ENVIRONMENTAL QUALITY OF WILMINGTON AND NEW HANOVER COUNTY WATERSHEDS, 2024

by

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Stream rehabilitation at Clear Run

Alligator at Greenfield Lake 2024

Sediment sampling Squash Branch

Algal bloom on Greenfield Lake 2024

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Executive Summary

This report represents results of Year 27 of the Wilmington Watersheds Project. Water quality data are collected by researchers from the University of North Carolina Wilmington's Center for Marine Sciences and are presented from a watershed perspective, regardless of political boundaries. The 2024 program involved 6 watersheds and 20 sampling stations. In this summary we first present brief water quality overviews for each watershed from data collected between January and December 2024. As part of a change in priorities, sampling at Howe, Motts and Whiskey Creek were suspended for the time being to emphasize upper Bradley Creek and the Greenfield Lake watershed, both of which are undergoing restoration measures; also two sites in Barnards Creek upstream in Carriage Hills are currently being sampled. Note that several months in summer and early fall were not sampled due to late receipt of funds from the City. From funding sourced by the City of Wilmington partial dredging of nutrient polluted sediments (30%) in Squash Branch was achieved in 2024.

<u>Barnards Creek</u> – Barnards Creek drains into the Cape Fear River Estuary. It drains a 4,173 acre watershed that consists of 22.3% impervious surface coverage, and a human population of approximately 12,200. In 2024 five samples were collected at two upper creek sites near Carriage Hills close to a wet detention pond (CHP-U and CHP-D). Turbidity was low, dissolved oxygen was fair, but both stations suffered from high fecal coliform counts. One major algal bloom occurred at CHP-D.

<u>Bradley Creek</u> – Bradley Creek drains a watershed of 4,583 acres, including much of the UNCW campus, into the Atlantic Intracoastal Waterway (AICW – Plate 1). The watershed contains about 27.8% impervious surface coverage, with a population of about 16,470. The uppermost site, BC-RD, is on upper Clear Run at Racine Dr., and subsequently drains downstream to BC-CA, Clear Run at College Acres. Below that is a new station, BC-MS, located at Mallard St. downstream of where Clear Run passes through the forest behind UNCW. The two lower sites currently sampled are BC-NB, Bradley Creek north branch at Wrightsville Ave., and BC-SB, Bradley Creek south branch at Wrightsville Ave. All five sites were sampled five times in 2024. Note that extensive stream rehabilitation work between College Acres and Mallard has wrapped up, while other rehabilitation work is ongoing at the headwaters of Clear Run above Station BC-RD.

High turbidity and suspended solids in 2024 were not problematic. Dissolved oxygen was likewise in Good to Fair condition at all sites. Nutrients were elevated in upper Clear Run compared with the other sites on Wrightsville Avenue. Two large algal blooms occurred in upper Clear Run in October. Fecal coliform bacteria counts were moderate at BC-NB but excessive at BC-RD, BC-CA and BC-MS, which had geometric mean counts exceeding the NC standard for safe waters of 200 CFU/100 mL.

<u>Burnt Mill Creek</u> – Burnt Mill Creek drains a 4,207 acre watershed with a population of about 23,700. Its watershed is extensively urbanized (39.8% impervious surface coverage) and drains into Smith Creek. Two locations were sampled during 2024, on

five occasions at both BMC-AP3 and BMC-PP. Fecal coliform conditions were rated Poor at the lowermost station BMC-PP at Princess Place and Good at the upper site BMC-AP3 below Anne McCrary Pond, the regional wet detention pond on Randall Parkway. Dissolved oxygen concentrations were Good at AP-3 and Fair at BMC-PP.

An algal bloom occurred at AP3 and two blooms occurred at BMC-PP in 2024. Several water quality parameters showed an increase in pollutant levels along the creek from the outfall from the detention pond to the downstream Princess Place sampling station, including fecal coliform bacteria, nitrogen, and phosphorus, indicating non-point pollution sources continue to pollute the lower creek.

<u>Futch Creek</u> – Futch Creek is situated on the New Hanover-Pender County line and drains a 3,813 acre watershed (12.3% impervious coverage) into the ICW. UNC Wilmington was not funded to sample this creek in 2024. New Hanover County employed a consulting firm to sample this creek and data may be requested from the County.

<u>Greenfield Lake</u> – This lake drains a watershed of 2,465 acres, covered by about 37% impervious surface area with a population of about 10,630. In the past this urban lake has suffered from low dissolved oxygen, algal blooms, periodic fish kills and high fecal bacteria counts. The lake was sampled at four tributary stream sites and three in-lake sites on 9 occasions. Of the tributaries of Greenfield Lake, Squash Branch (GL-SQB, near Lake Branch Drive), Squash Branch at the footbridge over the lower channel near the main lake (SQB-BR), Jumping Run Branch at Lakeshore Dr (GL-JRB) and GL-SQB suffered from major low dissolved oxygen problems, GL-JRB had minor DO problems, and GL-2340 in the main lake had major low DO issues.

Algal blooms are chronically problematic in Greenfield Lake and have occurred during all seasons. In 2024 massive summer-fall blue-green algal blooms (cyanobacteria) continued to occur. Previously published studies found a statistically significant relationship within the lake between chlorophyll *a* and five-day biochemical oxygen demand (BOD5) meaning that the algal blooms are an important cause of low dissolved oxygen, and high BOD occurred congruent with the blooms in 2024. Coupled with the blooms, an illegal discharge from an upstream source (with hypoxic water and very high fecal bacteria counts, > 30,000 CFU/100 mL) entered the lake at GL-2340 in late May concurrent with a massive fish kill. In 2024 all three upper tributary stations exceeded the fecal coliform State standard on >55% of occasions sampled and rated Poor; the in-lake stations were in Good condition for fecal bacteria except for GL-2340, rated Poor.

Greenfield Lake is currently on the NC 303(d) list for impaired waters due to excessive algal blooms. The thesis work of former UNCW graduate student Nick Iraola assessed the five main inflowing tributaries to the lake to demonstrate that the largest inorganic nutrient loads came in from Jumping Run Branch and Squash Branch.

In spring-summer 2024 the City of Wilmington funded a partial (30%) dredging of Squash Branch to remove phosphorus-laden sediments from the channel that enters Greenfield Lake. UNCW performed enhanced water and sediment sampling to assess effects. There were temporary localized increases in turbidity and TSS, but the effects on chlorophyll *a* (algal blooms) were indistinguishable from normal. A pulse of water column P occurred during the early dredging period, possibly a result of dredging or P release from decomposing algal blooms. Fecal coliform bacteria counts did not increase downstream as a result of dredging. There were large decreases in sediment P in and outside of Squash Branch following dredging. However, a tropical storm dumped large amounts of rainfall on the area during the same period, so sediment flushing by the storm was also a likely flushing factor.

<u>Hewletts Creek</u> – Hewletts Creek drains a large (7,478 acre) watershed into the Atlantic Intracoastal Waterway. This watershed has about 25.1% impervious surface coverage with a population of about 20,210. In 2024 the creek was sampled at three tidal sites on five occasions.

Low dissolved oxygen was not a problem in Hewletts Creek in 2024. Turbidity was low and did not exceed the state standard, and no major algal blooms occurred. Fecal coliform bacteria counts were within standard at SB-PGR but excessive at MB-PGR and NB-GLR, where the standard was exceeded 3/5 sampling times each.

<u>Howe Creek</u> – Howe Creek drains a 3,516 acre watershed into the ICW. This watershed hosts a population of approximately 6,460 with about 21.4% impervious surface coverage. Due to resource re-allocation, sampling was suspended here in 2020 but is scheduled to start again in mid-2025.

<u>Motts Creek</u> – Motts Creek drains a watershed of 3,342 acres into the Cape Fear River Estuary with a population of about 9,530; impervious surface coverage 23.4%. Due to Covid-19 and resource re-allocation, sampling was suspended here in 2020.

<u>Pages Creek</u> – Pages Creek drains a 5,025 acre watershed with 17.8% impervious surface coverage into the ICW. UNC Wilmington was not funded to sample this creek from 2008-2024. New Hanover County employed a private firm to sample this creek and data may be requested from the County.

<u>Smith Creek</u> – Smith Creek drains into the lower Northeast Cape Fear River just upstream of where it merges with the Cape Fear River (Plate 1). It has a watershed of 16,650 acres that has about 21.3% impervious surface coverage, with a population of about 31,780. One estuarine site on Smith Creek, SC-CH, is normally sampled by UNCW under the auspices of the Lower Cape Fear River Program (LCFRP). In 2024, 12 samples were collected and DO, turbidity, chlorophyll *a* and fecal coliform bacteria were all rated Good by UNCW.

<u>Whiskey Creek</u> – Whiskey Creek is the southernmost large tidal creek in New Hanover County that drains into the Atlantic Intracoastal Waterway (ICW, Plate 1). It has a watershed of 2,078 acres, a population of about 8,000, and is covered by approximately 25.1% impervious surface area. Due to resource re-allocation, sampling was suspended here for 2024.

<u>Water Quality Station Ratings</u> – The UNC Wilmington Aquatic Ecology Laboratory utilizes a quantitative system with four parameters (dissolved oxygen, chlorophyll *a*,

turbidity, and fecal coliform bacteria) to rate water quality at our sampling sites. If a site exceeds the North Carolina water quality standard (see Appendix A) for a parameter less than 10% of the time sampled, it is rated Good; if it exceeds the standard 10-25% of the time it is rated Fair, and if it exceeds the standard > 25% of the time it is rated Poor for that parameter. We applied these numerical standards to the water bodies described in this report, based on 2024 data, and have designated each station as Good, Fair, and Poor accordingly (Appendix B).

Fecal coliform bacterial conditions for the entire Wilmington City and New Hanover County Watersheds system (20 sites sampled) showed 35% to be in Good condition, 0% in Fair condition and 65**%** in Poor condition. Dissolved oxygen conditions (measured at the surface) system-wide (20 sites) showed 60% of the sites were in Good condition, 25% were in Fair condition, and 15% were in Poor condition. For algal bloom presence, measured as chlorophyll *a*, 65% of the 20 stations sampled were rated as Good, 15% as Fair and 20% as Poor. For turbidity, 100% of sites were Good. It is important to note that the water bodies with the worst water quality in the system also have the most developed watersheds with the highest impervious surface coverage; Burnt Mill Creek – 39% impervious coverage; Greenfield Lake – 37% impervious coverage; Bradley Creek – 28% impervious coverage.

Table of Contents

1.0	Introduction	8
1.1	Methods	8
2.0	Barnards Creek	10
3.0	Bradley Creek	13
4.0	Burnt Mill Creek	16
5.0	Futch Creek	22
6.0	Greenfield Lake	24
7.0	Hewletts Creek	40
8.0	Howe Creek	43
9.0	Motts Creek	45
10.0	Pages Creek	47
11.0	Smith Creek	49
12.0	Whiskey Creek	52
13.0	Report References Cited	54
14.0	Acknowledgments	57
15.0	Appendix A: Selected N.C. water quality standards	58
16.0	Appendix B: UNCW Watershed Station Water Quality Ratings	59
17.0	Appendix C: GPS coordinates for the New Hanover County Tidal Creek and Wilmington Watersheds Program sampling stations	60
18.0	Appendix D. Sampling station subwatershed drainage area and percent impervious surface coverage, 2015	62
19.0	Appendix E. University of North Carolina at Wilmington reports and papers concerning water quality in Wilmington and New Hanover County’s freshwater and tidal creeks.	64

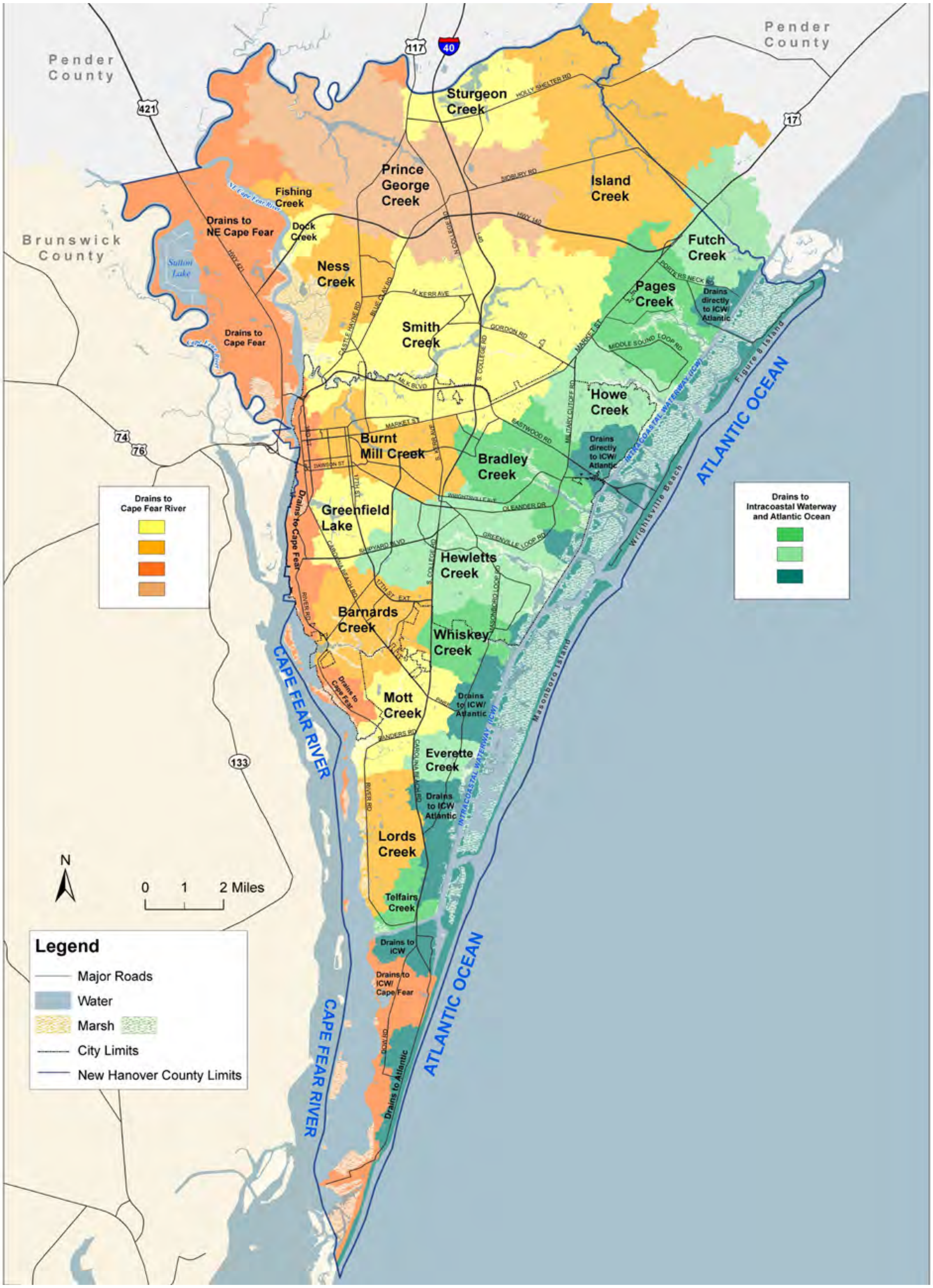


Plate 1. Wilmington and New Hanover County watersheds 2014 map by Wilmington Stormwater Services. Station coordinates are in Appendix C.

1.0 Introduction

In 1993 scientists from the Aquatic Ecology Laboratory at the UNC Wilmington Center for Marine Science Research began studying five tidal creeks in New Hanover County. This project, funded by New Hanover County, the Northeast New Hanover Conservancy, and UNCW, yielded a comprehensive report detailing important findings from 1993-1997, and produced a set of management recommendations for improving creek water quality (Mallin et al. 1998). Data from that report were later published in the peer-reviewed literature (Mallin et al. 2000) and were used in 2006-2009 by the N.C. General Assembly (Senate Bill 1967) as the scientific basis to redefine low density coastal areas as 12% impervious surface coverage instead of the previously used 25% impervious cover. In 1999-2000 Whiskey Creek was added to the program.

In October 1997 the Center for Marine Science began a project (funded by the City of Wilmington Engineering Department) with the goal of assessing water quality in Wilmington City watersheds. Also, certain sites were analyzed for sediment heavy metals concentrations (EPA Priority Pollutants). In the past 27 years we produced several combined Tidal Creeks – Wilmington City Watersheds reports (see Appendix E). In fall 2007 New Hanover County decided to stop funding UNCW sampling on the tidal creeks and UNCW has subsequently produced many reports largely focused on City watersheds (see Appendix E). In 2020 sampling at lower Barnards and Motts Creeks, Howe Creek and Whiskey Creek were suspended to emphasize upper Bradley Creek and the Greenfield Lake watershed, both of which are scheduled for restoration measures; in fall 2021 sampling at two locations in upper Barnard’s Creek near Carriage Hills wet detention pond was initiated.

Water quality parameters analyzed in the watersheds include water temperature, pH, dissolved oxygen, salinity/conductivity, turbidity, total suspended solids (TSS), nitrate, ammonium, total Kjeldahl nitrogen (TKN), total nitrogen (TN), orthophosphate, total phosphorus (TP), chlorophyll *a* and fecal coliform bacteria. Biochemical oxygen demand (BOD5) is measured at selected sites in Greenfield Lake. From 2010-2013 a suite of metals, PAHs and PCBs were assessed in the sediments of the creeks and Greenfield Lake. The 2014 report presented summary material regarding that study.

From 2010-2014 Wilmington Stormwater Services collaborated with UNCW to investigate potential sewage spills and leaks and illicit sanitary connections potentially polluting city waterways; the results of those sample collections have been provided in various reports. Currently, the City is emphasizing lake and stream restoration.

1.1 Water Quality Methods

Samples were collected on 5 to 9 occasions at 20 locations within the Wilmington City watersheds between January and December 2024. Field parameters were measured at each site using a YSI EXO 3 or Pro DSS Multiparameter Water Quality sonde linked to a YSI EXO or Pro DSS display unit. Individual probes within the instrument measured water temperature, pH, dissolved oxygen, turbidity, salinity, and conductivity. The YSI was calibrated prior to each sampling trip to ensure accurate measurements. The UNCW Aquatic Ecology Laboratory is State-Certified for field measurements (temperature, conductivity, dissolved oxygen and pH). Samples were collected on-site for State-certified laboratory analysis of ammonium, nitrate+nitrite (referred to within as nitrate), total Kjeldahl nitrogen (TKN), orthophosphate, total phosphorus, total suspended solids (TSS), fecal coliform bacteria, and chlorophyll *a*.

