

From Soil to Plants and Animals

Integrated PFAS Risk Assessment in Complex Exposure Environments at Airports



1

Niklas Törneman

Project Manager, Technical Lead PFAS

Sweco Sverige AB



Why risk assessment approach

Overall PFAS remediation costs are escalating, making risk-based investment decisions important.

The risk assessment approach presented

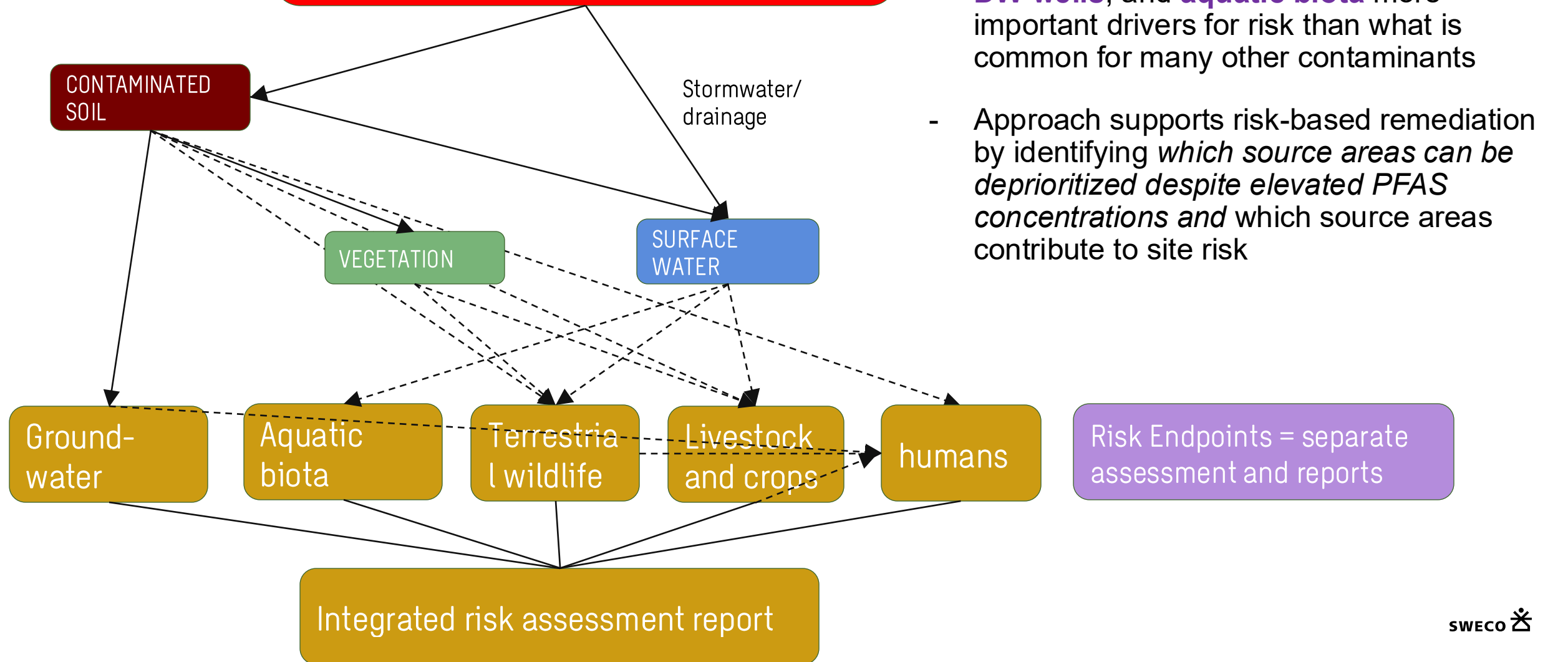
- Is less conservative than generic methods and identifies governing risks
- Provides a better basis for remediation investments

The presentation summarizes experience from multiple sites, R&D projects and >5,000 samples.

Focus is on cost-effective solutions for PFAS sites – however this sometimes demands advanced approaches

Integrated PFAS risk assessment

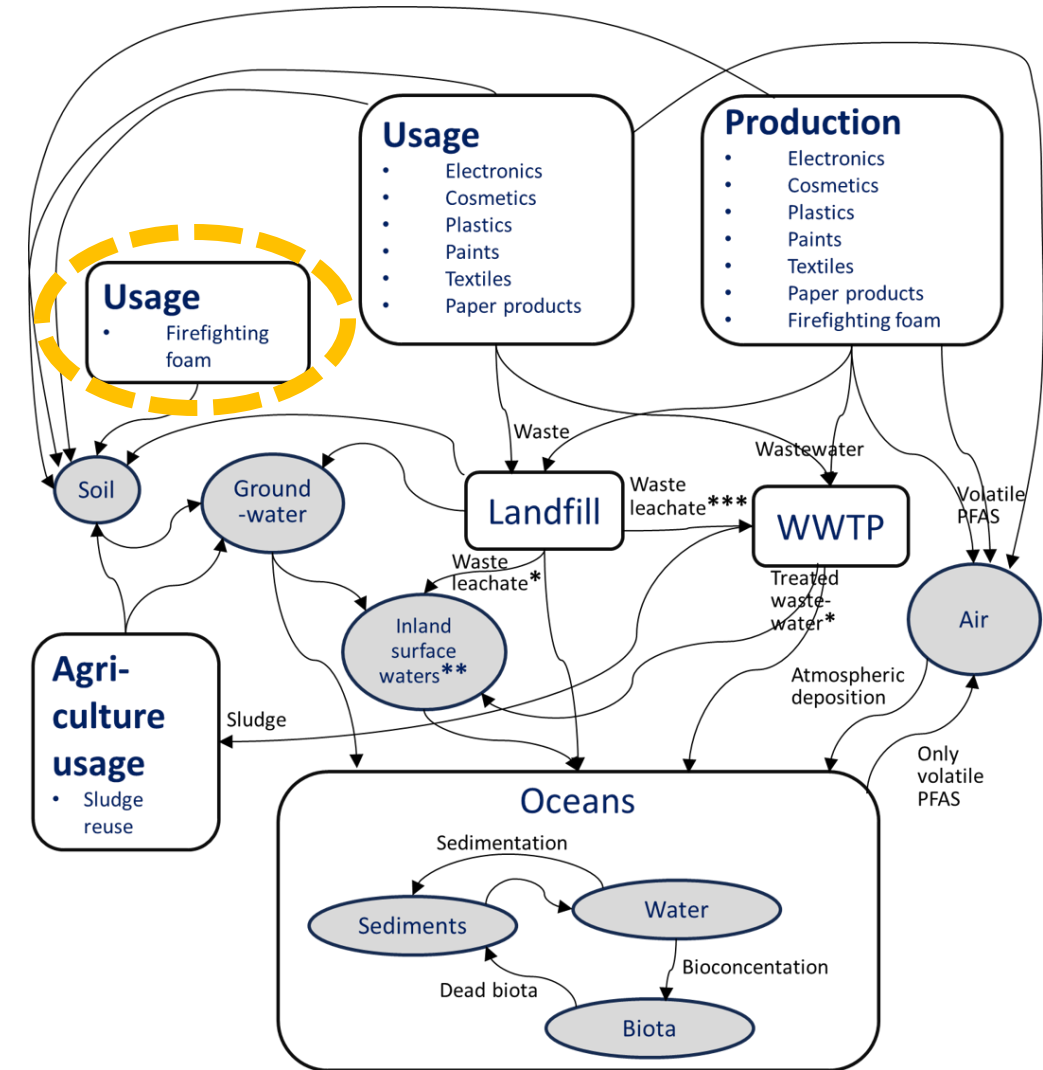
Industrial sites/Airports
→ Commonly several source areas
→ Industrial site > 30 source areas
→ Airports 5 – 20 source areas



