Water Quality Monitoring in the White Clay Creek National Wild & Scenic River Watershed in Delaware and Pennsylvania

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Chapter 1: Introduction and Purpose

1.1 Background

White Clay Creek is protected by the United States Federal Government as a result of its designation under the Wild and Scenic Rivers System by the National Park Service. Working together to protect and preserve the creek are White Clay Creek State Park, located in Delaware's New Castle County, and White Clay Creek Preserve, located in Pennsylvania's Chester County. A large portion of the 4,555 acres that make up both state parks was donated by the DuPont company, who had purchased it with plans to build a new reservoir. When this plan was protested and the companies water supply issues were solved, they were persuaded to donate the large amount of land that they had acquired. The Delaware state park was established in 1968 and the protected area in Pennsylvania was established in 1984. While these sections of the White Clay Watershed are protected, other nearby locations are commercially, residentially, and agriculturally developed. This impacts the water quality.

1.2 Justification

With the establishment of the Brandywine Creek sampling route within the First State National Park, the University of Delaware Water Resources Center (UDWRC) saw it necessary to sample other Delaware waterways, including White Clay Creek, where turbidity levels have been rising as a result of nonpoint source pollution. The WRC recognized this using gages provided by the United States Geological Survey (USGS) which retrieve water quality data for the main branches of White Clay Creek. Under the direction of Gerald Kauffman, sampling sites within the White Clay Watershed in both Delaware and Pennsylvania were chosen in January of 2015 by undergraduate researchers based on location of flow into the creek. Twenty one testing sites on each branch of White Clay Creek throughout the watershed were chosen. In order to create a comprehensive plan of action to improve water quality in White Clay Watershed, data was gathered from the tributaries. Water quality sampling, which was done by student research assistants and interns from the UDWRC, took place from in 2016 from February through December. The students took measurements for both turbidity and conductivity. The purpose of monitoring the water quality at these sites is to help narrow nonpoint source pollution locations which contribute to high turbidity levels. By determining the areas with the highest turbidity, they can be prioritized for funding and restoration efforts. We hope that this research can aid in improving the water quality of White Clay Creek and its tributaries.

Figure 1. White Clay Creek watershed location map

Chapter 2: Watershed Characterization

2.1 White Clay Watershed

The Christina Basin, part of the larger Delaware River Basin, is made up of four major watersheds. One of these is the White Clay Watershed, which is located in both New Castle County, Delaware and Chester County, Pennsylvania, with about 55% of its area in Pennsylvania, about 45% in Delaware, and a fraction of a percent in Cecil, Maryland. The 107 square miles that make up the White Clay Watershed are home to about 130,000 people who rely on it as a source of drinking water. The entire watershed has been federally protected under the Wild and Scenic system, which is something that had never been done before. Since only sections of rivers were previously given this classification, the designation makes the White Clay Watershed unique. This strategy does not ignore that the river's water quality and habitat is impacted by a variety of factors extending throughout its watershed. The area is operated by the National Park Service in partnership with stakeholders at the local, regional, and state levels. The conservation management plan that is used not only aims to protect the resources located within the watershed and the values they provide, but also includes recreation which attracts visitors and supports the local economy.

White Clay Creek Watershed

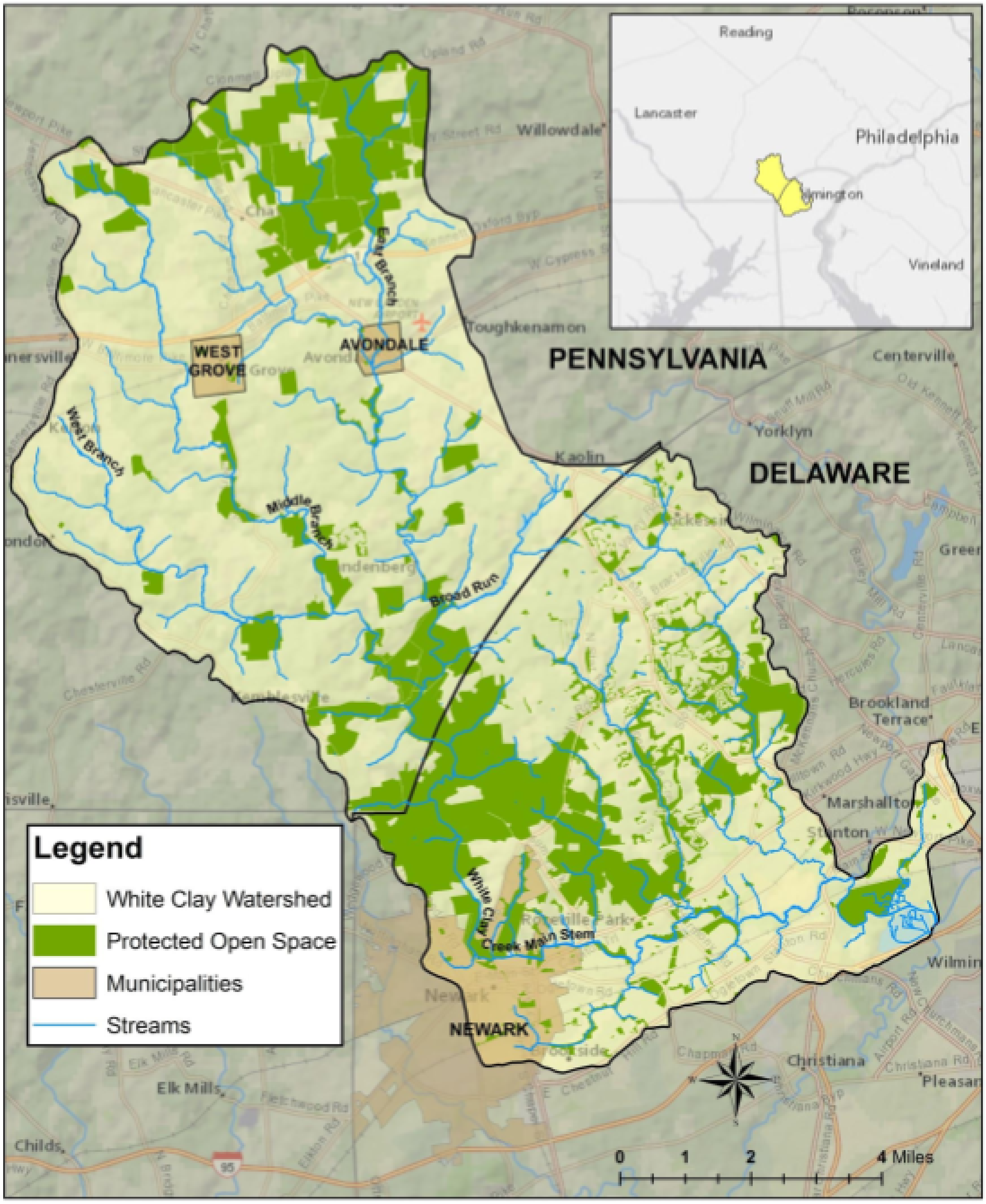


Figure 2. White Clay Creek watershed

2.2 Land Use

The portion of the White Clay Creek watershed that is located in Pennsylvania is largely rural with a few small towns and villages, such as West Grove and Avondale, and some suburban clusters. The slightly smaller section of the watershed which is in Delaware includes the City of Newark and is highly suburbanized, although several very large tracts of public open space remain intact and flank the river. Normal rainfall for this region supplies enough water to support a mature deciduous forest and an extensive freshwater tidal wetlands system downstream.

Looking at trends and changes in land use aids in understanding the processes impacting the water quality in the White Clay Creek watershed, which is composed as three major land cover types: developed land (37%), agriculture (33%), and natural areas (forests and wetlands, 30%), with the Delaware portion being more developed and the Pennsylvania portion with the most agriculture and natural lands. These trends can be seen in figure 3, which shows the land cover by acreage in each subwatershed, and figure 4, which shows the change in land cover of the three major categories. The Main Stem of the creek below Newark has the highest percentage of developed land cover and the lowest percentage of forest and wetlands. The East Branch above Avondale has the highest proportion of agriculture and the lowest of developed land. The area with the most highest proportion of forest and wetlands is the Main Stem above Newark. In the years 1996 to 2010, the East Branch below Avondale saw the largest increase in developed land and the largest decrease in agriculture. Middle Run saw the least amount of change.

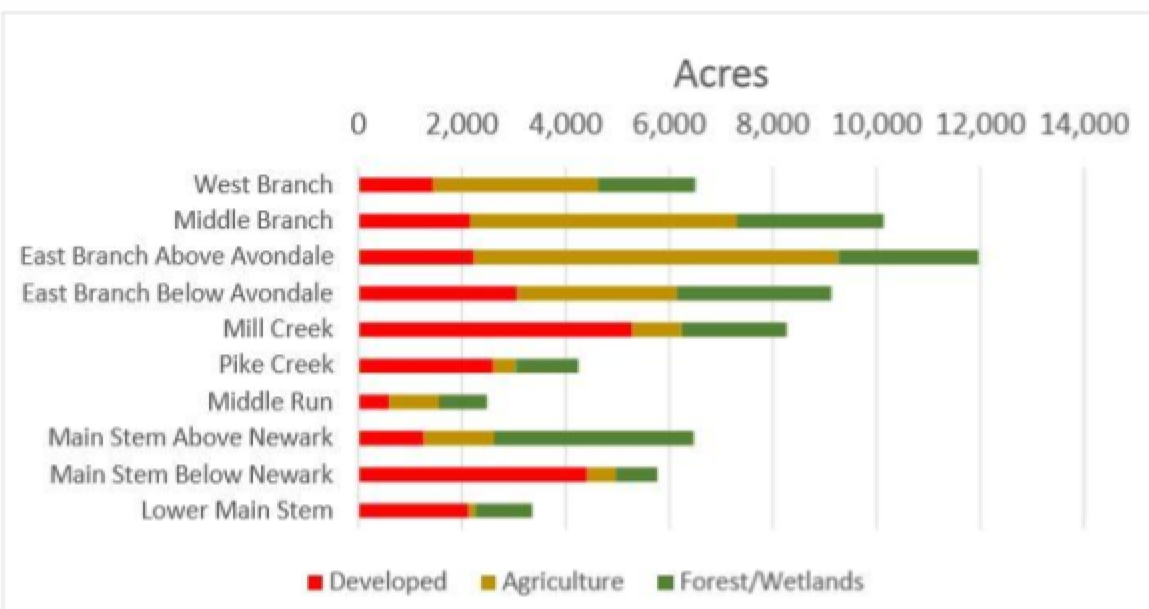


Figure 3. Land cover area in White Clay Creek watershed by subwatershed, 2010

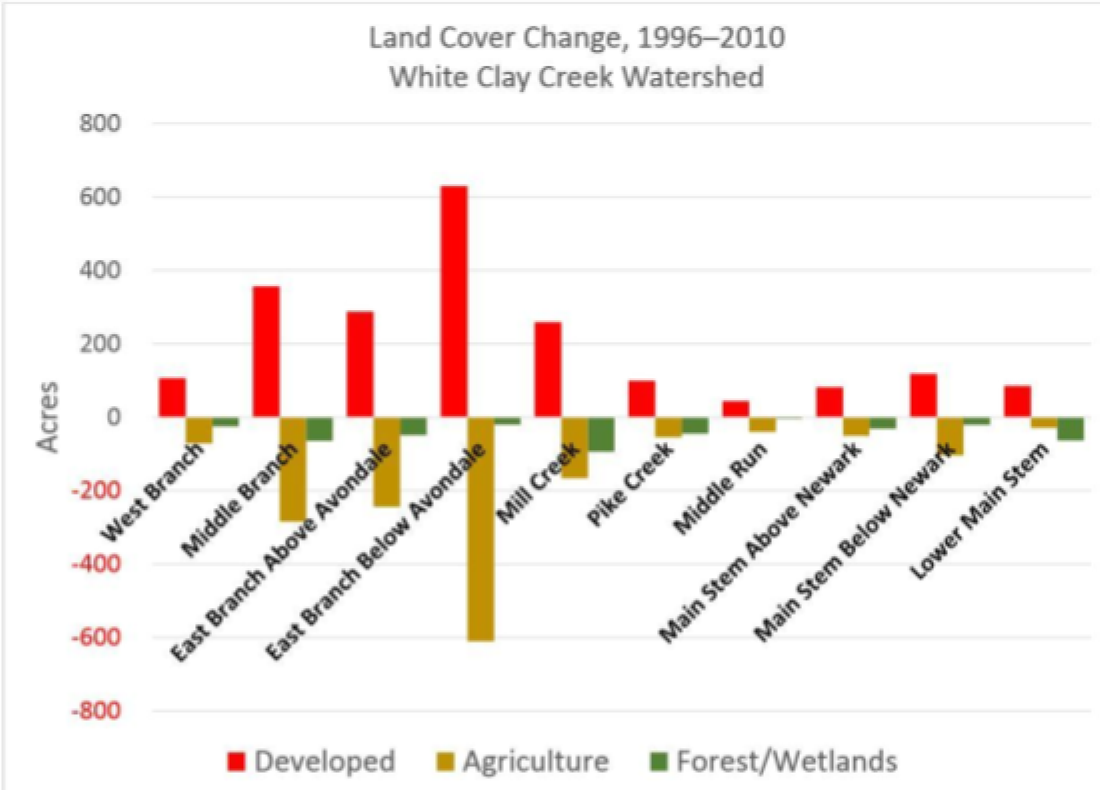


Figure 4. Land cover change in White Clay Creek watershed by subwatershed, 1996-2010

