Water Quality Sampling Field Report

First State National Park
Brandywine-Piedmont Watershed
2015-2016

April 2016

Prepared by:

Mika Ulmet
The Nature Conservancy of Delaware
Wilmington, Delaware

Erica Rossetti and Samantha Serratore
University of Delaware
Water Resources Center
Newark, Delaware

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Abstract

Several chemical, nutrient, and biological indicators can help determine water quality and ecosystem health. As a newly designated national park, students at the University of Delaware found it important to monitor, record, and analyze several parameters including temperature, pH, conductivity, dissolved oxygen, turbidity, bacteria, nutrients, and metals to determine the general health of tributaries flowing through the Brandywine-Piedmont watershed in Delaware's First State National Historic Park. Using probes and lab facilities from the City of Wilmington and the University of Delaware, data was gathered from twelve sites throughout the watershed several times over a period of nine months. Students analyzed data according to parameter, date, and statistical averages. When compared to standards, the results showed little to no nutrient and chemical impairments, but there were some indications of chemical and bacterial concern in sites adjacent to agricultural and commercialized areas, indicative of runoff pollution or other non-point sources. As a result of these conclusions, it is the researcher's hope that the newly designated First State National Historic Park will act as a natural water quality improvement system or that the National Park Service will proceed with further investigations in order to prevent the degradation of the water quality in the watershed as indicated by this preliminary research.

Chapter 1: Introduction and Purpose

1.1. Background

On March 25, 2013, President Barack Obama signed an Executive Order by authority of Theodore Roosevelt's 1906 Antiquities Act that created First State National Monument that includes the 1,100 acre Woodlawn Unit along the west bank of the Brandywine Creek in Delaware and Pennsylvania. The Mt. Cuba Center provided funds to acquire the property from the Woodlawn Trustees and transferred the title to the National Park Service. In December 2014, Congress voted to create the First State National Historical Park (FSNHP) in the National Defense Authorization Act of 2015, and the President signed the bill to make it Delaware's first national park.

1.2. Justification

The National Park Service is preparing a master plan for development of FSNHP as part of a foundation document with input from the Woodlawn Coalition, which is coordinated by The Nature Conservancy. During the months of June, July, October, November, and December in 2015 and March through April 2016, student research assistants and interns from the University of Delaware Water Resources Center conducted a water quality sampling project that focused on six streams feeding into the Brandywine Creek at the First State National Historical Park (FSNHP) in Beaver Valley, Delaware. The purpose of monitoring these sites is to further characterize Piedmont streams that flow west to the Brandywine Creek. Students chose twelve (12) prominent water quality sampling sites located in six (6) sub-watersheds of the Brandywine Piedmont watershed. These tributaries flow through areas impacted by agriculture, commercialized and industrialized zones, transportation byways, and residential neighborhoods. As these tributaries are connected to the primary source of Wilmington's drinking water, the Brandywine Creek, it is important to monitor the water quality levels of these streams to ensure that they are healthy enough for human uses and as an overall guide for actions that should be taken by the National Park Service as well as the Delaware Division of Parks and Recreation.

Beaver Creek, Talley Run, and Rocky Run are listed on the Draft Delaware Department of Natural Resources and Environmental Control (DNREC) 2014 Clean Water Act Section 303(d) for impaired habitat and biology. As a result, it is important to determine the root cause of these impairments whether it be from land erosion, heavy use of agriculture or waste/stormwater runoff. This project will help determine the current health of the tributaries flowing into the Brandywine Creek. Long term monitoring of variables such as temperature, pH, dissolved oxygen, conductivity, and turbidity will provide the framework for current and future trends. The areas in concern for this project include the FSNHP at

Woodlawn, which is operated by the National Park Service, and the adjacent Brandywine Creek State Park, which is owned by the Delaware Division of Parks and Recreation (Figures 1.2 and 1.3).

Figure 1.1. Summer 2015 field crew from the University of Delaware and The Nature Conservancy. Left to right: Seth Olson (DWRC undergraduate intern), Erica Rossetti (DWRC undergraduate intern), Kristen Molfetta (IPA WRA graduate research fellow), Laura Askin (IPA WRA graduate research fellow), and Mika Ulmet (The Nature Conservancy GLOBE intern). Not pictured: Maria Dziembowska (The Nature Conservancy), Maya Kassoff (UD undergraduate research assistant), Gerald Kauffman (UDWRC director and student advisor), and Samantha Serratore (DWRC undergraduate intern).

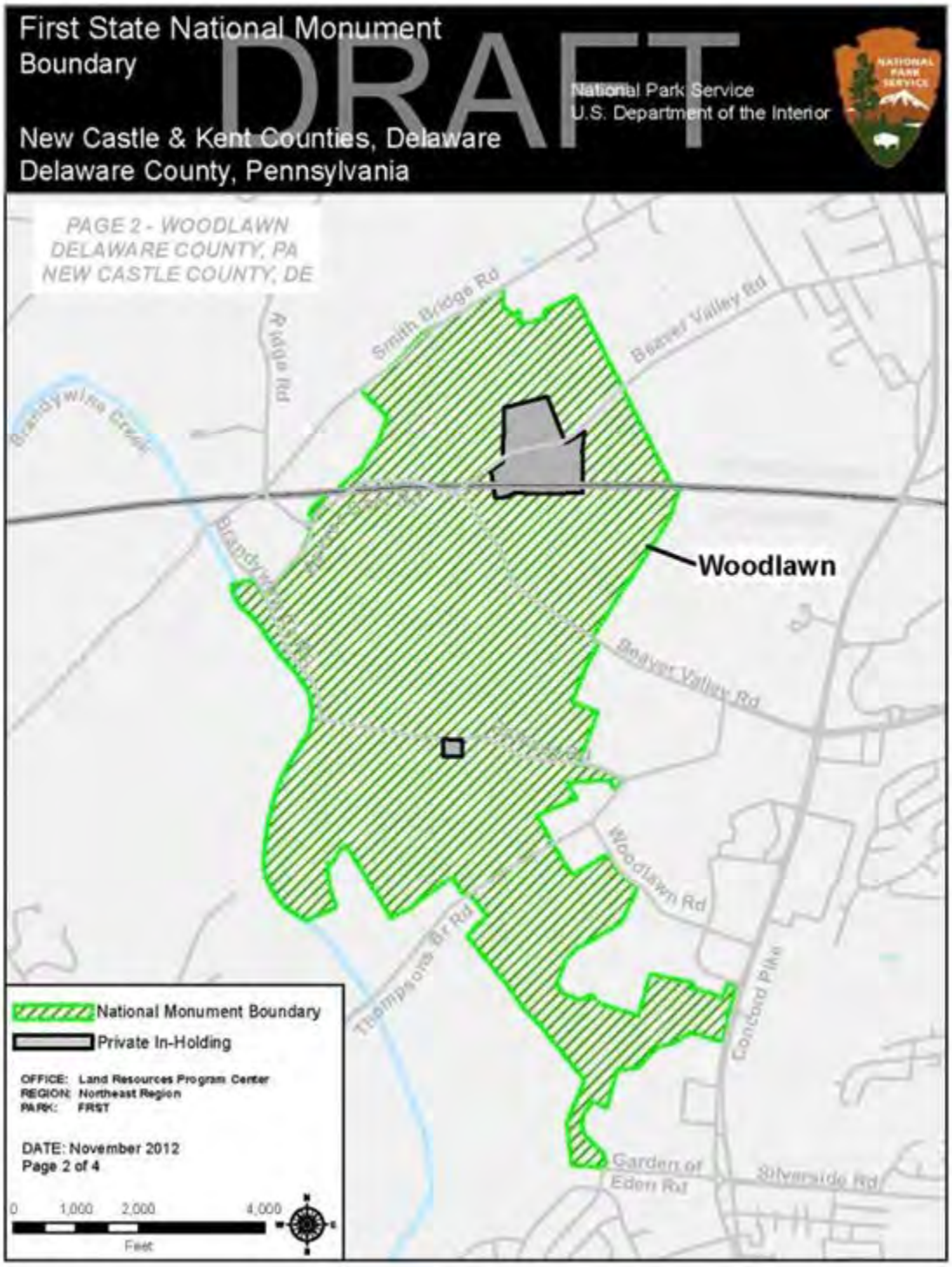


Figure 1.2. First State National Historic Park boundary

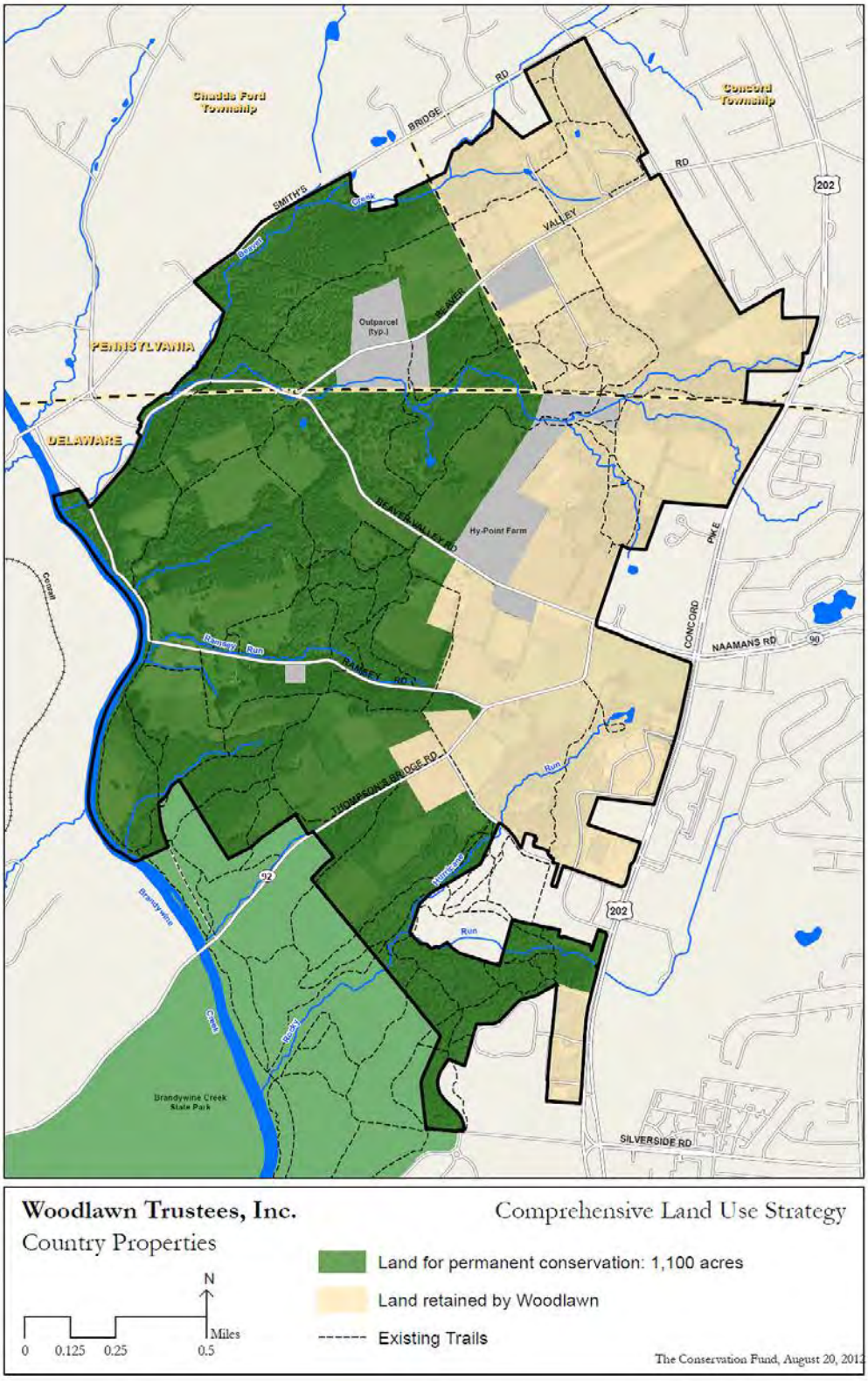


Figure 1.3. First State National Historic Park - Woodlawn Unit

Chapter 2: Watershed Characterization

The Brandywine Piedmont Watershed Plan (BPWP) is designed to protect and restore the scenic watersheds that flow through the newly designated First State National Historical Park at Woodlawn operated by the National Park Service and adjacent Brandywine Creek State Park owned by the Delaware Division of Parks and Recreation. The summer 2014 field crews from the University of Delaware characterized these watersheds by land use, impervious cover, slope, soils, and geology.

2.1. Ridge Run

The 262-acre Ridge Run watershed borders the northerly boundary of the FSNP Woodlawn unit and forms in the headwaters at 400 feet above sea level in Pennsylvania and flows for 1.5 miles into Delaware to the confluence with the Brandywine Creek at Smith's Bridge. The watershed is lightly developed (0.3% impervious) and land use is 19% forest/wetlands, 5% urban/suburban, and 77% agriculture primarily meadow, horse farms, and some corn and soybeans. The steeply sloped watershed (12% slopes) is covered by soils in all four hydrologic soil groups. Geology of the watershed is the Wissahickon Formation gneiss.

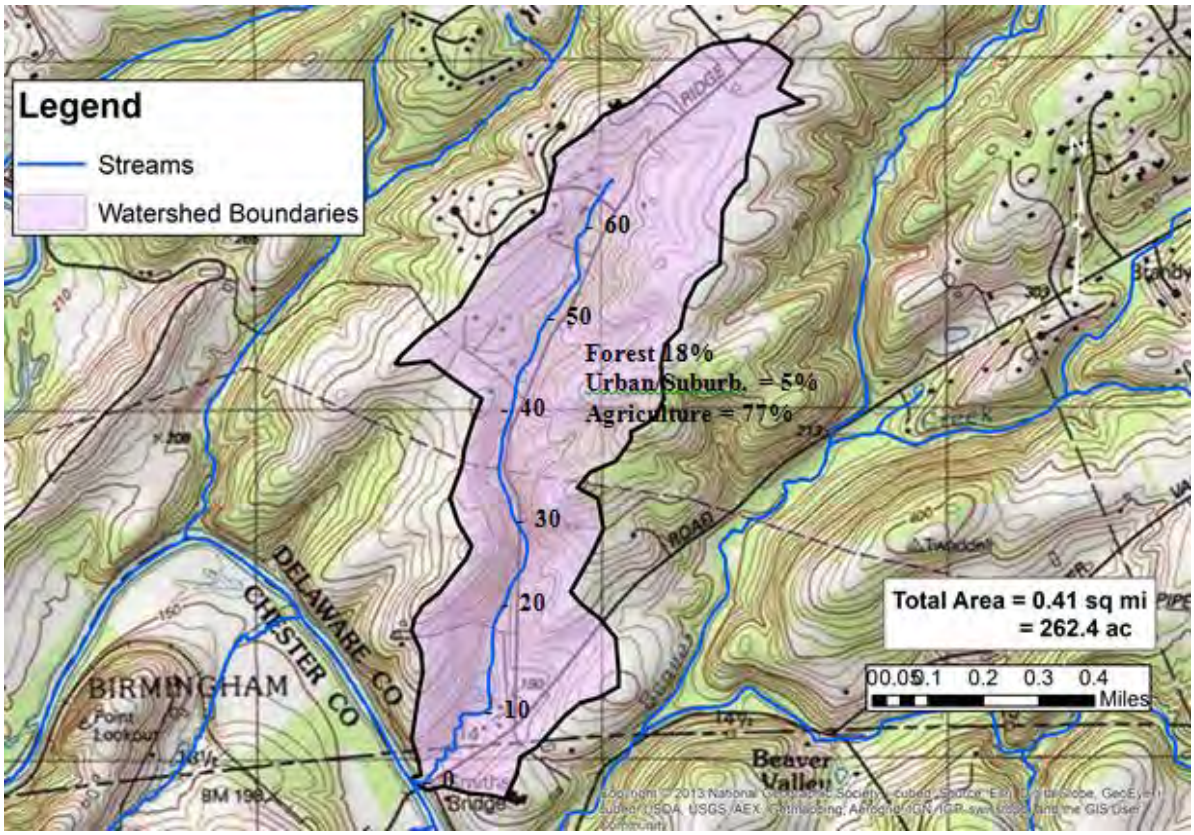


Figure 2.1. Ridge Run watershed delineation and topography

2.2. Beaver Creek

The Beaver Creek watershed is the largest watershed surveyed, and it drains 4 square miles from the north and south forks and main stem of the stream. It covers the northerly third of the First State National Park. The north fork of Beaver Creek originates near the densely developed shopping centers and neighborhoods along Concord Pike in Pennsylvania and flows southwest for three miles through horse farms into the forested First State National Park before joining the main stem about a half mile upstream from the Brandywine Creek. The south fork forms along the Delaware/Pennsylvania state line near the Brandywine Town Center shopping mall and flows west for four miles under Concord Pike. It then flows through horse farms and the forested Woodlawn tract before combining with the north fork near Beaver Valley Road, which is the location of one of the water quality sampling sites. The main stem flows for a half mile along Beaver Valley Road to the confluence with the Brandywine at a popular beach known as Peter's Rock. The watershed is moderately developed (9% impervious) mostly in the upper third near Concord Pike and mostly undeveloped in the stream valleys down below near the Brandywine. Watershed land use is 41% forest/wetlands, 28% urban/suburban, and 31% agriculture primarily horse farms and meadow. The steeply sloped watershed (9% slopes) is covered by soils of hydrologic soil group A. The geology of the watershed is mostly formed by the Wissahickon Formation gneiss, although the north fork is underlain by an outcrop of the Cockeysville marble, a high water yield carbonate rock that provides buffering capacity to the stream for trout populations.

