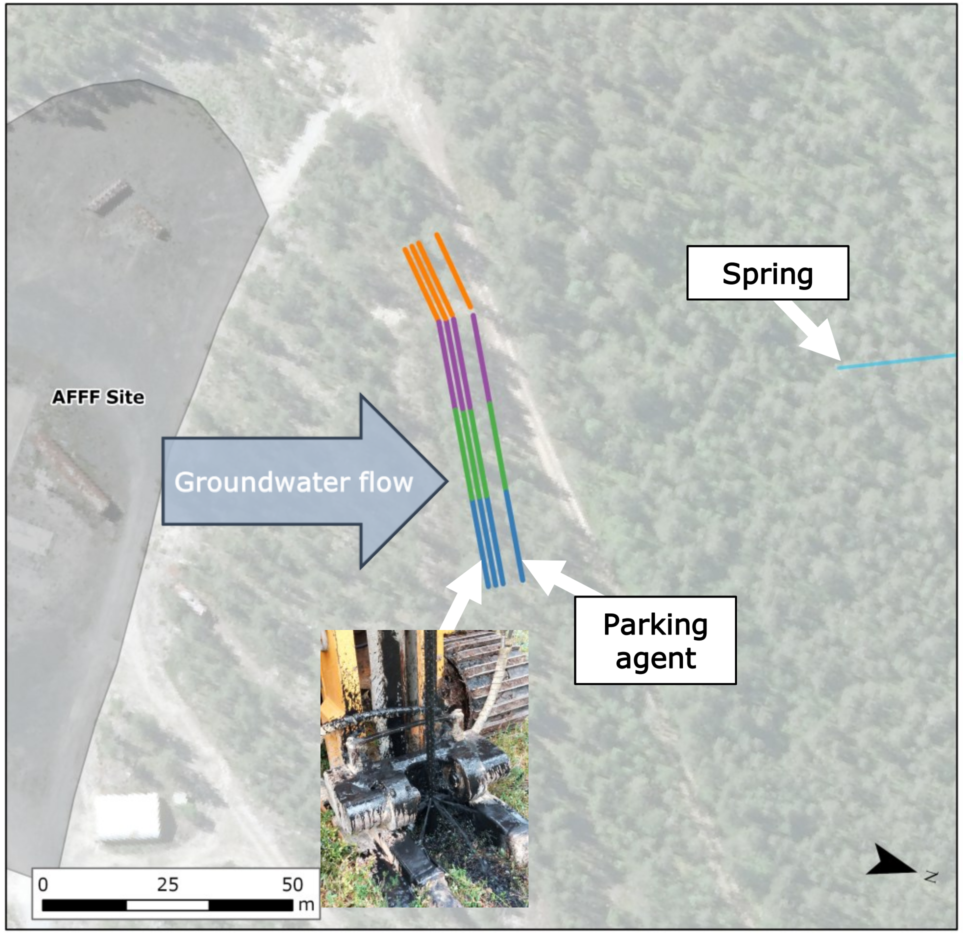
Colloidal activated Carbon (diameter 2 µm) with high affinity for PFAS injected through direct push techniques.

Injection carried out between 20 Sept and 21 Nov 2023.