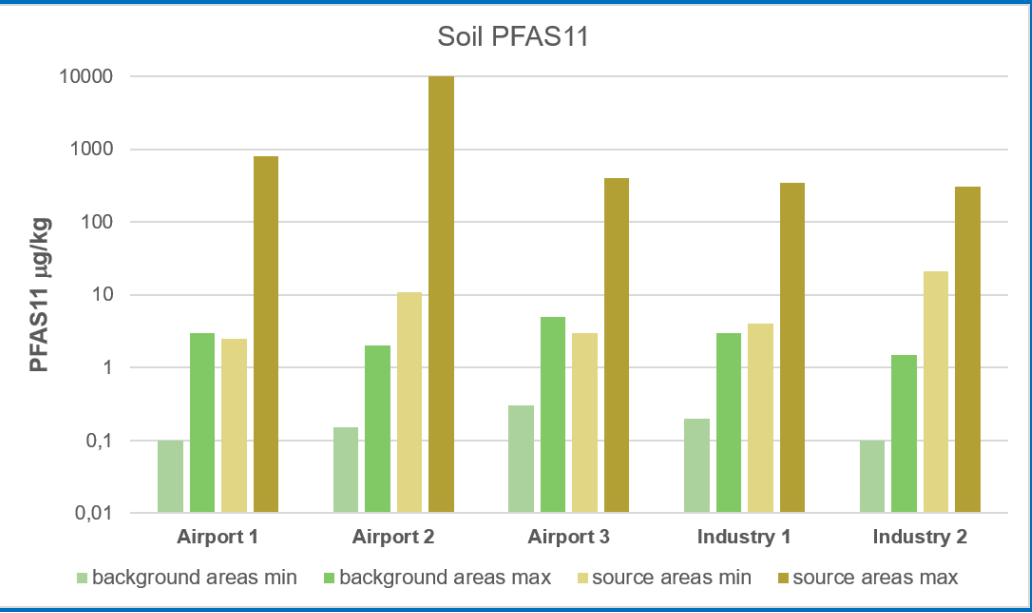
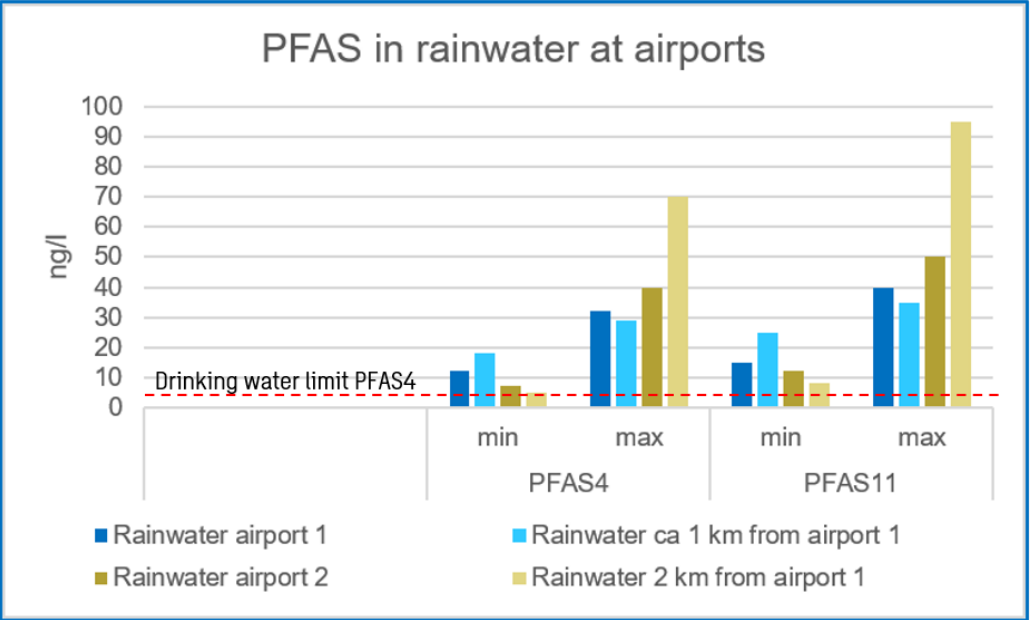
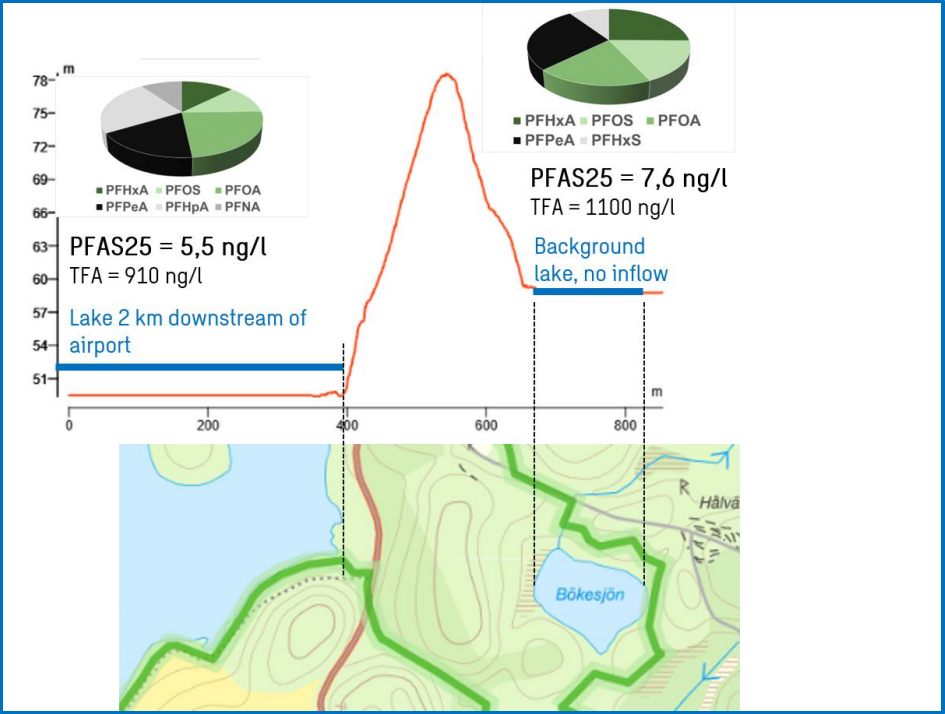
Background concentrations important in risk assessment

- PFAS is ubiquitous in biotic and abiotic matrices.
- Surface water background levels often exceed EQS values.
- Fish background levels consistently exceed new EQS biota.
- Soil background levels may exceed guideline values.
- Plant background levels remain uncertain due to high LOQs.
- In PFAS risk assessment:
 - ✓ Review local and national background data.
 - ✓ Collect additional background samples if needed
 - ✓ Always define and justify matrix-specific background levels before assessment.

PFAS usage and fate – firefighting foam only a limited part of total load 4



Project data related to background concentrations



Risk Assessment Wild Animals

A. Identification and Ranking of Sensitive Species

- Species database
- Wildlife damage register
- Red-list status
- Birds Directive etc..

Ecological factors influencing susceptibility to PFAS:

- Diet, foraging, habitat, breeding, migration etc.

B. Calculation of Theoretical PFAS Exposure in Wildlife within contaminated areas. Compared with measured concentrations.

Birds and mammals:
Species-specific input data:
intake, body weight, TRVs etc..

