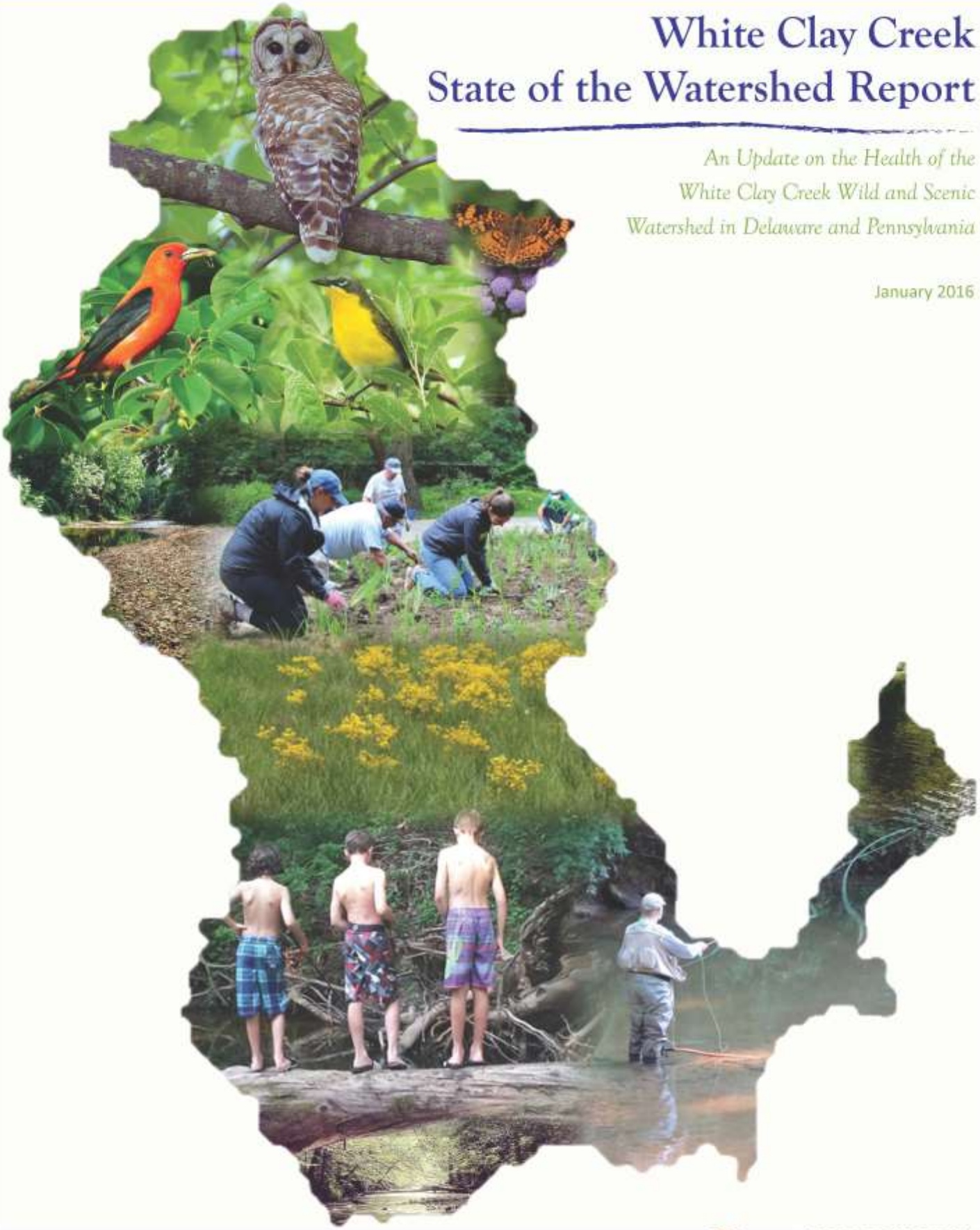
White Clay Creek
State of the Watershed Report

An Update on the Health of the White Clay Creek Wild and Scenic Watershed in Delaware and Pennsylvania

January 2016



UNIVERSITY OF DELAWARE

WHITE CLAY CREEK
National Wild & Scenic River
Ours to Enjoy. Ours to Protect.

White Clay Creek State of the Watershed Report

An Update on the Health of the White Clay Creek Wild and Scenic Watershed in Delaware and Pennsylvania

January 2016

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Introduction

The White Clay Creek State of the Watershed (January 2016) report provides an overview of the White Clay Creek watershed, the value of the watershed, and education and outreach efforts in the watershed. The focus of this report is to provide an up-to-date examination of the conditions and status of the White Clay Creek watershed. Based on a review of available scientific data and select indicators from the White Clay Management Plan (2000) and the White Clay Creek State of the Watershed Report (2008), this report provides an update on the health of the White Clay Creek Wild and Scenic watershed. The following 20 indicators are grouped in four major categories and examined in detail:

Landscape

1. Population
2. Land Cover
3. Land Preservation
4. Riparian Buffers
5. Natural Resources Ordinances

Hydrology

11. Precipitation
12. Streamflow
13. Flooding

Water Quality

6. Dissolved Oxygen
7. Phosphorus
8. Nitrogen
9. Total Suspended Sediment
10. Bacteria

Habitat

14. Macroinvertebrates
15. Impaired Streams
16. Birds
17. Freshwater Mussels
18. Fish
19. Fish Passage
20. Fish Consumption Advisories

The concluding section of this report provides a status update for each indicator. This section also provides a synopsis of the recommendations provided in the 2008 report, the progress made, and recommendations for moving forward for a healthy White Clay Creek watershed.

"White Clay Creek is a gem that shines brightly in Delaware's diverse ecosystem, and we have worked tirelessly to protect its beauty for future generations."

U.S. Senator Christopher Coons (D-DE)

The White Clay Creek Wild and Scenic Watershed

The White Clay Creek watershed is one of only a few relatively intact, unspoiled, and ecologically functioning river systems remaining in the highly congested and developed corridor linking Philadelphia, Pennsylvania, with Newark, Delaware. The watershed spans almost 108 sq. miles from southeast Pennsylvania to northwest Delaware. Fifty-five percent of the watershed lies in Pennsylvania while 45% lies in Delaware and less than 1% lies in Maryland. The Chester County, Pennsylvania, portion includes the East, Middle, and West Branches and the top of the mainstem; the White Clay Creek then flows into New Castle County, Delaware, and is joined by Middle Run, Pike, and Mill Creeks before emptying into the Christina River.

GOVERNING ENTITIES IN THE WATERSHED

States
- Delaware
- Pennsylvania

Counties:
- Chester
- New Castle

Municipality:
- City of Newark

Townships and Boroughs (12):
- Avondale
- East Marlborough
- Franklin
- Kennett
- Londonderry
- London Britain
- London Grove
- New Garden
- New London
- Penn
- West Grove
- West Marlborough

Only a select group of rivers in the United States—less than half of 1%—are designated in the National Wild and Scenic Rivers System. In October 2000, the President and Congress signed a law adding 190 miles of the White Clay Creek and its tributaries to the national wild and scenic river system. The White Clay Creek is the first wild and scenic river in the United States designated on a watershed basis rather than a river corridor basis. In December 2014, the White Clay Wild and Scenic Expansion Bill was passed adding nine stream miles to the White Clay Creek Wild and Scenic designation. The new segments include a 1.6-mile stretch of Lamborn Run in Delaware and a 7.4-mile stretch in Pennsylvania including portions of the East Branch and Egypt Run.

The White Clay Creek Watershed Steering Committee, along with local partners and municipalities, represents several watershed stakeholders, binds these diverse interests together in a common purpose, and guides the decision making and strategic plan for the White Clay Wild and Scenic Management Committee.

Focus Area

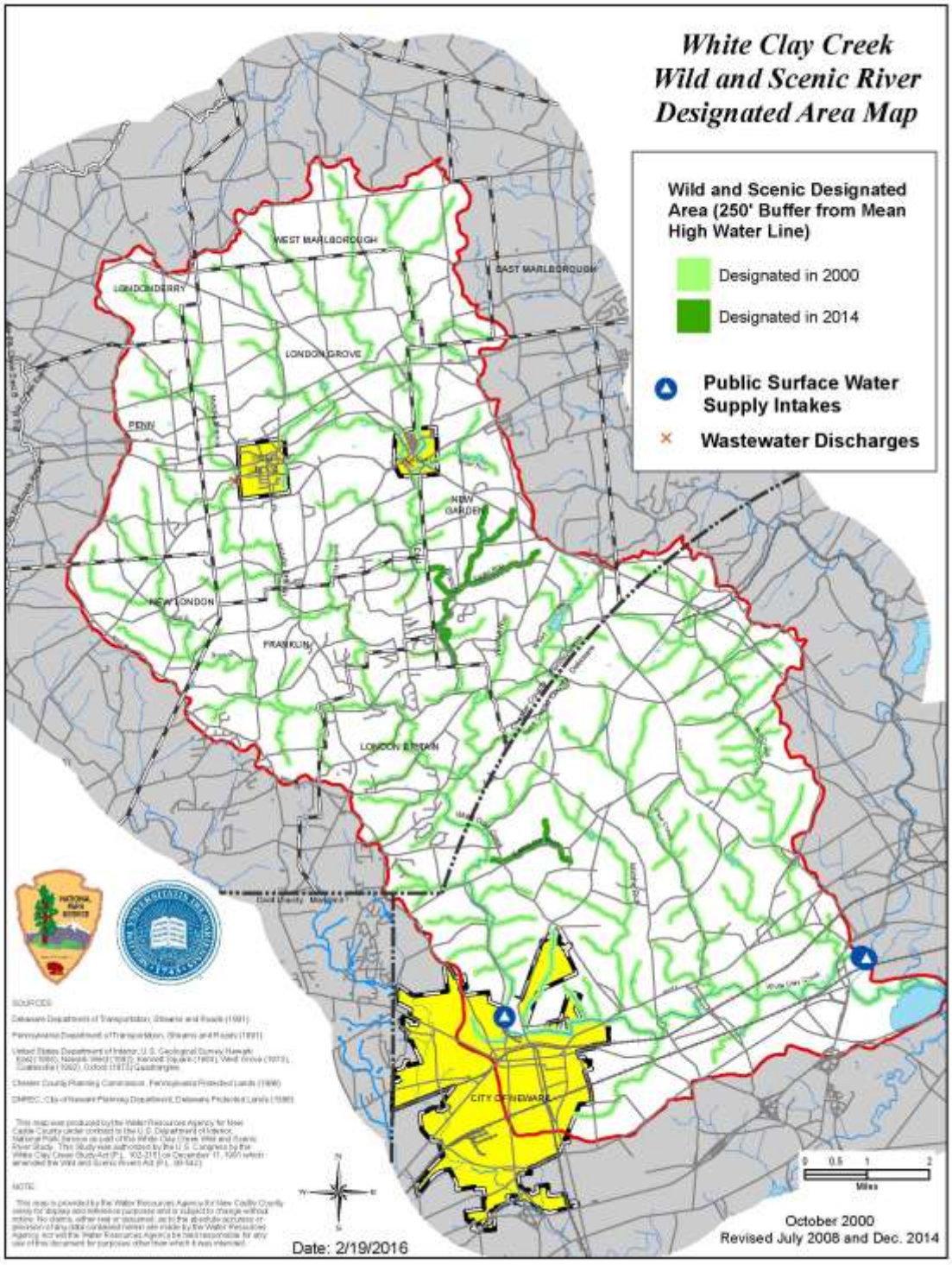

Figure 1. White Clay Creek Watershed

The Economic Value of the White Clay Creek Watershed

The water, natural resources, and ecosystems in the White Clay Creek watershed contribute an estimated economic value of $55 million to $500 million annually to the Delaware and Pennsylvania economies (Table 1). This value is calculated through three different examinations, discussed below (Miller, Cruz-Ortiz, 2013). This economic value is calculated in three different ways: economic value directly related to the White Clay Creek watershed's water resources and habitat, value of goods and services provided by the White Clay Creek watershed's ecosystems, and employment related to the White Clay Creek watershed's resources and habitats. These estimates demonstrate that the White Clay Creek watershed provides real and significant economic benefits to Pennsylvania and Delaware and is worthy of investment to keep these natural resources healthy and productive.

1. Economic value directly related to the White Clay Creek watershed's water resources and habitat. The White Clay Creek watershed contributes more than $500 million in annual economic activity from water quality, water supply, fish/wildlife, recreation, agriculture, forests, and public parks.

2. Value of goods and services provided by the White Clay Creek watershed's ecosystems. Using natural capital as a measure of value, habitat in the White Clay Creek watershed provides $165 million annually in ecosystem goods and services in 2010 dollars, with a net present value (NPV) of $5 billion calculated over a 100-year period.

3. Employment related to the White Clay Creek watershed's resources and habitats. Using employment as a measure of value, natural resources within the White Clay Creek watershed directly and indirectly support more than 25,000 jobs with over $55 million in annual wages.

Table 1. Annual Economic Value of the White Clay Creek Watershed

	Economic Activity	**Ecosystem Services**	**Jobs**
Amount	$500 million	$165 million	>25,000 ($55 million in wages)
Elements	Activity: • Water Quality • Water Supply • Fish/Wildlife • Recreation • Agriculture • Forests • Public Parks	Ecosystem Type: • Freshwater Wetlands • Marine • Farmland • Forest Land • Saltwater Wetlands • Barren Land • Urban • Beach/Dune • Open Water	Sector: • Direct Watershed-Related • Indirect Watershed-Related • Coastal • Farm • Fishing/Hunting/Birding • Watershed Organizations • Water Supply Utilities • Public Wells • Wastewater Utilities

Education Efforts in the Watershed

The White Clay Wild and Scenic Rivers Program in conjunction with guidance from the Education and Outreach Subcommittee, hosts, co-hosts, and supports education and outreach activities. These programs increase general awareness of the watershed and its issues and raise awareness and appreciation for the natural, cultural, and recreational resources of the watershed. The White Clay Wild and Scenic Program provides educational materials and shares current information at public events and meetings including best management practices (BMPs) information for residents, research findings related to issues of importance in the White Clay Creek watershed and regionally, and recommendations for resource protection and water quality improvement.

The program's largest outreach event, the annual White Clay Creek Fest hosted at White Clay Creek State Park, is a four-hour outdoor celebration that brings members of the community, local nonprofits, and local private businesses together to share information and celebrate the natural resources of the watershed. Suez Delaware (formerly United Water Delaware) provides attendees with reusable water bottles with messaging to promote sustainable resources. Fest-goers can attend several hikes and activities offered throughout the event. Attendance at this event has grown annually from 100 attendees at the inaugural event in 2009 to 1,400 in 2015, and participation from local watershed stakeholder groups exhibiting at the event has risen from fewer than 10 in 2009 to over 30 in 2015.

In addition to the activities directly hosted by the Wild and Scenic program, the Wild and Scenic Steering Committee members attend and host smaller workshops with residents and township officials on BMPs for the White Clay and assist and contribute to regular municipal newsletters and the White Clay Wild and Scenic blog (whiteclay.org). Through smaller workshops and newsletters, the program strives to increase awareness and appreciation for the natural resources of the White Clay. The program also encourages protection and restoration activities by providing practical advice that can be applied by watershed residents and employers alike, such as conservation landscaping and property management tips.

The White Clay Wild and Scenic River Program also provides environmental education awards to schools in the watershed. These awards include funding for transportation and program costs that enable students to experience hands-on learning opportunities about the watershed. Through these programs the students are immersed in studies on watershed flora and fauna, history, and ecological functions. Over the past five years (2000–2015) White Clay Wild and Scenic has

partnered with Stroud Water Research Center, Delaware Nature Society, and Delaware State Parks to provide varied opportunities for over 1,500 school children to explore, enjoy, and experience the White Clay.