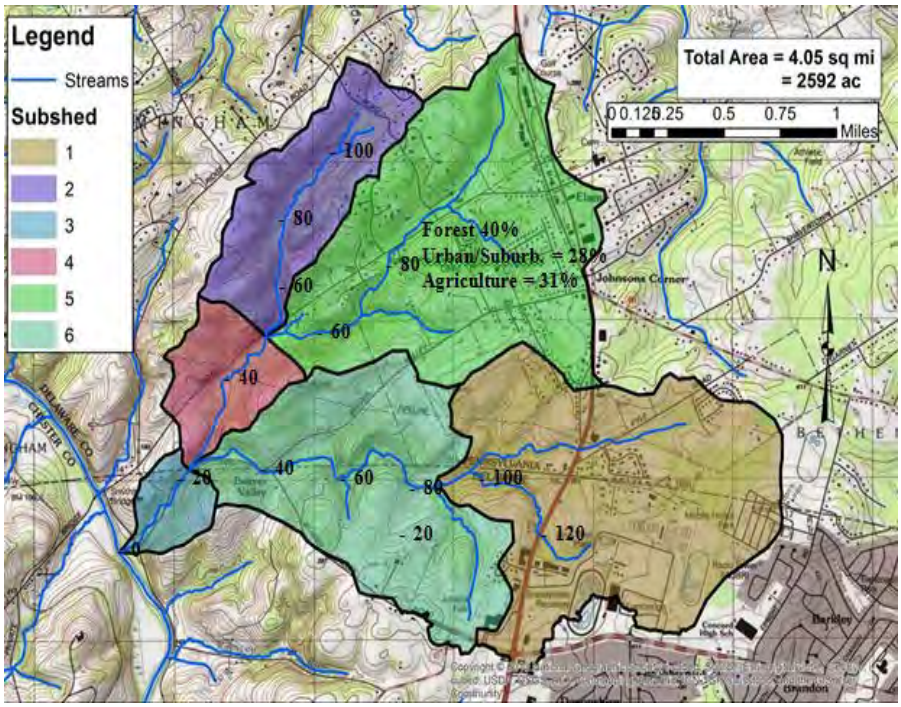


Figure 2.2. Beaver Creek watershed delineation and topography

2.3. Talley Run

The 128-acre Talley Run watershed lies entirely within Delaware in the Woodlawn tract of FSNP. The small creek forms on a 400 ft. high hill near Beaver Valley Road and flows for ¾ mile through a beautiful valley cupped by trail system down to elevation 70 above mean sea level (msl) to feed the Brandywine Creek (Figure 21 and 22). The watershed is lightly developed (0% impervious) and land use is 54% forest/wetlands, 3% urban/suburban, and 43% agriculture (primarily horse farms, meadows, and corn/soybeans). The steeply sloped (13%) watershed is covered by soils of hydrologic soil group A and B. The geology of the watershed is the Wissahickon Formation gneiss.

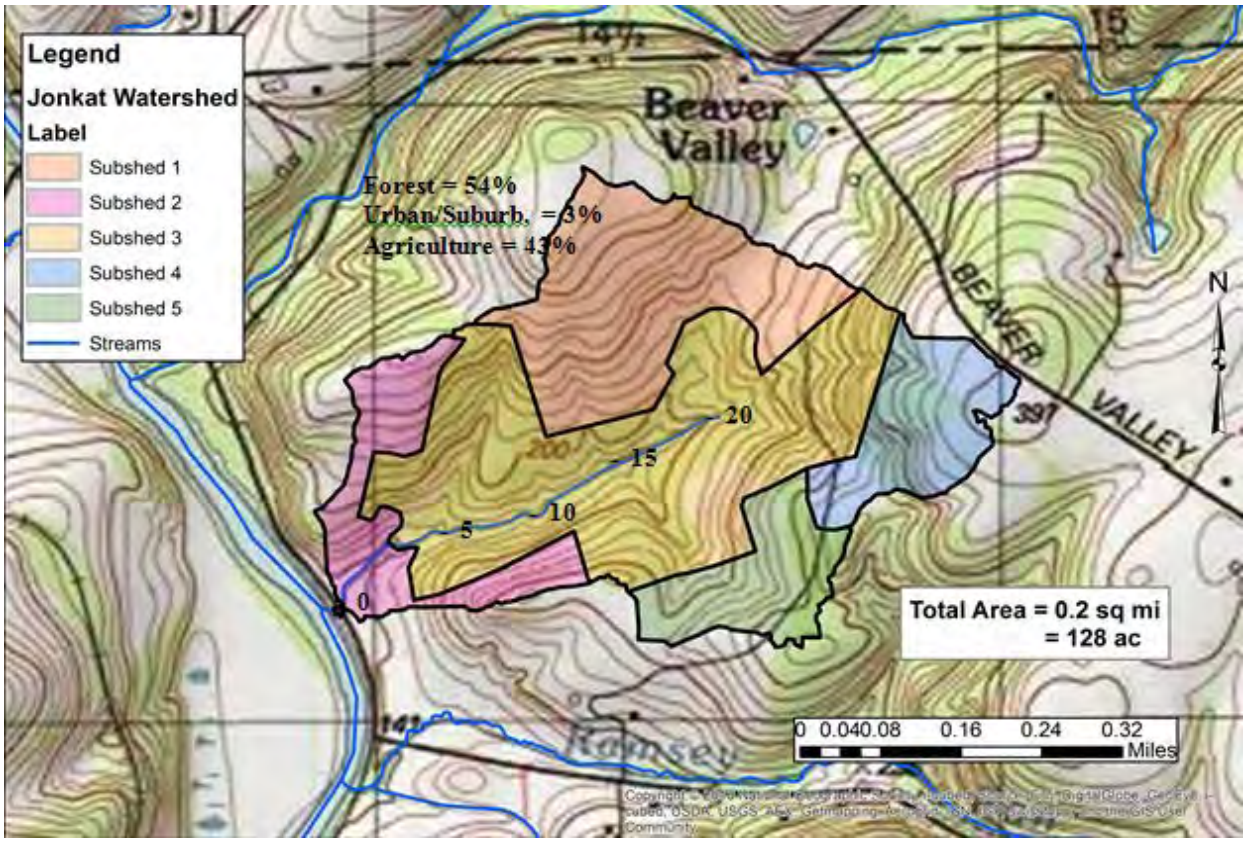


Figure 2.3. Talley Run watershed delineation and topography

2.4. Ramsey Run

The 230-acre Ramsey Run watershed drains the Ramsey Farm and rises at 420 feet msl and flows for a mile along the road and then through a bridge under the foot trail along Brandywine Creek (Figures 23 and 24). The watershed is almost entirely undeveloped (0.2% impervious) and land use is 36% forest/wetlands, 5% urban/suburban, and 59% agriculture primarily pumpkin farm, meadow, and horse farm. The steeply sloped (11%) watershed is covered by soils are % hydrologic soil group A and. The geology of the

watershed is the Wissahickon Formation gneiss with an outcrop of amphibolite downstream near the Brandywine.

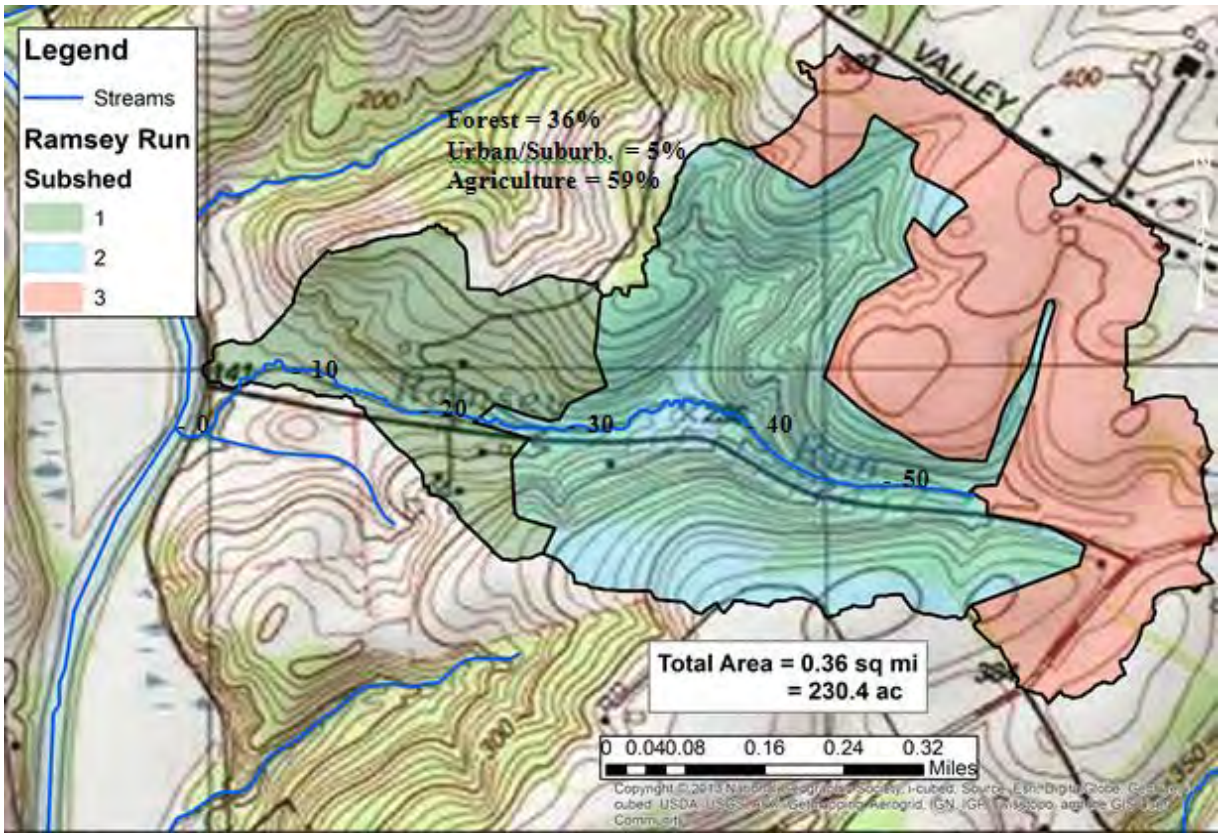


Figure 2.4. Ramsey Run watershed delineation and topography

2.5. Carney Run

The 122-acre Carney Run watershed originates at 400 ft. above sea level and flows for almost a mile along the road to join the Brandywine Creek just upstream from Thompson Bridge. The watershed is lightly developed (0.1% impervious) and land use is 61% forest/wetlands, 3% urban/suburban, and 36% agriculture primarily horse farm, meadow, and corn/soybeans. The steeply sloped (15%) watershed is covered by soils are % hydrologic soil group A and. The geology of the watershed is the Wissahickon Formation gneiss.

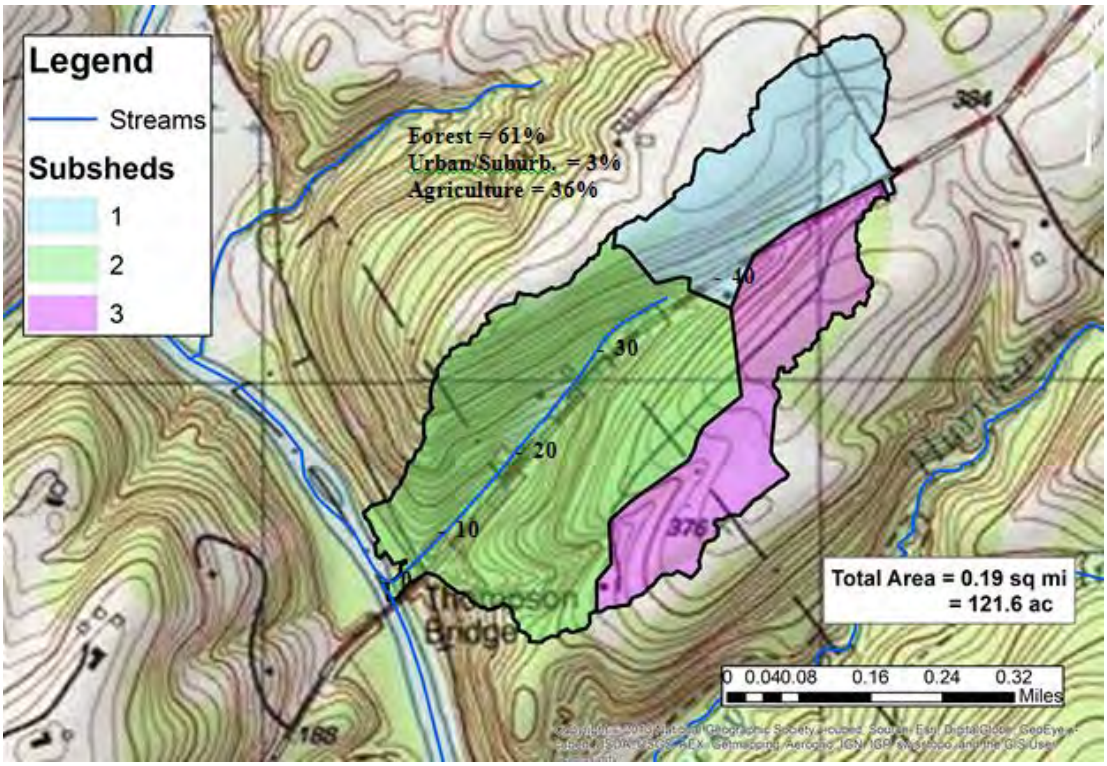


Figure 2.5. Carney Run watershed delineation and topography

2.6. Rocky Run

The Rocky Run watershed drains 1.8 square miles from the north (Hurricane Run) and south forks and main stem of the stream and covers the southerly portion of the First State National Park before flowing west through the Brandywine Creek State Park . Hurricane Run originates near the densely developed shopping centers and neighborhoods along Concord Pike in Pennsylvania and flows southwest for two miles through into the forested First State National Park before joining the main stem about a half mile upstream from the Brandywine Creek. The south fork forms in the neighborhoods of New Castle County behind Concord Mall near the Brandywine Town Center shopping mall and flows west for four miles under Concord Pike then into the forested Brandywine Creek State Park. The main stem flows for a half mile to the confluence with the Brandywine about a half-mile south of Thompson's Bridge. The watershed is highly developed (19% impervious) in the upper third near Concord Pike and mostly undeveloped in the stream valleys down below near the Brandywine. Watershed land use is 28% forest/wetlands, 40% urban/suburban, and 32% agriculture (primarily corn, soybean, and meadow). The steeply sloped watershed (10% slopes) is covered by soils from hydrologic soil group A. The geology of the watershed is mostly formed by the Wissahickon Formation gneiss, although the north fork is underlain by an outcrop of the Cockeysville marble, a high water yield carbonate rock that buffers the acidity of the stream for trout populations.