Exposure model
Wildlife Exposure Handbook (US EPA, 1993) and (Conder, Arblaster, & Bridges, 2021)

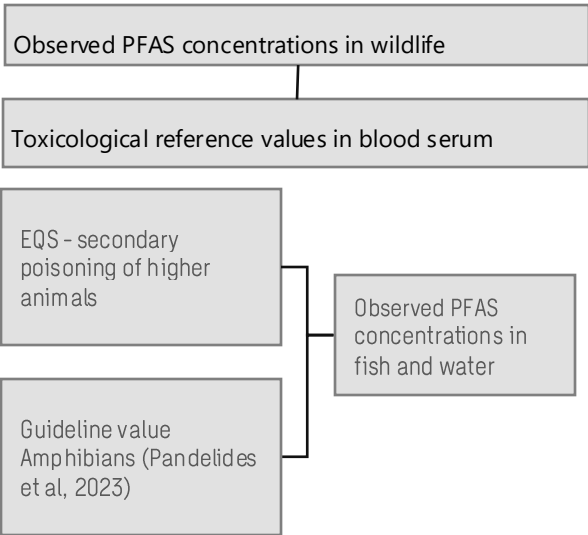
$$Do_{sart,x} = \frac{(\sum(DFI \cdot C_{foda,y} \cdot P_{foda,y})) + (DWI \cdot C_{vatten}) + (DSI \cdot C_{jord})}{BW_{art,x}}$$

Measured or estimated PFAS concentrations:

- Fish,
- Insects,
- Plants
- Soil,
- Sediment,
- Water

C. Comparison of measured PFAS concentrations in wildlife in background areas and contaminated areas .

D. Comparison of measured PFAS concentrations in wildlife, surface water and fish with relevant benchmark values



Selected project data wild animals

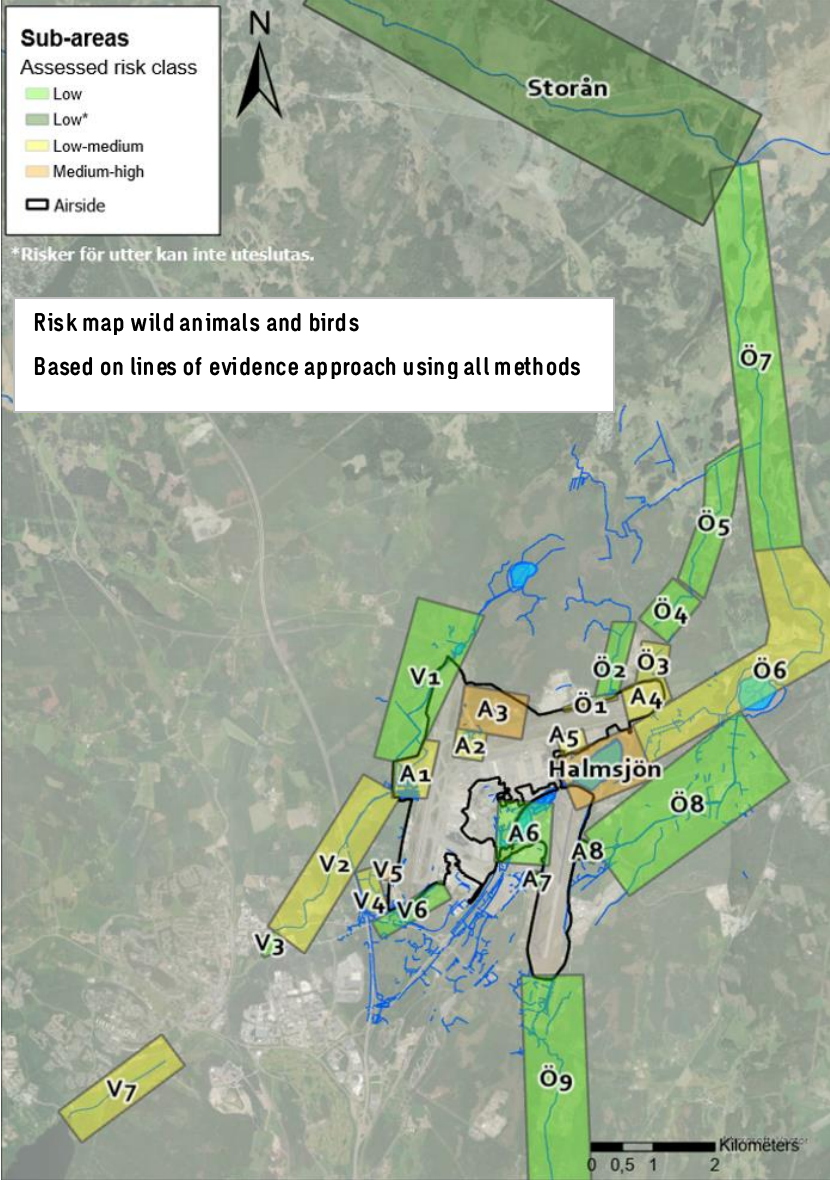
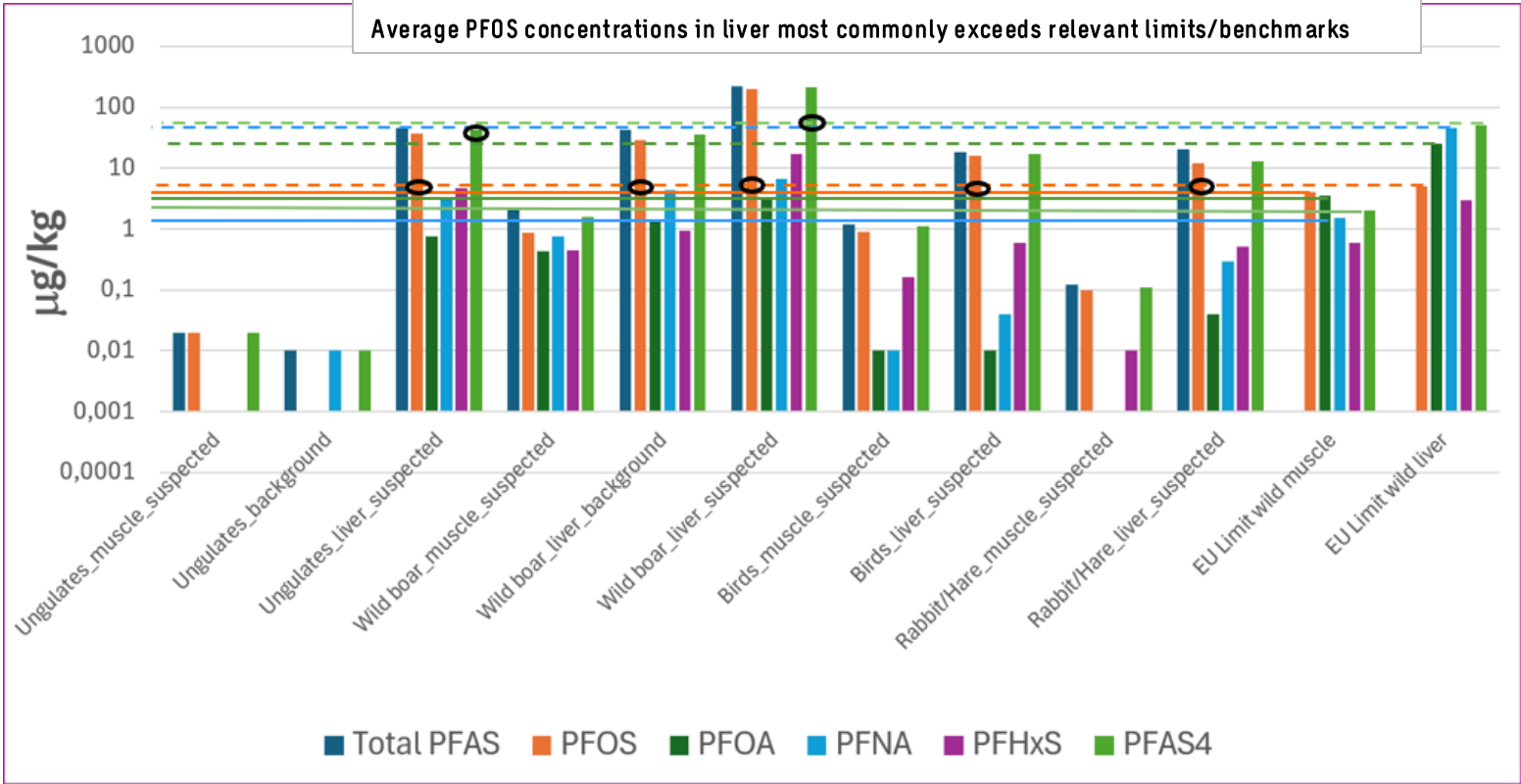
Average PFAS levels, three airports