2.3 Soils

The White Clay Creek watershed is divided by a unique geological feature, the Fall Line, separating the hilly, rocky Piedmont and the sandy, flat Coastal Plain. These differences allow different types of soil to be present in the watershed and produce a wide variety of flora and fauna, including 20 species of ferns, 200 species of wildflowers, and over 60 varieties of tree and shrub species. There are six different soil associations in Delaware and Pennsylvania. These include: Glenelg-Manor-Chester, Hagerstown-Conestoga-Guthrie, Glenelg-Manor-Glenville, Elsinboro-Delanco-Urban, Sassafras-Fallsington-Matapeake, and Aldino-Keyport-Mattapex-Urban, as shown in the image below. There are concerns about soil erosion and degradation of the topsoil in the White Clay Creek watershed based on high agricultural land use.

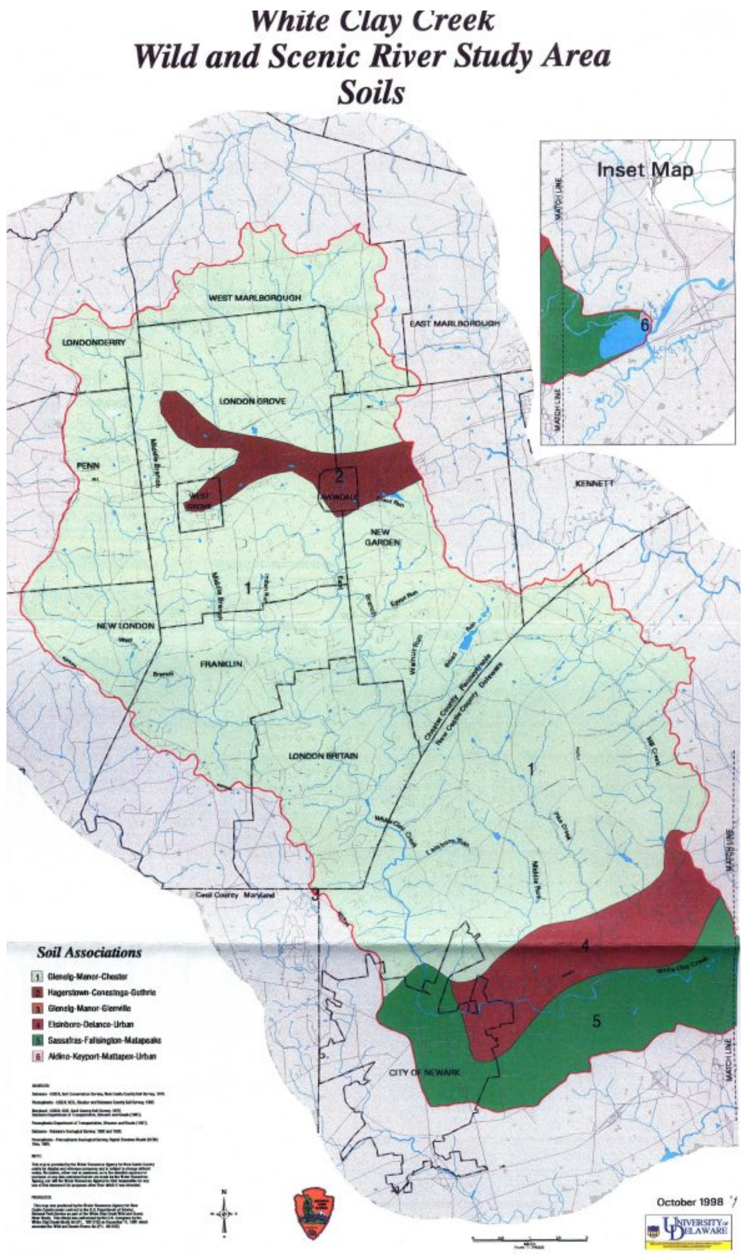


Figure 5. Soil Associations in the White Clay Creek watershed

2.4 Geology

White Clay Watershed is located along a fall line, which is a transition zone between an upland region and a plain. This geological boundary between the Piedmont, characterized by hills and rocks, and the sandy coastal plain gives a wide variety of geological conditions and soil types which support diverse flora and fauna.

Chapter 3: Methodology

3.1 Schedule

Stream sample sites at White Clay Creek were visited and mapped out in mid-January of 2016. Sampling for the spring began on February 26th, 2016 and ended on May 6th, 2016. The team collected data once a week on Friday, with the exception of the week of April 1st when no samples were taken. Sampling was done once during the summer on June 17th, 2016. Sampling for the fall began on September 16, 2016 and ended on December 2, 2016. Fall sampling occurred following a period of heavy rain, indicating high flow.

February 26, 2016: All sites except sites 18,19,20, and 21
March 4, 2016: All sites except 18, 19, 20, 21
March 11, 2016- All sites except 19
March 18, 2016- All sites
March 25, 2016- All sites
April 8, 2016- All sites except 14 and 15
April 15, 2016- All sites
April 22, 2016- All sites
April 29, 2016- All sites
May 6, 2016- All sites- Turbidity data collected on this date was removed from graphical analysis
June 17, 2016- All sites except 18, 19, 20, and 21
September 16, 2016- All sites except 18, 19, 20, and 21
September 22, 2016- All sites except 18, 19, 20, and 21
November 4, 2016- All sites except 11, 12, 13, 14, 16, 18, 19, 20, and 21
December 2, 2016- Sites 11, 12, 13, 14, and 16

Figure 6. Field reporters sampling at Jenney's Run (Andrea Miller-front and Maya Kassoff-back)

3.2 Parameters

Table 1. Water quality standards of tested parameters

Parameter	**Unit**	**Water Quality Standard**
Turbidity	FNU	Cannot exceed natural levels by more than 10 FNU
Conductivity (EC)	µS	Should be between 150-500 µS

3.3 Equipment

- Combination pH, EC (Conductivity), TDS (Total Dissolved Solids), and temperature Hanna Instruments Waterproof Tester from the University of Delaware (Figure 3.1)- used to measure EC
- Salinity, TDS, and EC Tracer PockeTester probe from the Delaware Nature Society (Figure 3.2)- used to measure EC
- Conductivity TDScan3 probe from the University of Delaware (Figure 3.3)
- Milwaukee Turbidity Meter from the University of Delaware (Figure 3.4)
- 2 10 mL glass cuvettes with stoppers
- Cloth for wiping the cuvettes
- 0, 10, and 500 FNU calibration standards for the turbidity meter
- Field notebook and pen

Figure 7
Top: Turbidity Meter
Bottom left: Conductivity probe
Bottom middle: Salinity, TDS, and EC probe
Bottom right: pH, EC, TDS, and temperature probe

3.4 Site Descriptions

Water quality sampling of the 21 locations within the White Clay Watershed took place according 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. 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.