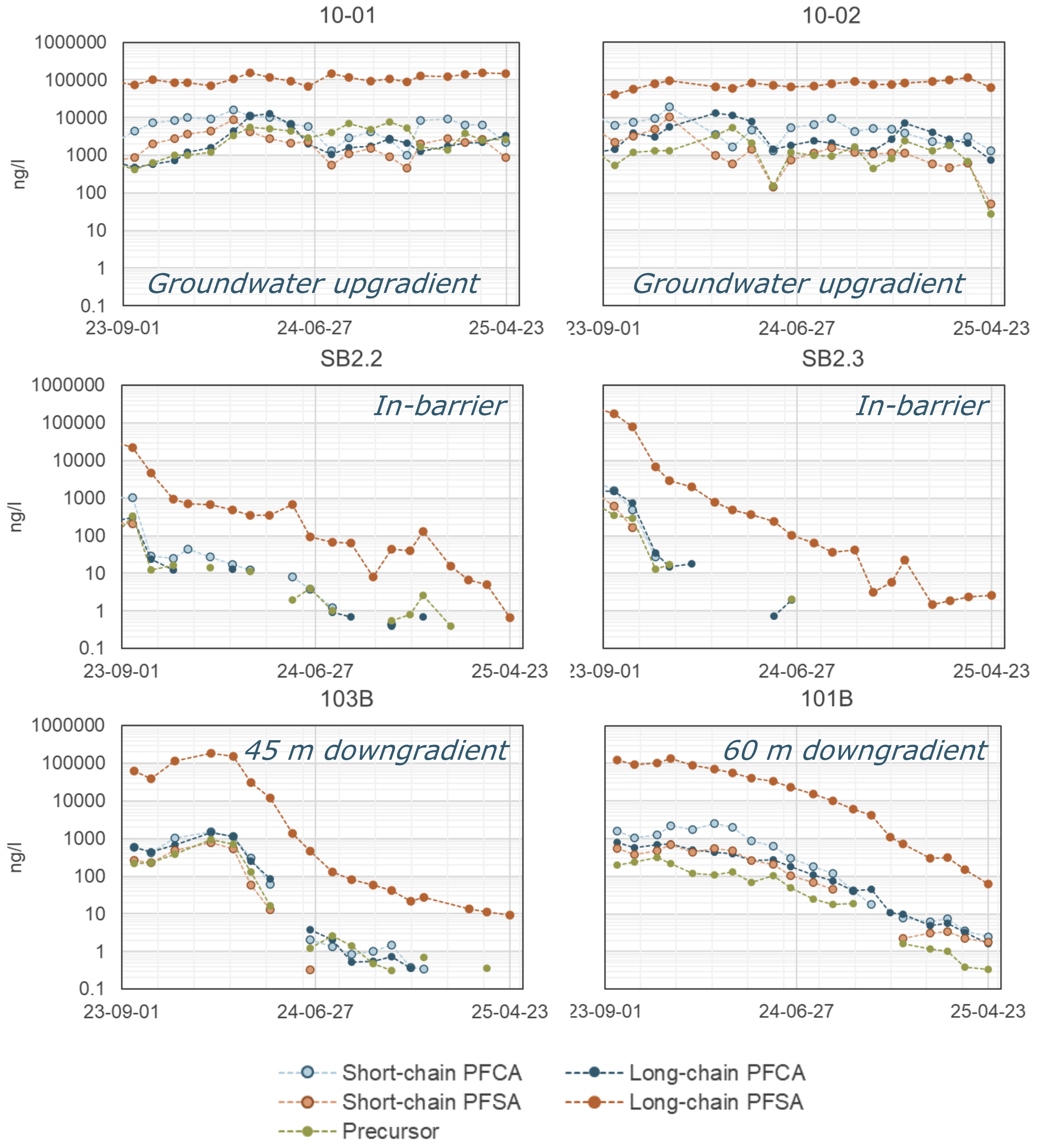
Barrier constructed with 3 rows injectate and 1 row “parking agent” ($CaCl_2$).

- 1.5 m point spacing, 47 pts/row.
- 5-6 m treatment horizon.
- 500-600 kg PlumeStop/pt.

76.7 tons PlumeStop injected



SWEREF 99 TM, Background: Lantmäteriet



EFFECT OF CAC BARRIER ON GROUNDWATER CONCENTRATIONS

Concentrations in groundwater reduced by 99.9% relative to pre-barrier concentrations.

Timing of reduction in a specific observation well dependent on groundwater flow.

Geological heterogeneities can cause treated water to arrive earlier than the bulk flow, and likely influence rate of change in groundwater concentrations.

Evidence of non-target precursors with significantly retarded transport present.

Concentrations still decreasing. No significant breakthroughs at present.

