

Below the Limit of Detection: The Impact of Censored Data on Trinity River PFAS Assessments

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INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are thousands of synthetic chemicals characterized by extremely strong carbon-fluorine (C-F) bonds, giving them thermal and chemical stability and resistance to environmental degradation.

Environmental Behavior

- Long-chain PFAS (e.g., PFOS, PFOA): sorb strongly to sediment
- Short-chain PFAS (e.g., PFBA, PFBS): highly mobile

Health Significance

- Health effects linked to PFAS exposure include immune suppression, endocrine disruption, elevated cholesterol, and cancer



Regulatory Context

- The EPA finalized National Primary Drinking Water Regulation (NPDWR) in April 2024 with MCLs for selected PFAS compounds: PFOS: 4 ng/L; PFOA: 4 ng/L; PFNA: 10 ng/L; PFHxS: 10 ng/L; HFPO-DA (GenX): 10 ng/L

Key challenges in PFAS reconnaissance:

- ~80% of results often fall below reporting limits
- Non-detect handling affects screening totals
- Limited integration of permit data with river networks

OBJECTIVES

- Characterize the spatial occurrence, detection frequencies, and mixture composition of PFAS
- Estimate site-level PFAS sums using multiple imputation of left-censored data
- Assess whether catchment land use and river-network distance to NPDES facilities explain spatial variability

MATERIALS AND METHODS

Study Area:

- Upper Trinity River, Fort Worth, Texas
- Ten sampling sites strategically selected across airports, landfill sites, water treatment plant and a military base