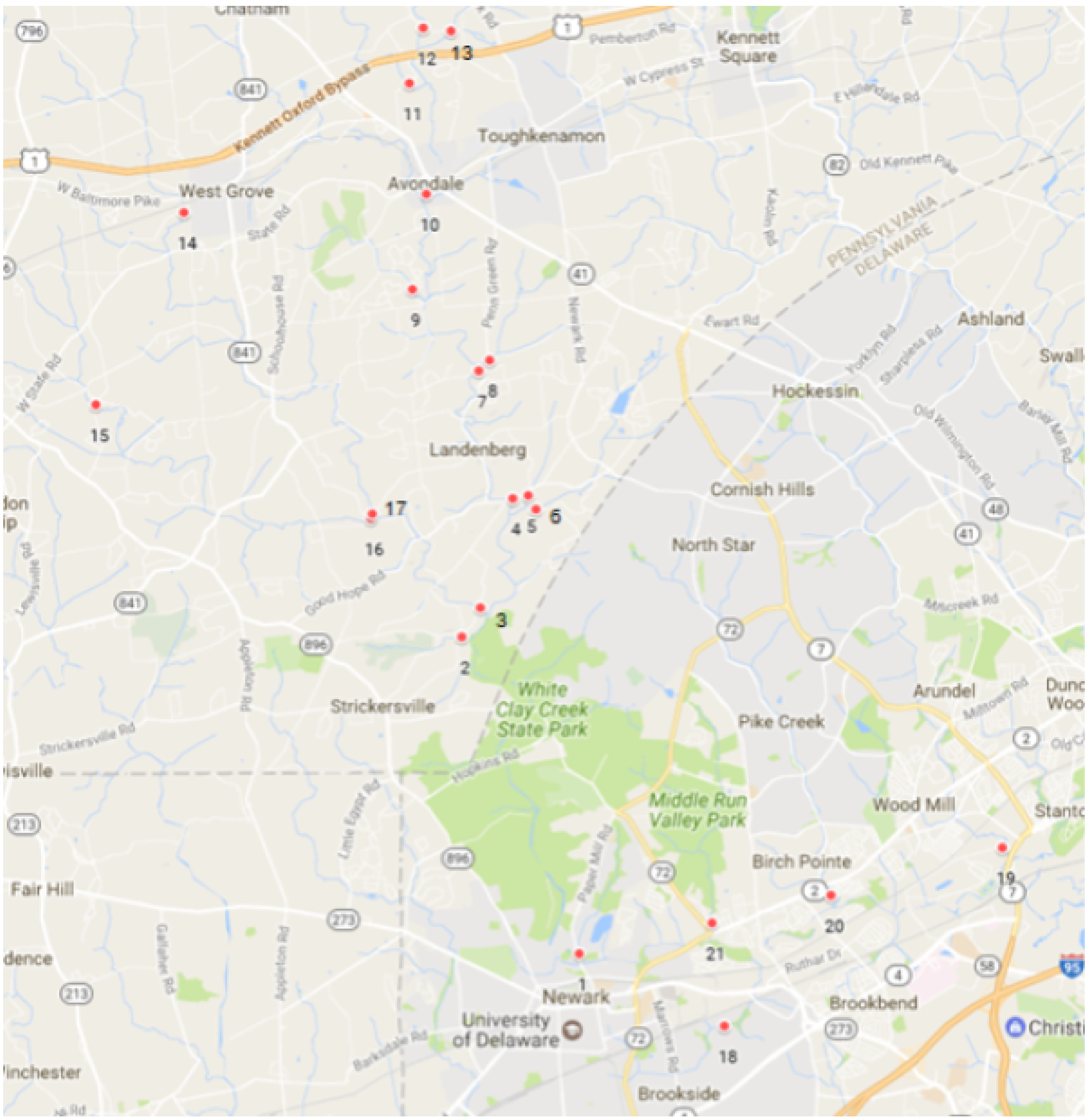


Figure 8. White Clay Creek sampling sites

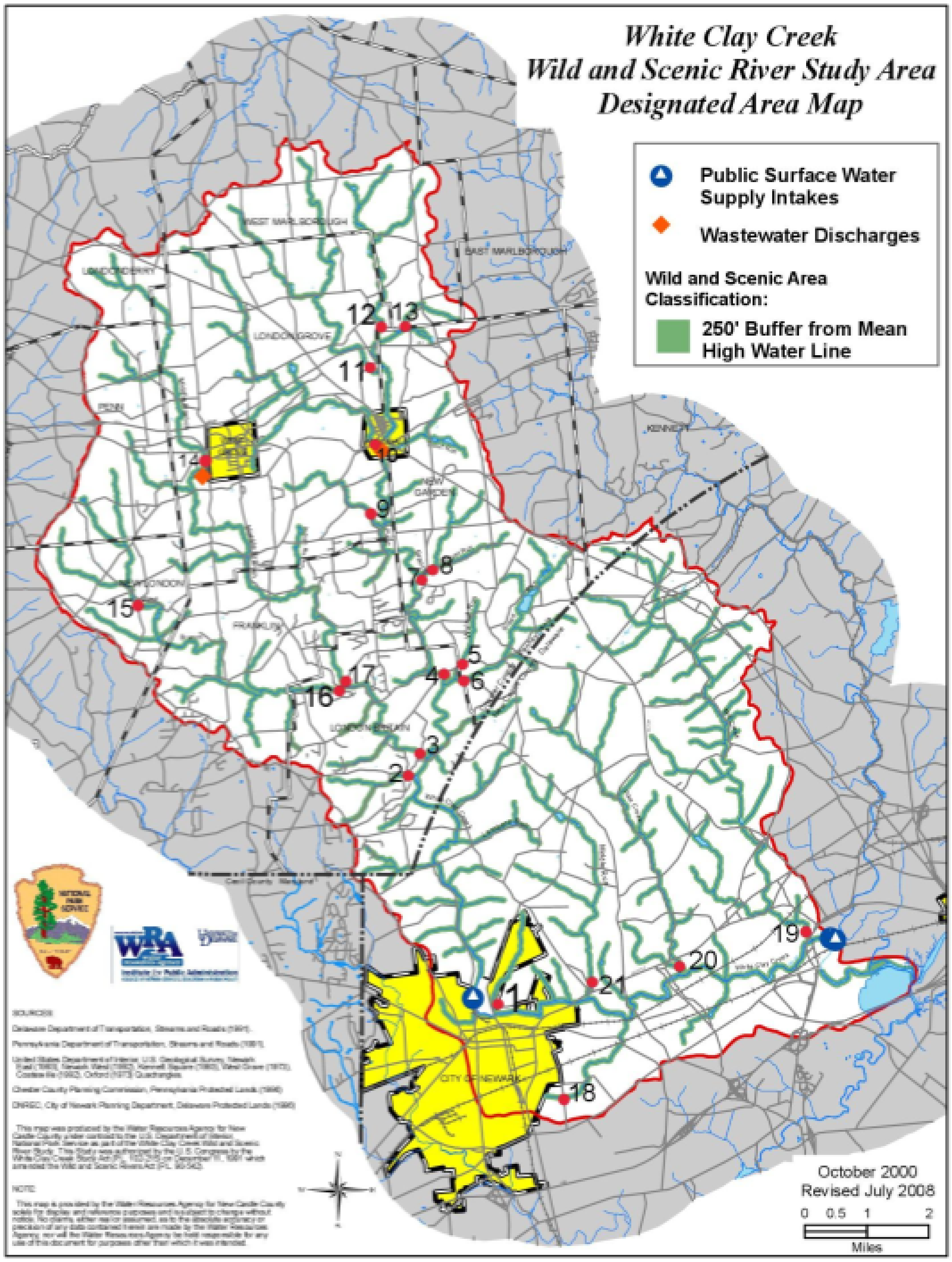


Figure 9. Map of White Clay Creek watershed with sampling sites

Table 2. Key to map above (Figure 3.5) with site location and detail

Site Number	Location Code	Location (Road)	Surrounding Area	Latitude	Longitude
1	WCJR	Jenney's Run	Paper Mill. Rd	39.690975	-75.749029
2	WCSB	South Bank	State park	39.745542	-75.775057
3	WCWB1	South Bank WB	State park	39.750381	-75.771108
4	WCEB1	London Tract Road EB	Horse farm/open space	39.769248	-75.763906
5	WCWR	Watson Mill	Immediate grasses, neighborhood	39.769652	-75.760507
6	WCBR	Broad Run	Wood/suburb	39.767369	-75.758633
7	WCEB2	Auburn Road	Farm/forest	39.791165	-75.771386
8	WCER	Egypt Run	Immediate grasses, neighborhood	39.793101	-75.768808
9	WCAD	Angelica	Grasses/trees	39.805135	-75.786024
10	WCIR	Indian Run	Park - wastewater treatment plant	39.821389	-75.782889
11	WCGB	Glen Willow	Immediate agriculture	39.840456	-75.786784
12	WCEB3	McCue EB	Farm/grasses	39.849833	-75.783753
13	WCEV	Loch Naim	Golf course/grasses	39.849517	-75.777428
14	WCMB1	Valley Road MB	Mushroom composting facility	39.818287	-75.837040
15	WCWB2	School Road WB	Grasses	39.785314	-75.856480
16	WCMB2	North Creek WB	Farm	39.765732	-75.795424
17	WCWB3	Mercer Mill MB	Forest	39.766592	-75.794871
18	WCCR	Cool Run	Immediate trees, neighborhood	39.678724	-75.716743
19	WCMC	Mill Creek	Golf course/grasses	39.709194	-75.655036
20	WCPC	Pike Creek	Neighborhood	39.701190	-75.692931
21	WCMR	Middle Run	Swim club/backroads	39.696225	-75.719544

Site 1- Jenney's Run (WCJR)- Jenney's Run is located on the main stem of White Clay Creek within the White Clay Watershed. The testing site is directly adjacent to Paper Mill Road in Newark, Delaware, where the water flows beneath a small bridge. The water arrives here from the protected area that is White Clay Creek State Park, located north of the sampling site. From here, the creek flows east past various commercial buildings and large parking lots.

Site 2- South Bank (WCSB)- South Bank is a small stream located on the west branch of the White Clay Creek outside of the White Clay Creek Preserve within the White Clay Watershed. The testing site is located near Strickersville, Pennsylvania off South Bank Road. The water flows east toward White Clay Creek underneath a bridge next to London Tract Church. The site is surrounded by forested land and an abandoned building is located nearby.

Site 3- South Bank WB (WCWB1)- South Bank WB is located on the west branch of White Clay Creek within the White Clay Watershed. The testing site is near Landenberg, Pennsylvania, just north of the state's preserved area, the White Clay Creek Preserve. The water flows from the west through undeveloped forest and some suburban neighborhoods. From here, the creek flows south into the protected area.

Site 4- London Tract Road EB (WCEB1)- London Tract Road EB is located on the east branch of the White Clay Creek within the White Clay Watershed. The testing site is located within Landenberg, Pennsylvania where the water flows under Broad Run Road. This is outside of the White Clay Creek Preserve. The site is surrounded by open space and a nearby horse farm. The water flows from a small patch of undeveloped forest to the northwest and from here flows past the horse farm and south into another patch of undeveloped forest.

Site 5- Watson Mill (WCWR)- Watson Mill is located on a section of White Clay Creek known as Walnut Run which branches off of the Broad Run branch of the creek. The testing site is located in Landenberg, Pennsylvania within the White Clay Watershed, outside of the nearby protected areas. This section of the creek is surrounded by suburban neighborhoods and grassy open spaces. From here, the creek meets up with Broad Run and flows into an area of undeveloped forest.

Site 6- Broad Run (WCBR)- Broad Run is located in the White Clay Watershed off Watson Mill Road near Broad Run, (located in the middle branch). The testing site is located in Landenberg, Pennsylvania within the White Clay Watershed. The section is surrounded by forest in between suburban developments on either side of the creek. Located off of Watson Mill Road, the testing site flows underneath a bridge and flows into the White Clay Creek.

Site 7- Auburn Road (WCEB2)- Auburn Road is on the east branch of White Clay Creek. The sampling site is located in Landenberg, Pennsylvania within the White Clay Watershed. Water flows to the site past a farm to the north and flows south into a section of undeveloped forest.

Site 8- Egypt Run (WCER)- Egypt Run is located in the east branch of the White Clay Watershed. The testing site is located north of Landenberg, Pennsylvania off of Egypt Run Road. The site is covered by a bridge with thick greenery surrounding it on both sides. It flows southwest into the White Clay Creek (east branch) and is surrounded by scattered housing developments.

Site 9- Angelica (WCAD)- Angelica is located in northern Landenberg, Pennsylvania, just south of Avondale and within the White Clay Watershed. This site is on the east branch of White Clay Creek. The testing site is surrounded by trees, which are adjacent to grassy suburban neighborhoods. From here, the creek flows south through the same type of environment.

Site 10- Indian Run (WCIR)- Indian Run is located on the east branch of White Clay Creek in Avondale, Pennsylvania, which is within the White Clay Watershed. Nearby this sampling site is a park, a wastewater treatment plant, and suburban neighborhoods. From here, the water flows south through the same type of environment.

Site 11- Glen Willow (WCGB)- Glen Willow is located on the east branch of White Clay Creek in Avondale, Pennsylvania, which is within the White Clay Watershed. This sampling site, which is located where the creek crosses Glen Willow Road, is surrounded by agricultural farms which continue as the creek flows east and then south.

Site 12- McCue EB (WCEB3)- McCue EB is the first of two sites located where the creek crosses McCue Road in Avondale, Pennsylvania. The sampling site is on the east branch of White Clay Creek within the White Clay watershed. The surrounding areas are made up of farms and grassy open spaces. The water comes from slightly more forested areas to the north and flows south by a golf course.

Site 13- Loch Naim (WCEV)- Loch Naim is the second of two sites located where White Clay Creek crosses McCue Road in Avondale, Pennsylvania. This sampling site is to the east of McCue EB on a different offshoot of the east branch. Water flows to the site from the northeast through grassy open spaces. From here, the creek continues to the southwest through a golf course.

Site 14- Valley Road MB (WCMB1)- Valley Road MB is located south of West Grove, Pennsylvania off the mainstem of the middle branch of the White Clay Creek. This sampling site is off of Valley Road covered by a bridge. It is covered by dense plants on one side, and the Hy-Tech Mushroom Compost on the other side. This flows south to eventually connect with the other stems of the White Clay Creek. The West Grove Sewer Plant is located downstream from the testing site.

Site 15- School Road WB (WCWB2)- School Road WB is located northeast of New London Township off of the mainstem of the west branch of White Clay Creek. The testing site is accessible via School Road where it flows under a bridge. The land surrounding the site is covered by farmland, tall grasses, and houses spread far apart. The creek flows southeast to meet with other streams flowing into the west branch.

Site 16- North Creek WB (WCMB2)- North Creek WB is located in Landenberg, Pennsylvania within the White Clay Watershed. The testing site is on the middle branch of White Clay Creek north of the White Clay Creek Preserve. The water flows from the west through Meadowset farm and continues east into a section of undeveloped forest.

Site 17- Mercer Mill MB (WCWB3)- Mercer Mill MB is located on the middle branch of White Clay Creek in Landenberg, Pennsylvania, which is within the White Clay Watershed. Water flows to the testing site from the north through undeveloped forest and continues to the east and then south through the same type of environment.

Site 18- Cool Run (WCCR)- Cool Run is located southeast of Newark, Delaware off Brennen Drive near Cool Run. The sampling site is off of Brennen Drive where it is covered by a bridge and surrounded by immediate trees and neighborhoods. Water flows east through developments and a park area, then northeast to connect with the White Clay Creek.

Site 19- Mill Creek (WCMC)- Mill Creek is located southwest of Stanton, Delaware near Mill Creek. This testing site is located outside of Delaware Park underneath a bridge surrounded by immediate tall grasses and a golf course. Water flows southeast to meet with the White Clay Creek and flows into the Christina River.

Site 20- Pike Creek (WCPC)- Pike Creek is located northeast of Newark, Delaware off Green Valley Road near Pike Creek. The sampling site is located beneath a bridge that is surrounded by immediate trees and a neighborhood. Water flows from Pike Creek southeast into the White Clay Creek.