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NUMERICAL MODELLING

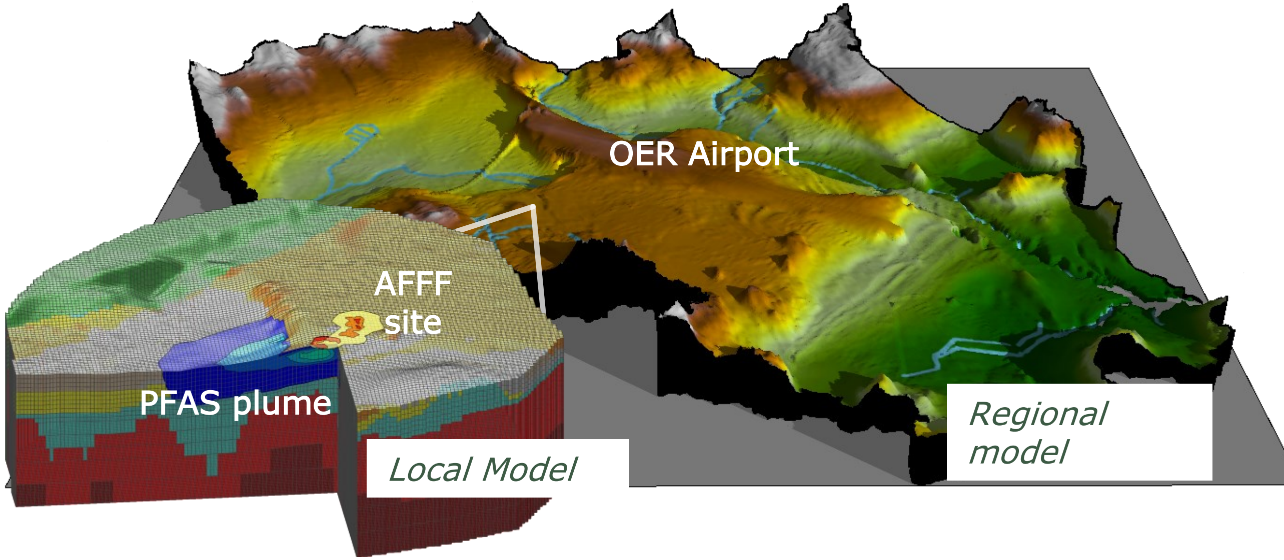
Groundwater flow critical for interpreting PFAS transport.

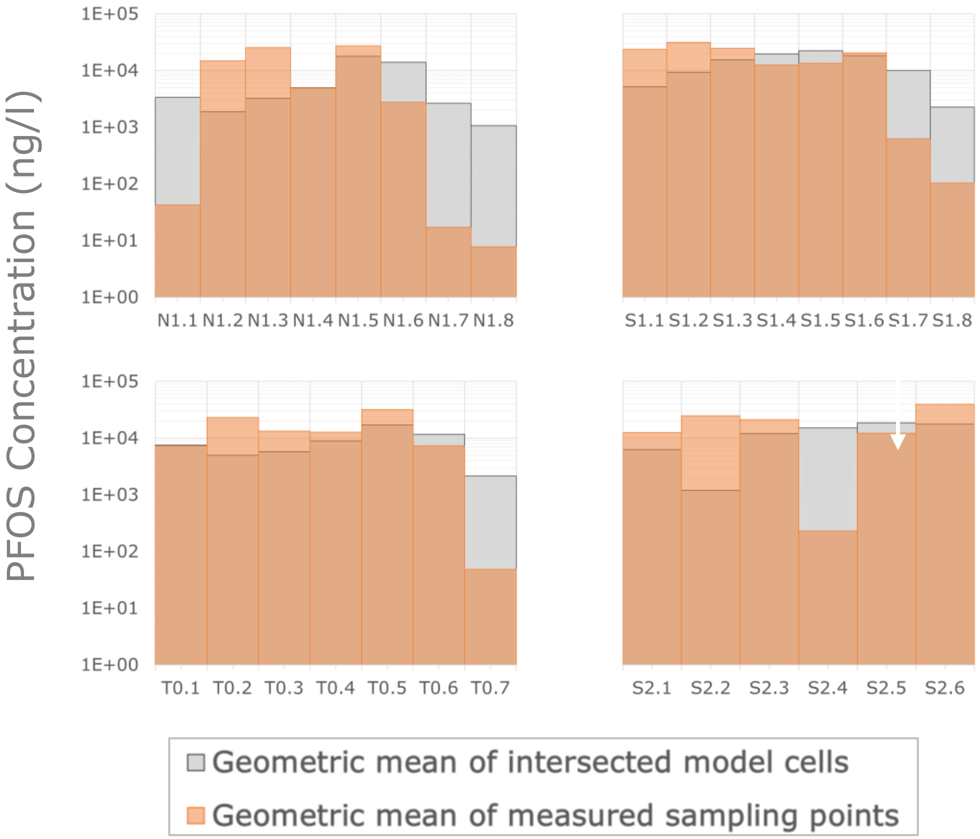
MODFLOW/MT3D used to model the groundwater flow and PFAS transport. Transport models calibrated against depth-specific groundwater samples.