The analytical method used by the UNCW Aquatic Ecology Laboratory to measure chlorophyll *a* is based on Welschmeyer (1994) and Method 445.0 from US EPA (1997). All filters were wrapped individually in aluminum foil, placed in an airtight container and stored in a freezer. During the analytical process, the glass filters were separately immersed in 10 ml of a 90% acetone solution and allowed to extract the chlorophyll from the material for three to 24 hours; filters were ground using a Teflon grinder prior to extraction. The solution containing the extracted chlorophyll was then analyzed for chlorophyll *a* concentration using a Turner AU-10 fluorometer. This method uses an optimal combination of excitation and emission bandwidths that reduces errors in the acidification technique. UNCW Aquatic Ecology Laboratory is State-Certified for laboratory chlorophyll *a* measurements.

Nutrients (nitrate, ammonium, total Kjeldahl nitrogen, orthophosphate, total phosphorus) and total suspended solids (TSS) were analyzed by a state-certified laboratory using EPA and APHA techniques. We also computed inorganic nitrogen to phosphorus molar ratios for relevant sites (N/P). Fecal coliform concentrations were determined using a membrane filtration (mFC) method (APHA 1995). For a large wet detention pond (Ann McCrary Pond on Burnt Mill Creek) we collected data from input and outfall stations.

As noted, the City funded a partial dredging operation to remove phosphorus polluted sediments from Squash Branch between April and August (about 30%) of the branch's sediments were dredged. As such, UNCW performed enhanced sampling of the sediments in the branch, the removed sediments, and the water during and after dredging, reported within.

2.0 Barnards Creek

Snapshot
Watershed area: 4,161 acres (1,690 ha)
Impervious surface coverage: 22.3%
Watershed population: Approximately 12,200
Overall water quality: Algal blooms occurred, and minor fecal coliform problems

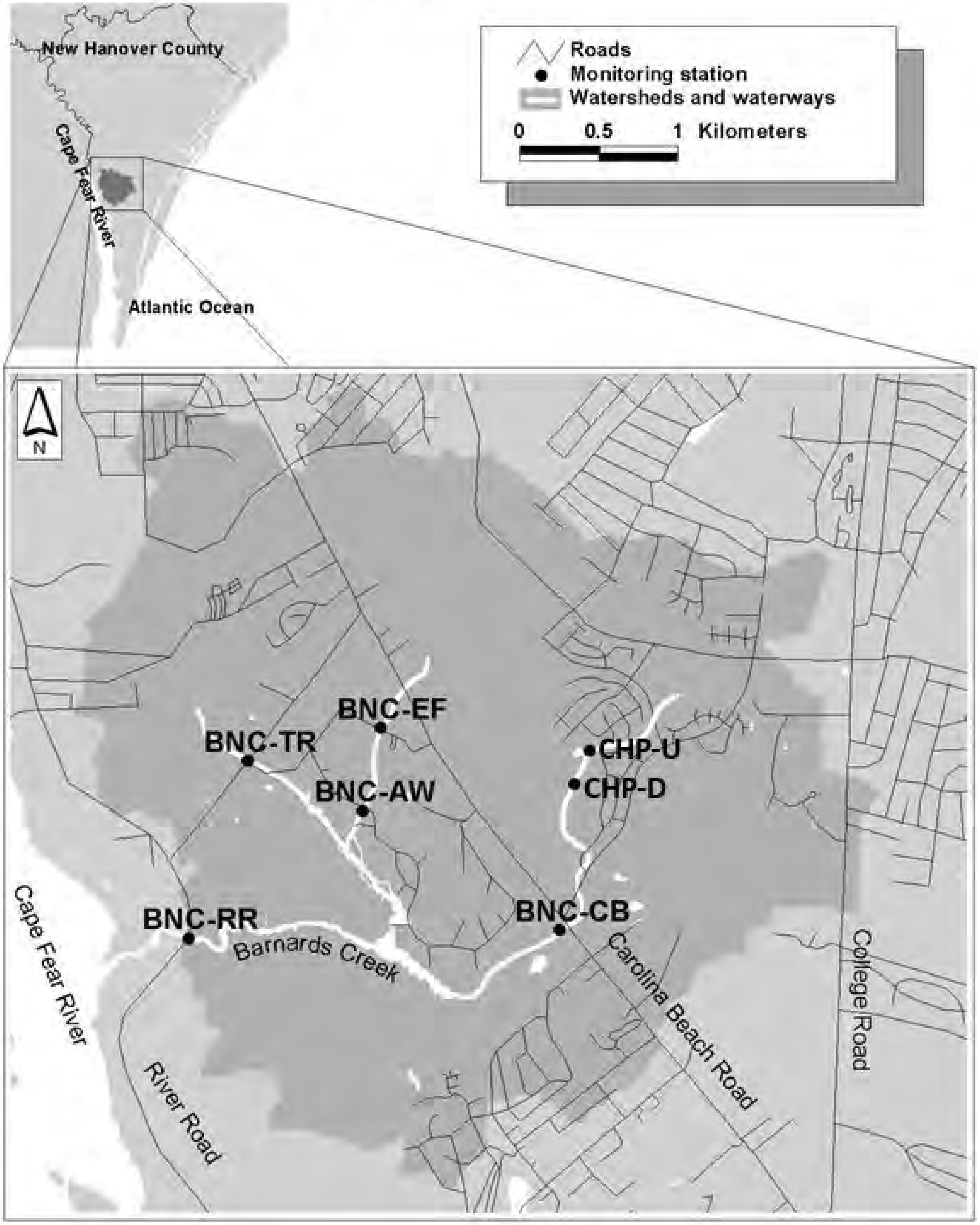
Lower Barnard's Creek drains single family and multifamily housing upstream of Carolina Beach Rd. in the St. Andrews Dr. area and along Independence Boulevard near the Cape Fear River. Another major housing development (River Lights) is well populated and under continuing construction between Barnards and Motts Creeks. This site was not sampled for several years due to lack of funding. However, renewed funding allowed UNCW to re-initiate sampling of Barnards Creek at River Road (BNC-RR) in 2018-2019. In 2020 sampling of this creek was suspended due to Covid-19 and resource re-allotment. In October 2021 the City commenced funding UNCW to sample two locations on upper Barnards Creek adjacent to Carriage Hills wet detention pond, CHP-U and CHP-D. these sites were picked to assess any adverse impacts to the creek from the pond.

The 2024 data (Table 2.1) show no dissolved oxygen issues, and low turbidity and low total suspended solids (TSS). Nutrients were generally low; there was one minor algal bloom at CHP-D, and both sites exceeded the state fecal coliform standard sufficient to be rated Poor, with geometric means at CHP-U and CHP-D at 216 and 254 CFU/100 mL, respectively.

Table 2.1. Selected water quality parameters at sites upstream (CHP-U) and downstream (CHP-D) of Carriage Hills wet pond in upper Barnards Creek, 2024 as mean (standard deviation) / range, inorganic N/P ratios as mean / median, fecal coliform bacteria presented as geometric mean / range, n = 5 samples collected.

Parameter	CHP-U	CHP-D
Salinity (ppt)	0.1 (0) 0.1-0.1	0.1 (0) 0.1- 0.1
Turbidity (NTU)	2 (1) 1-4	2 (2) 1-6
TSS (mg/L)	2 (2) 1-5	3 (1) 1-4
DO (mg/L)	7.3 (1.0) 5.9-8.2	7.3 (0.8) 6.0-8.2
Nitrate (mg/L)	0.06 (0.04) 0.01-0.10	0.05 (0.04) 0.01-0.10
Ammonium (mg/L)	0.08 (0.08) 0.01-0.22	0.11 (0.059 0.03-0.20
TN (mg/L)	0.69 (0.52) 0.35-1.62	0.40 (0.10) 0.23-0.51
Orthophosphate (mg/L)	0.02 (0.01) 0.01-0.03	0.01 (0.01) 0.010-0.03
TP (mg/L)	0.39 (0.53) 0.01-1.18	0.28 (0.38) 0.01-0.82
N/P inorganic	20 20	31 16
Chlorophyll *a* (µg/L)	9 (10) 1-26	15 (21) 1-51
Fecal col. (CFU/100 mL)	216 77-410	254 100-500

Figure 2.1 Barnards Creek watershed



3.0 Bradley Creek

Snapshot
Watershed area: 4,583 acres (1,856 ha)
Impervious surface coverage: 27.8% (2014 data)
Watershed population: Approximately 16,470
Overall water quality: fair-poor
Problematic pollutants: high fecal bacteria, occasional low dissolved oxygen

The Bradley Creek watershed was previously a principal location for Clean Water Trust Fund mitigation activities, including the purchase and renovation of Airlie Gardens by New Hanover County. There has been massive redevelopment of the former Duck Haven property bordering Eastwood Road and development across Eastwood Road; which drains to the creek. This creek has been one of the most polluted in New Hanover County, particularly by fecal coliform bacteria (Mallin et al. 2000) and has suffered from sewage leaks (Tavares et al. 2008) and stormwater runoff. Three upstream stations (BC-SB, BC-NB and BC-CA) have been sampled in previous years, both fresh and brackish (Fig. 3.1), and another site, BC-RD on Racine Drive was added in July 2021. Stream restoration activities are ongoing for this upper branch (also called Clear Run, see cover photo) both at its headwaters and from College Acres through the forest bordering the stream behind UNCW. and sampling at BC-CA was suspended in 2023 due to restoration related construction at the site, and re-established in 2024, slightly downstream from College Acres. The drainage area for BC-RD is approximately 90% impervious surface coverage. A new station, BC-MS, was established at the bridge on Mallard St. downstream of where Clear Run passes through the restored area and the forest behind UNCW. Thus, there were five samples collected at all sites in 2024.

Turbidity was not a problem during 2024; the standard of 25 NTU was not exceeded (Table 3.1). There are no NC ambient standards for total suspended solids (TSS), but UNCW considers 25 mg/L high for the Coastal Plain. As such, TSS did not exceed 21 mg/L at any of our sites in 2024. Dissolved oxygen went below standard (< 5.0 mg/L) only on one occasion at BC-CA and BC-RD during our 2024 collections.

Nitrate concentrations were low to moderate at all sites, and highest in the Clear Run Branch. Ammonium was elevated above 0.40 µg-N/L on several occasions at BC-NB, was periodically elevated in upper Clear Run, with a peak of 1.91 mg/L at BC-RD in December (Table 3.1). Total nitrogen (TN) was also highest in upper Clear Run branch. Orthophosphate concentrations were low in general at all the sites, but total phosphorus (TP) was periodically elevated above 0.50 mg/L at all sites in 2024. Two large algal blooms occurred at BC-RD and BC-CA in 2024, 56 and 147 µg/L chlorophyll *a* in October. Median nitrogen to phosphorus ratios at most sites except BC-SB were elevated above 21, indicating potential P limitation of phytoplankton.

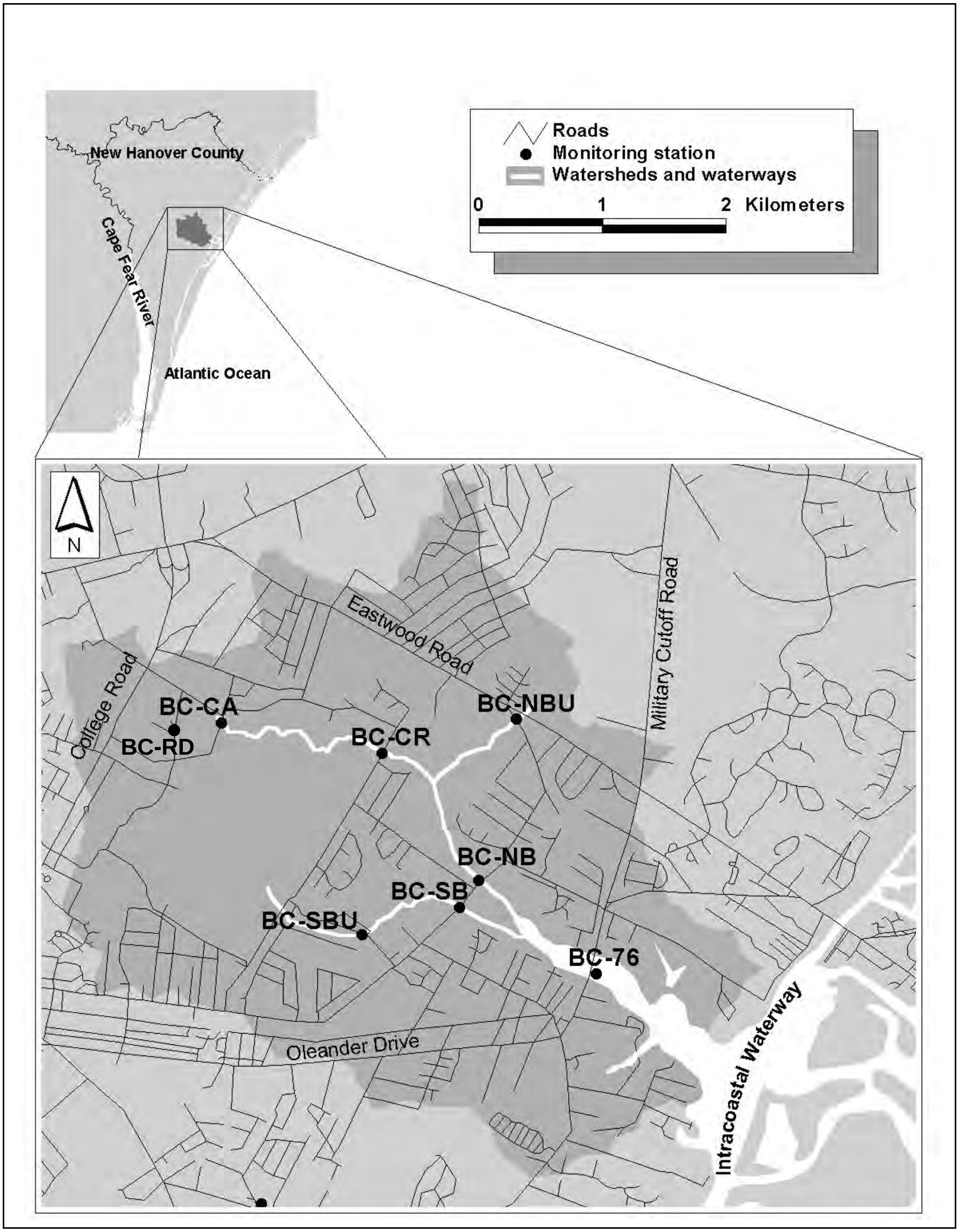
Fecal coliform bacteria counts were low at BC-NB, but high at the other sites, especially BC-RD and BC-CA, with geometric means of 992 and 432 CFU/100 mL, and a maximum of 2,100 CFU/100 mL compared with the NC standard of 200 CFU/100 mL for freshwater safety. Note that upper Clear Run receives considerable drainage from across College Road (Fig. 3.1) where there are large parking lots and high (>90%)

impervious surface coverage. There is also a considerable amount of dog feces lying on the ground near BC-RD between the nearest apartment parking lot and the creek.

Table 3.1. Water quality parameter concentrations at Bradley Creek sampling stations, 2024. Data as mean (SD) / range, N/P ratio as mean/median, fecal coliform bacteria as geometric mean / range, n = 5 samples collected.

Station	BC-RD	BC-CA	BC-MS	BC-NB	BC-SB
Salinity (ppt)	0.1 (0.1) 0.1-0.1	0.1 (0.1) 0.1-0.2	0.1 (0.0) 0.1-0.1	24.3 (8.8) 13.5-33.1	15.1 (13.3) 1.8-32.4
DO (mg/L)	5.8 (1.2) 4.3-7.2	6.4 (1.9) 3.4-8.1	7.9 (0.3) 7.3-8.2	7.4 (2.1) 5.0-9.8	8.0 (1.1) 6.8-9.6
Turbidity (NTU)	5 (5) 1-14	2 (1) 0-4	2 (2) 0-6	4 (2) 2-6	5 (3) 2-9
TSS (mg/L)	4 (3) 1-10	2 (1) 1-4	4 (6) 1-14	14 (5) 10-21	12 (3) 9-15
Nitrate (mg/L)	0.14 (0.12) 0.06-0.34	0.18 (0.14) 0.05-0.39	0.19 (0.09) 0.06-0.26	0.01 (0.00) 0.01-0.01	0.01 (0.00) 0.01-0.01
Ammonium (mg/L)	0.56 (0.75) 0.16-1.91	0.25 (0.06) 0.14-0.30	0.02 (0.02) 0.01-0.05	0.44 (0.28) 0.12-0.72	0.20 (0.31) 0.01-0.71
TN (mg/L)	1.15 (0.68) 0.76-2.01	0.86 (0.16) 0.63-0.99	0.60 (0.23) 0.41-0.94	0.54 (0.25) 0.28-0.95	0.52 (0.16) 0.35-0.74
Orthophosphate (mg/L)	0.04 (0.01) 0.01-0.05	0.04 (0.01) 0.03-0.06	0.01 (0.01) 0.01-0.02	0.01 (0.01) 0.01-0.02	0.02 (0.01) 0.01-0.03
TP (mg/L)	0.29 (0.38) 0.04-0.28	0.35 (0.39) 0.04-0.89	0.33 (0.48) 0.01-1.11	0.29 (0.42) 0.01-1.02	0.30 (0.38) 0.01-0.87
N/P	35 29	28 22	37 29	79 89	35 4
Chlorophyll *a* (µg/L)	13 (24) 1-56	32 (64) 2-147	6 (5) 2-14	6 (5) 1-12	16 (15) 2-38
Fecal coliforms (CFU/100 mL)	992 410-2,100	432 200-1,090	212 86-410	41 5-109	140 37-591

Figure 3.1. Bradley Creek watershed and sampling sites.



