White Clay Creek State of the Watershed Report

"A Report Card on the Health of the White Clay Creek Wild and Scenic River Watershed in Delaware and Pennsylvania"

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Prepared for

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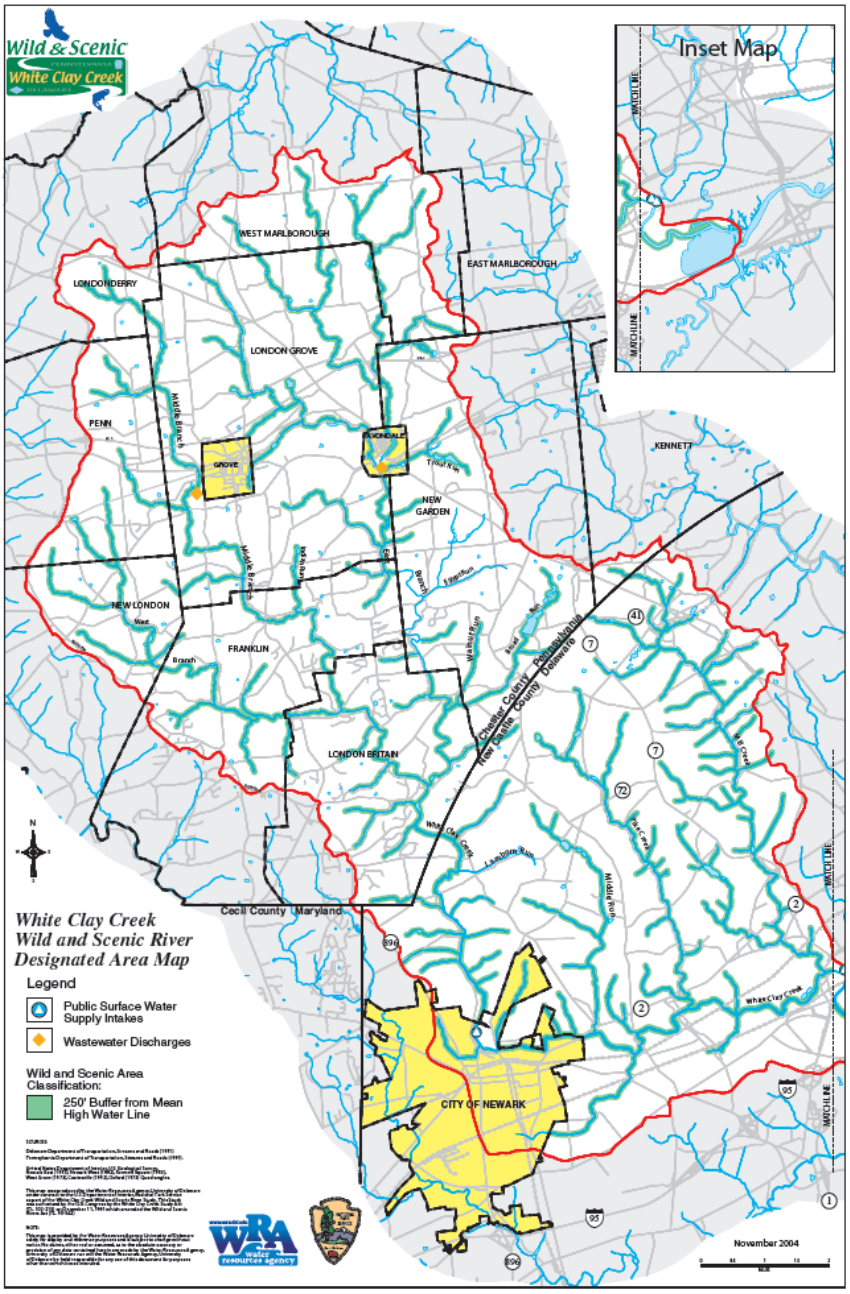
Wild & Scenic PENNSYLVANIA White Clay Creek DELAWARE

NATIONAL PARK SERVICE



The White Clay Creek National Wild and Scenic River program is administered by the bi-state Watershed Management Committee that includes residents, interest groups, and state and local governments. The National Park Service provides funds and staff assistance to further the implementation of the Management Plan. The committee meets on a regular basis and works to:

- Improve and conserve water quality and water quantity.
- Conserve open space, woodlands, wetlands, and geologic features.
- Protect native plant and animal species.
- Preserve cultural, historical, and archaeological sites.
- Enhance outdoor recreation opportunities.
- Encourage environmental education and watershed awareness.

For more information visit **www.whiteclay.org**.

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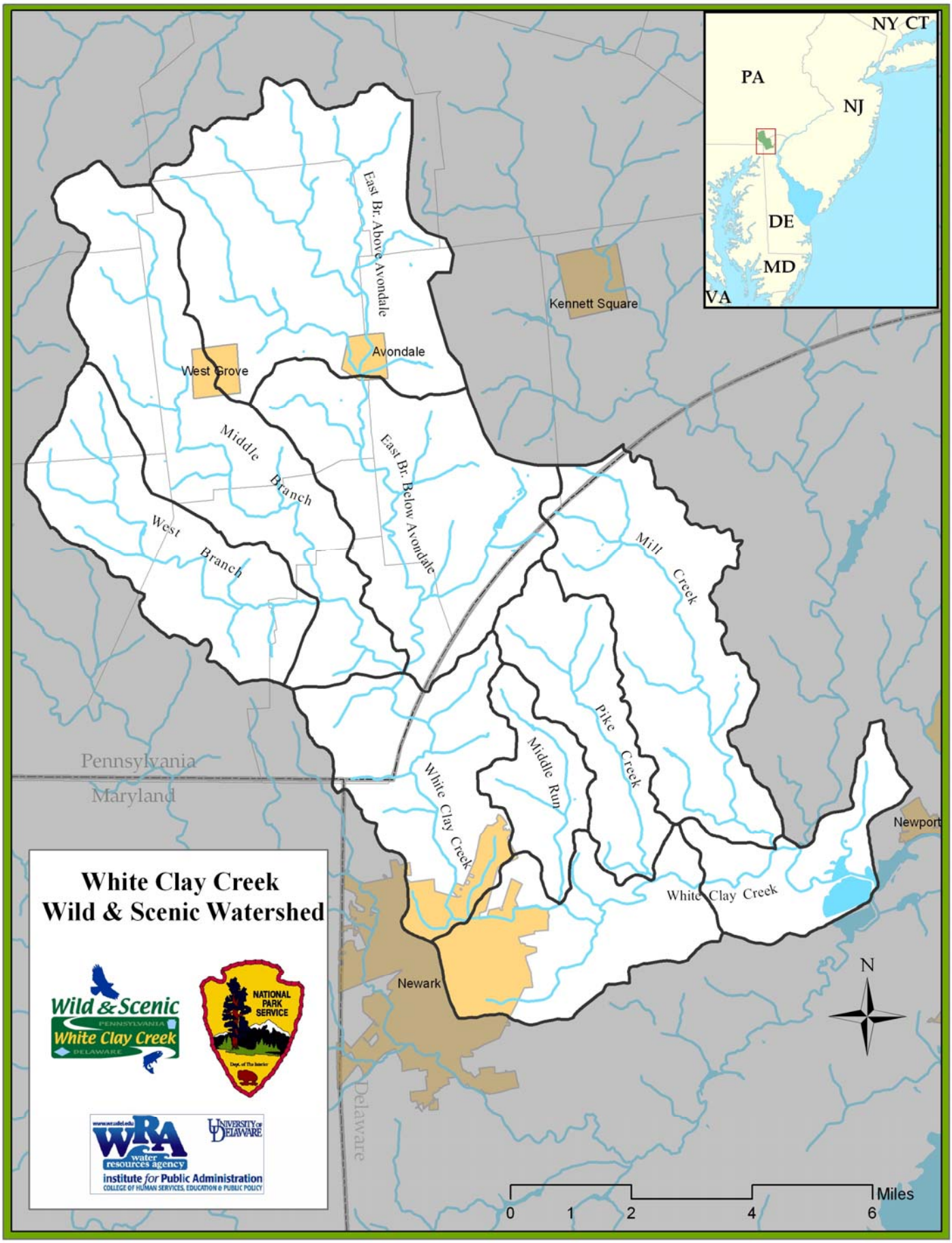
Cover: Nicole Minni, UD's IPA-WRA. Cover Photos: Jim White, Delaware Nature Society.