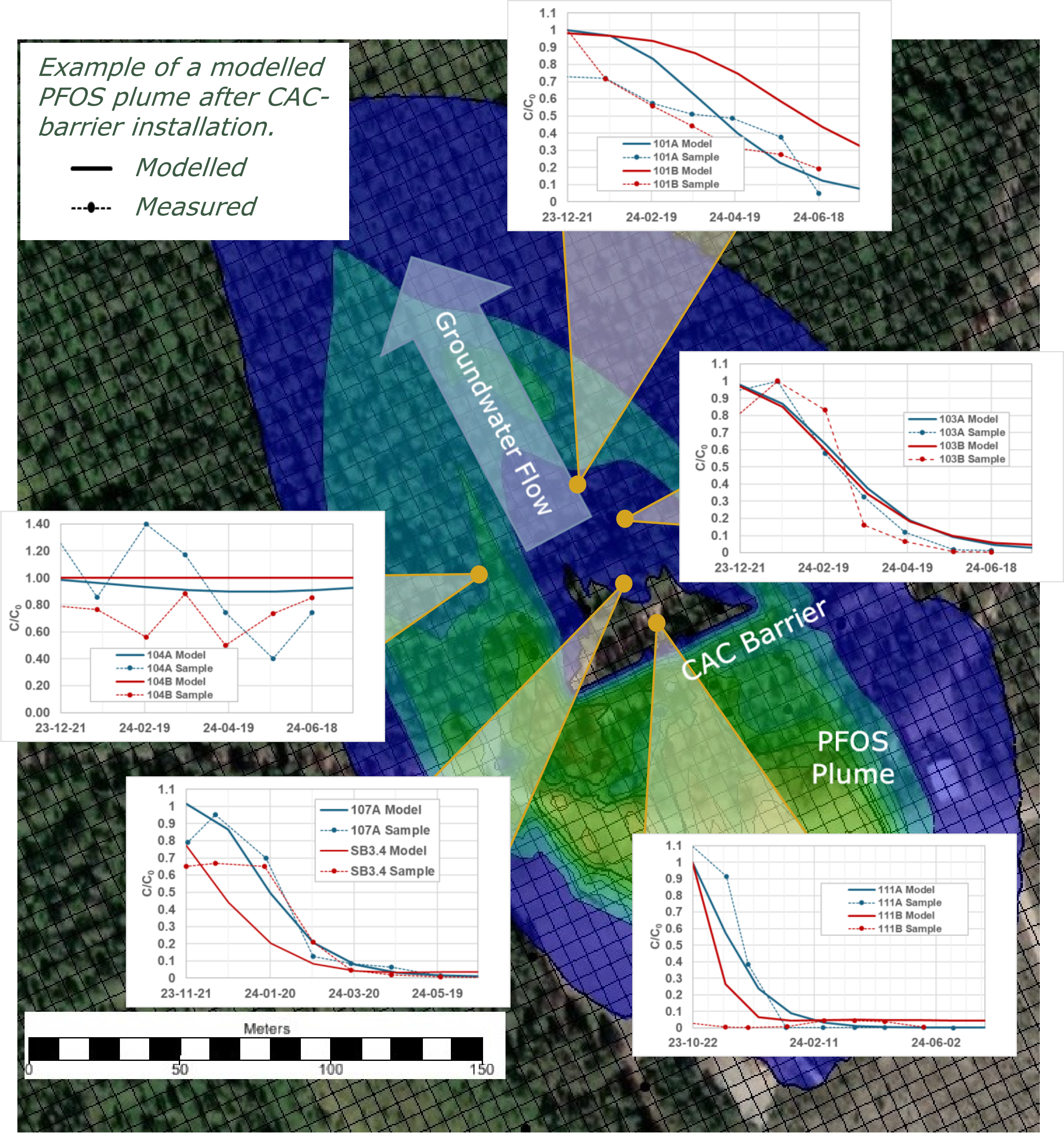
Understanding the transient behaviour of the post-barrier concentrations vital in evaluating effects and impacts of remediation measures over time.