Site 21- Middle Run (WCMR)- Middle Run is located just northeast of Newark, Delaware off Old Possum Road near Middle Run. The testing site is accessible via Old Possum Park Road. The site is covered by a bridge with a forested area and a swim club just upstream. Water flows south from Middle Run to meet with the White Clay Creek. The site is located right off of Delaware Route 2 and surrounded by back roads.

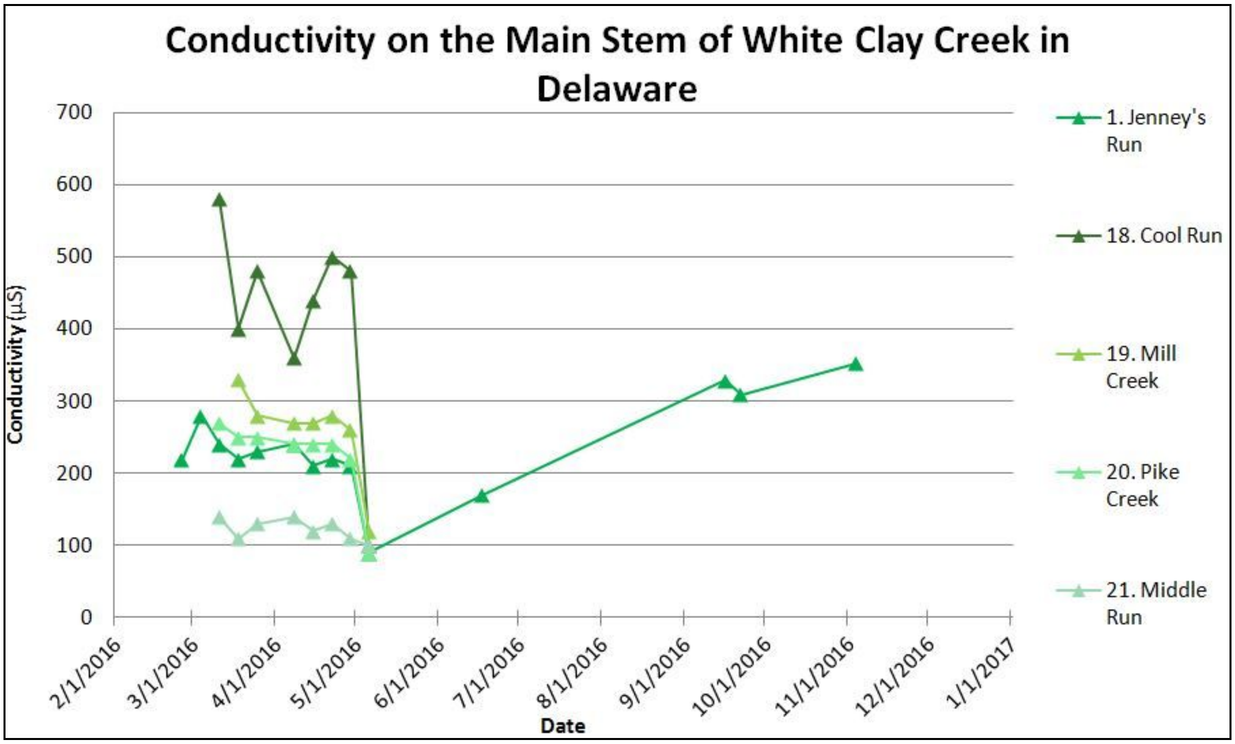
Chapter 4: Field Monitoring Results

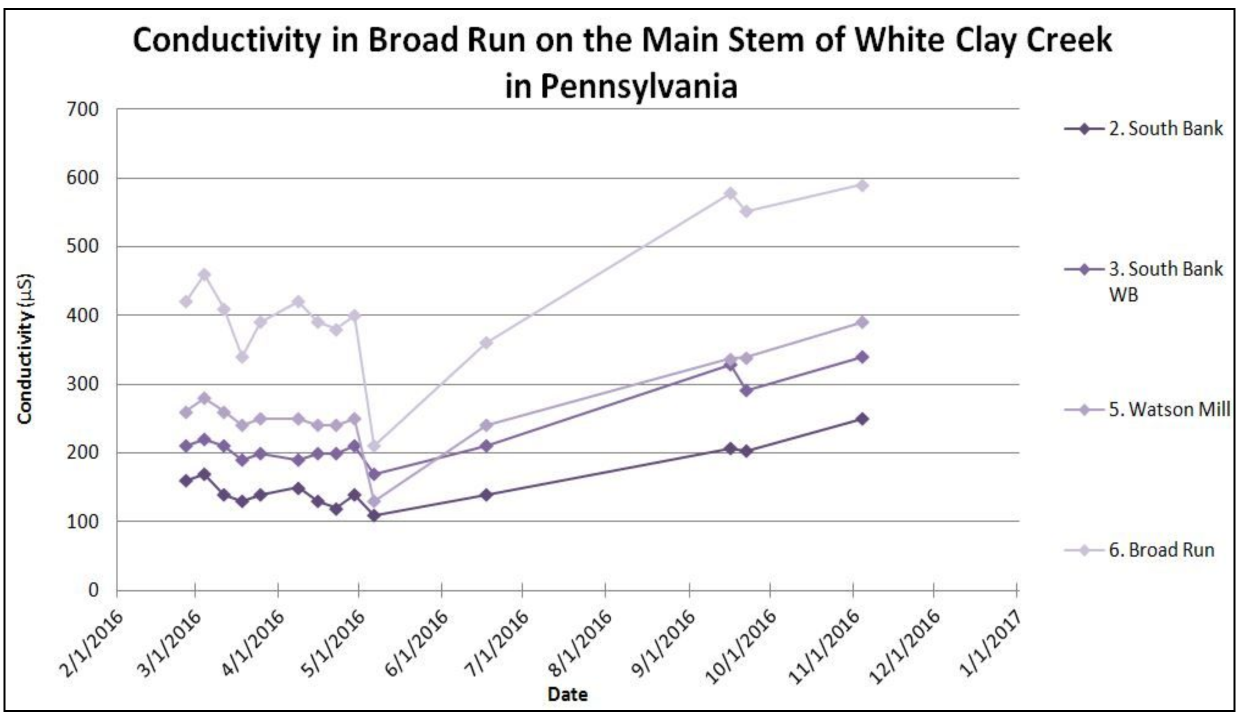
4.1 Chemical Results

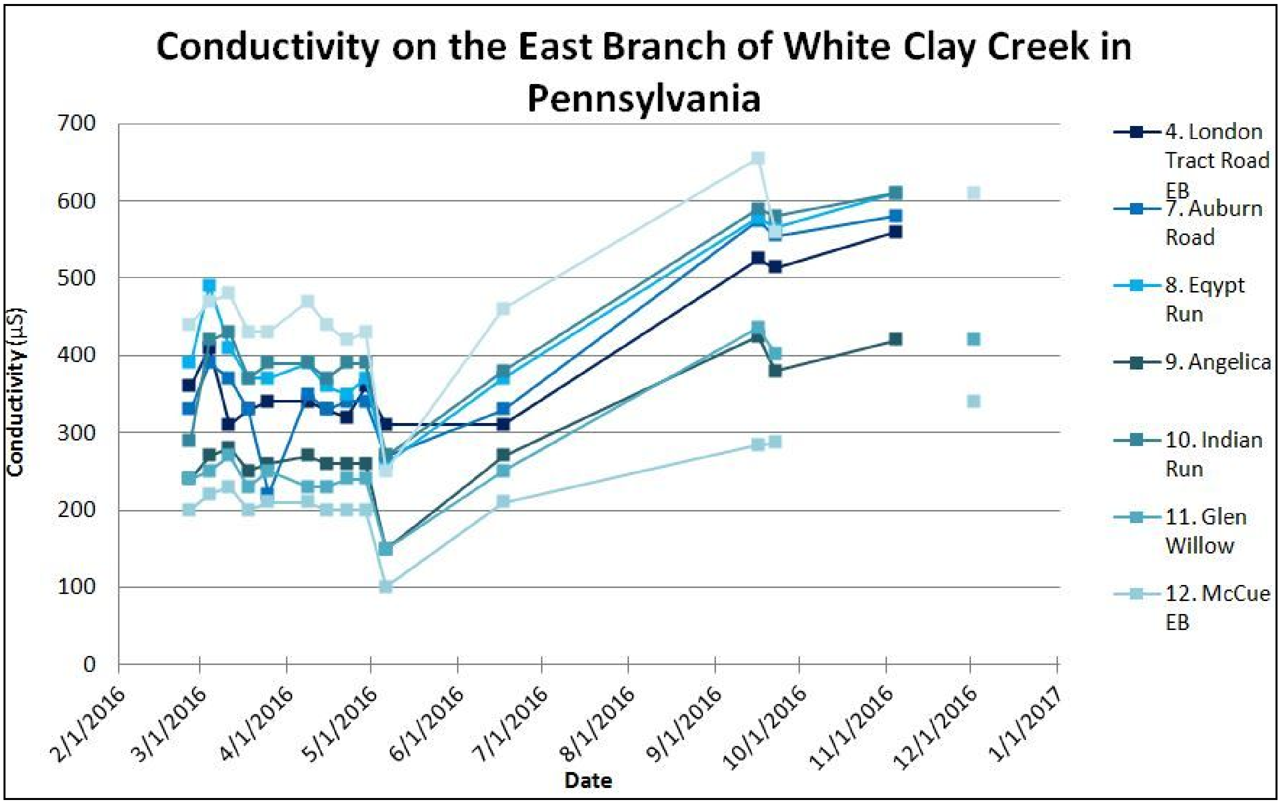
The results from the chemical assessments that were conducted at each location over the eleven month period are displayed as graphs. The graphs show the progression of each parameter (conductivity and turbidity) throughout the year, comparing the different branches of the creek. There are four graphs which group the testing sites based on their location. There are five sites on the main stem of White Clay Creek in Delaware, four sites or the main stem in Pennsylvania, eight sites on the east branch in Pennsylvania, and four sites on the west branch in Pennsylvania. In addition to the four graphs for each parameter which show progression over time, there is a box and whisker plot for each site for each parameter which show the median values, the distribution, and the variability of the results over the entire testing period. This helps to better analyze the overall conditions at each of the 21 locations.

