A Hydrogeological Modeling Approach to Understand the Fate and Transport of PFAS in the Cape Fear Watershed

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Overview

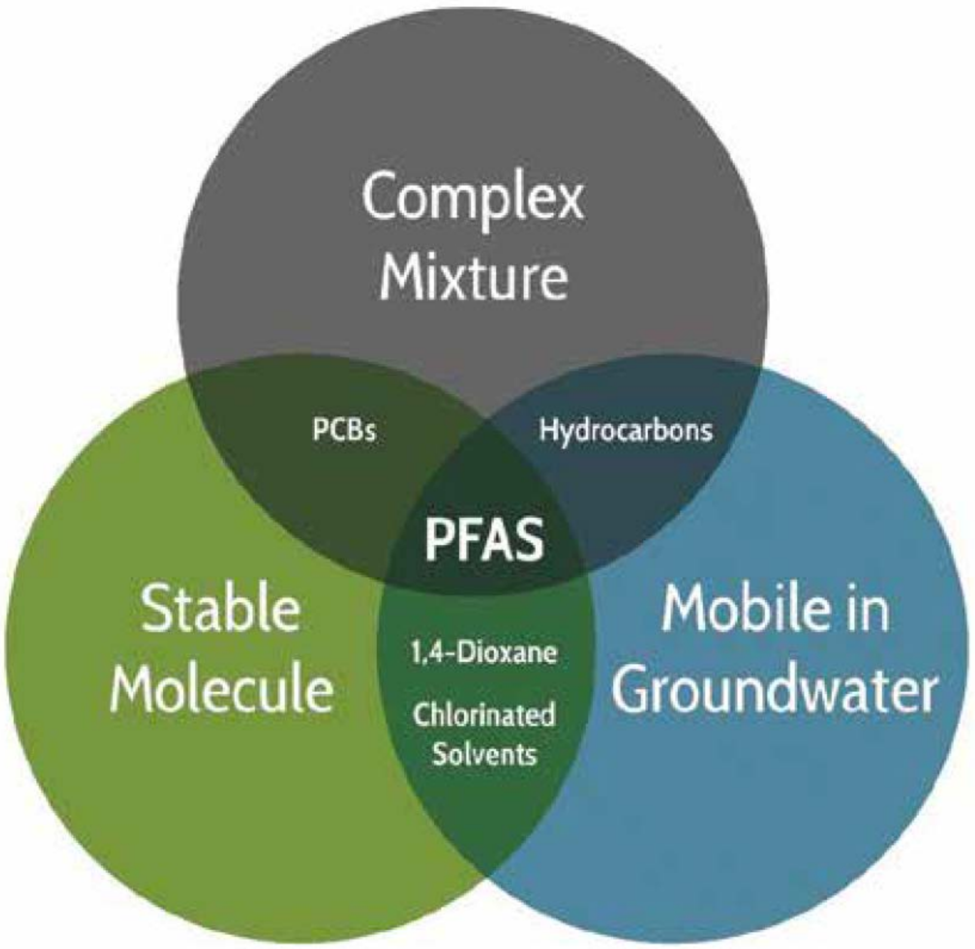
This presentation overviews an approach to model historical PFAS contamination of drinking water in three communities within the Cape Fear Watershed using available data and information.

- PFAS Compounds as a Unique Chemical Class
- Hydrogeologic Modeling Overview
- Historical Reconstruction of PFAS in Drinking Water

PFAS Compounds as a Unique Chemical Class

What is so special about PFAS?