Figure 1. The White Clay Creek Wild and Scenic watershed.



THE WHITE CLAY CREEK WATERSHED

The White Clay Creek (Figure 1) drains 107 mi² and is one of the four major watersheds in the 565 mi² Christina River Basin. The Christina River Basin is part of the larger 13,000 mi² Delaware River Basin (Figure 2). In 2000, the President signed a law adding 190 miles of the White Clay Creek and its tributaries to the National Wild and Scenic Rivers 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.

Approximately 55% of the White Clay Creek watershed lies in Pennsylvania, 45% lies in Delaware, and less than 1% lies in Maryland. The northern portion of the watershed in Chester County, Pennsylvania, includes the East, Middle, and West Branches of the White Clay Creek. The White Clay Creek flows southeast into New Castle County, Delaware, and is joined by Middle Run and Pike and Mill Creeks before emptying into the Christina River. Towns within the White Clay Creek watershed include Newark, Delaware, and Avondale and West Grove, Pennsylvania. Table 1 summarizes the drainage areas of the seven streams that make up the White Clay Creek watershed.

Figure 2. The White Clay Creek as part of the Delaware River Basin and the Christina River Basin.

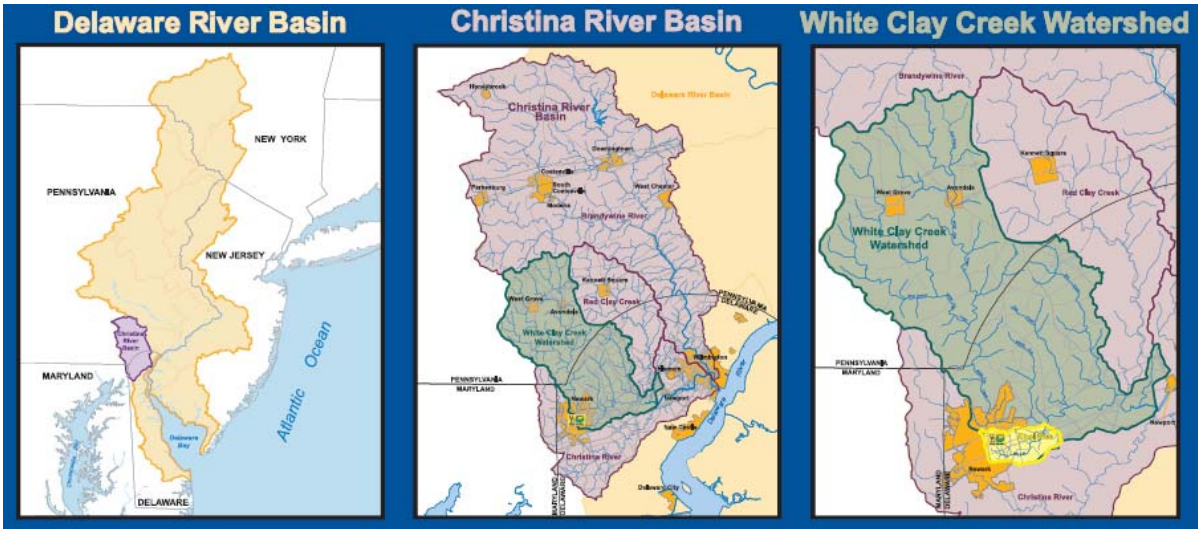


Table 1. White Clay Creek watershed area.

Stream	Drainage Area (mi²)
East Branch White Clay Creek	33
Middle Branch White Clay Creek	16
West Branch White Clay Creek	10
Main Stem White Clay Creek	25
Middle Run	4
Pike Creek	7
Mill Creek	13
Total Area	**108**

The White Clay Creek watershed includes many unique and outstanding resources. The unique qualities and assets of this watershed are described in more detail below.

Botanical Resources

The White Clay Creek watershed contains a rich assortment of flora. Botanical surveys have found that there are over 500 plant species native to the watershed and more than 500 wild flowers, including nine native orchids. Trees also contribute significantly to the area's character as tall tulip trees, stark sycamores, massive beeches, and oaks define the landscape. A survey of the White Clay Creek State Park and Preserve found 24 Delaware "species of special concern" and numerous plant species from Pennsylvania's endangered plants list.

Designated Uses

The tributaries of the White Clay Creek have several state designations that garner protection and regional significance. The Pennsylvania Department of Environmental Protection (PADEP) has identified the East Fork of the White Clay Creek's East Branch, from the northern boundary of the Avondale Borough to the headwaters, as Exceptional Value Waters (EV), while the remainder of the East Branch is designated as Cold Water Fisheries (CWF) for the propagation of trout. The PADEP has provided additional protection to the Middle and West Branches through its Trout Stocking designations. The Delaware Department of Natural Resources and Environmental Control (DNREC) classifies the White Clay Creek from the Delaware state line to the dam at the former Curtis Paper Mill in Newark as Exceptional Recreational or Ecological Significance Waters (ERES).

Educational and Research Opportunities

The White Clay Creek watershed and the resources contained within it play an important role in research and education. The Stroud Water Research Center (SWRC)—an internationally acclaimed nonprofit organization for its pioneering work on streams and rivers—hosts a 1,800-acre experimental watershed located on the East Fork of the White Clay Creek. The SWRC uses this experimental watershed for educational outreach and research and applies many of the principles learned in the White Clay Creek watershed to ecosystems throughout the world. The University of Delaware is also located in the White Clay Creek watershed. Various departments throughout the University, such as the Water Resources Agency and the Department of Entomology and Wildlife Ecology, conduct research in and incorporate the White Clay Creek, the watershed, and its natural resources into course curricula.