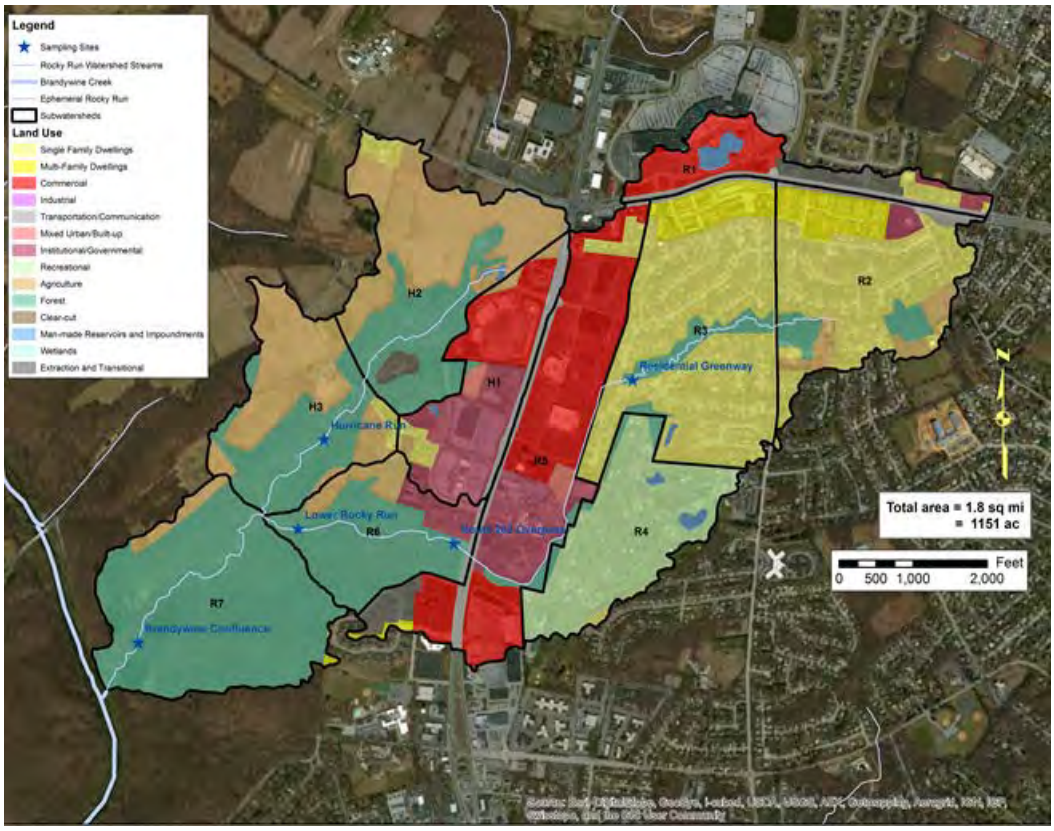


Figure 2.6. Rocky Run watershed land use map

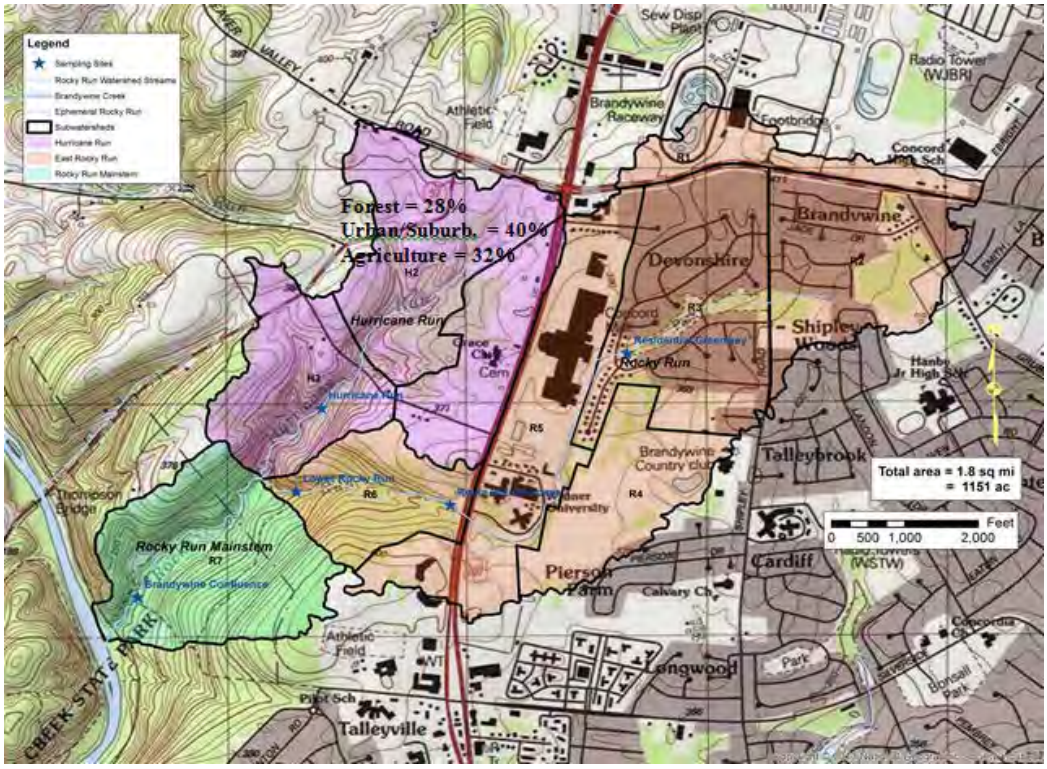


Figure 2.7. Rocky Run watershed delineation and topography

2.7. Land Use

The six streams that flow through the First State National Historical Park capture a drainage area of 4,485 acres or 7.0 square miles. Land use in the six watersheds covers 36% forest, 1% wetlands, 27% urban/suburban, and 36% agriculture with an overall impervious coverage of 10% (Table 2.1 and Figure 2.2). Watershed land use is mostly urban/suburban and commercial to the east on the 400 feet heights of the Piedmont plateau along Concord Pike (Route 202) and changes to agriculture as the streams flow west and downstream over 300 feet in elevation through the steeply sloped forested valleys to the Brandywine Creek. The flat Piedmont heights were developed and farmed and the forested, steeply sloped stream valleys were conserved in a nearly natural state. The least developed watersheds are small catchments (< 300 acres) such as Ridge Run, Talley Run, Ramsey Run, and Carney Run that do not extend too far east from the banks of the Brandywine into the urbanized/commercialized Route 202 corridor.

Table 2.1. Land use in the Brandywine Piedmont watersheds

Watershed	**Area (ac)**	**Forest (ac)**	**Wetlands (ac)**	**Urban/Sub. (ac)**	**Agriculture (ac)**	**Impervious (ac)**
Ridge Run	262	47	1	13	202	0.8
Beaver Creek	2,592	1037	21	726	804	233
Talley Run	128	69	0	4	55	0
Ramsey Run	230	83	0	12	136	0.5
Carney Run	122	74	0	4	44	0.1
Rocky Run	1,151	322	2	460	368	218
	4,485	**1,633**	**24**	**1,218**	**1,608**	**452**
Watershed	**(ac)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
Ridge Run	262	18%	0.4%	5%	77%	0.3%
Beaver Creek	2,592	40%	0.8%	28%	31%	9.0%
Talley Run	128	54%	0.0%	3%	43%	0.0%
Ramsey Run	230	36%	0.0%	5%	59%	0.2%
Carney Run	122	61%	0.0%	3%	36%	0.1%
Rocky Run	1,151	28%	0.2%	40%	32%	19.0%
	4,485	**36%**	**1%**	**27%**	**36%**	**10.0%**

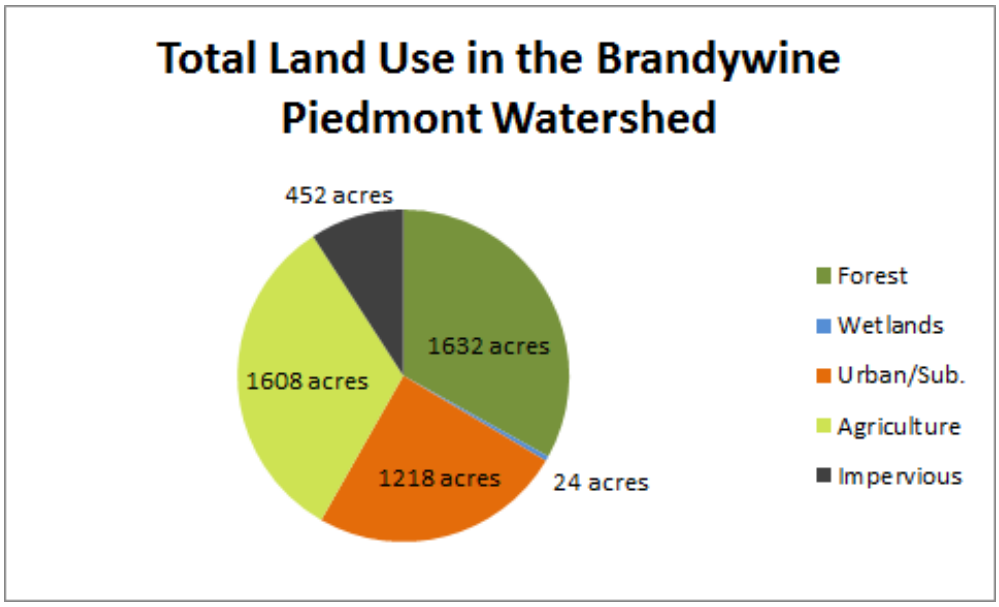


Figure 2.8. Land use in the Brandywine Piedmont watershed

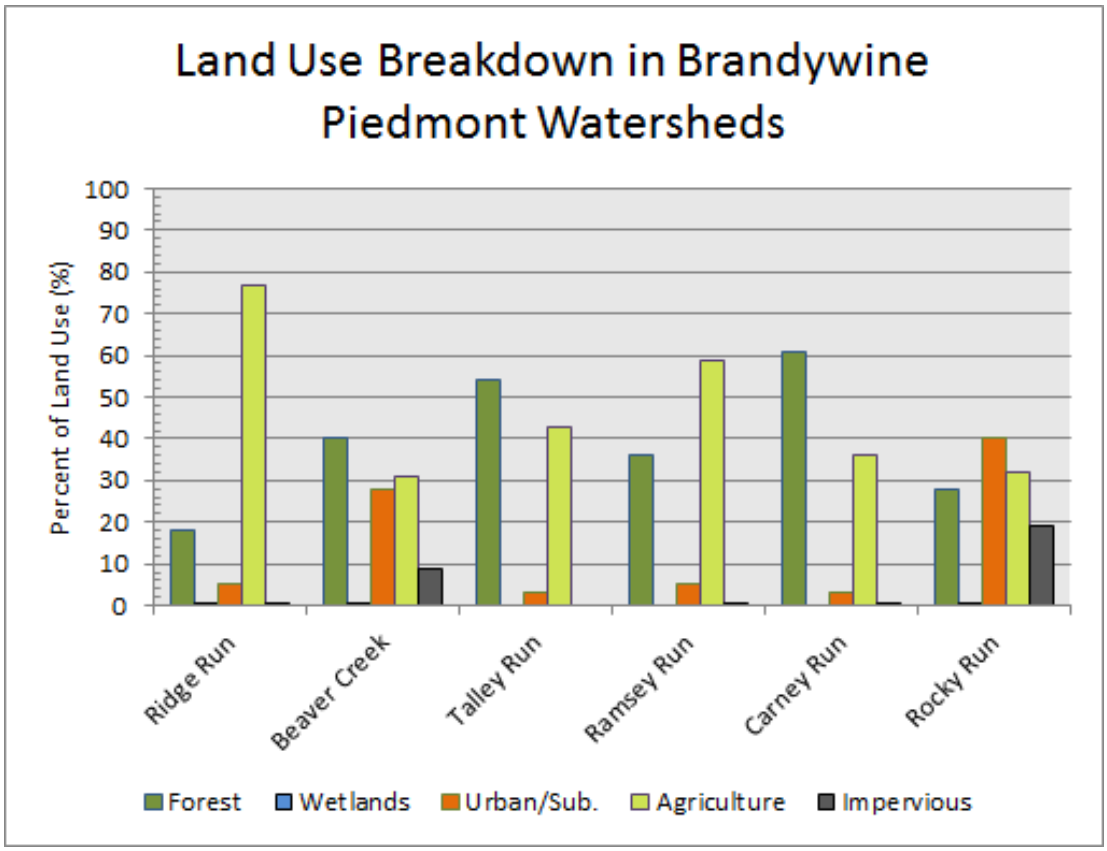


Figure 2.9. Land use by sub-watershed in the Brandywine Piedmont watersheds

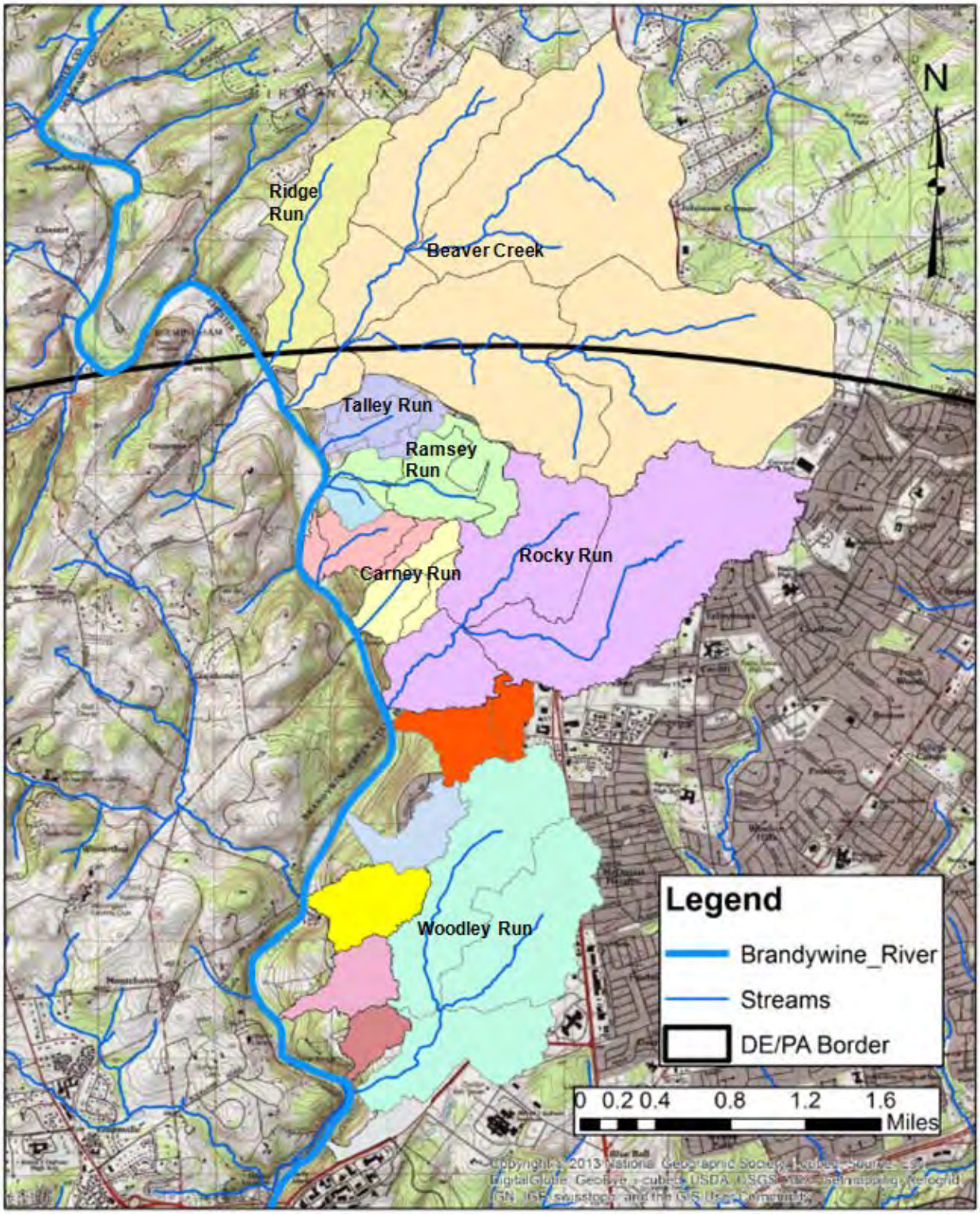


Figure 2.10. Brandywine-Piedmont watersheds at First State National Historic Park

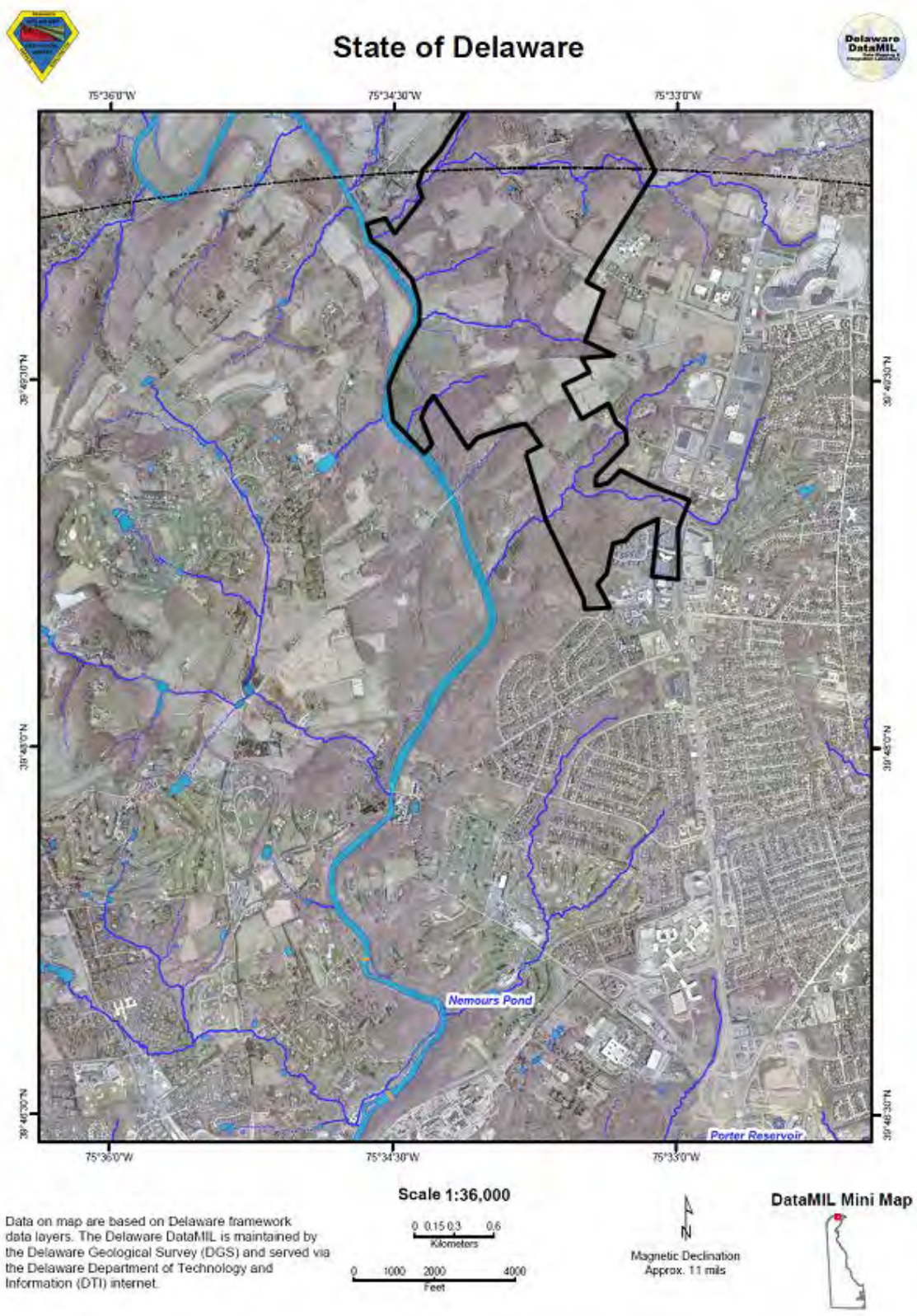


Figure 2.11. Streams within FSNHP boundary

2.8. Basin Characteristics

The USGS Streamstats model (Table 2.2) indicates the watersheds are steeply sloped (6%-15% slopes), at least 15% forested (18%-61%), with minimal wetland coverage (0.2%-0.8%). The small watersheds are mostly undeveloped with impervious coverage less than 0.3% of the catchment area. The larger watersheds, Beaver Creek and Rocky Run, are covered by higher amounts of impervious cover (9.0% and 19.0%) as these watersheds form in the neighborhoods and shopping centers along the commercialized Concord Pike (Route 202) corridor (Figure 2.5).

