Quantifying the Influence of Onsite Wastewater Nutrient Inputs to Falls Lake, NC

An Update to the North Carolina Department of Environment Quality Nutrient Scientific Advisory Board

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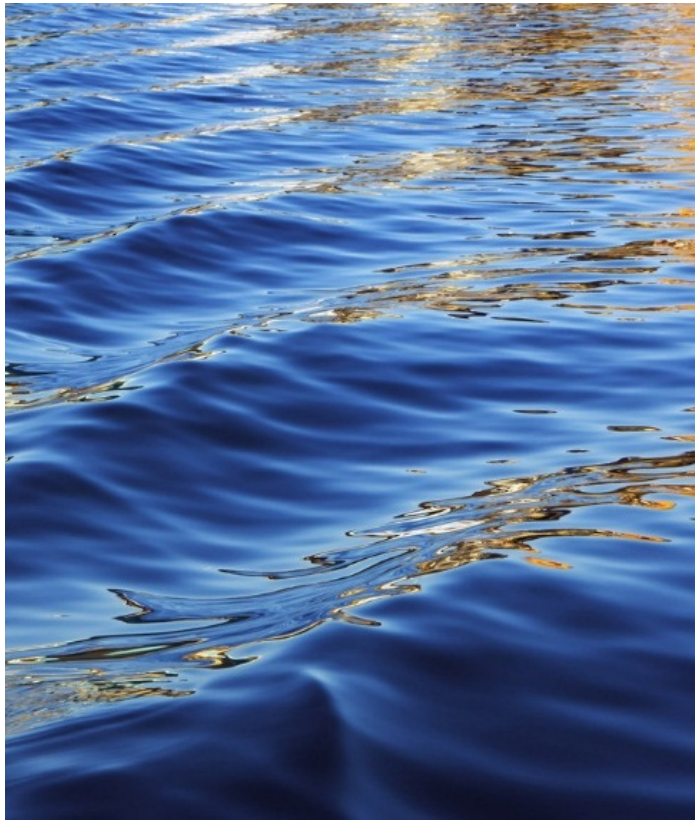
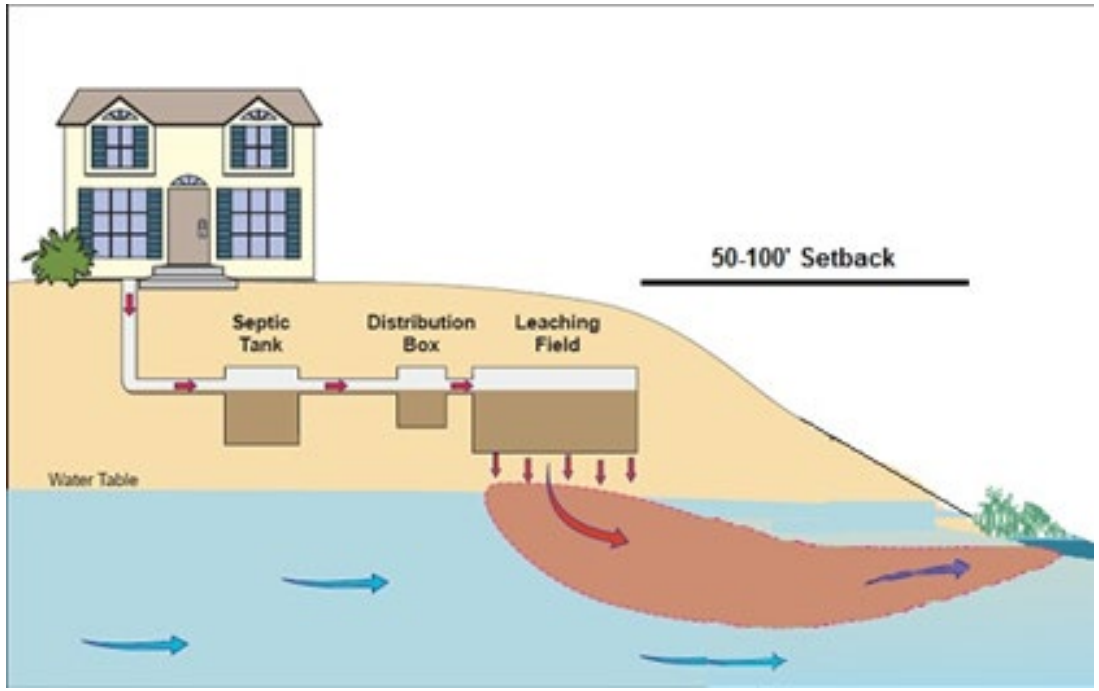


Outline

- Research Questions:
  - Do onsite wastewater treatment systems (septic systems) contribute nutrients to Falls Lake?
  - If so how much?
  - What factors play a role?
- Recent and Ongoing Studies
  - NC Policy Collaboratory 2019-2020 Study
  - NC Policy Collaboratory 2020-2021 Study
  - NC DEQ 319 Study
- Future Work

Research Questions

- Do onsite wastewater treatment systems contribute nutrients to Falls Lake?
  - Yes! … or they have potential to
- If so, how much?
  - Highly variable, nitrogen tends to be more variable than phosphorus
- What factors play a role?
  - Septic system density
  - Soil type
  - Water use
  - Depth to water table
  - Distance to creek
  - Condition of riparian buffer
  - Age and presence of a biomat
  - System type & functionality, etc.

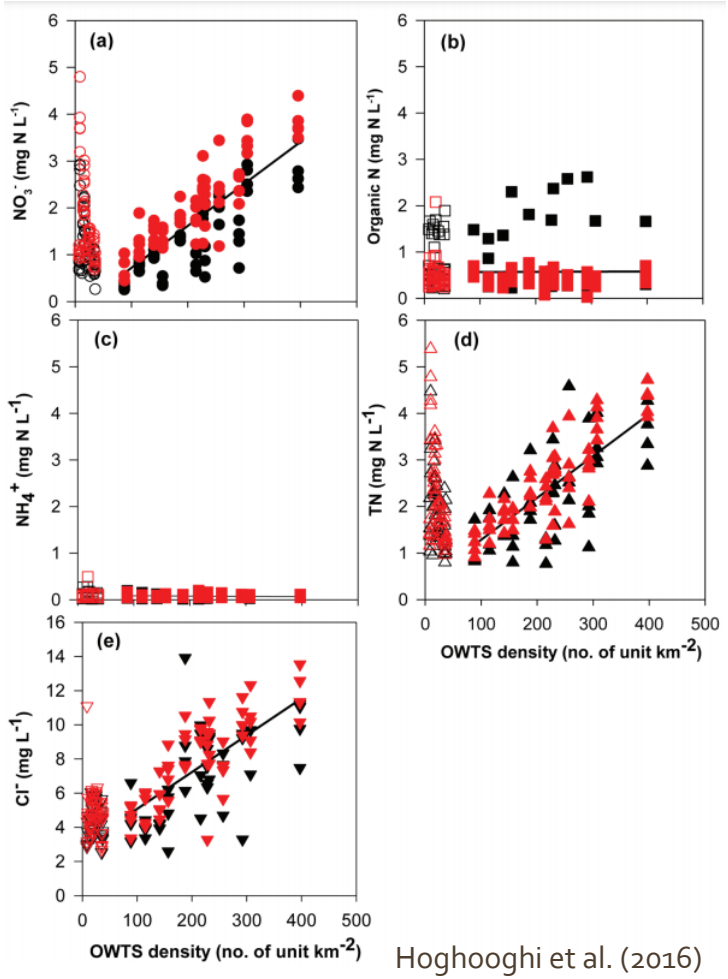


- Groundwater beneath DF (Piedmont)
  - TDN → 3.45 – 3.66 mg/L
  - PO_4-P → 0.006 – 0.061 mg/L
- Groundwater adjacent to stream (Piedmont)
  - TDN → 0.3 – 2.60 mg/L
  - PO_4-P → 0.009 – 0.029 mg/L