Suspected = animals occupy areas around or within airports

EU limits = Regulation (EU) 2023/915 on contaminants in food

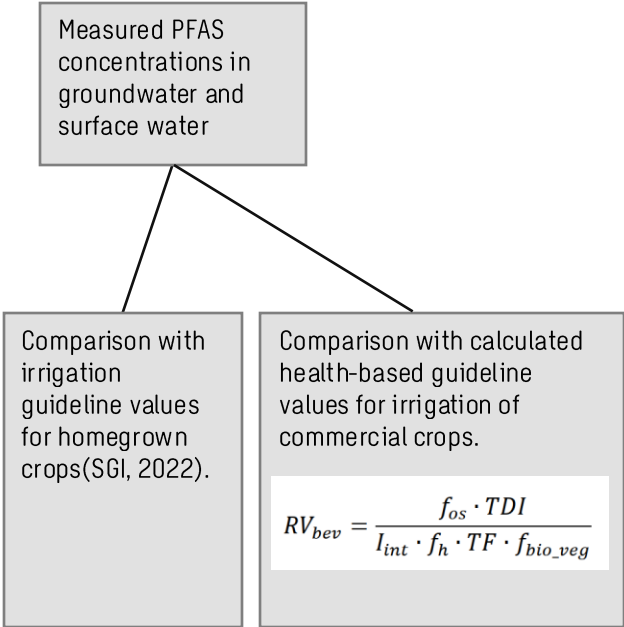
No exceedance for average muscle levels → individual samples do exceed

Average PFOS concentrations in liver most commonly exceeds relevant limits/benchmarks