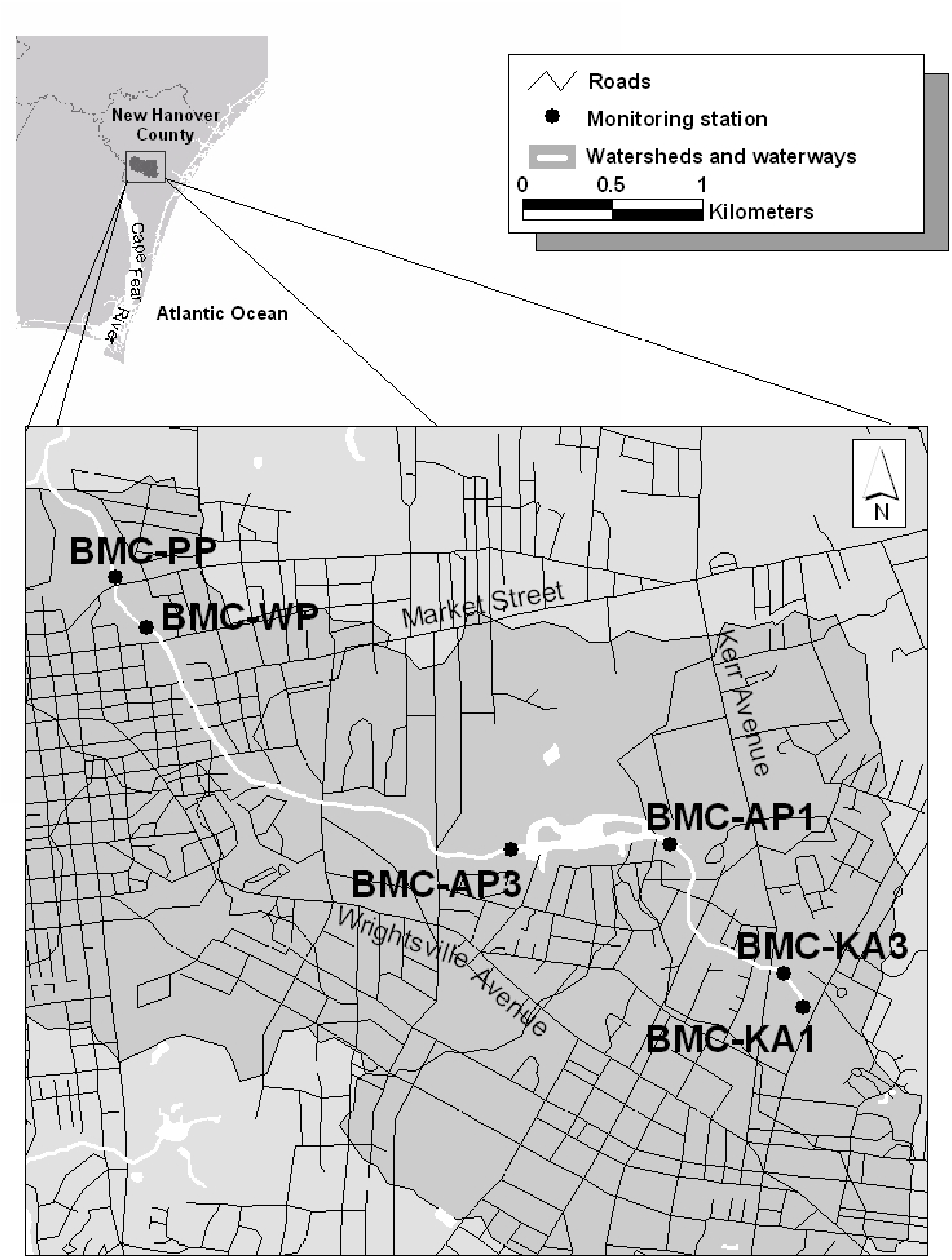
4.0 Burnt Mill Creek

Snapshot
Watershed area: 4,207 acres (1,703 ha)
Impervious surface coverage: 39.3%
Watershed population: Approximately 23,700
Overall water quality: poor, on NC 303(d) list for impaired benthic community
Problematic pollutants: Fecal bacteria, periodic algal blooms, some low dissolved oxygen issues, contaminated sediments (PAHs, Hg, Pb, Zn, TN, and TP), water hyacinth overgrowths in 2021

Burnt Mill Creek is an urban creek flowing entirely through the City of Wilmington. Its high impervious surface coverage (about 39%) puts it at risk for excessive pollutant loads. A prominent feature in the Burnt Mill Creek watershed (Fig. 4.1) is the Ann McCrary Pond on Randall Parkway, which is a large (28.8 acres) regional wet detention pond draining 1,785 acres, with a large apartment complex (Mill Creek Apts.) at the upper end. The pond itself has periodically hosted growths of submersed aquatic vegetation, with *Hydrilla verticillata, Egeria densa, Alternanthera philoxeroides, Ceratophyllum demersum* and *Valliseneria americana* having been common at times (some of these taxa are invasive). There have been efforts to control this growth, including addition of triploid grass carp as grazers. The ability of this detention pond to reduce suspended sediments and fecal coliform bacteria, and its failure to reduce nutrient concentrations, was detailed in a scientific journal article (Mallin et al. 2002). Numerous waterfowl utilize this pond as well. Burnt Mill Creek has been studied by a number of researchers, and water quality results of these continuing studies have been published in technical reports and scientific journals (Perrin et al. 2008; Mallin et al. 2009a; 2009b; 2010; 2011). This creek is currently on the NC 303(d) list for impaired waters, for an impaired benthic community. Sediment toxicant analysis (summarized in Mallin et al. 2015) found elevated concentrations of polycyclic aromatic hydrocarbons (PAHs), mercury, lead and zinc at several locations in this creek. We note that in 2021 there was a large nuisance growth of water hyacinth *Eichhornia crassipes* that completely blocked the creek, this growth was subsequently removed by Wilmington Stormwater Services.

<u>Sampling Sites</u>: During 2024 samples were collected on five occasions from BMC-PP and BMC-AP3 sampling at BMC-AP1 site ended as City priorities changed in summer 2023) (Fig. 4.1). The latter site is located in the upper creek just upstream of Ann McCrary Pond (Fig. 4.1) and BMC-AP3 is located about 40 m downstream of the pond. Several km downstream of Ann McCrary Pond is Station BMC-PP, located at the Princess Place bridge over the creek, respectively (Fig. 4.1). This is a main stem station in what is considered to be the mid-to-lower portion of Burnt Mill Creek, in a mixed residential and retail area.

Figure 4.1. Burnt Mill Creek watershed and water quality sampling sites.



<u>The Upper Creek</u>
About one km downstream from Kerr Avenue along Randall Parkway is the large regional wet detention pond known as Ann McCrary Pond. Data were collected at the outflow (BMC-AP3) station on five occasions in 2024. Dissolved oxygen concentrations were within standard on all sampling occasions at BMC-AP3. The NC standard for turbidity in freshwater streams is 50 NTU; there were no exceedences of this value during our 2024 sampling, and total suspended solids concentrations were low to moderate on most sampling occasions in 2024 (Table 4.1). Fecal coliform concentrations at BMC-AP3 were generally low (Table 4.1). In 2024 there was one major algal bloom of 69 µg/L chlorophyll *a* at Station BMC-AP3.

<u>Lower Burnt Mill Creek</u>
The Princess Place location (BMC-PP) was the only lower creek station sampled in 2024. One parameter that is key to aquatic life health is dissolved oxygen. Dissolved oxygen at BMC-PP was below standard (< 5.0 mg/L) on only one sampling occasion. Turbidity concentrations at BMC-PP did not exceed the State standard on any of our sampling occasions and total suspended solids (TSS) were low.

The North Carolina water quality standard for chlorophyll *a* is 40 µg/L. In 2024 there were excessive blooms of 155 and 87 µg/L at BMC-PP. Algal blooms can cause disruptions in the food web, depending upon the species present (Burkholder 2001), and decomposing blooms can contribute to low dissolved oxygen (Mallin et al. 2006).

In waters where the inorganic N/P ratio is well below 16 (the Redfield Ratio for algal nutrient composition; Hecky and Kilham 1988) it is generally considered that algal production is limited by the availability of nitrogen (i.e. phosphorus levels are sufficient); where N/P ratios are well above 16, additions of phosphate should encourage algal blooms. If such values are near the Redfield Ratio, inputs of either N or P could drive an algal bloom. At AP-3, mean and median N/P ratios were below the Redfield Ratio, at 10 and 13, respectively, indicating that the algae and macrophytes in the pond took up more N relative to P. Ratios increased downstream at BMC-PP to 28 and 15, respectively along with increases in nutrients, especially N.

Important from a public health perspective are fecal coliform bacteria counts. AP-3 had a geometric mean below the state standard, but BMC-PP had a geometric mean of 268 CFU/100 mL. That station exceeded the State standard for human contact waters (200 CFU/100 mL) on three of five occasions in our 2024 samples. Fecal coliform counts were greater than the State standard on 60% of sampling occasions at BMC-PP, and on no occasions at AP-3. Whereas geometric mean fecal coliform counts at BMC-AP3 were 25 CFU/100 mL, counts then increased along the passage to the Princess Place location (geometric mean 268 CFU/100 mL; Fig. 4.2), as in previous years. It is likewise notable that nitrate, ammonium, total nitrogen, total phosphorus and orthophosphate concentrations increased from the outflow from Ann McCrary Pond downstream to the lower station BMC-PP (Table 4.1; Fig. 4.3). Clearly, there are inputs of pollutants to this creek as it passes from the large detention pond to its lower reaches.

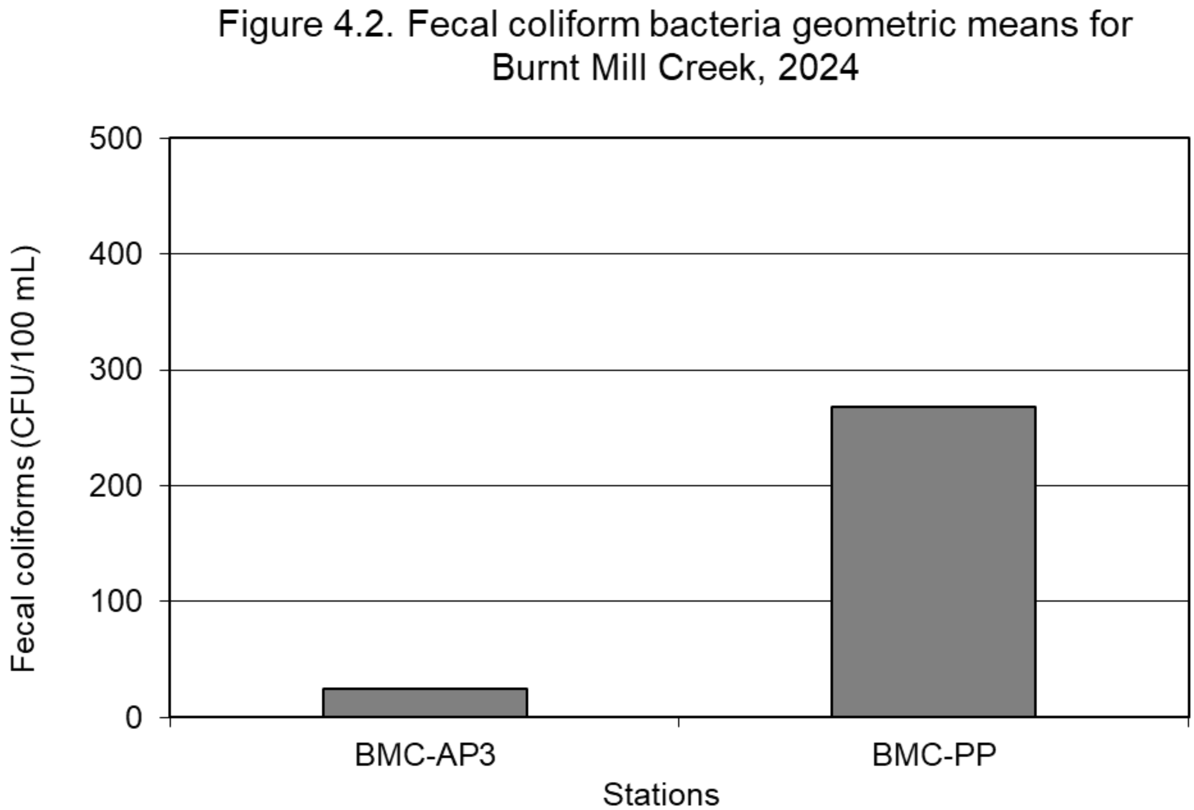


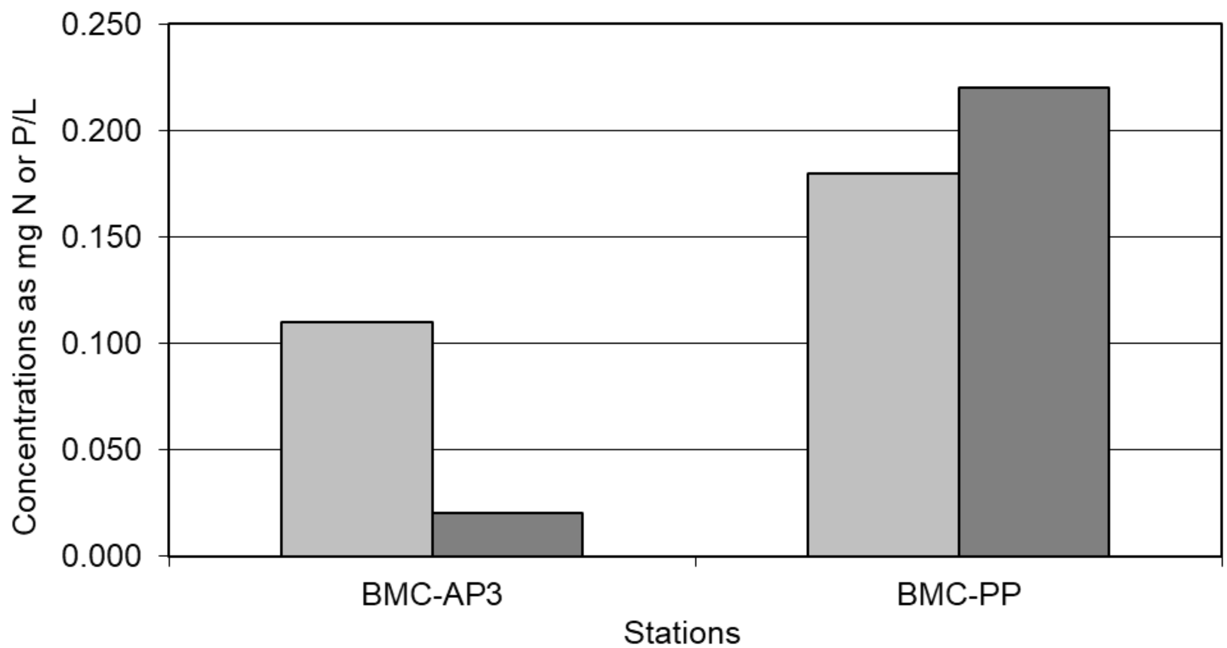
Figure 4.2 Geometric mean fecal coliform bacteria counts in Burnt Mill Creek downstream from AP3 to Princess Place bridge.

To summarize, in some years Burnt Mill Creek has had problems with low dissolved oxygen (hypoxia) at the Princess Place station BMC-PP, but in 2024 most samples were within standard. Two major algal blooms occurred at BMC-PP (69 and 155 µg/L). Median N/P ratios in the lower creek indicate that inputs of nitrogen were likely to stimulate algal bloom formation in 2024, but such ratios have differed in previous years. It is notable that nutrient concentrations increased from the outfall of the regional Ann McCrary wet detention pond as one moves downstream toward the lower creek (Fig. 4.3). An important human health issue is the periodic high fecal bacteria counts found at BMC-PP and occasionally in the upper creek. As NPDES point source discharges are not directed into this creek, the fecal bacteria (and nutrient) loading appears to be caused either by non-point source stormwater runoff, illegal discharges, or leakage from sanitary sewer lines. We note that strong statistical correlations between fecal coliform counts, TSS, BOD and rainfall have been previously demonstrated for this creek (Mallin et al. 2009b), indicating as stormwater runoff pollution problem. As this is one of the most heavily developed creeks in the Wilmington area, it also remains one of the most polluted.

Table 4.1. Water quality data in Burnt Mill Creek, 2024, as mean (standard deviation)/range. Fecal coliforms as geometric mean; N/P as mean/median, n = 5 samples collected.

Parameter	BMC-AP3	BMC-PP
DO (mg/L)	11.1 (2.4) 4.9-9.2	6.8 (2.1) 4.9-9.2
Cond. (µS/cm)	239 (38) 186-277	397 (95) 292-545
pH	8.0 (0.4) 7.6-8.5	7.3 (0.1) 7.2-7.5
Turbidity (NTU)	4 (2) 2-6	3 (2) 1-6
TSS (mg/L)	5 (2) 3-7	6 (8) 1-19
Nitrate (mg/L)	0.02 (0.02) 0.01-0.04	0.122 (0.11) 0.01-0.04
Ammonium (mg/L)	0.04 (0.03) 0.010-0.09	0.05 (0.020 0.01-0.09
TN (mg/L)	0.79 (0.23) 0.58-1.13	0.86 (0.32) 0.63-1.43
OrthoPhos. (mg/L)	0.01 (0.01) 0.01-0.03	0.03 (0.02) 0.01-0.07
TP (mg/L)	0.11 (0.15) 0.01-0.37	0.18 (0.21) 0.01-0.53
N/P molar ratio	10 13	28 15
Chlor. *a* (µg/L)	33 (25) 15-69	55 (65) 5-155
FC (CFU/100 mL)	25 5-82	268 137-1000

Figure 4.3. Average TP and nitrate concentrations by station for Burnt Mill Creek, 2024; TP as light grey, nitrate as dark grey.

