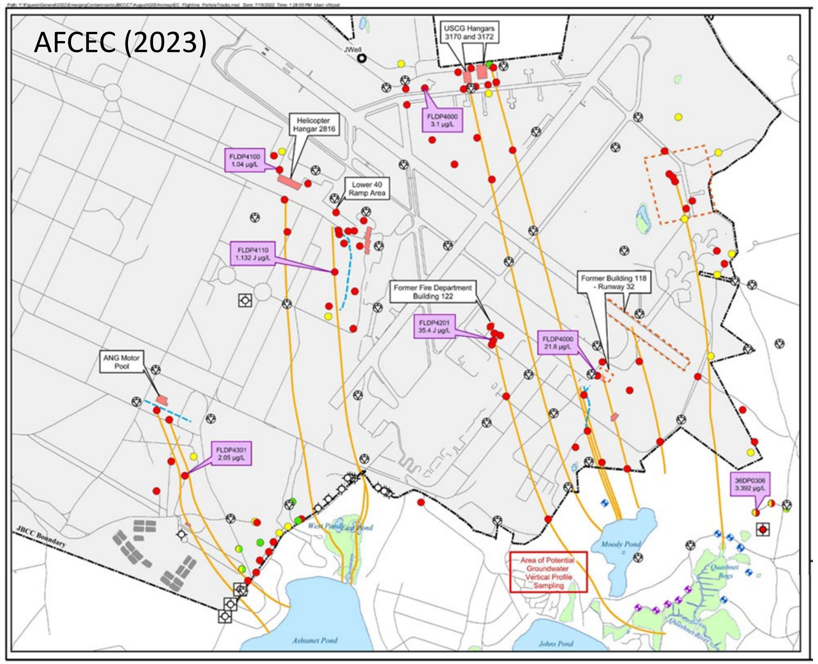
The PFAS challenge: Multiple sources in complex groundwater/surface-water systems

View looking north of the Joint Base Cape Cod (JBCC) flightline with Ashumet and Johns Pond in foreground



PFAS sources on JBCC flightline and predicted groundwater flow paths in 2018

Understanding flow paths and discharges can help guide source-to-receptor investigations and selection of most impactful remediation alternatives

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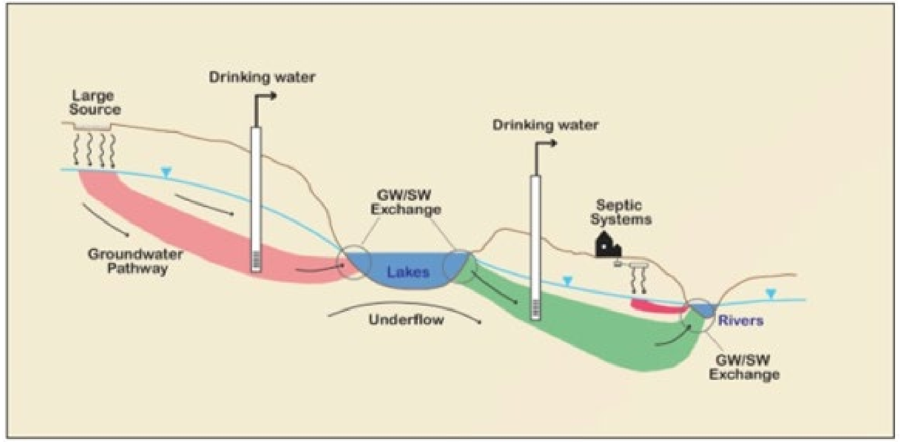
A Multitool Hydrologic Approach to Differentiate PFAS Sources and Guide Investigation and Remediation: Example from Joint Base Cape Cod

Federal Remediation Technologies Roundtable
October 29, 2024



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Presented by:

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Air Force Civil Engineer Center (AFCEC)

Environmental Security Technology Certification Program (ESTCP)

USGS Environmental Health Program

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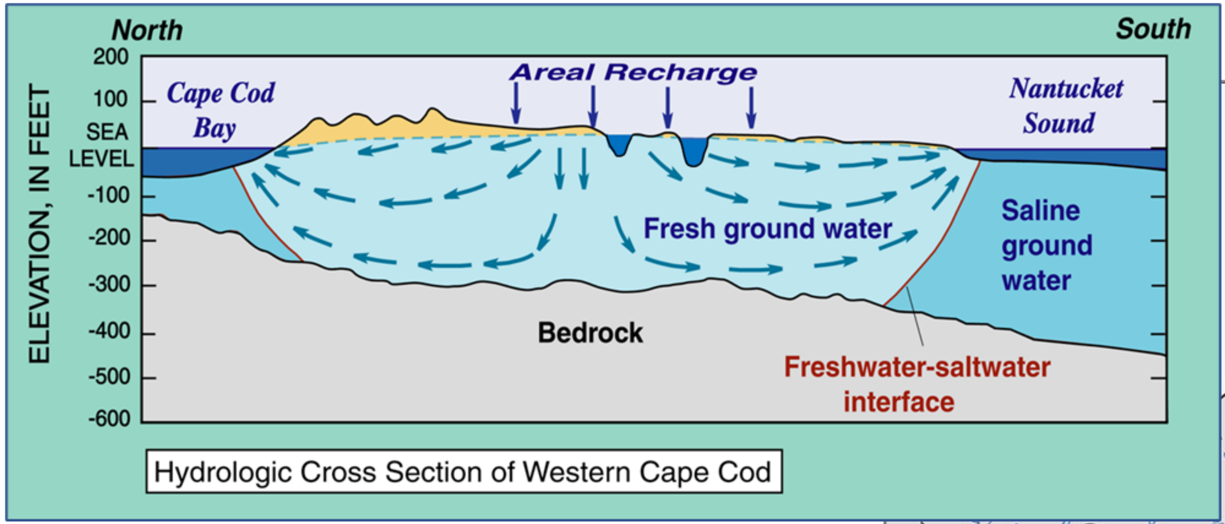
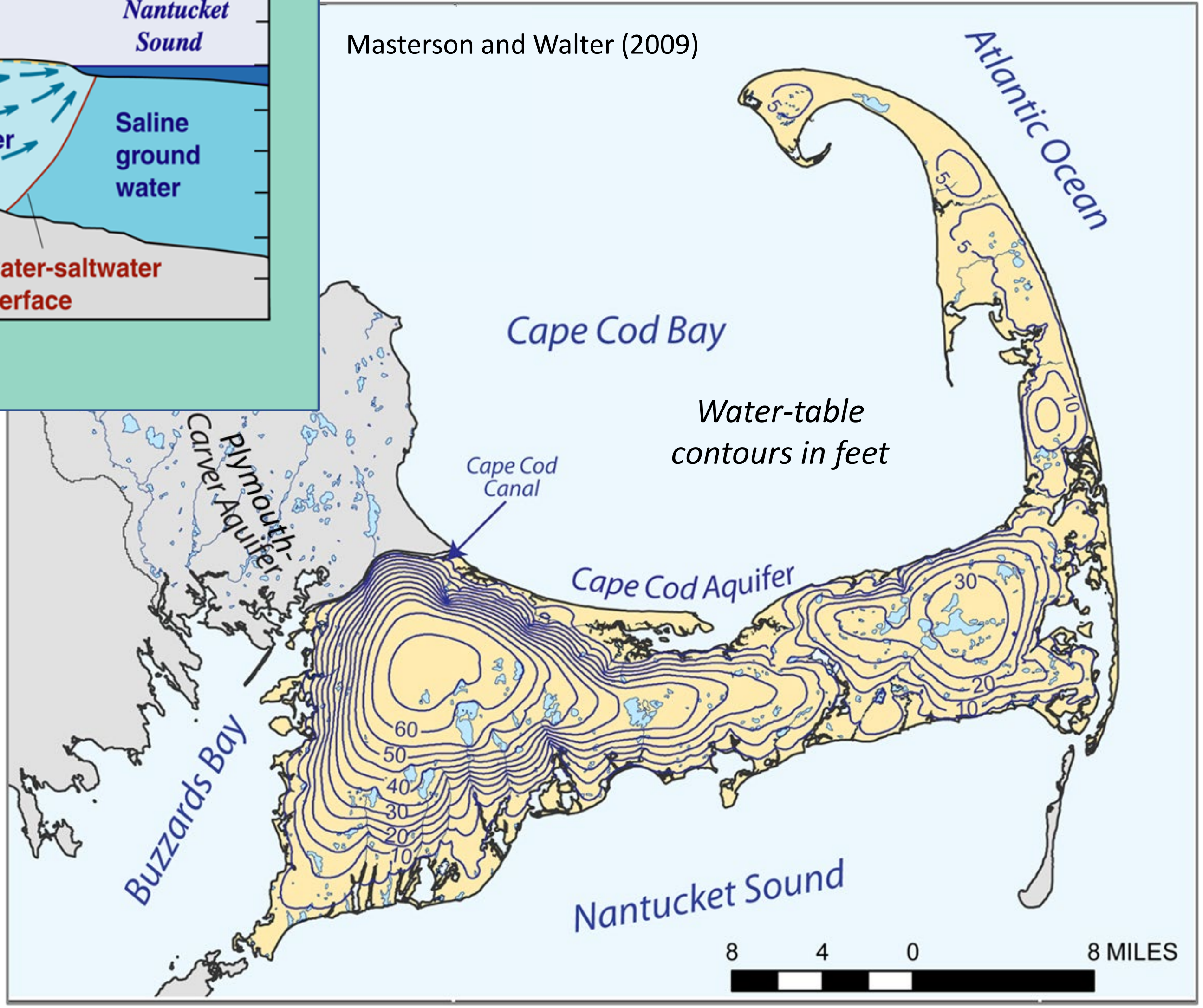
Hydrologic setting and JBCC plumes

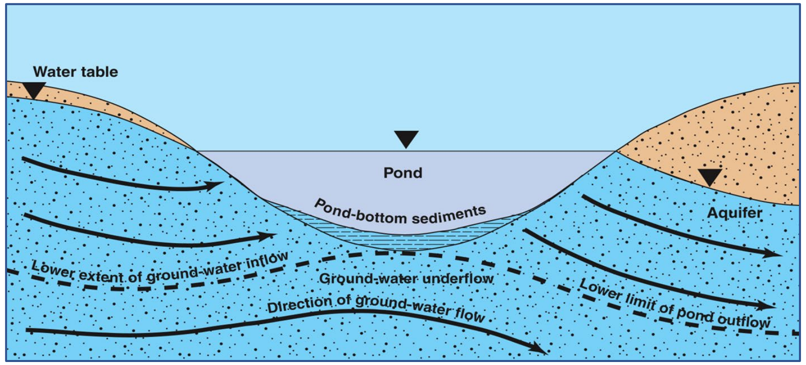


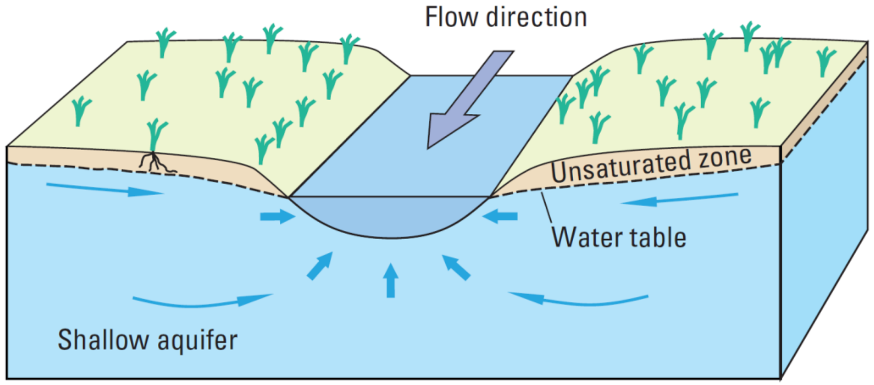


Cape Cod is a
sole-source unconsolidated
glacial sand and gravel aquifer

- Recharge rate ~ 27 inches per year
- Groundwater flow rate ~ 1-2 feet per day

Hydrologic setting and JBCC plumes

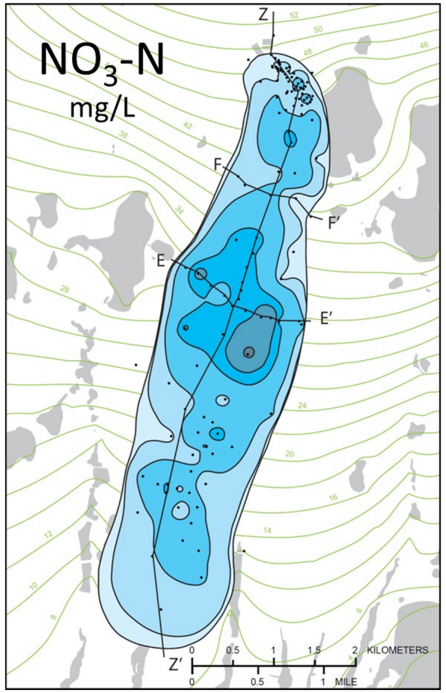




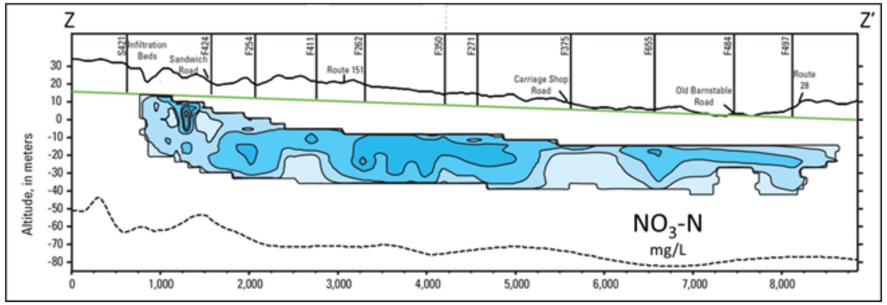
Kettle ponds are groundwater flow-through lakes