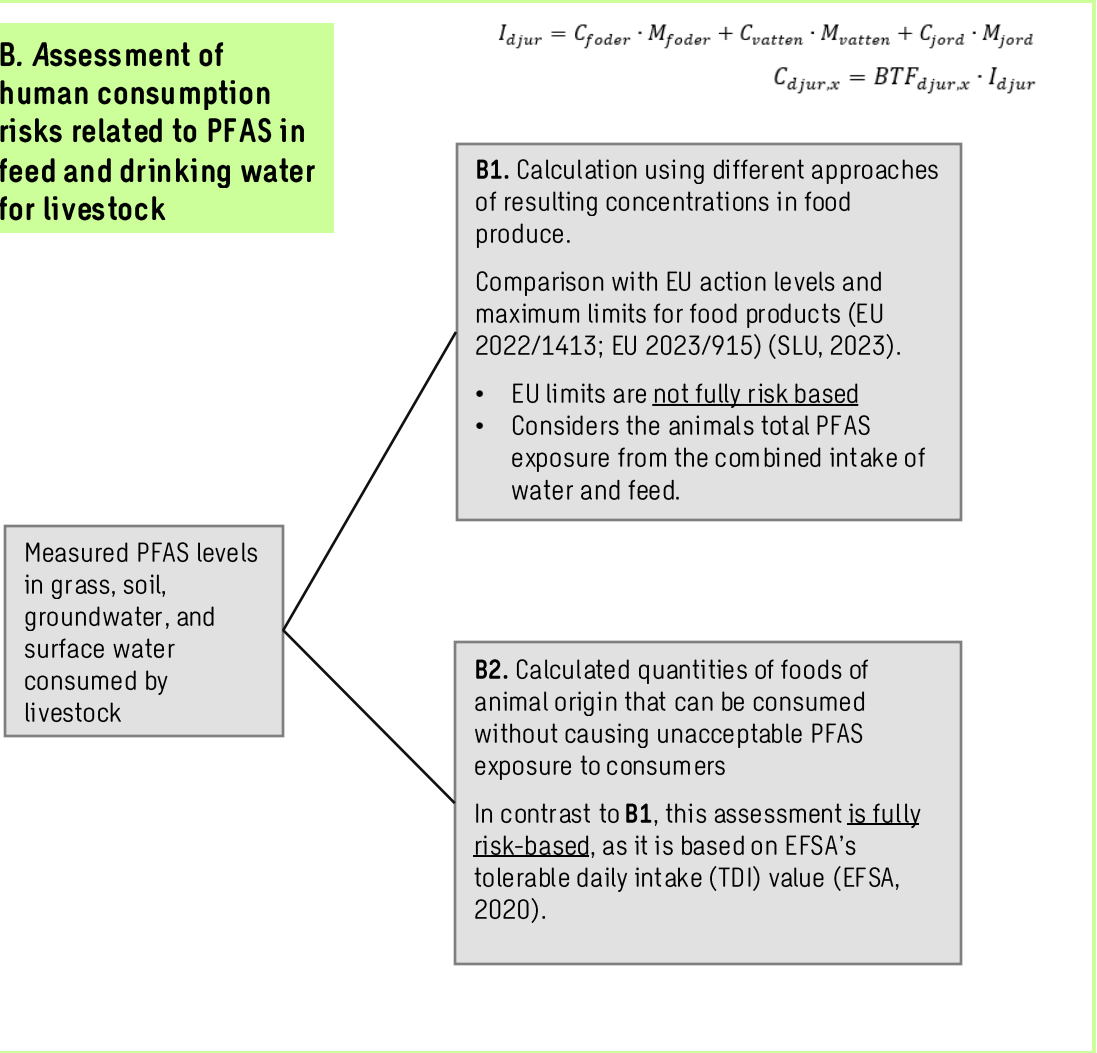


Risk Assessment Method Agricultural

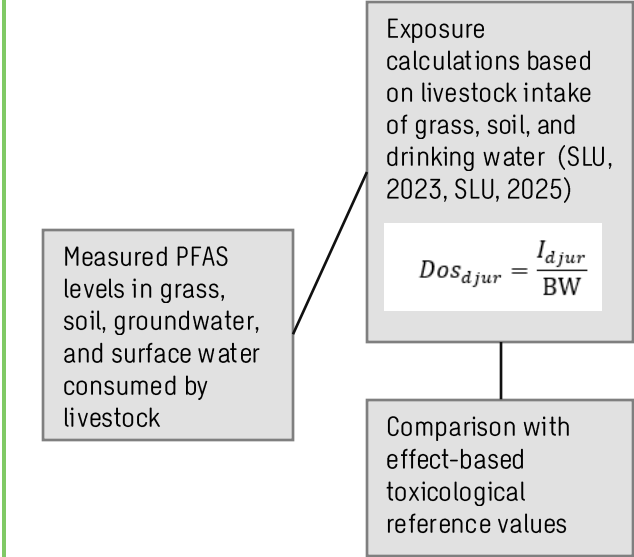
A. Assessment of water for irrigation



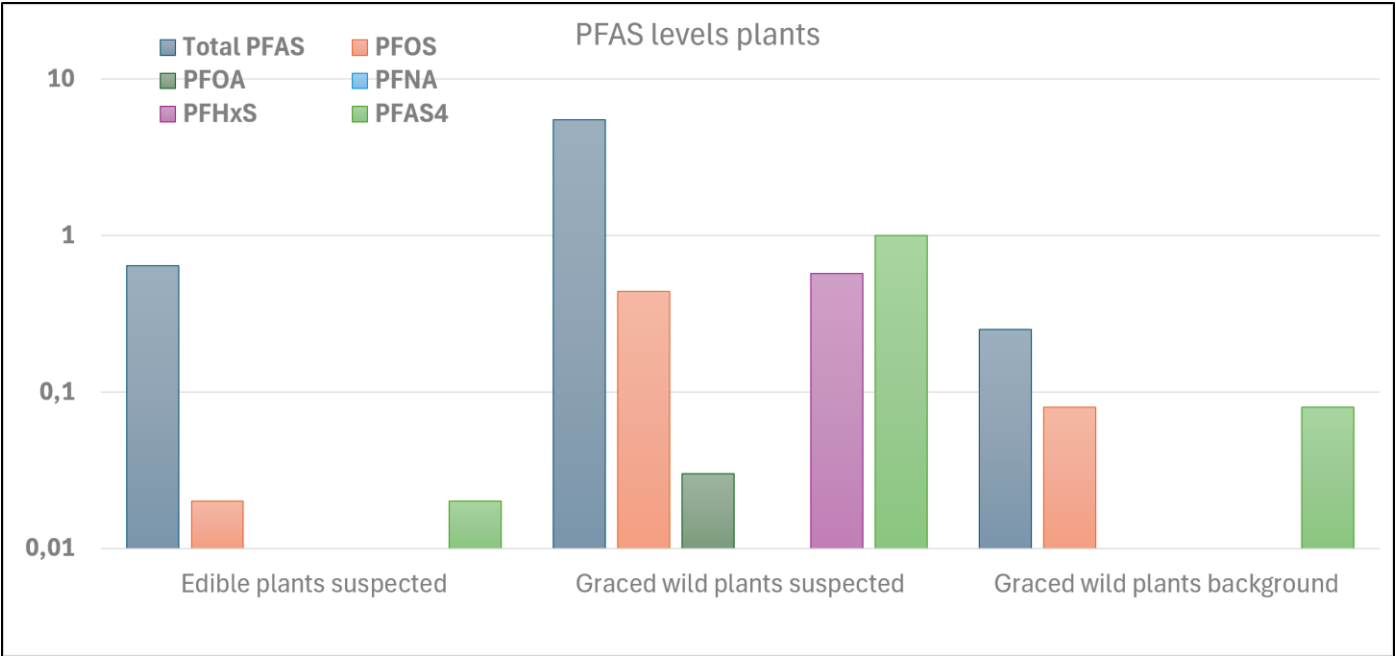
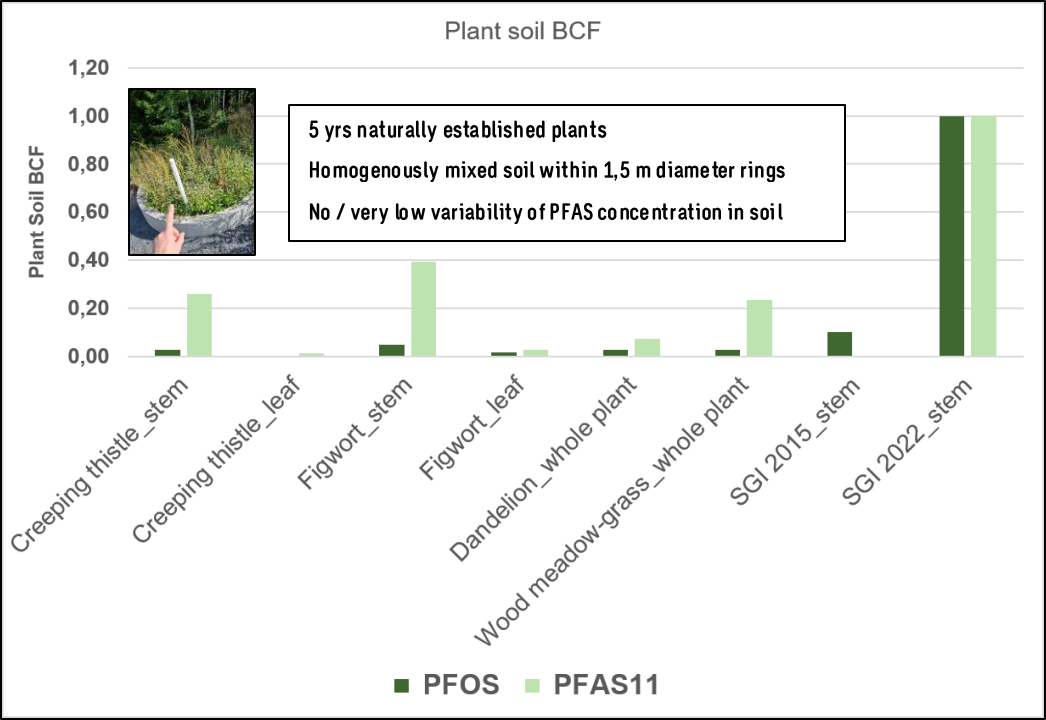
B. Assessment of human consumption risks related to PFAS in feed and drinking water for livestock



C. Assessment of risks for livestock consuming water and feed with PFAS



Selected project data related to agricultural risks

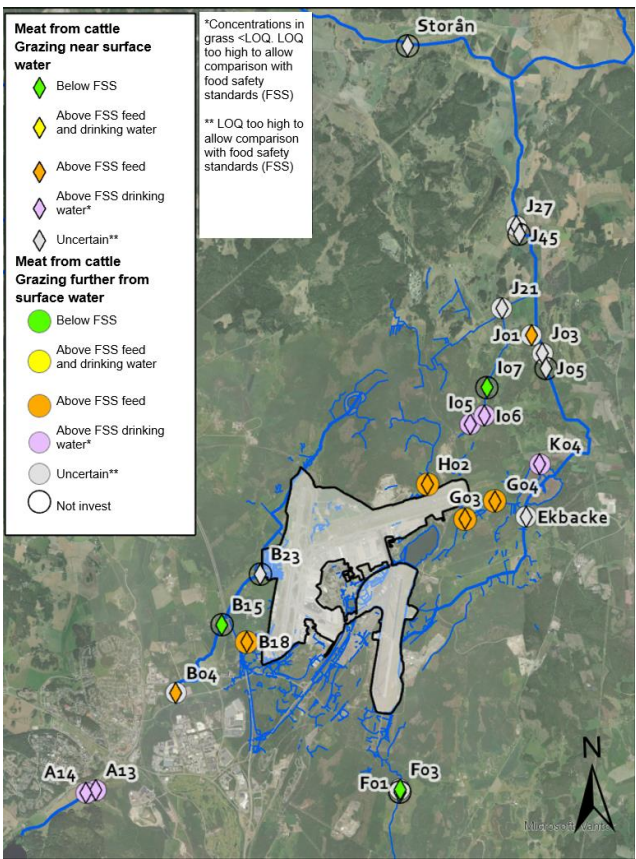


Agriculture typical risk assessment results

A. Assessment of water for irrigation

	PFAS4 (ng/l)	PFAS4 + PFOA-ekvi (ng/l)	Calculated guideline value for irrigation of commercial crops (ng/l)		RV SGI (2022) (ng/l)
			Farmgate sales	Food retail sales	
Surface water					
Damm J21	94	100	44	280	120
S lake	230	230			
Damm I05	240	240			
H lake	280	290			
M lake	140	150			
N lake	14	18			

B. Assessment of consumption risks due to PFAS in feed and water of farm animals



C. Assessment of risks to farm animals consuming feed and water

Comparison of calculated doses for animals with toxicological reference values (TRVs).

All doses in ng/kg BW,d

Toxicological reference value		Dairy cow	Cattle	Horse	Sheep	Laying hen
PFAS4		1 000	1 000	1 000	1 000	5 000
A13	Near SW	28	16	26	38	28
	Further from SW	26	15	7,9	15	18
A14	Near SW	37	21	26	46	36
	Further from SW	37	21	12	27	26
B04	Near SW	130	81	190	240	92
	Further from SW	27	22	14	29	27
B18	Near SW	1 700	1 000	2 600	3 100	1200
	Further from SW	400	250	380	580	300
F03	Near SW	1,3	0,7	1,1	1,7	1,3
	Further from SW	1,0	6,7	3,0	1,2	7,0
G03	Near SW	40	24	40	59	33
	Further from SW	35	25	28	42	29
G04	Near SW	85	52	94	130	64
	Further from SW	47	31	23	48	39

Groundwater Risk assessment

11

Groundwater areas

- Defined within the whole assessment area based on catchment, and hydrogeology
- Many project span tens of km