In 2013, the White Clay Wild and Scenic Program expanded the K-12 outreach to include post-secondary students through a summer internship program with assistance from the Delaware Nature Society. Intern tasks include water quality sampling and stream assessments throughout the recreational season (June–September). Since its inception, the program has provided three college students (one per summer) with hands-on experience in watershed science and management. Upon completion of the internship, the students return to their respective colleges prepared to share their knowledge and have gained meaningful experience that may lead them to an environmental career. Finally, the program partnered with the University of Delaware to provide practical watershed management field experiences such as implementation and management of watershed BMPs, native plant identification, invasive species removal, and riparian buffer plantings to undergraduates enrolled in the course Conservation of Natural Resources.

Table 2. White Clay Wild and Scenic Education and Outreach, 2008–2015

Program	Description	Year
White Clay Creek Fest	Created and hosted the annual White Clay Creek Fest with Delaware State Parks and Suez Delaware. Each year attendance has increased, approximately 100 people attended the inaugural event and in 2015 the attendance was up to 1,400 people.	2009–Present
White Clay Creek Symposium	Hosted the first White Clay Creek Symposium focusing on research in the White Clay watershed at the Stroud Research Center with over 40 people in attendance.	2012
City of Newark National Wildlife Federation and Community Habitat	Supported Delaware Nature Society in providing Community Habitat workshops in an effort to certify the City of Newark as a National Wildlife Federation (NWF) Community Habitat and educate residents about the importance of native plants and habitats (30 participants each). Awarded funds to Newark residents in attendance to install rain gardens on their properties. The City of Newark achieved NWF certification in 2014.	2011–2014
Shad in Schools Program	Provided funding for the Shad in Schools program, in partnership with the University of Delaware Water Resources Agency. Funds were provided to schools in the watershed to participate in the program. The program focuses on the culture, history, and biological aspects of American shad while teaching about watersheds and water quality through hands-on activities with shad eggs and fry. The program reached 149 students directly and 800 students indirectly in the participating schools.	2011–2014
White Clay Creek Passport	Developed the White Clay Creek Passport, designed to get children and families out and about in the watershed. The passport provides participants with suggested hikes, watershed stewardship activities, and fun facts about the watershed.	2013–Present

Environmental Indicators for the White Clay Creek

Landscape Indicators

The landscape of the watershed greatly impacts the overall health of the watershed and the water quality in the creek and its tributaries. Landscape indicators that were assessed in this report include:

1. Population
2. Land Cover
3. Land Preservation
4. Riparian Buffers
5. Natural Resources Ordinances

Population

Approximately 124,000 people live in the basin, according to the 2010 decennial census. Over the past 40 years, the population in the basin has nearly doubled from approximately 65,000 in 1970. Figure 2 shows the growth in the basin and projected future growth by subwatershed, between 1970 and 2030. By 2020, the population is expected to reach over 128,000 and by 2030 over 131,000, an increase of approximately 7,000 residents.

Population is not evenly distributed across the watershed, with the lower reaches historically experiencing higher population densities. The subwatersheds within Delaware, where more urbanization has occurred, tend to have the highest populations, while the more rural and agricultural areas in Pennsylvania have been relatively less dense. While the Delaware subwatersheds below Newark, including the Main Stem, Mill Creek, and Pike Creek, have the highest populations, population growth in these areas have leveled off since about 1990. Most growth (as a percentage) is now focused in the subwatersheds in Pennsylvania (Figure 3). The East, West, and Middle branches (lying entirely or mostly in Pennsylvania) have seen and are expected to see continued population pressures in the coming decades. Though the majority of watershed residents live in Delaware, increasing density in the upper subwatersheds of Pennsylvania will likely have negative impacts on water quality in the downstream portions of the watershed (Figure 4).

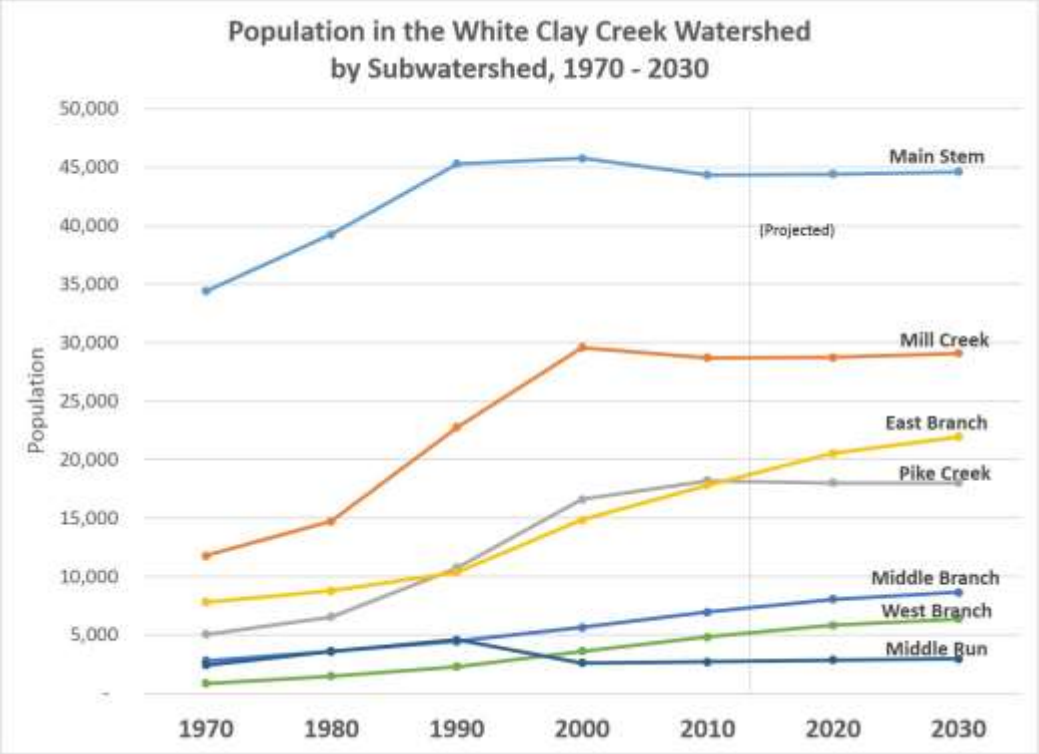

Figure 2. Population by Subwatershed in the White Clay Creek

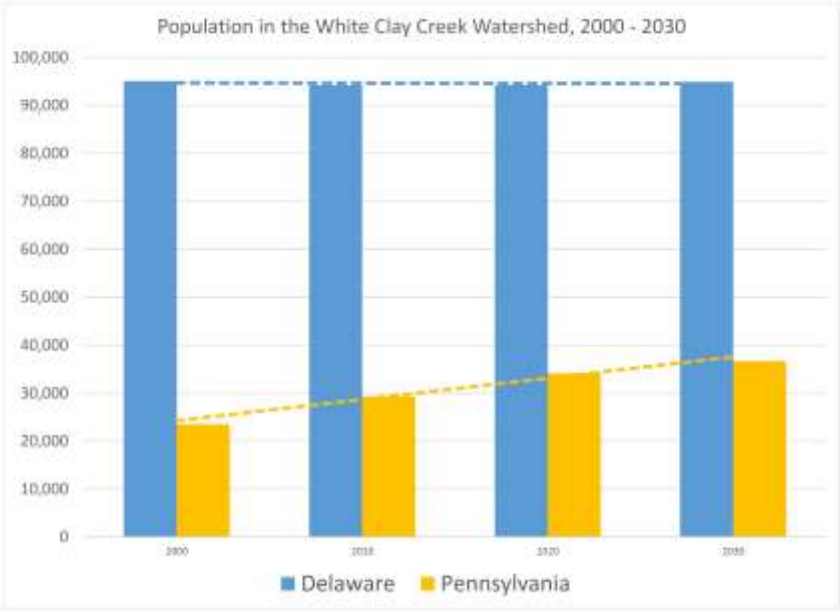

Figure 3. Population Trends in the White Clay Creek Watershed by State, 1970–2030

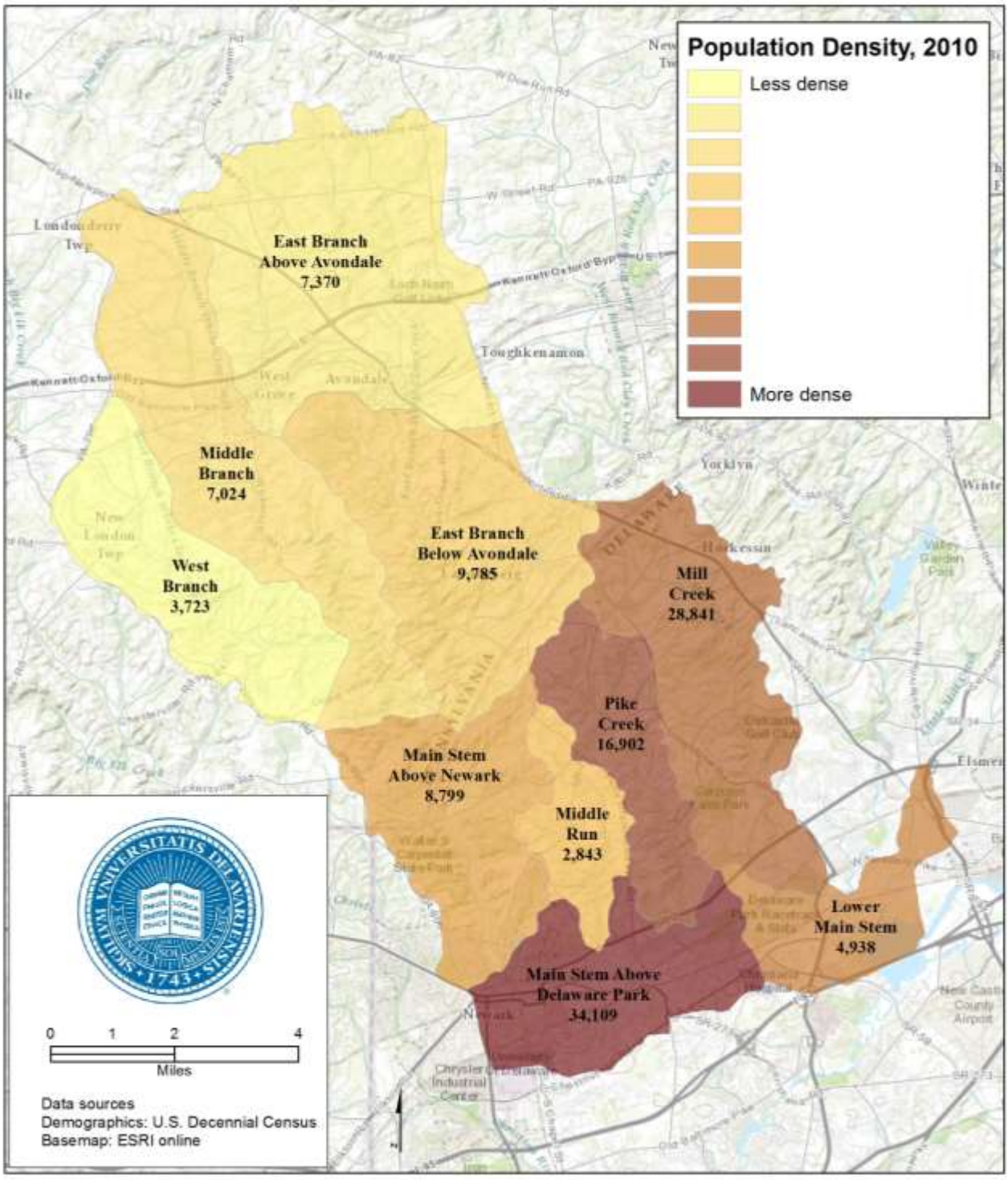

Figure 4. Population Densities in the White Clay Creek Watershed, 2010
(Numbers indicate total population.)

Land Cover

Land cover indicates the physical land types such as forest or open water whereas land use documents how people are using the land (NOAA). Land cover data and maps document land use trends and changes and help us to better understand the processes affecting watershed health. The White Clay Creek watershed is fairly evenly composed of three major land cover types: developed land (37%), agriculture (33%), and natural areas (forests and wetlands, 30%). Development is focused primarily in the Delaware portion of the watershed, with most of the agricultural and natural lands occurring in the Pennsylvania portion.

Figures 5 and 6 illustrate the trends and conditions of land cover in the White Clay Creek watershed. Figure 5 provides a summary of the land cover acreage by subwatershed in the White Clay Creek watershed in 2010. The Main Stem below Newark had the highest proportion of developed land cover (77%) and the lowest proportion of forest/wetland land cover (14%). The East Branch above Avondale had the highest proportion of agriculture land cover (59%) and the lowest proportion of developed land cover (19%). The Main Stem above Newark had the highest proportion of forest/wetland land cover (60%). Figure 6 shows the increase or decrease in the major land cover categories between 1996 and 2010 by subwatershed. The largest increase in developed land and decrease in agriculture has occurred in the East Branch below Avondale. The lowest amount of absolute change in land cover occurred in the Middle Run.