Streams are predominantly groundwater drains

Hydrologic setting and JBCC plumes



Barbaro et al. (2013)



Plumes align with groundwater flow and generally have sharp boundaries

Explosives, ClO_4

VOCs, EDB

Several contaminant plumes intersect surface-water bodies

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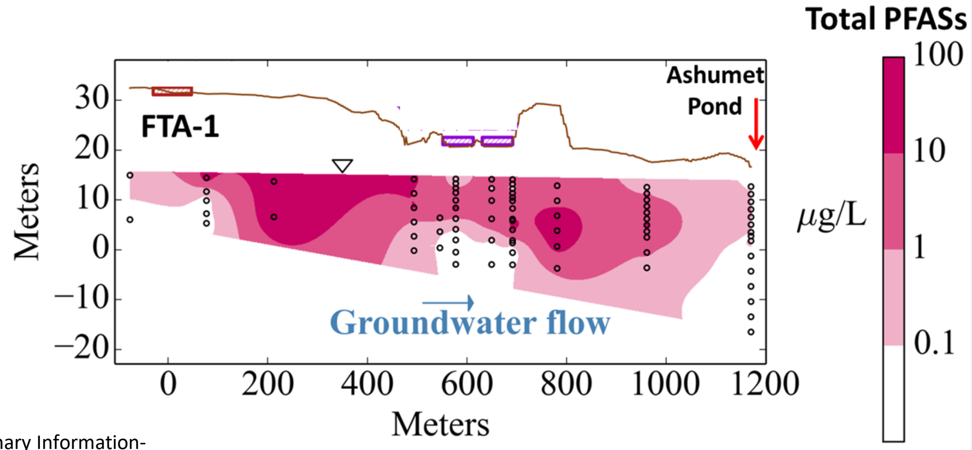
Groundwater/lake interactions affect fate of FTA PFAS plume

PFAS from former fire-training area discharges into Ashumet Pond

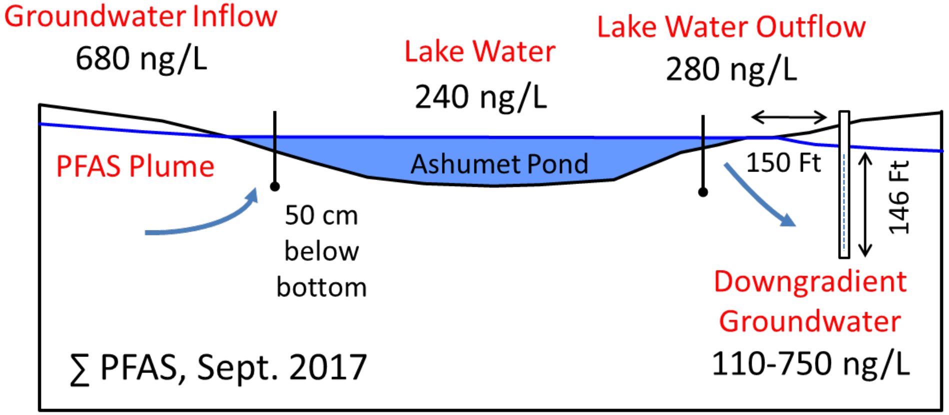
Fire-training area in 1984

Fire training at JBCC (date unknown)

PFAS samples in groundwater/lake study analyzed at Harvard University by LC-MS/MS

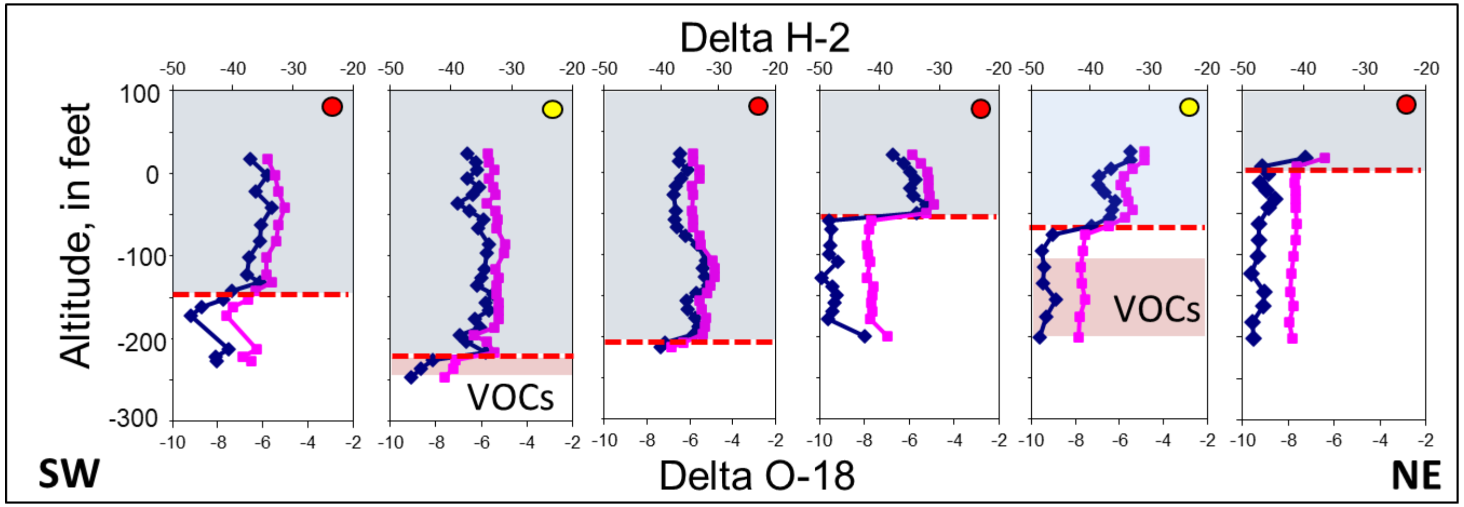


Weber et al. (2017)

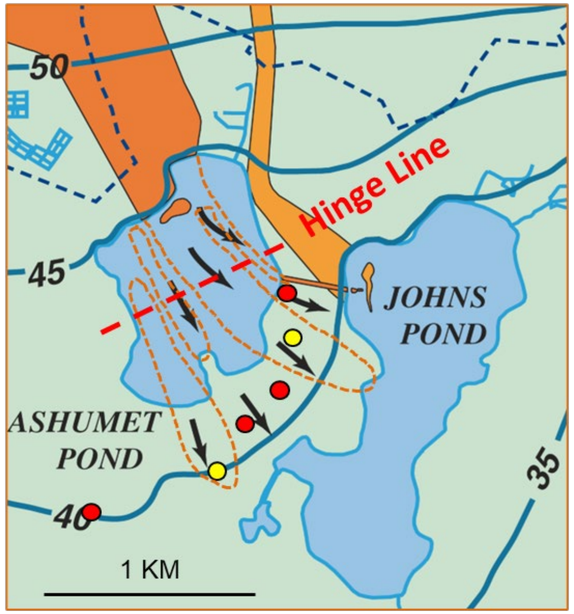


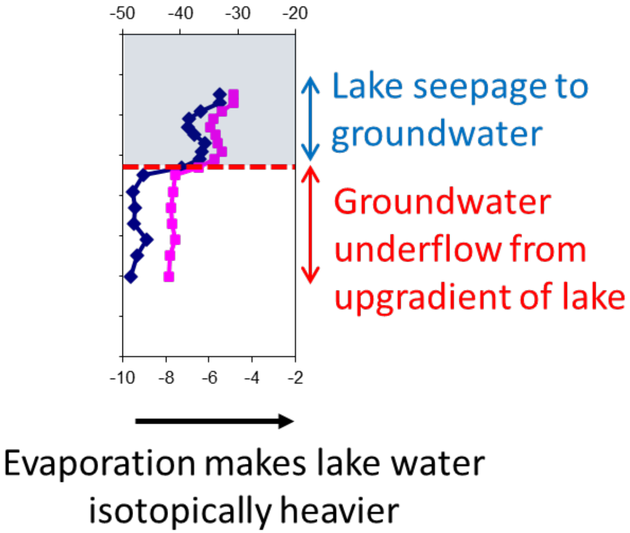
Tokranov et al. (2021a)

Groundwater/lake interactions affect fate of FTA PFAS plume



VOC plumes found beneath isotopically mapped "lake shadow"





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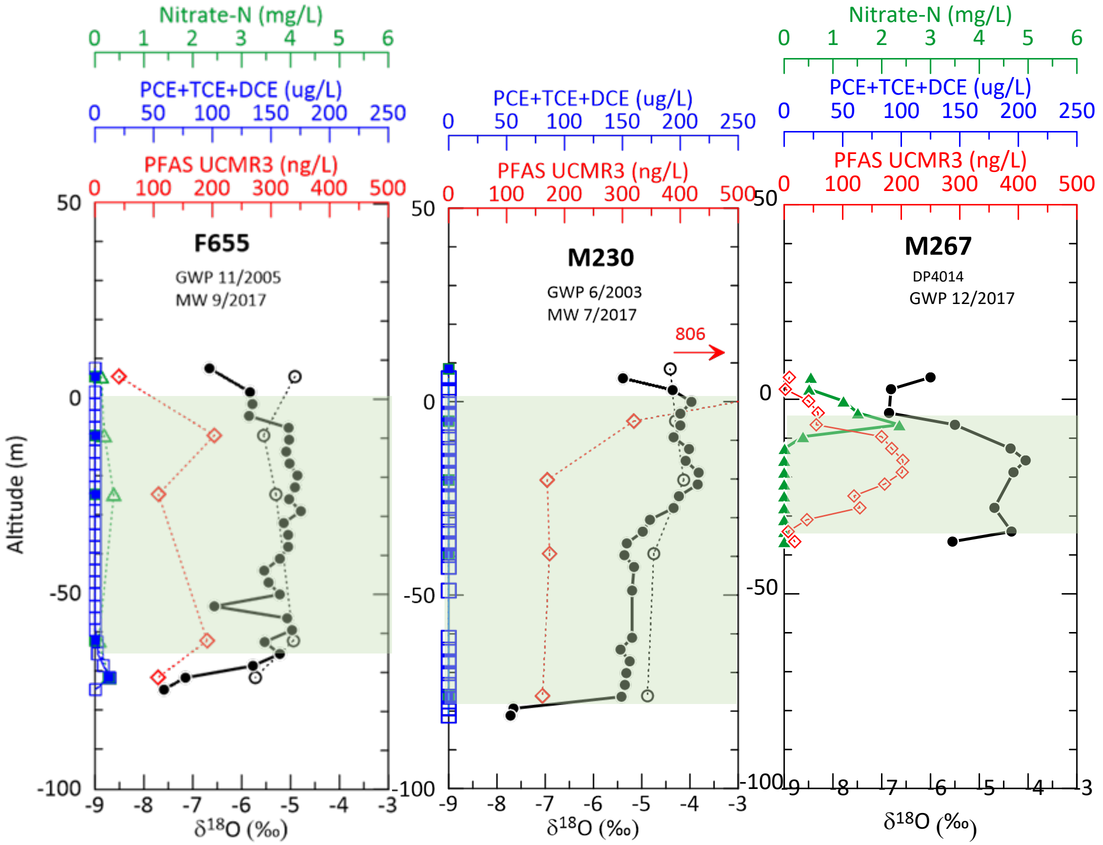
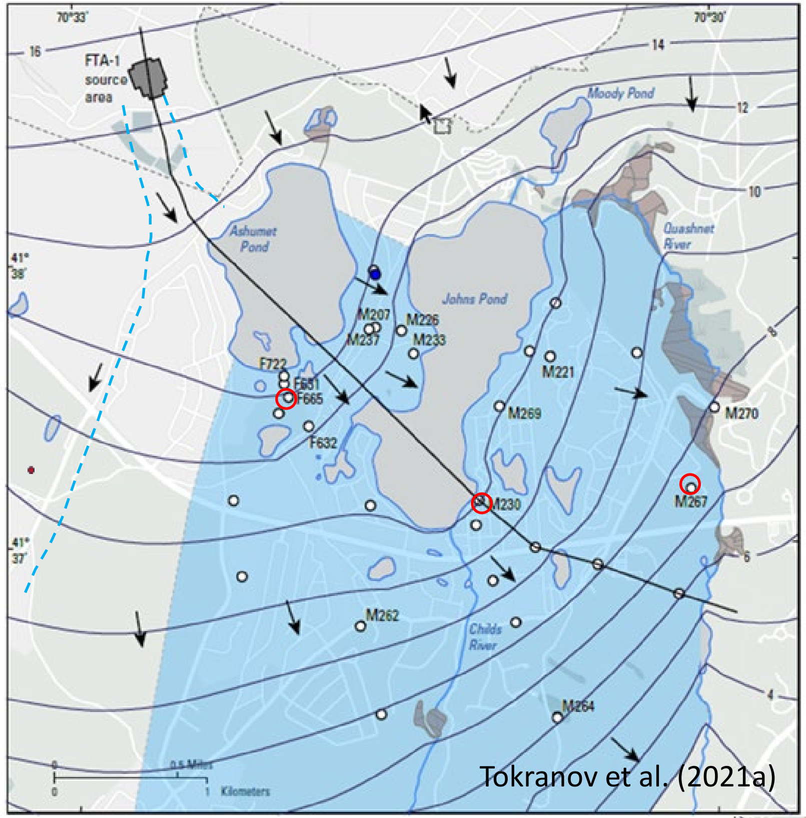
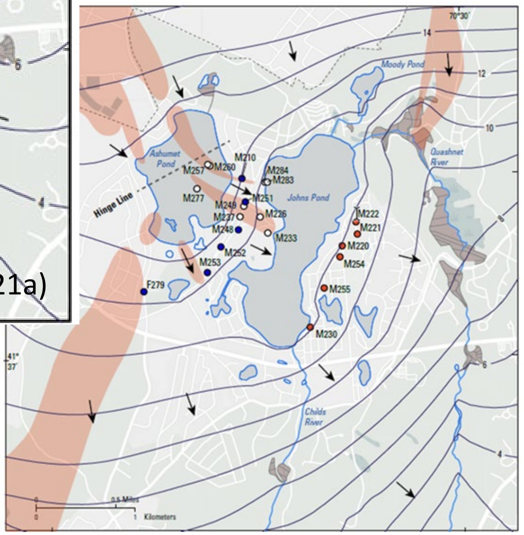
Groundwater/lake interactions affect fate of FTA PFAS plume