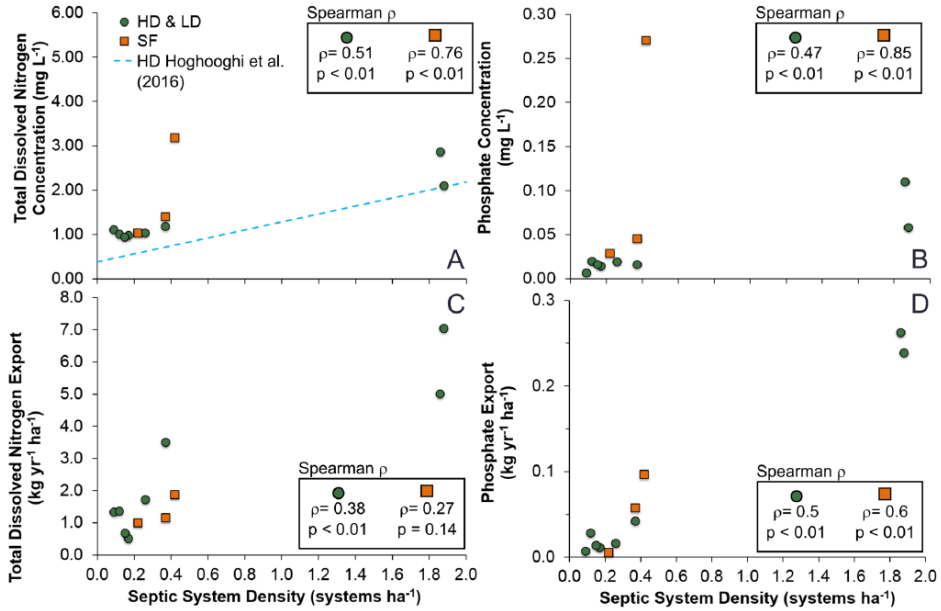
(EPA 2002; McCray et al. 2005, 2009; Karathanasis et al. 2006; Lowe et al. 2009; Bradshaw & Radcliffe, 2013; Hazen & Sawyer 2013; D'Amato et al. 2016; Humphrey et al. 2016a, 2016b; Iverson et al. 2018)

Watershed Scale Impacts

- Nutrient concentrations
  - TN → 0.1 – 13.9 mg/L
  - PO_4-P → < 0.01 – 0.54 mg/L
- Nutrient exports
  - TN → 1.8 – 14.4 kg/yr/ha
  - PO_4-P → <0.01 – 0.14 kg/yr/ha
- Septic system density → a good watershed scale indicator?
- Watersheds with septic system densities > 1 system/ha as a threshold?



Hoghooghi et al. (2016)



Iverson et al. (2018)

(Groffman et al. 2004; Shields et al. 2008; NC DENR 2009; Line 2013; Ferrell and Grimes 2014; Iverson et al. 2018; Hoghooghi et al. 2016)

Recent and Ongoing Work

- NC Policy Collaboratory 2019-2020 Study
  - Evaluated 3 sewered and 10 septic sub-watersheds and performed Piedmont watershed literature review to evaluate onsite wastewater nutrient inputs in Falls Lake watershed
- NC Policy Collaboratory 2020-2021 Study
  - Evaluating 30 septic sub-watersheds and the potential for in-stream bioreactors to reduce nutrient loads
- NC DEQ (319) – Falls Lake Onsite Wastewater Nutrient Study (2020-2021)
  - Selected 28 sites (6 sewered; 22 septic sub-watersheds) for broader analysis of potential onsite wastewater nutrient inputs
  - Sampling has been ongoing since Sept. 2020 (monthly)- continue until Sept. 2021

NC Policy Collaboratory 2019- Study Objectives

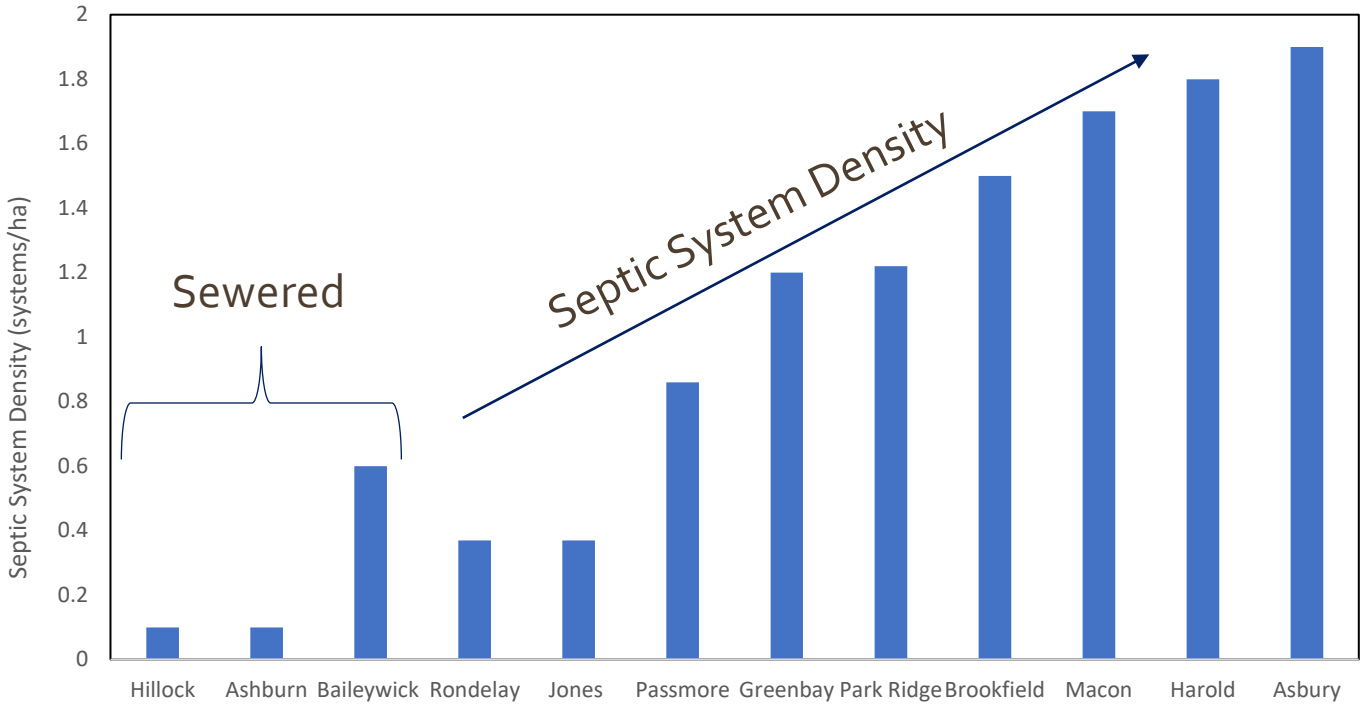
Summarize nutrient concentrations, discharge volume, and loading data for a recent study of tributaries of Falls Lake.

Develop a suggested monitoring plan and collect surface water quality data to evaluate the influence of onsite wastewater systems on nutrient concentrations and loading to Falls Lake.

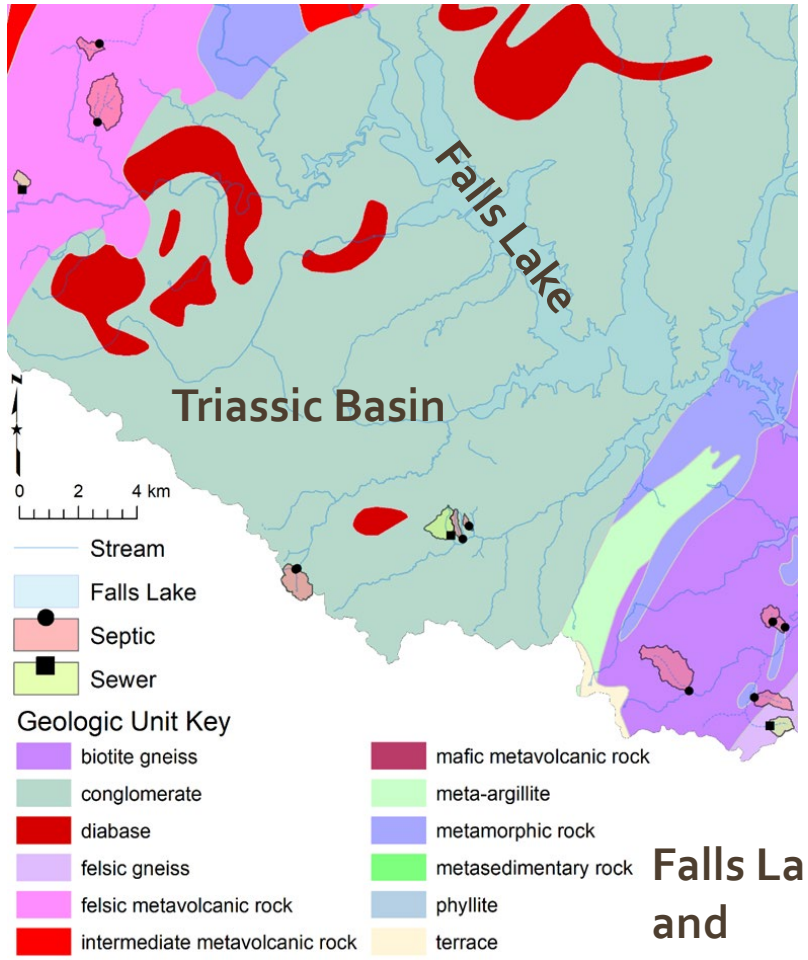
Conduct a literature review on nutrient treatment by conventional and sand filter-septic systems. Utilize these and current study data to develop onsite wastewater nutrient attenuation factors for Falls Lake nutrient loading model.