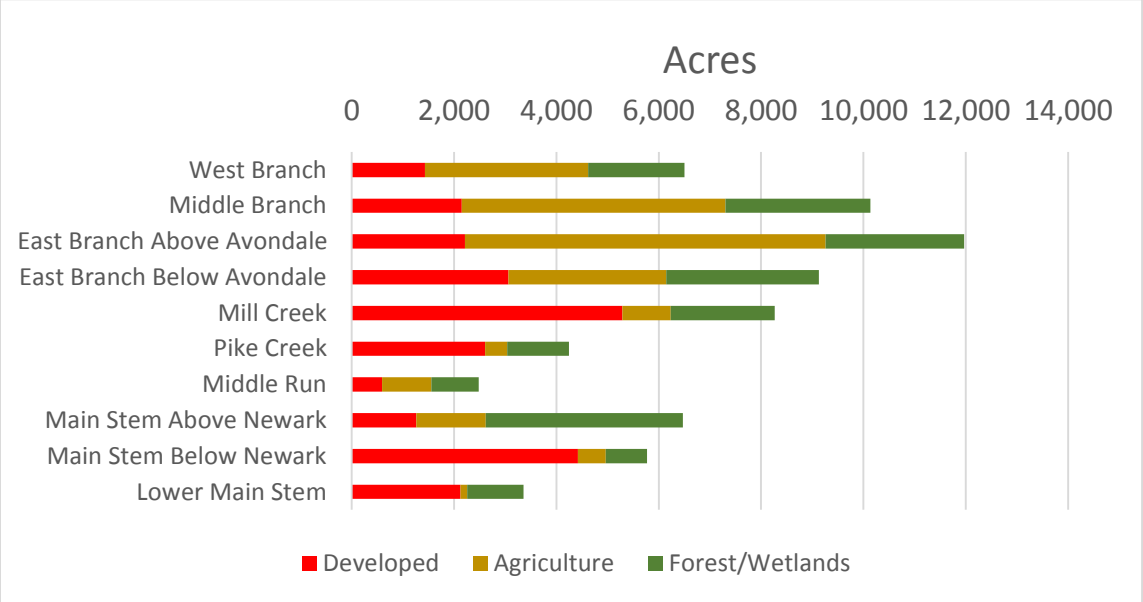

Figure 5. Land Cover Area by Subwatershed, 2010

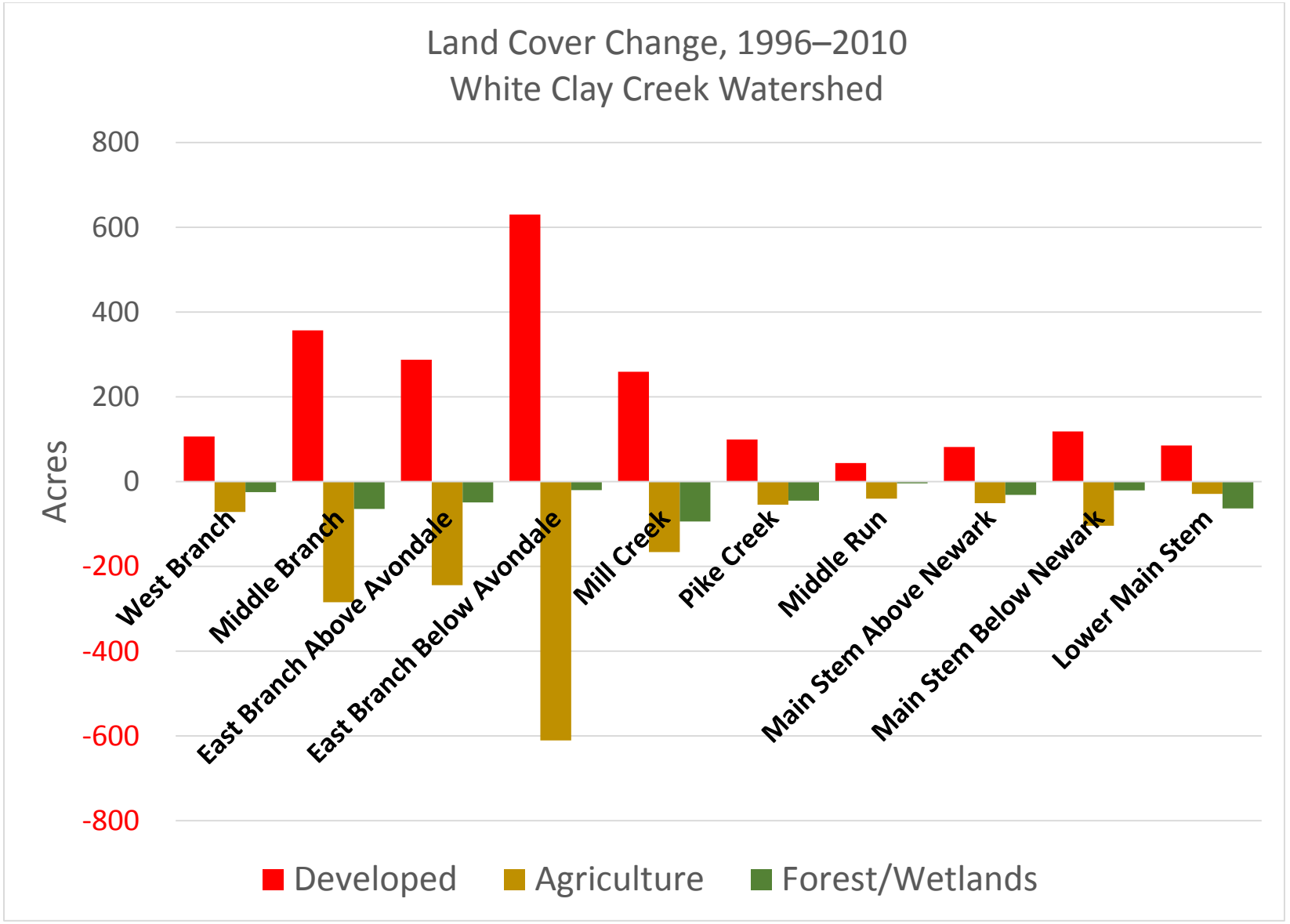

Figure 6. Land Cover Change by Subwatershed, 1996–2010

Land Preservation

Land preservation, such as open space and conservation easement acquisition, are vital to watershed health. Based on analysis conducted by the Brandywine Conservancy, Figure 7 provides a summary of the total acreage of open space and easements in the watershed.

In 2005 approximately 17% of the watershed was protected open space and in 2015 over 20,000 acres, or 29%, of the watershed is protected open space.

The open space acreage in each category has increased significantly from 2005 (11,611 acres) to 2015 (20,005 acres) with the largest increase realized in the homeowner category (337 to 2,400 acres, respectively) and the lowest increase in state lands (4,496 to 4,923 acres, respectively) (Figure 7). The White Clay Wild and Scenic Program has directly contributed to a significant portion of the preservation in the watershed through the contribution of National Park Service and partner funds. Since 2000, the White Clay Creek National Wild and Scenic River Program has directly contributed to the preservation of just under 2,000 acres of open space and $88,760 directly to land preservation/acquisition.

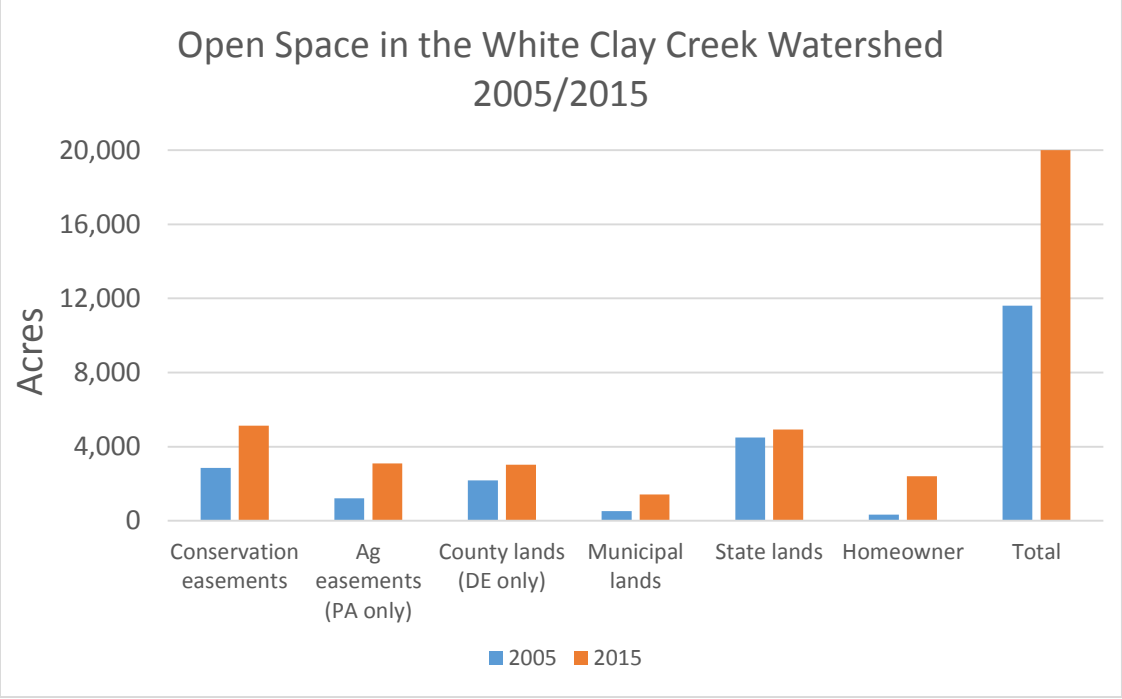

Figure 7. Open Space Preservation in the White Clay Creek Watershed (Brandywine Conservancy, 2015)

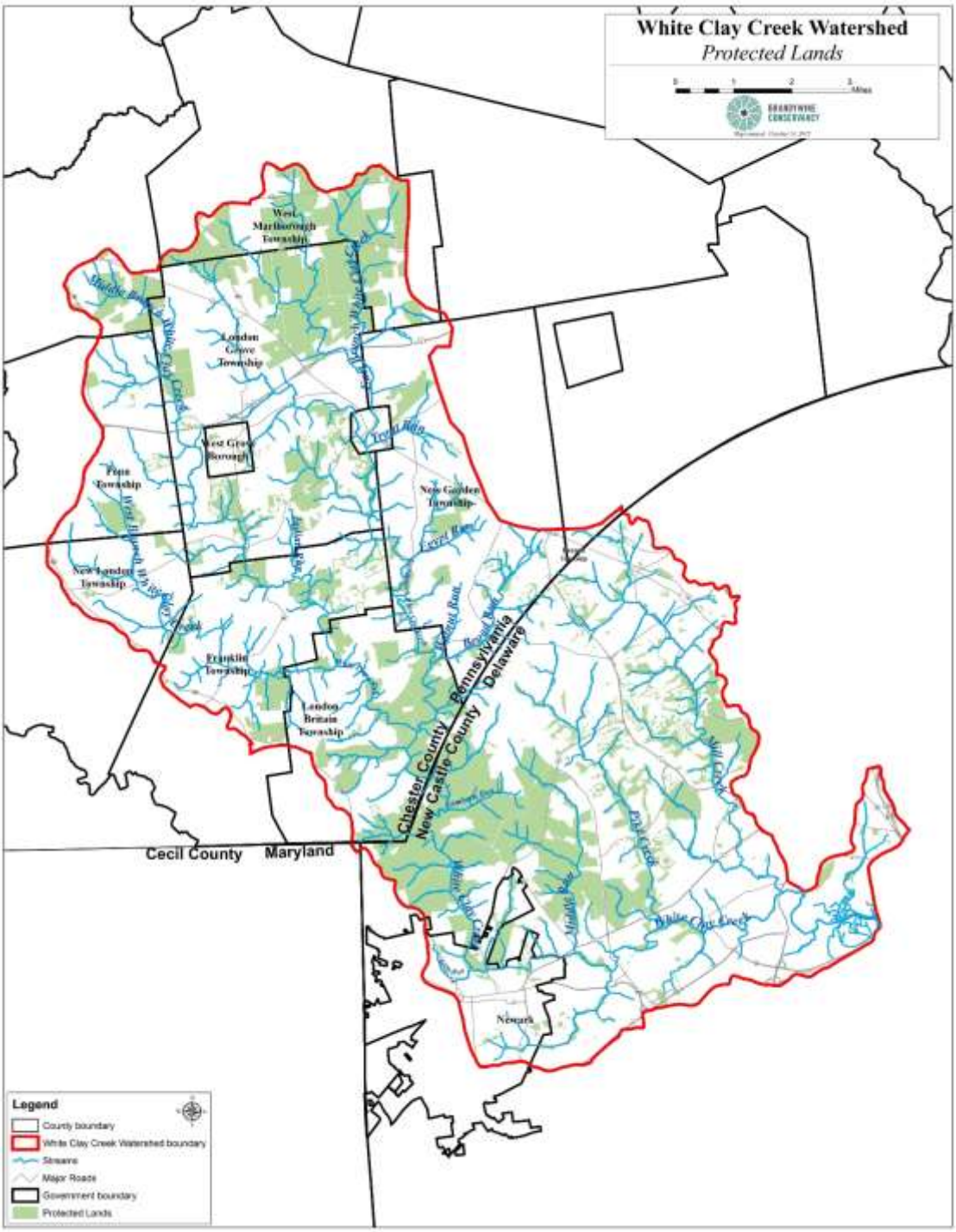

Figure 8. Land Preservation in the White Clay Creek Watershed (Brandywine Conservancy, 2015)

Riparian Buffers

Riparian buffers are a critical watershed management tool and an essential element of the landscape to achieve a healthy watershed. Based on analysis conducted by the Stroud Water Research Center and the Brandywine Conservancy in 2006, the White Clay Creek had 346 stream miles fully buffered and 282.9 stream miles partially buffered. This analysis found that in 2006 in the White Clay Creek watershed there were 209.1 stream miles available to install buffers (Corrozi, et al., 2008). Since the publication of the White Clay Creek Reforestation Plan in October 2009, and based on the best available data, 12,300 linear feet have been buffered (or 2.3 miles) from 2010 to 2015 (Table 3).

The majority of land in the White Clay Creek watershed is privately owned making it difficult to effectively install and protect riparian buffers. In 2015, in an effort to successfully locate, approach, and recruit private (and public) landowners for potential planting projects, the Brandywine Conservancy completed GIS mapping to identify gaps in the forested riparian areas of the entire White Clay watershed. The stream layer was superimposed on 2013 aerial photography by Chester County, Pennsylvania, and New Castle County, Delaware, and a one-hundred-foot-wide riparian buffer zone was digitized, based on a visual assessment of the vegetation—as either having an existing forested buffer or as lacking a forested buffer, a riparian gap. The riparian gaps are further defined as any non-forested lands larger than one acre on a single parcel or contiguous parcels under the same ownership. These more refined maps will enable us to take a closer look at missing links and their connectivity to surrounding protected lands and critical habitat areas.

Planting in riparian gaps may create more interior forest and fewer forest edges, creating a healthier and more stable forest in the long run. By combining this GIS gap analysis with the updated Natural Resource Heritage Inventory records and scaling reforestation projects in terms of installation ease for each municipality, municipal reforestation projects will be prioritized, giving precedence to publicly owned lands. Further priority for reforestation projects would be given to lands under public ownership or permanently protected.

The information learned from this analysis will enable the White Clay Wild and Scenic Program to provide watershed municipalities with detailed maps of priority areas for reforestation and identify smaller shovel-ready projects (i.e., gap of fewer than three acres) that the municipality can undertake on its own using the Pennsylvania Horticultural Society's TreeVitalize program. The gap analysis complements the more scientifically rigorous White Clay Creek Reforestation Plan (2009) but is more action-oriented with the goal of getting more trees into the ground in multiple locations and as quickly as possible.

Table 3. Riparian Buffer Implementation in the White Clay Creek Watershed, 2010–2015

Year	Acreage	Trees Planted	Stream Buffer (linear feet)
2010	10	3000	2400
2012	2.44	1150	1850
2013	8.18	2800	1400
2014	0.6	100	470
2015	12.7	3105	6180
Total	**33.92**	**10155**	**12300 (2.33 miles)**

Natural Resources Ordinances

Establishing natural resource protection through ordinances is critical to achieve a healthy watershed and water quality improvement. In 2014, two independent sources, Kate Miller (Master's Thesis, 2014) and Chester County Planning Commission (Natural Resources Ordinance Review for White Clay Watershed and Municipalities, 2014), conducted a natural resource protection inventory in the townships and municipalities in the White Clay Creek watershed. Using these assessments a three-step metric was used to point out the areas of strength and the areas where efforts should be focused to establish stronger natural resource protection. Table 4 provides an overview of the status of natural resource protection in the watershed based on the two natural resource inventories. A quick scan of the chart columns shows that woodland protections are not as strong as steep slope protections and could be substantially improved. A quick scan of the rows shows that a few municipalities could use better resource protections and outreach to those municipalities should be prioritized. Township and municipality names have been redacted at the discretion of the authors.

Table 4. Natural Resource Protection Ordinance Assessment for the White Clay Creek Watershed

Township/Municipality	Natural Resource Protection					
	Source Water	Wetlands	Floodplains	Riparian Buffers	Steep Slopes	Woodlands
Municipality 1						
Municipality 2						
Municipality 3						
Municipality 4						
Municipality 5						
Municipality 6						
Municipality 7						
Municipality 8						
Municipality 9						
Municipality 10						
Municipality 11						
Municipality 12						
Municipality 13						
Municipality 14						

Source: Data compiled from analysis conducted by Kate Miller (2014), University of Delaware Water Resources Agency; Shane Morgan (2015), Management Plan Coordinator, White Clay Creek Wild and Scenic Rivers Program, and Chester County Planning Commission, Natural Resources Ordinance Review for White Clay

Color Key:
Rigorously Protected
Somewhat Protected
Unprotected

Hydrology Indicators

The hydrology of the White Clay Creek watershed is directly impacted by the landscape indicators discussed in the previous section and will affect the water quality in the White Clay Creek. Hydrology is important to consider when determining the status of the White Clay Creek's watershed health. The hydrology indicators that were assessed in this report include:

1. Precipitation
2. Streamflow
3. Flooding

Precipitation

For the 20-year period 1994–2014, the annual precipitation measured at the Wilmington Airport in Delaware averages 44 inches per year, ranging from 27.76 inches in 1997 to 56.75 inches in 2004 (Figure 9). Precipitation as measured by a five-year moving average has remained relatively constant, with a slight increase in the second half of the 20-year period. Overall the precipitation trend has remained relatively unchanged over the past 20 years.

The mean annual flow in the White Clay Creek near Newark fluctuates based on precipitation and averages 133 cubic feet per second (cfs) (20 inches per year) or half the average annual precipitation. This relationship has remained unchanged since the analysis conducted in the 2008 report. As discussed in the 2008 report, this indicates relatively plentiful groundwater recharge to stream baseflow. As the intensity of storms increase, the more urbanized watersheds in the White Clay Creek watershed will see reduced recharge and negative impacts to streamflow.

