



Predictive Groundwater Modeling to Develop PFAS Source Remediation Priorities

RAMBOLL

Bright ideas.
Sustainable change.

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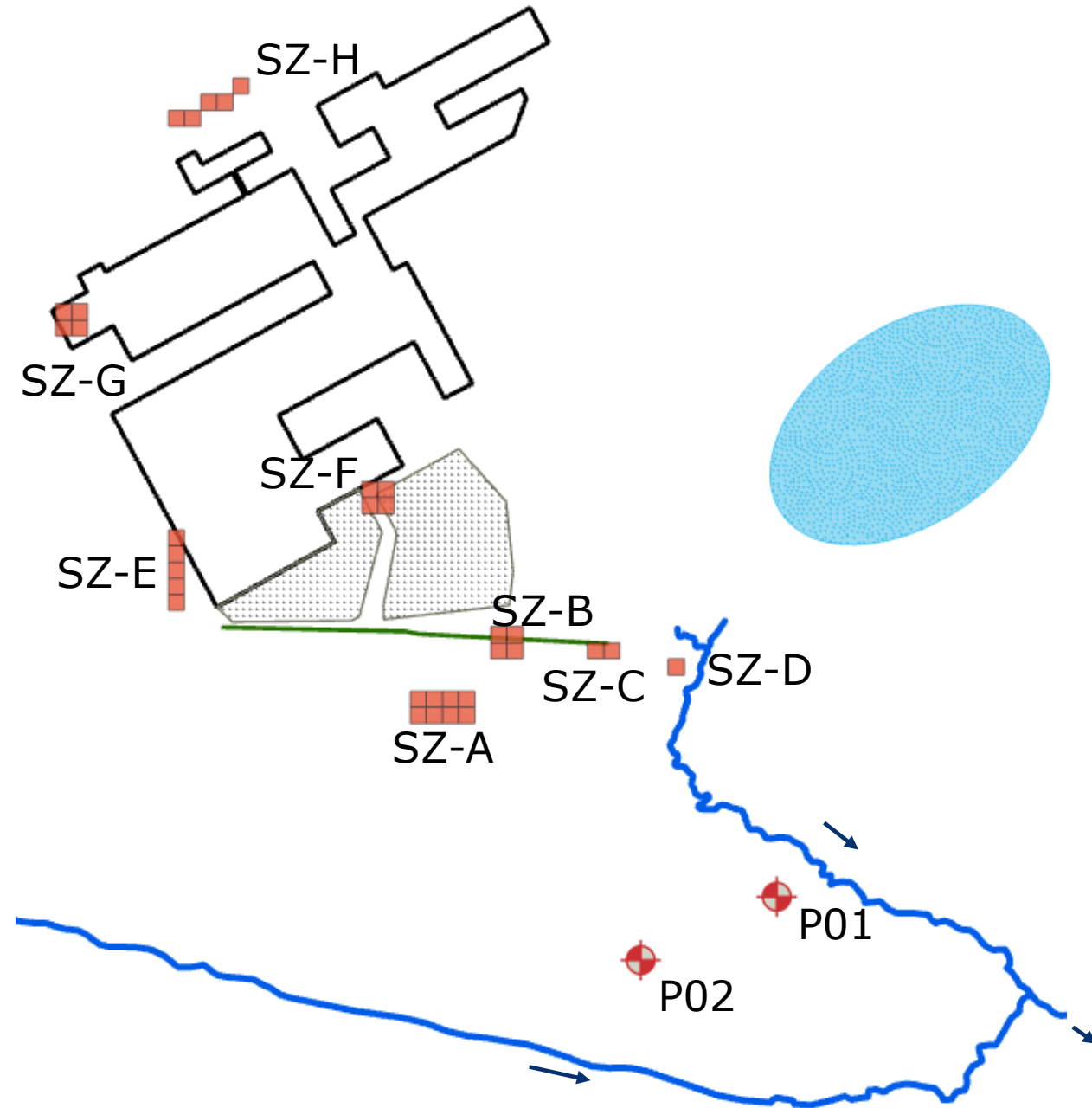
Challenge to Modeling PFAS

Modeling PFAS movement in groundwater is problematic

- Large population of PFAS compounds
- Transport properties unique to each PFAS
- Transformation from one PFAS to a different PFAS
- Lack of well constrained literature values for these transport properties such as distribution coefficients

Our Endpoint

- Calibrated site-specific distribution coefficients (K_d)
 - PFOS, PFOA, PFNA, PFUnA, PFTTrDA
- Calibrated groundwater source concentrations
- Prioritized source remediation locations among many separate source areas
- Prioritized by magnitude of impact at the Treatment Plant



Groundwater Monitoring

- >100 Monitoring wells
 - All 4 hydrogeologic units
 - Distributed throughout the site
- > 10 Years of water level data
- 2 Extraction wells
 - Onsite treatment plant constructed for VOCs