Photo Credit: Kathy Atkinson

Fish and Wildlife Resources

The watershed is home to a wide variety of fish and wildlife. The waters of the White Clay Creek support over 24 species of fish. The creek is stocked annually by both Delaware and Pennsylvania and is considered Delaware's premier trout-fishing stream. Surveys estimate that 93 species of birds nest in the White Clay Creek watershed. Migrants include the Hooded and Cerulean Warblers, the latter a rare northern species that breeds in Delaware only in the Piedmont Province of the watershed. Thirty-three species of small mammals have been documented in the watershed. Beavers and an occasional river otter are seen swimming in the creek. On summer evenings, bats—red, big brown, little brown, hoary, and eastern pipistrel—flutter skyward from daytime perches. Twenty-seven species of amphibians and reptiles live in the watershed, among them the rare bog (muhlenbergs) turtle, which was recently added to the list of threatened species by the U.S. Fish and Wildlife Service. The rare long-tailed salamander and the four-toed salamander have also been found breeding in the springs, streams, and marshes of the White Clay Creek watershed.

Geology
The White Clay Creek watershed is perched along the geologically unique Fall Line. The Fall Line runs through a line stretched between Newark and Wilmington and separates the hilly, rocky Piedmont from the flat, sandy Coastal Plain Provinces. This transition zone results in a wider array of flora and fauna and enhances the opportunities for nearby researchers.

Historical Significance
The White Clay Creek watershed is historically significant. The region was originally settled by the Native Americans, followed by the Dutch and Swedes in the early- to mid-1600s. Many noteworthy historical events followed, including: William Penn's acquisition of the land (including White Clay Creek) in the 18th century, the flourish of farms and small mills; the march of American and British armies through the watershed on their way to battle in 1777; the advent of railroad tracks throughout the region; and the opposition of a proposed dam on the White Clay Creek, which resulted in the creation of the White Clay Creek Watershed Association in 1965. Today, after the hard work of many citizens, the states' acquisition of land, and the donation of thousands of acres of land, the total area of Pennsylvania's White Clay Creek Preserve and Delaware's White Clay Creek State Park exceeds 5,000 acres and the watershed achieved the National Park Service's federal designation of Wild and Scenic.

Land Use
The Pennsylvania portion of the watershed is largely rural with a few small towns and villages, such as West Grove and Avondale, and some suburban clusters. The Delaware portion of the watershed 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.

Open Space and Recreation
About 17% of the watershed is protected open space, with two-thirds of that in Delaware. Open space is a major platform for recreation in the White Clay Creek watershed. The White Clay Creek State Park, managed by Delaware, and the White Clay Creek Preserve, managed by Pennsylvania, are maintained as natural areas accommodating passive recreation. Other parks in the watershed are designed for heavier uses including: sport fields, basketball courts, and picnic facilities. Additionally, the streams of the White Clay Creek are an extremely popular fishing destination in the tri-state region. More than 20,000 brown and rainbow trout are stocked in the Pennsylvania portion of the White Clay Creek, while over 18,000 trout are stocked in the Delaware portion.


Photo Credit: Chuck Barcsz

Water Supply
The surface water of the White Clay Creek and the aquifers in the watershed provide over 120,000 residents with drinking water. The Creek serves as a major drinking water source for much of northern Delaware, accounting for 33 million gallons per day (mgd) of the overall production of water supply from the watershed. Delaware and Pennsylvania residents in the White Clay Creek watershed also receive a significant amount of their water supply from groundwater resources in the watershed. The City of Newark's groundwater supplies provide up to 1.8 mgd from five wells in the watershed. The Artesian Water Company operates six wells that provide up to 1.9 mgd in the Cockeysville Marble Formation near Hockessin, Delaware. The Cockeysville Marble Formation is an exceptional aquifer, which is an important source of drinking water. It also supplies continuous and relatively high base flows to the stream.

ENVIRONMENTAL INDICATORS

The White Clay Creek watershed is rich in natural resources and history and provides numerous benefits to people. However, increasing suburbanization and legacy pollutants threaten to degrade the ecological landscape of the White Clay Creek. The University of Delaware's Institute for Public Administration-Water Resources Agency (IPA-WRA) has reviewed 21 environmental indicators to assess the state of the White Clay Creek watershed. These indicators are divided into four major categories: landscape, hydrology, water quality, and habitat (Table 2).

Based on a review of available scientific data, IPA-WRA assigned trends and grade ratings to assess the state of the watershed. A green triangle pointing upward (▲) represents an improving (positive) trend. A blue circle (●) represents a constant or unchanging trend. A red triangle pointing downward (▼) represents a degrading (unfavorable) trend. When sufficient data was not available to define a trend, an (ND) was assigned (Table 3). Grades were assigned according to a report card approach. Grades range from "A=excellent to F=very poor" (Table 4).

Table 2. Environmental indicators for the White Clay Creek watershed.

Landscape	1. Population	2. Forest	3. Open Space	4. Riparian Buffers	5. Impervious Cover
Hydrology	6. Precipitation	7. Stream Flow	8. Groundwater	9. Flooding	
Water Quality	10. Dissolved Oxygen	11. Phosphorus	12. Nitrogen	13. Sediment	14. Bacteria
Habitat	15. Macroinvertebrates	16. Impaired Streams	17. Birds	18. Fish	19. Trout Streams
	20. Fish Advisories	21. Fish Passage (Dams)			

Table 3. Trend criteria.

Symbol	Trend
▲	Improving
●	Constant
▼	Degrading
ND	Not Enough Data

Table 4. Grade criteria.