- ~5,000 PFAS compounds, often found in complex mixtures
- Stable (once transformed)
- Toxic and (possibly) carcinogenic
- Bioaccumulation potential
- Capable of air transport - wet and dry deposition
- Mobile in groundwater

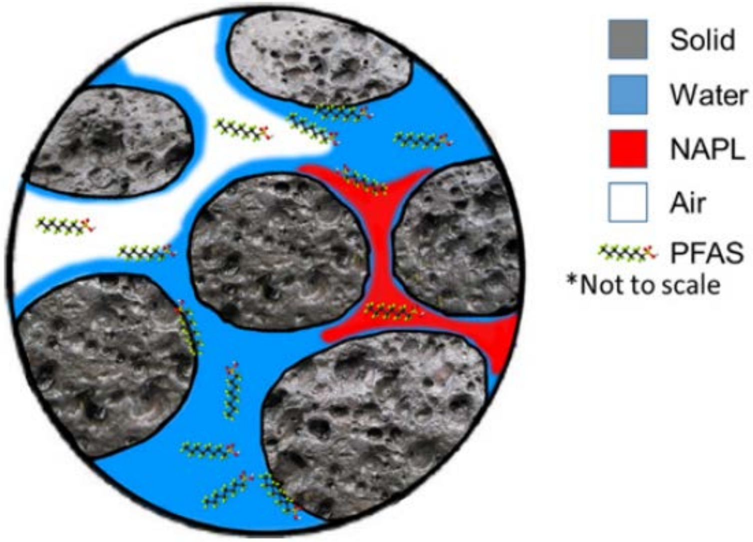


PFAS Properties, Continued

Conventional modeling approaches for volatile organic compounds / soluble contaminants **do not capture PFAS lab and field behavior**

- PFAS change surface tension of water, thereby the way water flows
- Unlike most organic compounds, there is not linear solid phase sorption behavior (Kd = Koc * foc)
- Limited data on PFAS other than PFOS and PFOA, pre-cursors and end products

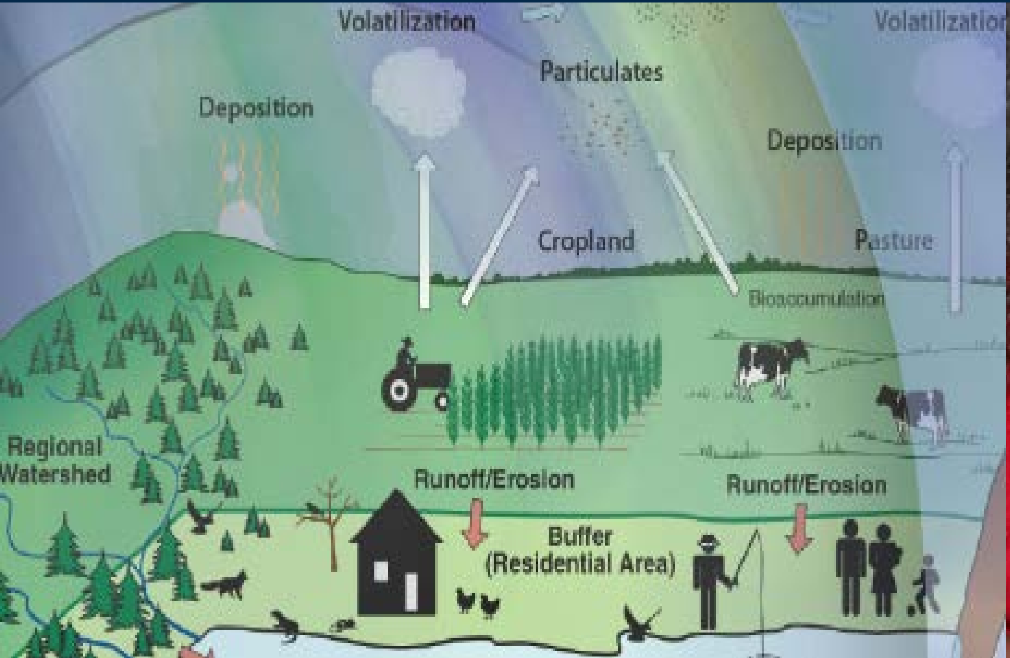
Vadose zone – a subsurface **PFAS reservoir** and **long-term groundwater contaminant source**



PFAS compounds are interface-loving, making unsaturated zone transport behavior more complex

Reproduced from Brusseau 2018. *Assessing the potential contributions of additional retention processes to PFAS retardation in the subsurface.* Science of the Total Environment 613-614 (2018) 176-185.