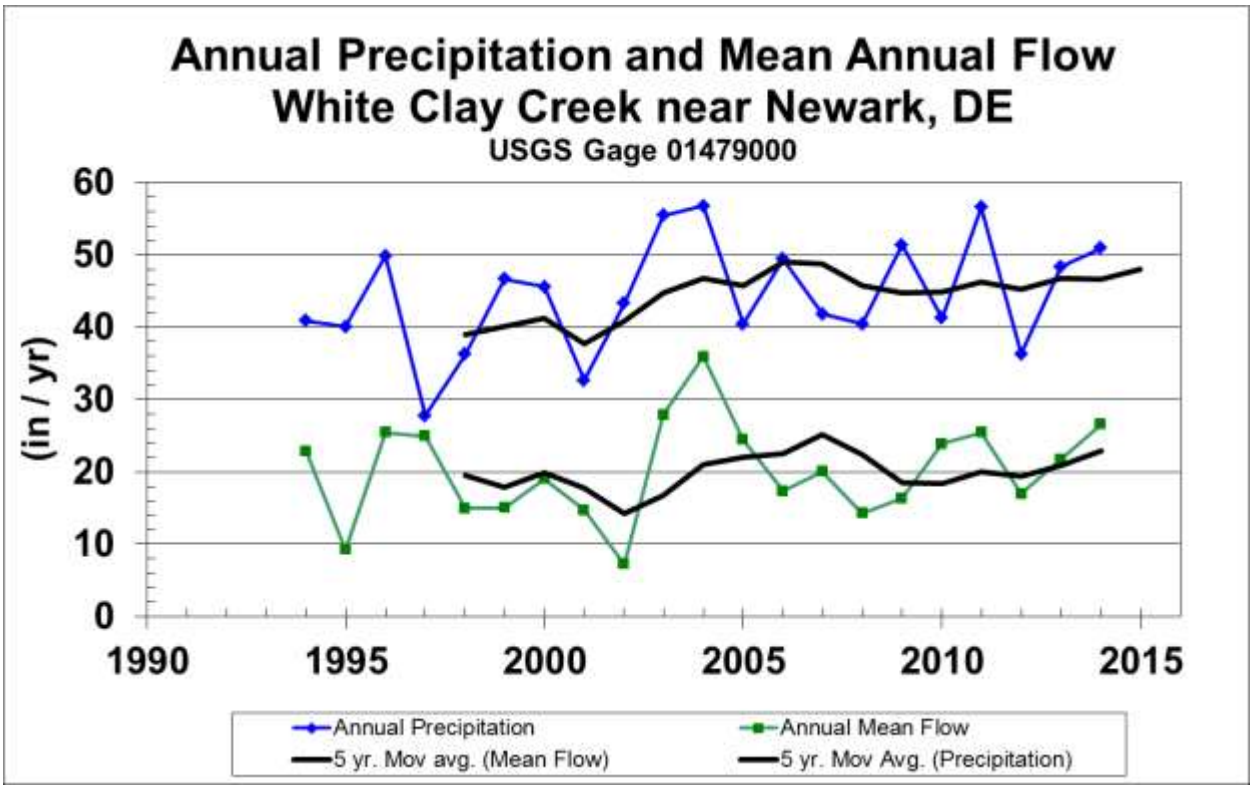

Figure 9. Annual Precipitation (Wilmington Airport) and Mean Annual Flow, along the White Clay Creek near Newark, 1994–2014

Streamflow

Based on the five-year moving average, there is no significant trend for the peak flow or minimum daily flow from the period of record, 1943–2014 (Figure 10). Further analysis of the peak flow data shows that for the years 1943–2014, the first peak flow of record greater than 10,000 cfs was recorded in 1989 (11,600 cfs). For this period of record, the five highest peak flows (>10,000 cfs) have occurred in the past 25 years: 11,600 cfs (1989), 13,900 cfs (2003), 14,700 cfs (2014), 17,000 cfs (2011), and 19,500 cfs (1999).

The White Clay Wild and Scenic Program has implemented several BMPs to capture, infiltrate, and treat stormwater that reduce the negative impacts such as increased flashiness of the stream and higher peak flows. Since 2013, with the support of the White Clay Wild and Scenic Program, 12 BMPs have been implemented throughout the watershed that will help to reduce impacts to streamflow (Table 5).

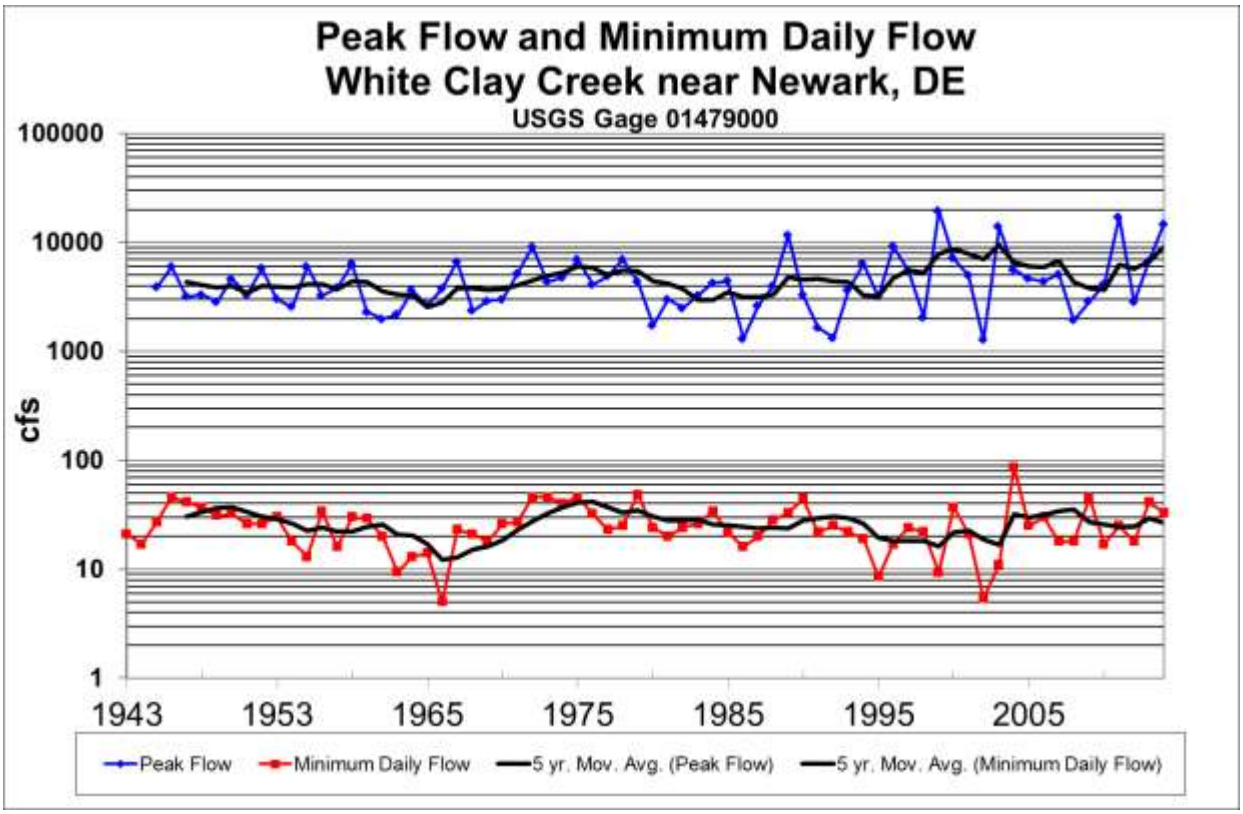

Figure 10. Peak Flows and Minimum Daily Flows along the White Clay Creek near Newark, 1943–2014

Table 5. White Clay Wild and Scenic Funded BMPs Installed in White Clay Watershed, 2013–2015

Year	BMP	Number	Location	Description
2013	Stormwater Basins	3	City-owned land outside the Hunt at Louviers, City of Newark, DE	Retrofitted three stormwater basins (@64,000 sq. ft.) in the City of Newark to improve water infiltration and nutrient uptake from a 53.8 acre drainage area.
2013	Grass Swales	2	Swift Park, Hockessin, DE	Regraded and replanted two (2,500 sq. ft.) formerly mowed grass swales in Hockessin, DE with native perennial plants.
2014	Rain Basins	2	Goddard Park, London Grove Township, PA	Retrofitted two rain basins (8,500 sq. ft.) in London Grove Township with native vegetation.
2014	Manure Management	1	Heifer Farm, Franklin Township, PA	Installed 1,000 ft. of pasture fencing and 470 ft. of stream bank fencing and planted 0.6 acres of streamside forest buffer.
2014	Habitat Planting	1	Landenberg Junction Trail Head, New Garden Township, PA	Planted 3,500 sq. ft. of barren soil in the floodplain.
2015	Manure Management	1	Concentrated Animal Feeding Operation (dairy), London Grove Township	Upgraded current liquid manure storage to a water- tight containment structure with leak-detection line.
2015	Riparian Buffer and Floodplain Enhancement	1	New Garden Township Park, PA	Planted 1,500 linear feet of a second-order stream.
2015	Riparian Buffer and Floodplain Enhancement	1	Curtis Mill Park, Newark, DE	Installed along 300 linear feet of the main branch (1 acre).

Flooding

The University of Delaware Water Resources Agency has compiled data from the USGS stream gage, White Clay Creek near Newark, Delaware (01479000). Based on this data since 1943, the highest storms of record and flooding events have occurred in the last 25 years. The highest storm of record was Hurricane Floyd on September 16, 1999, at 19,500 cfs and has a 200-year return interval. The second and third highest storms, Hurricane Irene (August 28, 2011) and an unnamed storm (May 1, 2014) peaked at 16,700 cfs and 14,600 cfs, respectively, and have a 100-year return interval.

Table 6. Highest Storms of Record in the White Clay Creek Watershed, 1943–Present

USGS Gage: White Clay Creek near Newark, Delaware (01479000)			
Date	**Storm**	**Top Peak Flows[1] (cfs)**	**Return Interval[2]**
7/22/72	Agnes	9,080	25-yr
7/05/89	4th of July	11,600	>25-yr
1/19/96	Unnamed	9,150	25-yr
9/16/99	Floyd	19,500	>200-yr
9/15/03	Henri	13,900	>50-yr
8/28/11	Irene	16,700	>100-yr
10/29/12	Sandy	6,740	
5/01/14	Unnamed	14,600	<100-yr

1. www.usgs.gov 2. Ries, K. G. and J. A. Dillow, 2006. Magnitude and Frequency of Floods on Nontidal Streams in Delaware. U. S. Geological Survey. Scientific Investigations Report 2006-5146.

Water Quality Indicators

Although the White Clay Creek watershed is designated as Wild and Scenic, more than two-thirds of its streams are affected by pollution. To characterize the water quality and stream health, water quality trends were derived 1995–2014 at White Clay Creek stations in Delaware for the following parameters:

1. Dissolved Oxygen (DO)
2. Phosphorus – Total Phosphorus (TP) and Orthophosphate
3. Nitrogen – Total Nitrogen (TN) and Inorganic Nitrogen
4. Total Suspended Sediment
5. Bacteria – *Enterococcus*

Water quality stations and trends for these seven water quality parameters were assessed and are provided in Table 7 and Figure 11 below. Based on the data collected between 1995 and 2014, the overall trends across the three monitoring stations in Delaware for phosphorus, DO, TSS, and bacteria display improvement for six of the seven parameters. Unacceptable levels are decreasing or meeting the water quality standard. However, nitrogen levels display a negative trend (levels exceed the standard and are generally increasing).

To assess the current trends in water quality in the watershed, the concentrations of each parameter were graphed over time. Data was provided by the Delaware DNREC Watershed Assessment Section at STORET long-term monitoring stations along the White Clay Creek from three locations: Chambers Rock Road, Delaware Park Boulevard (USGS gage 014790000), and McKees Lane. For each monitoring station within each water quality parameter, water quality data were plotted as annual medians and instantaneous grab samples to provide visual examination of the results. A map showing the location of each monitoring station is shown in Figure 12.

Table 7. Water Quality Trends in the White Clay Creek Watershed, 1995–2004

Parameter	Number of Stations			
	Improved	**Constant**	**Degraded**	**Total**
DO	2	1		3
Enterococcus	1	2		3
Inorganic N		1	2	3
Total N		3		3
Ortho P	2	1		3
Total P	2	1		3
TSS	1	2		3
Total	**8**	**11**	**2**	**21**