PFAS persists in lakes and spreads extensively in “lake shadow” groundwater downgradient from the lakes



Inferred PFAS plume from lake-water downwelling



Historical VOC plumes

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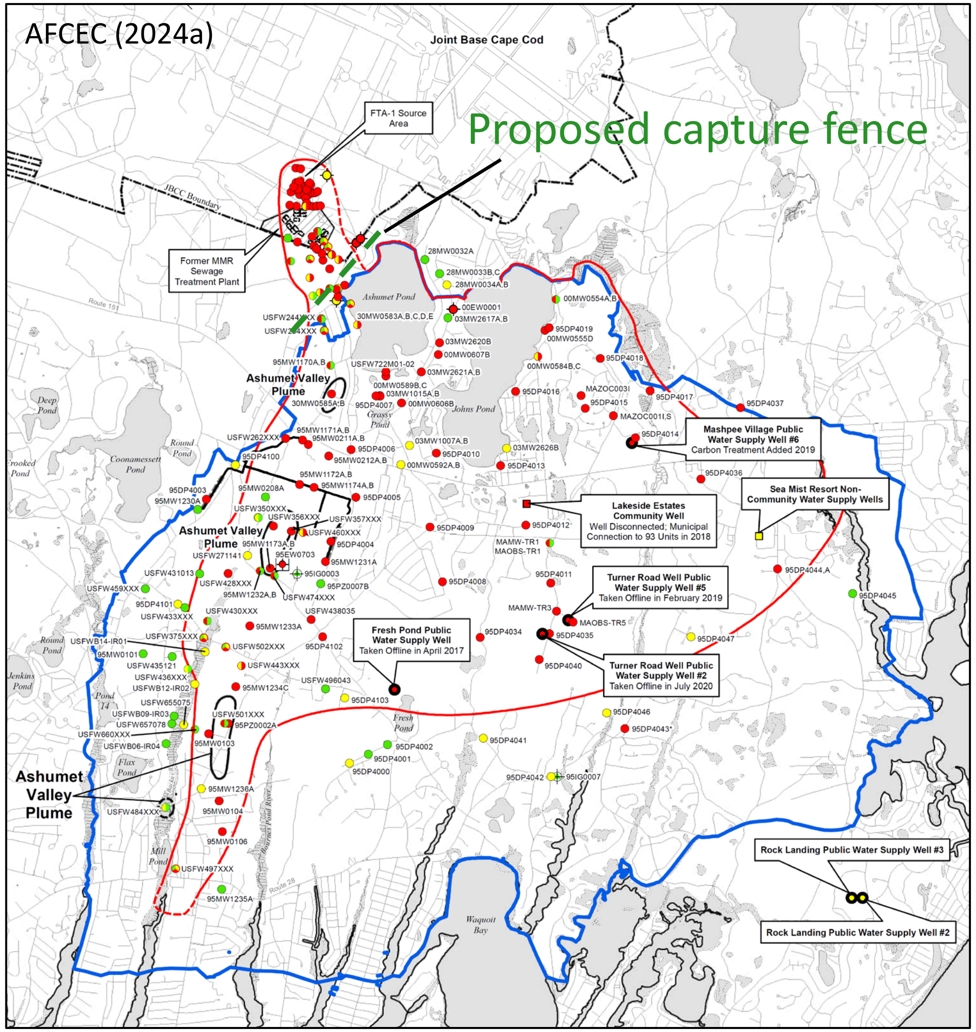
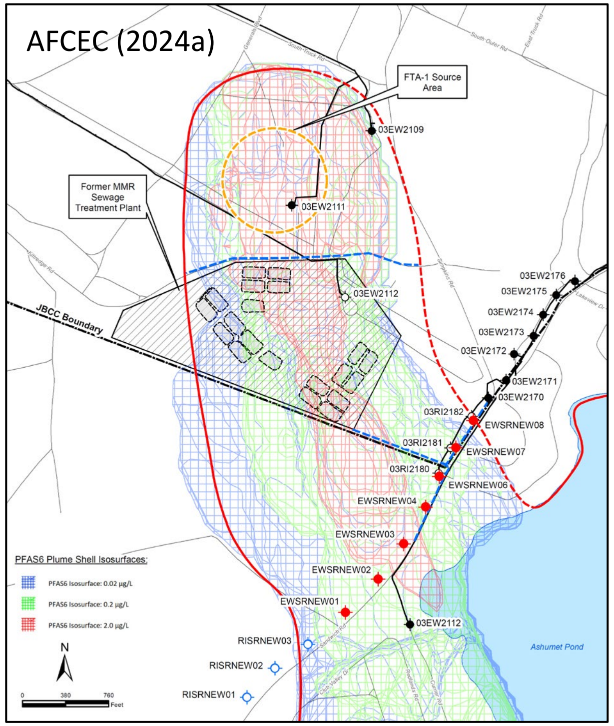
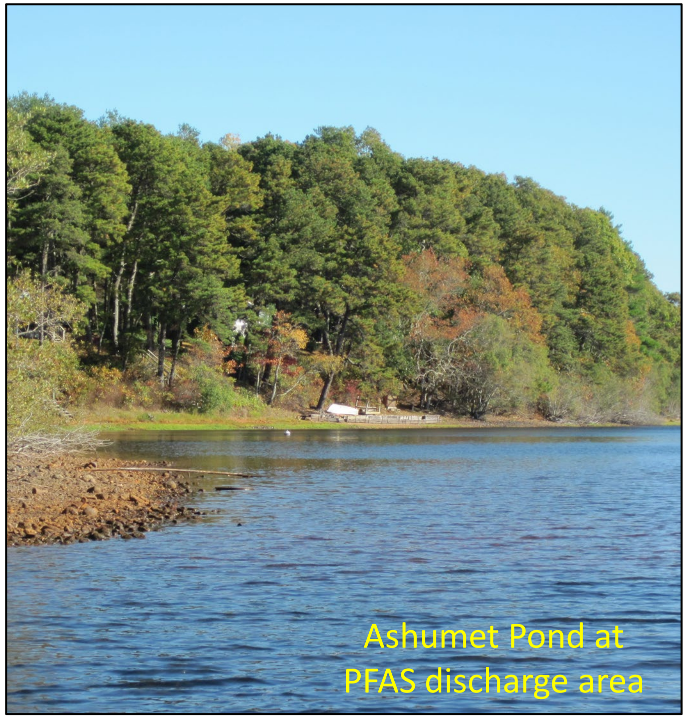
Groundwater/lake interactions affect fate of FTA PFAS plume







Capturing FTA plume before it discharges to Ashumet Pond will accelerate PFAS flushing from the aquifer

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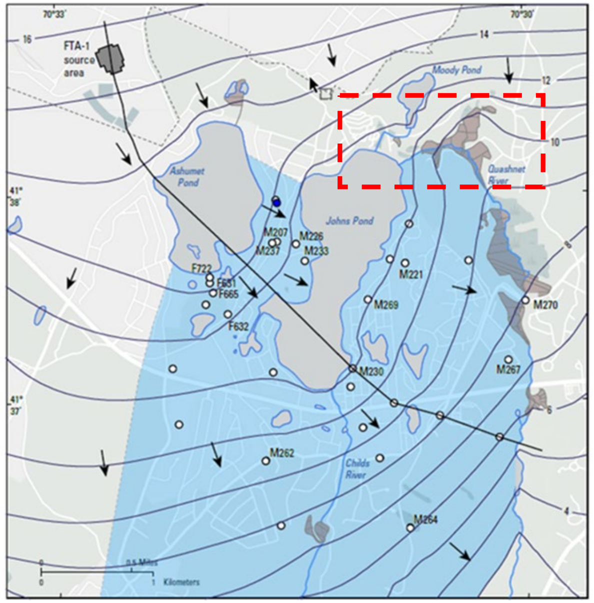
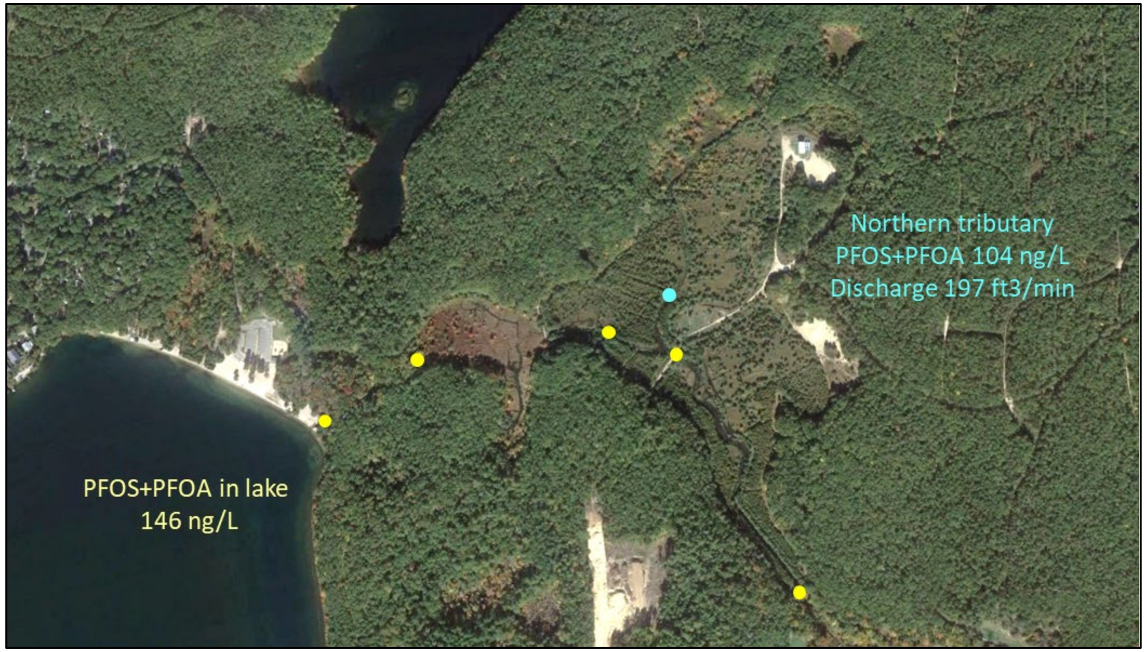
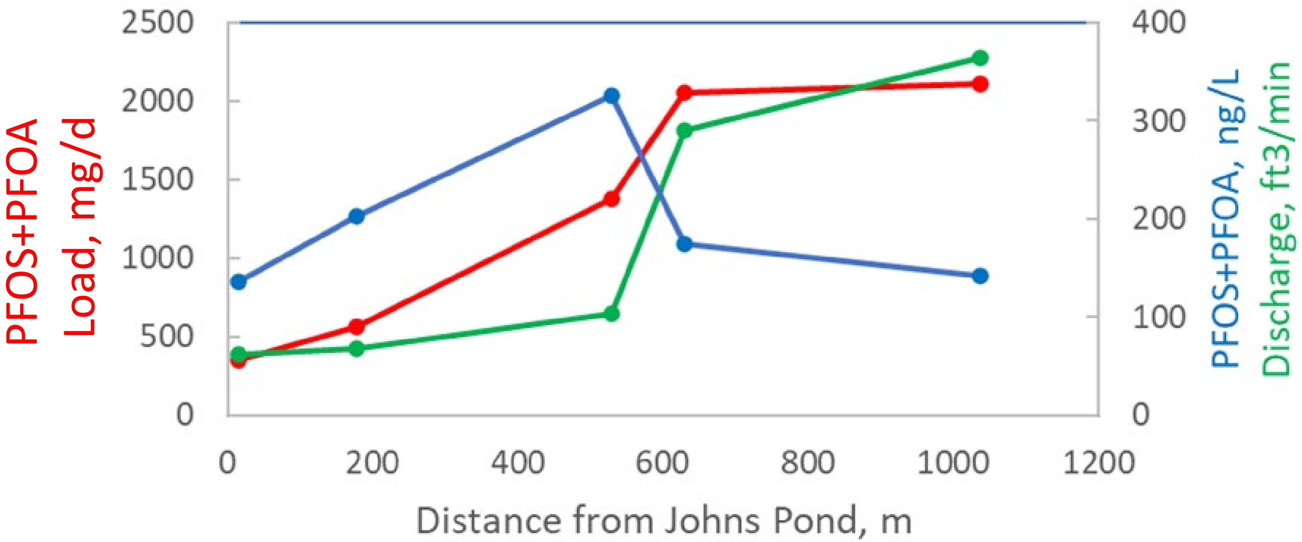
Stream and wetlands intercept PFAS from multiple sources