Hydrogeologic Modeling Overview



Why Model?

Hydrogeologic modeling allows us to get a better understanding of the potential fate and transport of PFAS compounds <u>than the use of sampling data alone</u>.

Modeling is especially useful when we have major gaps in data or knowledge, such as:

- Non-specific information on historic releases
- Limited concentration data and a lack of longitudinal data

From Source to Risks – A One Health Paradigm

Source

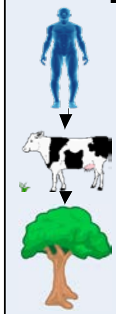
Media
- Air
- Groundwater
- Surface Water
- Sediment
- Soil

Food Chain
- Farm
- Terrestrial
- Aquatic

Release Processes
volatilization,
leaching,
runoff & erosion

Food Concentrations
produce, animal feed, animal products, prey items

Exposures and Risk



Human

Animal

Environmental Health

Interactions

✓ ***Human–Environmental health***
- –Drinking water, produce, air, and soil health

✓ ***Human–Animal health***
- –Consumption of animal products (beef, milk) & fish

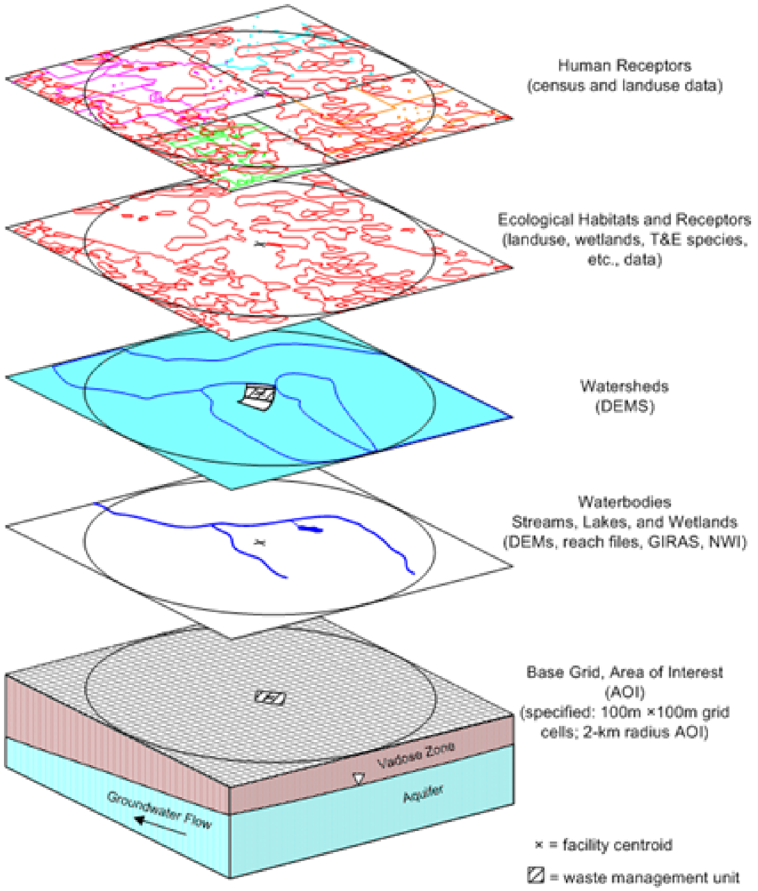
✓ ***Environmental–Animal health***
- –Cattle grazing on fields

Historical Reconstruction of PFAS Contamination in Drinking Water

We use available information and data on current or historic releases, develop a conceptual model, and simulate fate and transport under varying conditions to provide probabilistic estimates of PFAS concentrations in drinking water.