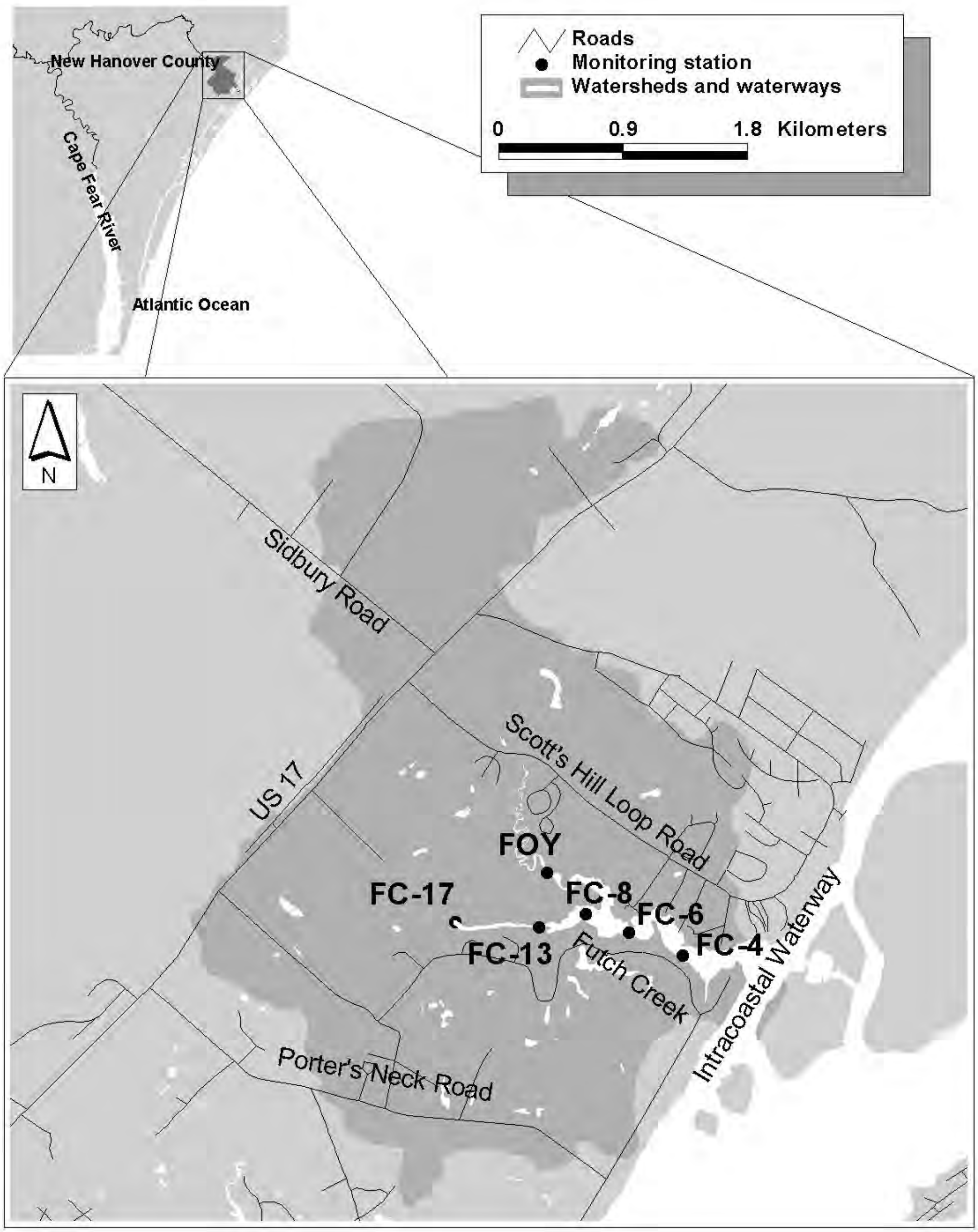


5.0 Futch Creek

Snapshot
Watershed area: 3,813 acres (1,544 ha)
Impervious surface coverage: 12.3%
Watershed population: 4,620

Six stations were sampled by the University of North Carolina Wilmington's Aquatic Ecology Laboratory in Futch Creek from 1993 through 2007. UNCW was not funded by the County to sample Futch Creek following 2007. We present the above information and map below purely for informational purposes. A private firm is sampling Futch Creek for the County and the County should be contacted for information.

Figure 5.1. Futch Creek watershed and sampling sites.



6.0 Greenfield Lake Water Quality

Snapshot
Watershed area: 2,551 acres (1,033 ha)
Impervious surface coverage: 37% (2013 data)
Watershed population: 10,630
Overall water quality: Poor, on NC 303(d) list for algal blooms
Problematic pollutants: High fecal bacteria, low dissolved oxygen, and nutrient loading in tributaries, high BOD and algal blooms in main lake, sediments contaminated with metals, PAHs and phosphorus

Four stations on tributaries to Greenfield Lake were sampled for a full suite of physical, chemical and biological parameters on 9 occasions in 2024 (Table 6.1, Fig. 6.1). Of those, SQB-BR is located at the walking bridge over Squash Branch, and is generally lake-like rather than stream-like. Some tributary stream sites suffered from low dissolved oxygen (DO), as GL-SQB (Squash Branch, formerly called GL-LB) showed DO concentrations below the state standard (DO < 5.0 mg/L) on 78% of sampling occasions (Table 6.1; Appendix B). Station GL-JRB (Jumping Run Branch) had substandard DO on five sampling occasions, while JRB-17 had two violations. Turbidity concentrations were generally low in the tributary stations, with no violations of the freshwater stream standard of 50 NTU (Table 6.1). Suspended solids were likewise low at the stream stations (Table 6.1).

Nitrate, ammonium and TN concentrations were elevated at GL-SQB with JRB-17 and GL-JRB also elevated (Table 6.1). Highest phosphorus concentrations occurred at GL-JRB and GL-SQB. We note that both JRB-17 and GL-JRB are downstream of a golf course, which covers 22% of the Jumping Run Branch watershed surface area. The chlorophyll *a* concentration was high in November at GL-JRB and JRB-17 with blooms of 30 and 33 µg/L. However, SQB-BR (near the main lake) had three large blooms ranging from 62-103 µg/L. The geometric mean fecal coliform bacteria counts for 2024 exceeded the state standard at all three upper tributary stations (Table 6.1), and the fecal coliform standard was exceeded on >55% of sampling dates at all three upper stream stations. Fecal coliform counts at SQB-BR were low, well within standard.

Table 6.1. Mean and (standard deviation) / range of selected field water quality parameters in tributary stations of Greenfield Lake, 2024. Fecal coliforms (FC) given as geometric mean, N/P ratio as mean / median; n = 9 samples collected at most sites, but five times at SQB-BR.

Parameter	JRB-17	GL-JRB	GL-SQB	SQB-BR
DO (mg/L)	6.8 (1.7) 4.6-10.2	5.2 (1.3) 3.5-7.9	3.7 (1.9) 0.9-6.5	8.3 (1.7) 6.3-10.2
Turbidity (NTU)	3 (1) 1-5	2 (1) 1-3	2 (1) 1-4	3 (4) 0-8
TSS (mg/L)	6 (5) 1-15	3 (1) 1-4	6 (5) 3-20	3 (2) 1-5
Nitrate (mg/L)	0.17 (0.05) 0.09-0.25	0.15 (0.07) 0.03-0.24	0.23 (0.19) 0.03-0.61	0.01 (0.01) 0.01-0.01
Ammon. (mg/L)	0.08 (0.03) 0.05-0.13	0.04 (0.02) 0.01-0.07	0.19 (0.18) 0.01-0.65	0.03 (0.04) 0.01-0.09
TN (mg/L)	0.94 (0.38) 0.48-1.82	0.77 (0.21) 0.55-1.23	0.97 (0.30) 0.64-1.59	0.85 (0.37) 0.39-1.26
Ortho-P. (mg/L)	0.02 (0.01) 0.01-0.04	0.02 (0.01) 0.01-0.05	0.04 (0.02) 0.01-0.07	0.02 (0.01) 0.01-0.03
TP (mg/L)	0.22 (0.29) 0.03-0.98	0.18 (0.14) 0.07-0.43	0.23 (0.32) 0.05-1.07	0.12 (0.10) 0.03-0.24
Inorganic N/P ratio	40 44	31 28	40 19	4 5
Chlor. *a* (μg/L)	14 (12) 2-33	11 (10) 1-33	11 (8) 2-24	54 (47) 4-103
FC (CFU/100 mL)	212 100-546	229 91-682	586 180-1,150	11 3-46

Three in-lake stations were sampled on 9 occasions (Figure 6.1). Station GL-2340 represents an area receiving an influx of urban/suburban runoff (but buffered by wetlands), GL-YD is downstream and receives some outside impacts, and GL-P is at the Greenfield Lake Park boathouse, away from inflowing streams but in a high-use waterfowl area (Fig. 6.1). Low dissolved oxygen (< 5.0 mg/L) did not occur at GL-YD and only once at the Park station GL-P in 2024 (see also Section 6.1). However, DO was substandard on 56% of occasions sampled at GL-2340. Turbidity was at or below the state standard on all sampling occasions. There was a sharp peak in suspended solids (100 mg/L) on May 13 at GL-2340, concurrent with an influx of hypoxic runoff water from upstream that led to a massive lake fish kill. Five major algal blooms occurred from May-December at GL-P, ranging from 48-165 µg/L chlorophyll *a*, while two blooms occurred at GL-YD ranging from 173-207 µg/L. Thus, this lake continues to suffer from large nuisance blooms. In-lake fecal coliform concentrations exceeded the standard eight times at GL-2340, but not at all at GL-P and GL-YD.

Concentrations of all inorganic nutrients in-lake were mixed with highest nitrate at the upstream station GL-2340, but highest TN and TP at the lower stations where the highest algal biomass was (Table 6.2). Inorganic N/P molar ratios can be computed from ammonium, nitrate, and orthophosphate data and can help determine what the potential limiting nutrient can be in a water body. Ratios well below 16 (the Redfield ratio) can indicate potential nitrogen limitation, and ratios well above 16 can indicate potential phosphorus limitation (Hecky and Kilham 1988). Based on the mean and median N/P ratios in the lake (Table 6.2), phytoplankton growth in Greenfield Lake at GL-2340 can likely be limited by P due to the higher N at that upper lake location, but ratios at GL-YD (mixed) and GL-P (low), indicating that algae can be readily stimulated by nitrogen (i.e. inputs of nitrogen can cause algal blooms). Our previous bioassay experiments indicated that nitrogen was usually the stimulatory nutrient in this lake, although P can stimulate blooms at GL-2340 at times (Mallin et al. 1999; 2016).

Phytoplankton blooms are problematic in Greenfield Lake (Table 6.2), and usually consist of green or blue-green algal species, or both together (Grogan et al. 2023). These blooms have occurred during all seasons. As such, two blooms exceeding the North Carolina water quality standard of 40 µg/L of chlorophyll *a* were sampled at GL-YD, three at SQB-BR and five at GL-P. For the year 2024, chlorophyll *a* exceeded the state standard on 26% of occasions sampled at the three in-lake sites, but also five other times at SQB-BR. The North Carolina Division of Environmental Quality placed this lake on the 303(d) list in 2014 for high chlorophyll, and the chlorophyll a levels in this lake are reflective of eutrophic conditions (Wetzel 2001). Biochemical oxygen demand (BOD5) for 2024 was elevated at GL-YD and GL-P in summer-fall (Table 6.1) with a maximum of 10 mg/L in at GL-P in June. Because phytoplankton (floating microalgae) are easily decomposed sources of BOD, the blooms in this lake are a periodic driver of low dissolved oxygen; chlorophyll *a* is strongly correlated with BOD in this lake (Mallin et al. 2016; Iraola et al. 2022).

Table 6.2. Mean and (standard deviation) / range of selected field water quality parameters in lacustrine stations of Greenfield Lake, 2024. Fecal coliforms (FC) given as geometric mean, N/P ratio as mean / median; n = 10 samples collected.

Parameter	GL-2340	GL-YD	GL-P
DO (mg/L)	5.0 (1.5) 2.6-6.8	8.1 (1.5) 5,4-10.5	9.0 (3.5) 1.6-11.8
Turbidity (NTU)	1 (1) 0-1	1 (1) 0-2	3 (3) 0-10
TSS (mg/L)	12 (33) 1-100	3 (2) 1-6	5 (5) 1-14
Nitrate (mg/L)	0.30 (0.08) 0.18-0.39	0.08 (0.21) 0.01-0.64	0.01 (0.00) 0.01-0.02
Ammonium (mg/L)	0.11 (0.19) 0.01-0.60	0.04 (0.-05) 0.01-0.14	0.01 (0.01) 0.01-0.03
TN (mg/L)	1.20 (1.25) 0.56-3.97	1.37 (1.36) 0.61-5.78	0.99 (0.78) 0.43-2.46
Orthophosphate (mg/L)	0.02 (0.01) 0.01-0.05	0.02 (0.01) 0.01-0.03	0.04 (0.07) 0.01-.023
TP (mg/L)	0.25 (0.22) 0.04-0.62	0.23 (0.30) 0.01-0.98	0.25 (0.21) 0.03-0.69
N/P molar ratio	58 45	25 4	4 4
Fec. col. (CFU/100 mL)	248 105-637	19 3-100	13 3-145
Chlor. *a* (μg/L)	4 (3) 1-9	63 (79) 6-207	68 (67) 3-165
BOD5	1.1 (0.3) 2.0-2.0	2.3 (1.3) 1.0-5.0	4.7 (2.9) 2.0-10.0

Figure 6.1. Greenfield Lake watershed.

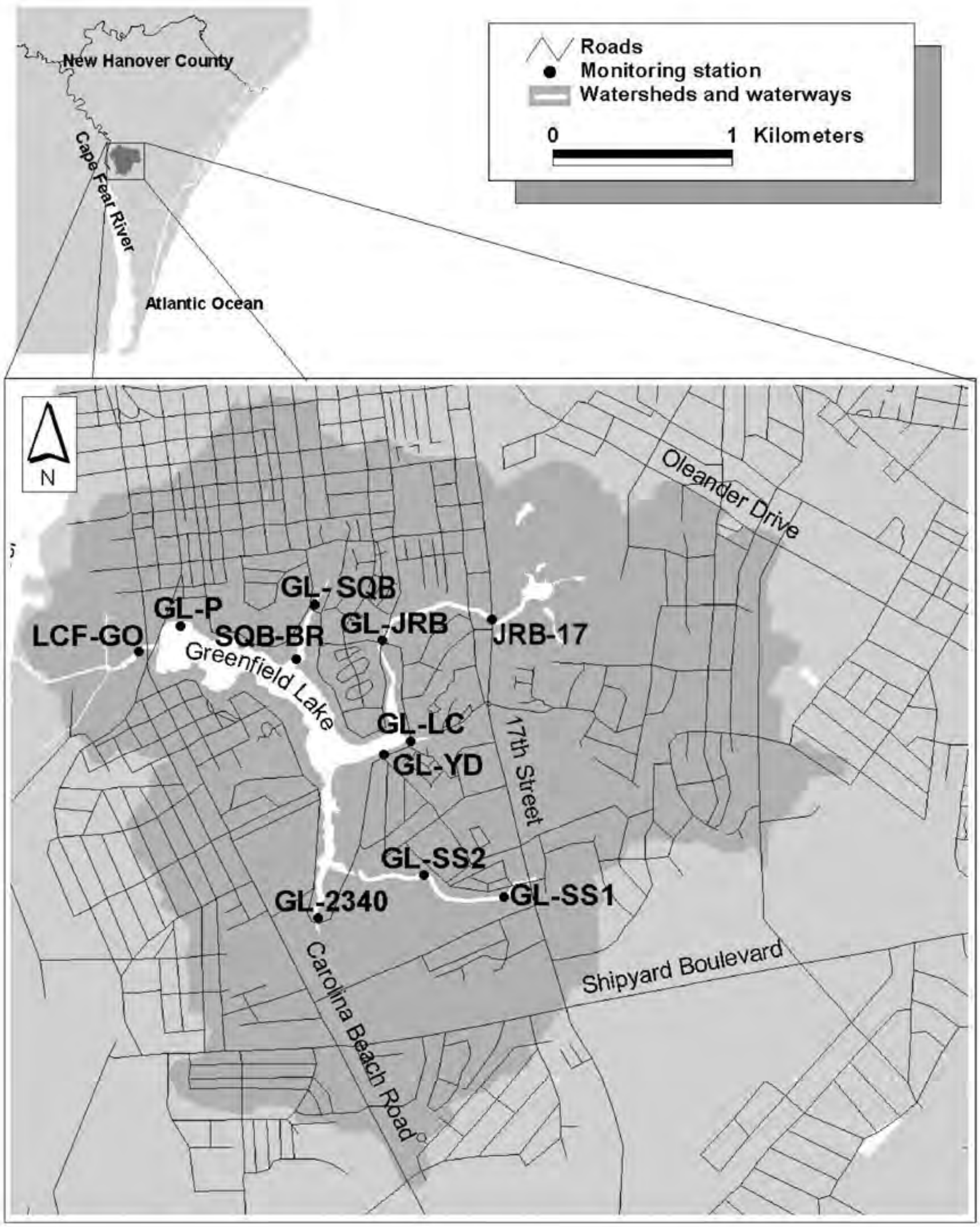
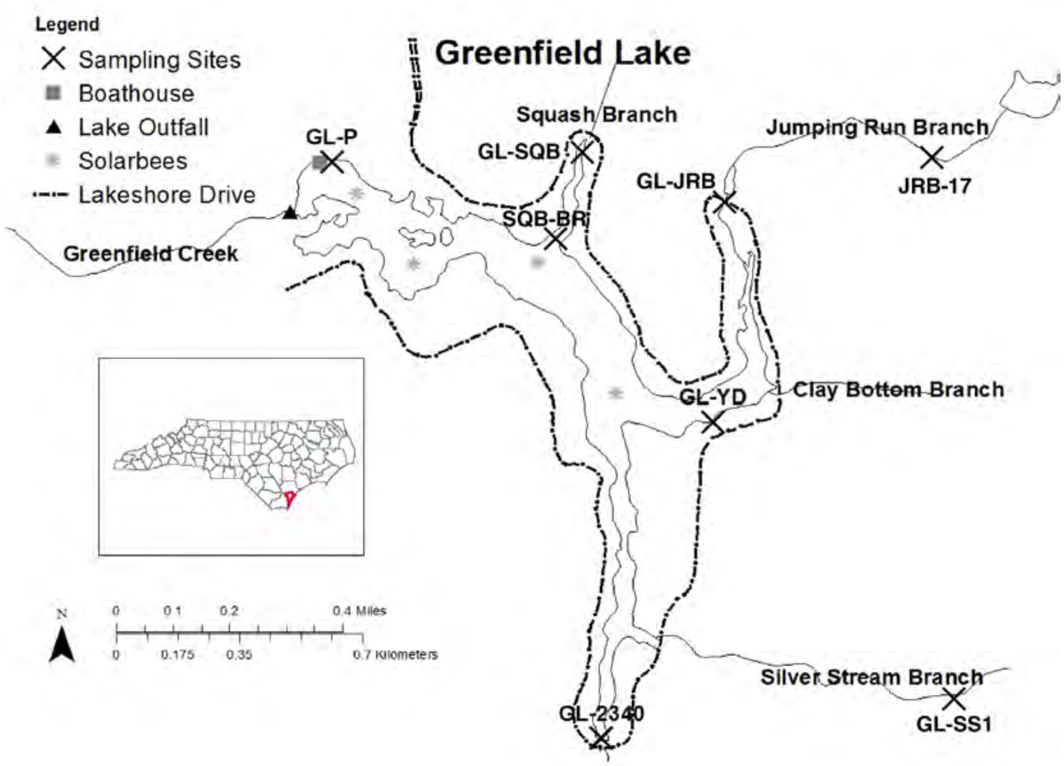


Figure 6.2. Greenfield Lake feeder stream stations sampled at various times; note that GL-SQB is also known as GL-LB, and GL-CBB is also known as GL-LC.