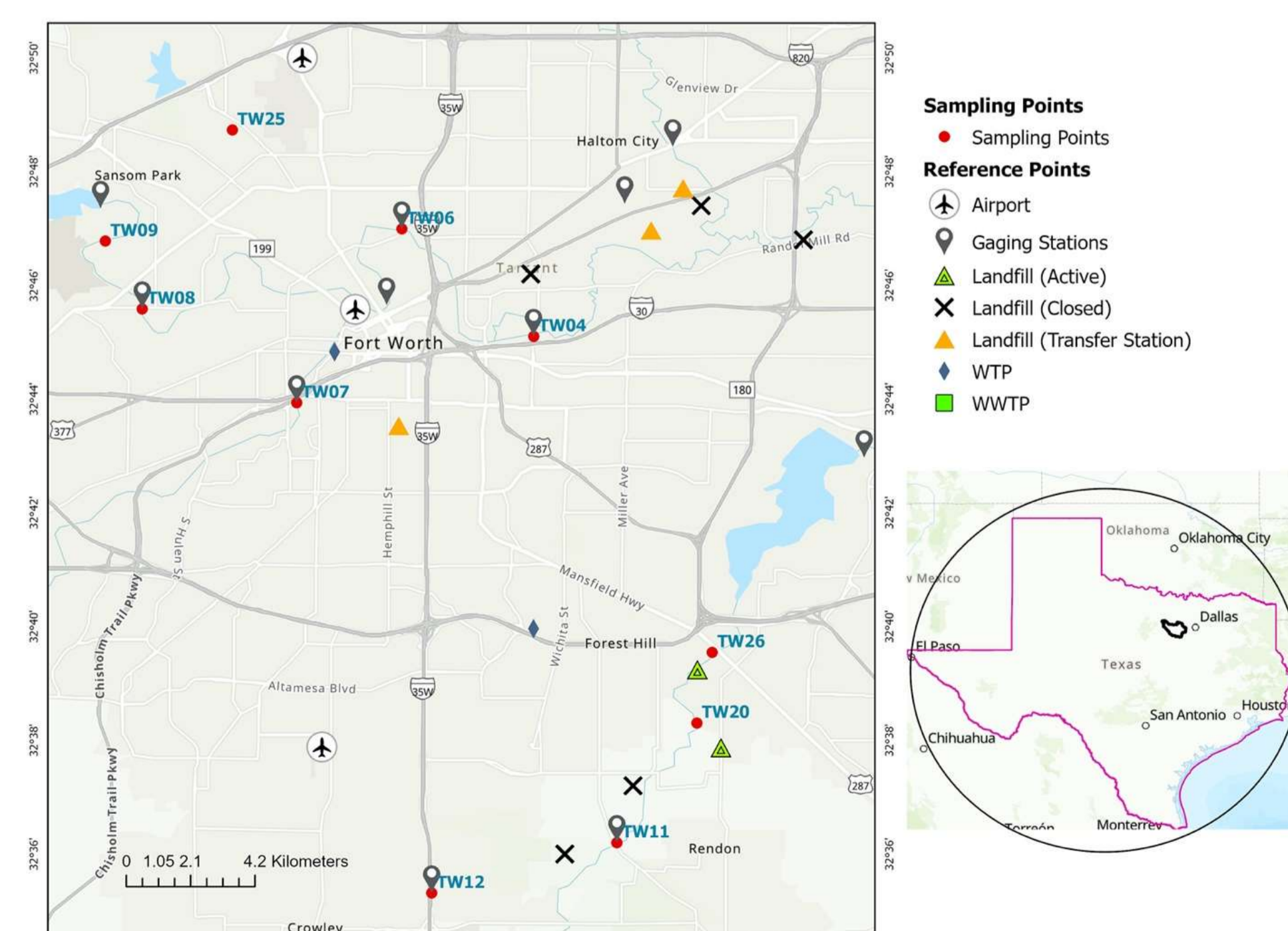


Figure 2. Study area location within Texas



Figure 3. Sampling location along Trinity River

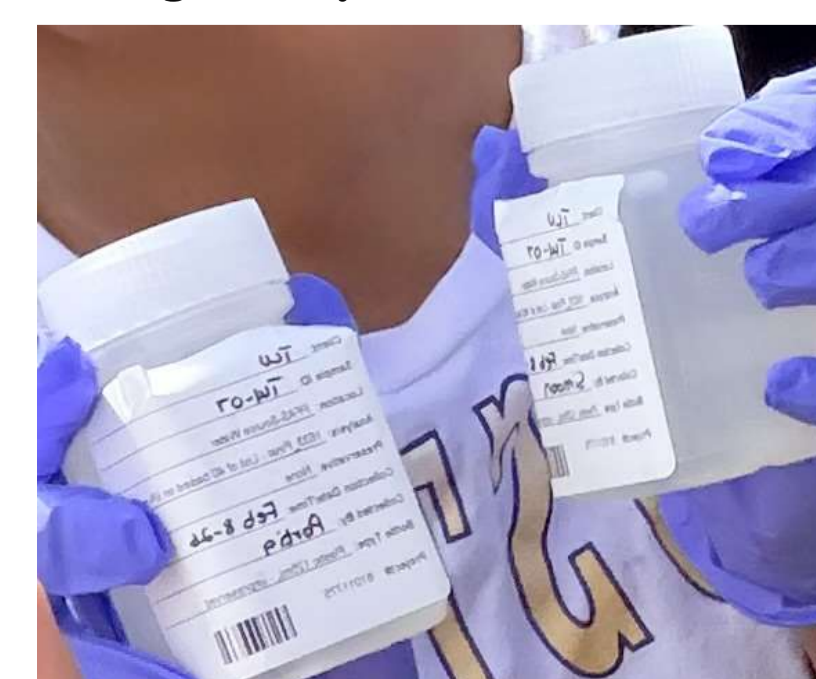


Figure 4. Sample collection and labeling (HDPE bottles)

MATERIALS AND METHODS

Data

- Samples were taken as grabs in 125 mL HDPE bottles on December 21, 2025
- Samples transported to Eurofins Southbend, IN for analysis
- Arriving <48 hours at a temperature of 3.4°C
- "I" qualifier: Ion ratio exceedance (PFOS at TW12, TW20, TW26); sensitivity analysis performed
- "G" qualifier: Elevated RL (8:2 FTS at TW08); compound not positively identified