Sources

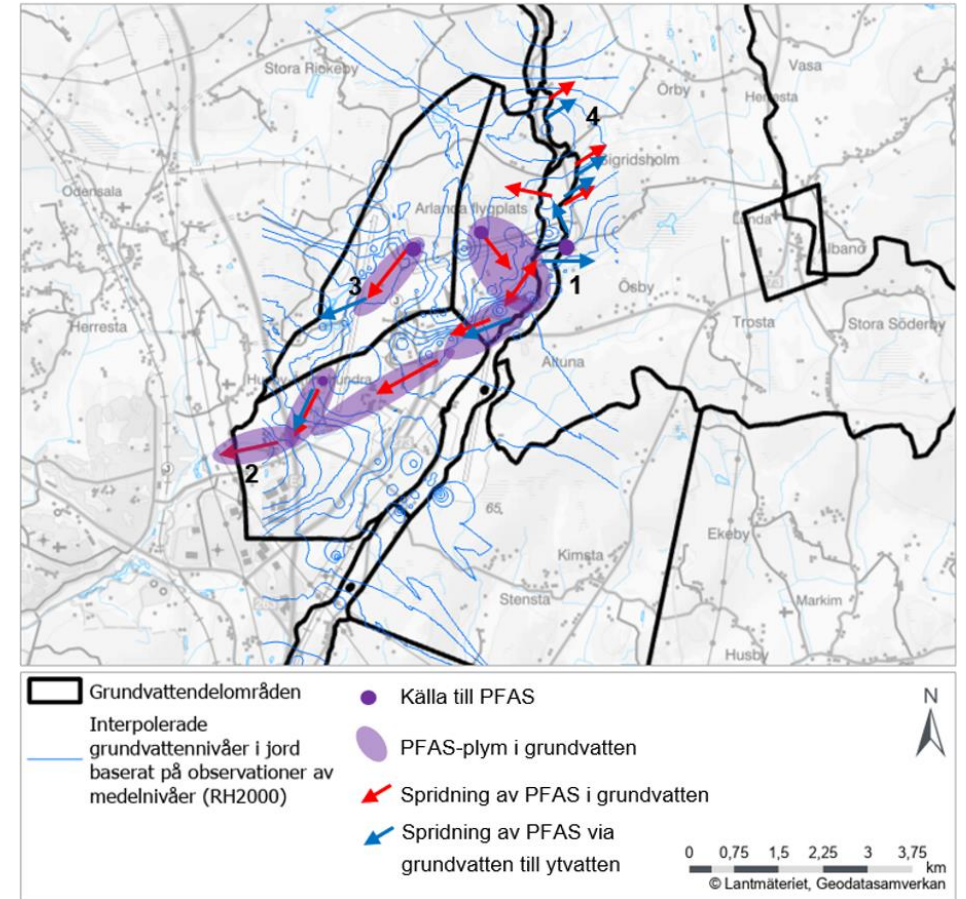
- What are the sources of PFAS within the groundwater areas?

Transport

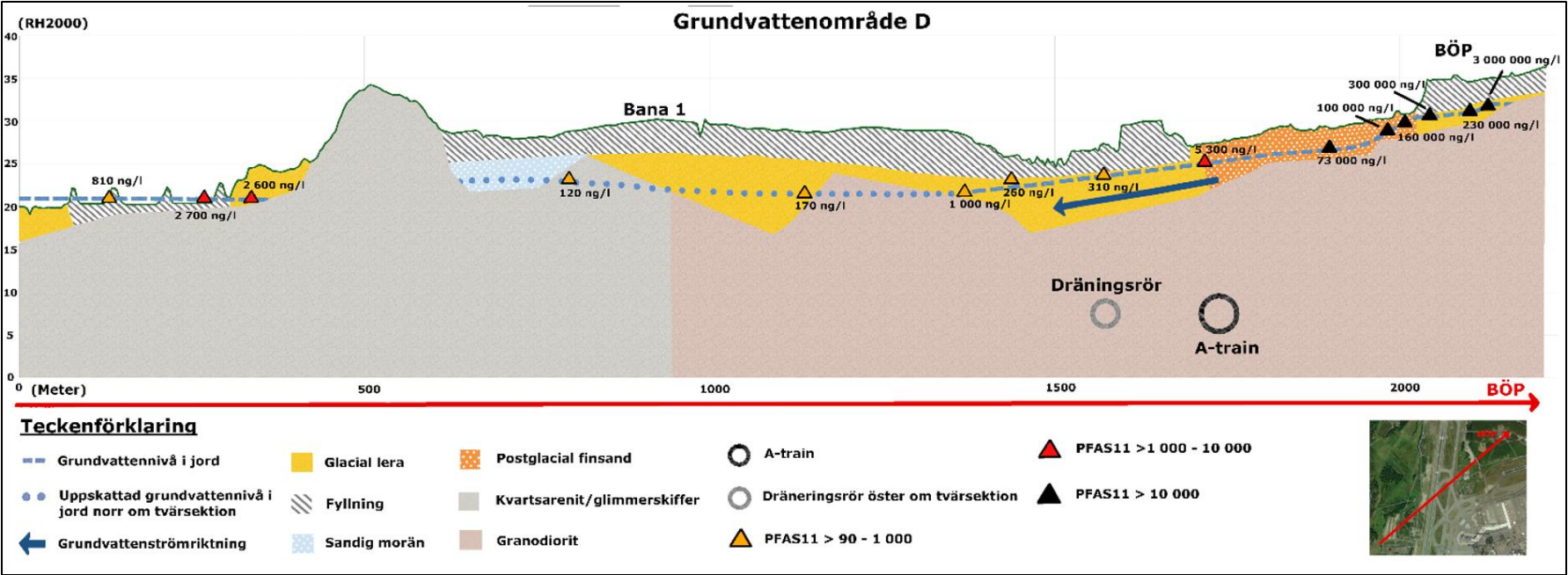
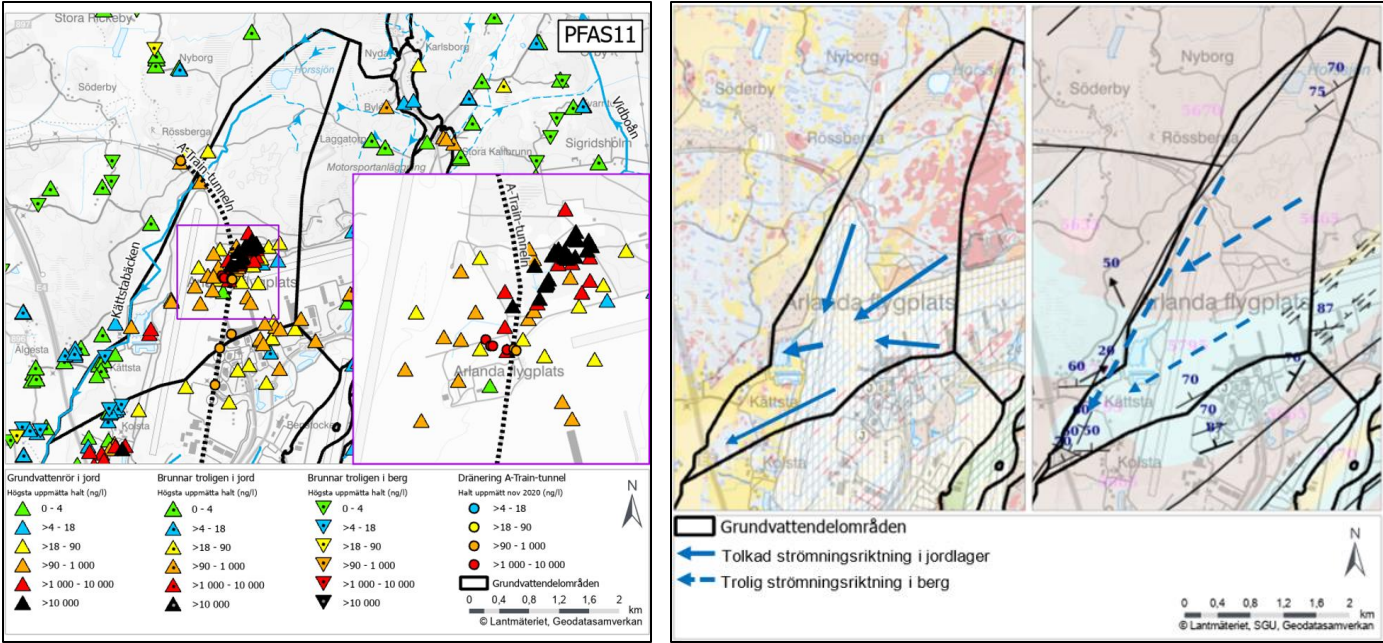
- Has the extent of PFAS occurrence and migration in bedrock and overburden groundwater been delineated in all relevant flow directions?
- Does infrastructure influence PFAS transport in groundwater, and if so, how?