Stream and wetlands receive lake-water outflow and direct groundwater discharge



PFAS load in stream increases along reach through the wetlands



PFAS samples in stream/wetland study analyzed by EPA method 537.1

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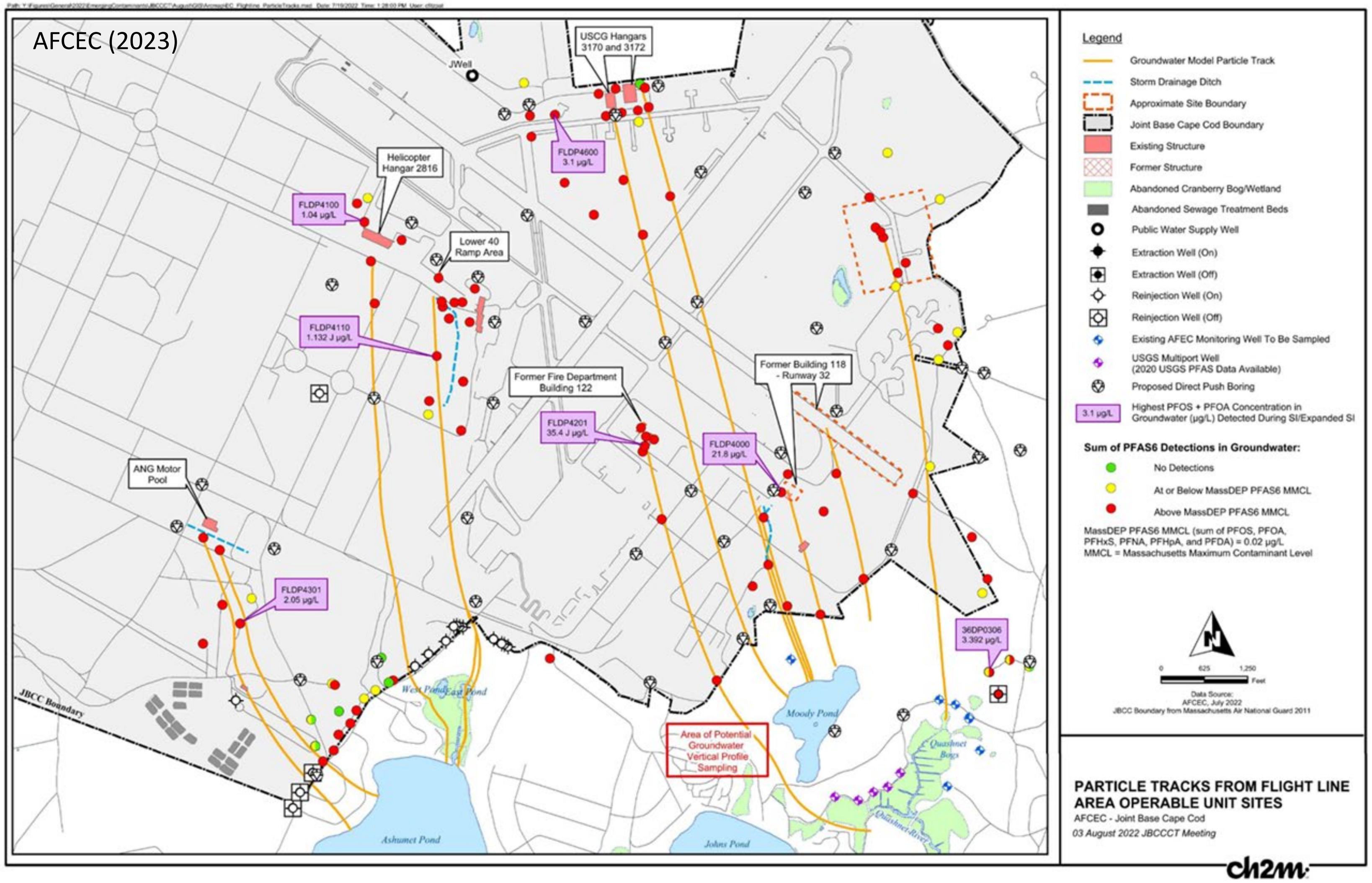
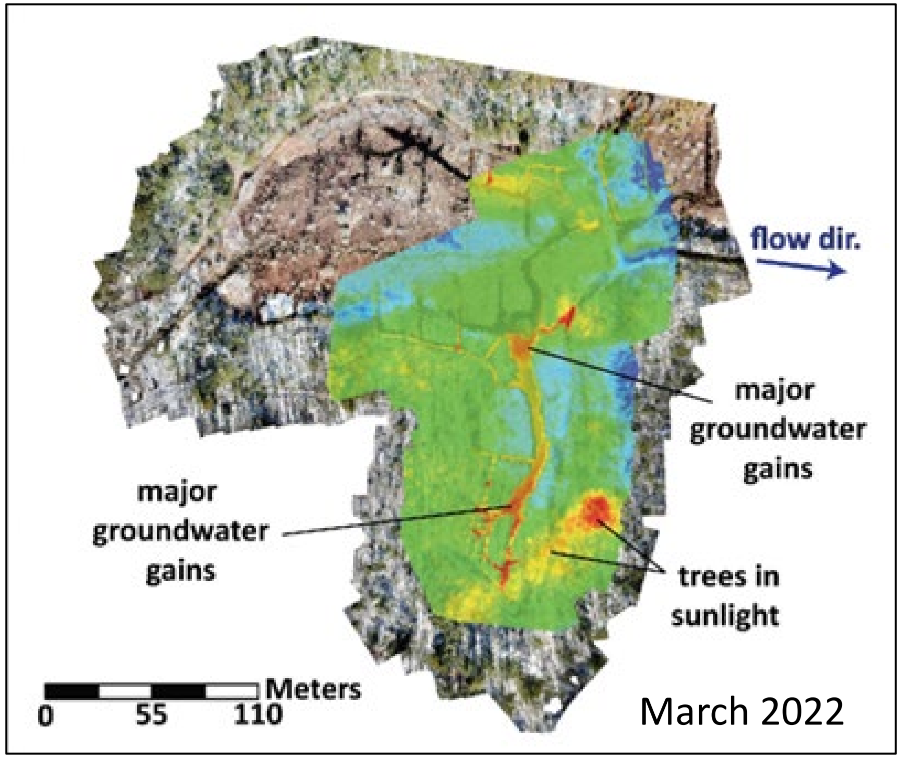
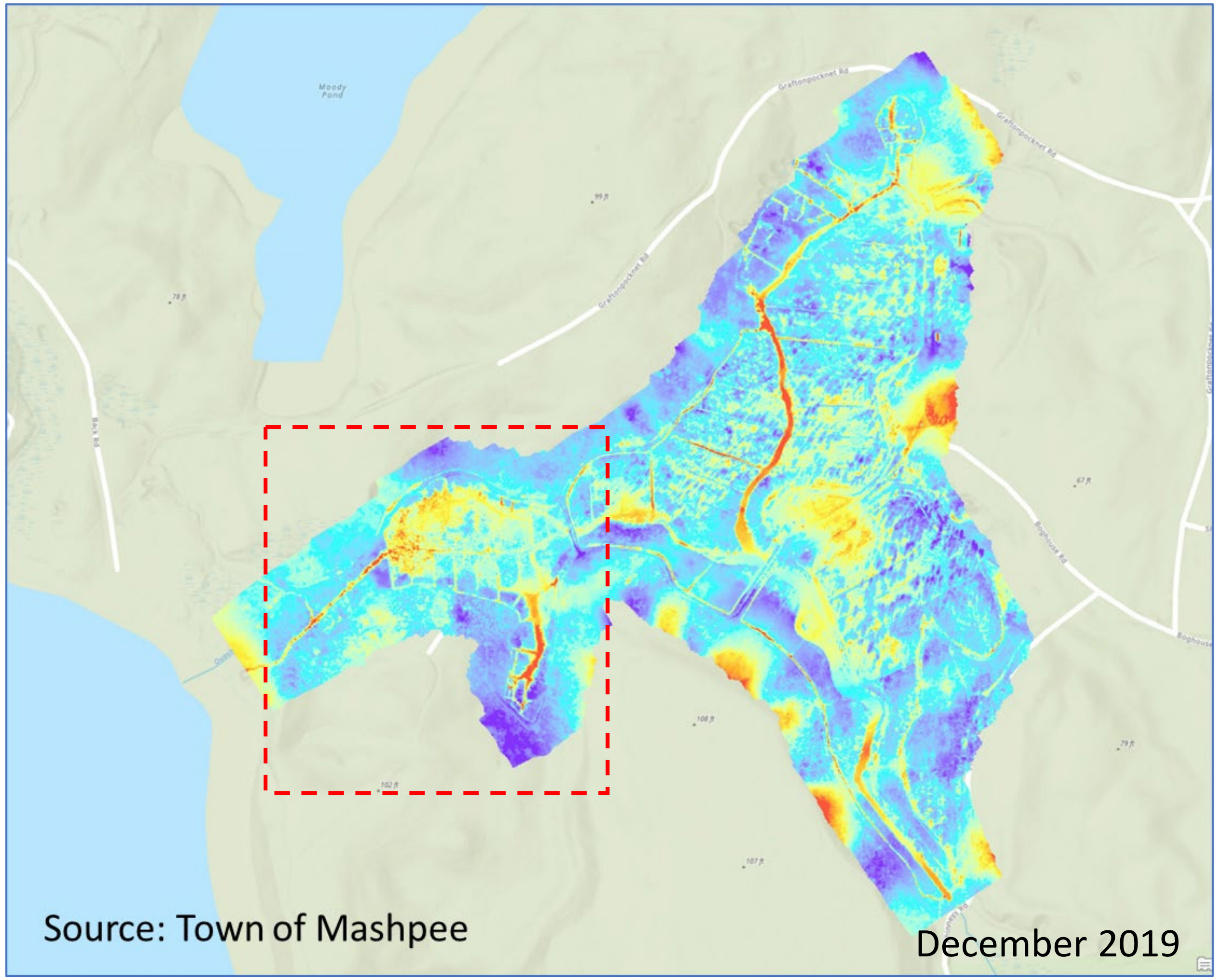
Stream and wetlands intercept PFAS from multiple sources

Simulated particle paths from PFAS sources track toward ponds, river, and former bogs