Site Selection- Sub-Watersheds

- Sub-watersheds ranging from 8.5-152 ha (21-376 acres)
- 12 sub-watersheds and one ditch draining an area with sand filters
- 9 sub-watersheds predominantly on septic systems, 3 predominantly sewered
- Sites clustered in Carolina Terrane, Triassic Basin, and Falls Lake/Crabtree Terrane Hydrogeologic Settings

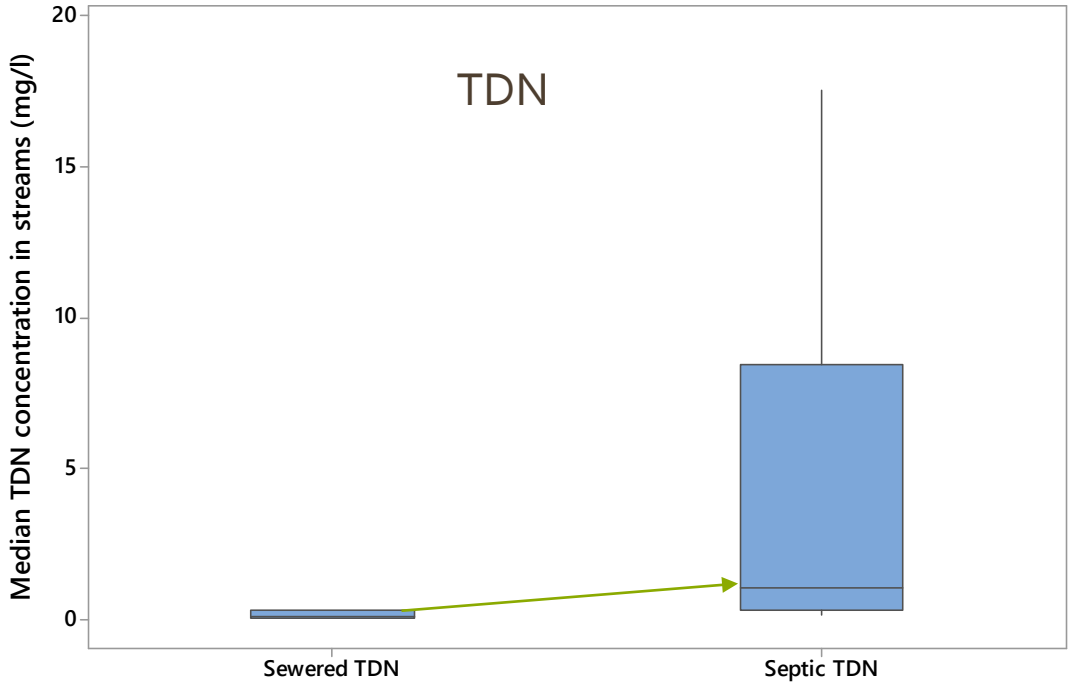


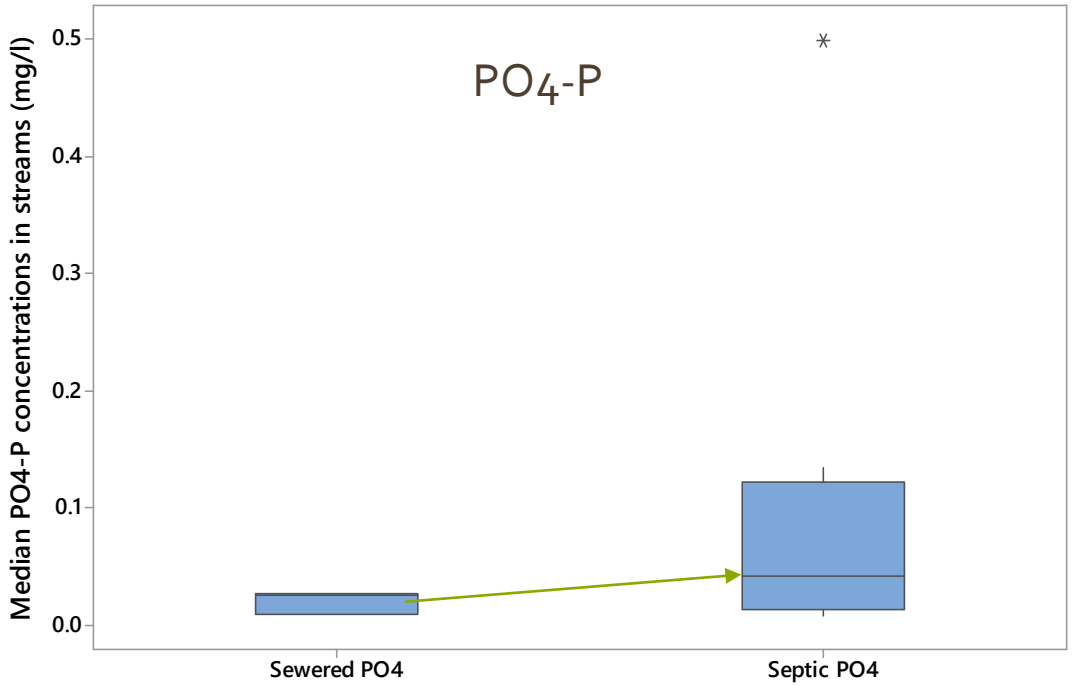
Carolina Terrane

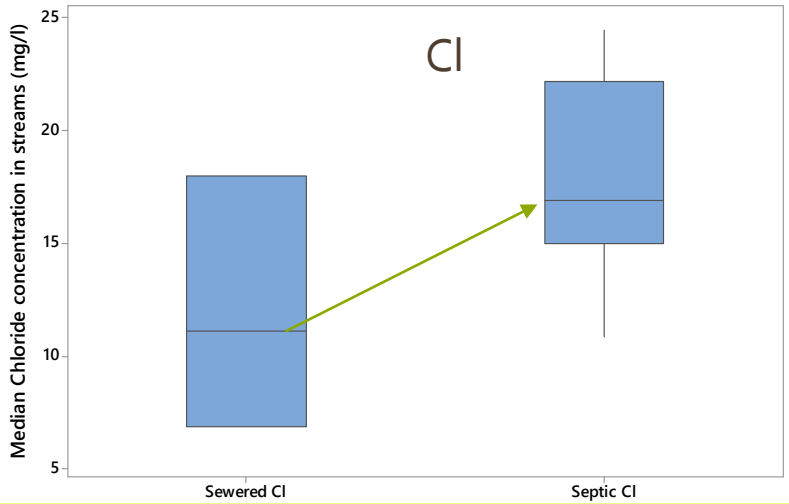


Falls Lake and Crabtree Terrane

Preliminary Results (Nov., Dec. 2019 and Feb. 2020 stream sampling)