Grade	Rating
A	Excellent
B	Good
C	Fair
D	Poor
F	Very Poor

1. POPULATION

GRADE

C

Fair

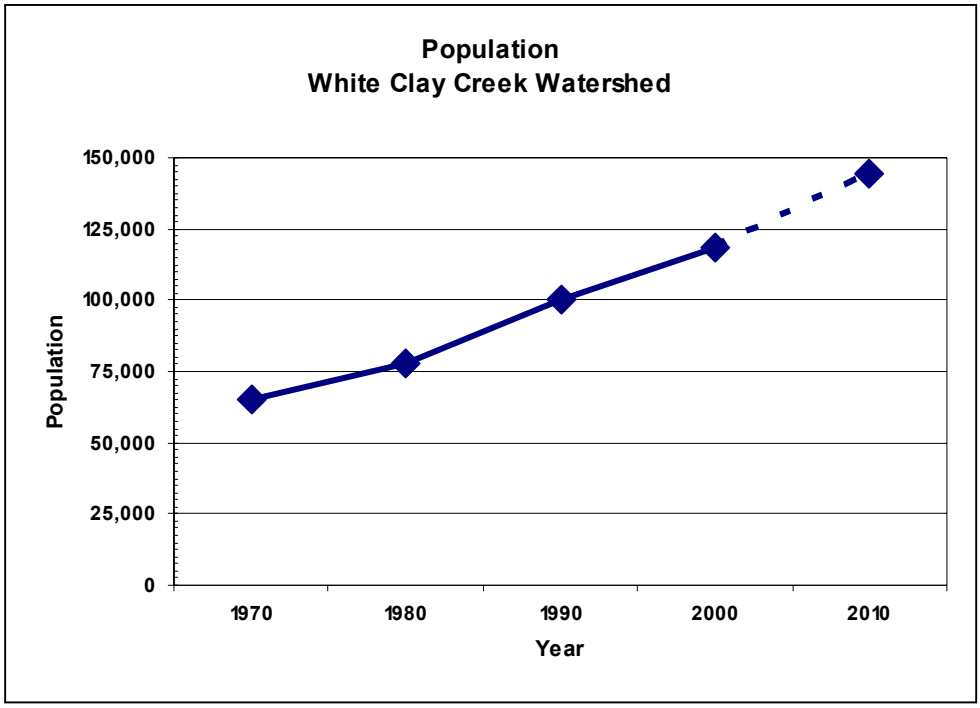
TREND

Population in the White Clay Creek watershed has doubled from over 60,000 in 1970 to nearly 120,000 in 2000. Table 5 presents the population in the White Clay Creek watershed from 1970 to 2000. In the 107 mi^2 watershed, the population density in 2000 was 1,100 people per mi^2, which according to the U.S. Census is classified as an urban area. By the next U.S. Census in 2010 the watershed may contain over 130,000 people if population growth continues at its current rate. Increasing population in the White Clay Creek watershed will lead to land use changes with potential negative impacts on water resources unless stormwater and environmental ordinances are implemented by local governments. Figure 3 depicts the increasing White Clay Creek population.

Table 5. Population in the White Clay Creek watershed (1970–2000). (source: Kim Cloud and U. S. Census Bureau)

Population	1970	1980	1990	2000
East Branch White Clay Creek	7,788	8,759	10,363	14,579
Middle Branch White Clay Creek	2,774	3,571	4,458	5,639
West Branch White Clay Creek	860	1460	2,300	3,285
Main Stem White Clay Creek	34,377	39,235	45,288	46,227
Middle Run	2,406	3,603	4,578	4,509
Pike Creek	5,040	6,546	10,744	16,804
Mill Creek	11,769	14,717	22,762	27,299
Total	**65,014**	**77,891**	**100,493**	**118,342**

Figure 3. Population trend in the White Clay Creek watershed (1970–2010).



GRADE

B

Good

TREND

2. FOREST

Land cover in the White Clay Creek watershed is a microcosm of the land cover found in the mid-Atlantic region and varies among three major land use categories: urban/suburban, agriculture, and forest/wetlands. Urban/suburban lands are predominant in the Wilmington to Newark corridor in Delaware and extend north through Hockessin, Delaware, into the Boroughs of Avondale and West Grove, Pennsylvania. About one-third of the watershed is cultivated for agriculture, and this land use type is predominant in the northern portion of the watershed in Pennsylvania. Large contiguous forests and open space are present in the White Clay Creek State Park and the White Clay Creek Preserve upstream from and north of Newark in Delaware and Pennsylvania.

Forest cover decreased from 33% of the watershed in 1990 to 30% by 2000 with a net loss of 3 mi² (Figures 4, 5, 6). Developed land increased from 31% to 38% of the watershed with a net gain of 8 mi². Agricultural land decreased from 36% to 32% in ten years or a loss of 5 mi². Figure 7 displays the most recent land use mapping for the White Clay Creek watershed depicting most of the forested land upstream from Newark in the upper White Clay Creek valley.

Figure 4. Changes in land use in the White Clay Creek watershed. (source: Kim Cloud, 2007)

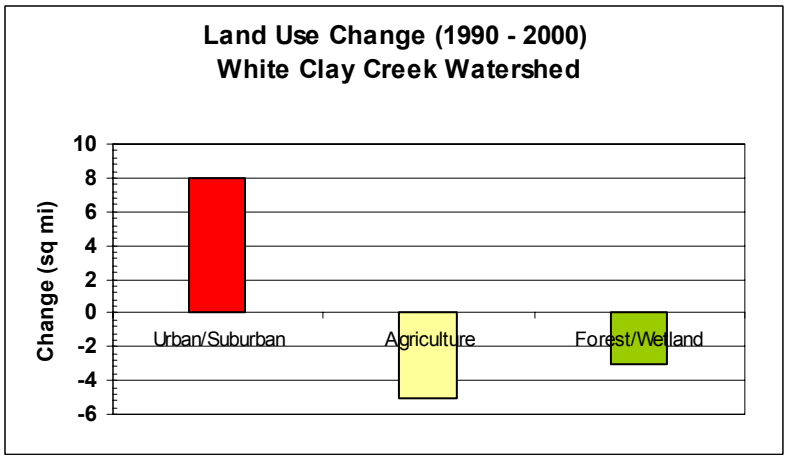


Figure 5. White Clay Creek land use (1990).

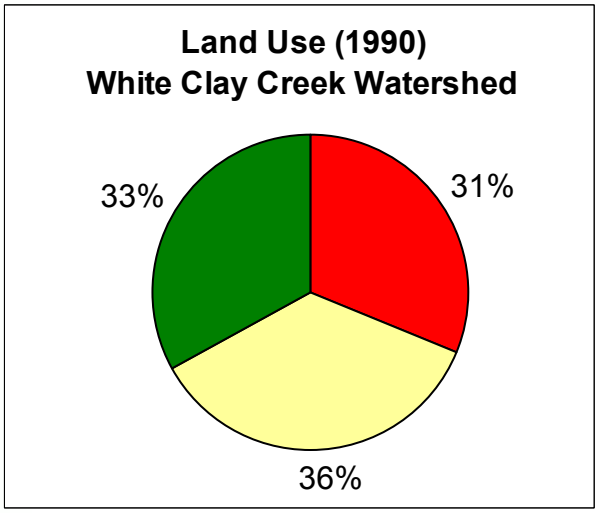


Figure 6. White Clay Creek land use (2000).