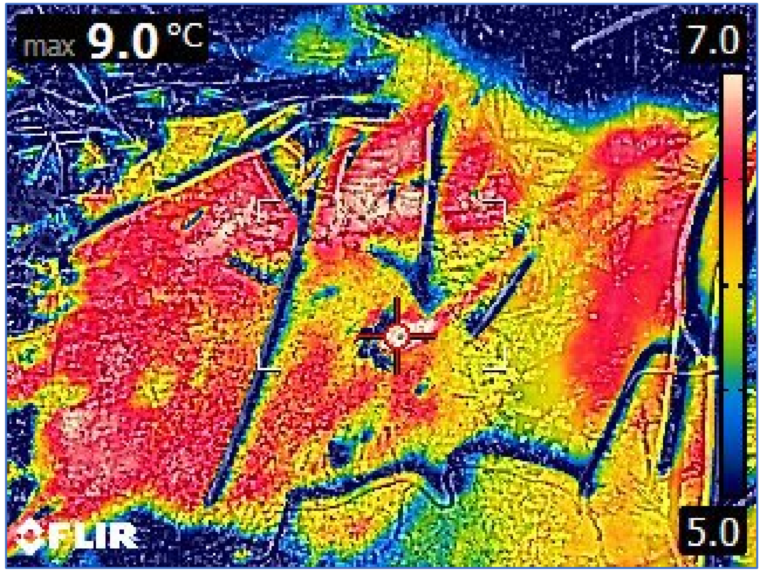






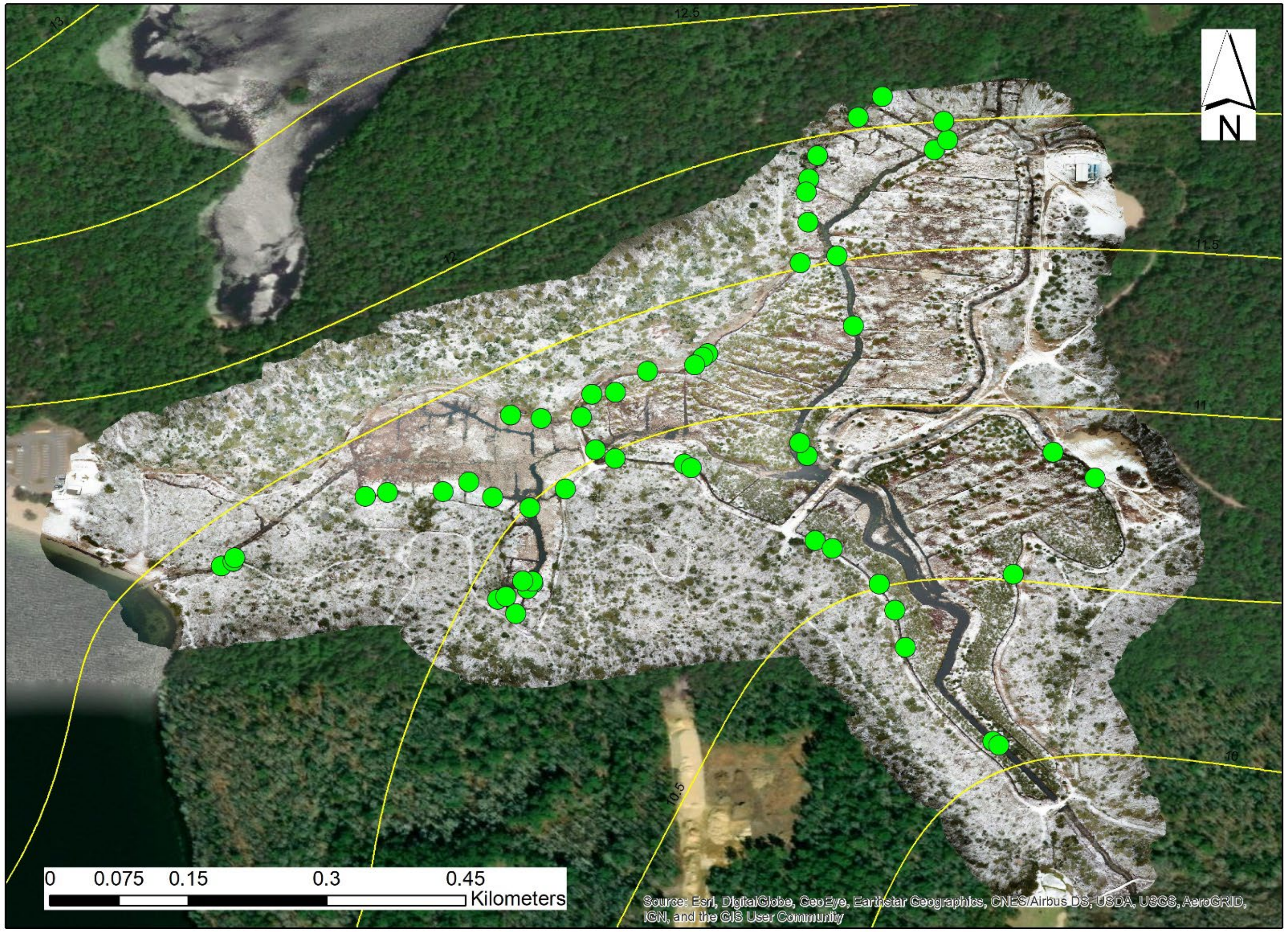
Infrared imagery from drones showed areas of groundwater discharge

Stream and wetlands intercept PFAS from multiple sources



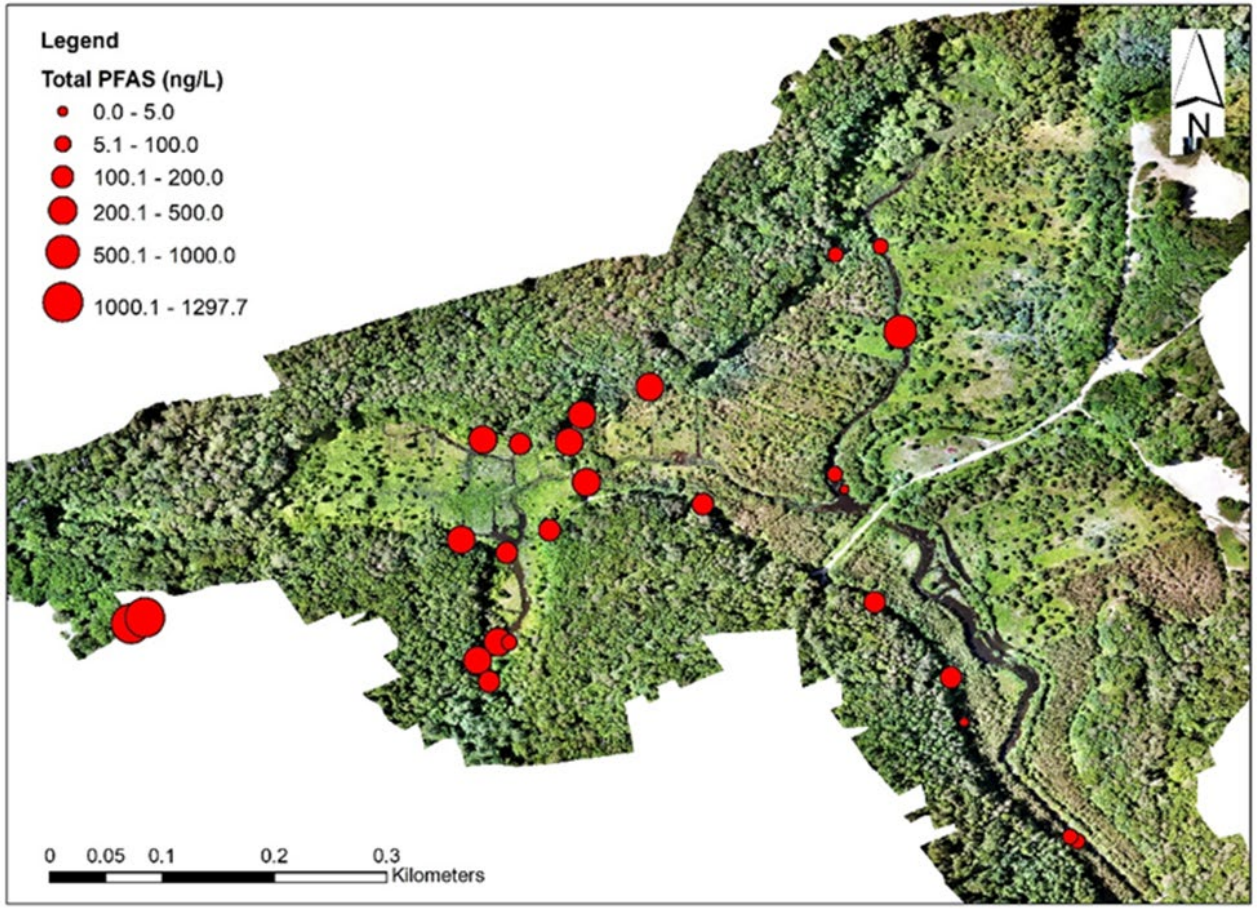
Handheld infrared camera located focused groundwater seeps

Stream and wetlands intercept PFAS from multiple sources



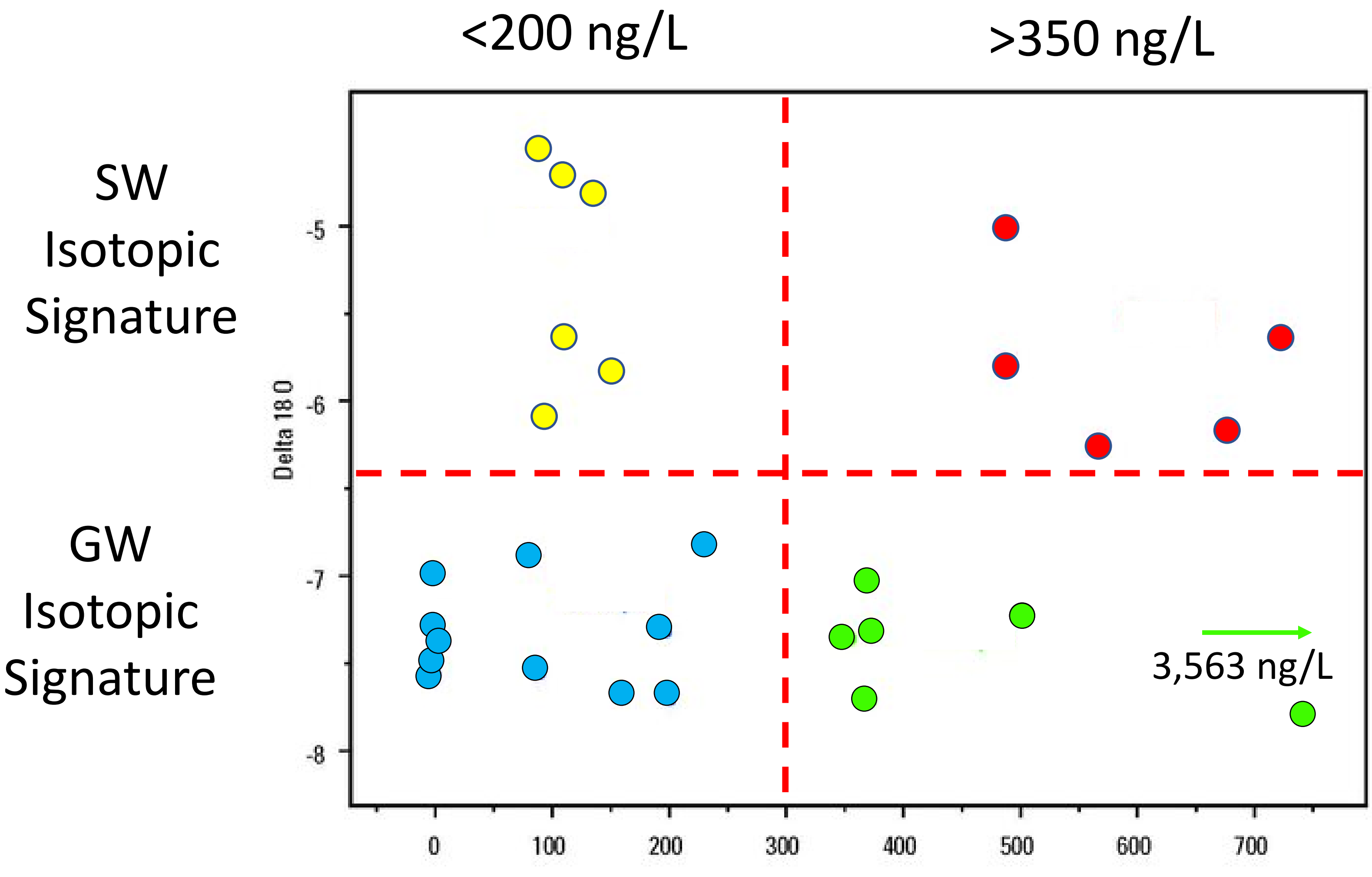
Temperature probe pushed into sediments identified seeps not visible with IR methods

Stream and wetlands intercept PFAS from multiple sources



Upwelling porewater at seeps sampled with pushpoints showed large range of PFAS concentrations.

Stream and wetlands intercept PFAS from multiple sources



Massachusetts Maximum Contaminant Level (MMCL PFAS6) (PFHpA+PFOA+PFNA +PFDA+PFHxS+PFOS)

Groups of similar seeps based on isotopes and PFAS concentrations suggest different flowpaths and possibly sources

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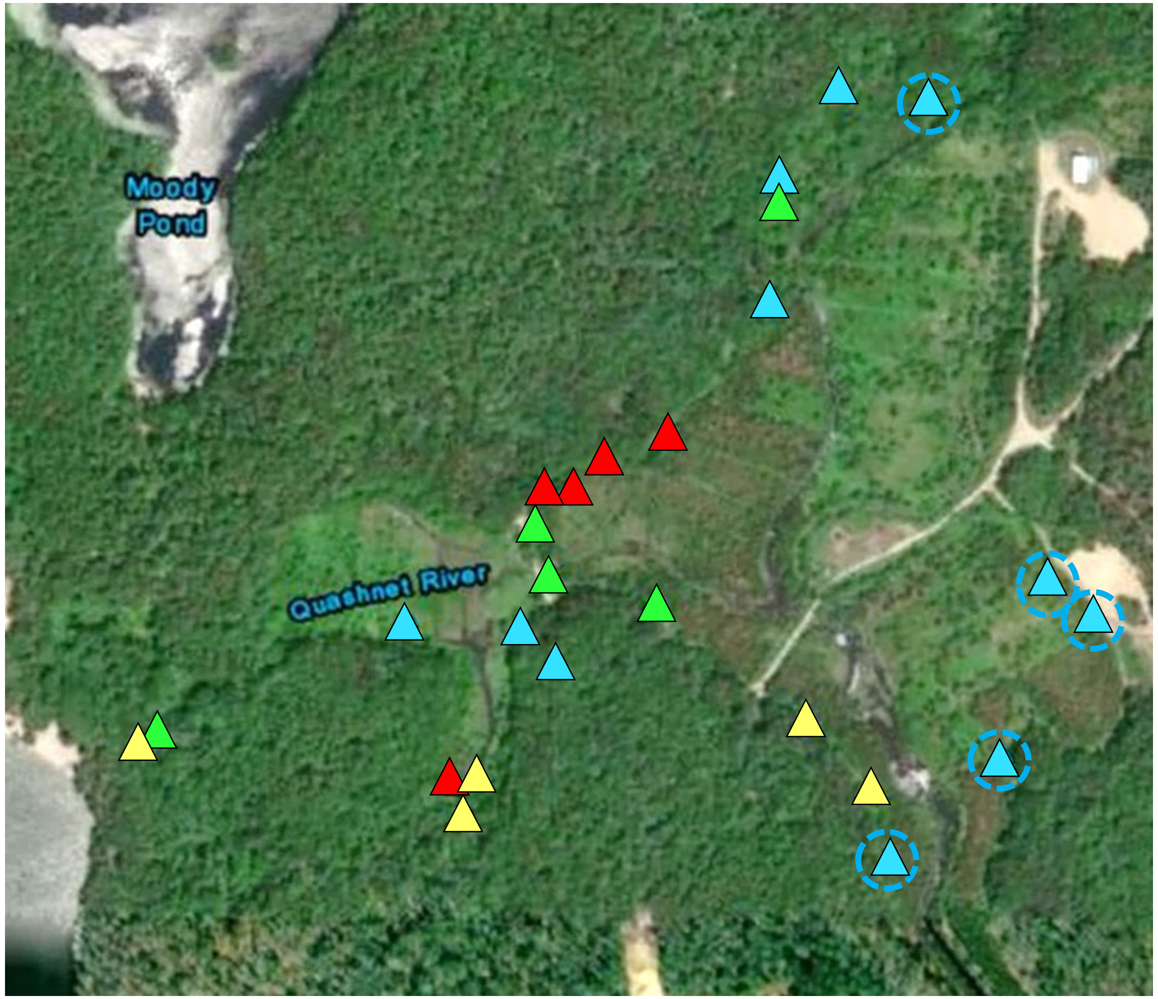
Stream and wetlands intercept PFAS from multiple sources