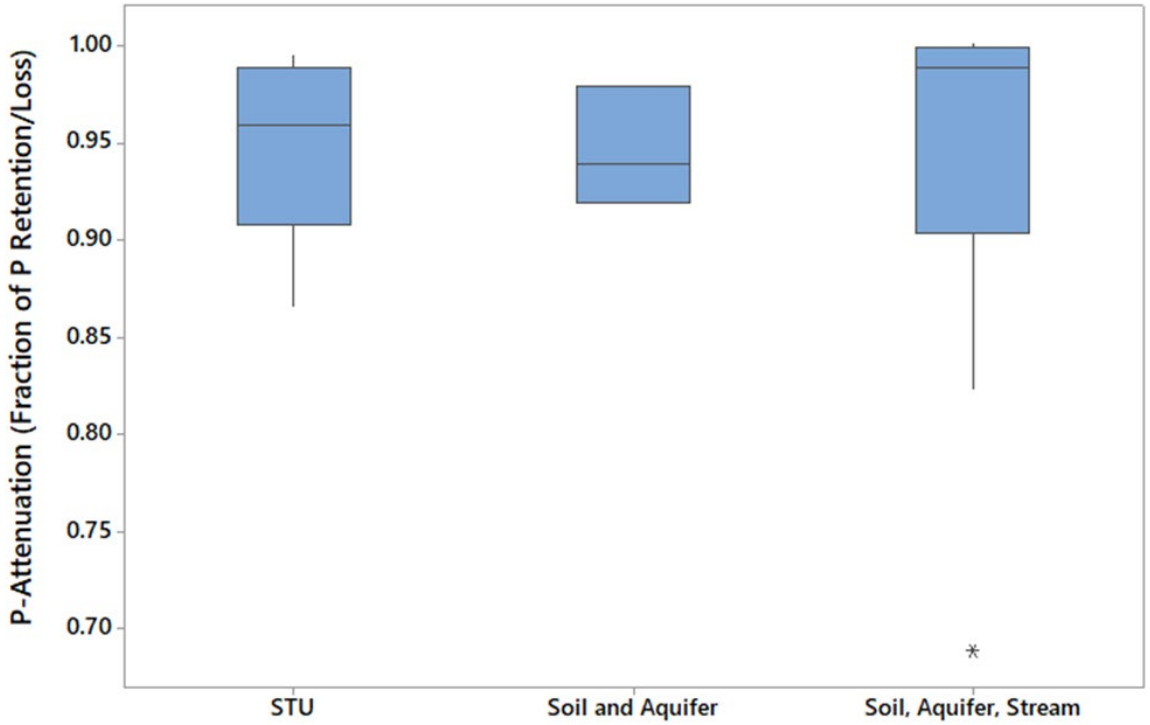


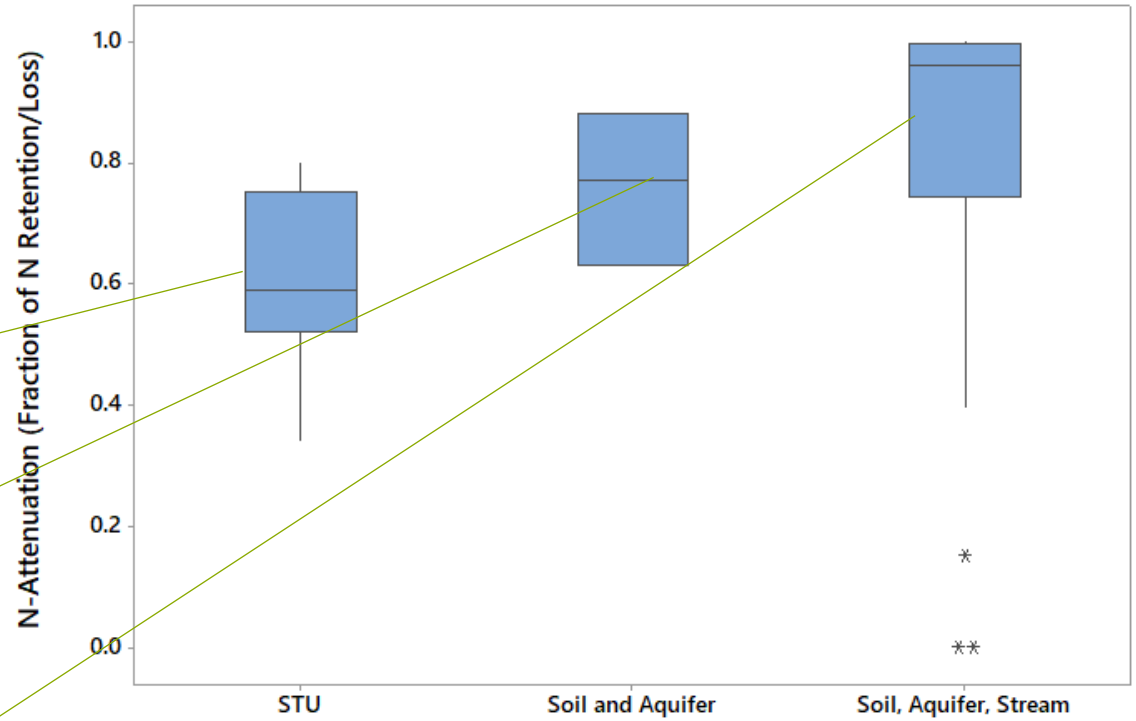


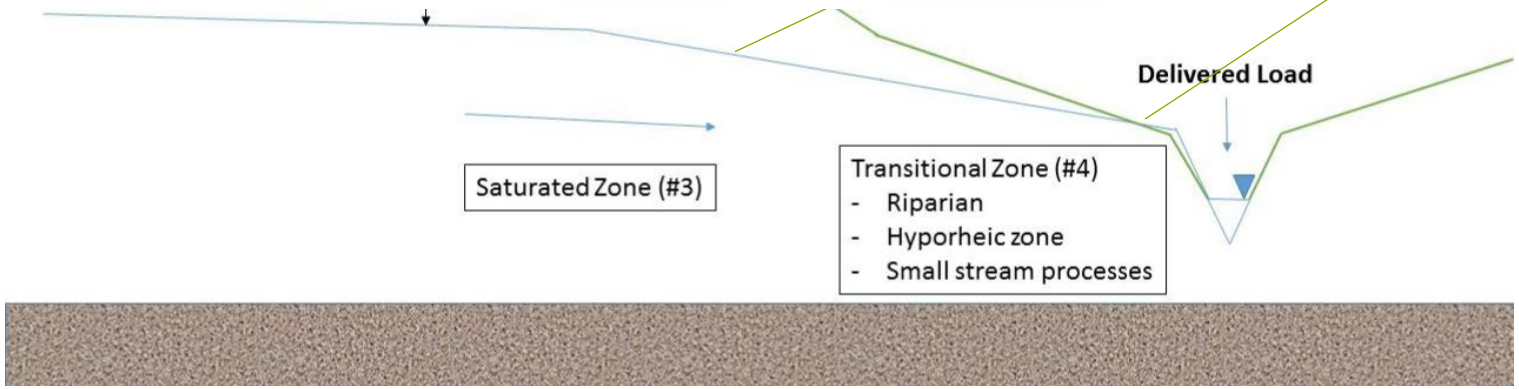
Nutrient and chloride concentrations

> Median concentrations and range for septic sub-watersheds

Onsite Wastewater Nutrient Attenuation in Piedmont Settings







N-attenuation factors estimated from literature on Piedmont soils and surficial aquifer data. Attenuation between the tank and stream (soil, aquifer, stream attenuation) is based on the surface water data collected during the Collaboratory study and previously collected surface water data. Data and references are found in **Table 3 in** O'Driscoll et al. 2020.

Estimates from McCray et al. 2009, Bradshaw and Radcliffe 2013, D'Amato et al. 2016, Humphrey et al. 2016, and Iverson et al. 2018.

Brief Overview of Collaboratory 2019-2020 Study Findings

Streams draining sub-watersheds that use onsite wastewater treatment systems (OWTS) were more likely to have elevated nutrient concentrations (especially nitrogen) relative to the 3 sewered watersheds studied.

Sub-watersheds with greater OWTS density (> 0.5 systems/ha) were more likely to have elevated nutrient concentrations in streams.

Estimates from prior research and from the current study suggest that attenuation of PO_4-P between conventional OWTS and streams was greater (>90%) than for N (>75%).

NC Policy Collaboratory 2020- Study Objectives

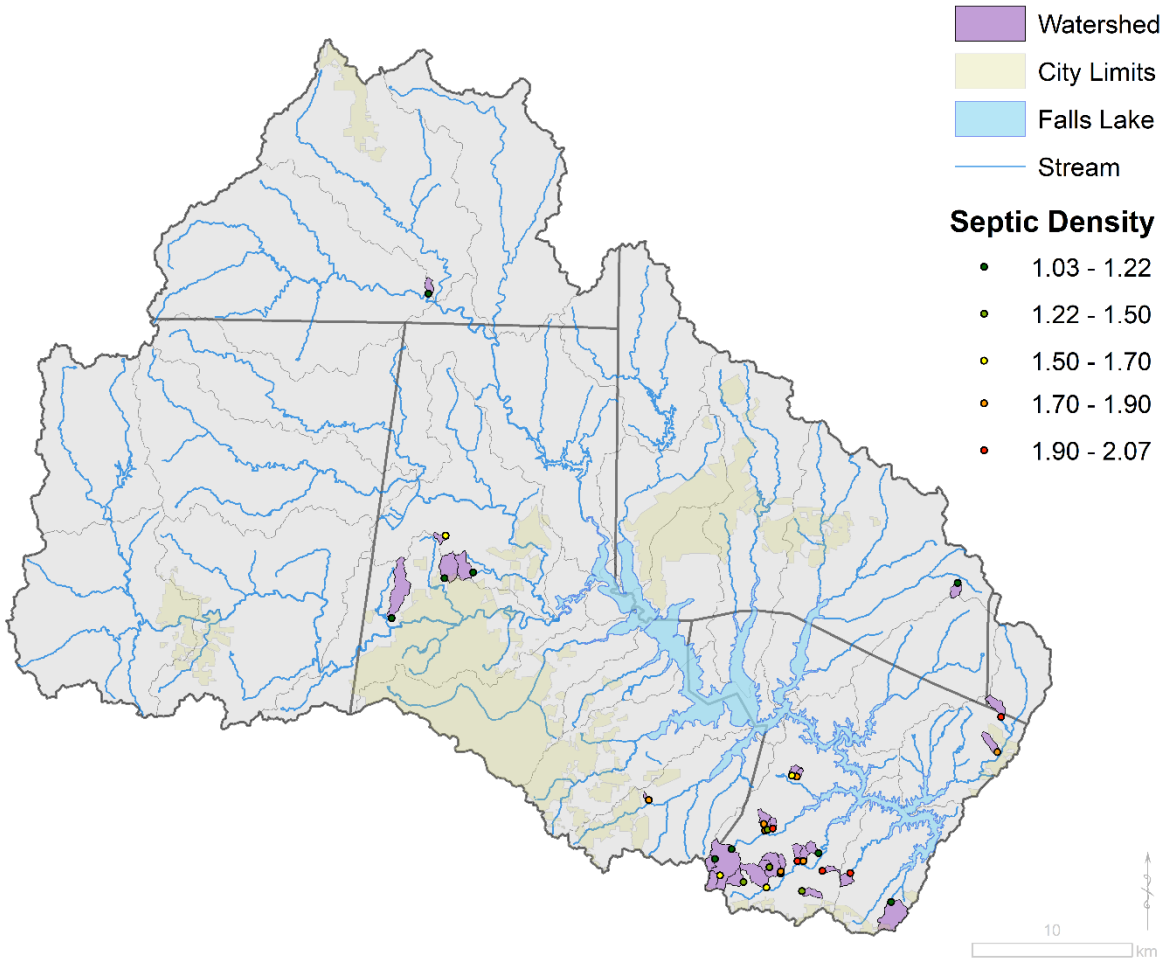
Investigate sub-watersheds of Falls Lake to determine which are most vulnerable to excess nutrient loading using septic system density as a potential predictor of elevated baseflow nutrient concentrations.