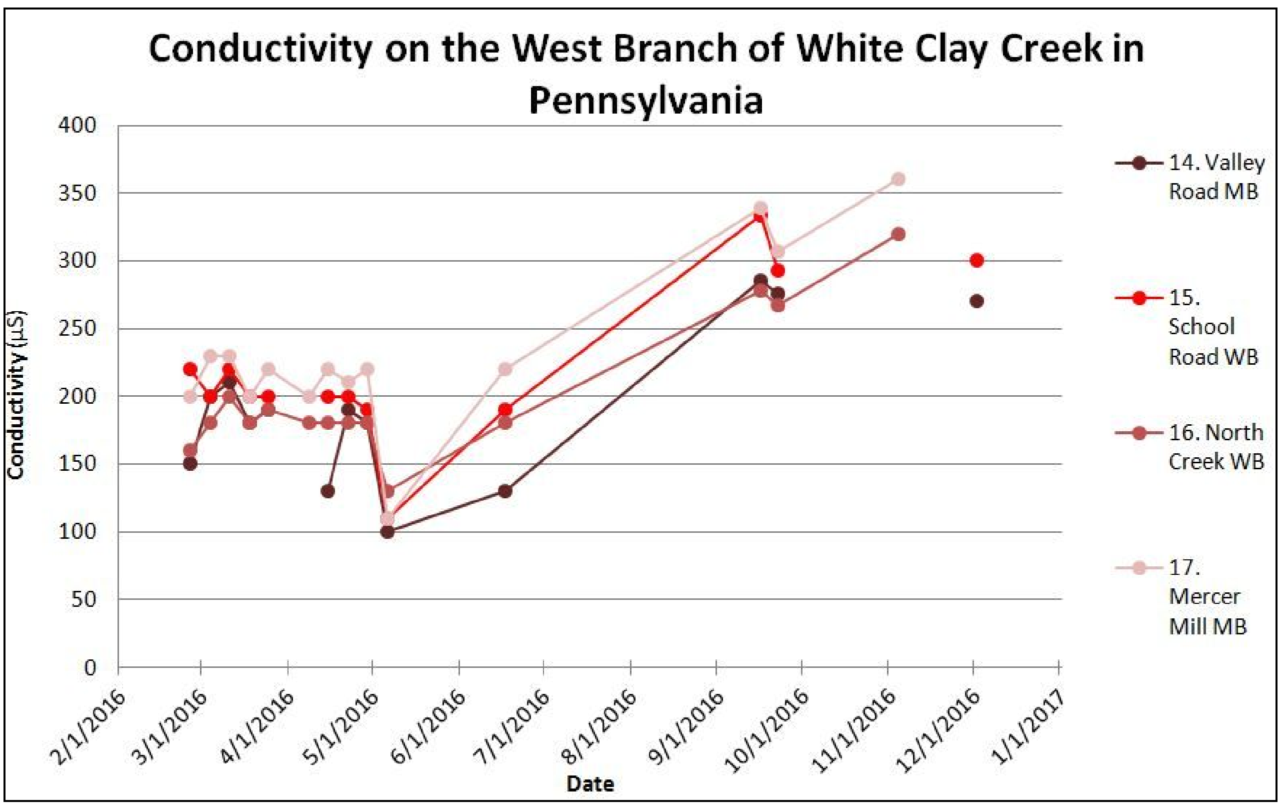
4.1.1 Conductivity

A sudden change in conductivity can be an indicator of pollution due to an increased influx of ions from an external source, such as agricultural runoff or residential waste leakage. This is not ideal for aquatic animals and plants, in which the suitable range of conductivity is between 150µS and 500µS, while surface waters are expected to range from 50µS to 1500µS. Over the eleven month period, three different conductivity meters were used to measure the conductivity of the 21 sites in the White Clay Creek. As shown in Figure 4.3, the highest conductivity reading was a value of 655µS which occurred on September 16, 2016 at Loch Naim (WCEV). On average, this site has the highest conductivity readings off all the sites tested and has the second highest median value, below Cool Run (WCCR) by 10µS. These readings at WCEV appear to be due to the adjacent golf course and farms. The lowest EC readings were seen at Jenney's Run (WCJR) and Pike Creek (WCPC), but Middle Run (WCMR) has the lowest mean and median values. EC readings at WCMR were consistently below 150µS, meaning that the EC is below the ideal range. South Bank (WCSB) also has a median value below 150µS. This may indicate low nutrient levels for aquatic life. These low values can be seen in Figure 4.1 and Figure 4.2 with medians shown in Figure 4.5. While there was at least one measurement either below or above the ideal range for EC at most testing sites, all but WCMR and WCSB have median values between 150µS and 500µS.


Conductivity on the Main Stem of White Clay Creek in Delaware
Conductivity (µS)
700
600
500
400
300
200
100
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
Date
1. Jenney's Run
18. Cool Run
19. Mill Creek
20. Pike Creek
21. Middle Run


Conductivity in Broad Run on the Main Stem of White Clay Creek in Pennsylvania
Conductivity (µS)
700
600
500
400
300
200
100
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
Date
2. South Bank
3. South Bank WB
5. Watson Mill
6. Broad Run


Conductivity on the East Branch of White Clay Creek in Pennsylvania
Conductivity (µS)
700
600
500
400
300
200
100
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
Date
4. London Tract Road EB
7. Auburn Road
8. Eqypt Run
9. Angelica
10. Indian Run
11. Glen Willow
12. McCue EB


Conductivity on the West Branch of White Clay Creek in Pennsylvania
Conductivity (µS)
400
350
300
250
200
150
100
50
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
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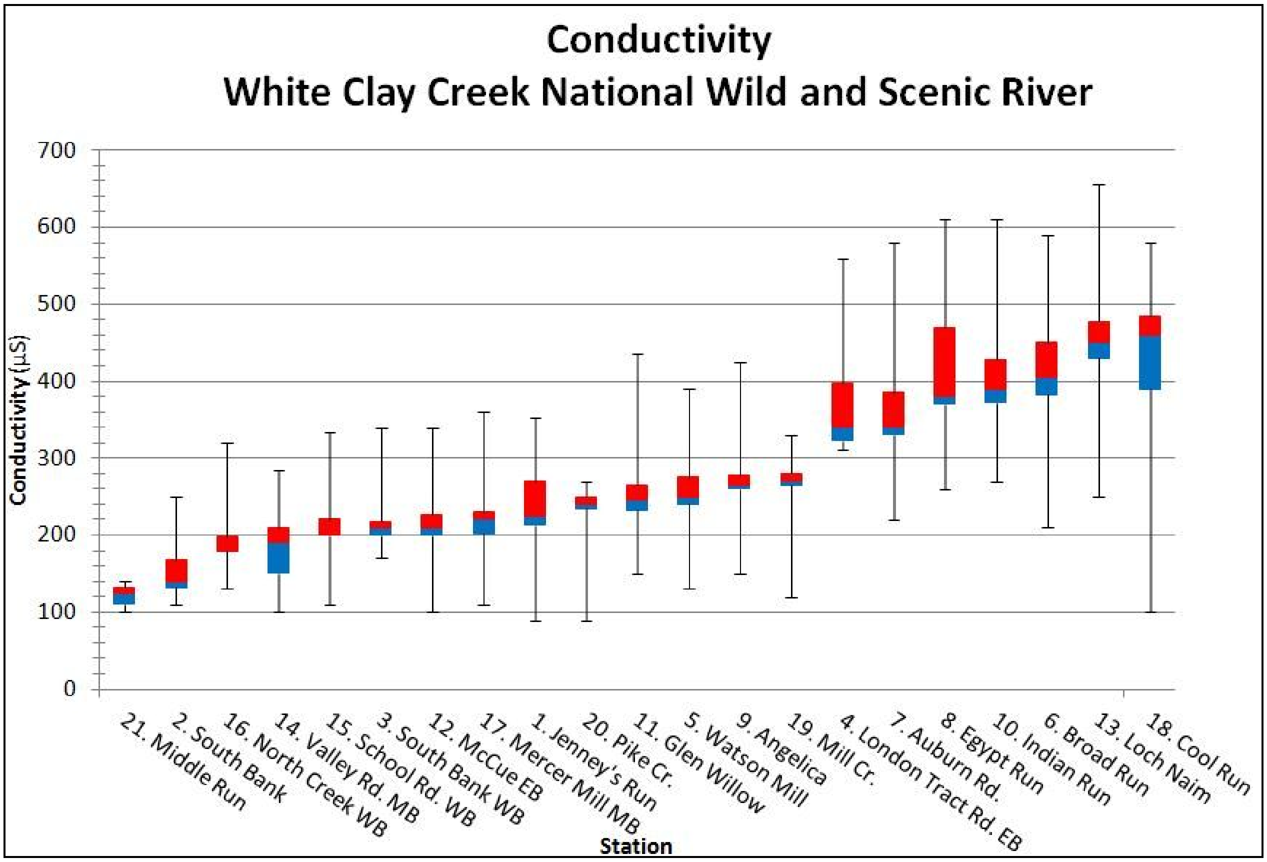
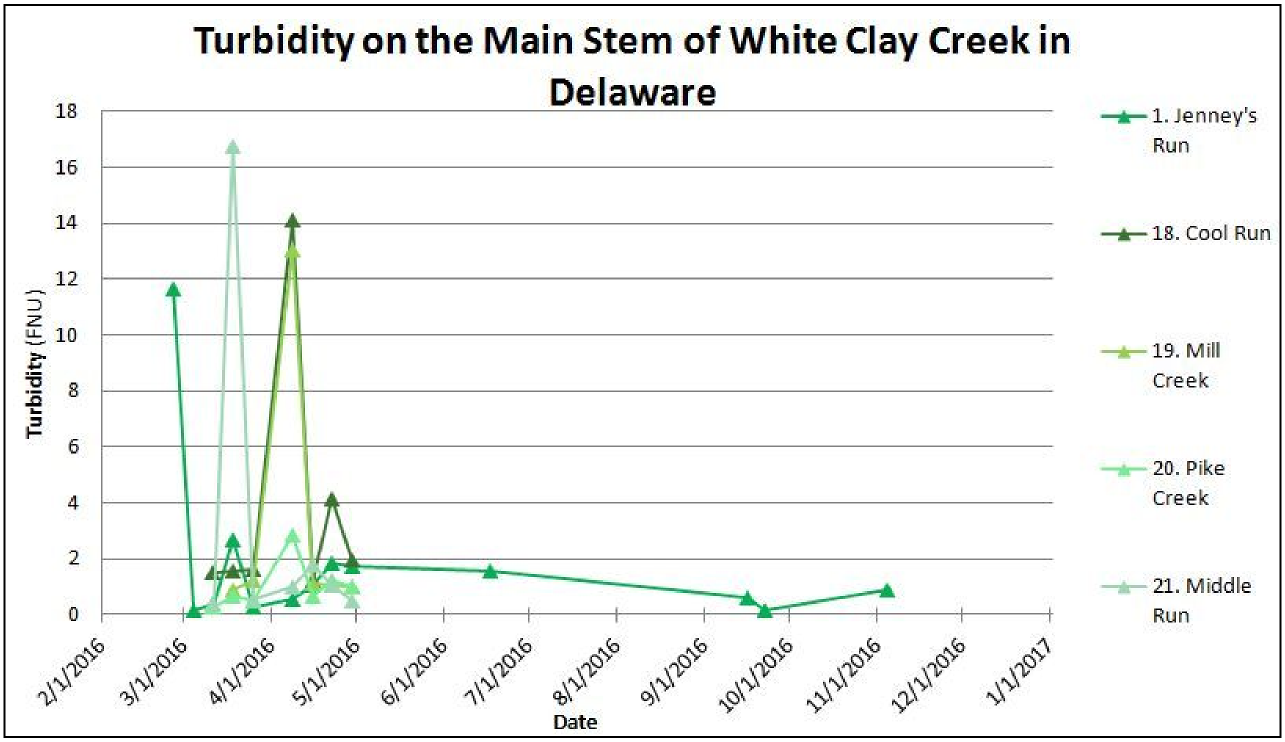
12/1/2016
1/1/2017
Date
14. Valley Road MB
15. School Road WB
16. North Creek WB
17. Mercer Mill MB



4.1.2 Turbidity

Turbidity is the measure of the clarity of water, specifically the suspended and dissolved particulate matter. The higher the turbidity, the murkier the water. In water quality analysis, turbidity is an important tool that can determine the potential occurrence of pollution in waterways. Notable sources of pollution are excess nitrogen and phosphorus from urban and agricultural runoff. Levels of high turbidity can be detrimental to aquatic life and cause harmful algal blooms (HABs). High turbidity can also create unaesthetic views for waterways and lead to lower recreational use. The turbidity of a healthy water sample should not exceed 10 FNU. Measurements taken on 5/6/2016 were eliminated from graphical analysis because they appeared to be strong outliers with much higher values than every other day at every testing site. Aside from data collected on this date, the highest turbidity value was measured at Indian Run (WCIR) on February 26, 2016. The highest median, however, was seen at Valley Road MB (WCMB1), which shows that this location had the most consistently high values. However, 10 FNU was only exceeded in one of our measurements and the median remains well below at 3.265 FNU. Overall, we measured a turbidity exceeding 10 FNU at least once at each testing site except for Pike Creek (WCPC), South Bank (WCSB), Watson Mill (WCWR), and McCue EB (WCEB1). Because of this, the turbidity should continue to be monitored.