Table 2.2. Characteristics of the Brandywine Piedmont watersheds

Watershed	Area (mi^2)	Basin Slope (%)	Forest (%)	Wetlands (%)	Impervious (%)
Ridge Run	0.4	12%	18%	0.4%	0.3%
Beaver Creek	4.2	9%	40%	0.8%	9.0%
Talley Run	0.2	13%	54%	0%	0.0%
Ramsey Run	0.4	11%	36%	0%	0.2%
Carney Run	0.2	15%	61%	0%	0.1%
Rocky Run	1.8	6%	28%	0.2%	19.0%
	7.0 mi^2				

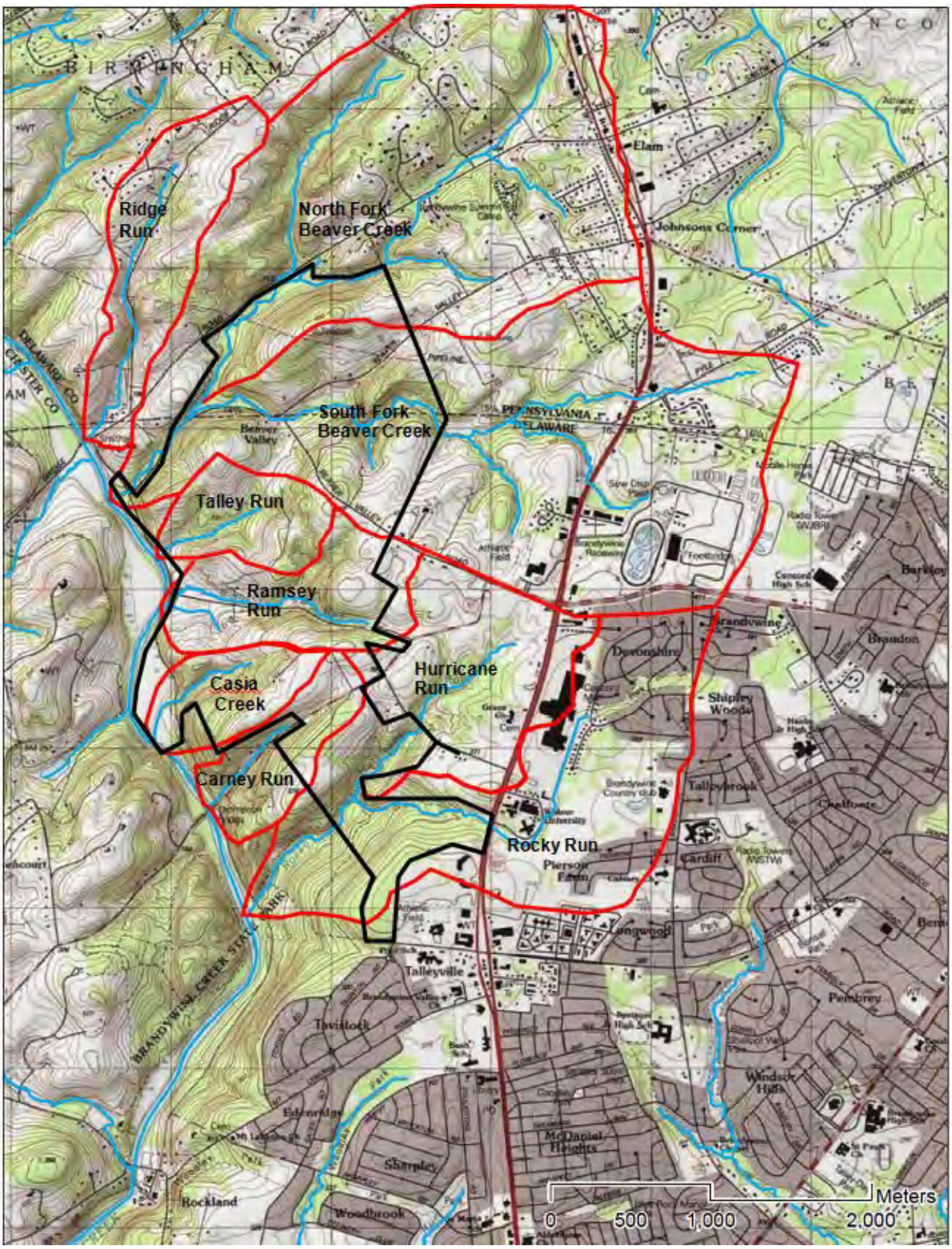


Figure 2.12. Topography of watersheds in FSNHP

2.9. Soils

According to the USDA soil survey, 2.9% of the FSNHP watershed soils are classified as quarry/water/urban bed rock, 10.2% are hydrologic soil group A (moderate permeability), 57% are HSG B (moderately drained), 28.5% are HSG C (low permeability), and 0.8% are HSG D (poorly drained/wetlands). To summarize, This data is represented graphically in Figure 2.6 below. The four hydrologic soil groups are:

Group A soils have a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B soils have a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C soils have a slow infiltration rate that impedes the downward movement of water or soils of moderately fine texture with a slow rate of water transmission.

Group D soils have a very slow infiltration rate (high runoff potential) when wet and are commonly hydric or wetland soils. These soils have a very slow rate of water transmission.

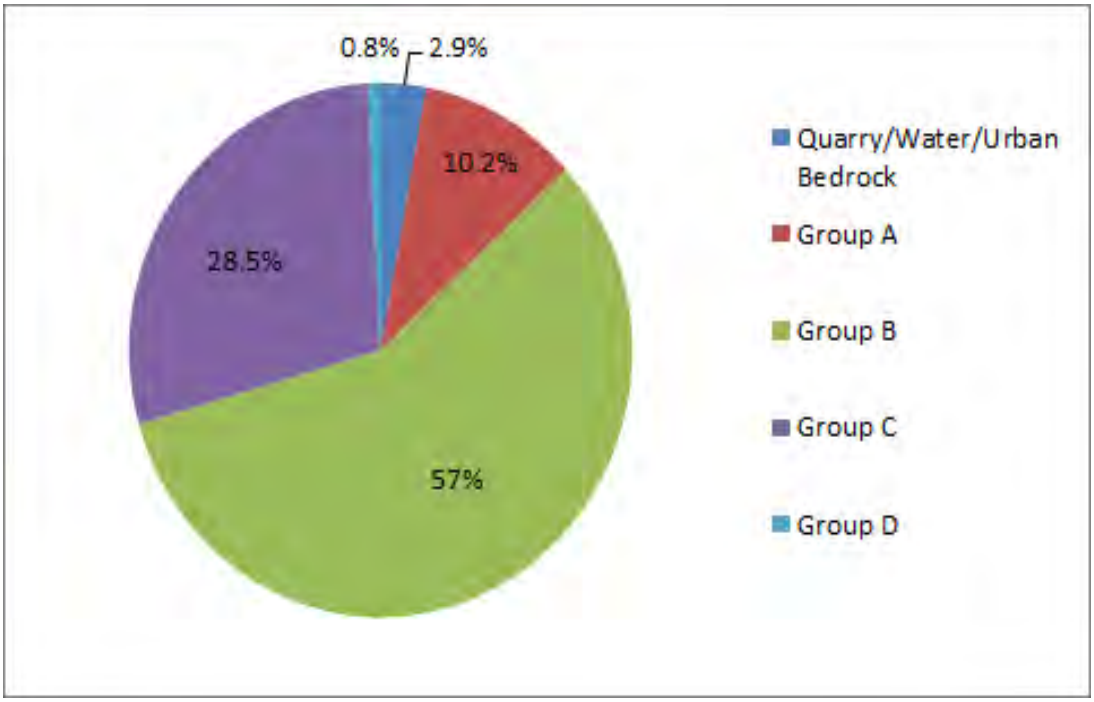


Figure 2.13. USDA Soil Survey - FSNHP watershed hydrologic soil group classifications

2.10. Geology

FSNP watersheds are underlain by outcrops of the Wissahickon Formation gneiss (Wilmington Blue Rock), which are blue-green in color and form large erosion resistant boulder and cobble complexes in the beds of the streams that tumble through the Piedmont (Figure 2.7). Rock types include mostly Wissahickon Formation, Amphibolite, and Cockeysville Marble.

Figure 2.14. Wilmington Blue Rock boulder complex in Beaver Creek, FSNHP, 2014

Chapter 3: Methodology

3.1. Schedule

Stream sample sites at the First State National Historical Park were visited and mapped out on June 15th, 2015. Official sampling for the summer began on June 22nd and ended on July 28th. The team collected data once a week (either on Monday or Tuesday) at the 12 locations in Beaver Valley. On days of bacterial sampling, samples were delivered to the City of Wilmington Water Quality Lab. Sampling for the fall began on October 9th and ended on December 4th and was conducted every other week. Nutrient samples were sent to the Soil Testing Program at the University of Delaware College of Agriculture and Natural Resources. Sampling in the spring was conducted three times in March and April 2016.

June 8th, 2015- Kick-off meeting
June 15th, 2015- Mapped out and visited each location
June 17th, 2015 - Visited City of Wilmington Water Quality Lab
June 22nd, 2015- Borrowed equipment from Wilmington, first official probe data collection
June 30th, 2015 - Second probe data collection, first bacterial and TSS sampling
July 6th, 2015 - Third probe data collection
July 13th, 2015 - Fourth probe data collection
July 20th, 2015 - Fifth probe data collection, second bacterial and TSS sampling
July 23rd, 2015 - Macroinvertebrate sampling- N./S. Fork of BC (The Nature Conservancy)
July 28th, 2015 - Sixth and final summer probe data collection
October 9th, 2015 - Seventh probe data collection- nutrient analysis (UD Soil Testing)
October 22nd, 2015 - Water samples from 10/9/15 dropped off for nutrient analysis at UD
October 23rd, 2015- Eighth probe data collection
November 6th, 2015 - Ninth probe data collection
November 13th, 2015 - Tenth probe data collection, sampled site 9 for nutrient analysis
November 17th, 2015 - water sample from 11/13/15 dropped off at UD Soil Testing
December 4th, 2015- Eleventh and final fall semester probe data collection
March 4th, 2016 - Twelfth probe data collection and first of the spring semester
March 21st, 2016 - Thirteenth probe data collection
April 8th, 2016 - Fourteenth and final probe data collection

3.2. Parameters

Table 3.1. Water quality standards of tested parameters

Parameter	Unit	Water Quality Standard
Temperature	°C	No more than 27.7°C
pH	standard pH unit	6.5-8.5
Turbidity	NTU	Cannot exceed 10 NTUs
Dissolved Oxygen (DO)	mg/L	Cannot be <5.5 average
Electrical Conductivity (EC)	µS	Should be between 150-500µS
Enterococci Bacteria	#/100mL	925/100mL
Aluminum (Al)	mg/L	0.75 mg/L acute 0.087 mg/L chronic
Boron (B)	mg/L	0.75 mg/L
Calcium (Ca)	mg/L	*
Copper (Cu)	mg/L	0.0134 mg/L
Iron (Fe)	mg/L	1 mg/L
Potassium (K)	mg/L	*
Magnesium (Mg)	mg/L	*
Manganese (Mn)	mg/L	0.5 mg/L
Sodium (Na)	mg/L	*
Phosphorus (P)	mg/L	0.2 mg/L
Sulfur (S)	mg/L	250 mg/L
Zinc (Zn)	mg/L	0.117 mg/L acute 0.118 mg/L chronic
NH4-N (Ammonia-Nitrate)	mg/L	Usually does not exceed 0.2 mg/L
NO3 (Nitrate)	mg/L	10mg/L

* Could not be retrieved from EPA or State of Delaware records

3.3. Equipment

Figure 3.1. Water quality probes (Left to right: temperature, pH, DO, and conductivity from Wilmington; TDScan conductivity from University of Delaware) Monitoring probes from the City of Wilmington (pH, DO, temperature, conductivity) and University of Delaware (TDScan 3 conductivity probe, turbidity meter) - Figures 3.1 and 3.4

- 4 oz. Nasco Whirl-pak bags - Fig. 3.3
- 100 ml Idexx sterilized and sealed bottles - Fig. 3.2
- 500 ml Nalgene sample bottles
- 100 ml plastic beakers
- Kimwipes
- 3 buffer solutions (pH 4, 7, and 10) for pH probe calibration
- Ice cooler and ice
- Label tags - Fig. 3.2
- Chain of Custody forms
- Field notebook, pen, and watch for time and latitude/longitude measurements

Figure 3.2. (above right) IDEXX sterilized and sealed 100mL bottles for bacterial testing

Figure 3.3. (above left) Whirl-pak bags for TSS testing

Figure 3.4. Turbidity meter, University of Delaware

3.4. Site Descriptions

Water quality sampling of the 12 locations along the six streams took place according to a method that would allow for the fastest and most effective way to collect data. The GPS coordinates of each location were recorded prior to sampling. In June and July 2015, stream monitoring occurred once a week in the morning between the hours of 9:30am and 12:00pm. In addition to chemical testing at each location, stream samples were collected twice during the month of July for bacterial and turbidity sampling. In October through December, stream monitoring occurred twice a month in the afternoon between the hours of 12:00pm and 3:00pm. Once during October, stream samples were collected for solution pH and nutrient analysis tests, performed by the University of Delaware Soil Testing Program. Three data collections were also taken in March and April 2016 between 2:30pm

and 4:30pm for turbidity and conductivity. Depending on the location, the characteristics of the streams were variable according to the vegetation, substrate material, depth, and bank stability amongst other habitat characteristics that would define a healthy stream. Not all sampling locations had a riparian vegetative buffer zone that protected the tributaries from erosion, runoff and deposition. For example, Rocky Run upstream of the Concord Pike is heavily channelized, with little to no vegetative protection, before it flows into the FSNHP.

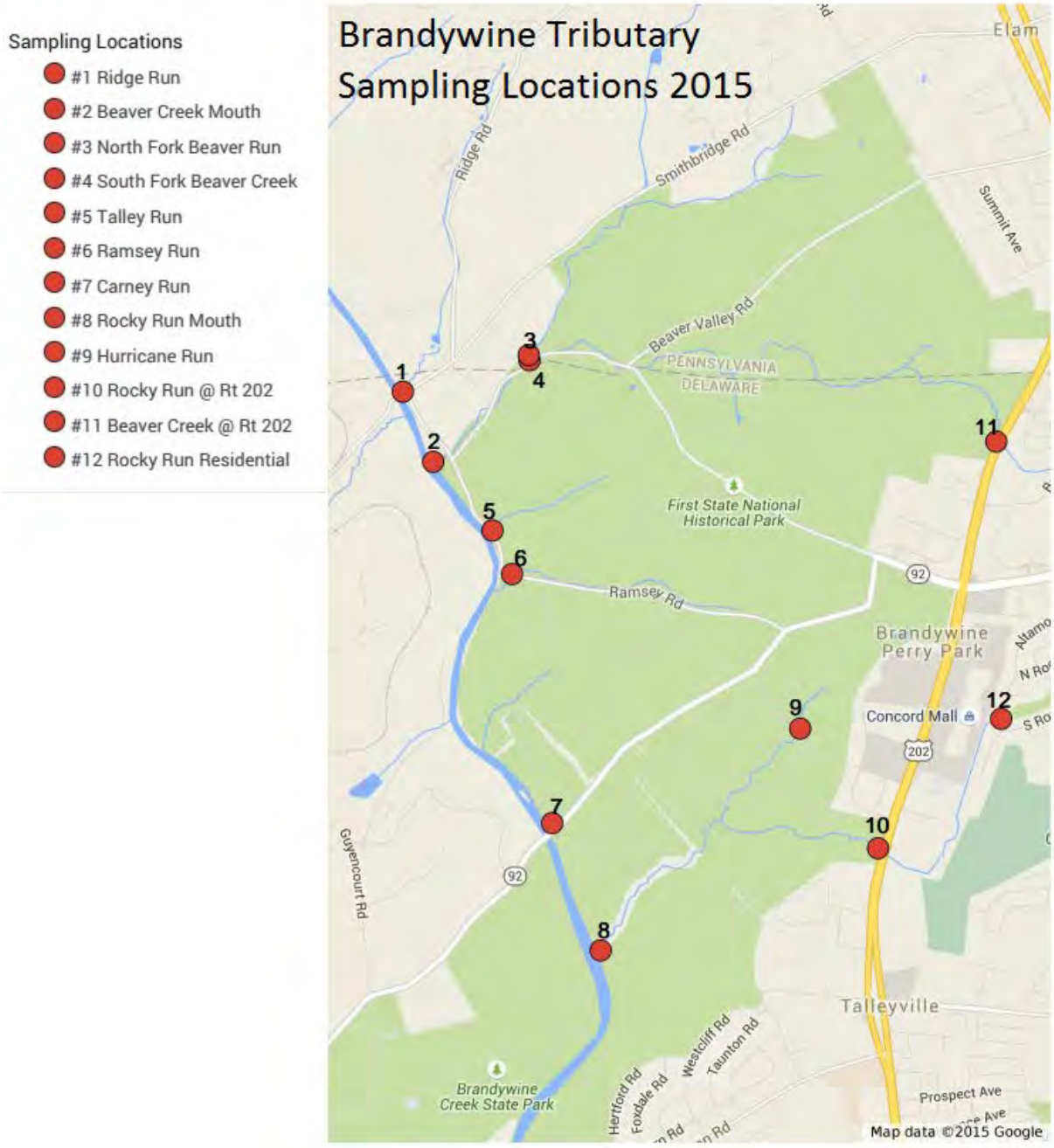


Figure 3.5. Sampling location map

Table 3.2. Latitudinal/longitudinal coordinates of sampling locations

Sampling Site ID	Monitoring Location	Monitoring Location GPS Coordinates
1	Ridge Run	Lat: 39°50'17"N Long: 75°34'44"W
2	Beaver Creek Mouth	Lat: 39°50'5"N Long: 75°34'44"W
3	Beaver Creek North Fork	Lat: 39°50'5"N Long: 75°34'17"W
4	Beaver Creek South Fork	Lat: 39°50'21"N Long: 75°34'16"W
5	Talley Run Mouth	Lat: 39°49'53"N Long: 75°34'24"W
6	Ramsey Run Mouth	Lat: 39°49'46"N Long: 75°34'24"W
7	Carney Run Mouth	Lat: 39°49'2"N Long: 75°34'10"W
8	Rocky Run Mouth	Lat: 39°48'42"N Long: 75°33'58"W
9	Hurricane Run	Lat: 39°49'3"N Long: 75°33'33"W
10	Rocky Run at Route 202	Lat: 39°48'59"N Long: 75°32'58"W
11	Beaver Creek at Route 202	Lat: 39°50'7"N Long: 75°32'33"W
12	Rocky Run Residential Area	Lat: 39°49'21"N Long: 75°32'31"W

Site 1 Ridge Run: Located slightly south of the border of Pennsylvania and Delaware, this is the northernmost tributary flowing into the Brandywine Creek in the First State National Historical Park (Fig. 3.6). This stream meanders into a private parcel of land containing a horse farm, grassy lawns, and housing areas along Smithbridge Road. The sampling site was downstream from these areas near the mouth of the tributary. On one side of the stream there is evidence of a narrow strip of vegetative buffer between the road and the tributary. There is some overhanging vegetation and little to no bank erosion.