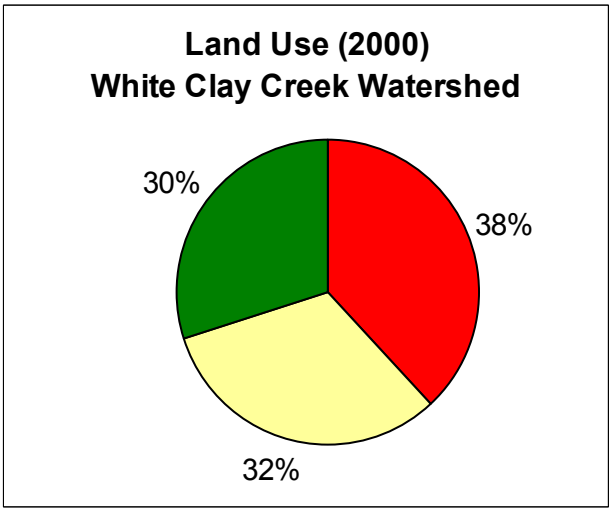
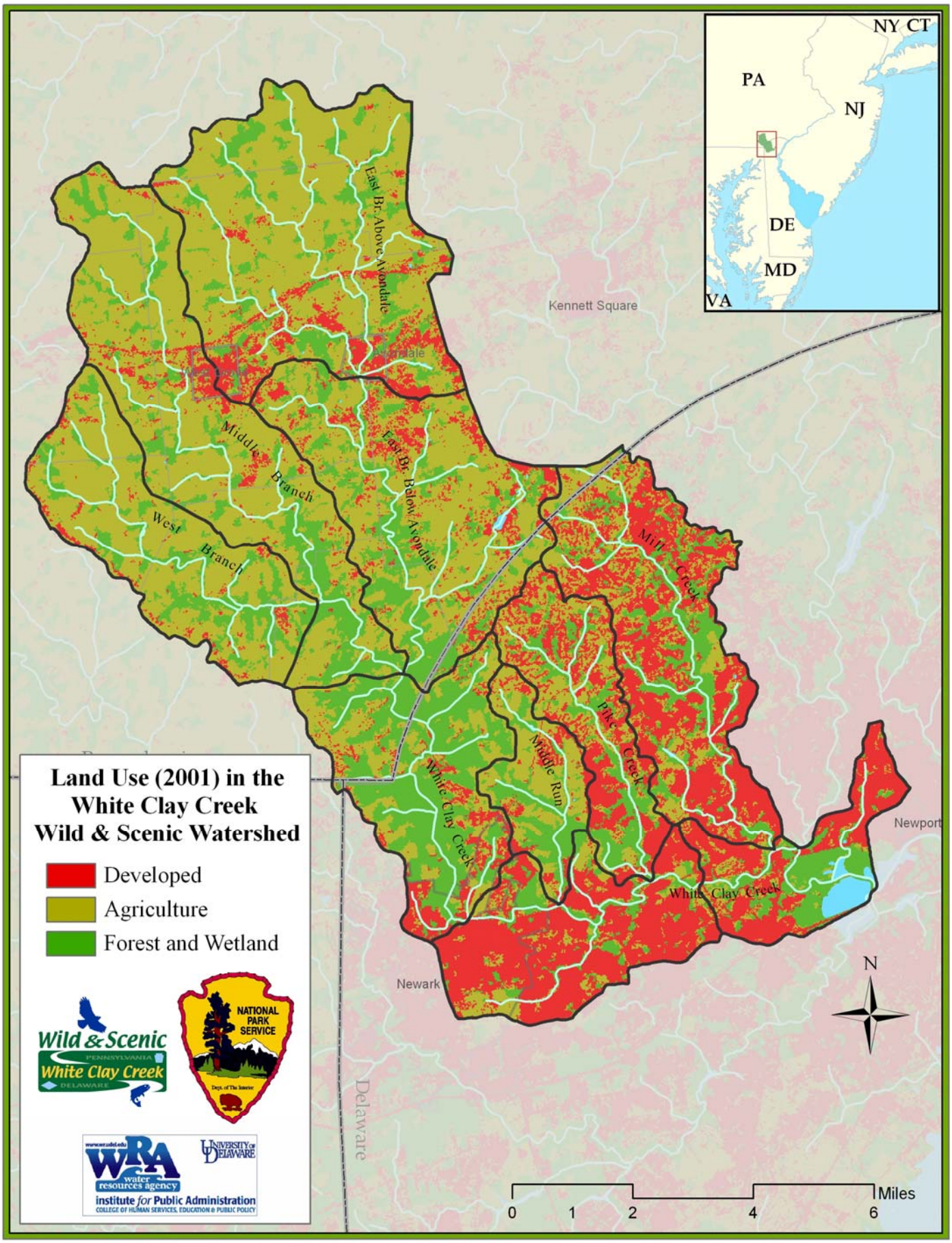


Figure 7. Land use in the White Clay Creek watershed, 2001.



3. OPEN SPACE

GRADE

A

Excellent

TREND

Open space, which is both a major recreational resource and ecologically beneficial, is an important land use in the White Clay Creek watershed. There are 11,610 acres of protected open space in the watershed (Figure 8), approximately 17% of the watershed. These include:

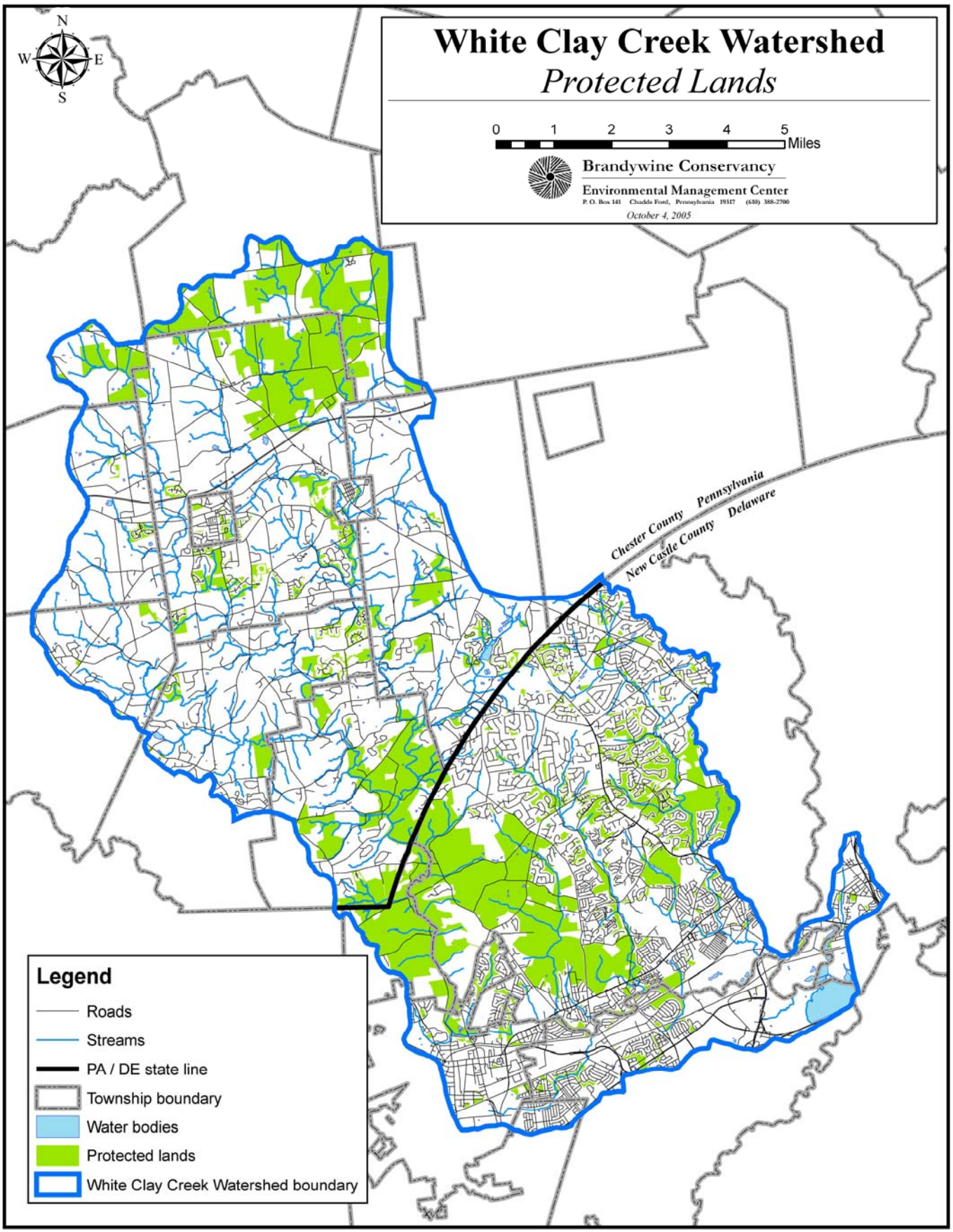
- Conservation easements 2,850 acres
- Agricultural easements 1,224 acres (Pa. only)
- County lands 2,178 acres (Del. only)
- Municipal lands 526 acres
- State lands 4,496 acres
- Homeowners' Associations 337 acres