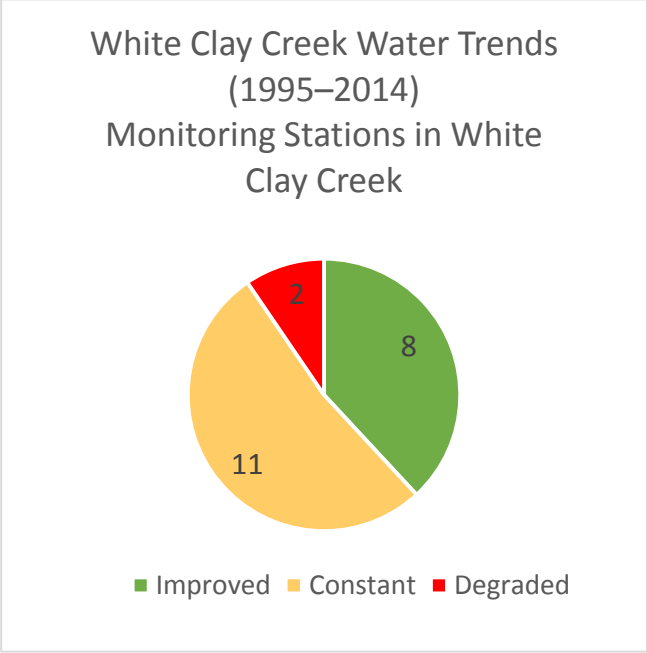

Figure 11. Water Quality Trends in the White Clay Creek Watershed, 1995–2014

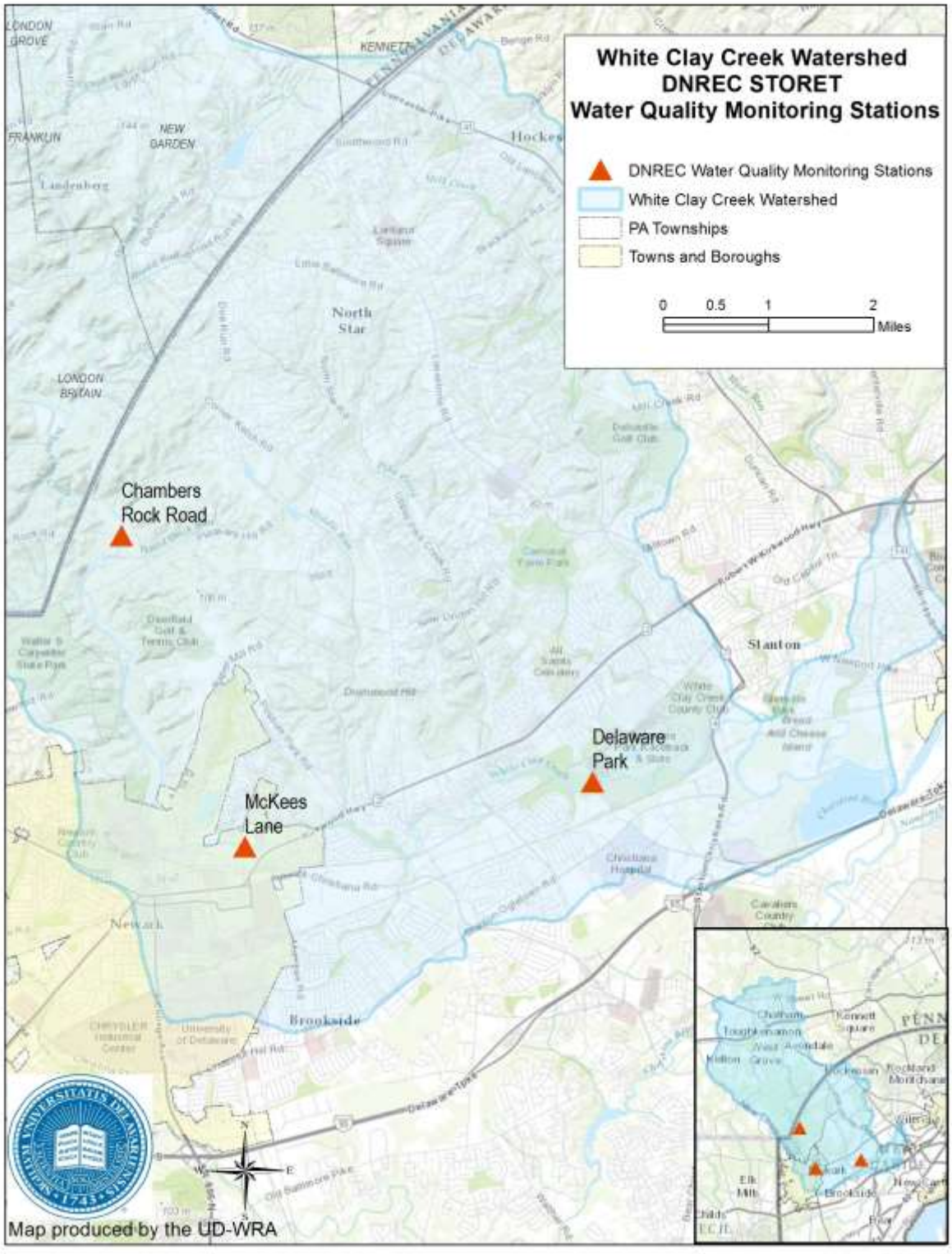

Figure 12. DNREC Water Quality Monitoring Stations in the White Clay Creek

Dissolved Oxygen

For all stations sampled, dissolved oxygen (DO) levels exceed the minimum standard set forth by the state of Delaware (4 mg/L). Since 1995, trends in median DO level have remained steady or shown slight improvement (Figure 13). Additionally, annual median levels are typically observed to exceed the standard by at least two times, a good indication for DO. The Delaware River Basin Commission (DRBC) has promulgated a more restrictive standard of 5 mg/L (dashed green line), and all stations also exceed this standard.

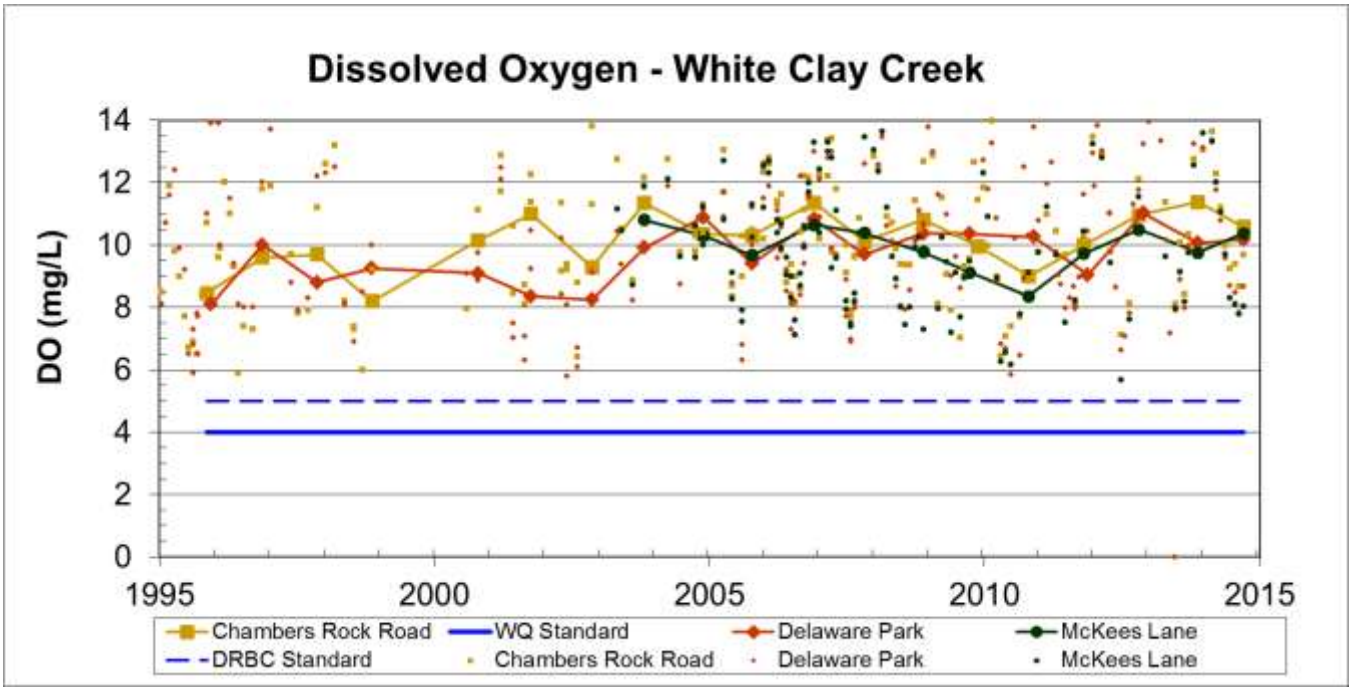

Figure 13. Dissolved Oxygen along the White Clay Creek in Delaware, 1996–2015 (DNREC)

Phosphorus

Median values for total phosphorous (TP) at the three monitoring stations have shown improvement since 2000, but have leveled off after about 2005. Current levels are near, but still slightly above the Delaware standard of 0.05 mg/L (Figure 14).

Orthophosphate is a form of phosphorus found in sewage. Levels at the three monitoring sites show a positive trend similar to that of TP, with median values dropping to near the 0.05 mg/L standard for phosphorous (Figure 15).

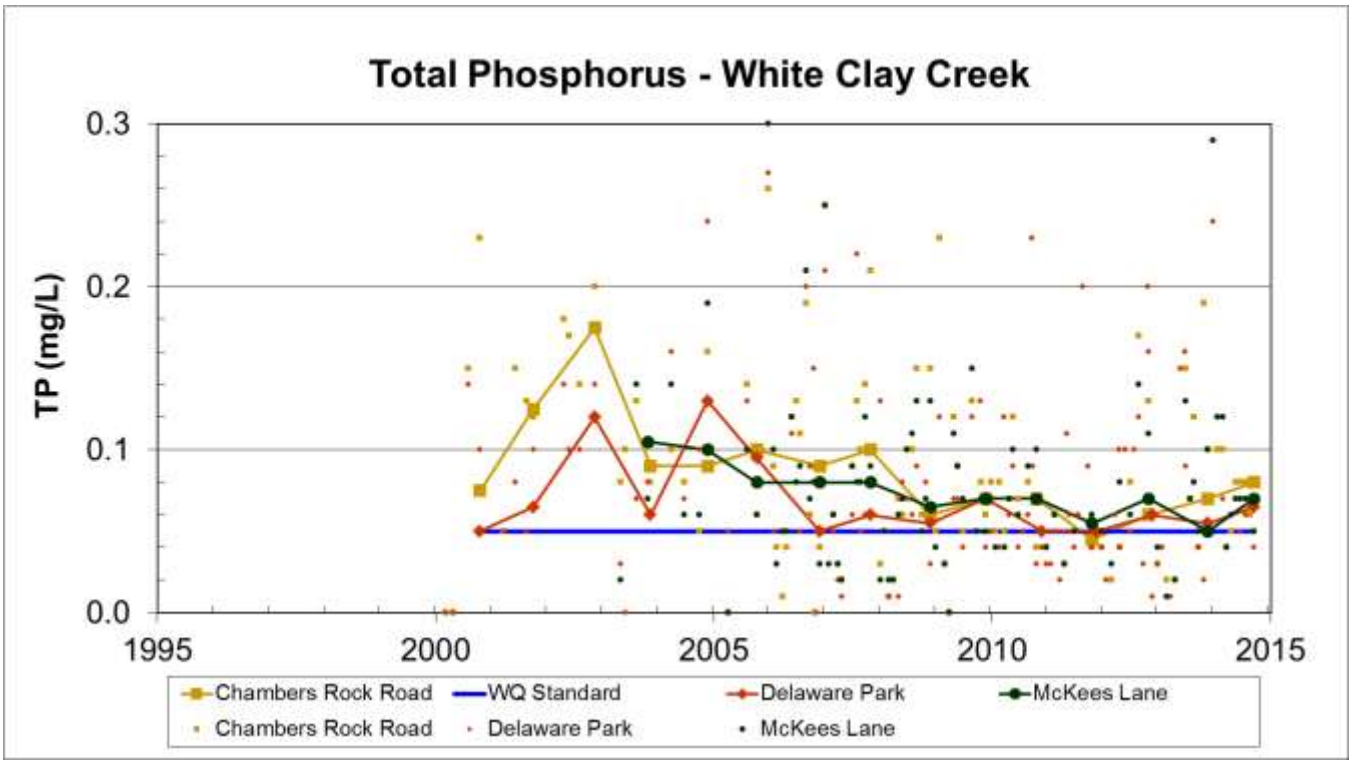

Figure 14. Total Phosphorus Trends in the White Clay Creek in Delaware (DNREC)

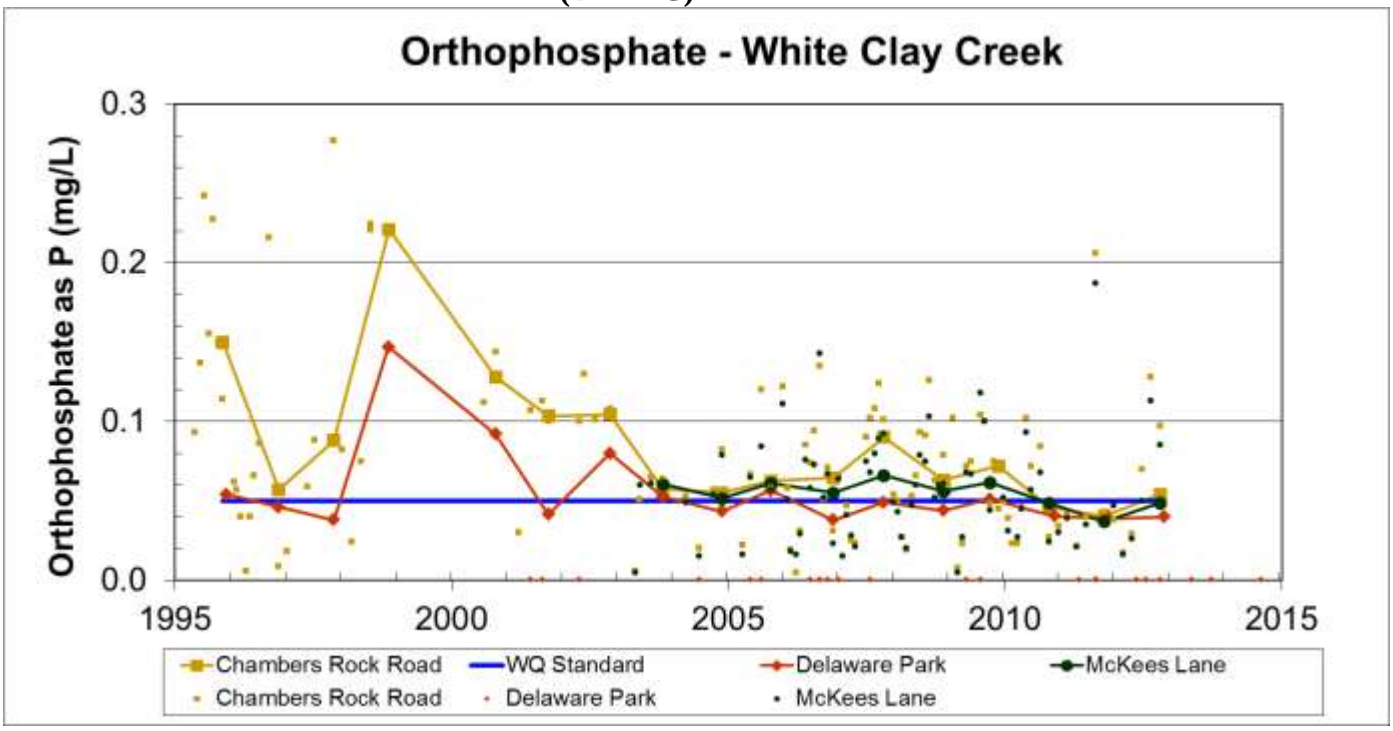

Figure 15. Orthophosphate Trends in the White Clay Creek in Delaware (DNREC)

Nitrogen

Nitrogen trends show levels well above the Delaware standard of 1.0 mg/L, both in terms of total nitrogen (TN) as well as inorganic nitrogen (nitrate + nitrite and ammonium) (Figures 16 and 17). These trends that consistently exceed the Delaware water quality standard indicate that in general, nitrogen levels remain poor in the White Clay Creek watershed. This tendency has persisted over the long term and is an issue of concern for overall watershed health. Excess nitrogen causes increased growth of aquatic plants and algae that can clog intakes, uses up DO, and blocks light to deeper waters.

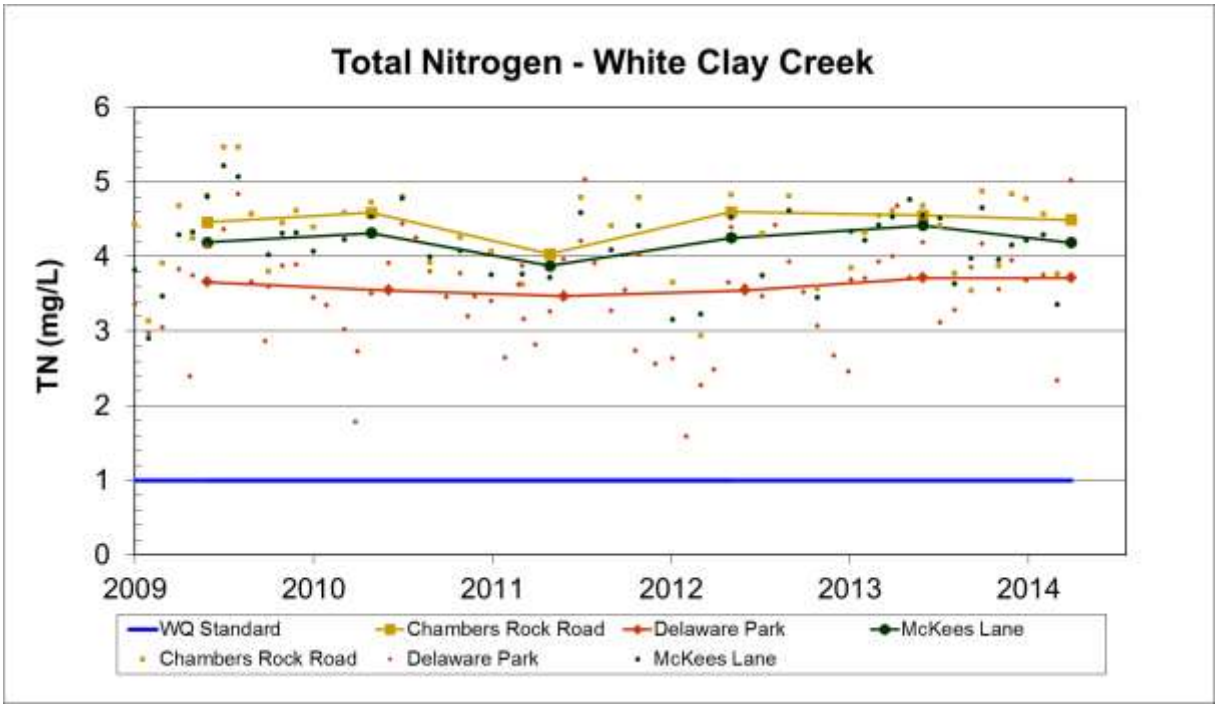

Figure 16. Total Nitrogen Trends in the White Clay Creek in Delaware (DNREC)