Conduct pilot-scale experiments to determine which porous media are most effective at reducing onsite nutrient transport

Identify optimal locations for bioreactors along low-order streams as a potential management strategy in watersheds with elevated baseflow nutrient concentrations

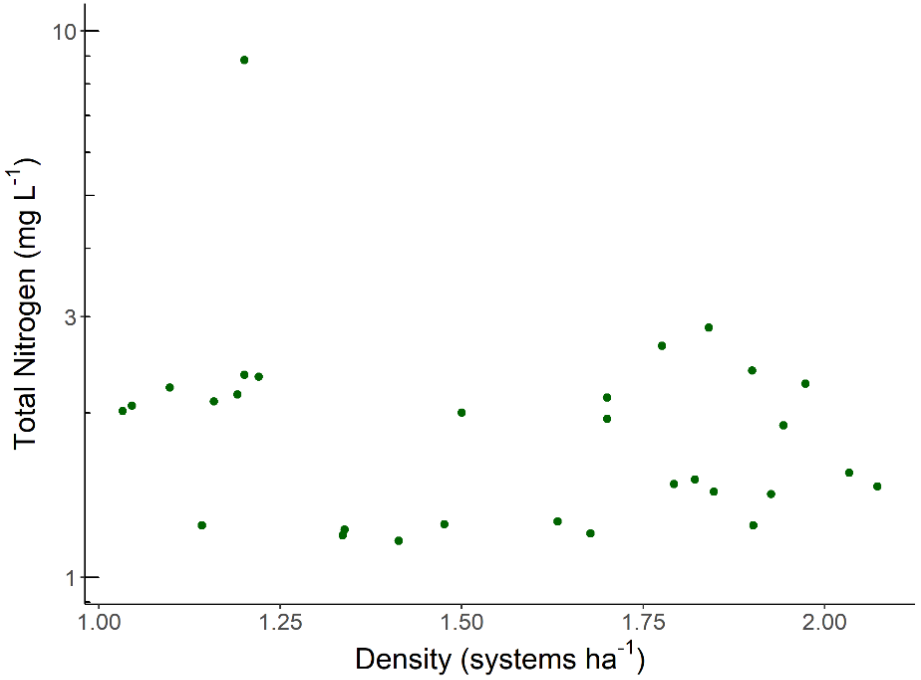
NC Policy Collaboratory 2020-2021 Study Watershed Monitoring

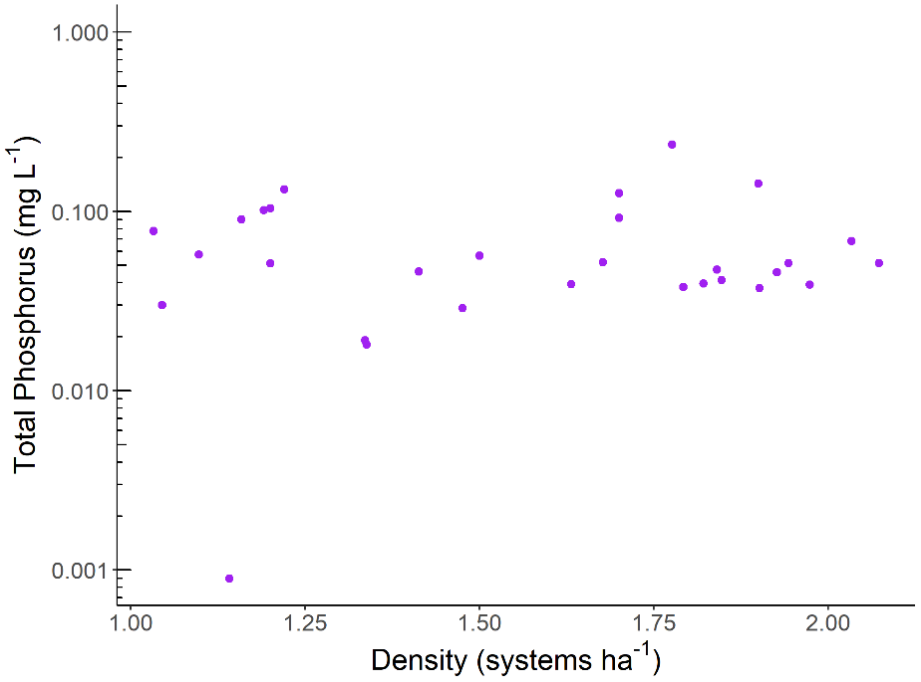
- 30 watersheds sampled from Wake, Durham, Franklin, Granville, and Person Counties
- Watershed area: 8.5 – 459 ha
- Septic system: ~ 14 – 479 systems
- Density: 1.0 – 2.1 systems ha^{-1}
  - Median: 1.7 systems ha^{-1}
- Soil and geology maps work in progress, but are similar to past Collaboratory project – more focus on the Wake County area based on density estimates



Preliminary Results – Dec 2020 (TN & TP)

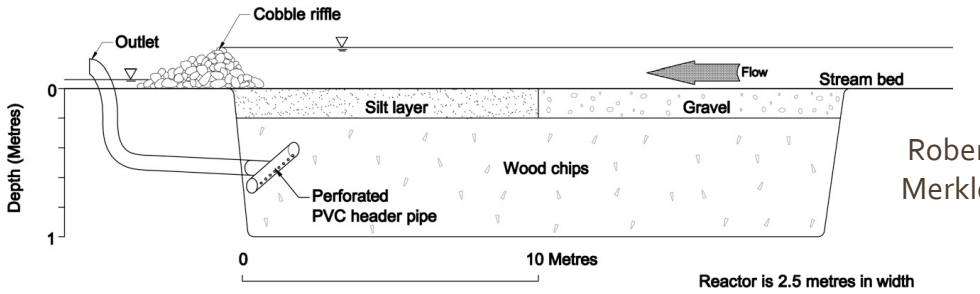
- Median nutrient concentrations were elevated across all watersheds with densities > 1 system ha^{-1}
  - Additional considerations: land use analysis, presence and condition of riparian buffer
    - Agriculture presence? Fertilizers?
- These sites fill in gaps from previous work in NC Piedmont based on density
- Limited temporal data (2 "wet" season sampling events)
- What management options are there?
  - The goal of these sampling efforts was to identify potential candidates for in-stream bioreactors
  - Nitrate-dominated watersheds the best candidates?



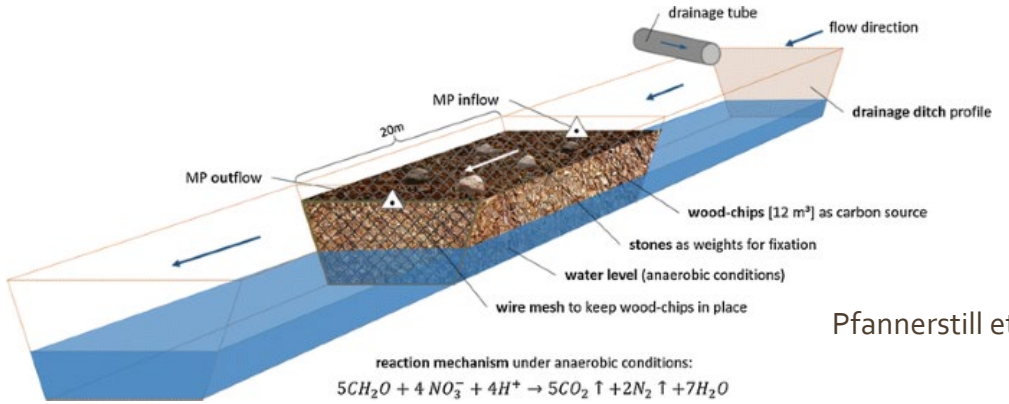


NC Policy Collaboratory 2020-2021 Study Bioreactor – Literature Highlights

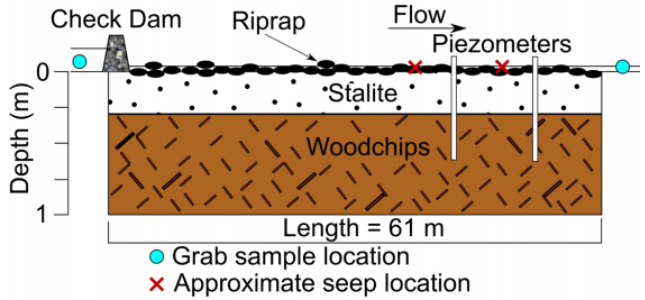
- Robertson and Merkley (2009): Mean influent NO_3-N of 4.8 mg/L was attenuated to 1.04 mg/L in an in-stream woodchip bioreactor (Canada)
- Pfannerstill et al. (2016): In-trench woodchip bioreactor reduced nitrate concentrations by 28% on average over two years (Germany)
- Iverson (2019): In-stream bioreactor containing woodchips and Stalite expanded slate aggregate achieved 78% nitrate and 74% phosphate annual median concentration reductions (Unnamed tributary to Lick Creek, NC)
  - These efforts were in the Falls Lake Watershed