Figure 3.6. Site 1: Ridge Run, July 2015 (facing upstream)

Site 2: Beaver Creek Mouth: Water samples were taken before the confluence of Beaver Creek and the Brandywine Creek (Fig 3.7). As shown in Figure 3.7, the stream is observed to be moderate in width (10-50m), shallow, and slow moving. Boulders and cobble were the main substrates found in this location. There is moderate bank erosion taking place on the right hand-side facing upstream, whereas on the left side there is minimal erosion due to the stabilization of the banks from the trees. On most days where sampling occurred, there have been signs of an overwhelming amount of trash deposited on the banks of the tributary due to the adjacent recreational state park area.

Figure 3.7. Site 2: Beaver Creek Mouth, July 2015 (facing upstream)

Site 3: Beaver Creek North Fork: Located further upstream and to the north of Beaver Creek Mouth, the north fork originates near the Concord Pike in Pennsylvania before entering the forested areas of the First State National Historical Park (Fig. 3.8). The area that was chosen for this site is located right before the confluence of Beaver Creek North and South. This study site is covered by overhanging vegetation and is characterized by deep pools, slow velocity, and no undercutting of the banks on either side. The northern fork does not run adjacent to any trails or roads, making it less susceptible to pollution from agricultural, industrial, commercial, or residential runoff.

Figure 3.8. Site 3: Beaver Creek North Fork, July 2015 (facing upstream)

Site 4: Beaver Creek South Fork: Similar to the north fork, the south fork of Beaver Creek originates in a heavily developed area and flows past the Concord Pike and into the National Park (Fig. 3.9). The stream meanders along the Beaver Valley Road and becomes narrower upstream. This site has both riffle and run sections where the velocity of the stream varies. There is an approximately five-foot-high vegetative hill between the tributary and the road at the sampling site, which is about 50 feet away from the intersection of the north and south forks.

Figure 3.9. Site 4: Beaver Creek South Fork, July 2015 (facing upstream)

Site 5: Talley Run: This specific location of Talley Run runs alongside Brandywine Creek Road and is covered by a heavy understory growth of vegetation (Fig. 3.10). There is very minimal vegetation acting as a buffer on the left side of the tributary facing upstream. This area of the stream has the characteristics of an intermittent stream such as its shallow depth, small width, but well-defined channel. There is no noticeable amount of erosion occurring at this sample site. The samples were taken near the mouth of the tributary several feet upstream of where it crosses underneath Brandywine Creek Road.

Figure 3.10. Site 5: Talley Run, July 2015

Site 6: Ramsey Run: Ramsey Run flows right underneath Ramsey Road before it converges with the Brandywine Creek (Fig. 3.11). There is lots of vegetation, (tall grasses, trees, wildflowers) on either side of this narrow stream, keeping the banks stabilized. The sampling site was directly upstream from the bridge where Ramsey Run crosses the road. The result of storm water runoff entering the stream from Ramsey Road, which often had polluted puddles, should be considered as a concern for nonpoint source pollution due to its close proximity.

Figure 3.11. Site 6: Ramsey Road, July 2014

Site 7: Carney Run: The location chosen for this sampling site is situated at the mouth of the tributary and directly downstream of a pedestrian trail bridge (Fig. 3.12). The stream consists of substrate such as gravel and boulder in areas that are visible and are not covered by vegetation. Both banks are overgrown with dense vegetation. Carney Run runs directly alongside Thompson's Bridge Road and is characterized by low flow.

Figure 3.12. Site 7: Carney Run, July 2015 (facing upstream)

Site 8: Rocky Run Mouth: This section of the stream is located near heavily used hiking and biking recreational trails (Fig. 3.13). There are big boulders scattered around in the stream with established trees lining both sides of the banks for stability. Stream sampling occurred between the mouth at the Brandywine Creek and a temporary pedestrian trail bridge that was built after the permanent bridge was wiped out in a large storm. Construction on the new bridge began in August 2015 and was completed that winter, which may have influenced our fall samples since our sampling site was directly downstream of the construction area. This section is located downstream of Hurricane Run and Rocky Run's confluence, so the water quality is a combination of all six of Rocky Run's sub-sheds after it flows through the protected areas of FSNHP.

Figure 3.13. Site 8: Rocky Run Mouth, July 2015 (facing upstream)

Site 9: Hurricane Run: At this shaded sampling site, the banks of Hurricane Run display moderate signs of erosion and drying up (Fig. 3.14). Due to a recent storm, there are also dead trees lying across the stream. The substrate in this section of the stream is mostly composed of cobblestones and gravel. The sampling site is directly upstream of where the tributary crosses beneath Woodlawn Road and flows into an extensive hiking/biking trail system.

Figure 3.14. Site 9: Hurricane Run, July 2015 (facing downstream toward Woodlawn Rd.)

Site 10: Rocky Run at Route 202: This area is located between the National Park Boundary and downstream (west) of the Concord Pike (Route 202) overpass (Figures 3.15 and 3.16). Long grasses cover the banks on either side of the stream. Slightly upstream and through the tunnels (Figure 3.16), the stream banks are channelized with concrete as it passes through the Concord Mall complex. On several occasions, there was a discoloration of the stream that made it look opaque/milky. There are also large pipes leading into Rocky Run that most likely drain the roadways and nearby urbanized areas, which may have an influence on water quality.

Figure 3.15. Site 10: Rocky Run at Route 202, July 2015 (facing downstream)

Figure 3.16. Site 10: Rocky Run at Route 202, July 2015 (facing upstream toward Rt. 202)

Site 11: Beaver Creek at Route 202: Beaver Creek also runs underneath the Concord Pike before it enters the National Park (Fig. 3.17). At this location, the vegetation is very dense and the banks on either side are steep. There is a lot of trash (broken bottles, plastic bags) scattered on the banks. The color of the water is murky but not to the degree found at the pool of water before the tunnel at Site 12 (Figure 3.18). The stream velocity was slow and there was little to no channel sinuosity. The sampling site was directly downhill and downstream from a horse farm and therefore is in danger of high nutrient levels.

Figure 3.17. Site 11: Beaver Creek at Route 202, July 2015 (facing upstream)

Site 12: Rocky Run Residential: Rocky Run originates slightly upstream of this residential area (Fig. 3.18). A deep pool of water is collected right downstream of the sampling site before the stream enters the tunnel and becomes channelized by concrete. The coloration of the pool is sometimes noted as copper orange, murky and opaque. The banks on either side of Rocky Run are steep and eroded. This site was chosen because it is downstream of a suburban community but directly upstream of the Concord Mall and Route 202 area, which is very developed.

Figure 3.18. Site 12: Rocky Run Residential, July 2015 (facing downstream toward Rt. 202)

3.5. Analysis Methods

The parameters tested at each of the stream sampling locations include pH, conductivity, temperature, turbidity, and dissolved oxygen. The pH, conductivity, and dissolved oxygen probes (Figure 3.1) were calibrated once a week using standardized procedures to ensure quality control. For example, buffer solutions of pH 4, 7, and 10 were used to calibrate the pH probe. To prevent damage to the probes, a beaker was filled with stream water and brought to a safe location for the chemical assessment. After each use, the probes were wiped off with a Kimwipe to prevent damage.

To test for turbidity (TSS), water samples were collected, stored, and transported to the City of Wilmington Water Quality Lab in 4oz Nasco Whirl-pak bags labeled with the stream name and location number prior to sampling (Figure 3.3). Using a 100ml beaker, the Whirl-pak bags were filled with stream water to the minimum sampling volume (4oz line). The tabs on either side of the Whirl-pak bags were then pulled to seal it tightly. The top of the bags were folded twice and flipped over once. The tabs were then folded inwards towards the bag to secure and prevent leakage. The Whirl-pak bags were placed upright in an ice-filled cooler immediately after sampling occurred. A second method of analyzing turbidity was using an MI 415 Turbidity meter borrowed from the University of Delaware. Vials of water were wiped with Kimwipes before each reading in order to ensure accuracy.

To test for nutrients, water samples were collected, stored, and transported to the University of Delaware College of Agriculture and Natural Resources Soil Testing Program in 500 mL Nalgene bottles labeled with the stream name and site number. The jars were kept in a cooler with ice, then transferred to a refrigerator until being brought to the UD Soil Testing Program.

Bacterial quality was tested through enterococci analysis. The City of Wilmington Water Quality Lab provided 100ml sterilized bottles for bacterial (enterococci) sampling (Figure 3.2), and team members were taught to use the proper technique for sampling by lab staff. Stream water was collected mid-stream in a plastic beaker and poured into a sterilized bottle until filled to the 100ml line. All team members practiced a sterile technique by refraining from touching the mouth of the bottle and setting the lid down while opening, sampling, and closing the bottle. The samples were immediately stored in an ice cooler with a temperature control and transported to the City of Wilmington Water Quality Lab within no more than three hours of collection. TSS and bacterial samples were collected twice during low flow stream conditions in the month of July.

3.6. Quality Control

Team members followed the City of Wilmington Water Quality Sampling guidelines, which comply with EPA's monitoring techniques. An additional resource that was used to double-check sampling techniques was EPA's Volunteer Stream Monitoring methods manual, which is a comprehensive document that is in accordance with the U.S Environmental Protection Agency policy and is designed to ensure the validity of field samples collected. To verify the temperature of the bacterial samples, a Temperature Control was used. A sterilized bottle filled with water was placed in the cooler and submitted along with the bacterial samples to the City of Wilmington lab. City of Wilmington Water Quality staff utilized the Temperature Control to monitor and record the temperature of the stream samples testing for bacteria. Additionally, members took samples and data collection from the same exact locations each field day to reduce chances of skewed data (with the exception of site 11 in which the location was moved a few feet downstream after November 6th, 2015 in response to a snake/insect infestation discovered underneath the Route 202 overpass).

Chapter 4: Field Monitoring Results

4.1. Chemical Results

The results from the chemical assessments that were conducted at each location over the nine month period are displayed as graphs. Graphs are organized into three categories: (1) tributaries flowing directly into Brandywine Creek, (2) tributaries of Beaver Creek watershed, and (3) tributaries of Rocky Run watershed. Categories are divided into the fluctuations of temperature, pH, turbidity, DO and conductivity over time as well as the averages of these parameters over the entire testing period in order to better analyze the overall conditions at each of the 12 locations.

Temperature: Temperature is also an important factor for water quality sampling as it can alter other chemical parameters, such as dissolved oxygen (high temperature reduces oxygen levels), conductivity, and pH. Temperature is crucial for maintaining the metabolism of an aquatic ecosystem. For example, temperature fluctuations can affect the success of organisms living in the water, as some organisms may have a higher tolerance to temperature changes than others. As stated in the EPA Delaware Freshwater Quality Standards manual, no human-induced increase of the true daily mean temperature above 82°F (27°C) should be allowed. According to Figures 4.4 through 4.6, Hurricane Run has the highest mean water temperature of 20.7°C, followed by Ridge Run with a mean temperature of 20°C. The lowest mean temperature of 16.1°C is recorded at Carney Run. Overall, there were no temperature issues in the twelve sampling sites for June through December 2015.

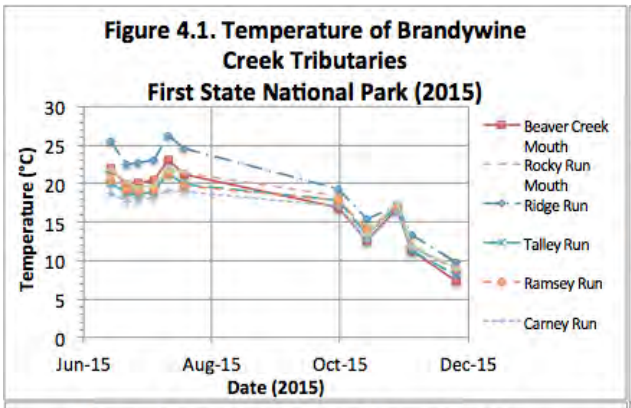


Figure 4.1. Temperature of Brandywine Creek Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
Jun-15
Aug-15
Oct-15
Dec-15
Date (2015)
Beaver Creek Mouth
Rocky Run Mouth
Ridge Run
Talley Run
Ramsey Run
Carney Run

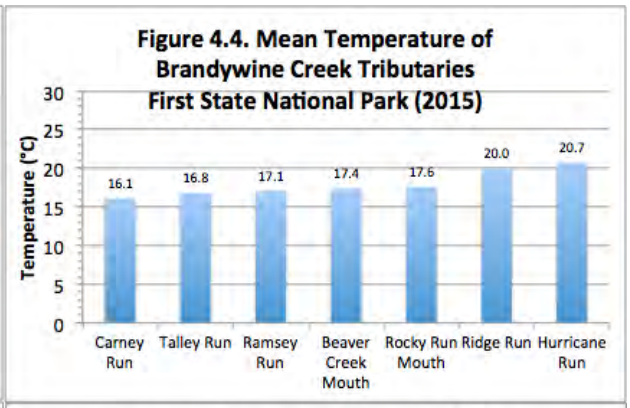


Figure 4.4. Mean Temperature of Brandywine Creek Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
16.1
16.8
17.1
17.4
17.6
20.0
20.7
Carney Run
Talley Run
Ramsey Run
Beaver Creek Mouth
Rocky Run Mouth
Ridge Run
Hurricane Run

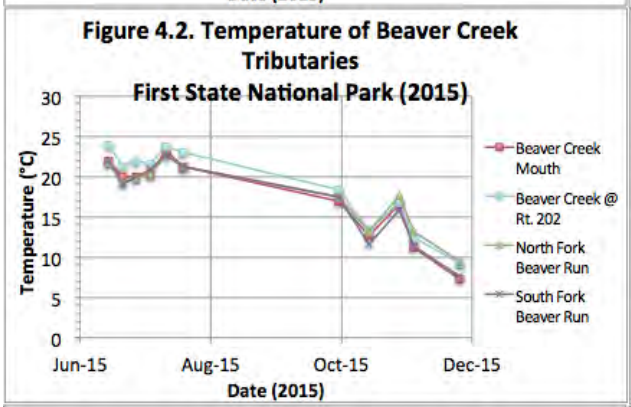


Figure 4.2. Temperature of Beaver Creek Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
Jun-15
Aug-15
Oct-15
Dec-15
Date (2015)
Beaver Creek Mouth
Beaver Creek @ Rt. 202
North Fork Beaver Run
South Fork Beaver Run

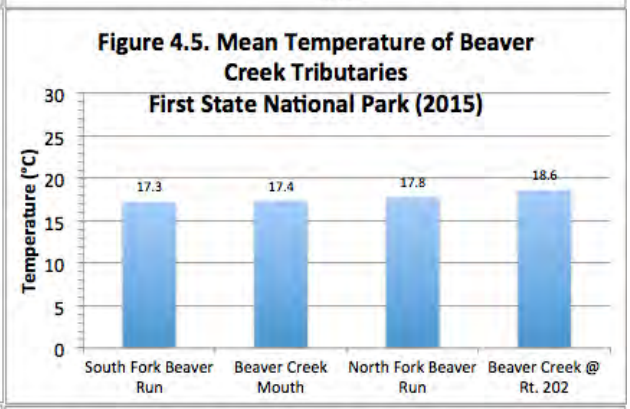


Figure 4.5. Mean Temperature of Beaver Creek Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
17.3
17.4
17.8
18.6
South Fork Beaver Run
Beaver Creek Mouth
North Fork Beaver Run
Beaver Creek @ Rt. 202

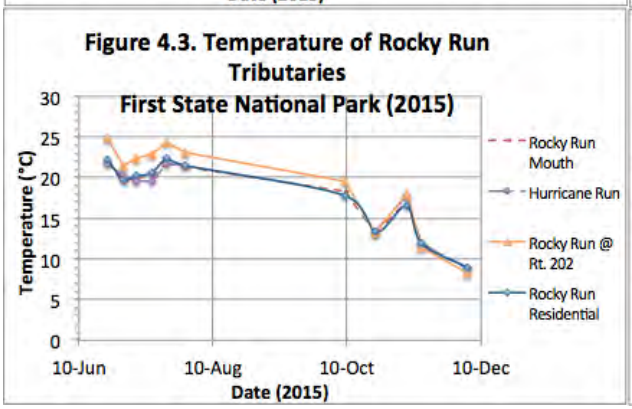


Figure 4.3. Temperature of Rocky Run Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
10-Jun
10-Aug
10-Oct
10-Dec
Date (2015)
Rocky Run Mouth
Hurricane Run
Rocky Run @ Rt. 202
Rocky Run Residential