Chapter 6 – Special Study: Sampling at Squash Branch To Assess Phase 1 Dredging Impacts

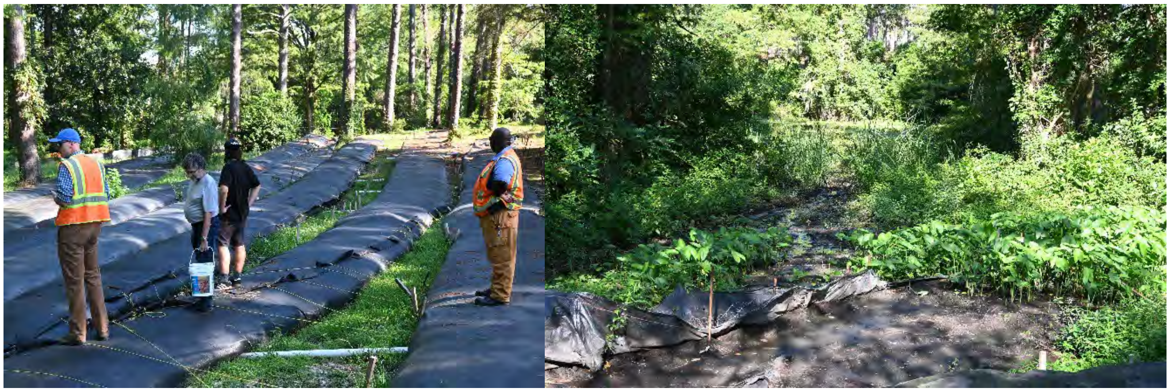


Plate 1a. (left) Array of Geotubes holding dredged sediment on shore near Squash Branch, August 2024, Plate 1b (right) Severe drainage from Geotubes passing through sediment fencing toward the lake, caused by heavy rains.

Background and Methods

Greenfield Lake, in Wilmington, North Carolina, is a highly eutrophic system characterized by springtime green algal blooms and summer and fall cyanobacterial (i.e. blue-green algal) blooms (Mallin et al. 2016; Iraola et al. 2022, Grogan et al. 2023). It has been on the North Carolina 303(d) list for impaired waters since 2014. A stormwater investigation (Iraola et al. 2022) determined that the greatest loading of nutrients, nitrogen (N) and phosphorus (P) entered the lake from Jumping Run Branch and Squash Branch. Sediment samples taken throughout the lake indicated that P was highest in the sediments of these two tributaries compared to elsewhere (Iraola et al. 2022). As such, a City of Wilmington-sponsored dredging program was begun in 2024 to remove P-laden sediments from approximately 30% of Squash Branch from the headwall where the incoming stream enters the branch, toward the main body of the lake. The goal was to reduce sediment P contributions to the overlying water column in hopes of reducing the persistent algal blooms. Dredging began April 29 and ended August 12, 2024. The dredged material was placed into geotubes situated on the shore near Squash Branch for several months until they drained and dried (Plates 1a, 1b). As noted, however, that funding was only available to dredge 30% of the stream channel, thus, success on only part of the proposed 1,200 ft channel can be measured at this point.

Impacts of dredging were followed by water column and sediment sampling by university researchers. The research team, led by Dr. Michael Mallin and Dr. Lawrence Cahoon of UNC Wilmington, assessed the impacts of the spring-summer 2024 dredging of Squash Branch in two media, water column and sediments.

Water Column Sampling Methods
First, impacts on the water column were of critical interest. UNCW conducted enhanced, City-sponsored biweekly water column sampling of multiple parameters starting before

dredging began and continued during dredging and for several months (until December 2024) following dredging to determine the impact on the water column quality. Samples have been taken biweekly to monthly just upstream of the operations (at the bridge on Lakeview Dr., Station GL-SQB) to serve as an upstream control before, during and following dredging. To assess the impact in the immediate vicinity, samples were collected just downstream of the dredged area at the walking bridge over Squash Branch, Station SQB-BR. While some samples were collected there, the City maintenance workers blocked off access to the bridge in fall, so the crew could not collect some samples.

To assess the impact of dredging on the lake water quality in general, samples were also taken at the Greenfield Park boathouse dock (GL-P), well downstream of the branch outflow. Samples were taken to assess water column changes in several ways, 1) turbidity and suspended solids caused by the dredging, 2) algal blooms as chlorophyll *a*, potentially a result of released sediment P, 3) water column phosphorus concentrations possibly increased by dredging – Mallin and Cahoon 2020, and 4) fecal coliform bacteria, because fecal coliforms are typically positively correlated with turbidity and suspended solids (Mallin and Cahoon 2020). Success criteria is measured by a lack of increase in water column phosphorus, turbidity, TSS and fecal bacteria in the water column due to dredging, as well as a lack of immediate algal bloom formation. Biweekly sampling ceased in December 2024 but is continuing monthly in 2025. Sampling and laboratory analyses were performed using State-certified methods.

We also noted that there was a fish kill on the lake (Plate 2a), reported May 13, beginning at the opposite side from SQB-BR. This was concurrent with a large influx of turbid, anoxic water from the GL-2340 inflow stream (Plate 2b), which is normally very clean. City staff noted there was groundwater pumping from the site of an abandoned outdoor theatre upstream that then passed though swampland, an area which also houses homeless camps. Also, at this time a large algal bloom began on the lake, and decomposition from it may have caused or contributed to the severe hypoxia and fish kill. The kill spread throughout the lake and researchers reported fish taking refuge up the tributary creeks. As the kill and hypoxia began across the lake, they do not appear to be a direct result of the dredging activity.

Plate 2a (left) Fish kill on Greenfield lake in May 2024. Plate 2b (right) Plume of brown anoxic water (DO=0.25 mg/L) entering the lake concurrent with onset of the fish kill.

Sediment Sampling and Analysis Methods

Since removal of phosphorus-laden sediments was the key goal, a suite of sediment samples in Squash Branch was sampled in April just before dredging began (Plate 3a). A second suite of sediment samples was conducted in early October 2024, after cessation of dredging. The goal was to measure differences in sediment P from before dredging compared to after dredging. Dredging was considered to be a success if there was reduction (> 50%) in channel sediment phosphorus concentrations. Also, samples were collected from the dredged sediments deposited into geotubes on the bank before removal to the landfill (Plate 3b), to assess impacts of dewatering on P concentrations in the dredged material as well as estimate total P in sediments removed.

Plate 3a. (left) Boat-based sediment sampling in Squash Branch, October 2024. Plate 3b (right) Sampling of geotubes on shore for phosphorus.

Specifically, Squash Branch sediments were sampled by boat using a hand-deployed coring device at four locations in April 2024 prior to dredging (Plate 3a). Sites SQB 1-4 were in upstream-downstream order from the Lakeshore Drive bridge to the wooden footbridge, respectively; Site 4 was downstream of the dredged area. Site SQB-M was at the Solar Bee unit off the mouth of Squash Branch, and Site GL-P was located well downstream near the boat docks at the park rental facility. Sediments at these latter two locations in the lake were sampled to facilitate a before-after/control-impact design. Sediment samples were taken in triplicate, stored in labeled containers, dried in the lab at 60 ℃ for >1 week, then homogenized by grinding with mortar and pestle. Precisely weighed (± 0.0001 g) subsamples were suspended in 10 mL of deionized water (DIW) amended with standard molybdenum-blue reagent (Parsons et al., 1984) and stirred for 24 hours to facilitate extraction of reactive P (RP) and color development. Absorbance vs DIW blanks was measured on a Genesys 20 spectrophotometer at 885 nm and µM RP was calculated using an 'F' value of 51. µM RP was then converted to µg RP/g sediment. Another precisely weighed sediment subsample was then ashed at 450 ℃ for 24 hrs, then weighed to calculate weight loss on ignition (WLOI), a measure of organic content of the sediment. Another precisely weighed combusted sediment subsample was then extracted, stirred and analyzed as above for total P (TP), also expressed as µg TP/g sediment.

Dredged sediments deposited in geotubes on the east side of Squash Branch were sampled initially in September 2024. The first samples taken from the Geotubes were shallow cores (top ~5 cm) from the surface of the sediment mass. In order to determine if sediments near the surface of the Geotube material were different from sediments deeper in the interior deeper cores (20-30 cm) were taken a few weeks later. These sediment samples were handled and analyzed as above for RP, TP and WLOI.

Water Column Results and Discussion

The data shown below are from water column samples collected monthly during 2023 and 2024 at GL-SQB and GL-P. Later SQB-BR was added shortly before dredging began and biweekly sampling commenced until December 2024.

Turbidity

Turbidity measures the cloudiness in the water column and its units are Nephelometric Turbidity Units (NTU). Dredging was expected to temporarily increase turbidity in the area. The State of North Carolina has a turbidity standard for lakes and reservoirs of 25 NTU. The standard was not reached at any of our sample sites between January 2023 and December 2024. The highest levels reached post-dredging was about 10 NTU in early June. Note also that turbidity is also positively correlated with chlorophyll *a* in this lake (Mallin et al. 2016), so increases are not necessarily a result of dredging activities.

Total Suspended Solids (TSS)

Another potential water column impact from dredging is an increase in total suspended solids (TSS) caused by disruption of the bottom. Figure 1 shows TSS concentrations (as mg/L) before, during and after dredging. North Carolina does not have a legal standard for TSS, but decades of our research has shown that TSS concentrations of 25 mg/L and higher can be considered high on the Coastal Plain. Whereas this concentration was not exceeded during our sampling, a number of peaks in TSS are evident, especially at GL-SQB, upstream of the dredging area, where stormwater runoff is measured. One notable peak nearing 25 mg/L occurred in May 2023 at GL-P, concurrent with an algal bloom. In June-July 2024 there were smaller peaks in TSS at SQB-BR, nearest the dredging area and at the park, GL-P. Those smaller peaks could be caused either by dredging activity or a midsummer algal bloom (Figs. 1,2).

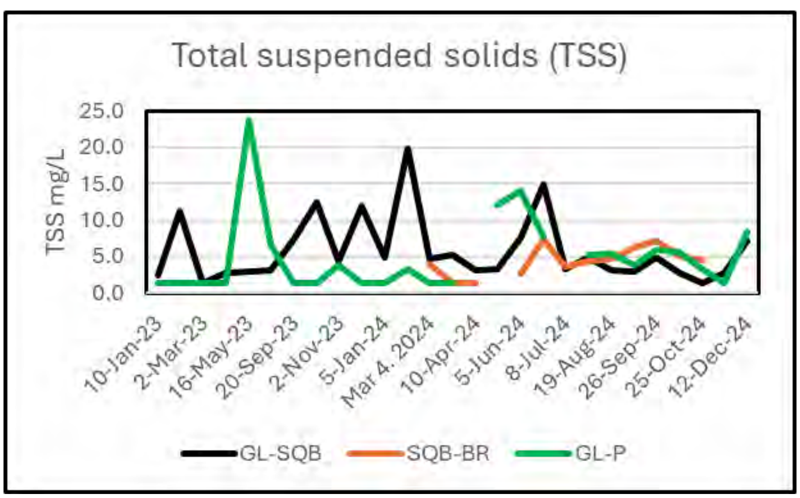


Figure 1. Total suspended solids (TSS) collected at the three sampling sites before, during and after dredging of upper Squash Branch beginning late April 2024.

Chlorophyll *a*

Chlorophyll *a* is a measure of algal bloom intensity and has been elevated in this lake for many years, even decades (Mallin et al. 2016; Iraola et al. 2022; Grogan et al. 2023). The NC standard for impaired waters is 40 µg/L (= ppb), which has been exceeded often in the past and was exceeded in this data set both before, during and after the dredging operations. The peak of about 250 µg/L occurred before dredging in January 2024 upstream of the dredging area at GL-SQB (Fig. 2). A large bloom beginning in May and ongoing through June 2024 at SQB-BR and GL-P, following the onset of dredging in late April and concurrent with the fish kill in mid-May. Researchers from UNCW and Cape Fear River Watch described burning sensations in the eyes and throat, suggesting a toxin was produced by this algal bloom. This bloom was lake wide; note that blooms have commonly occurred in this lake during the period April-September (Mallin et al. 2016; Grogan et al. 2023). The blooms receded in late summer, but then a secondary bloom in the lake occurred in September, well after dredging ceased. Chlorophyll *a* decreased in October but then rose with a winter lake bloom (Fig. 3), months after cessation of dredging. Thus, blooms have occurred in the lake before, during and after dredging.

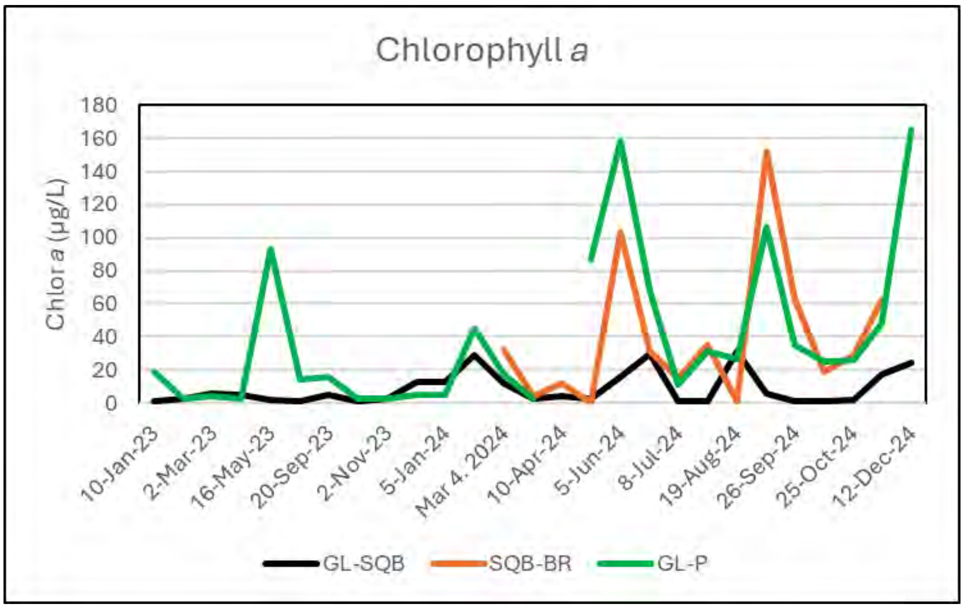


Figure 2. Chlorophyll *a* concentrations at the three sampling sites before, during and after dredging of upper Squash Branch beginning late April 2024.

Total Phosphorus

Total phosphorus (TP) is a measure of inorganic plus organic phosphorus, and includes the P incorporated within phytoplankton and zooplankton and P associated with TSS. Figure 3 shows TP variability at the three sites over time. TP was highest (> 1.2 mg-P/L) in the lake before dredging occurred in February 2023, and again high at GL-P in June 2023 (pre-dredging), possibly as a release from a phytoplankton bloom in May 2023 (Fig. 2). TP at the park was somewhat elevated in May 2024 and then all three sites were elevated in late July 2024, during dredging. Note that both a lakewide algal bloom and a fish kill occurred during early summer 2024. In fall there was a notable decrease at all three sites, then a pulse in December 2024 at both GL-SQB and GL-P (Fig. 3) concurrent with a winter algal bloom (SQB-BR was not accessible due to bridge maintenance at that time). In sum, elevated TP periodically occurs upstream of the dredged area, downstream and within the dredged area, usually concurrent with algal blooms.

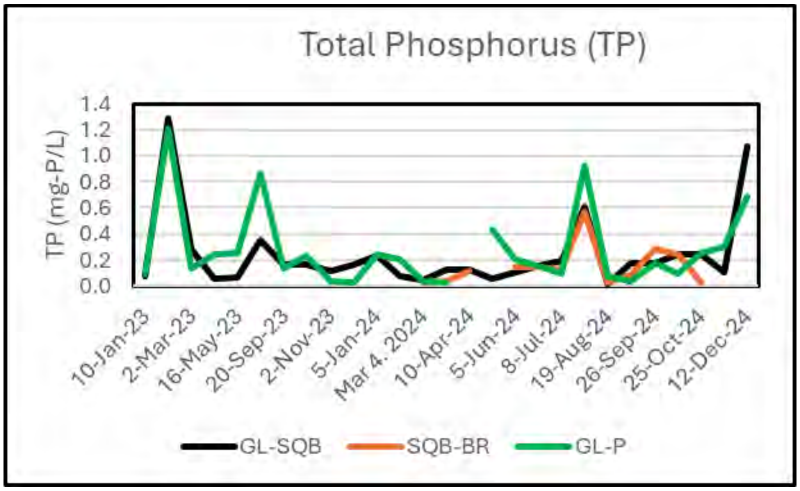


Figure 3. Total phosphorus concentrations at the three sites, before, during and after dredging of Squash Branch beginning late April 2024.