Robertson and Merkley, 2009



Pfannerstill et al., 2016



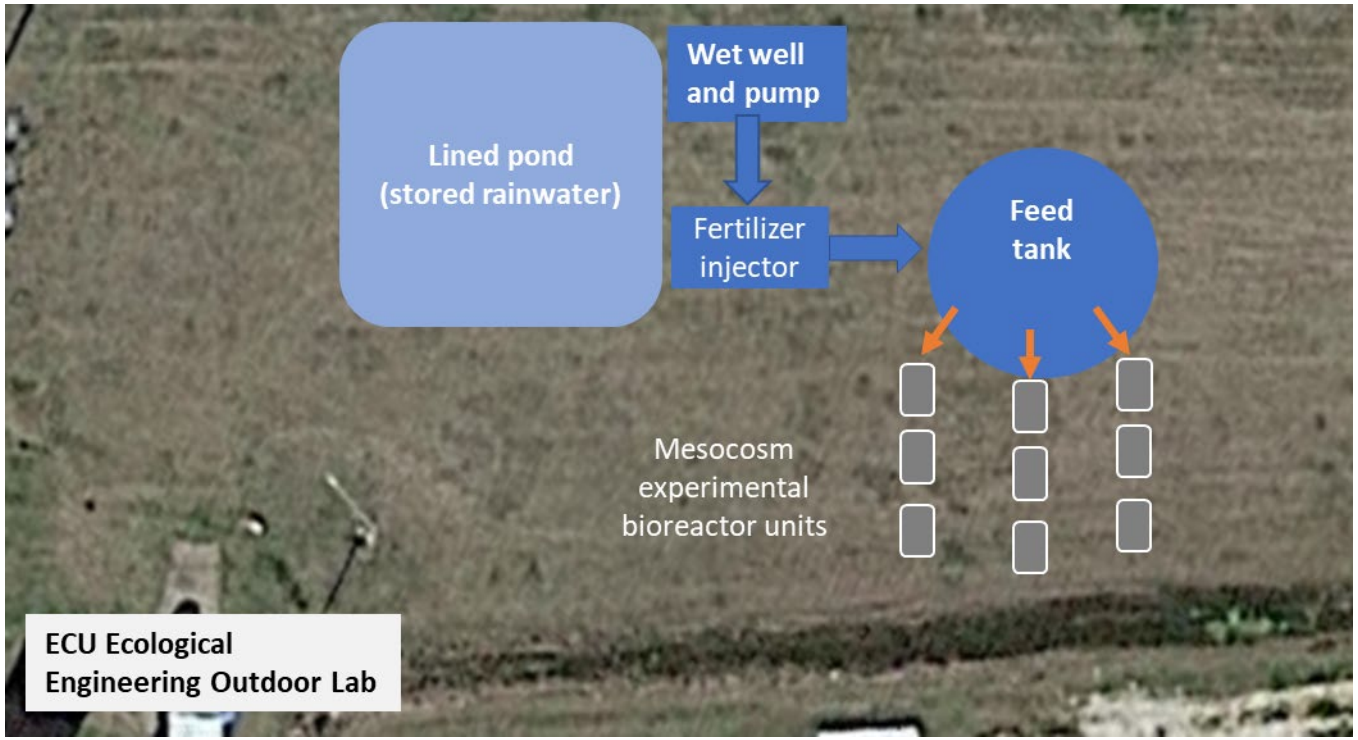
Iverson, 2019

NC Policy Collaboratory 2020-2021 Study – Mesocosm Study

- **Media types**
  - Denitrification:
    - Woodchips (3)
    - Pine bark nuggets (3)
    - Peanut shells (3)
  - Phosphate Sorption: Stalite expanded slate incorporated in all 9 experimental units

- **Analyses**
  - Dissolved organic carbon via Hach TNT810 Direct Method
  - Nitrate/nitrite, TKN, ammonium, phosphate, and TP via flow injection analysis
  - Continuous monitoring of effluent conductivity, temperature, pH, ORP, DO, fDOM, and turbidity via YSI EXO2 water quality sondes

- **Completed Tasks:**
  - Purchased materials and supplies
  - Trained graduate student on flow injection analytical techniques



- **Updated timeline**
  - March 2021: Complete construction and begin sample collection and analyses
  - September 2021: Conclude sample collection and analyses

A Paired-Watershed Approach to Evaluate the Influence of Onsite Wastewater Nutrient Inputs to Falls Lake, NC (NC DEQ-319 Grant: July 2020-21)

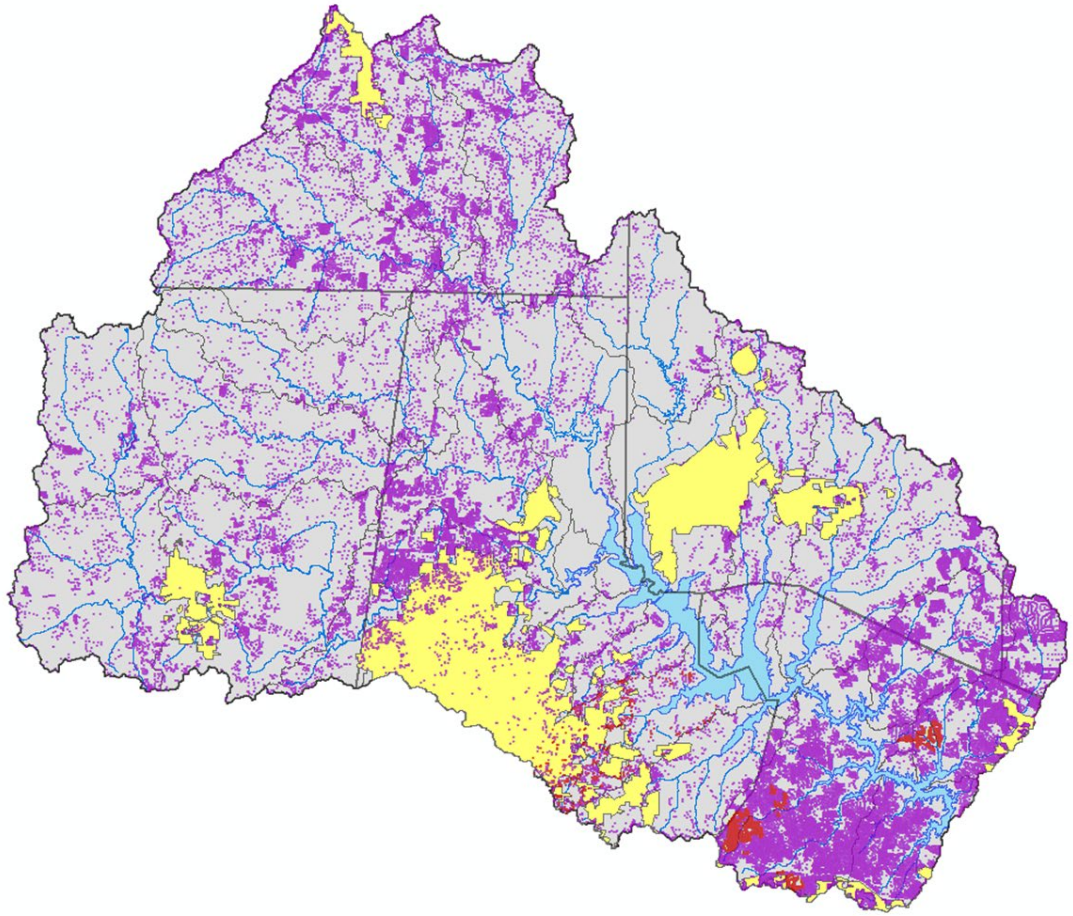
- This study will aim to quantify the influence of onsite wastewater inputs on nutrient loading to Falls Lake.

- Paired-watershed approach to evaluate onsite wastewater nutrient influence at the sub-watershed scale.