Surface Water Monitoring

- Flow
- Elevation

History of AFFF Use

- Required Insurance testing dates
- Leaking stormwater infrastructure

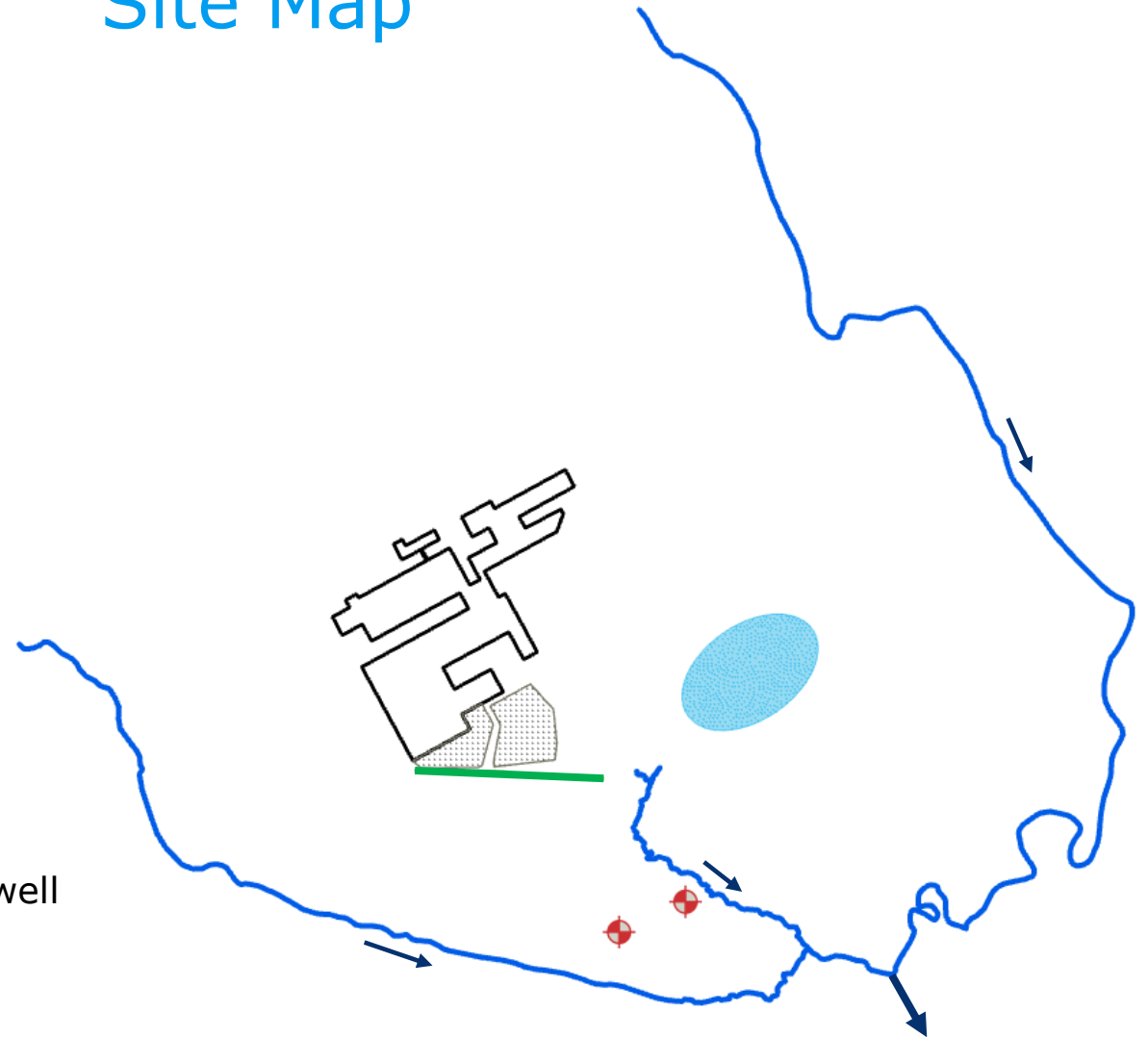
PFAS Data

- 3 rounds of groundwater sampling data
- 2 years of treatment plant influent and data at each extraction well