Orthophosphate

Orthophosphate (OP) is the inorganic P available in the water column. It can be sourced from upstream stormwater runoff, or remineralization from the sediments, dead animals or animal manures. The water column OP is low, not exceeding 0.30 mg-P/L at any site. There were several relatively small peaks in OP at GL-SQB and GL-P in 2023, before dredging. A minor peak occurred at the park (GL-P) during the May 13, 2024, sample, which may have been associated with dredging or a result of P remineralization from decomposing algae or fish from the kill occurring then. As noted above, a large algal bloom occurred in the lake in early June, following the OP peak and fish kill. The concentration of orthophosphate at SQB-BR is indistinguishable from that at GL-SQB and GL-P.

Fecal Coliform Bacteria

Fecal coliform bacteria are a measure of the potential presence of pathogenic fecal microbes in the water column – they are an indicator set of microbes. In freshwater, >200 colony-forming units (CFU) per 100 mL water is considered elevated. Table 1 shows summary statistical data for fecal coliform counts at SQB-BR and GL-P for the 2023-24 period; there is clearly no difference between these two in-lake stations, and concentrations are not high. In contrast, the inflowing stream GL-SQB upstream of the dredged area has very high counts from upstream generated stormwater runoff (Table 1), geometric mean 596 CFU/100 mL, median 687 CFU/100 mL, average 989 CFU/100 mL, maximum 6,500 CFU/100 mL. Neither the geometric mean nor median at SQB-BR and GL-P exceeded 14 CFU/100 mL, the average counts were 26 and 24 CFU/100 mL, respectively, and the maximum was only 145 CFU/100 mL. Thus, the dredging activities had no stimulatory impact on fecal coliform counts; they are driven primarily by upstream urban stormwater runoff.

Table 1. Fecal coliform bacteria counts, as geometric mean and median, at the three sampling locations 2023-2024.

Station	GL-SQB	SQB-BR	GL-P
Geometric mean	596	14	12
Median	687	12	12

2024 Conclusions – Water Quality

Results for several water quality parameters were presented above in relation to the 2024 (April 29-August 12) partial dredging of Squash Branch. Turbidity never exceeded the state standard of 25 NTU at any site, including just downstream for the dredge location at SQB-BR. There were brief upticks in total suspended solids at SQB-BR and GL-P after dredging commenced, but these were short lived and not as high as TSS concentrations frequently seen at the upstream control site GL-SQB. A cyanobacterial bloom occurred lake wide in June and July 2024, which is typical for any year. A fish kill began across the lake in May from Squash Branch and spread throughout; there was an influx of anoxic water from a stream at the other side of the lake concurrent with this fish kill, as well as the bloom. A spike in orthophosphate occurred in May, either from dredging or fish and algae decomposition. A peak in total phosphorus (TP) occurred in July 2024 at all three sites; possibly as a result of algal bloom decomposition coupled with fish decomposition. Note that other peaks in TP occurred in 2023 well before any dredging activity, especially in the upstream control location which collects stormwater runoff before it flows downstream. There was no impact of the dredging on downstream fecal coliform counts. Incoming stormwater-driven fecal coliform counts far exceeded any counts within the lower branch or lake. Note, however, observationally there was serious leakage and drainage of mucky material from the Geotubes toward the lake (Plate 1b) following heavy rain events, which needs addressing.

Sediment Study Results

April 2024: Sediment reactive phosphorus (RP) values averaged 2.84 ± 4.96 µg RP/g sediment and did not differ significantly among sites (by one-way ANOVA for April 2024 samples). Total phosphorus (TP) values averaged over two orders of magnitude higher than reactive P, averaging 462 ± 210 µg TP/g. To summarize, in some years Burnt Mill Creek has had problems with low dissolved oxygen (hypoxia) at the Princess Place station BMC-PP, but in 2024 most samples were within standard. Two major algal bloom occurred at BMC-PP (69 and 155 µg/L). Median N/P ratios in the lower creek indicate that inputs of nitrogen were likely to stimulate algal bloom formation in 2024, but such ratios have differed in previous years. It is notable that nutrient concentrations increased from the outfall of the regional Ann McCrary wet detention pond as one moves downstream toward the lower creek (Fig. 4.3). An important human health issue is the periodic high fecal bacteria counts found at BMC-PP and occasionally at the upper sites. As NPDES point source discharges are not directed into this creek, the fecal bacteria (and nutrient) loading appears to be caused either by non-point source stormwater runoff, illegal discharges, or leakage from sanitary sewer lines. We note that strong statistical correlations between fecal coliform counts, TSS, BOD and rainfall have been previously demonstrated for this creek (Mallin et al. 2009b), indicating as stormwater runoff pollution problem. As this is one of the most heavily developed creeks in the Wilmington area, it also remains one of the most polluted. but varied significantly among sites for April 2024 with SQB-4 highest and GL-P lowest. WLOI values did not differ significantly among sites (according to one-way ANOVA). WLOI values indicated *highly organic sediments*, with %WLOI averaging 35.9% and varying from ~11% to ~57%. There was no significant effect of WLOI on RP values (as per linear regression analysis) nor was there an effect of WLOI on TP values.

October, 2024 sediment samples: Sediment samples collected from the same locations as in April 2024 using the same methods exhibited a 90% plus <u>decline</u> in sediment P values in comparison (Table 2). RP values averaged 0.55 ± 0.40 ug RP/g sediment and TP values averaged 26.5 ± 8.23 µg TP/g sediment. One-way ANOVA demonstrated that there were no significant differences among sites with respect to RP or TP values, notably no differences between sites that had been dredged (SQB 1-SQB3) and sites that had not been dredged (SQB4, SQBM and G-LP), indicating a lake-wide change in sediment P values during the interval. Similarly, there was no significant difference among sites with respect to WLOI values by one-way ANOVA.

Comparisons of sediment phosphorus values between April and October sampling events demonstrated significantly higher RP values in April samples (with one outlier in the April data set removed) by one-way ANOVA ($F=14.0$, $df=1,33$, $p=0.0007$). Similarly, comparisons of TP values between April and October (Table 2) by one-way ANOVA demonstrated a significant decline between April and October ($p<0.0001$). Comparisons of WLOI values by one-way ANOVA, however, demonstrated no significant difference between sampling times.

Table 2. Total phosphorus (TP) concentrations in Squash Branch sediments between April (pre-dredging) and October 2024 (post dredging.

Station	TP-APR	TP-OCT	% reduction
SQB1	348.7	24.4	93
SQB2	591.4	34.1	94
SQB3	307.5	29.3	90
SQB4	738.0	28.9	96
SQBM	490.3	21.6	96
GLP	296.4	20.6	93

Potential Sediment Flushing by Major Rain Event

We considered the hypothesis that a heavy rain event or events in the interval between sampling times might have flushed the lake's sediments sufficiently to drive reduced sediment phosphorus values while not changing the lake's highly organic sediment feature. Sub-tropical system #8 impacted the southeast NC region Sept. 16-17, dropping as much as 20 inches of rain south of Greenfield Lake. The storm's impact was very localized. Using figures for Greenfield Lake's watershed area (2,465 acres), percent impervious cover (37%) and a conservative rainfall value of 4.2 inches (from the airport north of Wilmington), calculations yield an estimate of approximately 400,000 m^3 of runoff into the lake during those two days, assuming runoff derived only from the watershed impervious area. Based on the area of the lake (75 acres) and its average depth (2.2 m) the rainfall runoff into the lake would have displaced approximately 60% of the lake's total volume. Given the conservative values used in these calculations, it is likely that a large majority of the lake's water volume, including the easily disturbed near-bottom layers of soupy sediment, was flushed out to the Cape Fear River. Flushing may have contributed to the decline in sediment phosphorus values between April and October. (October sampling was conducted on Oct. 4, less than three weeks after the big rain event.) Regardless of the reason, dredging, or dredging plus rainfall-driven lake flushing, we were pleased to see the significantly lower sediment total phosphorus in October.

Geotube sampling: Reactive phosphorus (RP) concentrations in the first set of Geotube sediment samples averaged 4.1 ± 6.6 µg RP/g sediment and varied significantly among Geotubes, reflecting heterogeneity within the dredged sediments (one-way ANOVA, $F=5.03$, $df=6,24$, $p=0.0018$; Tukey's HSD). Total phosphorus (TP) concentrations in the first set of Geotube sediment samples averaged 26.1 ± 14.3 µg TP/g sediment and also varied significantly among Geotubes (one-way ANOVA, $F=3.36$, $df=6,24$, $p=0.015$; Tukey's HSD). RP concentrations in the second, deeper set of Geotube sediment cores averaged 8.31± 9.24 µg RP/g sediment, similarly variable but not significantly different than the values in the first set of Geotube sediment cores. TP concentrations in the second, deeper set of Geotube sediment cores averaged 35.0 ± 84.5 µg TP/g sediment, also quite variable but not significantly different than concentrations in the first set of Geotube sediment cores.

There was a strong negatively exponential relationship between RP and WLOI values in both sets of Geotube sediment samples, but a significant, positive relationship between TP and WLOI (Fig. 4), indicating stronger affinity of reactive phosphorus for sandy, less organic sediments, but higher TP concentrations in more highly organic sediments. These data also illustrate the considerable heterogeneity among individual sediment samples, which correspond to both horizontal and vertical heterogeneity in sediment composition within Squash Branch and, presumably, other portions of Greenfield Lake. Sandier sediments, with low WLOI values, also contain lower amounts of sediment P. Therefore, the greatest value of dredging would be obtained by targeting as much as possible the highly organic and P-enriched sediments, especially the surficial 'fluff' layer at the sediment-water interface

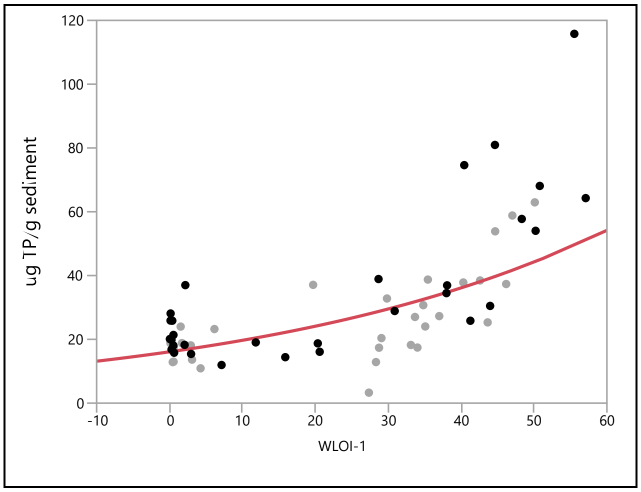


Figure 4. Bivariate log-transformed fit of µg TP/g sediment vs. WLOI in Geotube sediments (shallow (light gray symbols) and deeper (black symbols) core sample sets).

Transformed Fit Log: Log(ug TP/g sediment) = 2.78 + 0.02*WLOI, $p < 0.0001$

Calculated P Removal and Potential Impacts on Algal Growth

The Geotube TP data allow calculation of the mass of phosphorus removed by dredging and subsequent calculation of the potential impact/benefit thereof. The contractor estimates that approximately 900 m^3 of sediment were removed from Squash Branch (Z. Roman, pers. comm.). Assuming a bulk density of 2.0 g/cc or 2 metric tons (mt)/m^3 then approximately 1,800 mt of sediment were dredged from Squash Branch. If an average TP value of 31 µg/g sediment is used, then total P removal in that mass of sediment equals approximately 55 kg P. One way in which this value for P removal can be evaluated is to calculate the quantity of phytoplankton (algae) production that amount of P would support in the lake if that amount of P were dissolved into the whole lake's volume (~670,000 m^3). Assuming that phosphorus loading supports carbon production according to Redfield's ratio of 106 mol C: 1 mol P and that the ratio of µg carbon to µg chlorophyll *a* in phytoplankton (algae) is approximately 50:1, then 55 kg of P added to Greenfield Lake would theoretically support production of approximately 67 µg chl *a*/L (given adequate N) in the entire volume of the lake, which is now unavailable to the lake's phytoplankton.

Calculated Carbon Removal

Similarly, the Geotube sediment data allowed calculation of the quantity of organic matter removed by dredging. Decomposition of organic matter supports oxygen depletion in the bottom layers of Greenfield Lake's water column (i.e. biochemical oxygen demand, BOD), on top of whatever BOD the annual algae blooms add to the deoxygenation problem. Average WLOI for Geotube sediments was 23%, so we calculate that ~415 metric tons of organic matter were removed by dredging. Using a ratio of WLOI:Carbon of 1.7, we can calculate that ~245 metric tons of C (carbon) were removed by dredging. Removal of 55 kg P and 245 mt C yields a molar ratio of approximately 11,500 C:P, clearly a highly P-depleted reservoir of organic matter.

2024 Sediment Analysis Conclusions

1) Dredging can remove potentially significant amounts of organic matter and phosphorus, but targeting locations where and times when P is most heavily concentrated will have the highest cost:benefit ratio. In particular, removal of the 'fluffy', highly organic and relatively P-enriched material at the sediment-water interface will be most beneficial
2) Dewatering of dredged material onshore nearby may release dissolved (reactive) P and P associated with the finest sediment fraction, and may support aerobic decomposition and runoff of P-containing organic matter near the surface of geotubes particularly when rain soaks the Geotubes (Plate 1b). This suggests that prompt removal of dredged sediment from the watershed would be more protective of water quality; or at least, enhanced sediment fencing to control P-laden runoff.
3) The extremely high average C:P ratio in dredged sediments supports the inferences above, but also indicates that P is likely very rapidly recycled in Greenfield Lake sediments, with algal bloom implications.

7.0 Hewletts Creek

Snapshot
Watershed area: 7,478 acres (3,028 ha)
Impervious surface coverage: 25.1% (2013 data)
Watershed population: Approximately 20,200
Overall water quality: Good-Fair
Problematic pollutants: occasional high fecal bacteria, minor algal bloom issues

Hewletts Creek was sampled five times at three tidally influenced areas (NB-GLR, MB-PGR and SB-PGR) - Fig. 7.1). Based on these data, at all sites the physical data indicated that turbidity was well within State standards during this sampling period during all sampling events. TSS levels were below 25 mg/L at all times sampled (Table 7.2). Dissolved oxygen was within standard on all sampling occasions.

Nitrate concentrations were low in general but a bit higher at MB-PGR (Table 7.1) which receives inputs from the Wilmington Municipal Golf Course (Fig. 7.1; Mallin and Wheeler 2000). Ammonium concentrations were low to moderate at most sites. Total nitrogen was low to moderate at all sites. Orthophosphate concentrations were low, and total phosphorus concentrations ranged from low to moderate. Mean N/P ratios were somewhat elevated in most sites except, indicating that at times P can stimulate algal growth at most of these sites. Mallin et al (2004) demonstrated that P can occasionally be the limiting nutrient in upper tidal creek reaches, while N is typically limiting at lower creek sites. The chlorophyll *a* data (Tables 7.1) showed that no major blooms occurred during the sampling runs; NB-GLR had one minor bloom of 22 µg/L chlorophyll *a* in June. Fewer blooms have occurred in the past few years than had previously occurred in upper Hewletts Creek (Mallin et al. 1998; 2004; Duernberger 2009). We note that water quality in the south branch of Hewletts Creek improved significantly following construction of a large stormwater treatment wetland in 2007 (Mallin et al. 2012).

Fecal coliform bacteria counts did not exceeded the State standard at SB-PGR. However, the standard was exceeded three times at both NB-GLR and MB-PGR, where the geometric mean was 291 CFU/100 mL.

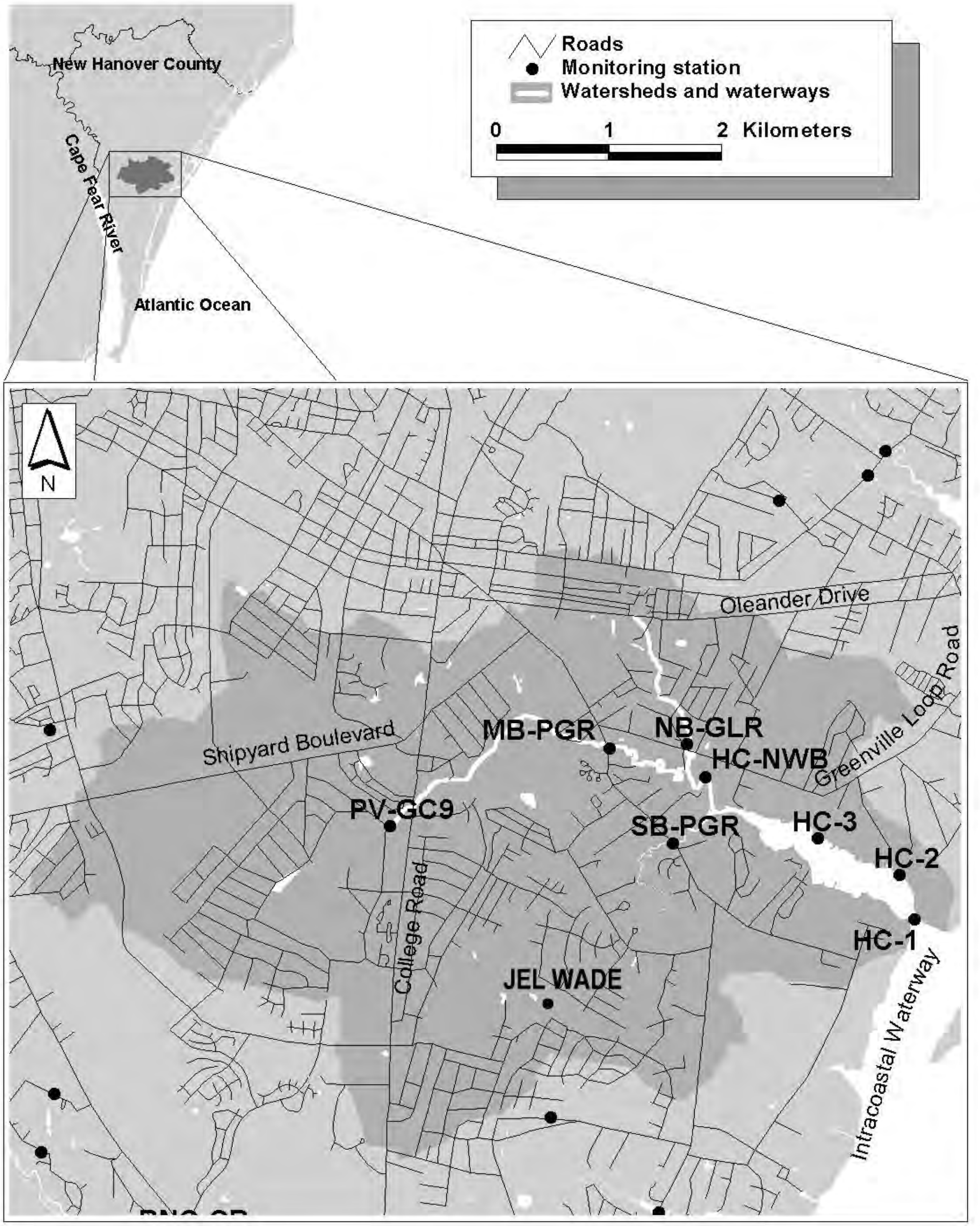


Figure 7.1. Hewletts Creek watershed.