Receptors

- Does groundwater discharge to surface waters, groundwater bodies, drinking water resources, or drinking water wells within the groundwater areas?
- Does PFAS migrate to deeper groundwater bodies



Typical assessment basis for one groundwater area



Surface Water Risk assessment

Mass transport (g/yr) to surface water recipients is calculated based on

- Measured and modelled water flow
- Spot sampling, passive sampling (DGT) and flow proportional sampling

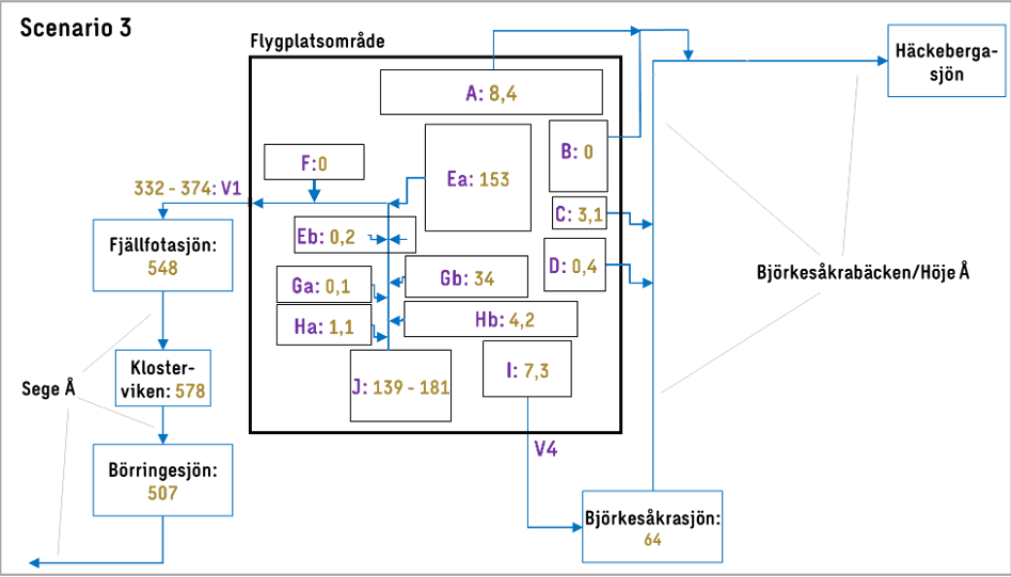
Risks are assessed through a lines of evidence approach based on

- Annual mass load
- Exceedance of background concentrations
- Exceedance of regulatory levels (EQS)
- Exceedance of levels protective of aquatic biota
- Exceedance of levels protective of secondary consumers of aquatic biota
- Fish concentrations

Selected results



Mass transport of PFAS within an airport, from the airport and between lakes

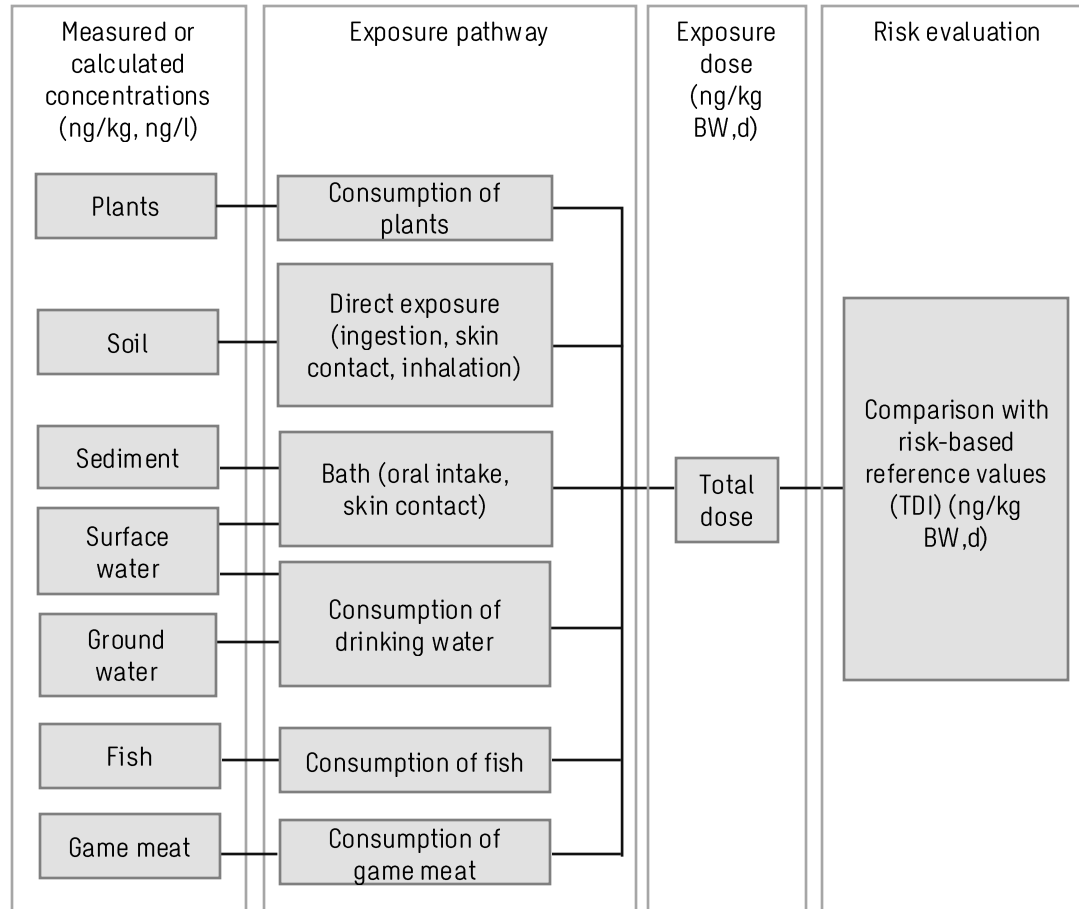


Evaluation of a river stretch

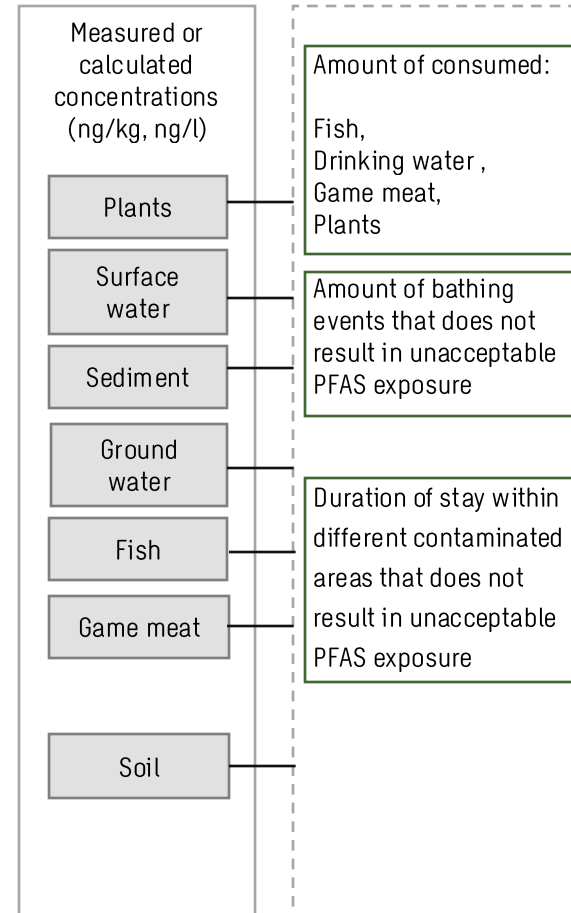
	0,65 ng/l	9,1 mg/kg	23 ng/l	0,47 ng/l	33 µg/kg	4 ng/l	13 µg/kg
Matrix	Water	Fish	Water	Fish	Fish	Water	Fish
Protective of	EQS water	EQS fish	Aquatic Ecosystems	Secondary poisoning	Secondary poisoning	Background concentration (urban)	Background concentration fish (urban)
Number of samples exceeding	30/30	31/31	30/30	30/30	32/33	30/30	31/33

Human Health Risk assessment

Exposure dose calculations:

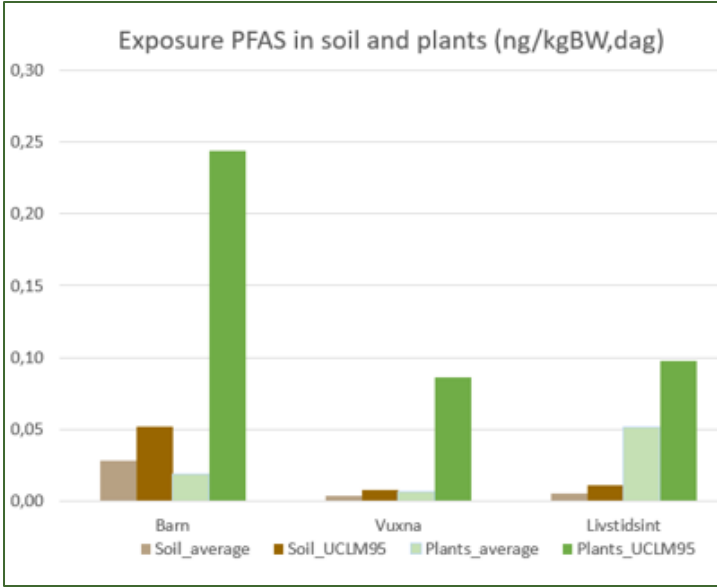
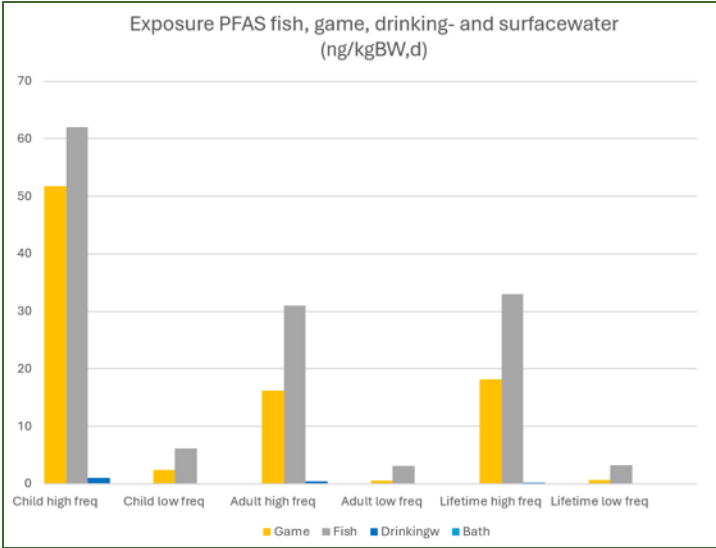
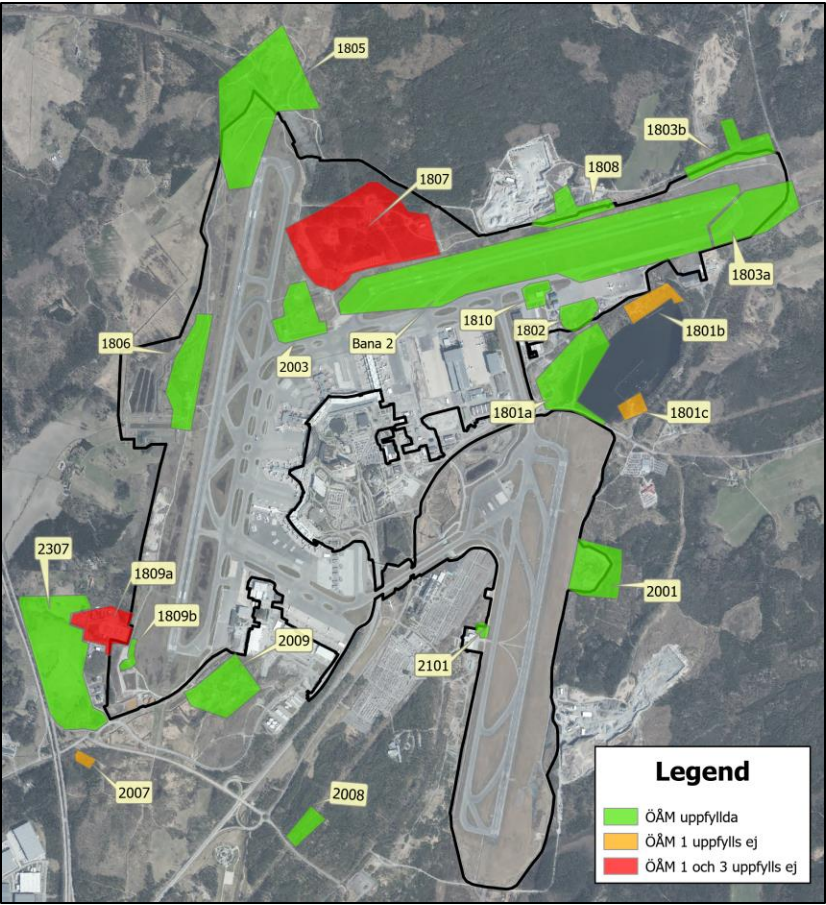


Other calculations:



Human Health typical risk assessment results

Assessment of human health risks in different PFAS contaminated areas



Overall risk assessment, lessons learned

Conclusions from one subarea

	PFAS is unlikely to necessitate remediation						
	PFAS may require remediation						
	PFAS is likely to require remediation						
	Description	Human Health Risks (including Drinking Water Wells)	Risks to the Local Soil Environment	Risks to Surface Water (EQS and Aquatic Ecology)	Risks to Protected Groundwater	Risks to Agriculture	Risks to Higher Animals
Transport via Stormwater	Significant PFAS transport via stormwater.	Fish PFAS levels may pose health risks; consumption rates remain uncertain.	No identified local soil environmental risks.	Clear EQS risks and possible impacts on aquatic ecosystems.	No significant impacts on protected groundwater expected.	Agricultural risks possible, but lower than east and northeast watercourses.	Risks to higher animals possible; magnitude remains uncertain.
Transport via Groundwater	Extensive ground-water transport affecting surface waters and nearby drinking water wells.	Fish PFAS levels may pose health risks; consumption rates remain uncertain.	No identified local soil environmental risks.	Clear EQS risks and possible impacts on aquatic ecosystems.	PFAS transport from the FTA via groundwater is not considered to affect protected groundwater resources.	Agricultural risks possible, but lower than east and northeast watercourses.	Risks to higher animals possible; magnitude remains uncertain.
Local Occurrence in Soil	Widespread soil contamination ; vertical extent uncertain pending further investigations.	Surface soil PFAS may pose human health risks.	Clear ecological risks from PFAS-contaminated surface soils.	No identified PFAS soil-related risks within the FTA.	No identified PFAS soil-related risks within the FTA.	No identified PFAS soil-related risks within the FTA.	Airside animals likely show elevated PFAS; remediation need remains uncertain.

Selected conclusions from all projects

17

→ In our projects, unacceptable risks have most commonly been associated with adjacent surface waters.

PFAS transport via stormwater to surface waters is often a key driver of risk and remediation needs

But GW transport to surface water also important, although harder to quantify

- Elevated soil concentrations commonly not a cause of unacceptable human health risks
- Health risks more related to off site exposure through drinking-water wells, fish and sometimes game consumption.
- Agricultural risks are clearly indicated by models and measurements of water and grazed plants, but measurements are needed of produce (milk, meat etc.) clearly connected to affected farms
- Background levels in all matrices, especially animals, are important when assessing risks
- The fact that risks are commonly associated with off-site transport rather than on site contamination has large impacts on the remediation design work

Upcoming work

- Focus on sediments as a missing link in mass transport budgets, - upcoming work includes measurement and models
- Measurements of PFAS in soil biota (insects) in soil field chambers with known PFAS concentrations
- Measurements of PFAS in background areas and affected areas in game animals – to improve statistics
- In-depth agricultural projects:
 - ✓ Sampling of animal produce hindered by administrative and legal issues
 - ✓ Alternative strategy may be to sample faeces

Not presented

- Risk assessment of soil-living animals
- Trials with irrigation of garden produce with PFAS contaminated groundwater
- Diffusion and leaching experiments of intact soil cores at different depths
- Etc.