- Soil sampling events

Multiple AFFF Source Areas

- Each with different mixture of PFAS in soil and groundwater
- Creating a commingled plume

Site Map

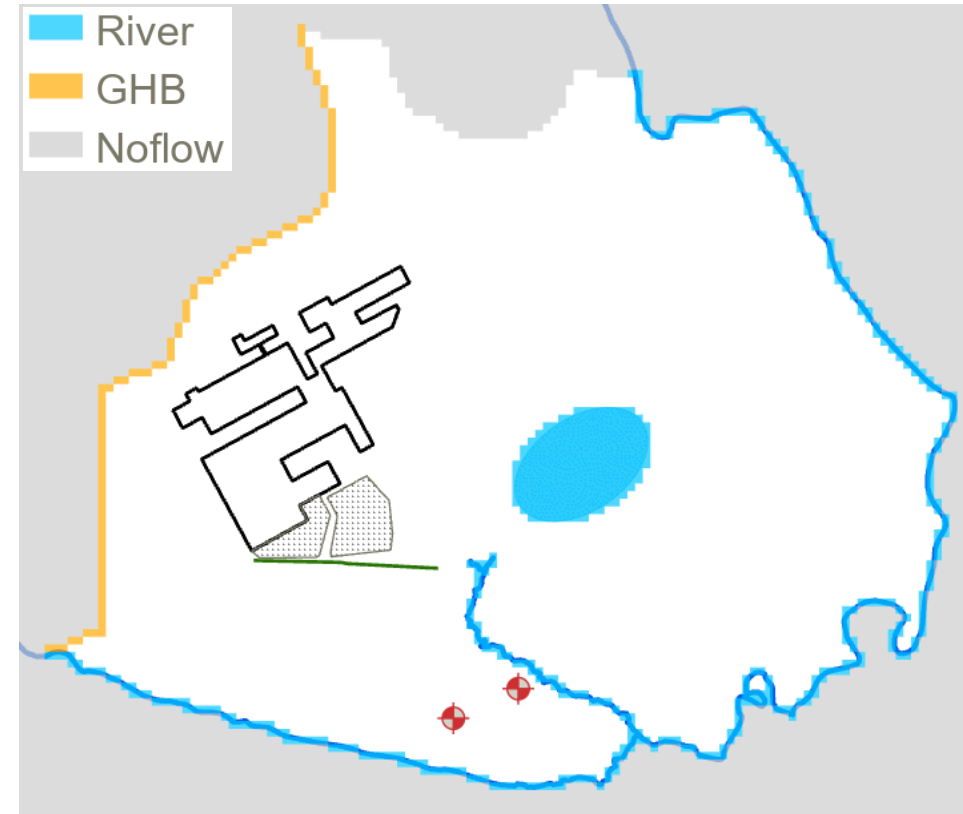
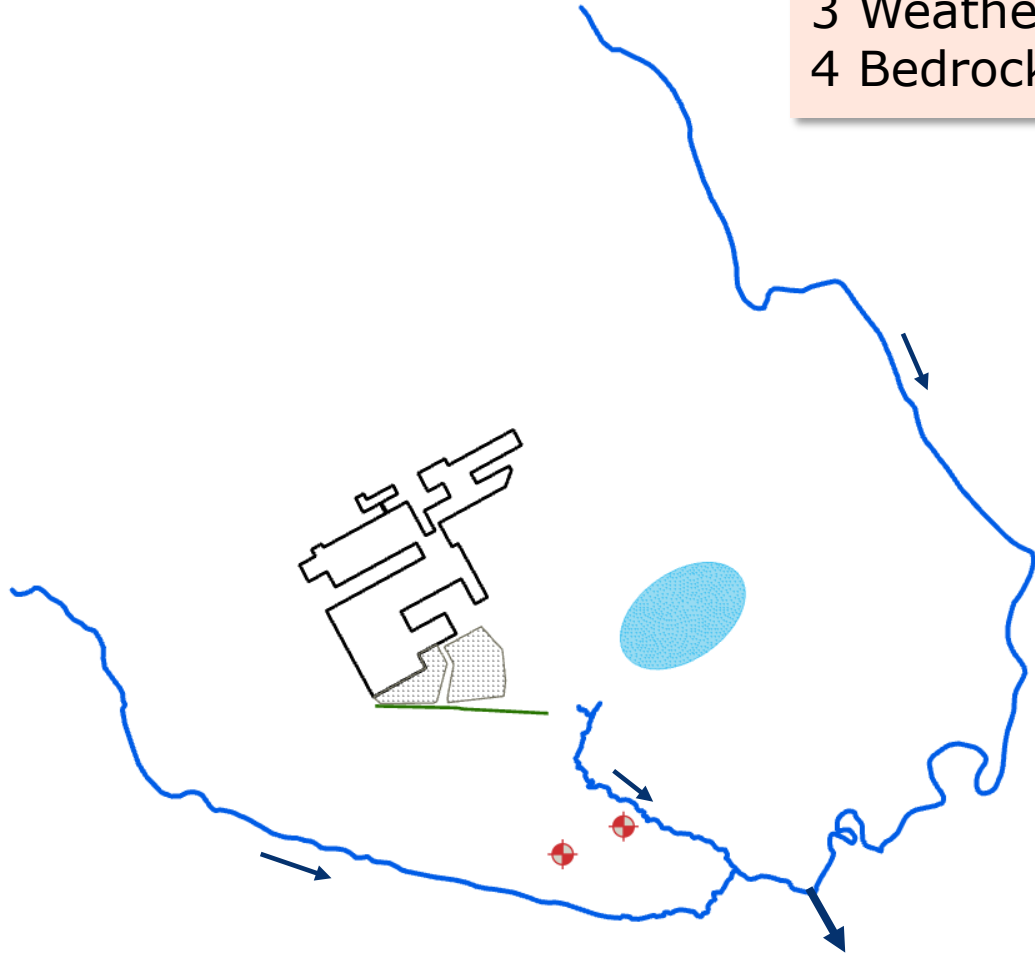