Higher PFAS, more like SW

Higher PFAS, more like GW

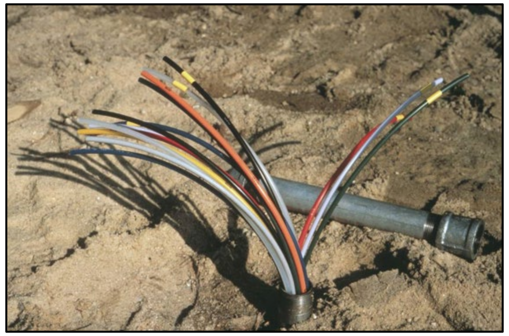
Lower PFAS, more like SW

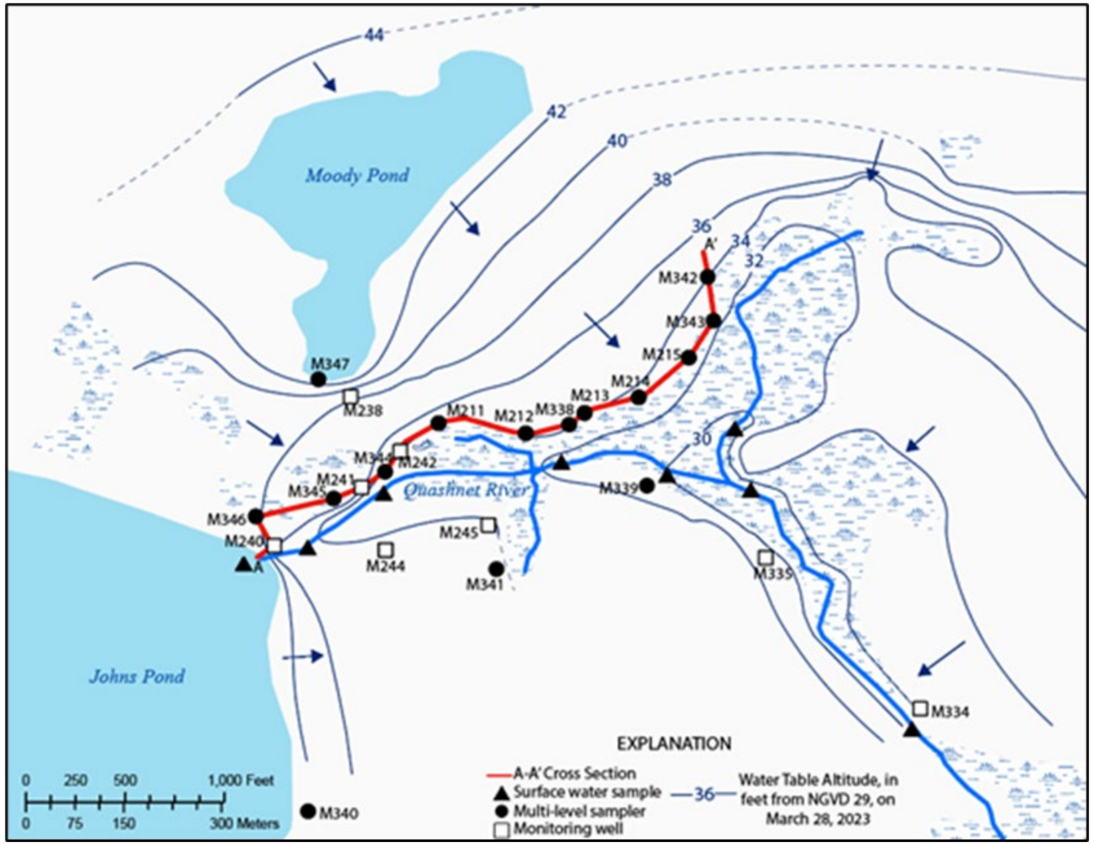
Lower to ND PFAS, more like GW

∑ 6 MMCL PFAS < 20 ng/L

Seep types differ chemically even over small distances

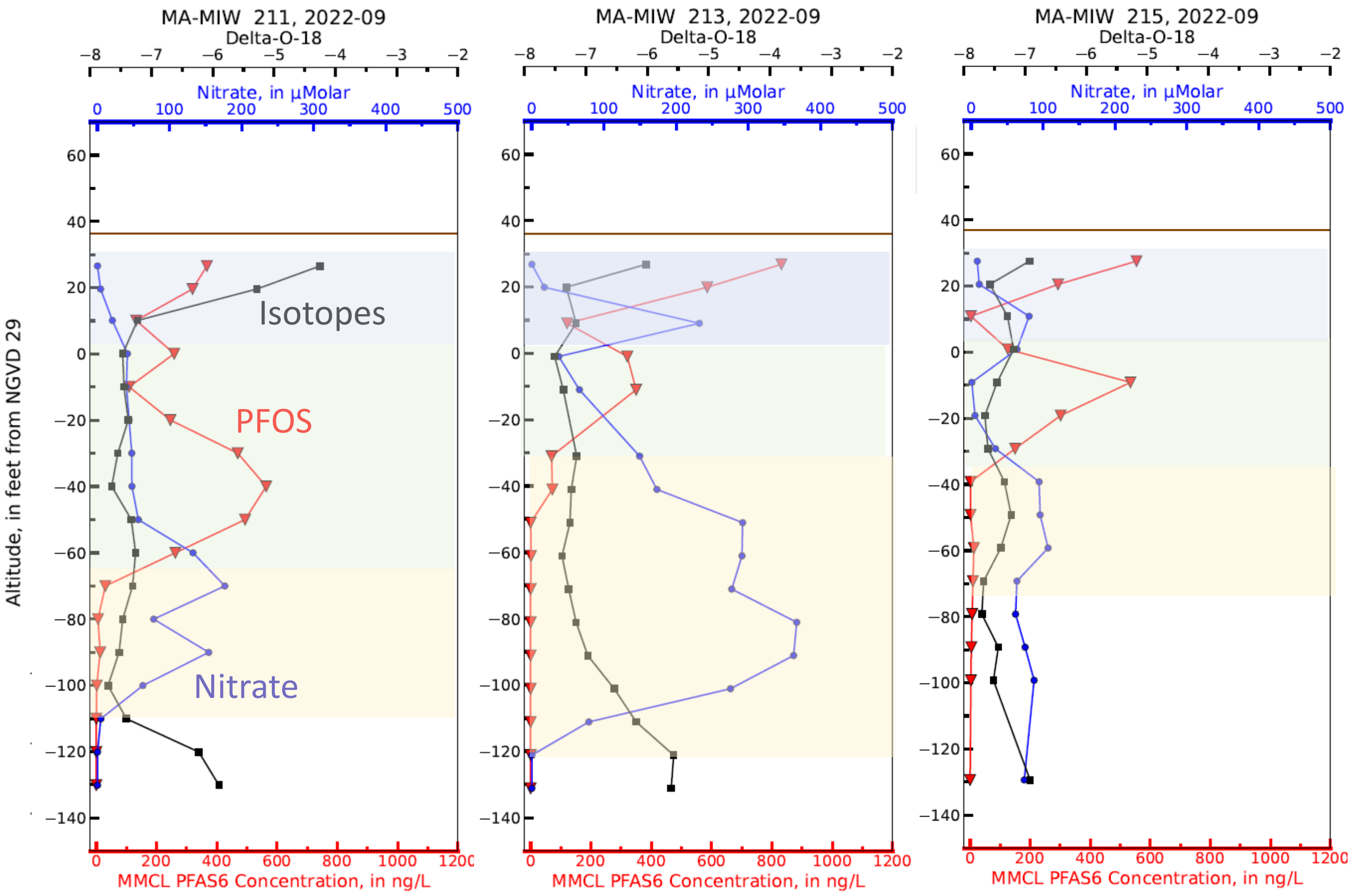
Stream and wetlands intercept PFAS from multiple sources

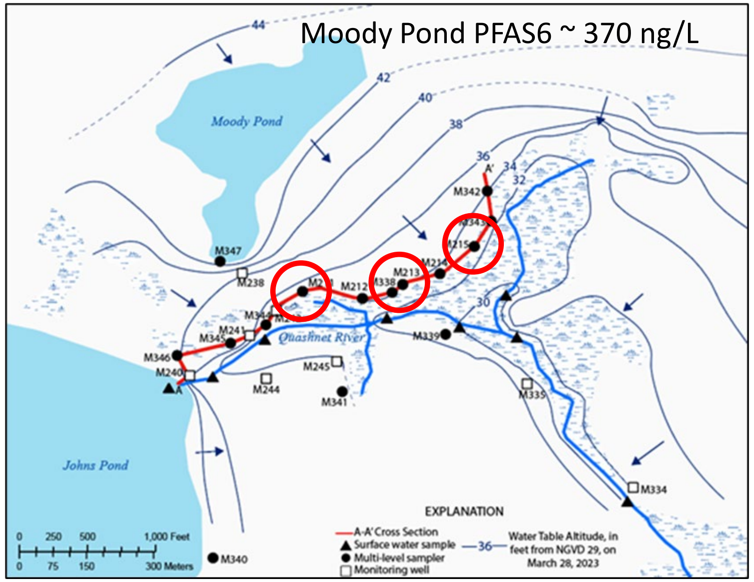




Detailed closely spaced vertical profiles used to map contaminant distributions with depth in the aquifer

Stream and wetlands intercept PFAS from multiple sources





PFAS occurrence varies greatly in the vertical direction but shows consistent patterns along the transverse section near bogs