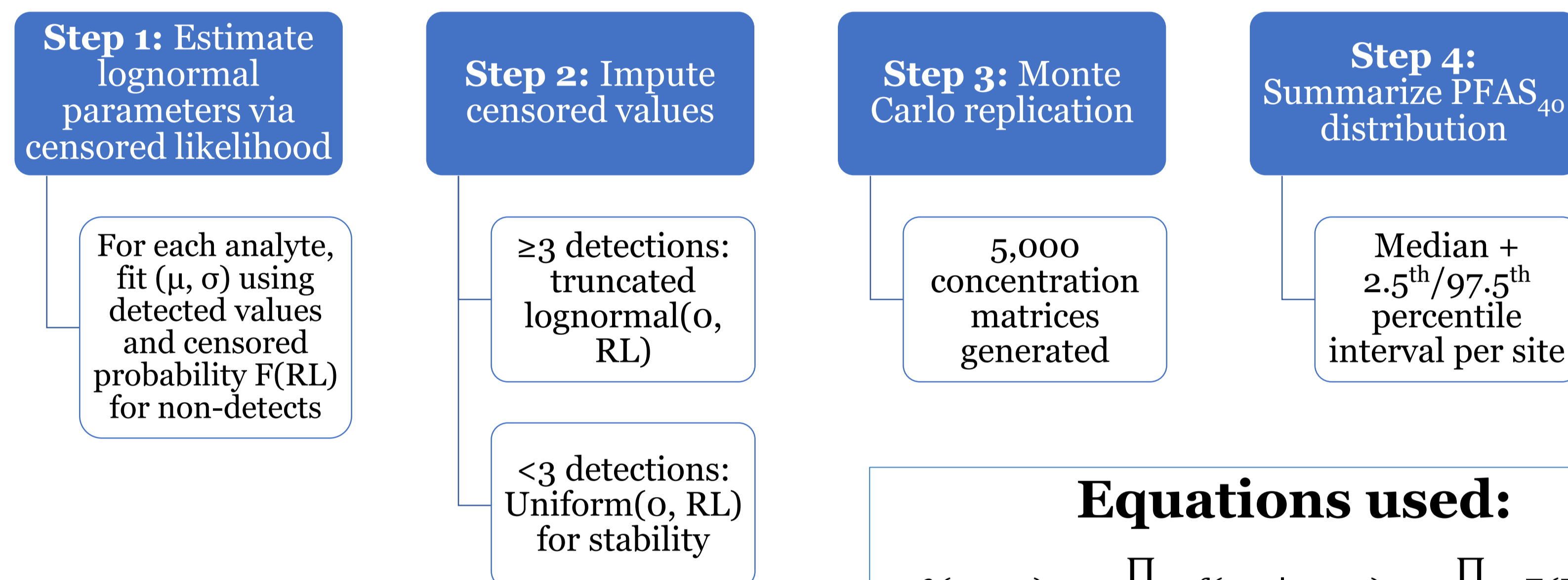
EPA Method 1633

- 40 targeted PFAS by LC-MS/MS with isotope dilution
- Reporting limits: 1.3-14 ng/L

Geospatial and Catchment Covariates

- Land cover: 2024 NLCD; fractional imperviousness from USGS
- NPDES inventory: EPA ECHO records

Multiple Imputation Handling of Left Censored Data



Equations used:

$$\mathcal{L}(\mu_a, \sigma_a) = \prod_{i \in D_a} f(y_{i,a} | \mu_a, \sigma_a) \times \prod_{i \in C_a} F(RL_{i,a} | \mu_a, \sigma_a)$$

$$u \sim \text{Uniform}(0, F(RL_{i,a}))$$

$$y_{\text{imputed}} = F^{-1}(u)$$

RESULTS AND DISCUSSION (continued)