PHISHES
PHysically-based Integrated Soil HEalth Simulation platform

UPPSALA UNIVERSITET







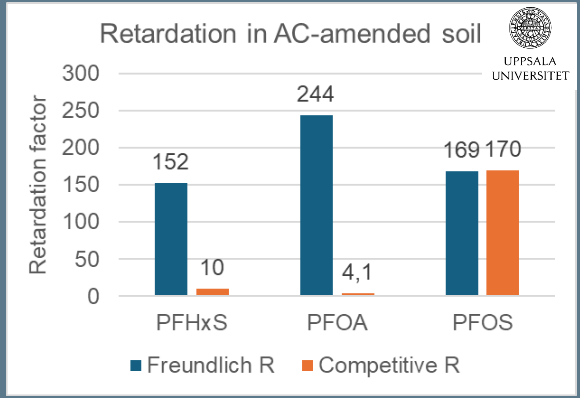
MODELLING THE EFFECTS OF THE BARRIER

Modelling vital in evaluating the timing and duration of the effect of the barrier.

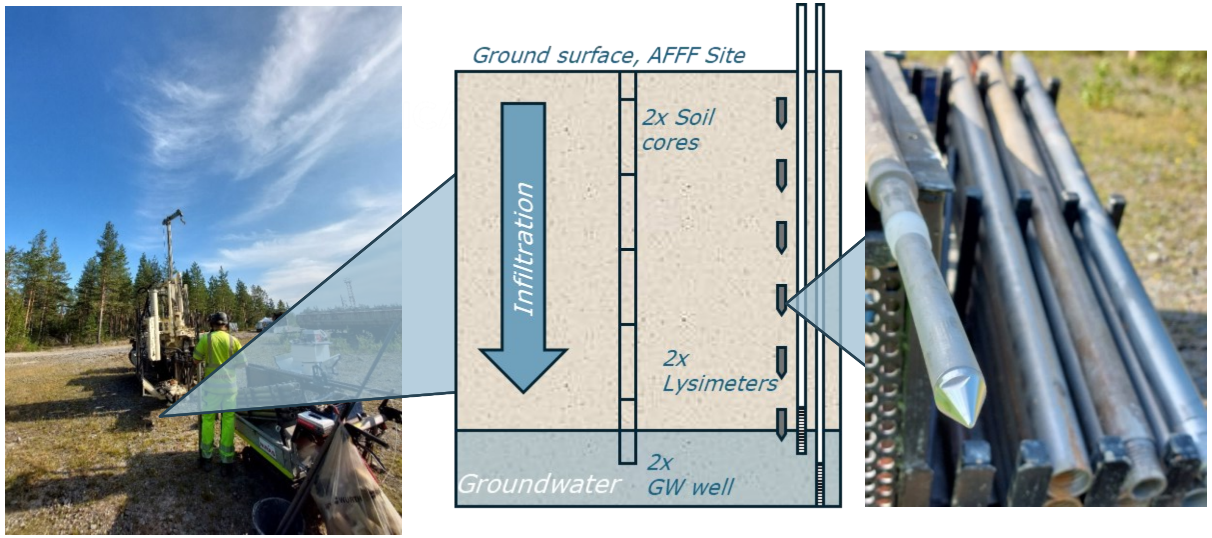
Seasonal variation not represented in the model but is a key factor in representing loading.