Conceptual Site Model

The CSM is the **foundation for reconstructing** the most likely historical movement of PFAS through the environment and estimating the **magnitude** and **timing** of PFAS concentrations ingested by receptors in the previous ~20 years.



Under 3MRA, RTI pioneered the use of geographic information systems data sources to parameterize environmental models.

The Environmental Setting

- ✓ Historical and current sources
- ✓ Water-intake specific characteristics
- ✓ Concentration data
- ✓ Watershed and surface water characteristics
- ✓ Soil Lithology
- ✓ Meteorological Data

Document Collection and Records Review: Known, Suspected, or Potential PFAS Sources in the Cape Fear Watershed of NC

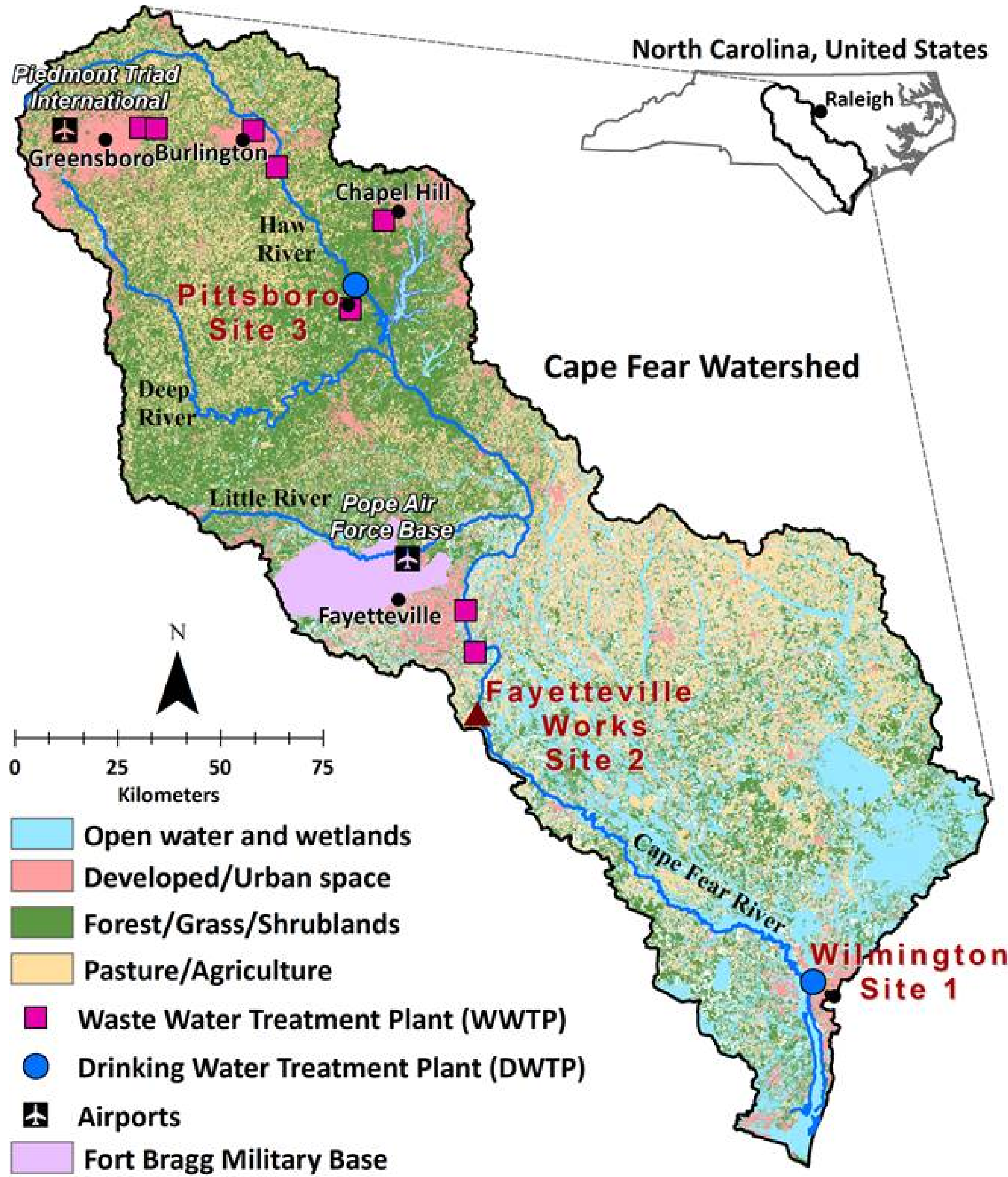
Location	Industrial	Municipal Wastewater Discharge	Aqueous Film Forming Foam (AFFF) Use	Agricultural (Biosolids)
Site 1 - Wilmington	DAK Americas, Smithfield Plant	Yes	Firefighting/ training	Yes
Site 2 - Private Well Community	Fayetteville Works	Yes	1) Greensboro Airport 2) Fort Bragg 3) Pope Air Force Base 4) Firefighting/ training	Yes
Site 3 - Pittsboro	Former/ current textile industry	Yes	Firefighting/ training	Yes