The bi-state White Clay Creek Park and Preserve, managed by both Delaware and Pennsylvania, is maintained as a natural area accommodating passive recreation. Many of these open space areas are also very important for active recreation use. The creek is the most heavily stocked trout stream and thus the most popular fly-fishing stream in Delaware. Other recreational opportunities in the watershed include hiking, jogging, bird watching, picnicking, horseback riding, biking, cross country skiing, skating, sledding, swimming, and limited deer hunting.

Open space in the White Clay Creek watershed has increased through the following acquisitions:

1968	The state of Delaware begins land acquisition efforts with the purchase of 24 acres, creating Walter S. Carpenter State Park, later renamed White Clay Creek State Park.
1968–1982	The State of Delaware purchases 13 more parcels to bring the park up to 560 acres.
1984	The DuPont Company donates almost 1,700 acres to the states of Pennsylvania and Delaware for inclusion in the White Clay Creek Bi-state Preserve to ensure its protection.
1980s	New Castle County acquires Middle Run Valley Natural Area (890 acres).
1998	The Delaware Division of Parks and Recreation acquires Judge Morris Estate (450 acres) from the University of Delaware and it is made part of the White Clay Creek State Park.
2000	The City of Newark acquires Koelig Farm for use as a park (109 acres).
2005	The latest in a series of land acquisitions raises the total area of Pennsylvania's White Clay Creek Preserve and Delaware's White Clay Creek State Park to 5,000 acres.
2007	Franklin Township acquires the Howard Property (29 acres).

Figure 8. Open space in the White Clay Creek watershed.
(source: Brandywine Conservancy)



GRADE

B

Good

TREND

ND

4. RIPARIAN BUFFERS

Riparian buffers are an essential management practice in the White Clay Creek watershed and will lead to a dramatic improvement in water quality while improving habitat and stabilizing stream banks. The Natural Resources Conservation Service (NRCS) funded the Stroud Water Research Riparian Forest Buffer Program to conduct an analysis of the state of the buffers in the White Clay Creek watershed and to identify opportunities for additional buffers in the watershed. According to this analysis, there are 346 stream miles that are fully buffered in the White Clay Creek watershed while there are 282.9 stream miles that are partially buffered. The White Clay Creek watershed has 209.1 stream miles available to install buffers. This data is summarized for the entire White Clay Creek watershed in Table 6 and mapped for the Delaware and Pennsylvania portions of the watershed in Figures 9 and 10.

Figure 9. Riparian buffers in the Delaware portion of the White Clay Creek watershed.
(source: Brandywine Conservancy)