Table 7.1. Selected water quality parameters at stations in Hewletts Creek watershed, 2024, as mean (standard deviation) / range, fecal coliforms as geometric mean / range, n = 5 samples collected.

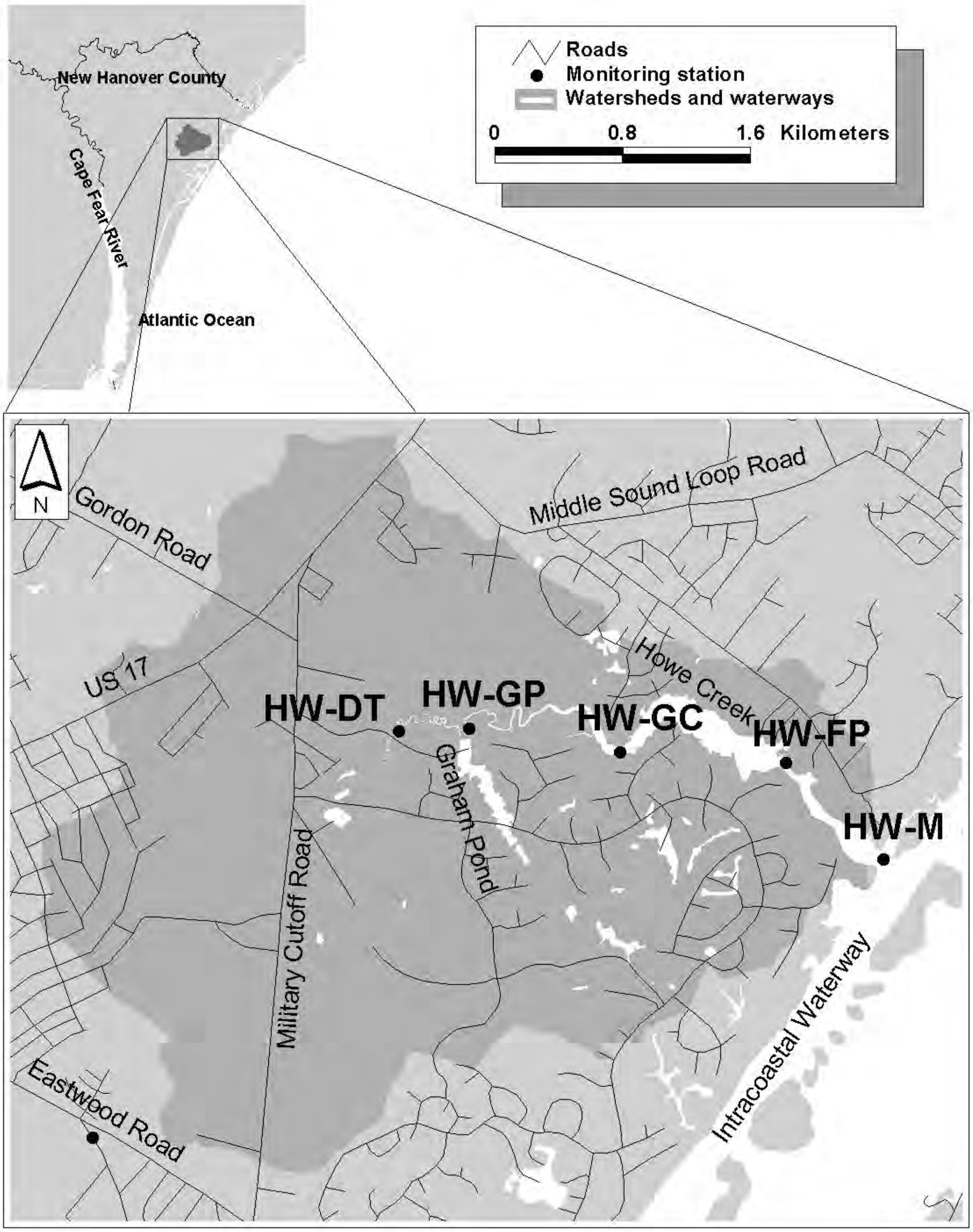
Parameter	SB-PGR	MB-PGR	NB-GLR
Salinity (ppt)	25.4 (8.1) 13.6-33.7	2.5 (5.1) 0.1-11.5	17.5 (11.9) 4.7-32.7
Turbidity (NTU)	4 (2) 2-6	1 (1) 0-3	4 (2) 2-6
TSS (mg/L)	14 (5) 10-23	3 (3) 1-8	13 (13) 7-21
DO (mg/L)	7.2 (1.9) 5.2-9.5	7.6 (0.7) 6.7-8.3	7.7 (1.6) 5.8-9.4
Nitrate (mg/L)	0.03 (0.03) 0.01-0.07	0.24 (0.03) 0.20-0.28	0.06 (0.04) 0.01-0.10
Ammonium (mg/L)	0.31 (0.22) 0.01-0.61	0.02 (0.01) 0.01-0.04	0.10 (0.11) 0.01-0.25
TN (mg/L)	0.60 (0.21) 0.41-0.96	0.62 (0.15) 0.39-0.73	0.66 (0.40) 0.31-1.35
Orthophosphate (mg/L)	0.02 (0.02) 0.01-0.05	0.02 (0.01) 0.02-0.04	0.02 (0.01) 0.01-0.03
TP (mg/L)	0.22 (0.32) 0.01-0.78	0.23 (0.21) 0.01-0.47	0.35 (0.41) 0.02-0.83
Mean N/P ratio Median	43 44	23 25	21 8
Chlor *a* (µg/L)	8 (6) 2-14	3 (3) 1-7	9 (8) 2-22
Fecal coliforms (CFU/100 mL)	55 3-150	291 127-1,320	217 41-637

8.0 Howe Creek Water Quality

Snapshot
Watershed area: 3,516 acres (1,424 ha)
Impervious surface coverage: 21.4%
Watershed population: Approximately 6,460
Overall water quality: Fair-Poor
Problematic pollutants: Fecal coliform bacteria, algal blooms

Howe Creek drains a 3,516 acre watershed into the ICW (Fig. 8.1). Two to five stations have been sampled in this creek in various years. Due to resource re-allocation, sampling was suspended for the time being in 2020, but sampling will recommence in summer 2025.

Figure 8.1. Howe Creek watershed and sampling sites used in various years.

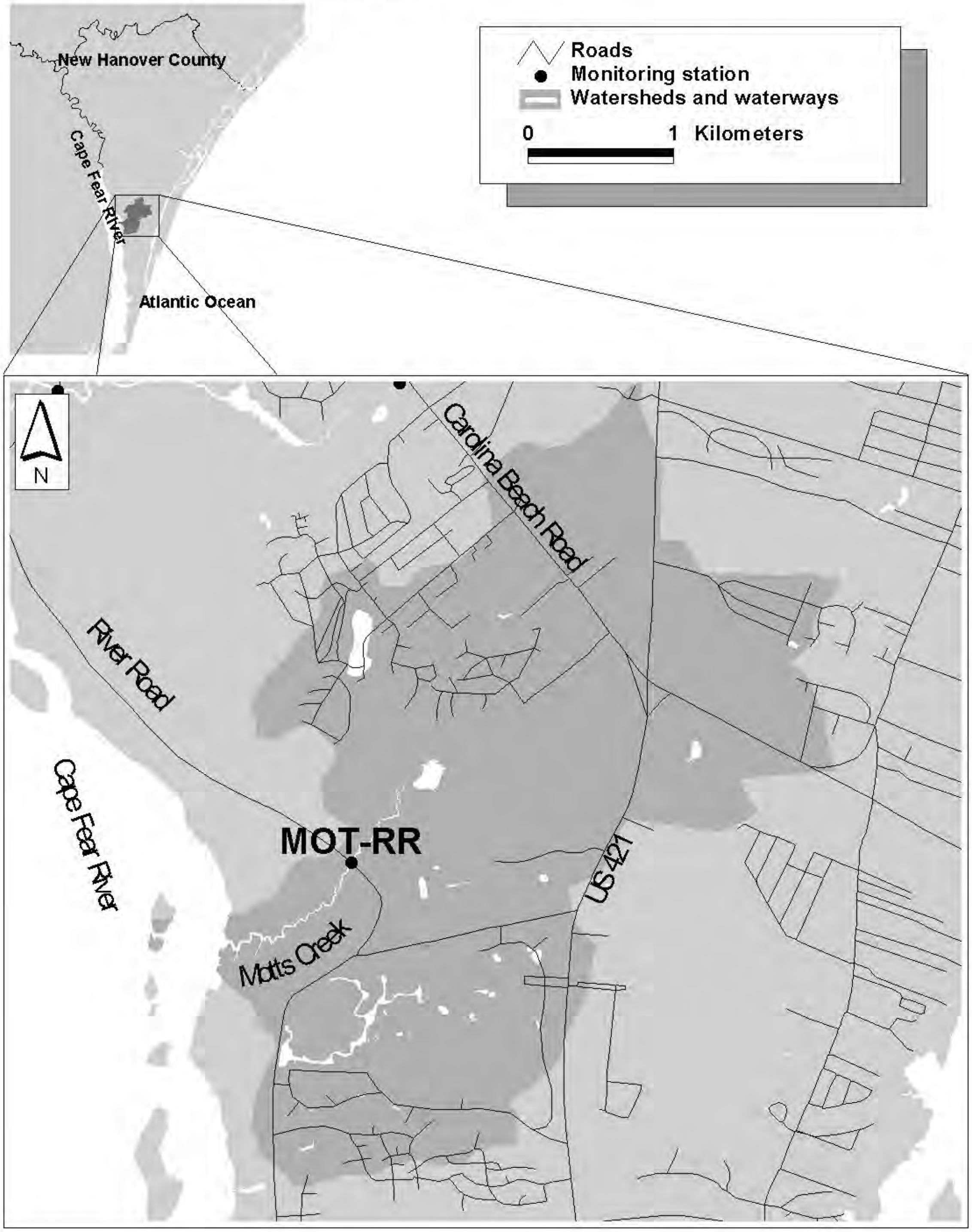


9.0 Motts Creek

Snapshot
Watershed area: 3,328 acres (1,354 ha)
Impervious surface coverage: 23.4%
Watershed population: 9,530
Overall water quality: poor
Problematic pollutants: Periodic algal blooms; high fecal coliform bacteria

Motts Creek drains into the Cape Fear River Estuary (Fig. 9.1), and the creek area near River Road has been classified by the State of North Carolina as a Natural Heritage Site because of the area's biological attributes. These include the pure stand wetland communities, including a well-developed sawgrass community with large cypress in the swamp forest. City funding received by UNCW in late 2017 allowed us to re-initiate sampling of Motts Creek at River Road (MOT-RR) 2018-2019. Due to resource re-assignment, city sampling is currently suspended on this creek.

Figure 9.1 Motts Creeks watershed

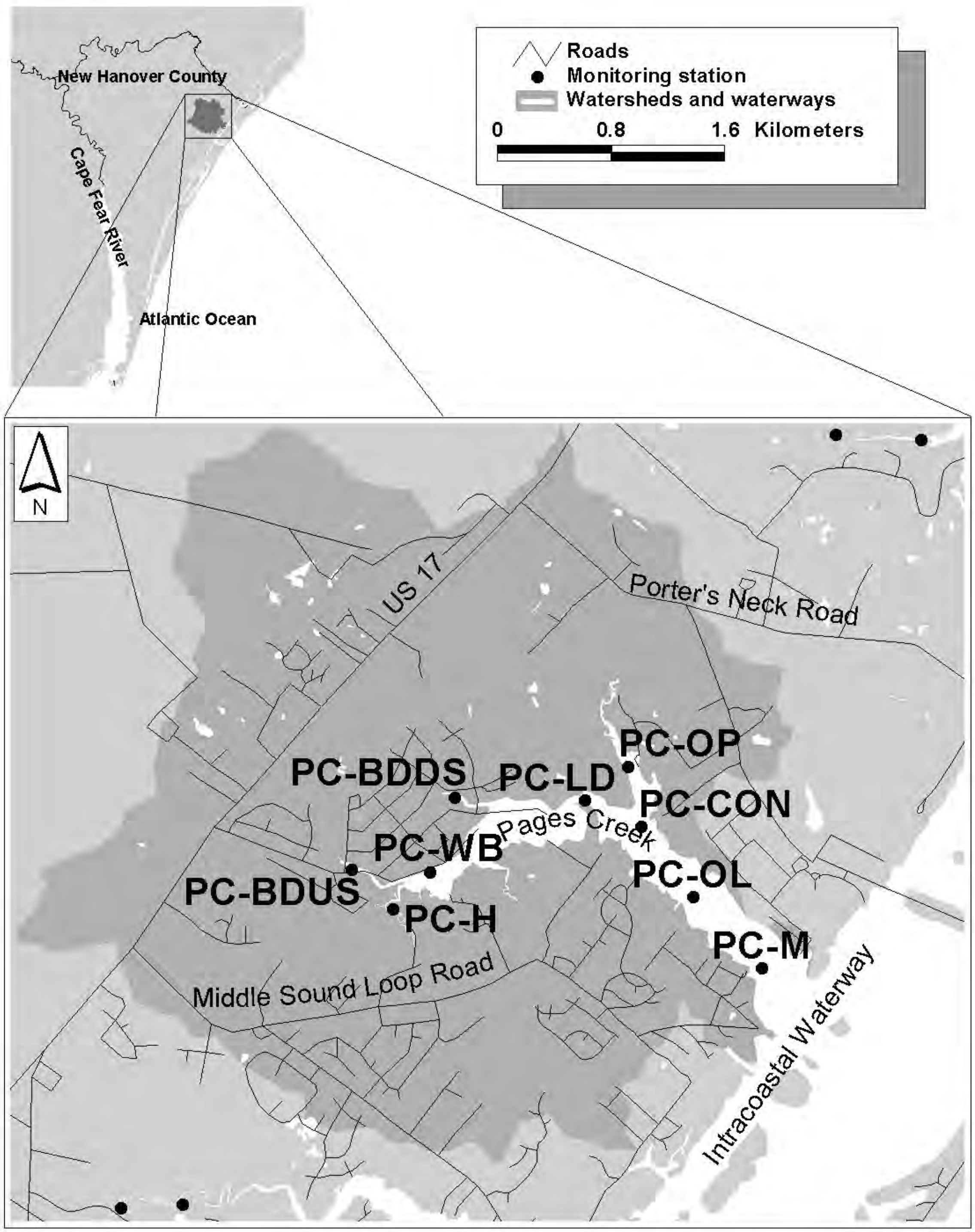


10.0 Pages Creek

Snapshot
Watershed area: 5,025 acres (2,035 ha)
Impervious surface coverage: 17.8% (2014 data)
Watershed population: Approximately 8,390

The University of North Carolina Wilmington was not funded by the County since 2007 to sample Pages Creek. Subsequent County-sponsored sampling of this creek was performed by a consulting firm, with data and information for this creek available from the County.

Figure 10.1. Pages Creek watershed and sampling sites.



11.0 Smith Creek

Snapshot
Watershed area: 16,650 acres (6,743 ha)
Impervious surface coverage: 21.3% (2014 data)
Watershed population: 31,780
Overall water quality: Good to Fair
Problematic pollutants: occasional turbidity, low dissolved oxygen and fecal coliform pollution, but all these parameters were rated Good in 2024.