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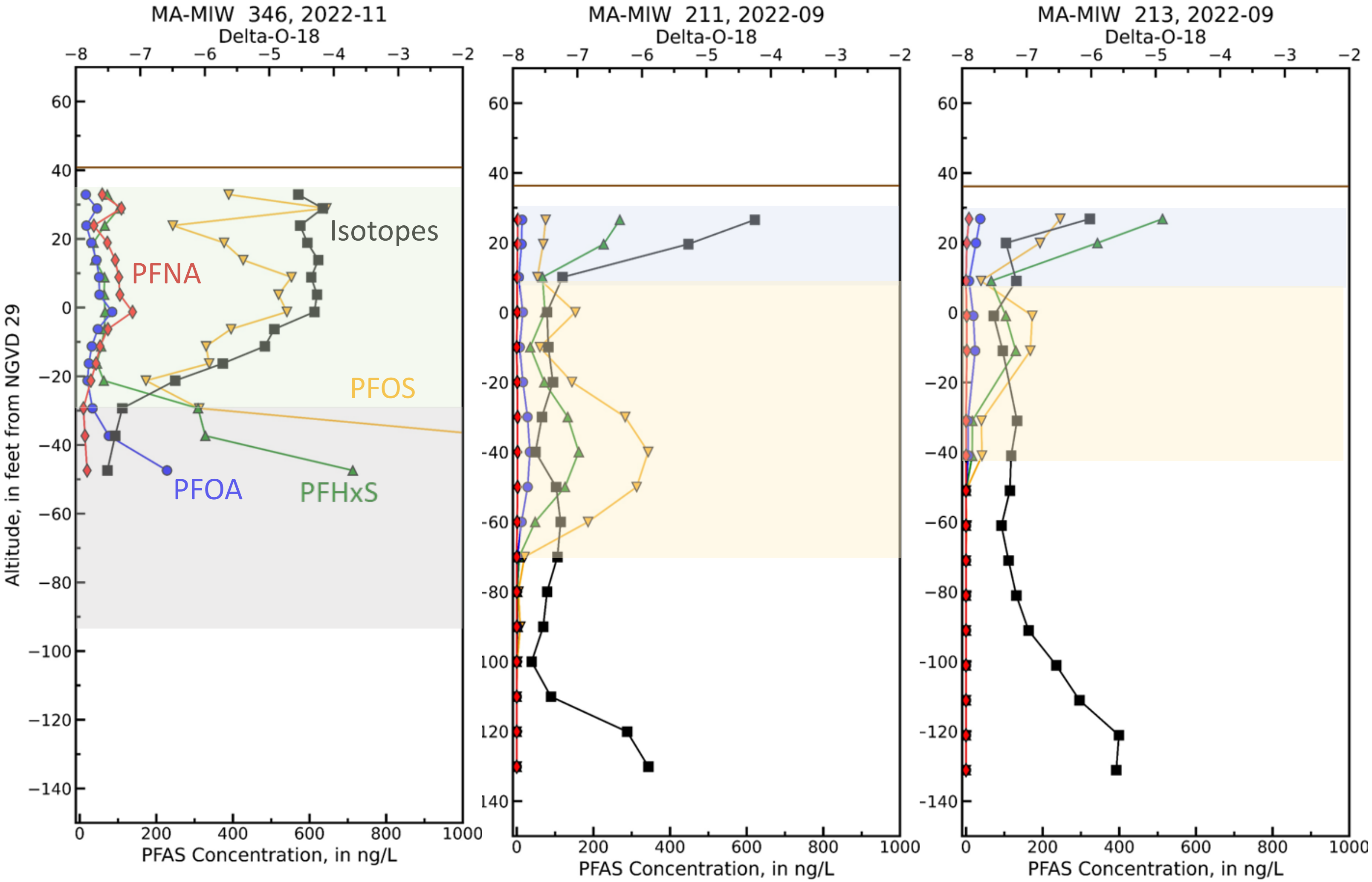
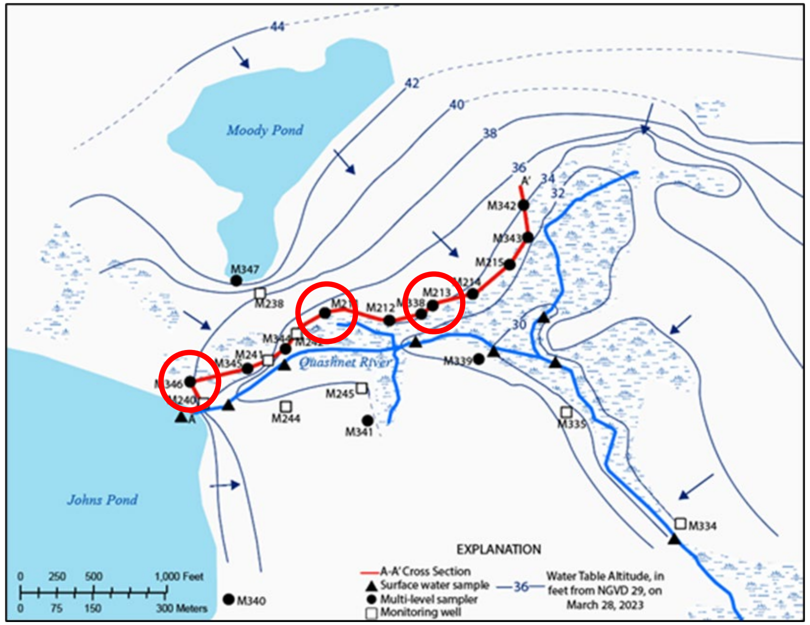
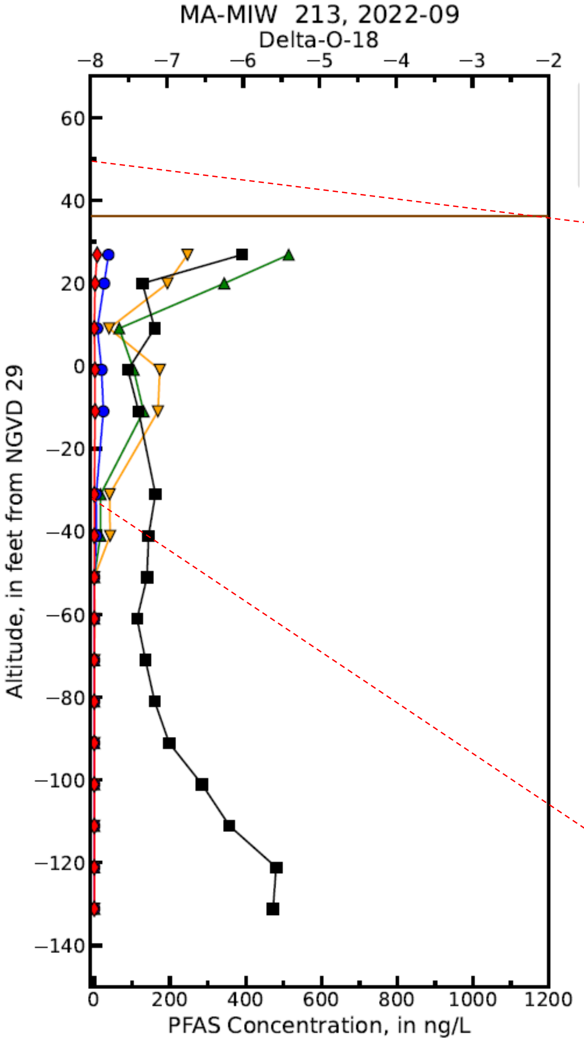
Stream and wetlands intercept PFAS from multiple sources

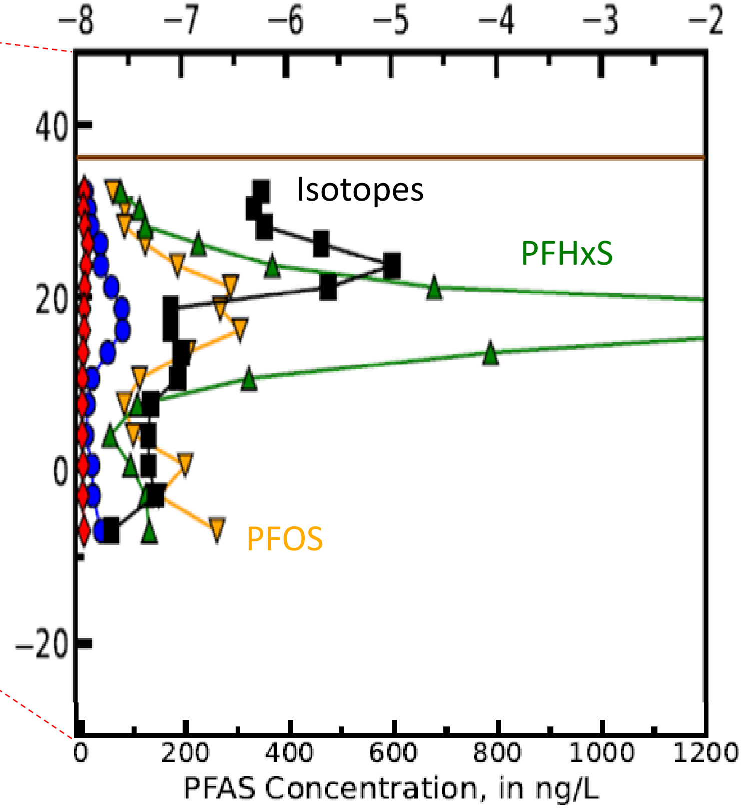


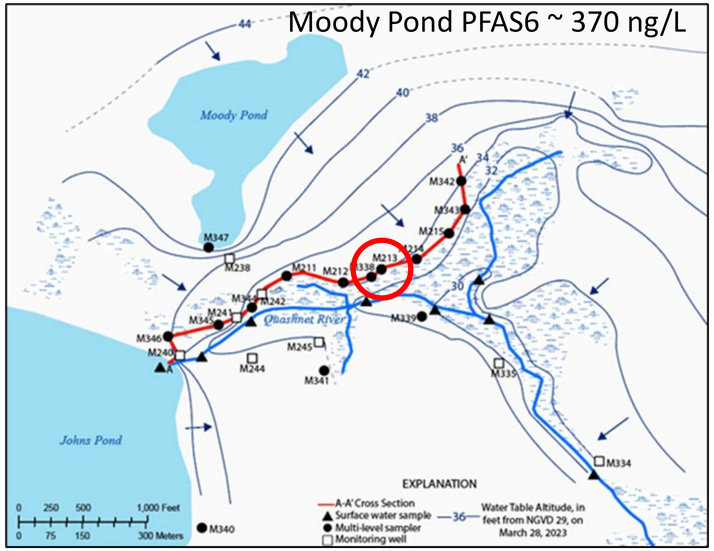


PFAS composition also varies greatly in vertical and transverse directions

Stream and wetlands intercept PFAS from multiple sources







Different chemically defined zones upgradient from river and bogs apparent from detailed sampling

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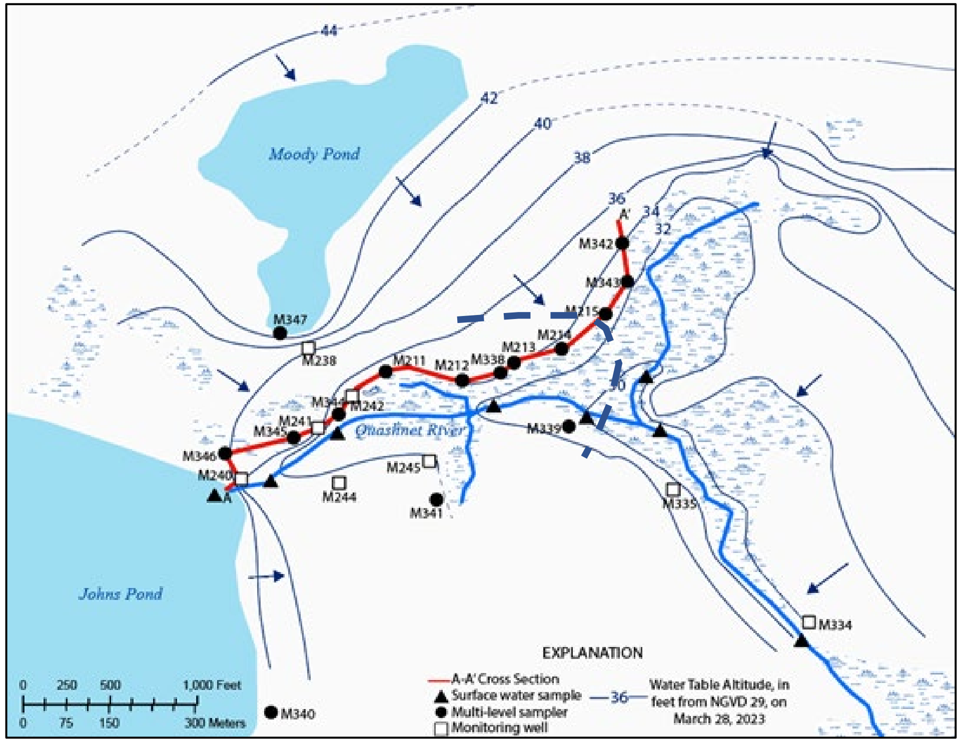
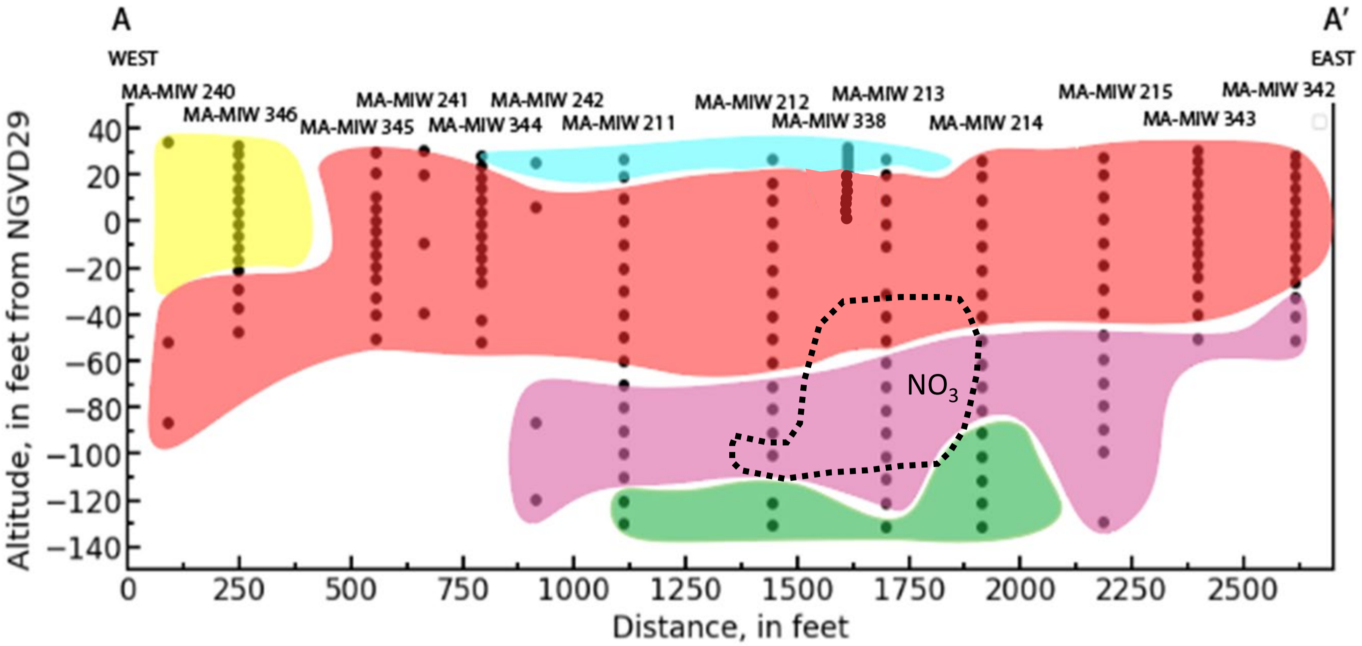
Stream and wetlands intercept PFAS from multiple sources