Site-Level PFAS Concentrations

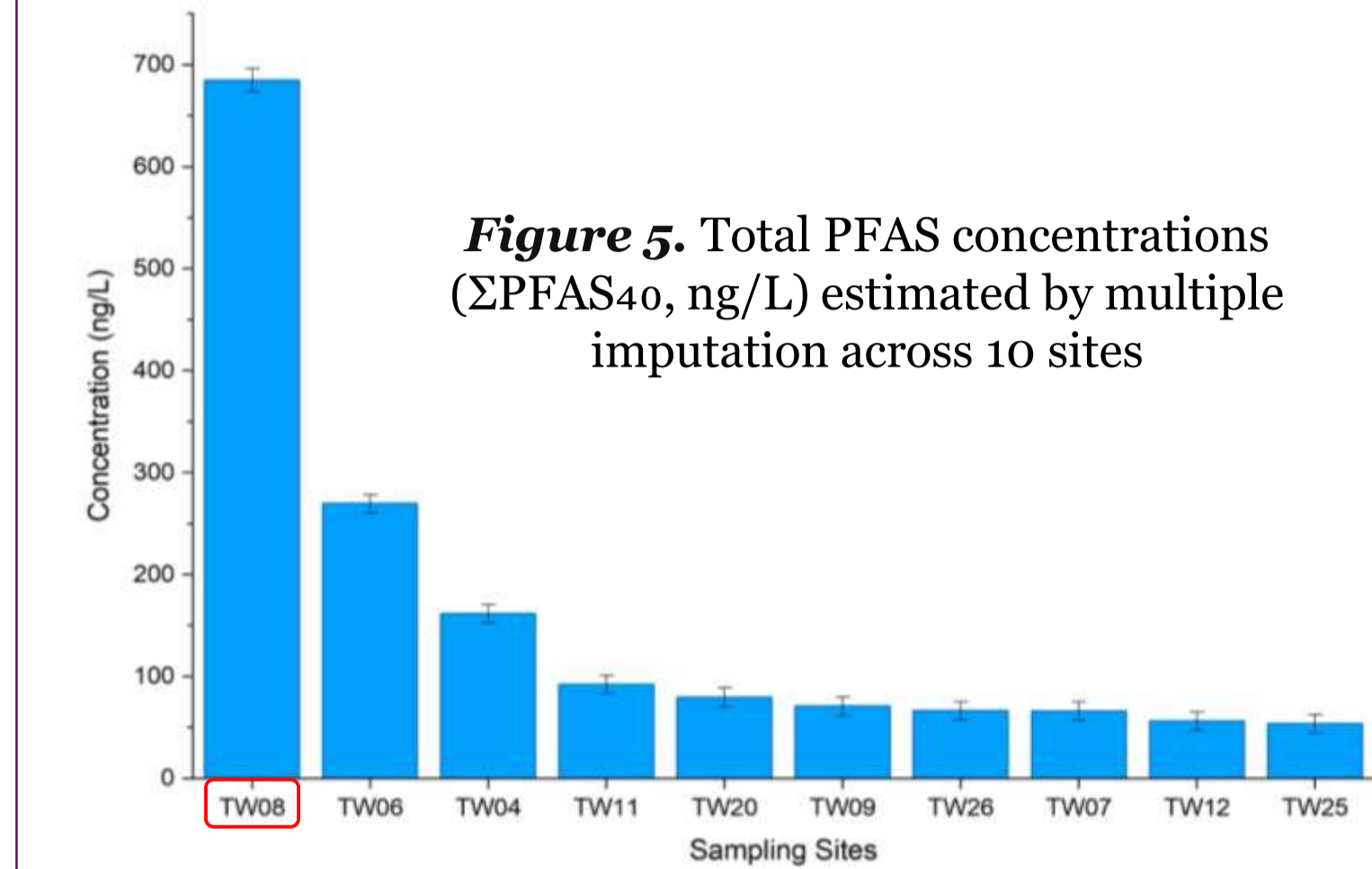


Figure 5. Total PFAS concentrations (ΣPFAS₄₀, ng/L) estimated by multiple imputation across 10 sites

Hotspot Identified

Site TW08 West Fork Trinity Downstream of NAS JRB	Dominant compounds: PFOS: 180 ng/L PFHxS: 120 ng/L 6:2 FTS: 81 ng/L
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Mixture Composition by Chemical Class