Model Construction

Site Hydrogeology

Layering

- 1 Alluvium (~40 ft)
- 2 Till (~30 ft)
- 3 Weathered bedrock (~5 ft)
- 4 Bedrock (>50 ft)



Flow Model Calibration

Calibration Parameters

- Hydraulic conductivity
- River boundary
- GHB boundary

Calibration Targets

- Water level
- Streamflow

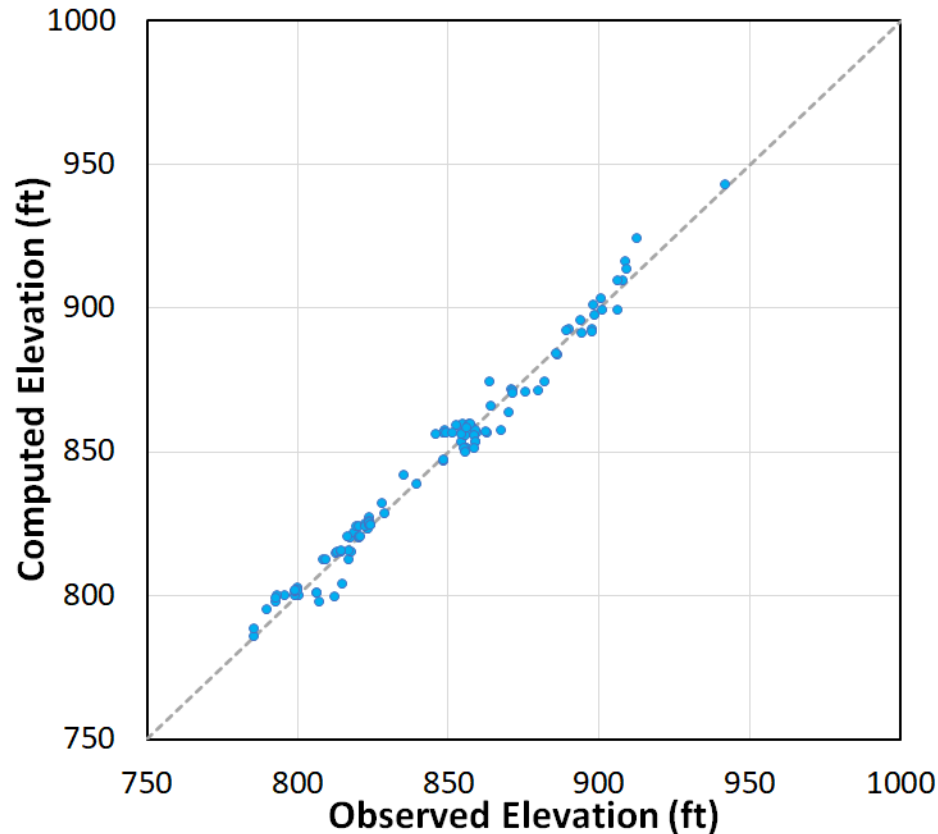
Calibration Method

- Manual
- Automated

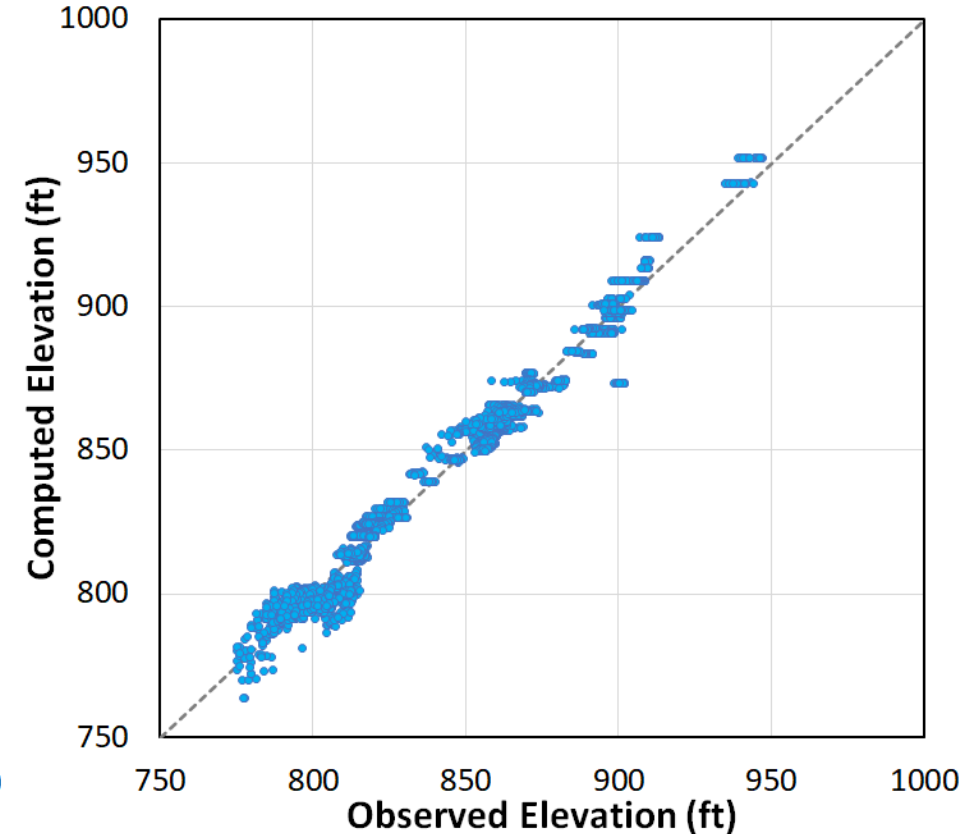
Validation

- Transient data 11 years
- Water level
- Groundwater extraction

**Steady State Calibration
Single Event Monitoring Data**