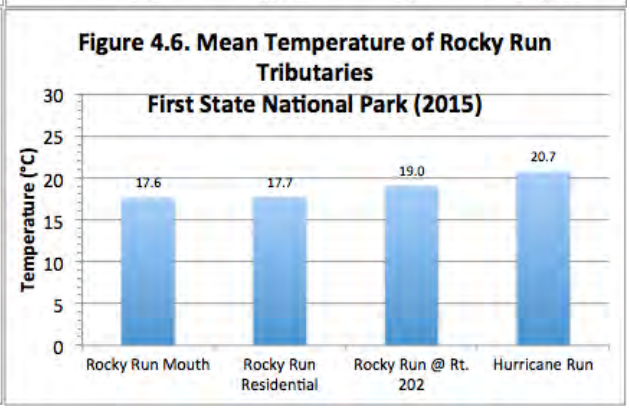
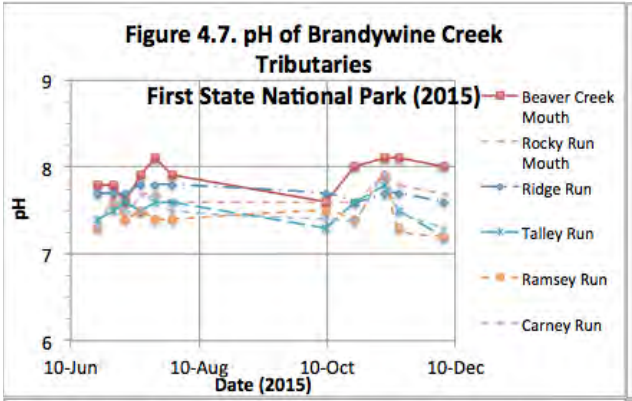
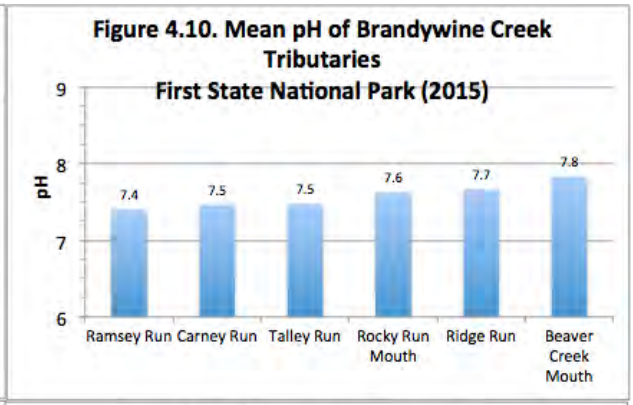
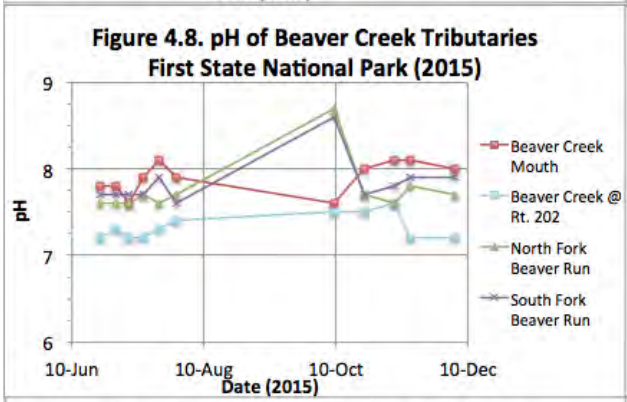


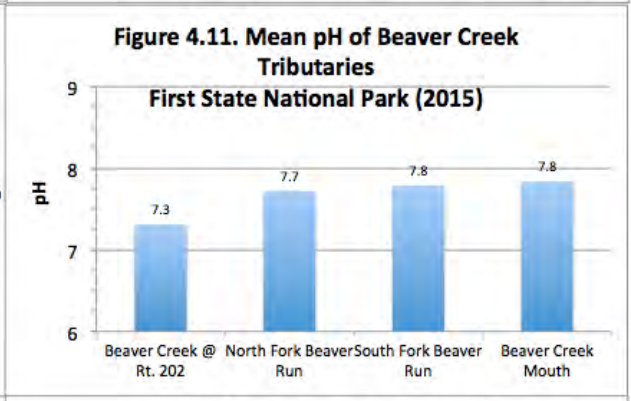
Figure 4.6. Mean Temperature of Rocky Run Tributaries
First State National Park (2015)
Temperature (°C)
30
25
20
15
10
5
0
17.6
17.7
19.0
20.7
Rocky Run Mouth
Rocky Run Residential
Rocky Run @ Rt. 202
Hurricane Run

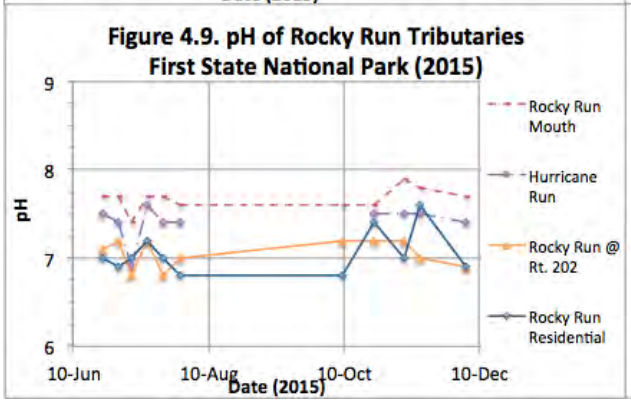
pH: According to the EPA Delaware Freshwater Quality Standards manual, all waters in the state of Delaware should have a pH in the range of 6.5 and 8.5 units in its unaltered state. The pH levels of the tributaries observed at each sampling site all fit within this range, thereby showing that there are no impairments in the pH levels (Figure 4.7 through 4.12). Rocky Run at 202 has the lowest average pH value of 7.04 whereas Beaver Creek Mouth has the highest average pH at a value of 7.83.

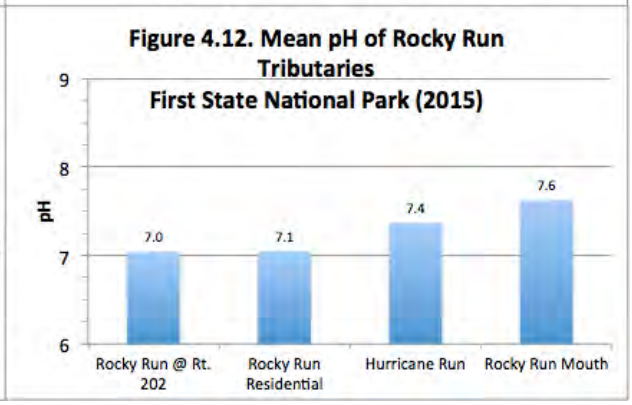






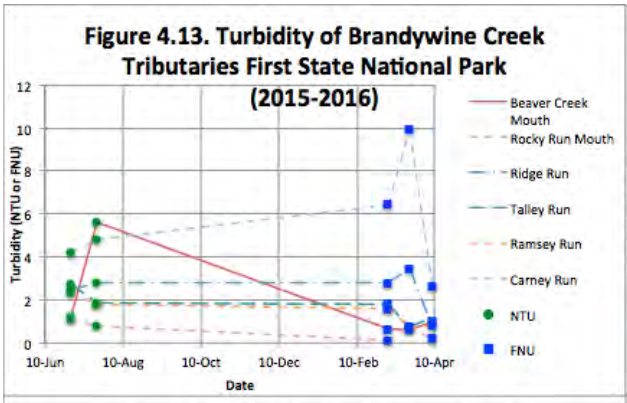


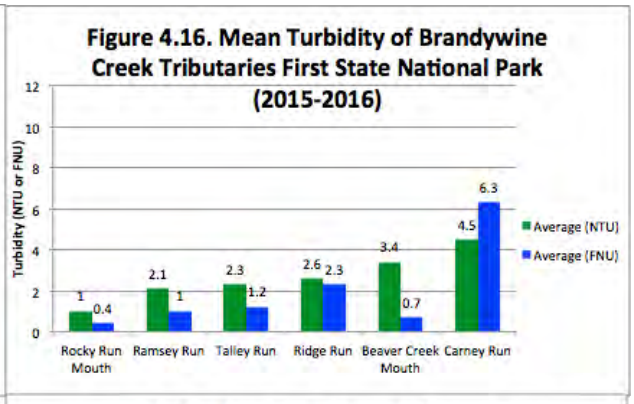


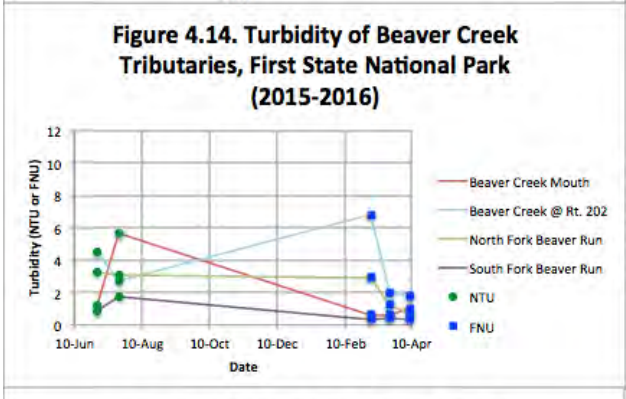


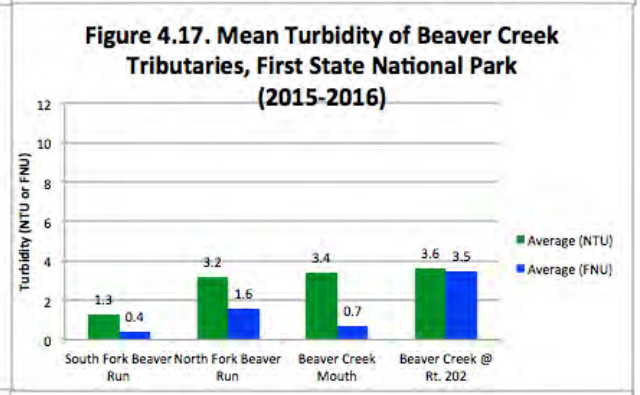
Turbidity: Turbidity measures both suspended and dissolved particulate matter in water, and is essentially a measure of water murkiness. The higher the turbidity, the "muddier" the water is. Turbidity is an important factor for water quality analysis because it may be a

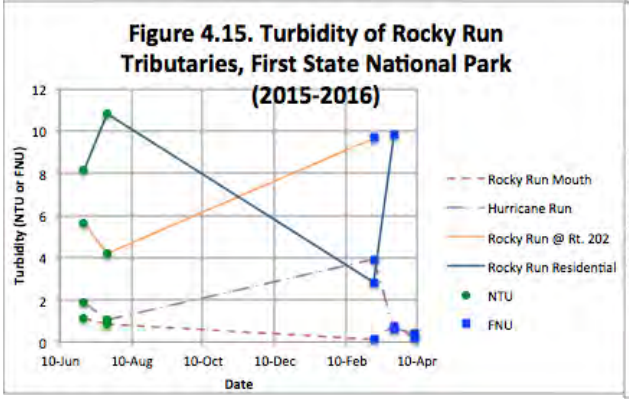
sign of pollution such as phosphorus pollutants that cause algae to grow. High turbidities have a variety of harmful effects on aquatic wildlife, including prevented development, modified movement and migrations, reducing food availability and growth, decreasing resistance to disease, or death. Additionally, waters with high turbidities are generally less aesthetic for recreational purposes. Turbidity should not exceed a level of 10 NTUs. Data was analyzed twice in NTUs at the Wilmington lab in the summer and three times in FNUs, a similar measurement, in the fall with a turbidity meter on site. According to figure 4.18, the upper Rocky Run sites (Rocky Run at Route 202 and Rocky Run Residential) have the most concern for exceeding 10 NTUs or FNUs. However, Rocky Run mouth has the lowest turbidity of all the sites, so there is little concern for turbid water entering the Brandywine Creek.

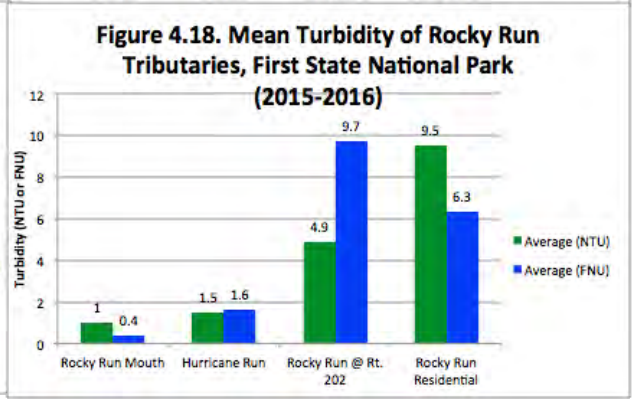




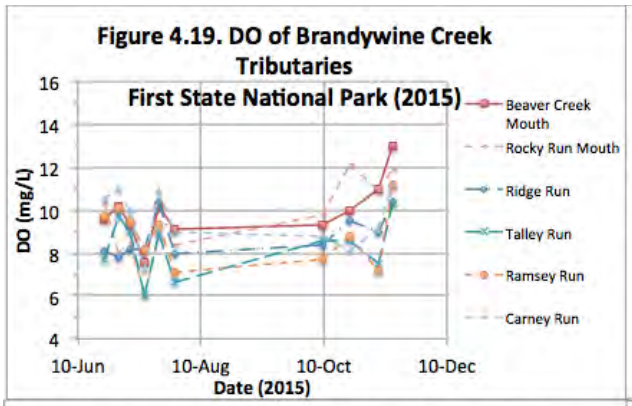


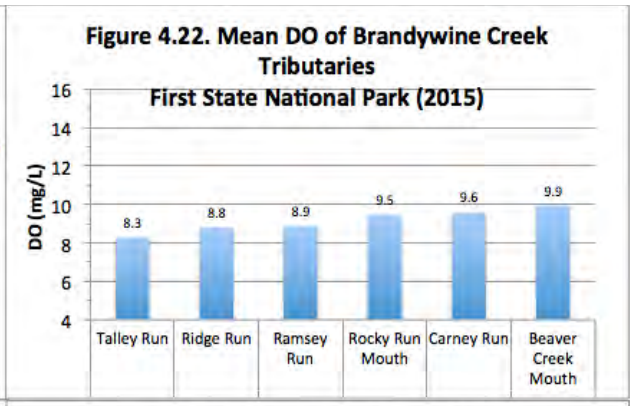


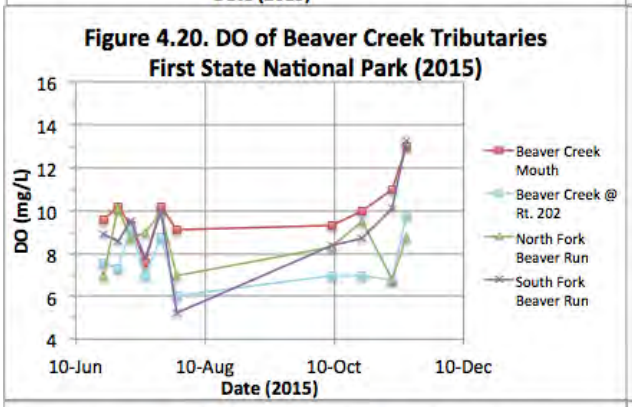


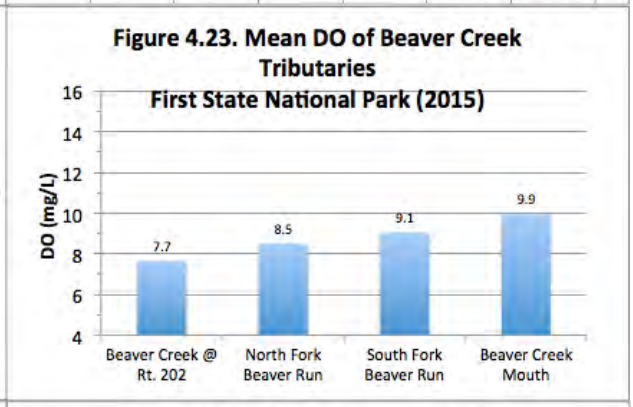


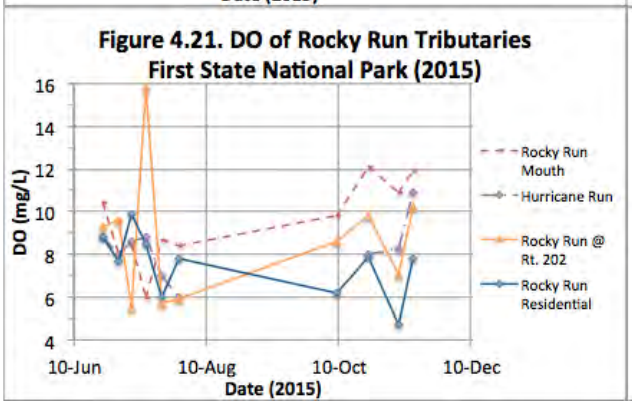
Dissolved Oxygen (DO): Fish, macroinvertebrates, plants and bacteria rely on dissolved oxygen to survive. A healthy stream, according to the Water Quality Standards manual, should not have a dissolved oxygen average below 5.5 mg/L. These conditions might occur in slow-moving, narrow waterways with little aquatic plant life. Fish species exposed to less than 5.5 mg/L of dissolved oxygen will have impaired functionality and lower survival rates. Looking at Figures 4.22 through 4.24, the tributaries in the First State National Historical Park all have average dissolved oxygen levels between 7 mg/L and 10 mg/L. The tributary with the lowest average dissolved oxygen (7.53 mg/L) is Rocky Run Residential and the tributary with the highest average dissolved oxygen (9.93 mg/L) is Beaver Creek Mouth. Rocky Run at Route 202 had three instances of coming within 0.2 mg/L of the standard in the month of July, which may be an area of concern for that tributary but not for the Brandywine.