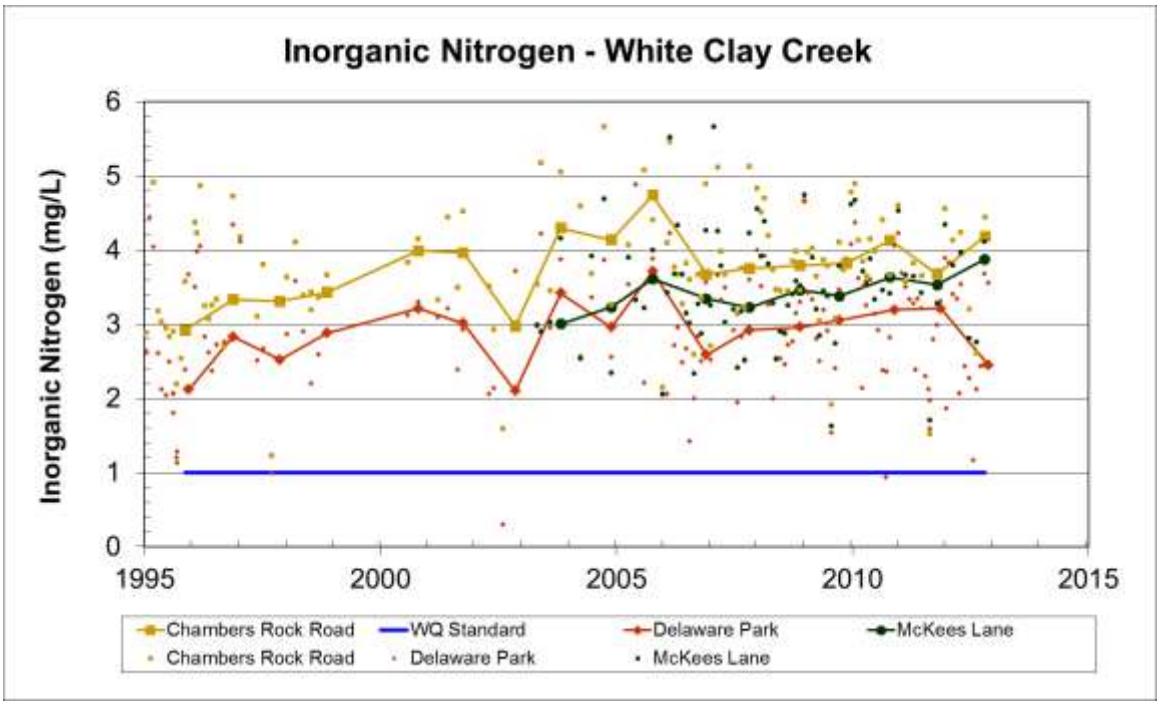

Figure 17. Inorganic Nitrogen Trends in the White Clay Creek in Delaware (DNREC)

Total Suspended Sediment

Delaware does not have a water quality standard for concentrations of total suspended sediment (TSS) in streams. The New Jersey standard of 40.0 mg/L (warm water streams) and 25.0 mg/L (cold water streams) is used as reference for the TSS levels in the White Clay Creek. TSS levels in the White Clay Creek have remained relatively constant between 1995 and 2014 and based on the New Jersey standard, are below an acceptable standard (Figure 18). Although the annual medians for TSS levels are consistently below the New Jersey standard, the instantaneous grab samples show the frequency and scale of exceedances in the White Clay Creek. The high levels of TSS due to the increased frequency and magnitude of these exceedances cause problems with stream health, aquatic health, and drinking water supplies as well as increased costs for water purveyors.

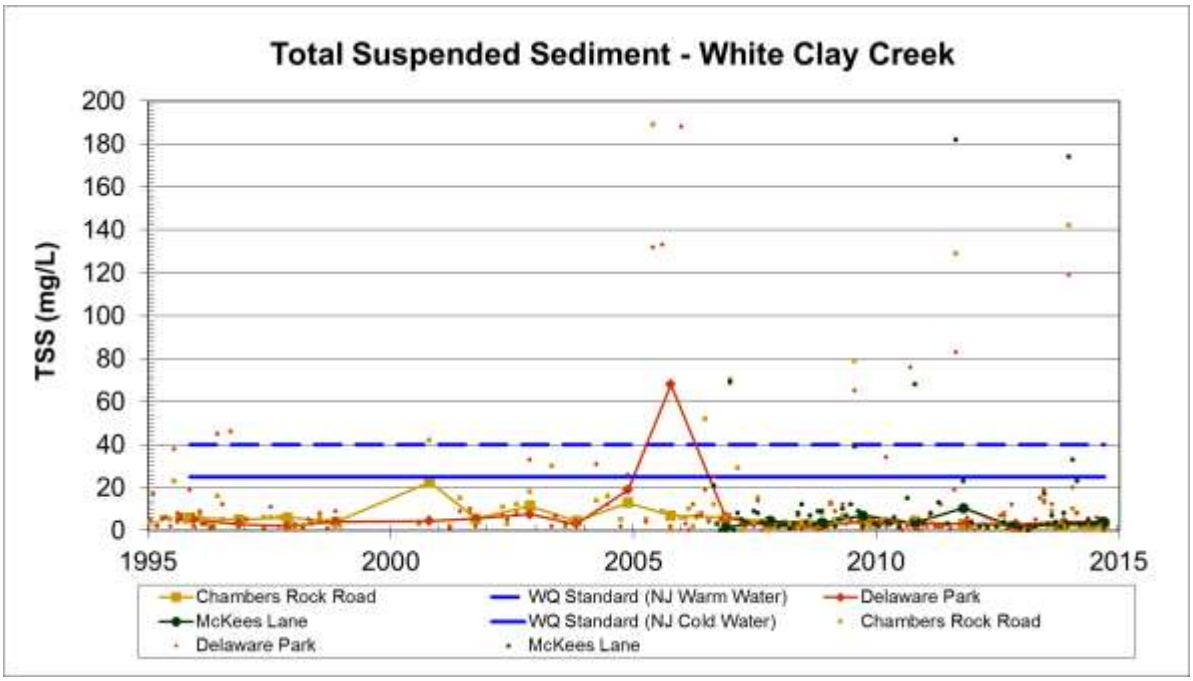

Figure 18. Total Suspended Sediment Trends in the White Clay Creek in Delaware (DNREC)

Bacteria

Delaware uses *Enterococcus* bacteria levels as the indicator to determine the impacts of pathogens in streams. Bacteria in streams can come from a wide variety of sources, including human and livestock waste and wildlife.

From 1995 through 2014, bacteria levels, expressed as a geometric mean, have shown an overall decrease, with levels after about 2000 consistently falling below the Delaware long-term standard of 100 colony forming units per 100mL (cfu/100mL) (Figure 19). The instantaneous measurements are also shown on the graph. These may be compared to the instantaneous bacteria standard in Delaware of 185 cfu/100mL, to determine the number of times per year the standard is exceeded. Over the period from 1995 to 2015, there has been no clear trend in the proportion of the number of exceedances to the total number of samples, likely due to the small number of samples. Sample sizes since 2006 have been somewhat larger and indicate a moderate decrease in exceedances at Delaware Park, an increase in exceedances at McKees Lane, and relatively steady number of exceedances at Chambers Rock Road.

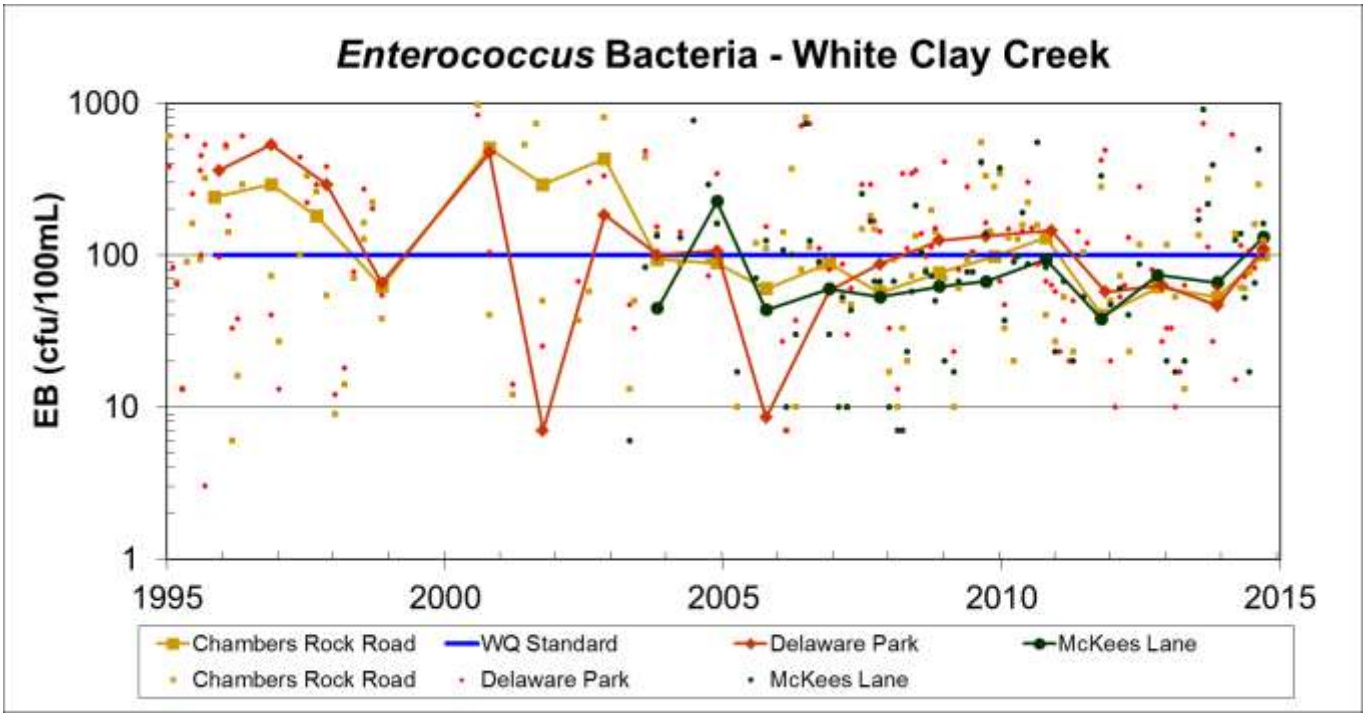

Figure 19. *Enterococcus* Trends in the White Clay Creek in Delaware (DNREC)

In the Pennsylvania portion of the watershed, the White Clay Wild and Scenic Program partnered with the Pennsylvania Department of Environmental Protection (DEP) to collect bacteria data in the Pennsylvania streams. Volunteers (2012), and student interns (2013–2015) collected 10 grab samples per season at up to 14 sites during each the recreational season over four years. The data collected shows elevated pathogen levels (E. coli and fecal coliform bacteria). This assessment resulted in adding 67 miles of bacteria impairments to the Pennsylvania impaired streams list (Figure 20).

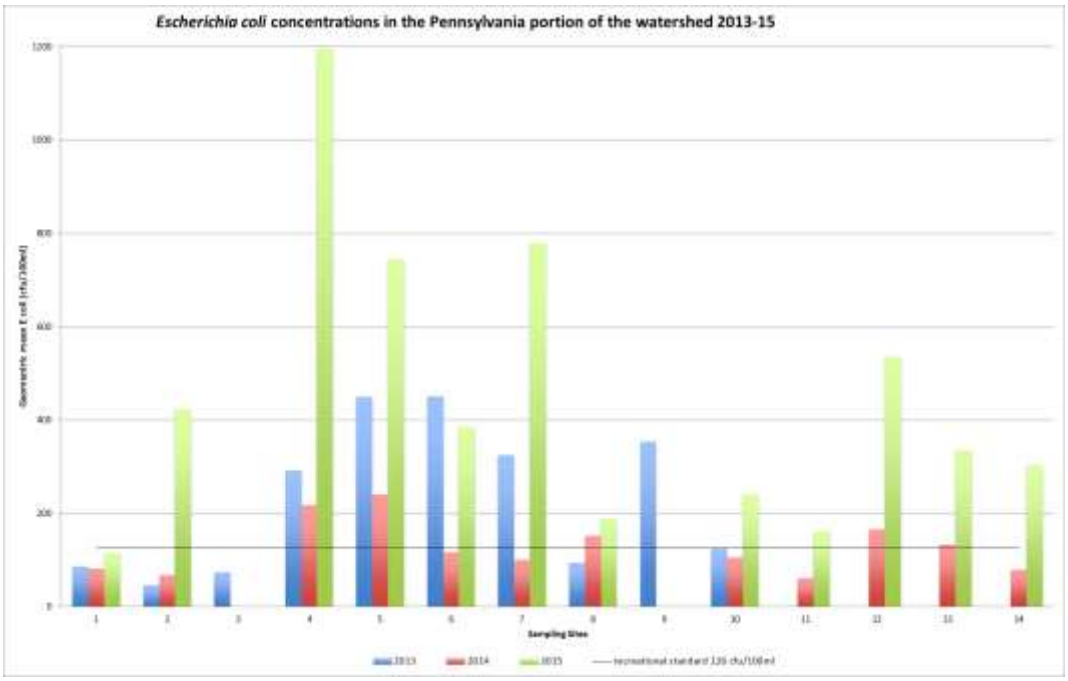

Figure 20. *E. Coli* Concentrations in the Pennsylvania Portion of the White Clay Creek (White Clay Wild and Scenic Management Committee)

Habitat Indicators

The habitat in the White Clay Creek watershed is directly impacted by the activities on the land as well as the overall water quality in the creek. The following habitat indicators were assessed to determine the status of the White Clay Creek watershed health:

1. Macroinvertebrates
2. Impaired Streams
3. Birds
4. Freshwater Mussels
5. Impaired Streams
6. Fish Passage
7. Fish Consumption Advisories

Macroinvertebrates

Benthic macroinvertebrates are aquatic organisms that live on the stream bottom. These serve as a useful tool to assess stream health at a specific site because they are directly impacted by water quality and physical conditions. In the 2008 White Clay Creek State of the Watershed Report the Stroud Water Research Center's stream watch data (2003–2005) provided a useful tool to assess the White Clay Creek environmental conditions based on 16 stream locations in the White Clay Creek watershed. Due to a lack of funding this sampling is no longer being conducted.

Photo credit: Delaware Nature Society

Since 1969, the USGS and Chester County Water Resources Authority (CCWRA) have an established biological monitoring network (Network) in Chester County. In 1998, the Network was modified to include 18 fixed-location sites and 9 flexible-location sites that measured baseflow conditions for water chemistry, instream habitat, and benthic macroinvertebrates (Reif, 2009). The Network includes two sampling site locations in the White Clay Creek, these include:

- East Branch White Clay Creek at Avondale, Pennsylvania
- Middle Branch White Clay Creek near Avondale, Pennsylvania

The scores for these sites, collected 1998–2009 are within the range of the data collected from 18 sites in nearby watersheds in Chester County, Pennsylvania, and indicate slightly impacted conditions based on HBI scores.

Biological data collected by the USGS at these same sites for the period 2007–2014 and published online also indicate good stream quality. The benthic-macroinvertebrate community at the East Branch White Clay Creek at Avondale is categorized as slightly impacted. The Middle Branch White Clay Creek near Avondale site ranges from nonimpacted (2007, 2008, 2014) to slightly impacted (2009–2013). According to the USGS website, a slightly impacted stream is less diverse than at nonimpacted sites but still contains mayflies, caddisflies, and possibly some stoneflies. The community structure typically is dominated by a few taxa including caddisflies, elmids (riffle beetles), and chironomids. Water quality and habitat conditions are having an effect on the benthic-macroinvertebrate community. This categorization indicates that these sites are receiving some wastewater inputs and (or) agricultural/urban runoff (USGS website).