**Transient Model Validation
11 Years of Monitoring Data**



Transport Model Construction

PFAS Compounds

- Mix varied with source area

Source Strength

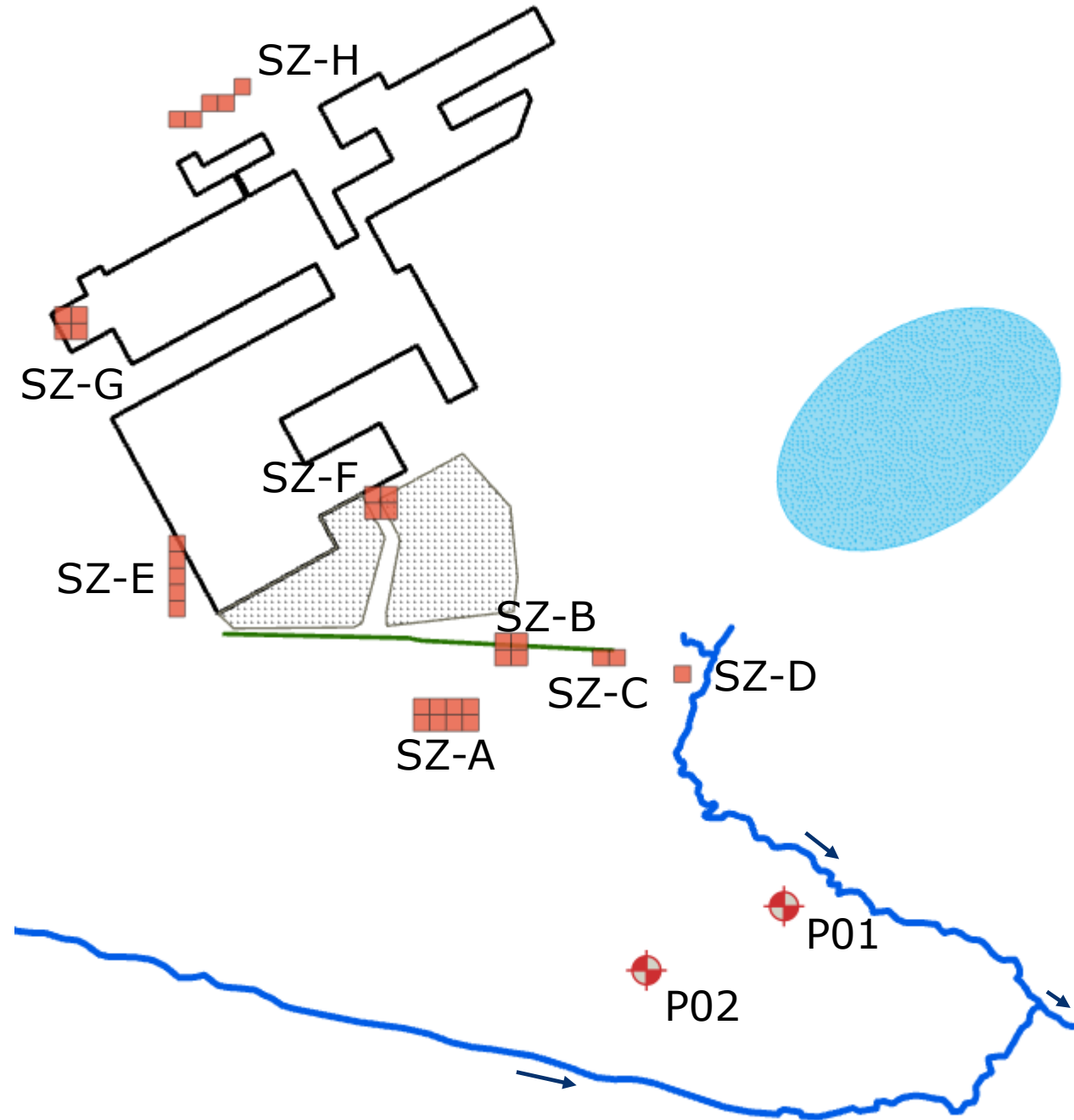
- Varied with source area

Distribution Coefficient K_d

- PFOS, PFOA, PFNA, PFUnA, PFTrDA

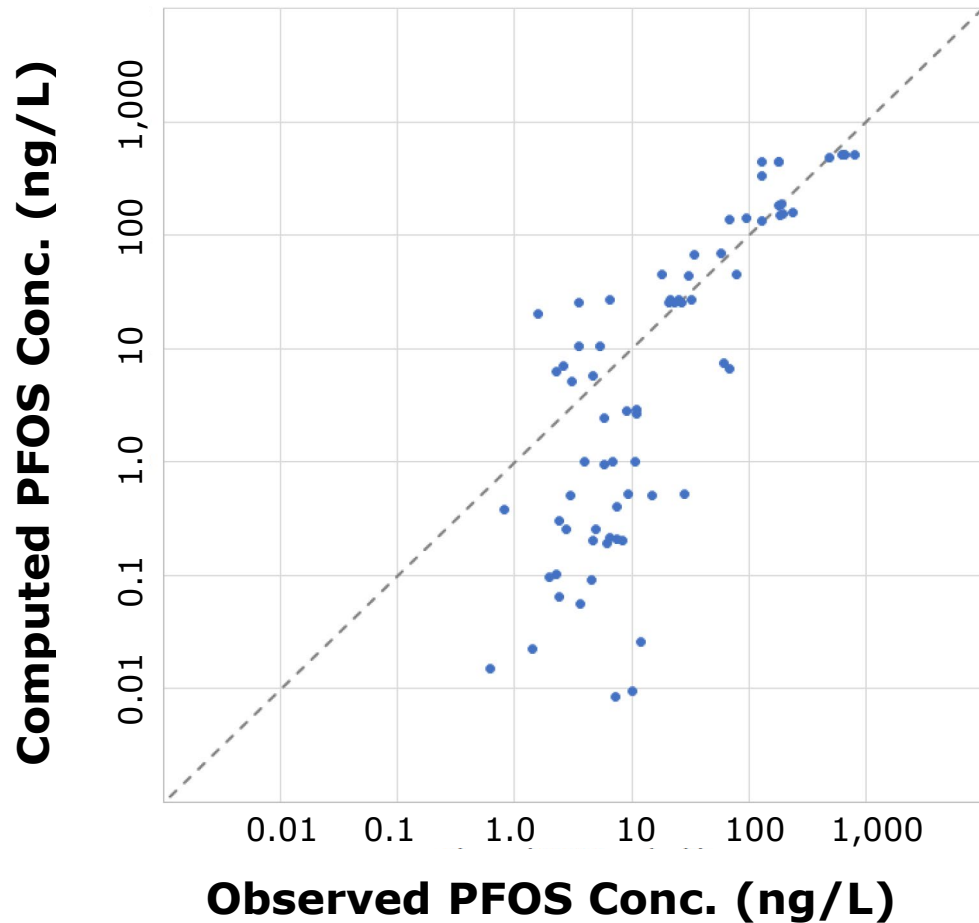
Source Zone Identification

- Spatial distribution of plumes
- Comingled plumes many sources
- Groundwater samples
- Soil samples



Transport Model Calibration

- K_d for each PFAS compound
- Source concentration for each PFAS compound at each source zone