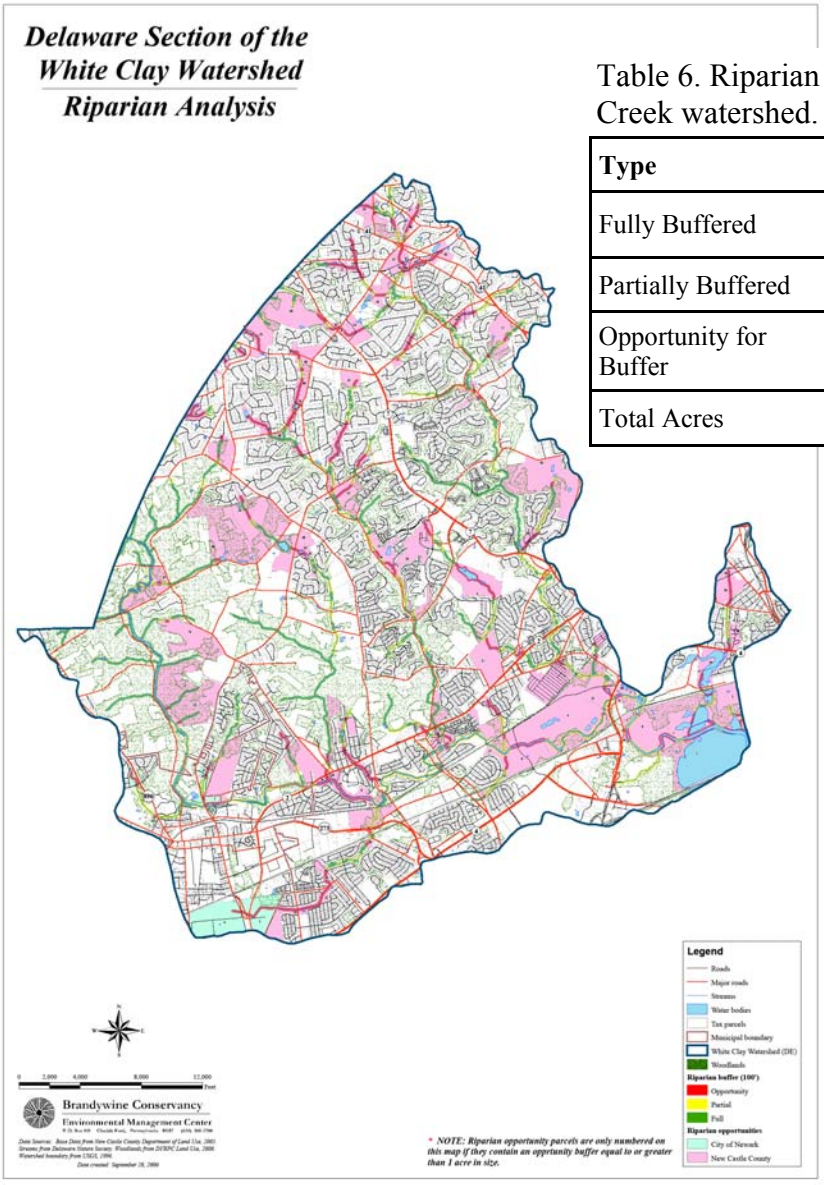
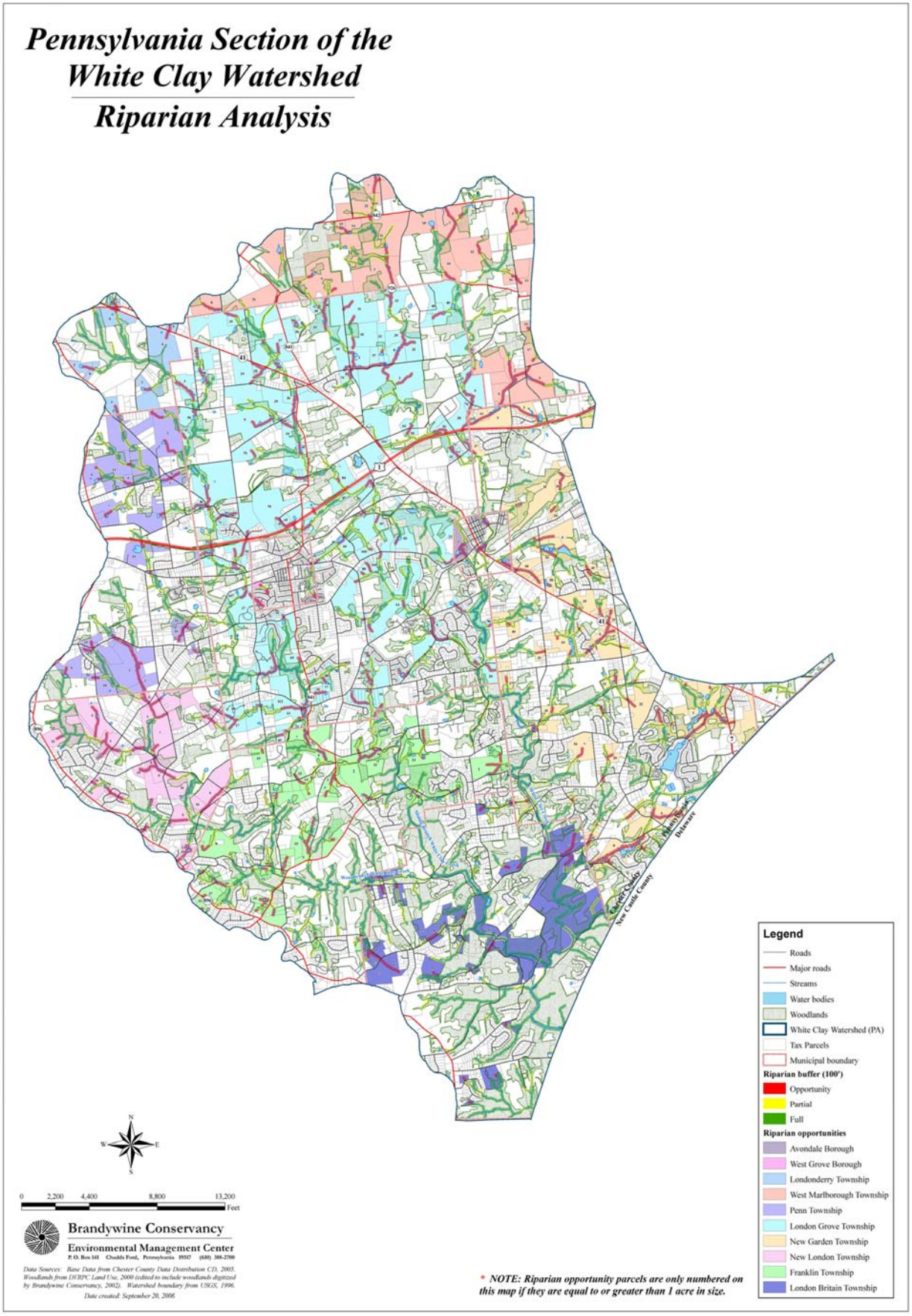


Table 6. Riparian buffers in the White Clay Creek watershed.

Type	Acreage	Stream Miles
Fully Buffered	2,076.0	346.0
Partially Buffered	1,697.1	282.9
Opportunity for Buffer	1,254.7	209.1
Total Acres	5,027.8	838.0

Figure 10. Riparian buffer analysis in the Pennsylvania portion of the White Clay Creek watershed.
(source: Brandywine Conservancy)



5. IMPERVIOUS COVER

GRADE

above Newark

B

Good

below Newark

D

Poor

TREND

Impervious surfaces—driveways, roads, parking lots, rooftops, and sidewalks—in the White Clay Creek watershed increased from 15% in 1990 to 20% by 2005, an increase of approximately 1% every two years (Cloud, 2007). Table 7 shows the increasing impervious cover in the White Clay Creek watershed from 1990 to 2005. Based on research in Delaware and elsewhere, streams can show signs of degradation and can be considered stressed in watersheds where the impervious coverage exceeds 10% to 15% of the watershed area. If the amount of impervious cover in the White Clay Creek watershed continues to increase at the current rate, watershed imperviousness is expected to reach over 22% by 2010.

Table 7 shows the proportion of impervious cover in the White Clay Creek watershed from 1990 to 2005 by subwatershed. Subwatersheds in the White Clay Creek watershed with impervious cover less than 15% and therefore likely to be in reasonably good health include: East Branch, Middle Branch, and West Branch of the White Clay Creek, the White Clay Creek above Newark, and Middle Run. Pike and Mill Creek subwatersheds are considered degraded with levels of impervious cover at 26% and 32% respectively. The White Clay Creek below Newark subwatershed is considered highly degraded with an impervious cover value of 50%. Figure 12 maps the proportion of impervious cover by subwatershed in the White Clay Creek watershed.

Research conducted by the University of Delaware's IPA-WRA in the White Clay Creek watershed has found that increased impervious cover correlates with decreased stream base flow (Figure 11).

Figure 11. Stream base flow vs. impervious cover in White Clay Creek watershed.