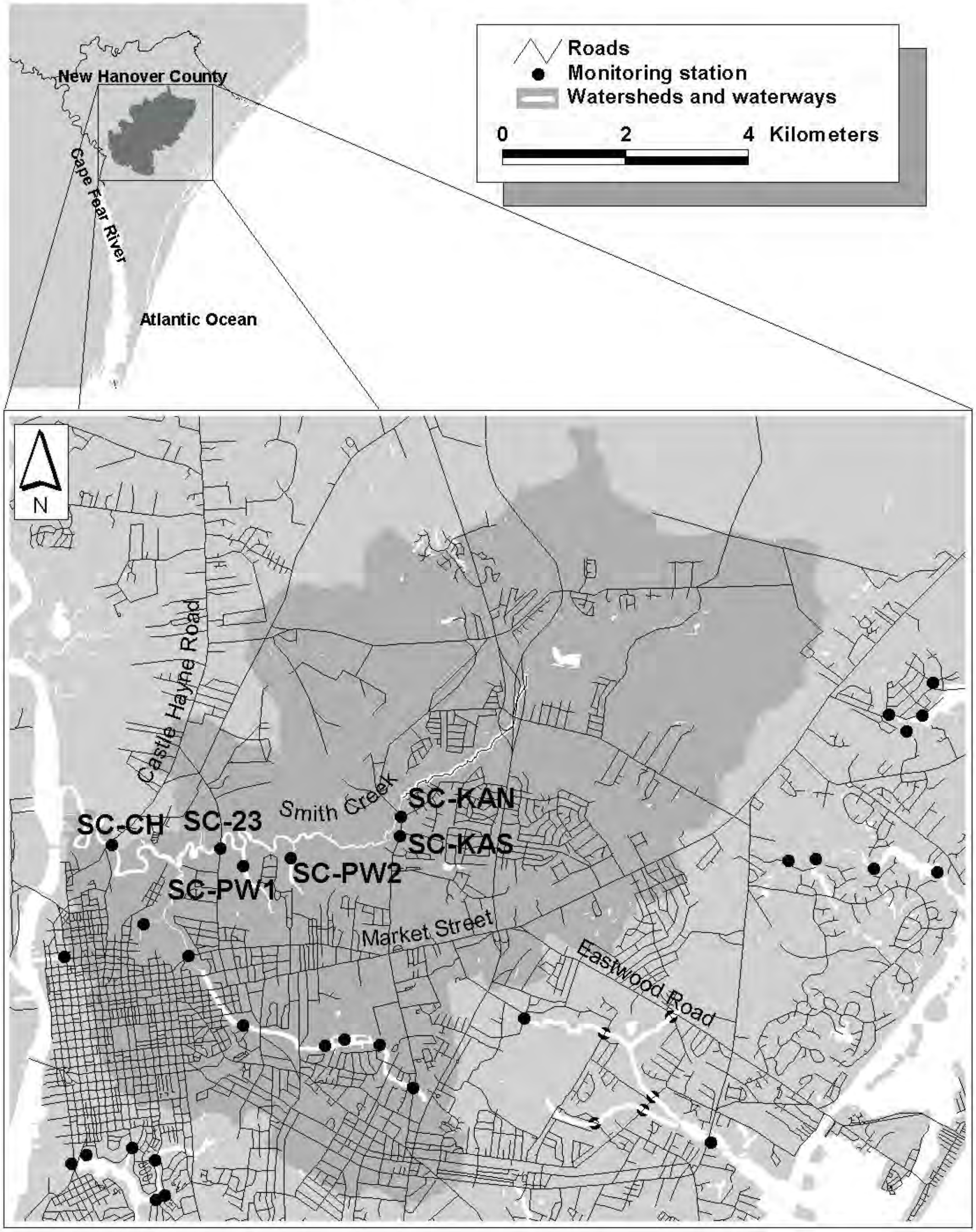
Smith Creek drains into the lower Northeast Cape Fear River just before it joins with the mainstem Cape Fear River at Wilmington (Fig. 11.1). One location on Smith Creek, SC-CH at Castle Hayne Road (Fig. 11.1) is normally sampled monthly by UNCW under the auspices of the Lower Cape Fear River Program for selected parameters (field physical parameters, nutrients, chlorophyll and fecal coliform bacteria) and these data are normally summarized below (Table 11.1). However, note that in 2023 no samples were collected as bridge construction was ongoing all year at the sampling station. Sampling began again in 2024 and 12 monthly collections were made.

Salinity averaged 4.8, making this a generally mesohaline station. All turbidity samples were well below the brackish standard of 25 NTU. TSS was generally low, with one elevated incidence of 34.4 mg/L October. Ammonium and nitrate were low to moderate. Total phosphorus (TP) low to moderate except for two incidents, June and August, where TP was 0.61 and 0.80 mg/L, respectively (Table 1.1). All chlorophyll *a* samples were below the state standard, and all fecal coliform samples were below 150 CFU/100 mL, thus, this station on Smith Creek was rated Good by UNCW researchers for 2024.

Table 11.1. Selected water quality parameters in Smith Creek watershed as mean (standard deviation) / range, 2024, n = 12 samples collected.

Parameter	SC-CH	
	Mean (SD)	Range
Salinity (ppt)	4.8 (4.7)	0.0-10.6
Dissolved oxygen (mg/L)	6.6 (1.9)	3.7-9.3
Turbidity (NTU)	8.4 (2.5)	5-14
TSS (mg/L)	14.8 (7.0)	7.8-34.4
Ammonium (mg/L)	0.09 (0.08)	0.01-0.19
Nitrate (mg/l)	0.23 (0.15)	0.01-0.40
Total nitrogen (mg/L)	1.24 (0.29)	0.91-1.95
Total phosphorus (mg/L)	0.25 (0.24)	0.07-0.80
Chlorophyll *a* (µg/L)	6.9 (9.5)	0.0-31.0
Fecal col. /100 mL (geomean / range)	33	1-145

Figure 11.1 Smith Creek watershed

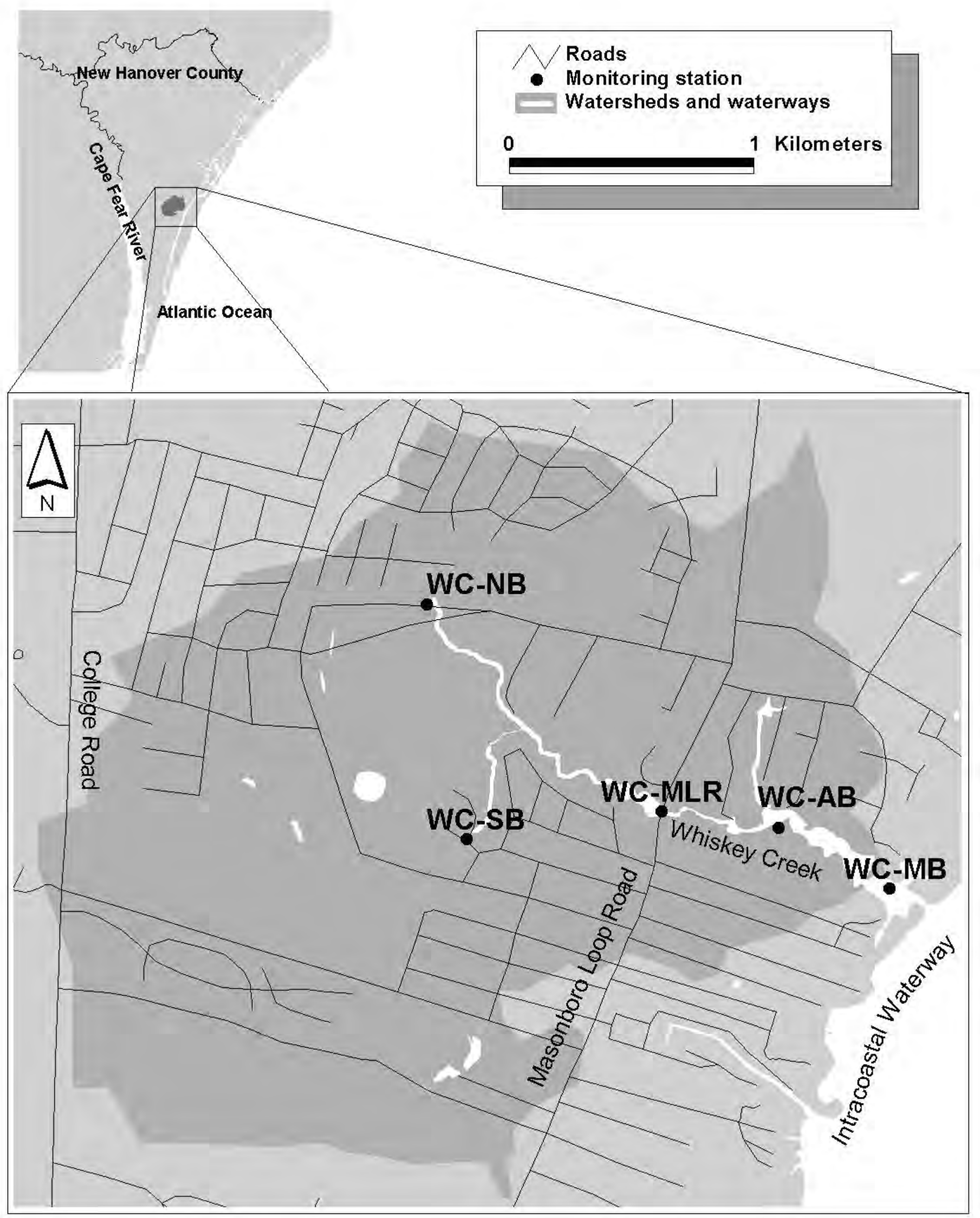


12.0 Whiskey Creek

Snapshot
Watershed area: 2,078 acres (842 ha)
Impervious surface coverage: 25.1% (2014)
Watershed population: 7,980
Overall Water Quality: Good-Fair
Problematic pollutants: Occasional high fecal coliform counts; occasional minor low dissolved oxygen issue

Whiskey Creek drains into the ICW. Sampling of this creek began in August 1999, at five stations. One station was dropped due to access issues in 2005; four stations were sampled until and including 2007; in 2008 this was reduced to one station, WC-MLR (from the bridge at Masonboro Loop Road – Fig. 12.1). Due to resource reassignment, sampling is currently suspended on this creek.

Figure 12.1. Whiskey Creek Watershed and sampling sites.



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14.0 Acknowledgments

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15.0 Appendix A. North Carolina Water Quality standards for selected parameters (NCDENR 2003; 2005). We note that these standards are general and differ with designated water body use. Details can be found at within the N.C. Division of Water quality website at: http://h2o.enr.state.nc.us/csu/documents/ncactable290807.pdf

Parameter	Standard
Dissolved oxygen	5.0 ppm (mg/L); for designated “swamp” waters it is 4.0 ppm
Turbidity	25 NTU (tidal saltwater) 50 NTU (freshwater streams), 25 NTU (lakes and reservoirs)
Fecal coliform counts	14 CFU/100 mL (shellfishing waters), and more than 10% of the samples cannot exceed 43 CFU/100 mL. 200 CFU/100 mL (human contact waters)
Chlorophyll *a*	40 ppb (μg/L)

CFU = colony-forming units
mg/L = milligrams per liter = parts per million
μg/L = micrograms per liter = parts per billion

16.0 Appendix B. UNCW ratings of sampling stations in Wilmington watersheds based on 2024, where available, for chlorophyll *a*, dissolved oxygen, turbidity, and fecal coliform bacteria (human contact standard) based in part on North Carolina state chemical standards for freshwater or tidal saltwater.

G (good quality) – state standard exceeded in ≤ 10% of the measurements
F (fair quality) – state standard exceeded in 11-25% of the measurements
P (poor quality) – state standard exceeded in >25% of the measurements

Watershed	Station	Chlor *a*	DO	Turbidity	Fecal coliforms
Bradley Creek	BC-RD	F	F	G	P
	BC-CA	F	F	G	P
	BC-MS	G	G	G	P
	BC-SB	G	G	G	P
	BC-NB	G	G	G	G
Barnards Creek	CHP-U	G	G	G	P
	CHP-D	G	G	G	P
Burnt Mill Creek	BMC-AP3	F	G	G	G
	BMC-PP	P	F	G	P
Greenfield Lake	JRB-17	G	F	G	P
	GL-JRB	G	P	G	P
	GL-SQB	G	P	G	P
	SQB-BR	P	G	G	G
	GL-2340	G	P	G	P
	GL-YD	P	G	G	G
	GL-P	P	F	G	G
Hewletts Creek	NB-GLR	G	G	G	P
	MB-PGR	G	G	G	P
	SB-PGR	G	G	G	G
Smith Creek	SC-CH	G	G	G	G

17.0 Appendix C. GPS coordinates for the Wilmington Watersheds Project sampling stations used during various years.

Watershed	Station	GPS coordinates	
Barnard's Creek	BNC-RR	N 34.15867	W 77.93784
	CHP-U	N 34.1682	W 77.9102
	CHP-D	N 34.1680	W 77.9102
Bradley Creek	BC-RD	N 34.23249	W 77.87071
	BC-CA	N 34.23260	W 77.86659
	BC-CR	N 34.23070	W 77.85251
	BC-SB	N 34.21963	W 77.84593
	BC-SBU	N 34.21724	W 77.85435
	BC-NB	N 34.22138	W 77.84424
	BC-NBU	N 34.23287	W 77.84036
	BC-76	N 34.21484	W 77.83368
Burnt Mill Creek	BMC-KA1	N 34.22215	W 77.88522
	BMC-KA3	N 34.22279	W 77.88592
	BMC-AP1	N 34.22917	W 77.89173
	BMC-AP2	N 34.23016	W 77.89805
	BMC-AP3	N 34.22901	W 77.90125
	BMC-WP	N 34.24083	W 77.92415
	BMC-PP	N 34.24252	W 77.92515
	BMC-ODC	N 34.24719	W 77.93304
Futch Creek	FC-4	N 34.30150	W 77.74660
	FC-6	N 34.30290	W 77.75050
	FC-8	N 34.30450	W 77.75414
	FC-13	N 34.30352	W 77.75760
	FC-17	N 34.30374	W 77.76370
	FOY	N 34.30704	W 77.75707
Greenfield Lake	GL-SS1	N 34.19963	W 77.92460
	GL-SS2	N 34.20051	W 77.92947
	GL-LC	N 34.20752	W 77.92976
	JRB-17	N 34.21300	W 77.92480
	GL-JRB	N 34.21266	W 77.93157
	GL-LB	N 34.21439	W 77.93559
	GL-2340	N 34.19853	W 77.93556
	GL-YD	N 34.20684	W 77.93193
	GL-P	N 34.21370	W 77.94362
Hewletts Creek	HC-M	N 34.18230	W 77.83888
	HC-2	N 34.18723	W 77.84307

	HC-3	N 34.19011	W 77.85062
	HC-NWB	N 34.19512	W 77.86155
	NB-GLR	N 34.19783	W 77.86317
	MB-PGR	N 34.19800	W 77.87088
	SB-PGR	N 34.19019	W 77.86474
	PVGC-9	N 34.19161	W 77.89177
Howe Creek	HW-M	N 34.24765	W 77.78718
	HW-FP	N 34.25468	W 77.79510
	HW-GC	N 34.25448	W 77.80512
	HW-GP	N 34.25545	W 77.81530
	HW-DT	N 34.25562	W 77.81952
Motts Creek	MOT-RR	N 34.12924	W 77.91611
Pages Creek	PC-M	N 34.27020	W 77.77123
	PC-OL	N 34.27450	W 77.77567
	PC-CON	N 34.27743	W 77.77763
	PC-OP	N 34.28292	W 77.78032
	PC-LD	N 34.28090	W 77.78485
	PC-BDDS	N 34.28143	W 77.79447
	PC-WB	N 34.27635	W 77.79582
	PC-BDUS	N 34.27702	W 77.80163
	PC-H	N 34.27440	W 77.79890
Smith Creek	SC-23	N 34.25794	W 77.91956
	SC-CH	N 34.25897	W 77.93872
	SC-KAN	N 34.26249	W 77.88759
	SC-KAS	N 34.25964	W 77.88778
Whiskey Creek	WC-NB	N 34.16803	W 77.87648
	WC-SB	N 34.15939	W 77.87481
	WC-MLR	N 34.16015	W 77.86629
	WC-AB	N 34.15967	W 77.86177
	WC-MB	N 34.15748	W 77.85640

18.0 Appendix D. Sampling station sub-watershed drainage area and percent impervious surface coverage, 2015 (compiled by Anna Robuck).

Sampling Station	Catchment Polygon Area (acres)	Percent Impervious
Hewletts Creek		
PVGC-9	1296.1	27.5%
MB-PGR	2044.5	27.5%
NB-GLR	876.4	29.8%
SB-PGR	1480.2	27.4%
HC-NWB	3185.1	27.4%
HC-3	5117.5	26.6%
HC-2	5557.1	25.3%
HC-M	5642.2	25.0%
Barnards Creek		
BNC-EF	154.6	20.8%
BNC-TR	277.4	25.5%
BNC-AW	196.0	22.2%
BNC-CB	1077.8	31.6%
BNC-RR	3437.3	25.3%
Burnt Mill Creek		
BMC-KA1	191.4	63.3%
BMC-KA3	195.1	62.3%
BMC-AP1	995.1	46.2%
BMC-AP2	1036.4	44.9%
BMC-AP3	1537.2	42.3%
BMC-GS	256.9	47.8%
BMC-WP	2981.9	39.5%
BMC-PP	3030.8	39.3%
BMC-ODC	772.0	47.8%
Bradley Creek		
BC-SBU	439.5	28.0%
BC-NBU	683.6	33.5%
BC-RD	98.5	90.0%
BC-CA	372.1	82.0%
BC-CR	649.7	46.3%
BC-SB	1022.3	28.9%
BC-NB	2047.6	31.9%
BC-76	3589.0	29.8%
Whiskey Creek		
WC-NB	211.6	31.1%
WC-SB	734.7	25.2%

WC-MLR	1378.1	26.0%
WC-AB	1552.2	25.5%
WC-MB	1643.3	25.0%
Futch Creek		
FC-13	726.6	25.6%
FC-17	692.5	25.9%
FC-FOY	2261.0	6.6%
FC-8	1086.6	24.2%
FC-6	3447.4	12.0%
FC-4	3651.2	12.4%
Greenfield Lake		
GL-SS1	140.2	66.8%
GL-SS2	264.1	53.4%
GL-2340	422.2	73.6%
JRB-17	595.4	22.3%
GL-JRB	795.8	25.9%
GL-LC	94.2	63.6%
GL-YD	978.0	30.4%
GL-SQB	130.8	49.2%
GL-P	2402.4	37.8%
Motts Creek		
MOT-RR	2350.1	27.7%
Howe Creek		
HW-DT	1255.2	29.4%
HW-GP	1794.3	25.5%
HW-GC	2368.2	25.0%
HW-FP	2737.1	23.8%
HW-M	3103.6	23.0%
Smith Creek		
SC-KAN	10605.4	19.5%
SC-KAS	2153.5	39.5%
SC-23	14803.3	22.6%
SC-CH	15837.8	22.5%
Pages Creek		
PC-BDUS	345.1	25.7%
PC-H	1019.7	22.8%
PC-WB	1444.6	22.9%
PC-BDDS	357.8	27.7%
PC-LD	2296.4	22.2%
PC-OP	1788.9	15.7%
PC-CON	1949.5	15.2%
PC-OL	4378.8	18.7%
PC-M	4615.9	18.3%

19.0 Appendix E. University of North Carolina at Wilmington reports and papers concerning water quality in Wilmington and New Hanover County's tidal creeks.

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