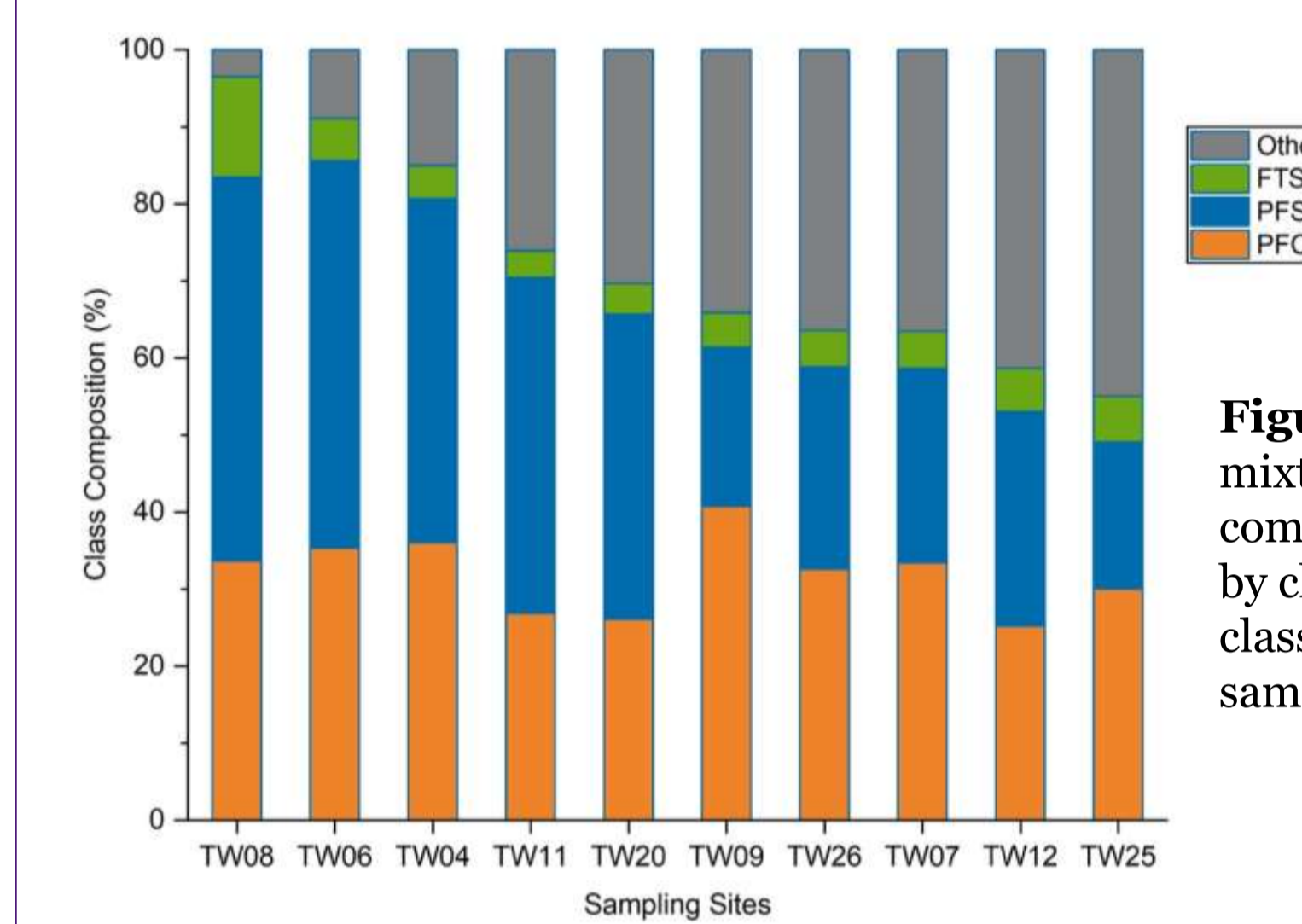


Figure 6. PFAS mixture composition (%) by chemical class across sampling sites

Interpretation

- Hotspot site: **PFSA**: 50%, **FTS**: 13%
✓ Associated with AFFF use
- Background: short-chain **PFCA** dominant
- Large "Other" fraction: diffuse mixed sources

Catchment Covariates

More urban = more PFAS
Catchments with impervious surface and developed land tend to have higher PFAS concentrations, consistent with stormwater runoff as a delivery pathway.