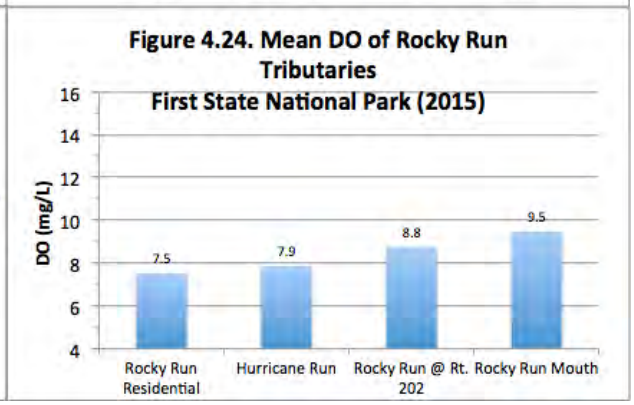






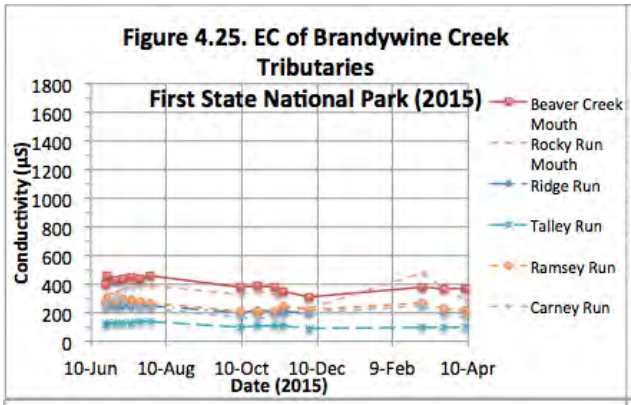


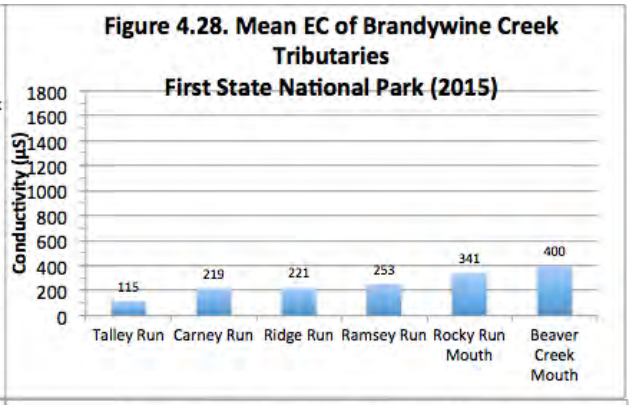


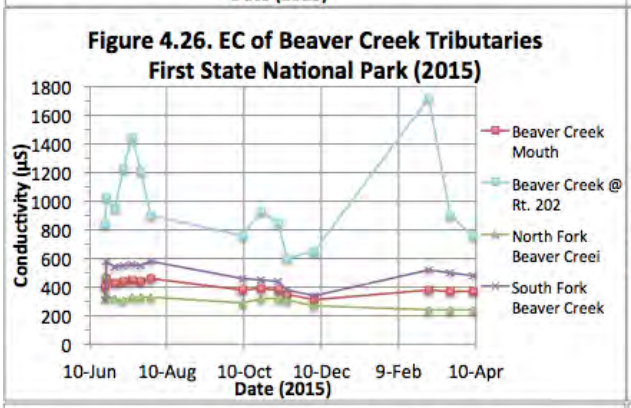


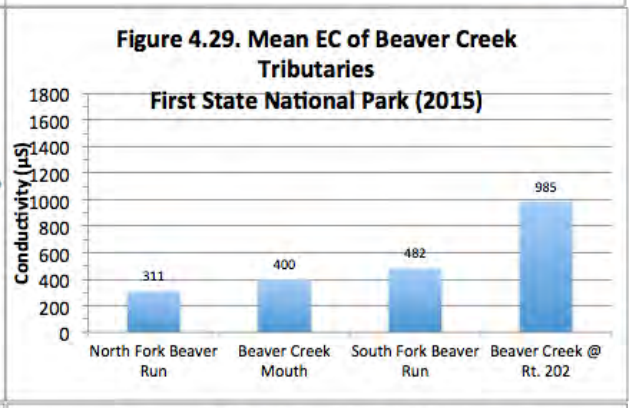
Electrical Conductivity (EC): A sudden change in conductivity can indicate pollution due to an increased influx of ions from an external source such as agricultural runoff or residential waste leakage. For aquatic organisms, the ideal value of conductivity is between 150µS and 500µS. However, normal conductivity levels for surface waters are expected to range from 50µS to 1500µS. As seen in Figure 4.29, the highest mean conductivity is found at Beaver Creek at Route 202 with a mean of 985µS. This high value is not ideal for aquatic organisms and may be damaging to the ecosystem. On March 4th, 2016, the conductivity for Beaver Creek at Route 202 spiked at a dangerously high level of 1720µS. We expect this was due to agricultural runoff from the adjacent horse farm. Talley Run has the lowest

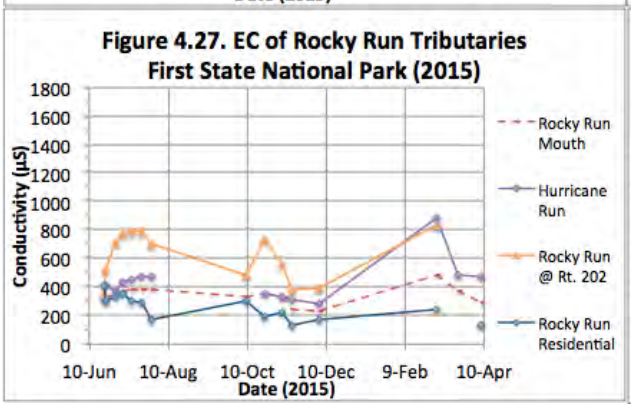
mean conductivity of 115µS (Figure 4.28), which may actually indicate low nutrient levels for aquatic life.

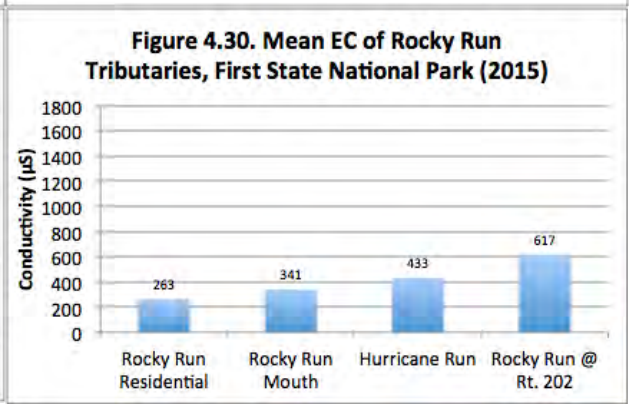












Nutrients and Metals: The University of Delaware College of Agriculture and Natural Resources Soil Testing Program performed nutrient Analysis from samples collected on October 9th, 2015. The parameters tested were aluminum, boron, calcium, copper, iron, potassium, magnesium, manganese, sodium, phosphorus, sulfur, zinc, ammonia, and nitrate. For the purposes of our study, we will only analyze copper, iron, manganese, phosphorus, zinc, ammonia, and nitrate as we deemed the others to be mostly inconsequential to the water quality. Overall, our results showed no problems with the

results of the nutrient and metal tests. Test results for all parameters can be found in Table 4.1 below.

Table 4.1. Nutrient and metal data

UDSTP Lab No.	Sam-ple No.	Site No.	Sample ID	Al (mg/L)	B (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)
24683	1	Site 1	Ridge Run 10/9/15	0.015	0.008	15.318	0.002	0.079	3.122	6.816
24684	2	Site 2	BC Mouth 10/9/15	0.007	0.010	29.819	0.003	0.116	3.200	13.621
24685	3	Site 3	BC North 10/9/15	0.020	0.003	6.560	0.001	0.071	0.782	3.113
24686	4	Site 4	BC South 10/9/15	0.039	0.009	30.447	0.003	0.065	3.621	14.182
24687	5	Site 5	Talley Run 10/9/15	0.028	0.006	10.127	0.000	0.084	2.702	4.865
24688	6	Site 6	Ramsey Run 10/9/15	0.032	0.006	13.941	0.003	0.078	2.552	7.303
24689	7	Site 7	Carney Run 10/9/15	0.041	0.004	11.134	0.002	0.073	1.705	5.369
24690	8	Site 8	RR Mouth 10/9/15	0.021	0.002	7.785	0.001	0.055	0.944	3.406
24691	9	Site 10	RR 202 10/9/15	0.398	0.010	32.819	0.003	0.373	2.940	12.993
24692	10	Site 11	BC 202 10/9/15	0.049	0.015	66.562	0.005	0.173	5.292	27.515
24693	11	Site 12	RR Residential 10/9/15	0.021	0.002	4.712	0.002	0.068	0.720	1.616

UDSTP Lab No.	Sam-ple No.	Site No.	Sample ID	Mn (mg/L)	Na (mg/L)	P (mg/L)	S (mg/L)	Zn (mg/L)	NH4-N (mg/L)	NO3-N (mg/L)
24683	1	Site 1	Ridge Run 10/9/15	0.001	14.467	0.025	4.956	0.001	<0.01	0.64
24684	2	Site 2	BC Mouth 10/9/15	0.004	34.223	0.031	4.973	0.000	<0.01	1.42
24685	3	Site 3	BC North 10/9/15	0.006	3.561	0.011	0.821	0.000	<0.01	0.22
24686	4	Site 4	BC South 10/9/15	0.001	49.852	0.032	5.757	0.000	<0.01	1.89

24687	**5**	**Site 5**	**Talley Run 10/9/15**	0.000	4.950	0.012	5.280	0.000	<0.01	0.98
24688	**6**	**Site 6**	**Ramsey Run 10/9/15**	0.013	19.822	0.011	3.821	0.000	<0.01	3.79
24689	**7**	**Site 7**	**Carney Run 10/9/15**	0.000	18.546	0.017	2.285	0.000	<0.01	1.34
24690	**8**	**Site 8**	**RR Mouth 10/9/15**	0.000	10.017	0.014	1.084	0.000	<0.01	0.33
24691	**9**	**Site 10**	**RR 202 10/9/15**	0.007	53.203	0.036	4.938	0.005	0.02	0.74
24692	**10**	**Site 11**	**BC 202 10/9/15**	0.044	98.327	0.055	9.156	0.002	<0.01	0.80
24693	**11**	**Site 12**	**RR Residential 10/9/15**	0.001	8.462	0.017	1.099	0.001	<0.01	0.30

Iron:

Pertaining to aquatic life, ferric irons are of primary concern in waterways. Iron's presence can also indicate organic or inorganic waste substances. The chronic criteria for Iron is 1 mg/L. None of the sampling sites reach this point. The site with the highest Iron levels is Rocky Run at 202 with 0.373 mg/L.

Nitrate:

The majority of nitrates in waterways sources from fertilizers in agricultural runoff. Other sources include organic waste, domestic effluent, industrial sewage discharge, and leaching from dumps. As a nutrient, high levels of nitrate can suffocate the oxygen in a water body and lead to eutrophication, causing an unhealthy environment for humans, fish, and wildlife. High levels can also cause diseases such as Methemoglobinemia. Nitrate becomes a systemic toxin at a level of 10 mg/L. None of the sites reach this point, but the site with the highest nitrate value (3.79 mg/L) is Ramsey Run. Since Ramsey Run is downstream of farms, nitrates from manure and other fertilizers may be the cause of this relatively high number.

Copper:

Copper can get into waterways from things such as construction and electric equipment and agricultural use to treat certain plant diseases. While it is an essential nutrient at low levels, copper becomes toxic to both aquatic organisms and humans when it reaches higher levels, leading to health issues including alterations in the nervous, gastrointestinal, hematological, and hepatic systems as well as mortality. None of the sites have a problem with Copper, which is not a toxin until it reaches .0134 mg/L; none of the sites exceed 0.005 mg/L.

Ammonia:
Ammonia comes from natural sources such as forest fires, animals and human waste, and nitrogen fixation processes, but is also used in commercial fertilizers and various other industrial processes, leading to the possibility of excess in waterways. At high enough levels, the toxin builds up in the tissues and blood of aquatic organisms, sometimes leading to death. According to the World Health Organization, the levels of ammonia in groundwater and drinking water usually does not exceed 0.2mg/L. Ammonia levels were not a problem for any of the sites. They all contained less than 0.02 mg/L.

Zinc:
Zinc enters water through both natural and human-induced processes, including mining, coal burning, and the burning and disposal of zinc wastes from metal manufacturing industries. Animals can take up zinc though eating and drinking and travels through the food chain as a toxin. The highest Zinc level seen in the tributaries in question is 0.005 mg/L and this element is not toxic until it reaches 7.4 mg/L.

Manganese:
Manganese is a naturally occurring element in water, but due to underground pollution sources and air pollution from power plants, it can reach harmful levels. Excessive exposure can lead to human health problems, such as negative impacts on the central nervous system. It also has toxic effects on a variety of aquatic organisms. The limit for Manganese is 0.50 mg/L and the highest seen in these sites is 0.044 mg/L (Beaver Creek at Route 202).

Phosphorous:
Phosphorous can get into waterways due to runoff from agricultural fertilizers, manure, and organic wastes from sewage. Phosphates are not toxic to people or animals unless they exist at high levels, where it can lead to eutrophication, where over-fertilized aquatic plants and algae use oxygen and choke the waterway. The limit for Phosphorus is 0.2 mg/L and the highest seen in these sites is 0.055 mg/L (Beaver Creek at 202).

4.2. Pathogen Results

It is necessary to monitor bacteria in surface waters because they can help detect the presence of harmful pathogens that can negatively affect the health of the people who utilize the streams and rivers both functionally and recreationally. The most common biological indicators are E. coli and enterococci as they both help indicate sewage contamination.

Healthy primary contact recreation fresh waters (swimming, fishing, drinking) should have a maximum single-sample value of 185 MPN. Secondary contact recreation fresh waters (wading, boating, rafting) can have up to 925 MPN for it to be a safe environment to be used recreationally. Results from the City of Wilmington Water Quality lab indicate that the enterococci levels are much higher in certain locations than others. Sampling sites that indicate extremely problematic enterococci levels higher than a mean of 925 MPN include Ridge Run, Hurricane Run, Beaver Creek at Route 202 and Rocky Run Residential Greenway. The lowest mean value was 322 MPN at Carney Run, which is still almost double the standard for recreational fresh waters.

Bacterial sampling should be re-done at these sample sites as the bacterial levels seemed abnormally high. If bacteria levels are indeed verified to be this high, then further measures to enforce people from swimming in these tributaries should be taken.

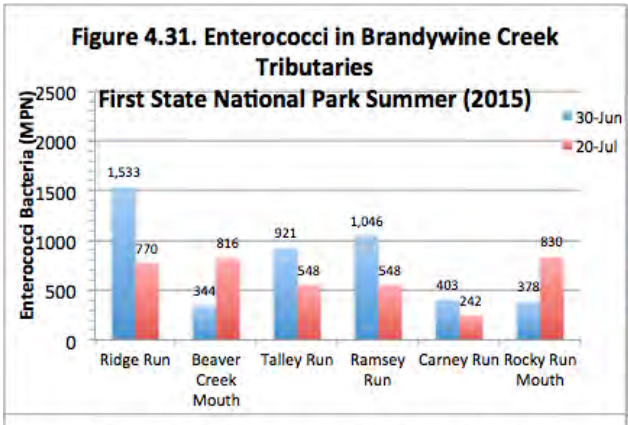


Figure 4.31. Enterococci in Brandywine Creek Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
30-Jun
20-Jul
1,533
770
344
816
921
548
1,046
548
403
242
378
830
Ridge Run
Beaver Creek Mouth
Talley Run
Ramsey Run
Carney Run
Rocky Run Mouth

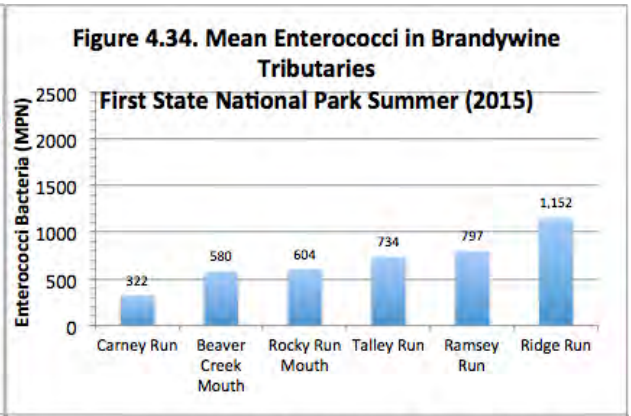


Figure 4.34. Mean Enterococci in Brandywine Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
322
580
604
734
797
1,152
Carney Run
Beaver Creek Mouth
Rocky Run Mouth
Talley Run
Ramsey Run
Ridge Run

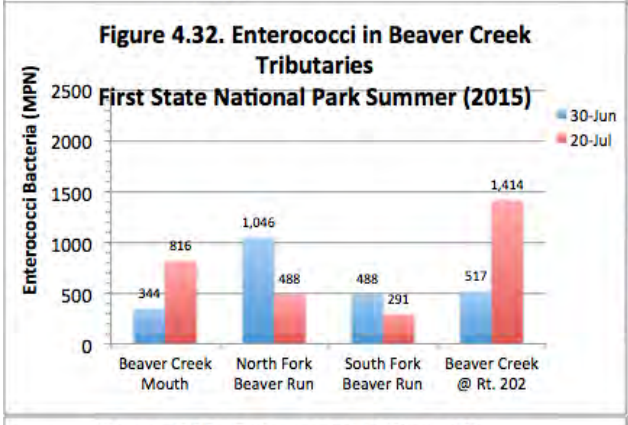


Figure 4.32. Enterococci in Beaver Creek Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
30-Jun
20-Jul
344
816
1,046
488
488
291
517
1,414
Beaver Creek Mouth
North Fork Beaver Run
South Fork Beaver Run
Beaver Creek @ Rt. 202