Turbidity on the Main Stem of White Clay Creek in Delaware
Turbidity (FNU)
Date
0
2
4
6
8
10
12
14
16
18
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
1. Jenney's Run
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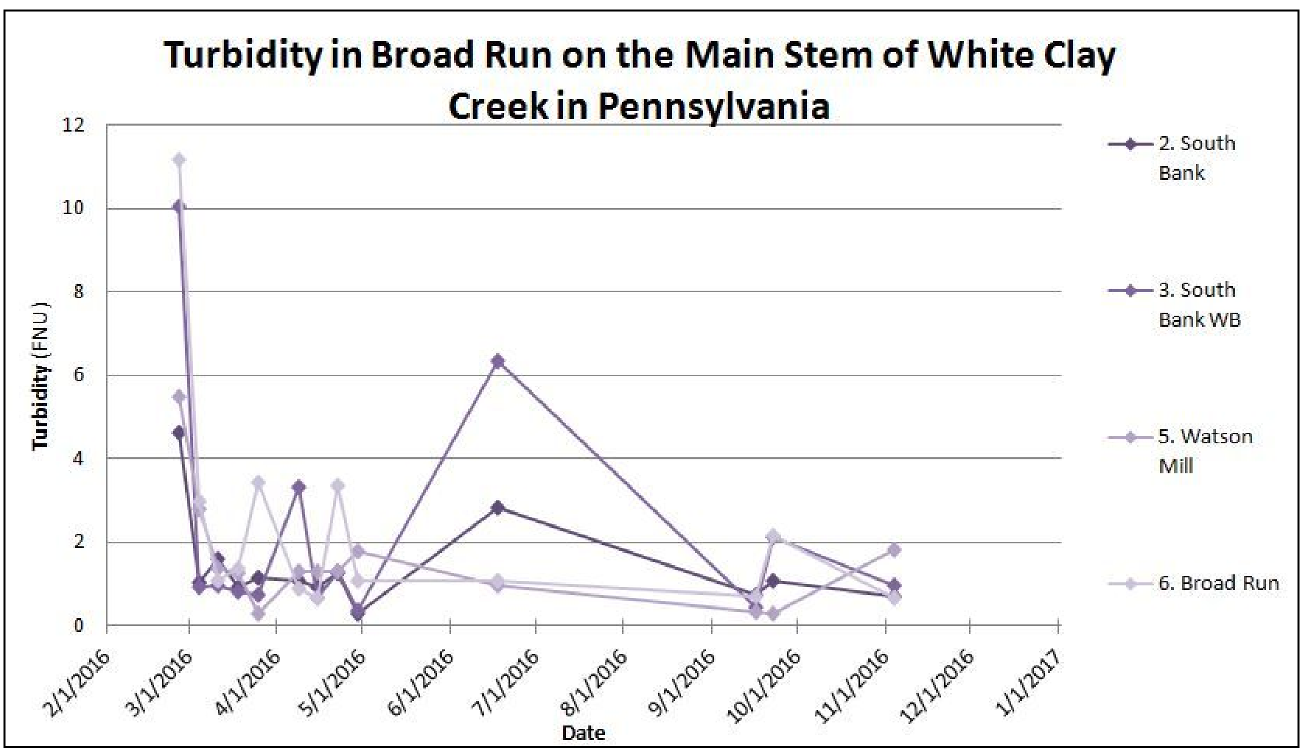
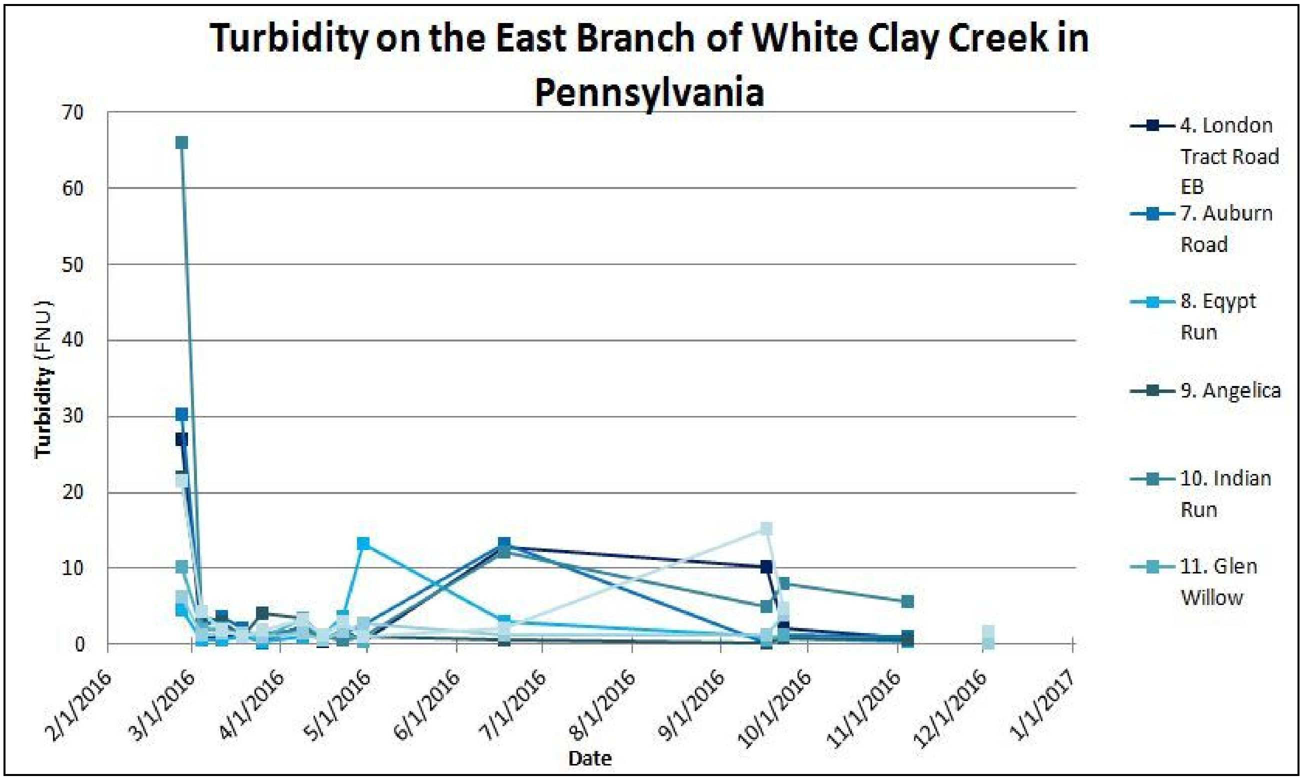
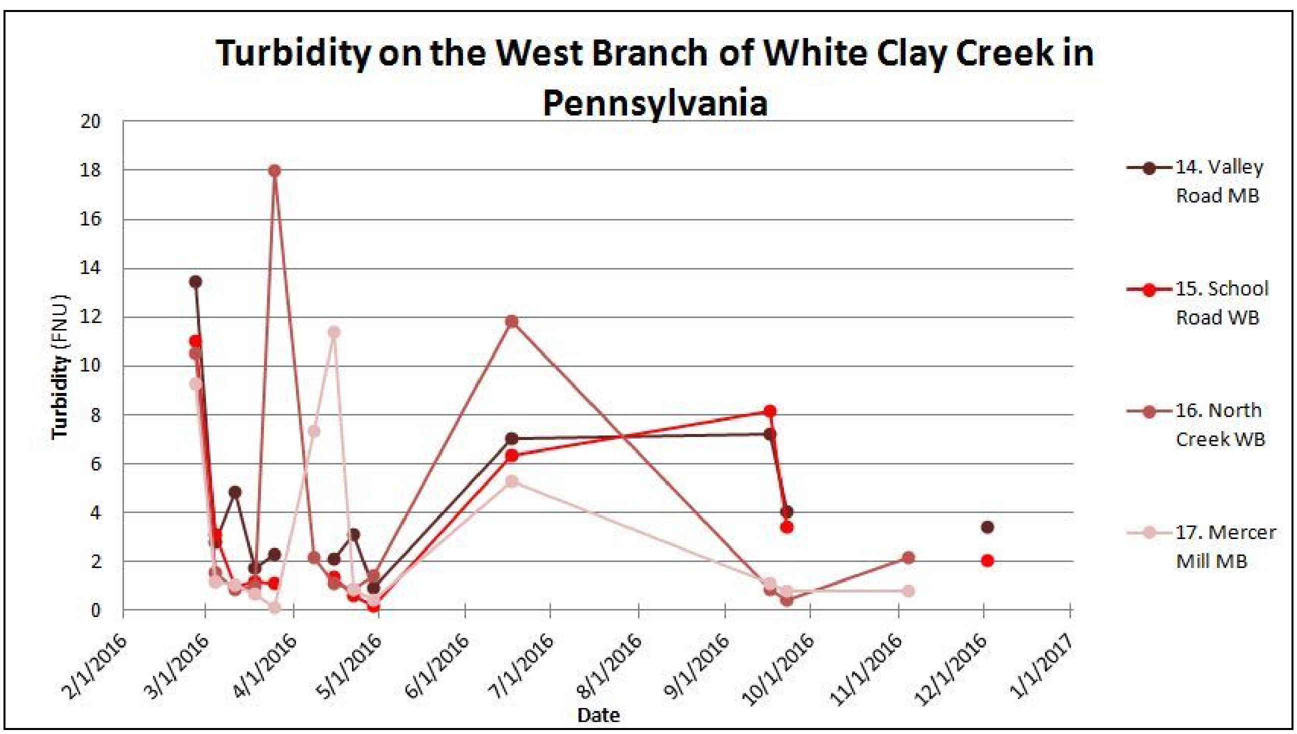
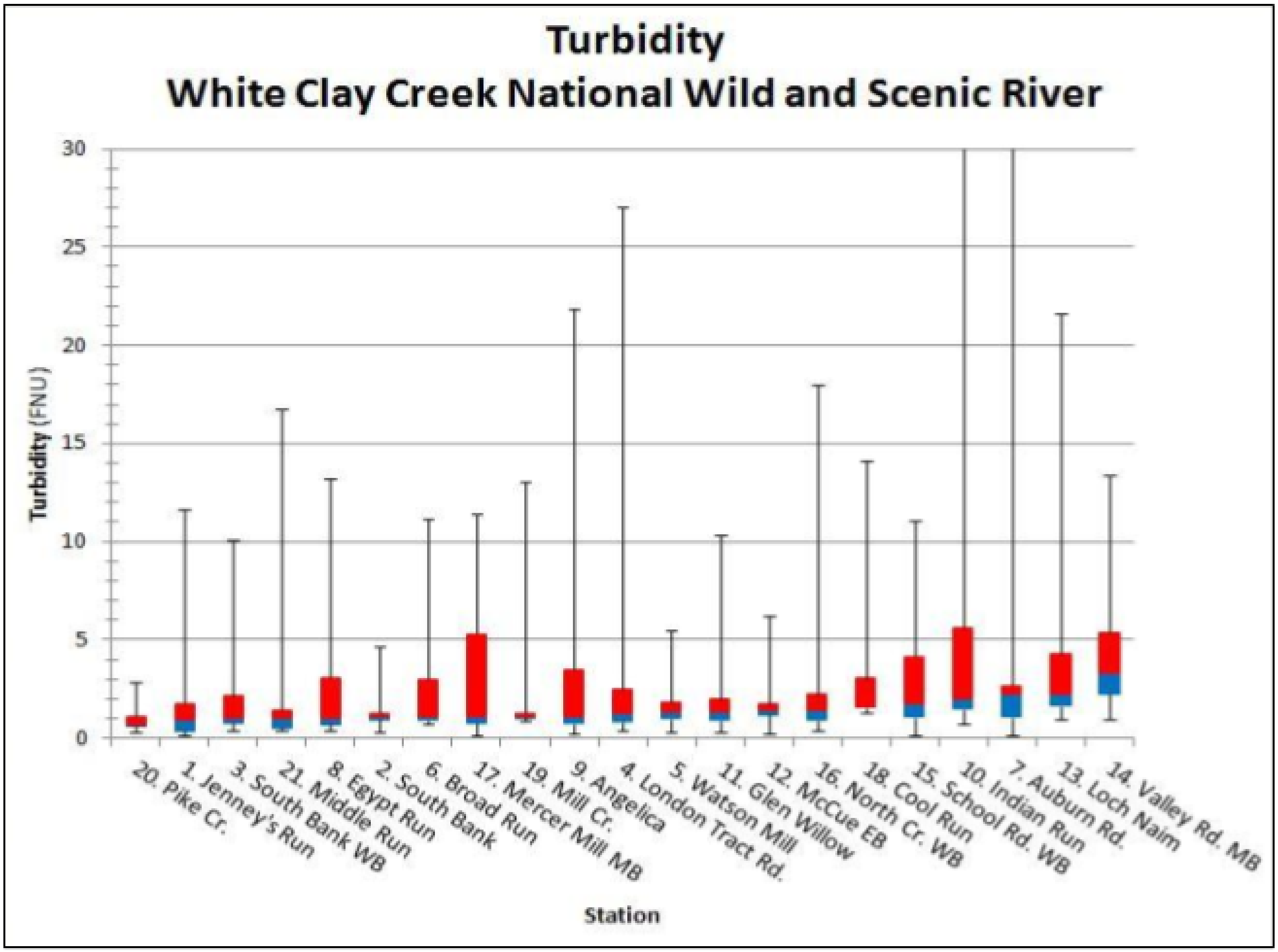
21. Middle Run


Turbidity in Broad Run on the Main Stem of White Clay Creek in Pennsylvania
Turbidity (FNU)
Date
0
2
4
6
8
10
12
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
2. South Bank
3. South Bank WB
5. Watson Mill
6. Broad Run


Turbidity on the East Branch of White Clay Creek in Pennsylvania
Turbidity (FNU)
70
60
50
40
30
20
10
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
Date
4. London Tract Road EB
7. Auburn Road
8. Eqypt Run
9. Angelica
10. Indian Run
11. Glen Willow


Turbidity on the West Branch of White Clay Creek in Pennsylvania
Turbidity (FNU)
20
18
16
14
12
10
8
6
4
2
0
2/1/2016
3/1/2016
4/1/2016
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
10/1/2016
11/1/2016
12/1/2016
1/1/2017
Date
14. Valley Road MB
15. School Road WB
16. North Creek WB
17. Mercer Mill MB



Note- The maximum values for WCIR and WCEB2 exceed the limits of the above graph. The values are 66 FNU and 30.33 FNU respectively.