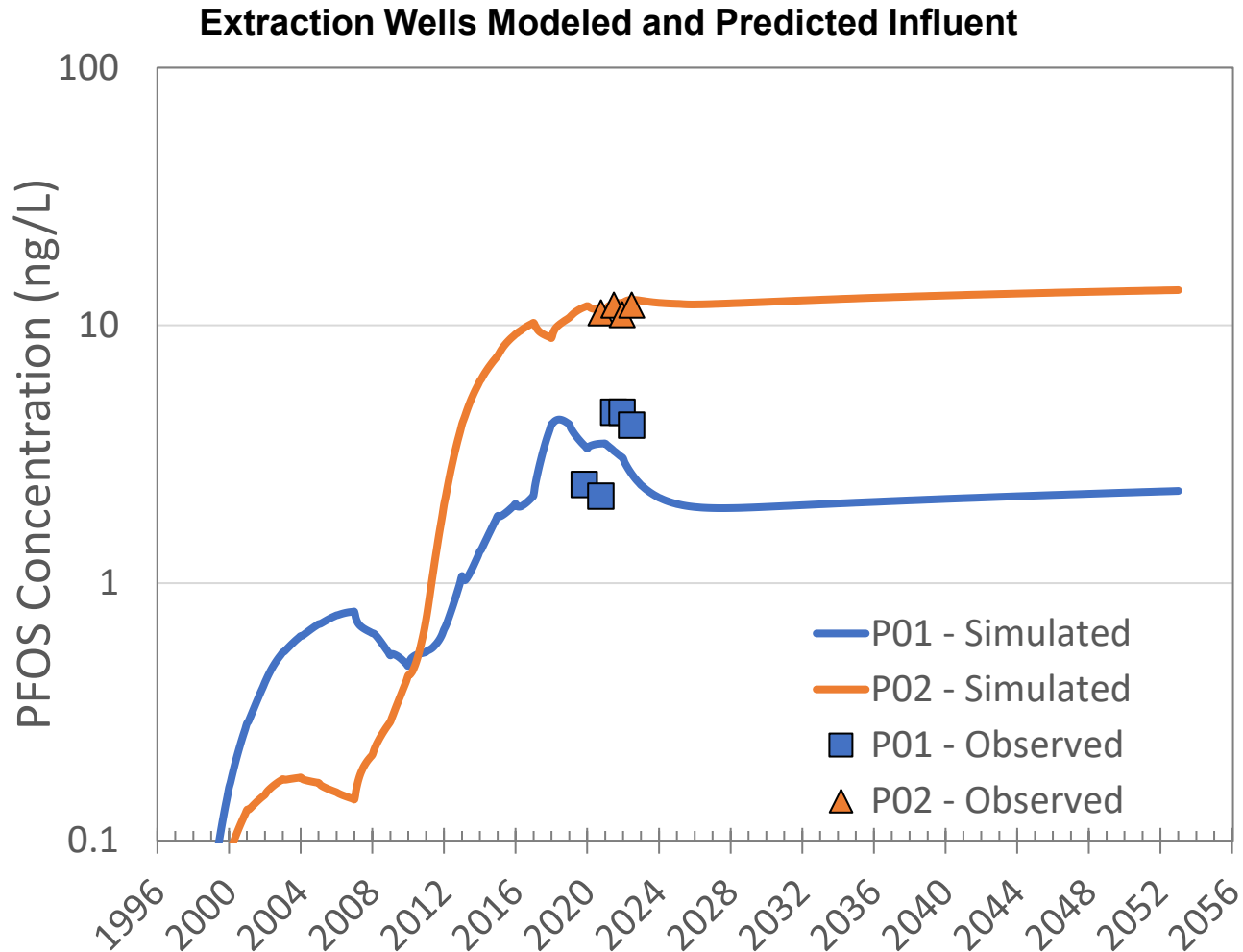


PFAS Compound	K_d (L/kg)	
	Calibrated Value	Literature Value*
PFNA	0.43	0.23 – 7.94
PFOA	0.12	0.05 – 0.79
PFOS	0.60	0.37 – 200
PFUnA	1.98	3.63 – 630
PFTrDA	16.25	5.13 – only value

*: K_d values calculated based on ITRC $\text{Log}(K_{oc})$ values for PFAS mixture in solution in soil assuming f_{oc} of 0.001

Predictive Simulation

Baseline Condition



Predict influent concentration
Baseline prediction - no action

Predict to 30 years into future

- Each extraction well
- Each PFAS compound

Effect of Potential Remediation at Treatment Plant

Reduce one source's mass flux by 50%

- Each PFAS compound

Observe magnitude of change

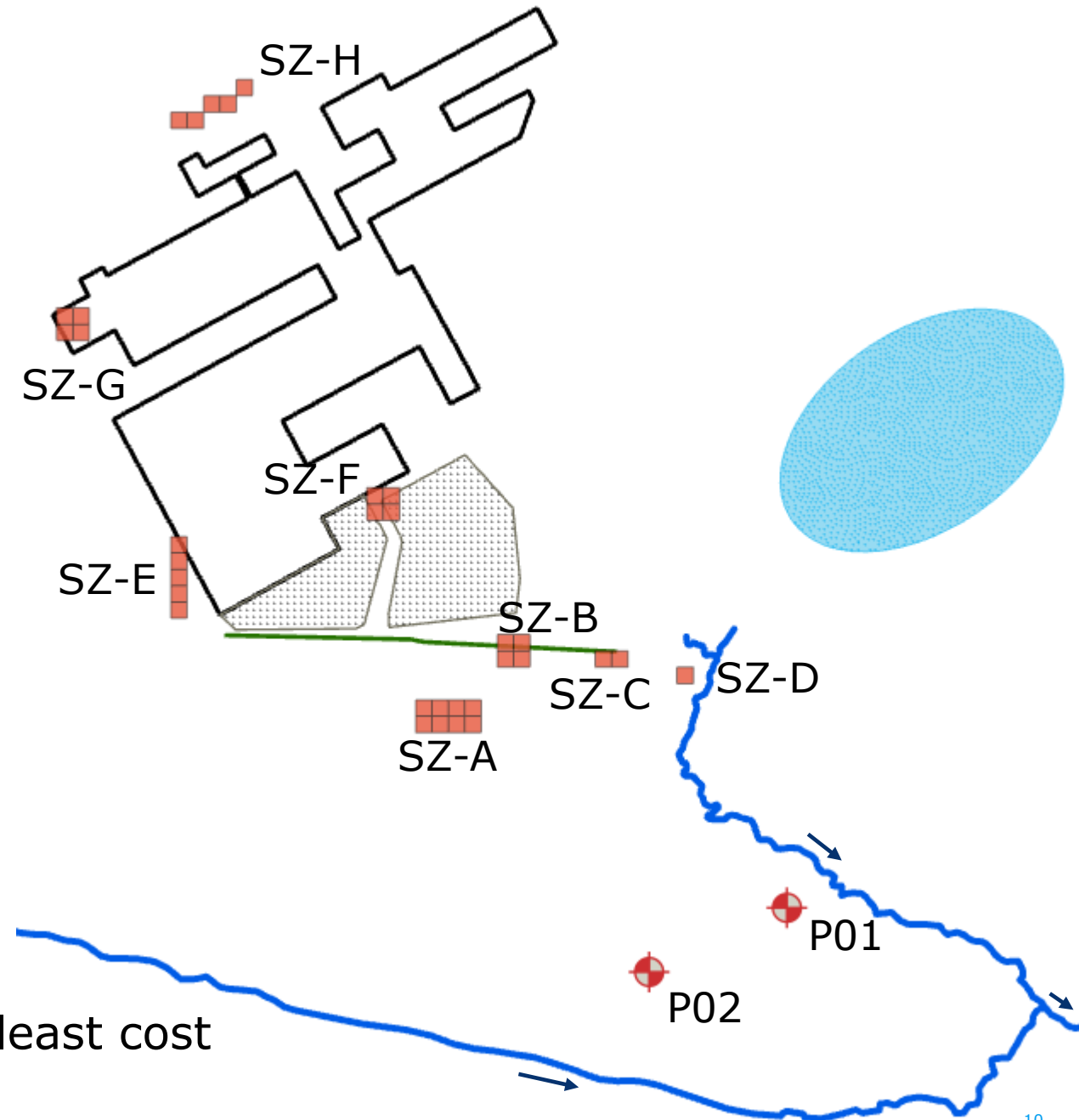
- Monitoring wells
- Extraction wells

Predict extraction well impact over 30 years

- Change in concentration over time
- Change in mass loading over time
- Change in PFAS mix over time