It is important to note the two USGS sampling sites are located in the upper portion of the watershed and reflect conditions in those areas and are not indicative of macroinvertebrate and water quality conditions watershed-wide.

Impaired Streams

New information collected over the past few years by Pennsylvania DEP has resulted in additional impairments to 67 stream miles on the list of impaired waters for the Pennsylvania portion of the White Clay Creek. Elevated pathogen levels (*E. coli* and fecal coliform bacteria) are responsible for the new listings (Pennsylvania DEP 2014 Pennsylvania Draft Integrated Water Quality Monitoring and Assessment Report). These pathogens are typically found in human and animal waste, however tracking the sources of these elevated levels of contamination will require further study and significant funding. The White Clay Wild and Scenic program funds are currently being used to collect and analyze pathogen levels and should provide an indication of potential sources of the bacteria.

In Delaware, the 2014 list of impaired waters indicates that, since 2008, several portions of streams in the state have achieved water quality goals for impairments for biology and habitat, but remain impaired for bacteria (Delaware uses *Enterococcus* bacteria as a measure of pathogen impairment), as well as nutrients (State of Delaware 2014 Combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs).

There is a need for significant funding to undertake stream water quality assessment in the White Clay Creek. This is demonstrated by the fact that so many new streams were determined to be impaired in Pennsylvania, and in Delaware many streams were determined to have insufficient data to perform an adequate assessment.

Birds

The White Clay Creek Watershed hosts a diverse array of bird species, with over 200 species recorded within the watershed. Year-round bird survey efforts at Middle Run Natural Area (in the southern end of the watershed) during the past five years have shown that more than 100 species breed within the watershed and another 100 species occur as migrants that utilize the area's fields, forests, and wetlands as stopover locations during spring and fall migration.

Derek Stoner of the Delaware Nature Society conducted a comparison of data from the Pennsylvania Breeding Bird Atlas (2004–2009) and the Delaware Breeding Bird Atlas (2008–2012) with previous atlas periods (twenty-five years ago) which reveals a notable increase in populations of certain sensitive species that depend on habitats of conservation concern. A total of 105 species of birds were confirmed as nesting within the watershed during the period 2010–2015 (Stoner, 2015).

The following is a list of the 27 bird species listed as Rare, Threatened, or Endangered by the states of Pennsylvania and Delaware that occur in the White Clay Creek Watershed. Of these, at least 20 are confirmed as breeding within the watershed, based on data collected in the Pennsylvania and Delaware Breeding Bird Atlases (Table 8).

> Great Blue Heron, American Bittern, Black-crowned Night-heron, Cooper's Hawk, Bald Eagle, Broad-winged Hawk, Yellow-billed Cuckoo, Black-billed Cuckoo, Long-eared Owl, Short-eared Owl, Pileated Woodpecker, Brown Creeper, Marsh Wren, Veery, Wood Thrush, Louisiana Waterthrush, Blue-winged Warbler, Kentucky Warbler, Hooded Warbler, Cerulean Warbler, Northern Parula, Yellow-throated Warbler, Yellow-breasted Chat, Scarlet Tanager, Blue Grosbeak, Bobolink, Eastern Meadowlark

There are three primary habitats in the White Clay Creek Watershed that support species of conservation concern: grasslands, early-successional habitat, and mature woodlands.

Grassland habitats, which in the watershed consist primarily of cool-season grass fields mowed for hay, are the most imperiled due to development and farming practices. Birds such as the Eastern Meadowlark, Bobolink, and Grasshopper Sparrow that previously nested in these fields are found in lower numbers than during the prior breeding bird atlas periods in the 1980s. Only the Eastern Meadowlark continues to persist as a breeding bird within the watershed. However, recent changes in mowing practices of hayfields in the watershed show promise in improving nesting success rates for grassland bird species.

Early-successional habitats are currently thriving in the watershed, due to the emphasis on reforestation on both public and private lands. Significant tree planting programs at Middle Run Natural Area, White Clay Creek State Park, and White Clay Creek Preserve help to augment

similar efforts on smaller, private properties in the watershed. Species of conservation concern that are directly benefiting from such reforestation efforts include Yellow-breasted Chat, Prairie Warbler, Blue-winged Warbler, Black-billed Cuckoo, and Blue Grosbeak.

Mature woodlands are a hallmark of the White Clay Creek watershed, protecting the critical clean water resource and providing homes for an abundance of wildlife. Thousands of acres of mature forests are the attraction for a wide variety of songbirds, raptors, and waterfowl that depend on healthy landscapes dominated by large trees. Species of conservation concern that are dependent on the watershed's extensive mature forests include Broad-winged Hawk, Yellow-billed Cuckoo, Pileated Woodpecker, Brown Creeper, Veery, Wood Thrush, Louisiana Waterthrush, Kentucky Warbler, Hooded Warbler, Cerulean Warbler, Northern Parula, Yellow-throated Warbler, and Scarlet Tanager.

While species of conservation concern are worthy of extra protection, many common species are also benefitting from land management practices within the watershed. Of particular note, the installation of hundreds of bird boxes by land managers on both public and private open space in the watershed over the past decade has notably improved the breeding success of cavity nesters such as Wood Ducks, Eastern Screech-Owls, House Wrens, Tree Swallows, and Eastern Bluebirds.

Table 8. Bird Species Recorded in the White Clay Creek Watershed, 2010–2015

Snow Goose	Solitary Sandpiper	**Horned Lark**	**Yellow Warbler**
Ross's Goose	Greater Yellowlegs	**Northern Rough-winged Swallow**	Chestnut-sided Warbler
Cackling Goose	Least Sandpiper	**Purple Martin**	Prothonotary Warbler
Canada Goose	Wilson's Snipe	**Tree Swallow**	Blackpoll Warbler
Mute Swan	**American Woodcock**	Bank Swallow	Black-throated Blue Warbler
Tundra Swan	Laughing Gull	**Barn Swallow**	Palm Warbler
Wood Duck	Ring-billed Gull	Cliff Swallow	**Pine Warbler**
Gadwall	Herring Gull	**Carolina Chickadee**	Yellow-rumped Warbler
American Wigeon	Caspian Tern	Black-capped Chickadee	**Yellow-throated Warbler**
American Black Duck	**Rock Pigeon**	**Tufted Titmouse**	**Prairie Warbler**
Mallard	**Mourning Dove**	Red-breasted Nuthatch	Black-throated Green Warbler
Blue-winged Teal	**Yellow-billed Cuckoo**	**White-breasted Nuthatch**	Canada Warbler
Northern Pintail	**Black-billed Cuckoo**	Brown Creeper	Wilson's Warbler
Green-winged Teal	**Eastern Screech-Owl**	**House Wren**	**Yellow-breasted Chat**
Ring-necked Duck	**Great Horned Owl**	Winter Wren	**Grasshopper Sparrow**
Greater Scaup	**Barred Owl**	**Carolina Wren**	American Tree Sparrow
Lesser Scaup	Northern Saw-whet Owl	Marsh Wren	**Chipping Sparrow**
Common Goldeneye	Barn Owl	**Blue-gray Gnatcatcher**	**Field Sparrow**
Redhead	Long-eared Owl	Golden-crowned Kinglet	Vesper Sparrow
Canvasback	Short-eared Owl	Ruby-crowned Kinglet	Fox Sparrow
Bufflehead	**Common Nighthawk**	**Eastern Bluebird**	Dark-eyed Junco
Hooded Merganser	**Chimney Swift**	**Veery**	White-crowned Sparrow
Ruddy Duck	**Ruby-throated Hummingbird**	Gray-cheeked Thrush	White-throated Sparrow
Common Merganser	Rufous Hummingbird	Swainson's Thrush	Savannah Sparrow
Ring-necked Pheasant	**Belted Kingfisher**	Hermit Thrush	**Song Sparrow**
Wild Turkey	Red-headed Woodpecker	**Wood Thrush**	**Grasshopper Sparrow**
Common Loon	**Red-bellied Woodpecker**	**American Robin**	Lincoln's Sparrow
Pied-billed Grebe	Yellow-bellied Sapsucker	**Gray Catbird**	Swamp Sparrow
Horned Grebe	**Downy Woodpecker**	**Brown Thrasher**	**Eastern Towhee**
Double-crested Cormorant	**Hairy Woodpecker**	**Northern Mockingbird**	Snow Bunting
American Bittern	**Northern Flicker**	**European Starling**	Summer Tanager
Great Blue Heron	**Pileated Woodpecker**	American Pipit	**Scarlet Tanager**
Great Egret	**American Kestrel**	**Cedar Waxwing**	**Northern Cardinal**
Snowy Egret	Merlin	**Ovenbird**	**Rose-breasted Grosbeak**
Little Blue Heron	Peregrine Falcon	**Worm-eating Warbler**	**Blue Grosbeak**
Cattle Egret	Olive-sided Flycatcher	**Louisiana Waterthrush**	**Indigo Bunting**
Green Heron	**Eastern Wood-Pewee**	Northern Waterthrush	Bobolink
Glossy Ibis	Yellow-bellied Flycatcher	Golden-winged Warbler	**Red-winged Blackbird**
Black-crowned Night-Heron	**Acadian Flycatcher**	**Blue-winged Warbler**	**Eastern Meadowlark**
Black Vulture	Alder Flycatcher	**Black-and-white Warbler**	Rusty Blackbird
Turkey Vulture	**Willow Flycatcher**	Tennessee Warbler	**Common Grackle**
Osprey	**Least Flycatcher**	Orange-crowned Warbler	**Brown-headed Cowbird**
Golden Eagle	**Eastern Phoebe**	Nashville Warbler	**Orchard Oriole**
Northern Harrier	**Great Crested Flycatcher**	Mourning Warbler	**Baltimore Oriole**
Sharp-shinned Hawk	**Eastern Kingbird**	**Kentucky Warbler**	**House Finch**
Cooper's Hawk	**White-eyed Vireo**	**Common Yellowthroat**	Purple Finch
Bald Eagle	**Yellow-throated Vireo**	**Hooded Warbler**	Red Crossbill
Red-shouldered Hawk	Blue-headed Vireo	**American Redstart**	White-winged Crossbill
Broad-winged Hawk	**Warbling Vireo**	Cape May Warbler	Red Crossbill
Red-tailed Hawk	Philadelphia Vireo	**Cerulean Warbler**	Pine Siskin
Rough-legged Hawk	**Red-eyed Vireo**	**Northern Parula**	**American Goldfinch**
Black-bellied Plover	**Blue Jay**	Magnolia Warbler	Evening Grosbeak
Killdeer	**American Crow**	Bay-breasted Warbler	**House Sparrow**
Spotted Sandpiper	**Fish Crow**	Blackburnian Warbler	

* Names in bold indicate a breeding species; names in red indicate species of conservation concern.

Freshwater Mussels

Freshwater mussels are small creatures with the capacity to provide significant water quality benefits and may also inadvertently be beneficiaries of dam removals. Despite their importance to natural aquatic ecosystems, freshwater mussels are among the most imperiled animals in both the Delaware River Basin and the nation as a whole. Their decline in (and in some cases, disappearance from) our waterways has prompted the Partnership for the Delaware Estuary to launch the Freshwater Mussel Recovery Program.

Preliminary research in the White Clay Creek indicated that food and water conditions were capable of supporting mussels, yet none were found during initial surveys. Once missing from a stream, it is difficult for mussels to recolonize easily because either there is no longer brood stock nearby, or dams and other obstacles to fish passage may block the natural spread of juveniles (via fish hosts) back into the stream. In an effort to learn more about where and in what conditions these mussels can survive, the Partnership transplanted 119 mussels from the nearby Brandywine River to select locations within the Delaware portion of the White Clay Creek and monitored for survivorship in 2013–2014.

Results from the first year of study indicate a 68% bed retention, meaning 81 of the 119 mussels remained where they were placed and survived their first year, demonstrating that mussels have the potential to survive non-ideal conditions in post-developed streams. This is just one part of the Partnership's efforts to restore healthy populations of freshwater mussels throughout the Delaware Basin.

Fish

To obtain accurate data on the current distribution of American shad in the White Clay Creek, DNREC's Division of Fish and Wildlife conducted two anadromous fish-sampling events April 22 and May 13, 2010, on the lower White Clay Creek watershed.

The starting point for the first sampling event on April 22, 2010, was about a quarter-mile downstream from Dam No. 1 (Delaware Park Dam). The water clarity was exceptional (approximately 4 ft.) combined with above-average flows and a warm, sunny day, making it a good day to sample anadromous fish. Sampling was conducted at three sites:

- Site 1, below Dam No. 1, River Mile (RM) 4.6, to the Mill Creek confluence, water temp. 14.2°C.
- Site 2, Mill creek confluence to Hale-Byrnes House, tidal capture structure (TCS) was lowered.
- Site 3, Hale-Byrnes to RM 0, water temp. 16.7°C.

The launch site for the second sampling event on May 13, 2010, was at Dam No. 2 (Red Mill Dam). Flows were 50% above normal. From Dam No. 2 to Dam No. 1, there were no anadromous fish present in the sampling timeframe (about 1 hour or 3,390 seconds of effort). The water temperature was 12.2°C.

The data collected during the sampling events is summarized in Tables 9 and 10. The sampling locations are shown in Figure 21. From the data collected, it is evident that the number of fish species and the abundance of fish are greater below Dam No. 1, indicating that dam removal would be beneficial to fish habitat and migration.

Table 9. Summary of Sampling Data, April 22, 2010

Fish Species	CPU			Visual Count			Description
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	
Hickory Shad	Approx. 500		70	1000	450	70	Very thick at Site 1
Alewives		71		0	350	130	Abundant
American Shad				1	0	0	One large female (unripe)
Blueback Herring				0	0	0	None observed, could be coming later, typically follow alewives and hickory shad runs
Sea Lamprey				0	1	0	
Eels				Present	Present	Present	Observed at all sites
Other Observed Fish Species Noted							White perch, white suckers, smallmouth bass, quillback, yellow perch, largemouth bass, redbreast sunfish, pumpkinseed sunfish, rainbow trout, fallfish, carp, chubs, and tiger trout

Table 10. Summary of Sampling Data, May 13, 2010

Fish Species	Number of Fish Present
Hickory Shad	340
White Perch	1
Striped Bass	20
White Perch	1
Sea Lamprey (adult)	8
Alewives	0
American Shad	0
Striped bass	20
White perch	1