Chapter 5: Discussion

Based on the two chemical parameters monitored during the 11 month time period in 2016, conductivity and turbidity, the overall results of this study indicate that there are some potential chemical impairments in White Clay Creek and its tributaries. Measurements of conductivity at most sampling sites show little to no impairments and turbidity measurements showed potential implications.

There are a few testing sites in which our measurements show potentially impaired waters. The two sites with the highest median values for conductivity are Cool Run (WCCR) and Loch Naim (WCEV). While their medians remain within the ideal range of 150µS to 500µS at 460µS and 450µS respectively, the measured values were consistently high. Each of these two sites had multiple EC measurements above 500µS. WCEV also showed the second highest median value for turbidity. While this median of 2.23FNU is well within the water quality standard, which recommends below 10 FNU, there were two measurements taken which are significantly above this standard. Because this site showed the second worst median values in both chemical parameters measured, it is important to continue to monitor WCEV. The impairments at this site are likely due to the adjacent golf course. WCCR, which had the highest EC median, did show one high turbidity measurement, but overall there is less cause for concern at this site than with WCEV. However, this site should still be monitored due to its high conductivity values. The residential neighborhoods surrounding WCCR are likely the result of its less-than-perfect measurements.

Middle Run (WCMR) also shows the possibility for impairment due to its consistently low conductivity readings. Each measurement resulted in EC values below 150µS and outside of the ideal range of 150µS to 500µS. These numbers suggest low nutrient levels, which may pose health risks to aquatic life. South Bank (WCSB) also displayed median conductivity levels below 150µS. Turbidity values for these sites do not lead to any additional concern, but monitoring these sites should be continued to check for harm to fish and other wildlife.

The highest median turbidity value of our 21 sites was seen at Valley Road MB (WCMB1). While this site had the most consistently high measurements, its median of 3.265 FNU is still significantly below 10 FNU, which is the water quality standard. Because the turbidity values were high throughout the testing period compared to the other sites, WCMB1 should be monitored in the future. This site is adjacent to a mushroom composting facility, which is a likely source of the impairments. Excluding the outlier data from 5/6/2016, the highest turbidity measurement was seen at Indian Run (WCIR). While most values measured on different days at this site were much lower, the site should still be monitored. WCIR is located near a wastewater treatment plant and is surrounded by residential neighborhoods, both of which could have resulted in the high measurements that were seen.

To improve the water quality of the tributaries mentioned above, native plants could be planted along the roadways where there is not enough of a buffer zone between the the stream and the more developed surroundings. Reforestation along streambanks is a method that helps to prevent further degradation. It is important to work with farmers and developers to limit commercial and agricultural runoff into the waterways, leading to a decrease in ecosystem health.

Chapter 6: Conclusion and Project Implications

In conclusion, we found that there is some reason for concern that chemical impairments exist in certain areas within the White Clay Creek watershed. Examples of lower water quality that were seen are likely a result of the environment surrounding the sampling site, such as being adjacent to a commercial, residential, or agricultural area. Hopefully our results will help to identify problem areas within the White Clay Creek Watershed. With this information, appropriate action can be taken to prevent further degradation and improve the water quality in these locations.

Chapter 7: References

Websites used
http://whiteclay.org/wild-and-scenic-history/
http://delawarewatersheds.org/piedmont/white-clay-creek/
http://www.wra.udel.edu/wp-content/publications/White_Clay_Creek_final_070408_0.pdf
https://ssdev.cr.usgs.gov/streamstats/
http://www.wrc.udel.edu/wp-content/uploads/2016/07/WhiteClayCreek_StateOfTheWatershedReport_Final_030116.pdf
http://whiteclay.org/environmental-and-cultural-resources/

Chapter 8: Appendix

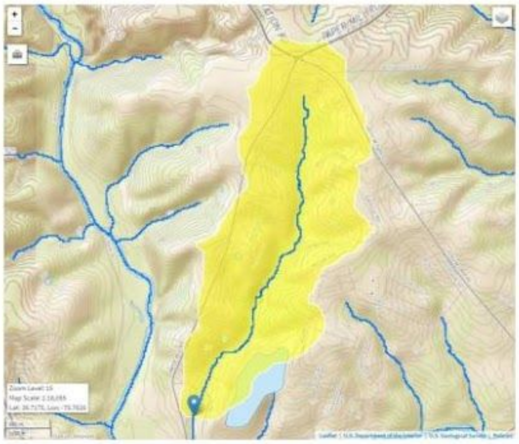
Date	Sites (µS)																				
	(1) WC JR	(2) WC SB	(3) WC WB 1	(4) WCE B1	(5) WC WR	(6) WC BR	(7) WCM B2	(8) WCW B3	(9) WCE B2	(10) WCE R	(11) WCA D	(12) WCIR	(13) WCGB	(14) WC EB3	(15) WC EV	(16) WCM B1	(17) WC WB2	(18) WCCR	(19) WC MC	(20) WC PC	(21) WC MR
2/26/16	220	160	210	360	260	420	160	200	330	390	240	290	240	200	440	150	220	-	-	-	-
3/4/16	280	170	220	410	280	460	180	230	390	490	270	420	250	220	470	200	200	-	-	-	-
3/11/16	240	140	210	310	260	410	200	230	370	410	280	430	270	230	480	210	220	580	-	270	140
3/18/16	220	130	190	330	240	340	180	200	330	370	250	370	230	200	430	180	200	400	330	250	110
3/25/16	230	140	200	340	250	390	190	220	220	370	260	390	250	210	430	190	200	480	280	250	130
4/8/16	240	150	190	340	250	420	180	200	350	390	270	390	230	210	470	-	-	360	270	240	140
4/15/16	210	130	200	330	240	390	180	220	330	360	260	370	230	200	440	130	200	440	270	240	120
4/22/16	220	120	200	320	240	380	180	210	340	350	260	390	240	200	420	190	200	500	280	240	130
4/29/16	210	140	210	360	250	400	180	220	340	370	260	390	240	200	430	180	190	480	260	220	110
5/6/16	90	110	170	310	130	210	130	110	270	260	150	270	150	100	250	100	110	100	120	90	100
6/17/16	170	140	210	310	240	360	180	220	330	370	270	380	250	210	460	130	190	-	-	-	-
9/16/16	329	207	329	525	337	578	278	339	574	578	425	589	436	284	655	285	334	-	-	-	-
9/22/16	309	203	291	514	339	552	267	307	555	566	380	581	402	287	560	276	293	-	-	-	-
11/4/16	352	250	340	560	390	590	320	360	580	610	420	610	-	-	-	-	-	-	-	-	-
12/2/16	-	-	-	-	-	-	-	-	-	-	-	-	420	340	610	270	300	-	-	-	-

Table 3. Conductivity data

	Sites (FNU)																				
Date	(1) WCJR	(2) WCS B	(3) WC WB1	(4) WCE B1	(5) WC WR	(6) WCBR	(7) WCMB 2	(8) WCW B3	(9) WCEB 2	(10) WCE R	(11) WCAD	(12) WCIR	(13) WCGB	(14) WCE B3	(15) WCE V	(16) WCMB 1	(17) WCW B2	(18) WCCR	(19) WC MC	(20) WC PC	(21) WC MR
2/26/16	11.65	4.62	10.06	27.04	5.50	11.17	10.5	9.29	30.33	4.45	21.89	66.0	10.3	6.23	21.6	13.42	11.04	-	-	-	-
3/4/16	0.14	1.04	0.93	0.81	2.78	2.98	1.57	1.18	2.31	0.53	3.70	2.06	1.92	1.27	4.28	2.77	3.12	-	-	-	-
3/11/16	0.36	1.62	0.98	1.07	1.39	1.08	0.88	1.08	3.77	0.69	2.93	1.99	2.05	1.40	1.92	4.84	1.01	1.51	-	0.27	0.41
3/18/16	2.67	0.93	0.82	1.21	1.28	1.36	1.01	0.68	2.22	1.03	1.08	1.53	1.30	1.47	1.16	1.72	1.19	1.56	0.90	0.69	16.75
3/25/16	0.26	1.15	0.75	0.63	0.30	3.43	17.98	0.14	0.14	0.38	4.10	1.47	0.89	1.16	2.03	2.31	1.09	1.59	1.25	0.52	0.55
4/8/16	0.53	1.07	3.32	2.44	1.30	0.89	2.20	7.32	2.68	0.97	3.44	1.86	3.40	1.44	3.19	-	-	14.12	13.08	2.83	1.01
4/15/16	1.04	0.93	0.66	0.43	1.29	0.67	1.11	11.37	0.64	1.20	1.09	1.04	0.85	0.51	1.27	2.13	1.38	1.25	1.10	0.69	1.77
4/22/16	1.85	1.28	1.31	2.00	1.30	3.37	0.85	0.87	1.43	3.58	0.56	0.72	1.80	1.70	2.95	3.11	0.63	4.13	1.07	1.21	1.06
4/29/16	1.74	0.31	0.37	0.42	1.80	1.08	1.42	0.43	2.48	13.18	1.12	1.12	0.30	2.80	0.95	0.93	0.17	1.94	1.00	0.98	0.47
5/6/16	129	177	73	174	76	314	340	87	226	129	191	295	168	150	56	274	119	123	116	175	233
6/17/16	1.57	2.82	6.34	12.74	0.97	1.08	11.83	5.28	13.26	3.07	0.58	12.23	402	1.20	2.23	7.04	6.33	-	-	-	-
9/16/16	0.59	0.73	0.46	10.2	0.34	0.70	0.89	1.14	0.26	1.09	0.21	4.96	0.59	1.38	15.24	7.20	8.15	-	-	-	-
9/22/16	0.15	1.07	2.12	2.06	0.31	2.15	0.41	0.79	1.34	0.81	0.83	8.04	1.22	3.81	4.82	4.02	3.41	-	-	-	-
11/4/16	0.91	0.72	0.98	0.80	1.81	0.68	2.14	0.79	1.05	0.46	0.71	5.59	-	-	-	-	-	-	-	-	-
12/2/16	-	-	-	-	-	-	-	-	-	-	-	-	1.31	0.23	1.63	3.42	2.03	-	-	-	-