PFAS Concentration Data in the Cape Fear Watershed

Location	Surface Water	Public Water Supply	Groundwater
Site 1 – Wilmington public water supply users	Cape Fear River Lock and Dam #1*, Sweeney DWTP intake: 2006: 1 EPA sample 6/14/13–10/13/13 (34 samples) 2014: 1 sample; 2015–2016: limited data June 2017-present: frequent data	2014: 1 sample; 2015–2016: limited data June 2017-present: frequent data	Richardson DWTP public water supply wells 2017–present: Limited finished tap water data 2019 data untreated wells
Site 2 – Private Wells surrounding plant	N/A	N/A	2017–present: ~1,000 private wells (DEQ, NC State)
Site 3 – Pittsboro public water supply users	DWTP intake at Haw River Bynum, 2006: 1 EPA sample 6/22/13–11/19/13 (almost daily), 2018/19: limited data	2018-present: limited data	N/A

Conceptual Watershed Model of the Cape Fear River Basin

Known, suspected, or potential historical or current PFAS sources and communities affected identified

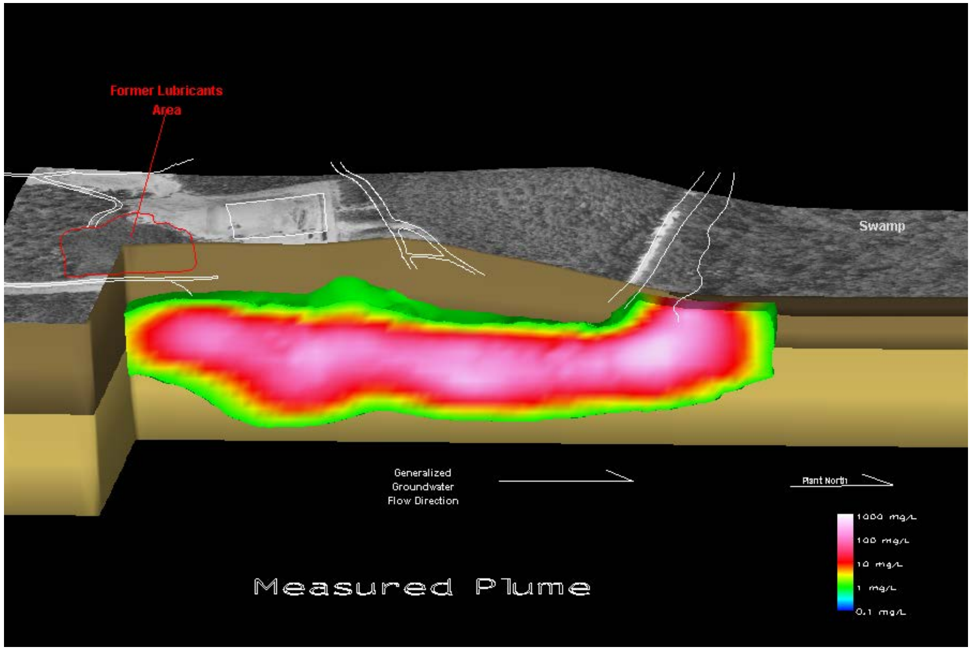


PFAS-Specific Modeling Approach for NC

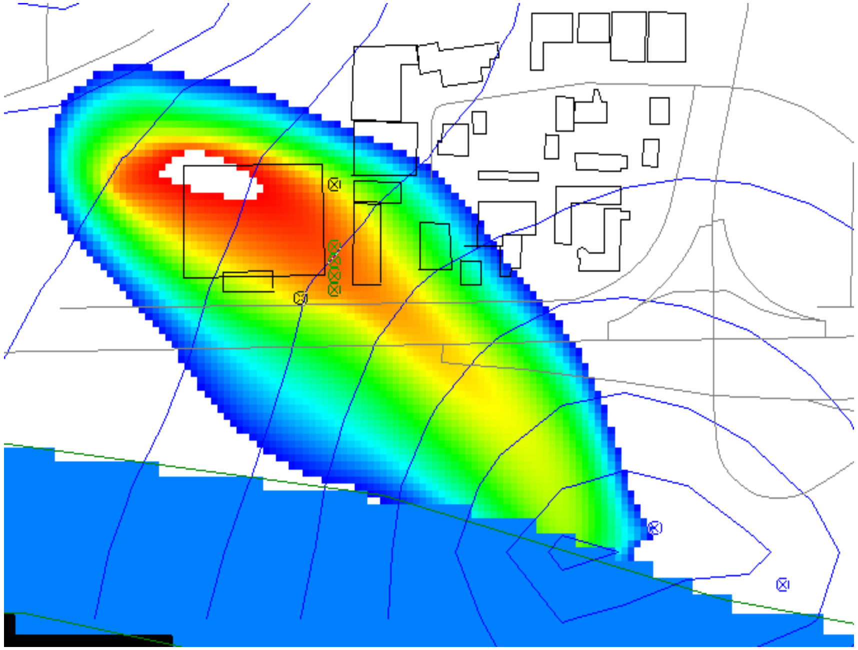
	Modeling Approach				Model Outputs
	Overland Flow	GW-SW Interaction	Air Deposition	Soil to Groundwater	
Pittsboro	Simple Mixing Model	--	--	--	In river concentrations at drinking water intake for Haw River
Fayetteville	Hydrologic modeling for Haw River, Deep River, and Little River confluence into Cape Fear River	Evaluate wells next to Cape Fear River	Air deposition to soil	Soil to groundwater, Groundwater to well	Air deposition mass/ concentrations; Vadose zone mass/ concentrations; Groundwater mass/ concentrations
Wilmington	Use Fayetteville Results and add additional downgradient point and non-point sources	--	--	--	Results of upstream hydrologic modeling plus additional modeling

Model Outputs

- Probabilistic estimates of drinking water concentrations over time across geographic locations based on varying conditions, data inputs, and assumptions
- This approach makes it possible to isolate and address uncertainty in key model inputs and PFAS sources.



Example of fate and transport of a contaminant plume.



A depiction of hydrogeological modeling predicting historical migration of PFAS in groundwater.

Where to go from here?

1) **How can we use available data and information** to most accurately reconstruct the historical fate and transport of PFAS compounds?

2) What **new data, information, or approaches** do we need **to improve modeling estimates**?

3) **What combined role should laboratory studies, field studies, and modeling studies have** in characterizing historical PFAS contamination?

4) What do we need to accurately estimate **current and future PFAS fate and transport into drinking water**?

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