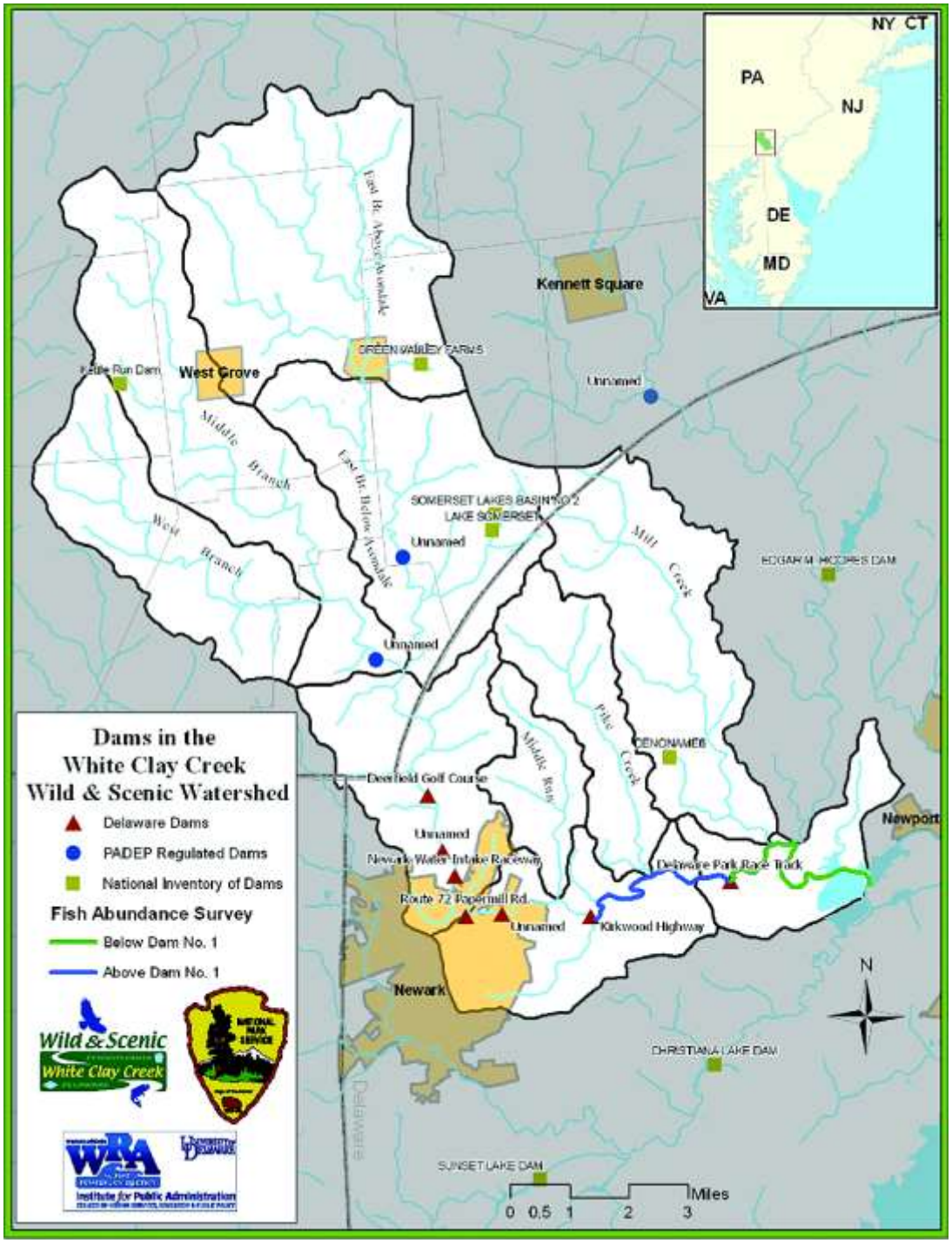

Figure 21. Location of Dams and Delaware DNREC Fish Abundance Surveys along the White Clay Creek, April and May 2010

Fish Passage

Photo credit: Rebecca Sheppard

In December 2014, the Byrnes Mill Dam, also known as Dam No. 1 and located on the White Clay Creek Country Club golf course at Delaware Park (Figure 21), was removed to restore fish passage. The removal connects 3.5 miles of the White Clay Creek National Wild and Scenic River to the tidal Christina and Delaware Rivers opening up close to four miles of the National Wild and Scenic River for domestic and anadromous fish passage. This is the first recorded dam removal in the state of Delaware and the first of seven planned removals along the creek between sea-level and the Delaware-Pennsylvania line. The University of Delaware, Water Resources Agency led the project with grant funding from the American Rivers and the National Oceanic and Atmospheric Administration (NOAA) Community-based Restoration Program, the National Fish and Wildlife Foundation, the FishAmerica Foundation, and the National Park Service.

Fish Consumption Advisories

The White Clay Creek has fish consumption advisories on approximately 25.9 miles of streams in the White Clay Creek watershed. The fish consumption advisories have full or partial fish consumption advisories as posted by the Pennsylvania DEP and DNREC. The fish consumption advisories in the Delaware portion of the White Clay Creek have remained unchanged since 2008 (Table 11).

Table 11. Trends in Fish Consumption Advisories in the White Clay Creek, 2008/2015

Waterbody	Species	Geographical Extent	Advisory (2015)*	Trend (2008/2015)
Tidal White Clay Creek	All Finfish	River Mouth to Route 4	●	No change
Non-Tidal White Clay Creek	All Finfish	Route 4 to Del./Pa. Line	○	No change
Designated Trout Streams	Stocked Trout	WCC above Newark, Pike Creek, and Mill Creek	○	No change

*Advisories due to PCB contaminants

● No consumption

○ No more than 1 meal/month

Environmental Indicator Summary and Progress Update

The White Clay Creek watershed is a unique resource in the region. It provides great value economically, recreationally, and biologically as well as serves the drinking water needs of over 120,000 people residing in the surrounding region. The health of the watershed is dependent upon effective natural resources management and preservation efforts of the many partners working in coordination with the White Clay Creek Wild and Scenic Management Committee.

Using the best available scientific data and the assigned trends from the 2008 report, UD WRA provides an updated assessment of the state of the watershed. In the following summary of the 20 environmental indicators discussed in this report the following symbols indicate the current status of each indicator:

✓	Very Good
●	Moderate
✗	Poor
ND	Not Sufficient Data

Each indicator is assigned a very good, moderate, or poor rating based on the best available data and the analysis provided in this report. For some environmental indicators there was not enough data to determine a rating and therefore that indicator is rated as "ND" or not sufficient data. The status information provided below is also enhanced with an update on the accomplishments and progress since the 2008 recommendations and recommendations going forward.

As future resources are allocated and management decisions are considered, the White Clay Creek Wild and Scenic Steering Committee shall reflect on the accomplishments and progress made since the White Clay Creek Watershed Management Plan (2000) and the White Clay Creek State of the Watershed Report (2008) and refer to the recommendations provided in the following summary as a guide to prioritize actions and investments to improve the health of the watershed.

Landscape	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
	Population ✗	Update the population estimates for the White Clay Creek watershed based on the upcoming 2010 U.S. Census.	Population estimates have been updated. Subwatersheds with increasing population trends or growth areas have been identified.	Continue to update and map high-growth areas in the watershed. Target areas where there is low development for preservation. Preserve agricultural lands and forest/wetlands from development.
	Land Cover (2008: Forests) ✗	2008 Forest: Reverse the decline in forest cover in the watershed through reforestation programs, particularly in headwaters, along riparian stream corridors, and contiguous to large wooded tracts. Remap land use coverage in the watershed after the release of the 2007 LIDAR data by the state of Delaware.	Using the land cover data, it is clear where the land conversion has occurred. Remapping the land cover is accomplished. Published the White Clay Creek Reforestation Plan for Pennsylvania (2009). Planted 34 acres of trees and buffers since 2010. Ordinance reviews show woodlands to be under-protected.	Use the Reforestation Plan to guide future protection of forests and buffers, and target future reforestation priorities. Work with municipalities to improve woodland protections.
	Land Preservation (2008: Open Space) ✓	Continue the geometric growth in protected lands by continuing to acquire public open space, parks, and private conservation easements.	29% (20,005 acres) of the watershed is protected open space. This represents a 12% increase in protected open space since 2005.	Continue working with Brandywine Conservancy and Natural Lands Trust to research and fund opportunities to protect agricultural and forested land, riparian corridors, and other open space.
	Riparian Buffers (2008 Only) ●	Install buffers on the 209.1 stream miles where there are opportunities to plant buffers.	In partnership with White Clay Wild and Scenic, the Brandywine Conservancy completed a riparian gap analysis in 2015 for the entire White Clay Creek watershed (PA/DE). The Brandywine Conservancy is currently consulting two watershed municipalities to improve their riparian buffer ordinances. Since 2008, 12,300 linear feet (2.33 miles) of stream miles gained buffers.	Use the gap analysis to help municipalities locate buffer projects to undertake and locate gaps and edges to be planted that would create more interior forest for outstanding resource values (ORVs) such as the Cerulean Warbler. Continue to work with all municipalities in the White Clay to adopt 100’ riparian buffer protections in their zoning and natural resource ordinances. Continue to work with willing landowners to install buffers on the remaining stream miles.

	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
Landscape (cont.)	**Natural Resources Ordinances (2008: Impervious Cover)** 	2008 Impervious Cover: Mitigate and minimize expected increases in impervious cover due to development by setting thresholds on pavement and roof areas and revising ordinances to set narrower road widths, allow porous paving, disconnect downspouts, and install sidewalks on one side of the street only.	Act 167, Pennsylvania Stormwater Ordinance, sets a threshold for impervious surface at 2000 sq. ft. Any increase over 2000 sq. ft. must be mitigated. Research conducted at the University of Delaware and Chester County Planning Commission inventoried existing ordinance status and regulations as they relate to water resource protection in the White Clay Creek watershed (2014).	Use the inventory to identify and conduct outreach to those townships in need of improving ordinances to better protect water resources. Conduct outreach to townships and land owners to minimize the effects of impervious surface cover with BMPs, removal of existing, non-use impervious cover, and improve natural resources protections in development and redevelopment ordinances. Continue to work with municipalities and private landowners to implement BMPs in an effort to reduce or remove impairments and protect quality waters.

	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
Hydrology	**Precipitation** 	Install a real-time precipitation gage at the USGS stream gage White Clay Creek near Newark.	In 2015, UD WRA hosted two meetings with the USGS and White Clay Creek watershed stakeholders to discuss the implementation of stream gages on the White Clay Creek.	Continue to work with USGS to install a precipitation gage on the White Clay Creek near Newark.
	Streamflow 	Mitigate increased high flows and decreased low flows though green technology storm water best management practices, encourage recharge of runoff, and minimize impervious cover.	Since 2013, 12 BMPs have been installed in the watershed to help increase infiltration and reduce streamflow impacts.	Continue implementing BMPs to capture, infiltrate, and treat stormwater. Continue to support watershed municipalities as they implement their TMDL plans.
	Groundwater (2008 only) ND	Reduce development impacts on groundwater withdrawals and reduce base flows by including the White Clay Creek watershed in the Delaware River Basin Commission's (DRBC) Southeastern Pennsylvania Groundwater Protected Area.	Worked with DRBC and other watershed stakeholders to gain added protections for the proposed Artesian Broad Run Well Monitoring Plan.	Continue to work collaboratively with DRBC to set monitoring standards for future groundwater withdrawals in the White Clay.
	Flooding 	Rehabilitate and increase the capacity of the four bridges along the White Clay Creek prone to flood damage. Remove or flood proof the 106 structures in the 100-yr floodplain.	Reviewed projects that fall under Section 7 of the Wild and Scenic Act. UD WRA recorded historic and present day flooding events for analysis and future recommendations.	Continue to review projects that fall under Section 7 of the Wild and Scenic Act. Support efforts to manage stormwater during peak flows and protect natural floodways and floodplains.

	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
Water Quality	**DO** ✓	Continue water quality improvements by installing agriculture conservation projects, detecting and fixing leaking septic systems, and reducing nitrogen loads by targeting manure and fertilizer application on farms and in suburbia. Continue soil erosion and sediment control programs by the county conservation districts.	Based on the data collected, phosphorus, DO, TSS and bacteria are trending in a positive direction in Delaware, but still fail to consistently meet water quality standards with the exception of DO, which exceeds the standard. TSS and N continue to be water quality concerns in the White Clay Creek. Working with USGS, UD WRA has convened water purveyors and White Clay Creek watershed stakeholders to implement an Early Warning System for the White Clay Creek. This system will improve communications related to detecting and alerting water purveyors and stakeholders of potential contaminants and pollutant loads in the White Clay Creek.	Continue to look at land use to determine potential hot spots for nutrient and sediment loading and implement BMPs to control the sources of nutrients and sediment. Consider multiple and complementary tools to help improve water quality in addition to traditional BMPs such as freshwater mussel restoration.
	Phosphorus ●			
	Nitrogen ✗			
	Total Suspended Sediment ✗			
	Bacteria DE ● PA ✗		Initiated bacteria sampling program with Pennsylvania DEP in 2012–2014 during the recreational season (June–August) assessing both fecal coliform and *E. coli*. Continued to sample independently for *E. coli* at 14 sites in the Pennsylvania portion of White Clay in 2015.	Increase funding sources to strengthen the bacteria collection process and sampling analysis, including a microbial source tracking component. Conduct land use analysis for each sampling point and use it to conduct microbial source tracking in areas of highest concentrations to target priority areas for BMP implementation.

Habitat	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
	Macroinvertebrates 	Continue annual sampling by the Stroud Water Research Center to establish trends.	In the 2008 White Clay Creek State of the Watershed Report, the Stroud Water Research Center's stream watch data (2003–2005) provided a useful tool to assess the White Clay Creek environmental conditions based on 16 stream locations in the White Clay Creek watershed. Between 2007 and 2015, two sites in Pennsylvania were monitored and found to be slightly impacted based on HBI score.	Due to a lack of funding, this sampling is no longer being conducted. Work with Stroud to restore program and collect more recent macroinvertebrate data at the 16 original locations. Continue monitoring the existing USGS data for changes.
	Freshwater Mussels ND	N/A	Funded research conducted by the Partnership for the Delaware Estuary to look at the feasibility of restoring freshwater mussels to the White Clay Creek.	Continue to fund freshwater mussel research and outreach in the watershed.
	Fish Passage (Dams) 	Continue assessment of fish passage feasibility to remove dams or install fish ladders and rock ramps to restore migration of fish in the White Clay Creek such as shad and herring.	Dam No. 1 removed. Seeking grant funding opportunities for the dam removal design and implementation for Dams 2 and 3.	Continue to seek funding sources for dam removal analysis and implementation.
	Impaired Streams 	Remap the impaired streams in the White Clay Creek watershed after the release of the Delaware and Pennsylvania Section 303 (d) and Section 305 (b) reports, which are prepared every two years in 2008 and 2010.	Pennsylvania and Delaware impaired stream assessments completed in 2014. Based on increased monitoring, 67 miles of bacteria impairments added in Pennsylvania. Some impairments removed in the Delaware portion of the White Clay Creek.	Increase funding for real-time and continuous sampling. Increase funding for water quality improvement projects in an effort to get impaired streams delisted.

	Indicator	2008 Recommendation	Accomplishments/Progress	2015 Recommendation
Habitat (cont.)	**Birds** ✓	Conduct annual abundance surveys on the two properties in Franklin Township to establish trends in bird populations.	Completed survey and research work for Pennsylvania Audubon's Important Bird Area (IBA) certification for a portion of the watershed (2009). The Delaware Nature Society conducted surveys in the Middle Run Natural Area.	Coordinate with the Delaware Nature Society, Brandywine Conservancy, Natural Lands Trust, and Audubon to collect data on abundance and breeding surveys. Consider funding new bird abundance surveys as the need arises.
	Fish ND	Conduct fishery abundance surveys annually along the White Clay Creek above Newark (freshwater) and the White Clay Creek at Stanton (tidal) to establish trends in fish populations.	As part of the Dam No. 1 removal process, UD WRA coordinated with DNREC to conduct two anadromous fish sampling surveys in 2010 above and below Dam No. 1.	Fund fish abundance surveys as the need arises. Incorporate abundance surveys into the dam removal process when feasible.
	Trout Streams (2008 only) ND	Tabulate the annual totals in trout stamps issued in the White Clay Creek watershed as an assessment of trout fishing popularity.	Using DNREC data tabulate annual trout stamps sold (resident and non-resident).	Using DNREC data, annual trout stamps sold has been tabulated yet further refinement based on the location is necessary to make a correlation to the White Clay Creek streams.
	Fish Consumption Advisories ●	Annually remap the stream miles under Delaware and Pennsylvania fish consumption advisories in the White Clay Creek watershed.	No change.	Continue monitoring for any changes in the advisories for the White Clay Creek streams.

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U.S. Geological Survey (www.usgs.gov)

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The University of Delaware's Water Resources Agency, a unit of the Institute for Public Administration, provides technical assistance for water resources and watershed policy to governments in Delaware and the Delaware Valley through the University's public service, education, and research roles. The program is funded by the state of Delaware, New Castle County, the City of Newark, and the City of Wilmington as well as from grants from public and private sources. The Water Resources Agency's office is located on the University's Newark campus in the Delaware Geological Survey Annex off Academy Street.

Funding for the printing of this report was provided by the National Park Service.