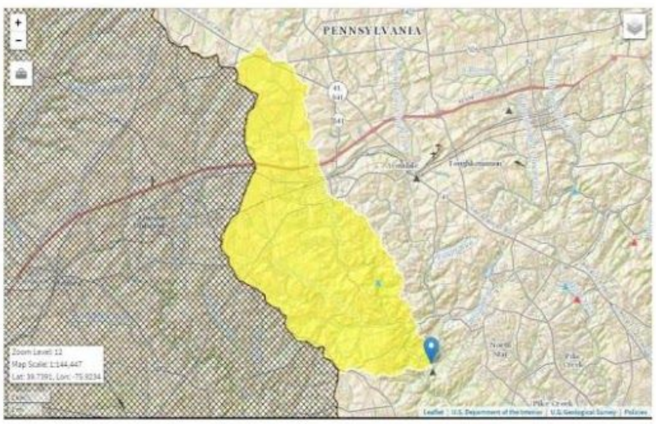
Table 4. Turbidity data

Delineated White Clay Creek Sites

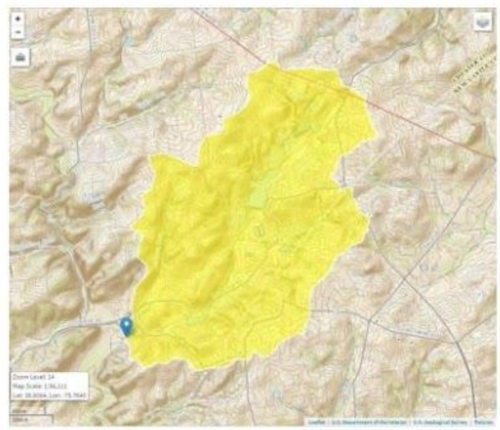


1. Jenney's Run

2. South Bank



3. South Bank WB



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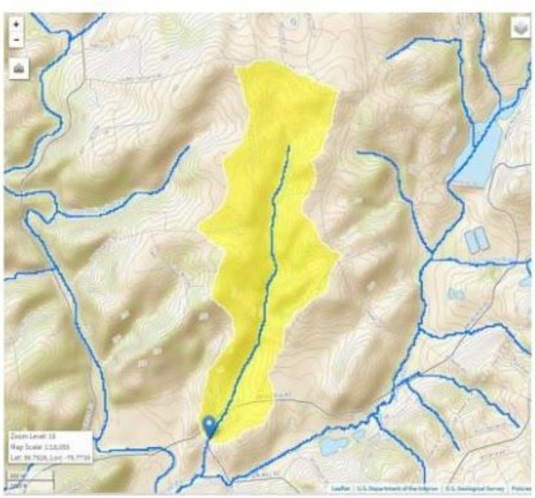
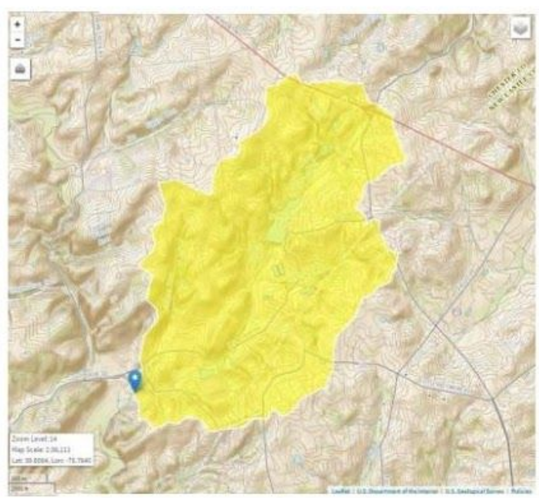
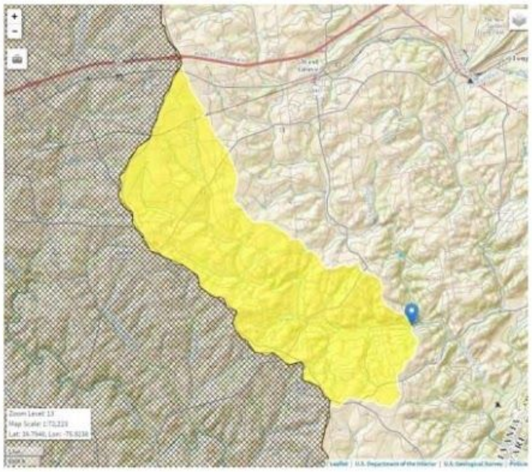


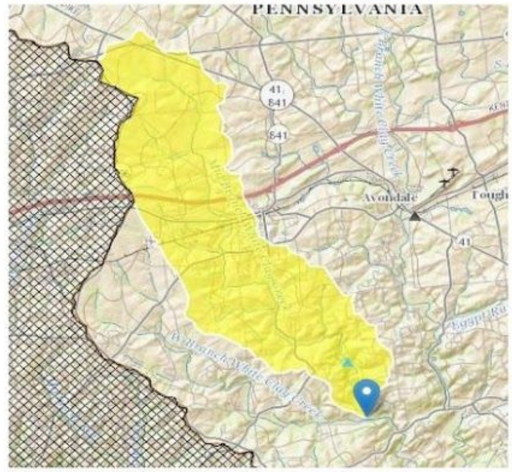
5. Watson Mill



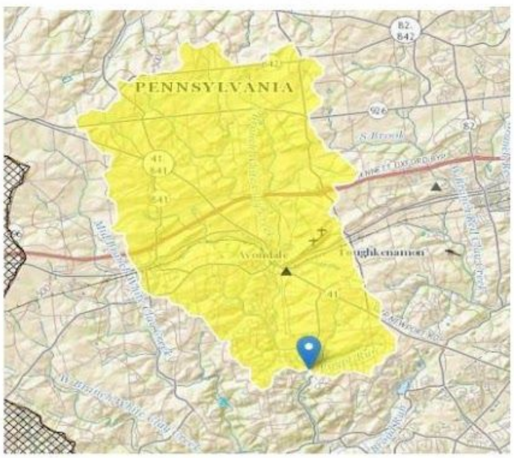
6. Broad Run



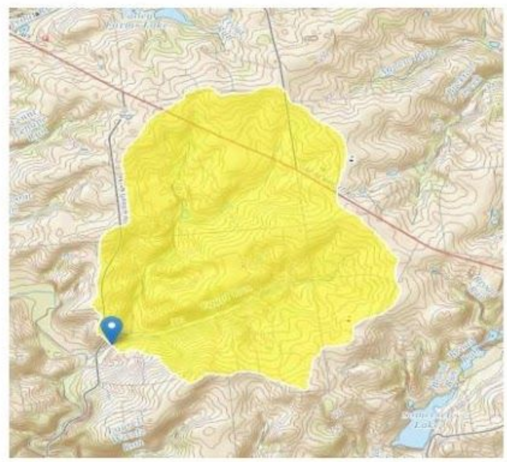
7. Auburn Road



8. Egypt Run

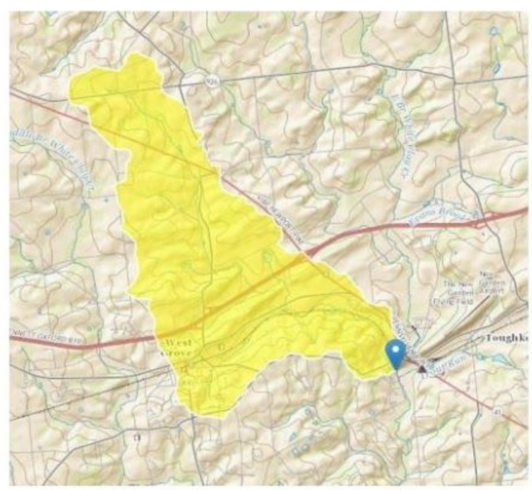


9. Angelica

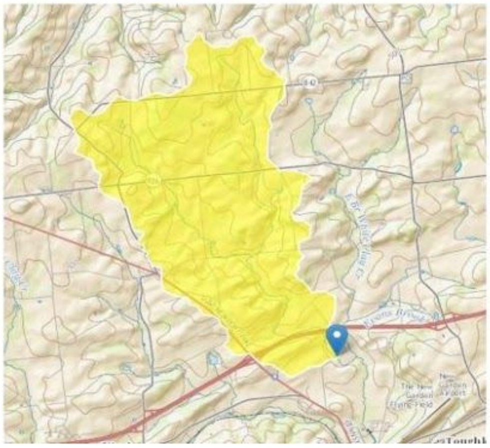


10. Indian Run

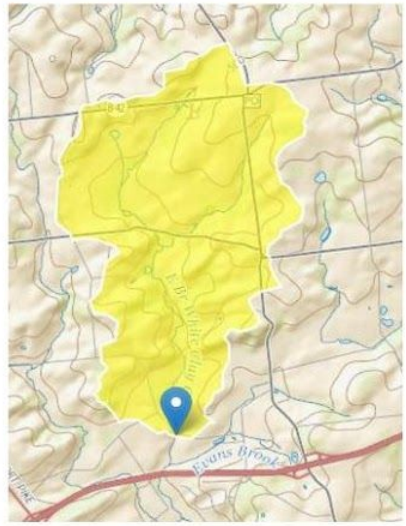
11. Glen Willow



12. McCue EB

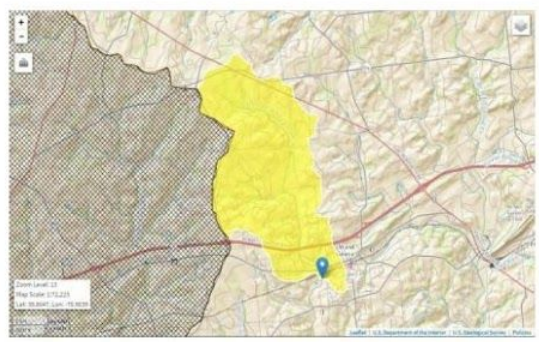


13. Loch Naim

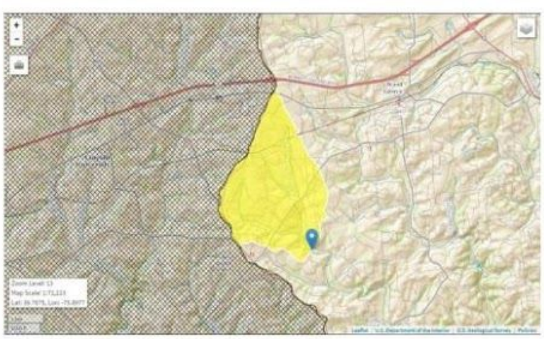


14. Valley Road MB

15. School Road WB

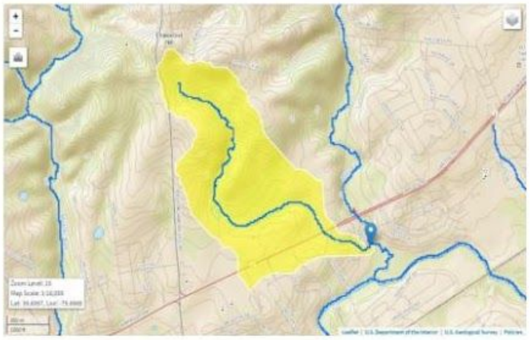


16. North Creek WB

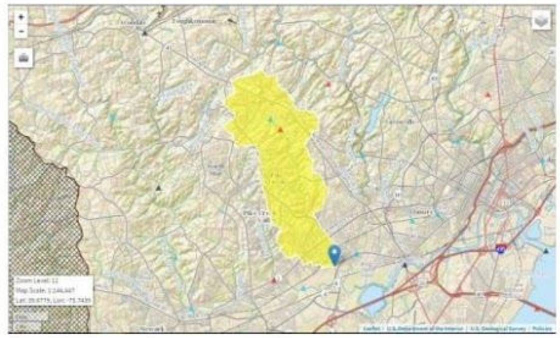


17. Mercer Mill MB

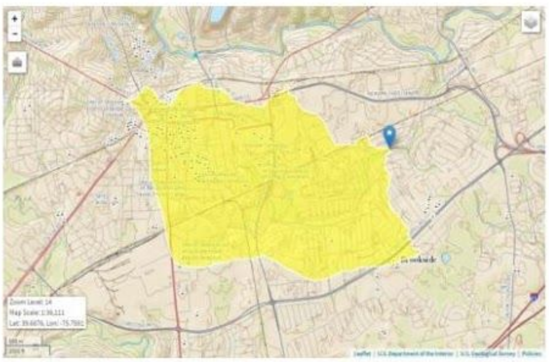
18. Cool Run



19. Mill Creek



20. Pike Creek



21. Middle Run

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