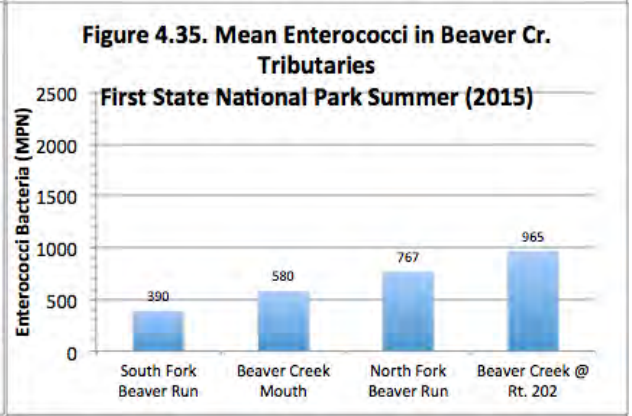


Figure 4.35. Mean Enterococci in Beaver Cr. Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
390
580
767
965
South Fork Beaver Run
Beaver Creek Mouth
North Fork Beaver Run
Beaver Creek @ Rt. 202

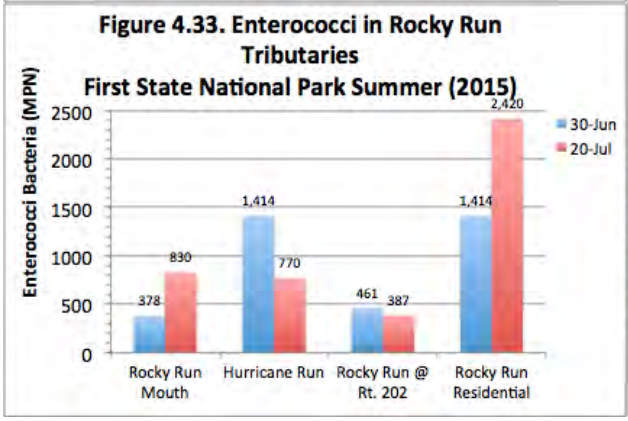


Figure 4.33. Enterococci in Rocky Run Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
30-Jun
20-Jul
378
830
1,414
770
461
387
1,414
2,420
Rocky Run Mouth
Hurricane Run
Rocky Run @ Rt. 202
Rocky Run Residential

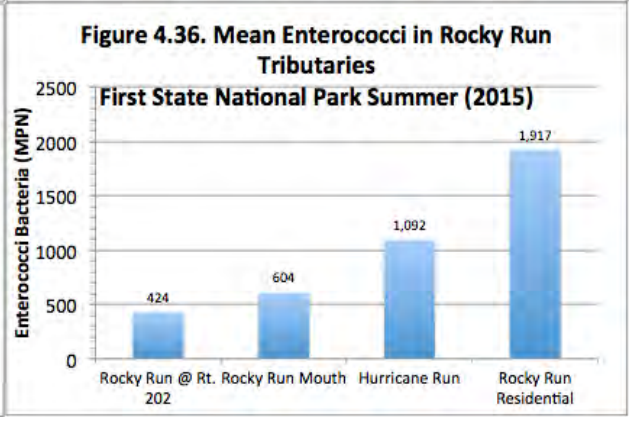


Figure 4.36. Mean Enterococci in Rocky Run Tributaries
First State National Park Summer (2015)
Enterococci Bacteria (MPN)
2500
2000
1500
1000
500
0
424
604
1,092
1,917
Rocky Run @ Rt. 202
Rocky Run Mouth
Hurricane Run
Rocky Run Residential

Chapter 5: Discussion and Conclusions

Based on the chemical parameters monitored over the course of 10 months and the several standards found for each parameter, the overall results from this study indicate that there are little chemical impairments, no nutrient impairments, and possible bacterial impairments in the tributaries flowing into the Brandywine Creek.

There are a few tributaries that are close to reaching the borderline of having impaired waters. Beaver Creek at Route 202 has the lowest dissolved oxygen levels, the highest conductivity values, and sodium levels that miss the limit by less than 2mg/L. The water quality of this stream may be affected due to its proximity to the Concord Pike and heavy impact of urban development as runoff flows downstream from these areas to the sampling site. This site also had high levels of bacteria, which may be an indication of sewage runoff issues from the surrounding residential, highway, and business areas directly upstream.

Rocky Run at Residential Greenway is another example of a tributary that may be impacted more seriously by commercialized areas as indicated by high turbidity and dangerous levels of bacteria. However, other results show that water quality conditions at the mouth of Rocky Run are within healthy conditions, which suggests that the protected vegetation in the First State National Historical Park may help restore the water quality of unhealthy streams.

Beaver Creek Mouth has the highest mean pH value of 7.8 when compared to the rest of the sampling sites. Considering that both Beaver Creek North and South Forks also have higher mean pH values and that they converge into Beaver Creek, the highest pH value may be a result of these two streams combining. Ridge Run has the second highest pH values, which may be due to its closeness to a horse ranch. The higher pH value may indicate the presence of increased levels of nitrogen and phosphorus from residual runoff from horse manure or other agricultural practices.

To improve the water quality of the tributaries mentioned above, native plants could be planted along roadways where there is clearly not enough of a buffer zone between the road and stream. Furthermore, as Beaver Creek, Talley Run and Rocky Run are currently listed as impaired for habitat and biology, implementing reforestation techniques along heavily eroded banks would be a method to prevent further degradation. Since the Brandywine State Park and First State National Historic Park contain many horse and agricultural farms, it is imperative that preventative measures are taken to prevent nutrient runoff and bacteria from further endangering the adjacent waterways.

In conclusion, we found no nutrient impairments in the Brandywine Creek tributaries. There are some concerns for chemical impairments, specifically conductivity, in certain sites that were adjacent to commercialized or agricultural areas. This may indicate high levels of nutrients from runoff that may impair the ecosystem. There are also concerns about bacterial contamination in many sites, although this research should be continued to add more statistical data. Hopefully these results will help the National Park Service and Delaware State Park to identify problems areas in the Brandywine-Piedmont watershed that may affect water quality and take appropriate actions to prevent further degradation.

Chapter 6: References

A. Dowtin, G. Kauffman. 2015. Field Report First State National Park Brandywine-Piedmont Watershed Plan.

Agency for Toxic Substances and Disease Registry, 2014. Toxic Substances Portal. <http://www.atsdr.cdc.gov/substances/index.asp>

C. Cruz-Ortiz, A. Dowtin, K. Miller, E. Rubino. 2015. Field Report Plan for Rocky Run Environmental Protection (PRREP).

Delaware Department of Natural Resources and Environmental Control, 2014. Draft Determination for the State of Delaware2014 Clean Water Act Section 303(d) List of Waters Needing TMDls. Dover, Del.

Delaware River Basin Commission, 2013. Water Quality Regulations. <http://www.state.nj.us/drbc/library/documents/WQregs.pdf>

Department of Natural Resources and Environmental Control, 2011. State of Delaware Surface Water Quality Standards. <http://water.epa.gov/scitech/swguidance/standards/wqslibrary/upload/dewqs.pdf>

Kiliszek, Alison, 2010. Development and Use of Water Quality Indices (WQI) to Assess the Impact of BMP Implementation on Water Quality in the Cool Run Tributary of the White Clay Creek Watershed. University of Delaware.

M. Kumar, A. Puri. 2012. A Review of Permissible Limits of Drinking Water. Indian J Occup Environ Med, 16(1): 40-44. Accessed 19 February 2016 through National Center for Biotechnology Information.

Minnesota Pollution Control Agency, 2008. Turbidity: Description, Impact on Water Quality, Sources, Measures. <https://www.pca.state.mn.us/sites/default/files/wq-iw3-21.pdf>.

Schenck, W.S., M. O. Planck, and L. Srogi, 2000. Bedrock Geologic Map of the Piedmont of Delaware and Adjacent Pennsylvania. Delaware Geological Survey.

Sheffer, Marla, ed., 2003. Ammonia in Drinking Water. World Health Organization.

Stream Testing Protocols. Delaware Riverkeeper Network, 8 September 2010. Web. 3 August 2015.
<http://www.delawareriverkeeper.org/pdf/gas_drilling_stream_watchdog_protocols.pdf>.

Appendix

Table A.1. Temperature data

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
DATE	Ridge Run	Beaver Creek Mouth	North Fork Beaver Ru	South Fork Beaver Rur	Talley Run	Ramsey Run
23-Jun	25.5	21.9	21.7	22	20.1	20.4
30-Jun	22.5	19.9	19.2	19	18.7	19.1
6-Jul	22.7	20	19.8	19.9	18.5	18.9
13-Jul	23.1	20.4	20.4	20.9	19	19.2
20-Jul	26.3	23.1	22.7	22.7	21.3	21.4
28-Jul	24.5	21.2	21.2	21.3	19.9	19.7
9-Oct	19.4	16.9	17.5	17.5	17.8	17.9
23-Oct	15.4	12.6	13.1	11.6	13.3	14
6-Nov	17.1	16.6	17.6	15.9	17	16.9
13-Nov	13.4	11.2	13.1	11.4	11.3	11.9
4-Dec	9.7	7.3	9.5	7.6	8.1	8.9
AVERAGES	19.96363636	17.37272727	17.8	17.25454545	16.81818182	17.11818182

	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
DATE	Carney Run	Rocky Run Mou	Hurricane Run	Rocky Run @ Rt. 202	Beaver Cree	Rocky Run Residential
23-Jun	18.8	21.8	21.7	24.8	23.9	22.2
30-Jun	17.7	19.3	20.3	21.5	21.2	19.8
6-Jul	17.8	20	19.5	22.3	21.9	20.2
13-Jul	18.1	20.1	19.6	22.9	21.5	20.6
20-Jul	19.2	21.9	21.7	24.3	23.7	22.3
28-Jul	19	21.3	21.5	23.1	23	21.5
9-Oct	17.1	18.4		19.6	18.3	17.8
23-Oct	12.5	13.2	13.3	13.1	13.3	13.3
6-Nov	16.4	17	17.7	18	16.7	16.5
13-Nov	11.7	11.7	12	11.4	12.4	11.9
4-Dec	9.1	8.9	8.9	8.3	9.2	8.9
AVERAGES	16.12727273	17.6	20.71666667	19.02727273	18.645455	17.72727273

Table A.2. pH data

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
DATE	Ridge Run	Beaver Creek Mouth	North Fork Beaver Run	South Fork Beaver Run	Talley Run	Ramsey Run
23-Jun	7.7	7.8	7.6	7.7	7.4	7.3
30-Jun	7.7	7.8	7.6	7.7	7.5	7.6
6-Jul	7.7	7.6	7.6	7.7	7.6	7.4
13-Jul	7.8	7.9	7.7	7.7	7.5	7.5
20-Jul	7.8	8.1	7.6	7.9	7.6	7.4
28-Jul	7.8	7.9	7.7	7.6	7.6	7.4
9-Oct	7.7	7.6	8.7	8.6	7.3	7.5
23-Oct	7.6	8	7.7	7.7	7.6	7.4
6-Nov	7.7	8.1	7.6	7.8	7.8	7.9
13-Nov	7.7	8.1	7.8	7.9	7.5	7.3
4-Dec	7.6	8	7.7	7.9	7.2	7.2
AVERAGES	7.7090909	7.9	7.754545455	7.836363636	7.509091	7.4454545

	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
DATE	Carney Run	Rocky Run Mou	Hurricane Run	Rocky Run @ Rt. 202	Beaver Creek @ Rt. 20	Rocky Run Residential
23-Jun	7.3	7.7	7.5	7.1	7.2	7
30-Jun	7.6	7.7	7.4	7.2	7.3	6.9
6-Jul	7.5	7.4	6.9	6.8	7.2	7
13-Jul	7.5	7.7	7.6	7.2	7.2	7.2
20-Jul	7.7	7.7	7.4	6.8	7.3	7
28-Jul	7.5	7.6	7.4	7	7.4	6.8
9-Oct	7.4	7.6		7.2	7.5	6.8
23-Oct	7.4	7.6	7.5	7.2	7.5	7.4
6-Nov	7.9	7.9	7.5	7.2	7.6	7
13-Nov	7.5	7.8	7.5	7	7.2	7.6
4-Dec	7.3	7.7	7.4	6.9	7.2	6.9
AVERAGES	7.509090909	7.672727273	7.366666667	7.054545455	7.327272727	7.0545455

Table A.3. Turbidity data

	Site 3	Site 2	Site 11	Site 7	site 10	Site 12
DATE	North Fork Beaver Run	Beaver Creek Mouth	Beaver Cree	Carney Run	Rocky Run @ Rt. 202	Rocky Run Residential
30-Jun	3.28	1.23	4.48	4.18	5.62	8.15
20-Jul	3.09	5.62	2.71	4.82	4.18	10.8
4-Mar	2.93	0.63	6.79	6.42	9.67	2.8
21-Mar	1.24	0.6	1.98	9.92		
8-Apr	0.72	1	1.78	2.64		9.8
	North Fork Beaver Run	Beaver Creek Mouth	Beaver Cree	Carney Run	Rocky Run @ Rt. 202	Rocky Run Residential
Average (NTU)	3.2	3.4	3.6	4.5	4.9	9.5
Average (FNU)	1.6	0.7	3.5	6.3	9.7	6.3

	Site 8	Site 4	Site 9	Site 6	Site 5	Site 1
DATE	Rocky Run Mouth	South Fork Beaver Run	Hurricane Run	Ramsey Run	Talley Run	Ridge Run
30-Jun	1.1	0.838	1.87	2.36	2.72	2.44
20-Jul	0.814	1.79	1.07	1.77	1.86	2.83
4-Mar	0.12	0.33	3.9	1.57	1.8	2.77
21-Mar	0.75	0.42	0.62	0.73	0.75	3.45
8-Apr	0.19	0.36	0.39	0.82	1.17	0.75
	Rocky Run Mouth	South Fork Beaver Run	Hurricane Run	Ramsey Run	Talley Run	Ridge Run
Average (NTU)	1	1.3	1.5	2.1	2.3	2.6
Average (FNU)	0.4	0.4	1.6	1	1.2	2.3

(Note: the first two dates in green were analyzed in NTUs in Wilmington while the last three dates in blue were analyzed in FNUs using a turbidity meter from UD.)

Table A.4. DO data

	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
DATE	Carney Run	Rocky Run Mouth	Hurricane Run	Rocky Run @ Rt. 202	Beaver Creek @ Rt. 202	Rocky Run Residential
23-Jun	10.5	10.4	8.8	9.3	7.6	8.8
30-Jun	11	8	8	9.6	7.3	7.7
6-Jul	9.9	8.5	8.6	5.5	9.2	9.9
13-Jul	7.2	6	8.8	15.8	7	8.5
20-Jul	10.9	8.7	7	5.7	8.8	6
28-Jul	9	8.4	6	5.9	6	7.8
9-Oct	8.8	9.8		8.6	7	6.2
23-Oct	8.1	12.1	8	9.8	7	7.9
6-Nov	9.2	10.9	8.3	7.1	6.8	4.7
13-Nov	11.2	11.9	10.9	10.2	9.8	7.8
AVERAGES	9.58	9.47	7.866666667	8.75	7.65	7.53

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
DATE	Ridge Run	Beaver Creek Mouth	North Fork Beaver Run	South Fork Beaver Run	Talley Run	Ramsey Run
23-Jun	8.1	9.6	7	8.9	7.7	9.7
30-Jun	7.8	10.2	10.1	8.6	9.7	10.1
6-Jul	8.2	9.3	8.7	9.5	9	9.5
13-Jul	8.2	7.6	9	7.8	6	8.2
20-Jul	10.4	10.2	9.9	10	8.9	9.3
28-Jul	8	9.1	7	5.2	6.6	7.1
9-Oct	8.4	9.3	8.3	8.4	8.6	7.7
23-Oct	9.5	10	9.5	8.7	8.6	8.8
6-Nov	9	11	6.8	10.1	7.5	7.2
13-Nov	10.4	13	8.8	13.3	10.3	11.2
AVERAGES	8.8	9.93	8.51	9.05	8.29	8.88

Table A.5. Conductivity data

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
DATE	Ridge Run	Beaver Creek Mouth	North Fork Beaver Creek	South Fork Beaver Creek	Talley Run	Ramsey Run
22-Jun		400	480	310	115	265
23-Jun	246	461	342	577	130	295
30-Jun	238	432	315	535	124	283
6-Jul	245	435	311	551	127	296
13-Jul	251	445	326	561	132	284
20-Jul	250	435	328	545	137	280
28-Jul	252	461	331	577	136	271
9-Oct	200	380	290	460	100	210
23-Oct	220	390	320	450	110	210
6-Nov	210	380	320	440	110	210
13-Nov	210	350	310	380	110	250
4-Dec	200	310	270	340	90	220
3/4/16	200	380	240	520	100	270
3/21/16	180	370	240	500	100	230
4/8/16	190	370	240	480	100	220
AVERAGE	220.85714	399.9333333	310.8666667	481.7333333	114.7333	252.93333

	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
DATE	Carney Run	Rocky Run Mouth	Hurricane Run	Rocky Run @ Rt. 202	Beaver Creek @ Rt. 202	Rocky Run Residential
22-Jun	230	290	335	350	840	410
23-Jun	275	333	416	525	1032	307
30-Jun	299	342	372	717	952	330
6-Jul	275	373	434	773	1232	351
13-Jul	251	381	454	792	1444	305
20-Jul	243	387	477	796	1209	296
28-Jul	230	384	468	704	898	176
9-Oct	170	330		480	760	300
23-Oct	160	350	350	730	930	190
6-Nov	170	330	330	560	850	220
13-Nov	180	240	310	380	600	130
4-Dec	200	230	280	390	650	170
3/4/16	250	480	880	830	1720	240
3/21/16	180	370	480		900	
4/8/16	170	290	470		760	130
AVERAGE	218.86667	340.6666667	432.5714286	617.4615385	985.1333333	263.4615385

(Note: yellow highlight indicates data from that date was taken using the probe from Wilmington, while unhighlighted data was taken using the University of Delaware TDScan 3 probe. Both have the same units, micro Siemens.)