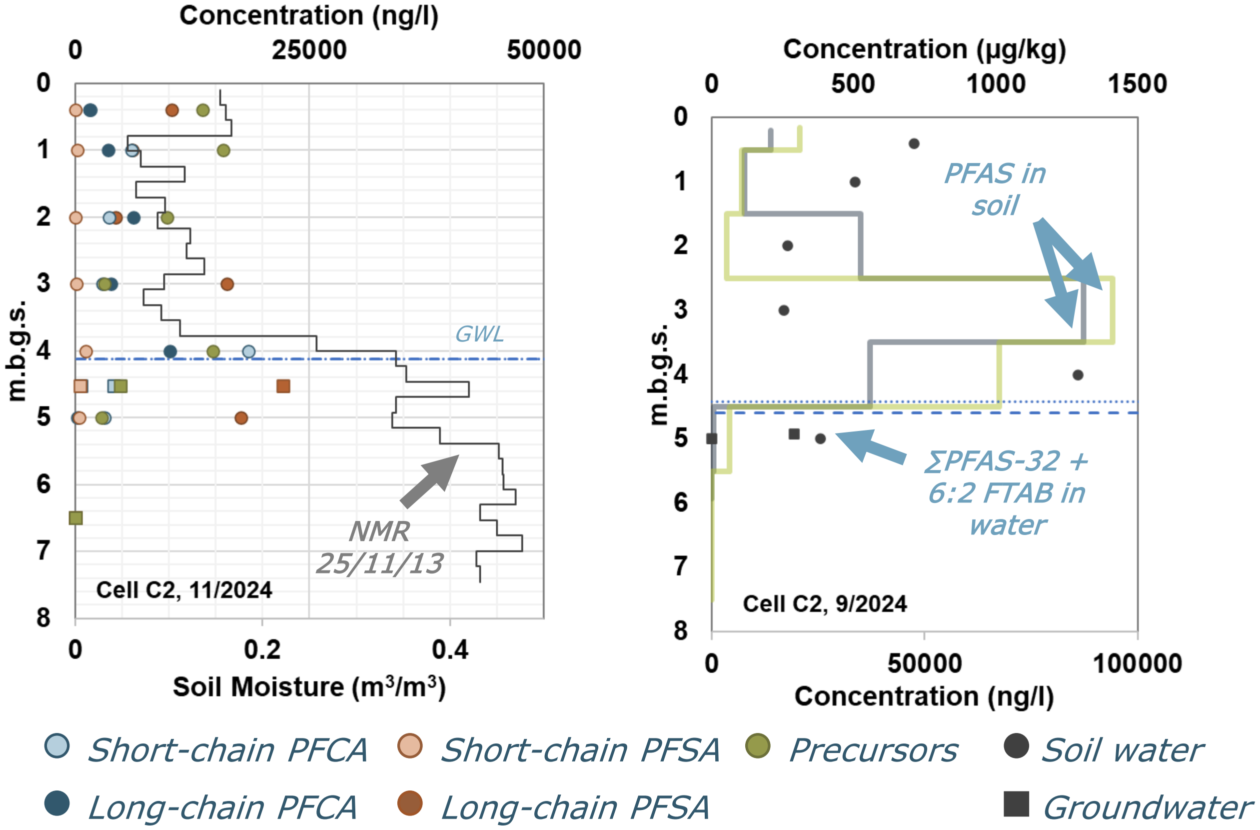
Partitioning coefficients <1 l/kg for several PFAS, in agreement with field and lab values.

Several modelling challenges remain such as loading from the unsaturated zone, barrier longevity and competition.



From: Fagerlund et al. (2024) *Modelling PFAS transport in groundwater accounting for competitive sorption.* NORDROCS 2024.





LOADING FROM THE SOURCE ZONE

Soil sampling and installation of monitoring wells and lysimeters were carried out in August-September 2024.

Differences arise between ΣPFAS in soil, soilwater and groundwater.

Much of the PFAS mass has migrated vertically within the soil column and is not surficial.

Moisture content likely significantly affects ΣPFAS and PFAS distribution.

Partitioning coefficients vary with depth in the vadose zone, likely due to AWI effects.

Loading estimates using lysimeters and recharge very likely to misrepresent the actual loading.

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FINAL WORDS AND TAKE-HOME MESSAGES

Promising results from field-scale pilot with a CAC barrier. Concentrations in groundwater declining more than 18 months after installation.

Groundwater modelling can play a vital role in assessing environmental risk and optimizing remediation strategies to inform policy decisions.

The influence of moisture content on sorption makes transport in the unsaturated zone very complex.

Loading from and transport in vadose zone still requires a great deal of research.