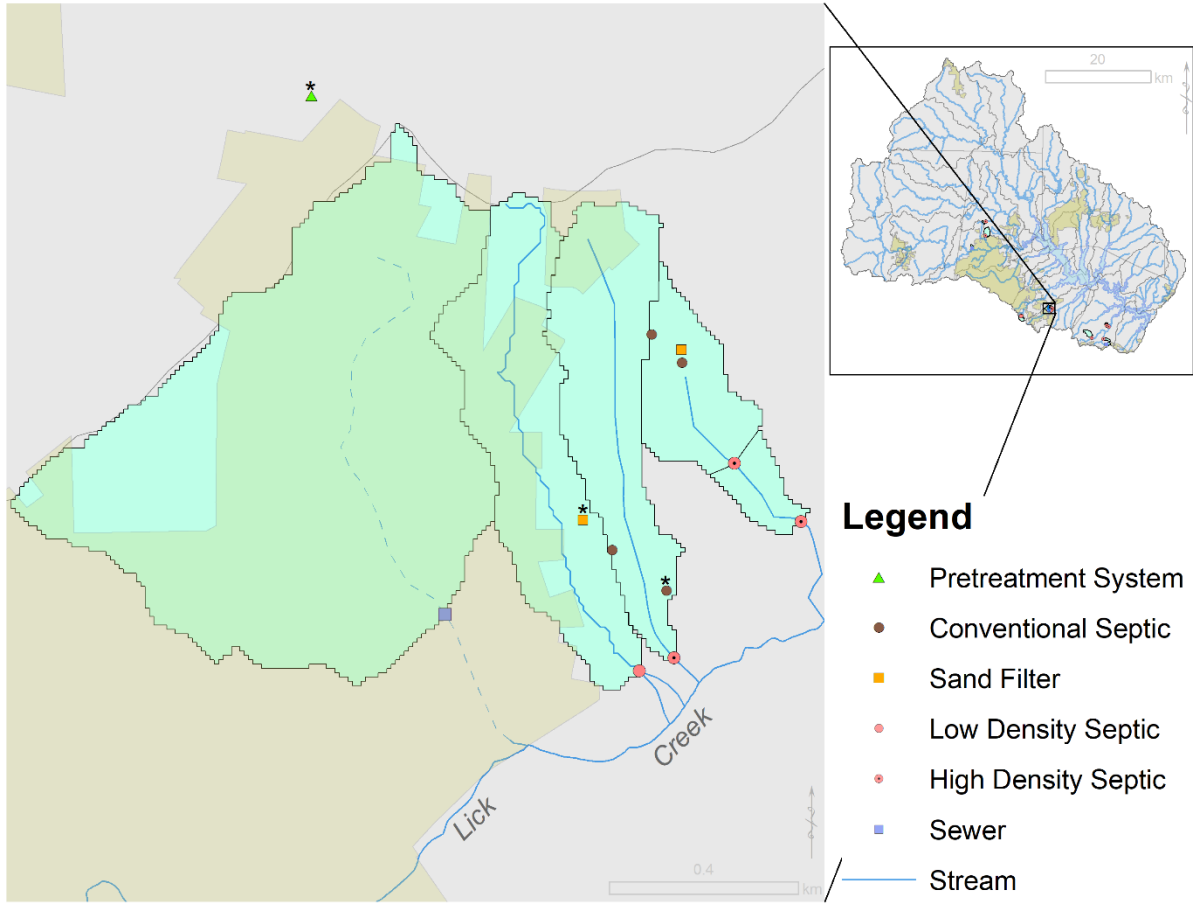
- Surface water quality sampling during baseflow conditions is being conducted monthly for 1 year

- Storm event sampling will be conducted to evaluate the influence of storm events .

Falls Lake Septic Systems (in purple)

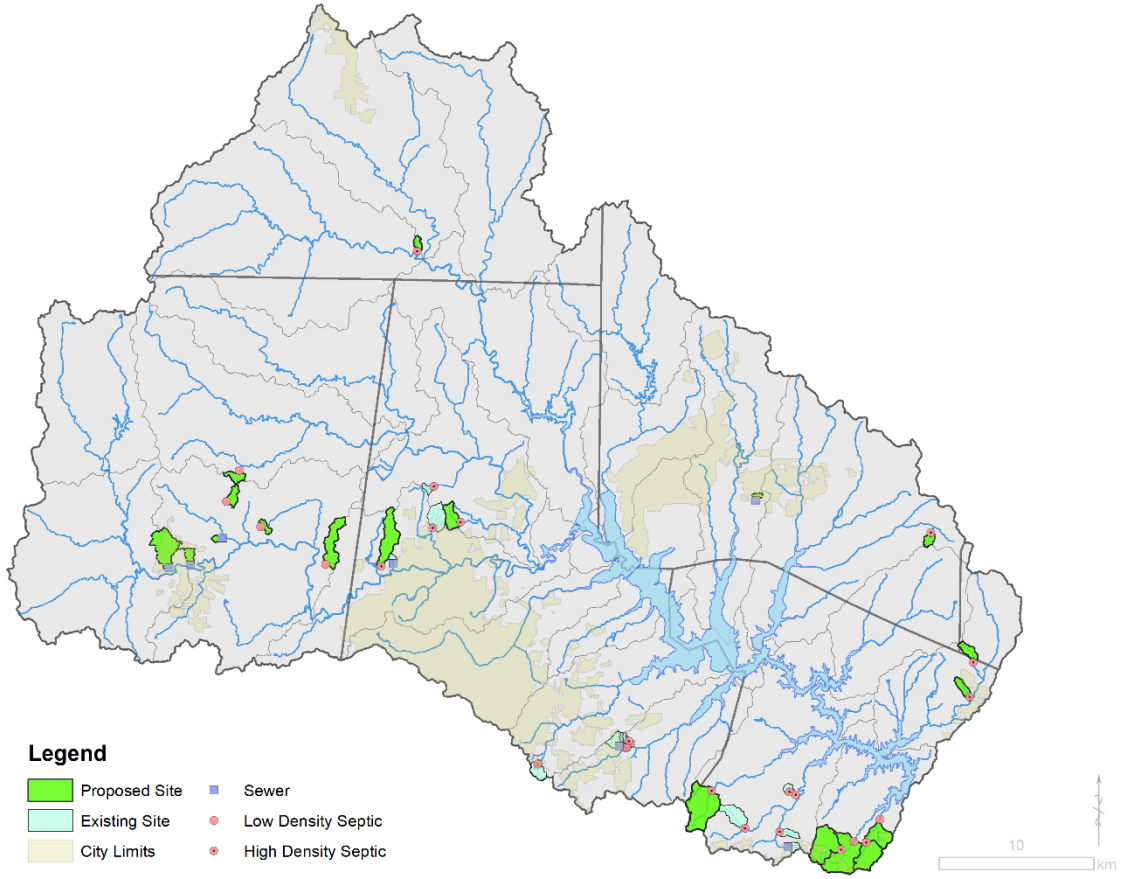


GW & SW Site Selection



- 5 onsite systems monitored (4 conventional, 1 sand filter)
- 2 conventional have drainfields < 3 yrs; other > 30 yrs
- Data help quantify onsite wastewater nutrient attenuation at the system and landscape-scales.