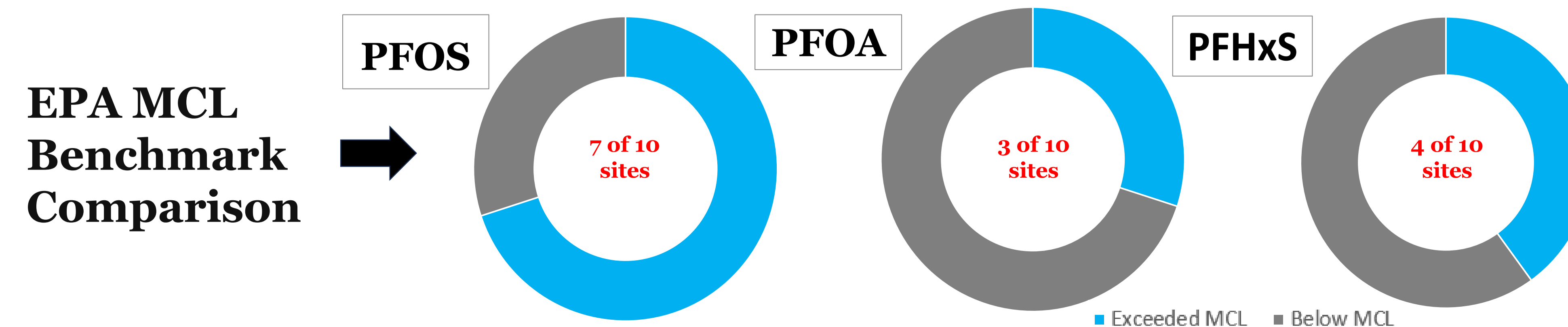
Distance to discharge points = inverse relationship
River-network distance to the nearest permitted facility shows sites closer tend to have higher PFAS and vice versa.

RESULTS AND DISCUSSION

Detection Summary

12/40 Analytes detected	100% Sites with detectable PFAS	21% Overall detection frequency	5 Analytes at 100% Frequency
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Compound	Class	Chain length	Detection %	Median (ng/L)	Max (ng/L)
PFBA	PFCA (C4)	Short-chain	100	9.4	50
PFPeA	PFCA (C5)	Short-chain	100	4.3	52
PFHxA	PFCA (C6)	Short-chain	100	3.0	67
PFBS	PFSA (C4)	Short-chain	100	7.0	19
PFOS	PFSA (C8)	Long-chain	100	6.5	180
PFOA	PFCA (C8)	Long-chain	90	2.5	38
PFHxS	PFSA (C6)	Long-chain	90	9.0	120
6:2 FTS	FTS		30	12.0	81
PFPeS	PFSA (C5)	Short-chain	40	4.3	15
PFHpA	PFCA (C7)	Short-chain	30	7.4	18
PFHpS	PFSA (C6)	Long-chain	20	3.3	4.9
PFNA	PFCA (C9)	Long-chain	20	1.8	2.2



CONCLUSION

- PFAS detected at all 10 sites. ΣPFAS₄₀ range 53.7-684.9 ng/L; 12 of 40 analytes detected.
- The strongest contamination was at TW08 (NAS JRB), consistent with historical use of AFFF firefighting foam at military bases.
- Several compounds exceeded the EPA drinking water limit, which is a direct concern for public health if the water is used as a potable source of water.
- No PFAS data appeared in Texas NPDES discharge records, showing a regulatory gap that needs to be addressed.
- Multiple imputation was more reliable for handling the high proportion of non-detects, adding 32-38 ng/L as compared to the sum of detects only.

Future Directions: Temporal replication, mass flux estimation, targeted source sampling, PFAS in TX NPDES permits

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REFERENCES

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Scan for additional references