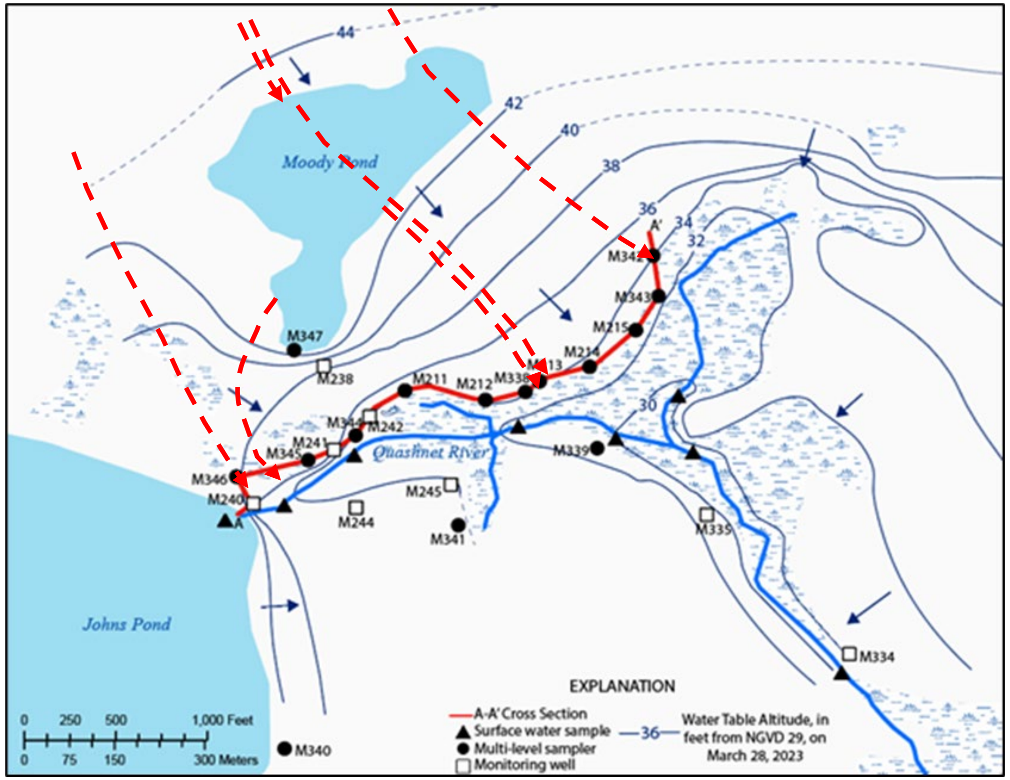


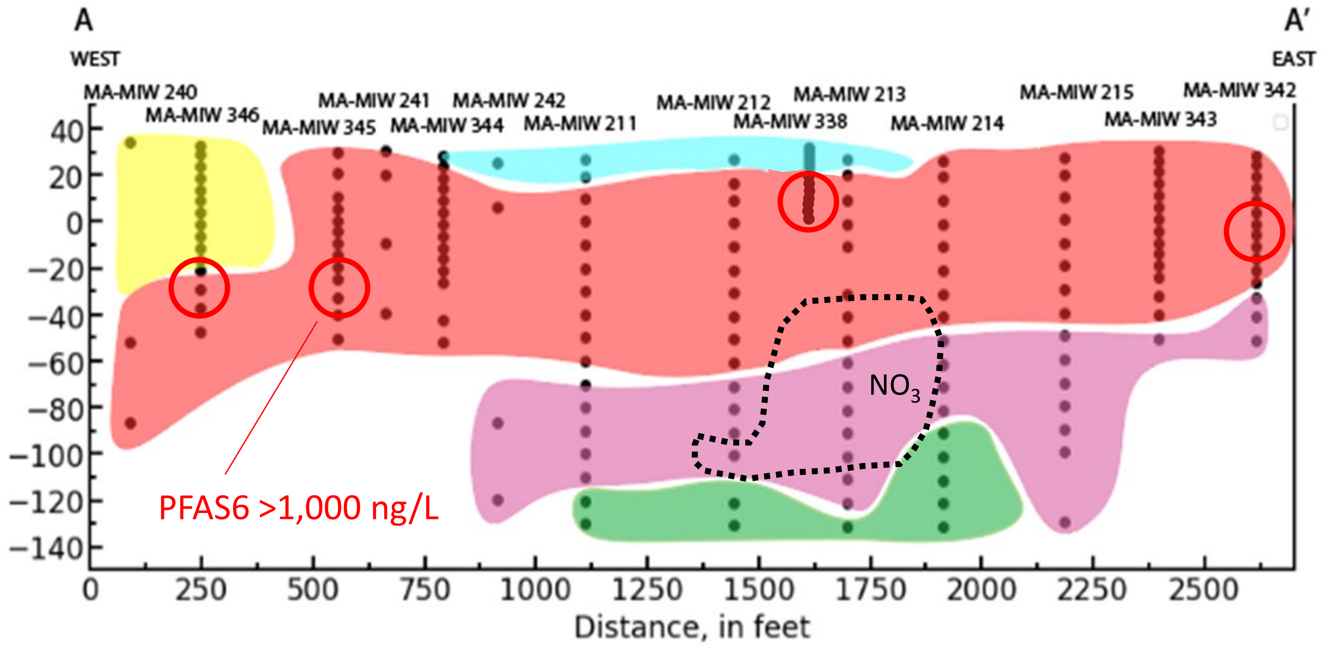


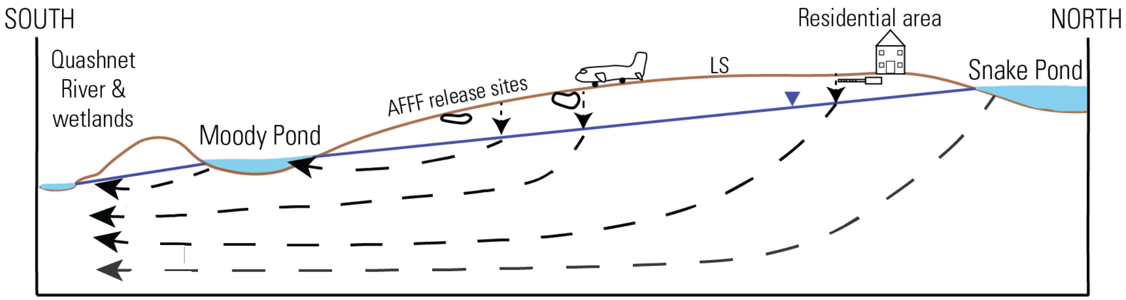
- High PFAS, heavy isotopes
- High PFAS, light isotopes
- No PFAS, light isotopes
- No PFAS, heavy isotopes
- High PFAS, PFNA present, heavy isotopes
- ······ NO_3-N > 2.8 mg/L

Different chemically defined zones upgradient from river and bogs apparent from detailed sampling

Stream and wetlands intercept PFAS from multiple sources

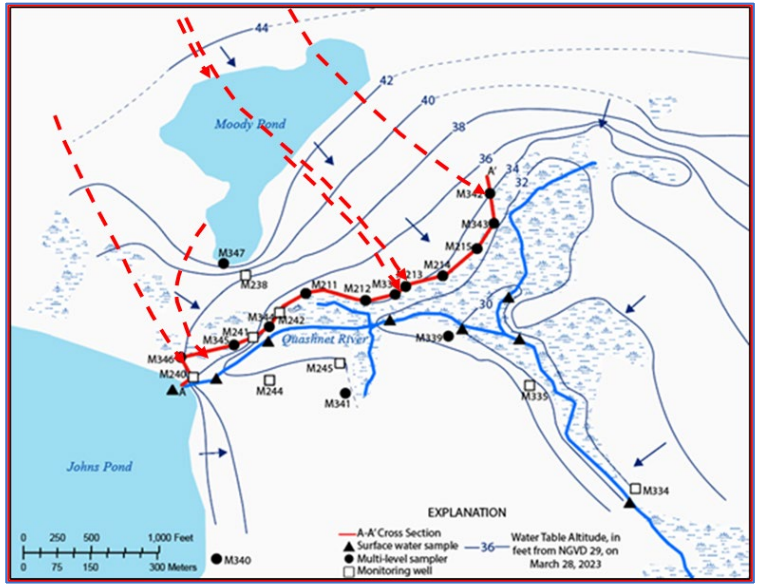


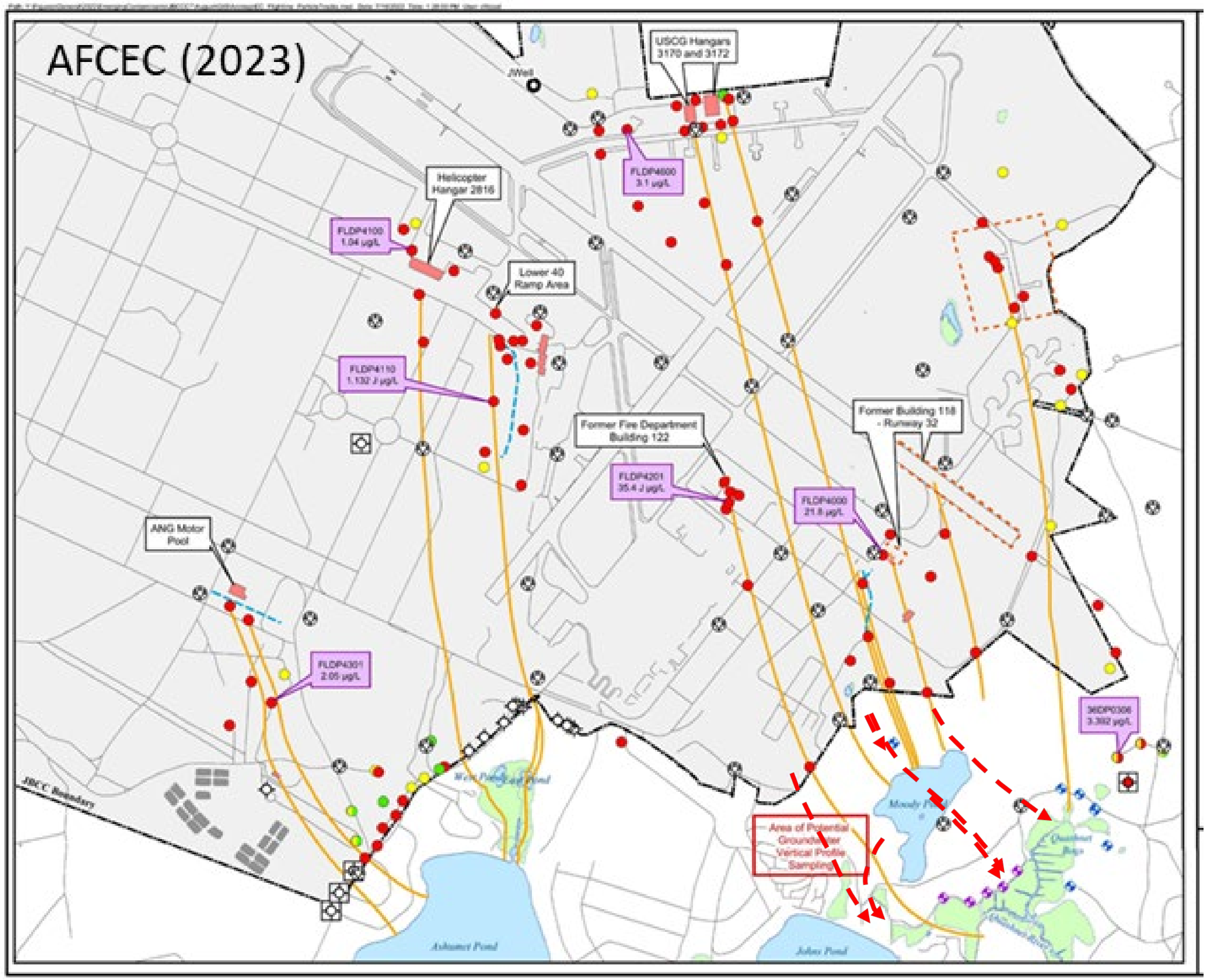




Detailed sampling reveals possible 3-D flowpaths to "hotspot" PFAS discharges to surface waters

Stream and wetlands intercept PFAS from multiple sources





Seep and groundwater data near river may help guide focus of upgradient investigations and link sources to receptors

Concluding Thoughts

- Groundwater/surface-water interactions can affect paths contaminant plumes
- Spatially detailed groundwater data near surface-water receptors can guide upgradient site investigations
- Discharge locations can guide selection of effective remediation
- Three reports are being prepared on these findings
- Work has begun on fine-scaled 3-D model of the groundwater/surface-water system and plume paths

Northern tributary of the Quashnet River in June 2022

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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