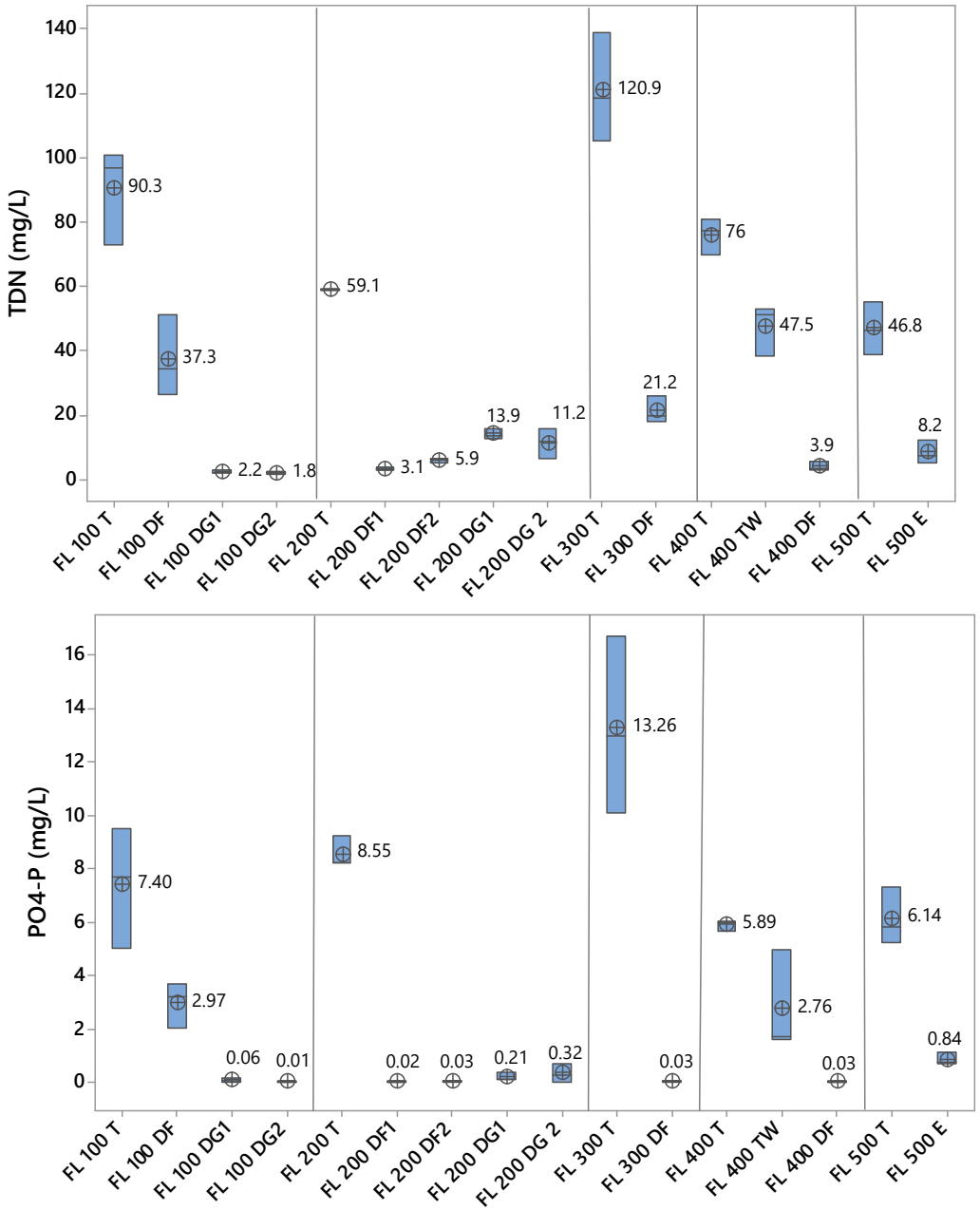
28 Watersheds Selected



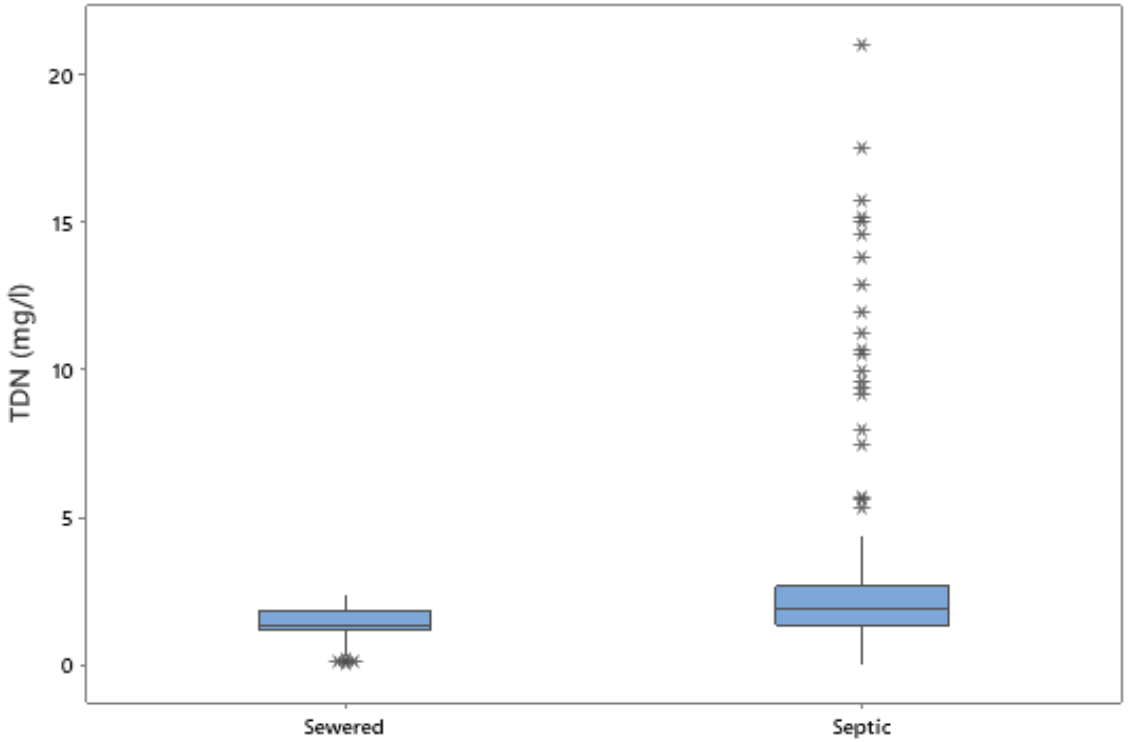
- 28 watersheds selected (22 septic, 6 sewered) based on WW and geology

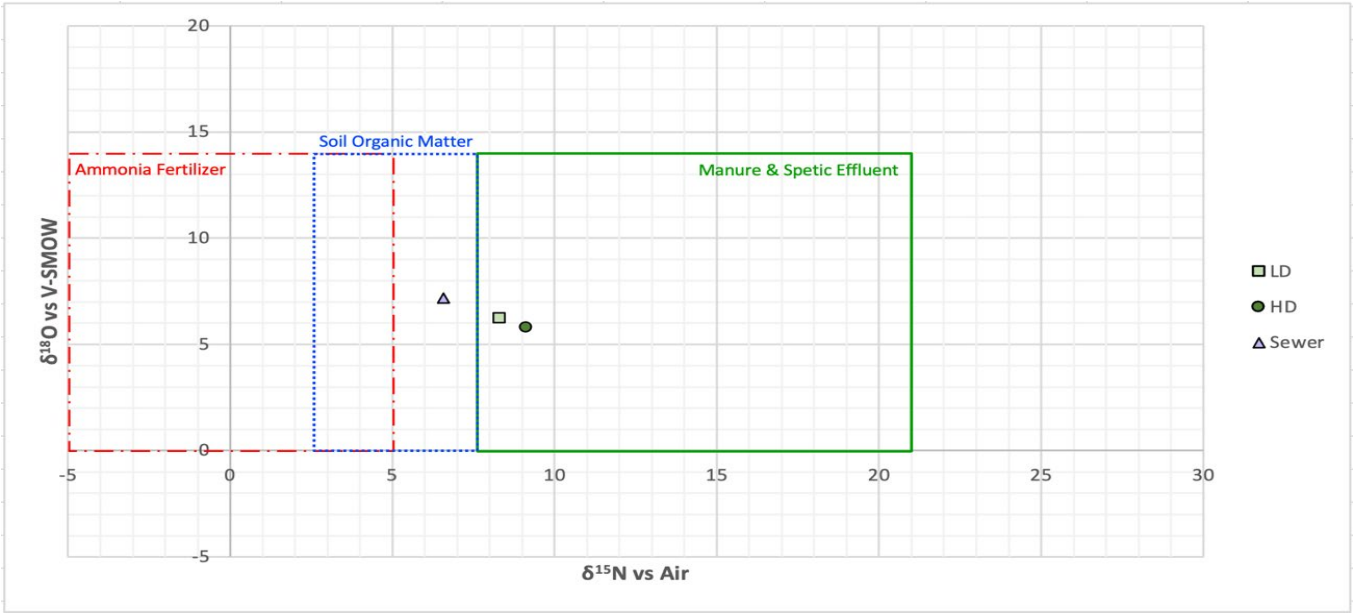
Preliminary Results – GW Study

- TDN concentration in GW near drainfields decreased by 59% - 95% compared to wastewater TDN in septic tanks
  - Site 100 showed even greater treatment reductions farther downgradient from the drainfield
- TDN concentration in sand filter effluent was 82% lower than wastewater TDN
- PO_4-P concentration in GW near drainfields were 59% - 99.8% lower than wastewater PO_4-P in septic tanks
- The sand filter system reduced PO_4-P by nearly 86%



SW- Preliminary Results





Median values for N-15 and O-18 in nitrate for high-density septic (HD), low-density septic (LD) and sewered sub-watersheds. This includes data from three sampling periods (February, June, and November 2020).

- Septic sub-watersheds had 0.57 mg/l greater median TDN (44% greater) relative to sewered
  - Based on first 5 months (Sept 2020-Jan 2021) and 2019-2020 data

- Average high-density (HD) and low-density (LD) septic watersheds → manure & septic effluent
- Average sewer watershed → soil organic matter

Future Plans

- Complete monthly sw sampling and site sampling by August 2021
- Evaluate land-use and septic system density influence on stream nutrient loading in the watershed
- Utilize results to help with the ongoing watershed nutrient modeling efforts
- Final DEQ report by Sept. 2021

- NC Policy Collaboratory Study
- Watershed mass load reductions and attenuation factors
- Evaluate potential for in-stream bioreactors to reduce nutrient exports at sites with elevated nutrient concentrations and exports

Questions?

- Thanks for your attention! If you have specific questions or inquiries, you can reach me at:

- Guy Iverson – iversong18@ecu.edu