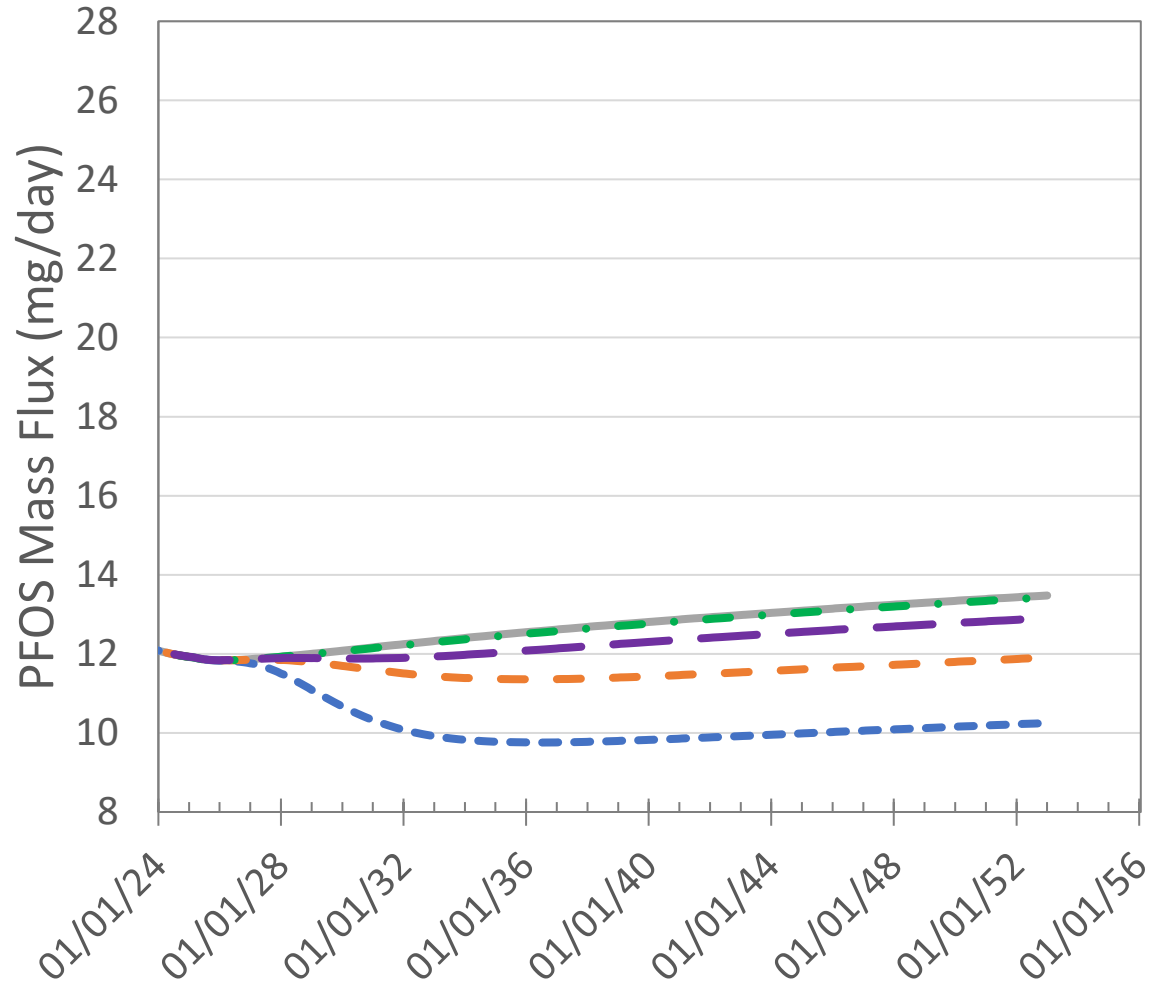
Prioritize remedial options

- Which source
- Maximize effect at the treatment plant for least cost

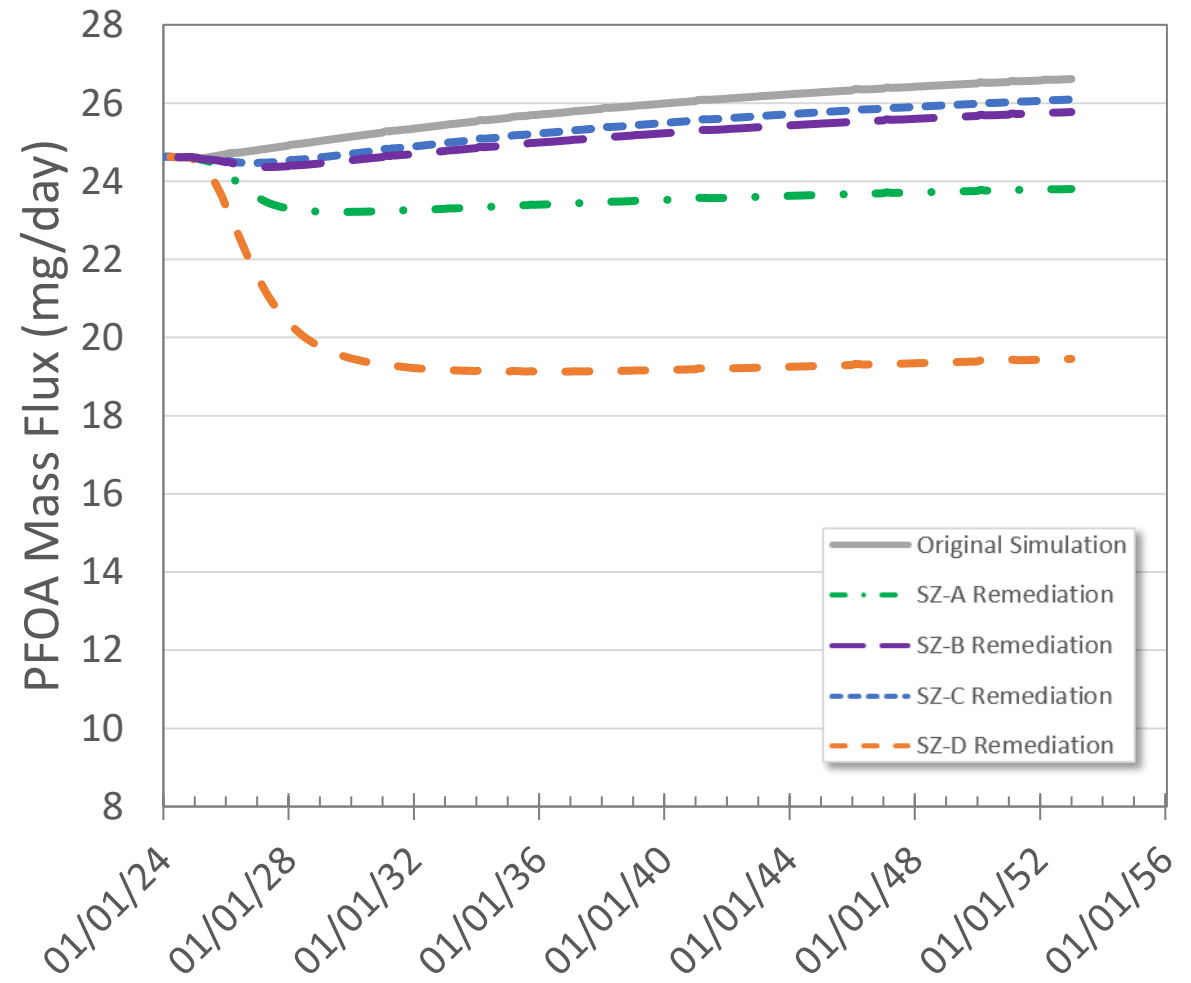


Predicted PFOS and PFOA Mass Flux Into Treatment Plant

Predicted PFOS Mass Flux at Treatment Plant



Predicted PFOA Mass Flux at Treatment Plant



Source Remediation Prioritization

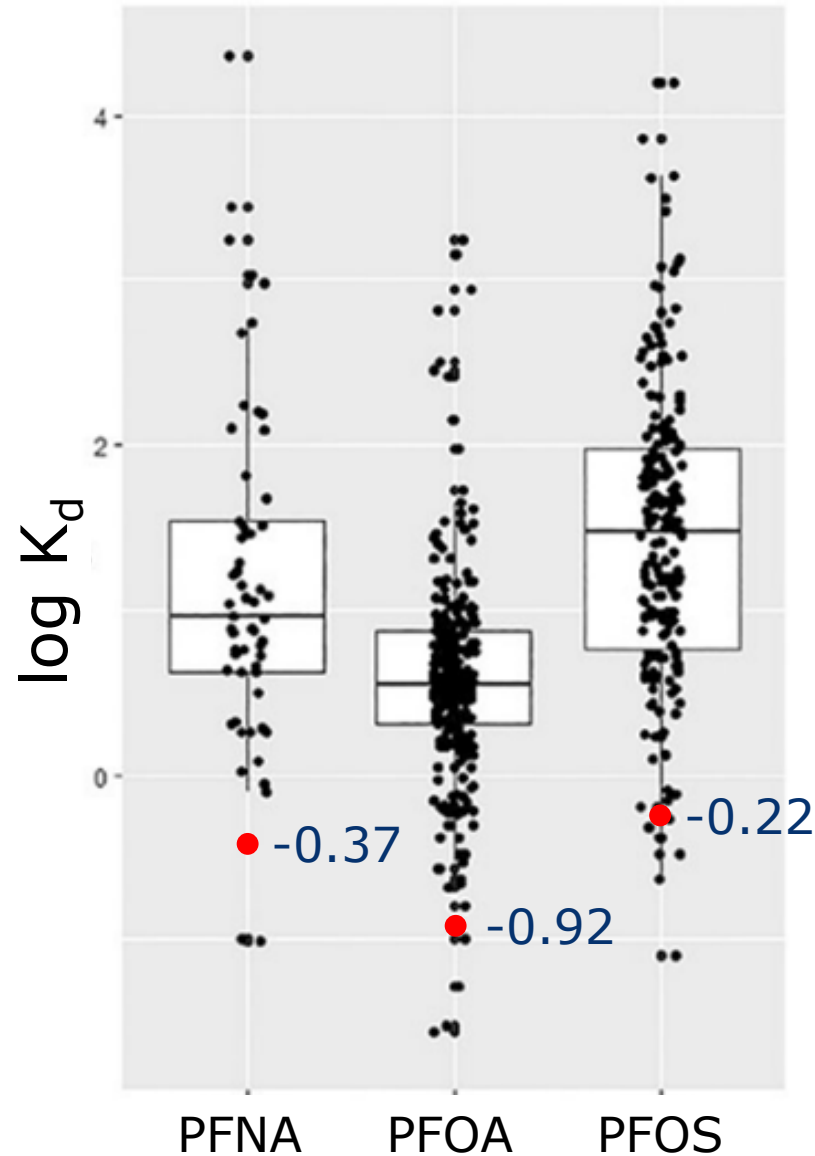
Source Zone	Ranking					
	PFNA	PFOA	PFOS	PFUnA	Sum	Overall
SZ-D	2	1	2	1	6	1
SZ-C	3	3	1	2	9	2
SZ-A	1	2	4	4	11	3
SZ-B	4	4	3	3	14	4
SZ-F	5	5	6	7	23	5
SZ-E	6	7	5	5	23	5
SZ-G	7	6	7	6	26	7
SZ-H	8	8	8	8	32	8

Impact on cost of remediation at the treatment plant

Action At Source Zone D would have the largest impact on total PFAS influent concentration at the treatment plant

Action At Source Zone H would have the least impact on total PFAS influent concentrations at the treatment plant

Calibrated Distribution Coefficients Plume Scale



PFAS Compound	Calibrated Value (L/kg)	
	K_d	$\log K_d$
• PFNA	0.43	-0.37
• PFOA	0.12	-0.92
• PFOS	0.60	-0.22
PFUnA	1.98	0.30
PFTTrDA	16.25	1.21

- Adsorption vs. Desorption
- Long-term field scale vs. Short-term lab scale
- Low concentration vs. High concentration