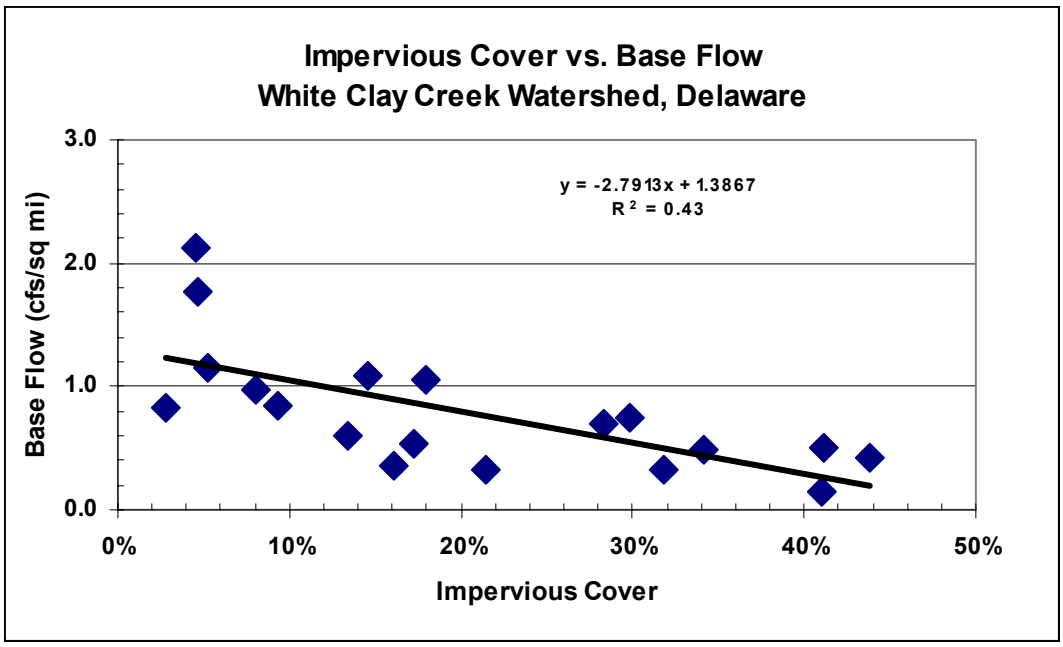
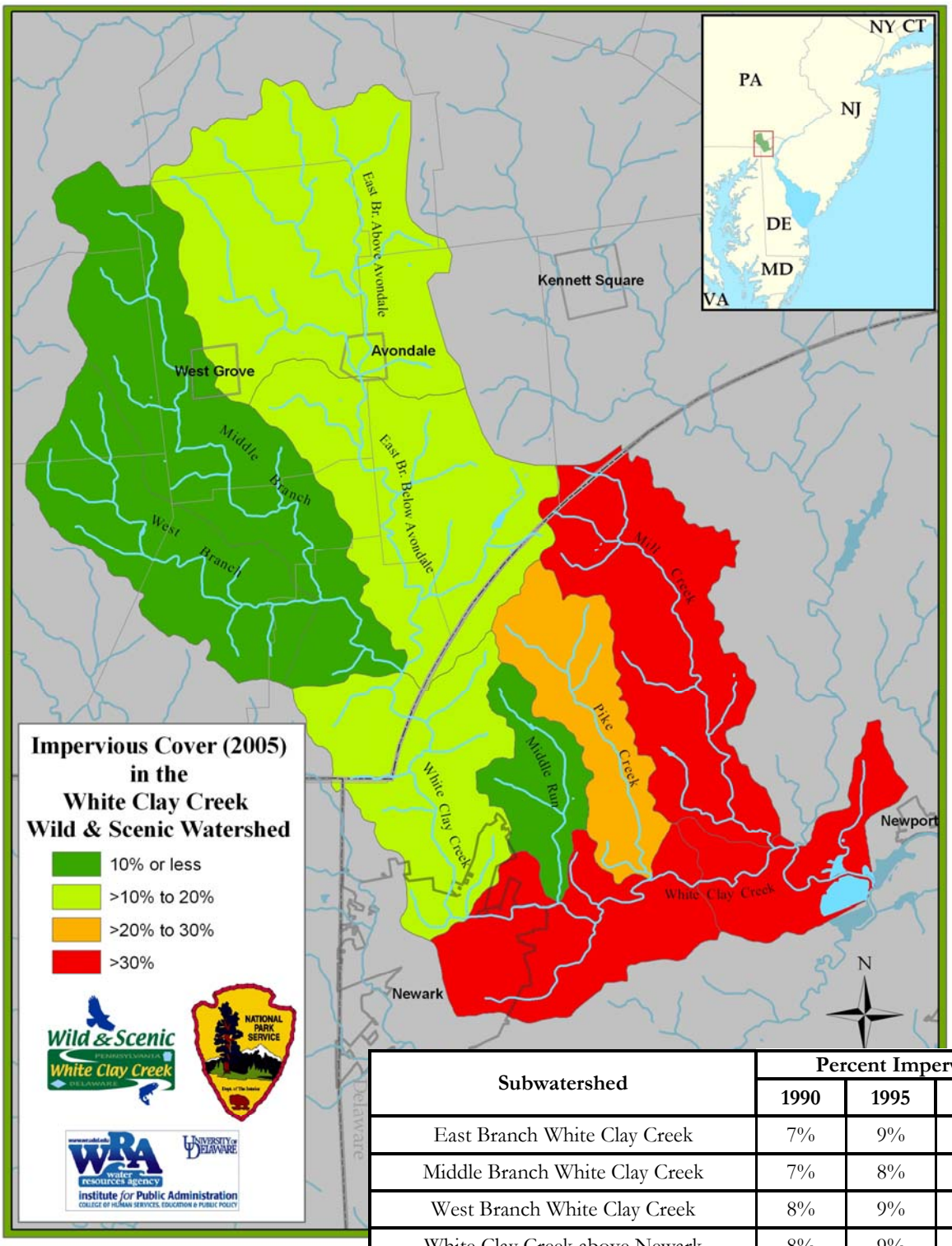


Figure 12. Impervious cover by subwatershed in the White Clay Creek watershed. (source: Kim Cloud, 2007)



Subwatershed	Percent Impervious Cover			
	1990	1995	2000	2005
East Branch White Clay Creek	7%	9%	11%	13%
Middle Branch White Clay Creek	7%	8%	9%	10%
West Branch White Clay Creek	8%	9%	9%	10%
White Clay Creek above Newark	8%	9%	10%	11%
White Clay Creek below Newark	42%	43%	47%	50%
Middle Run	6%	8%	9%	10%
Pike Creek	22%	24%	25%	26%
Mill Creek	27%	28%	30%	32%
Total	**15%**	**16%**	**18%**	**20%**

Table 7. Impervious cover in the White Clay Creek watershed.

GRADE

B

Good

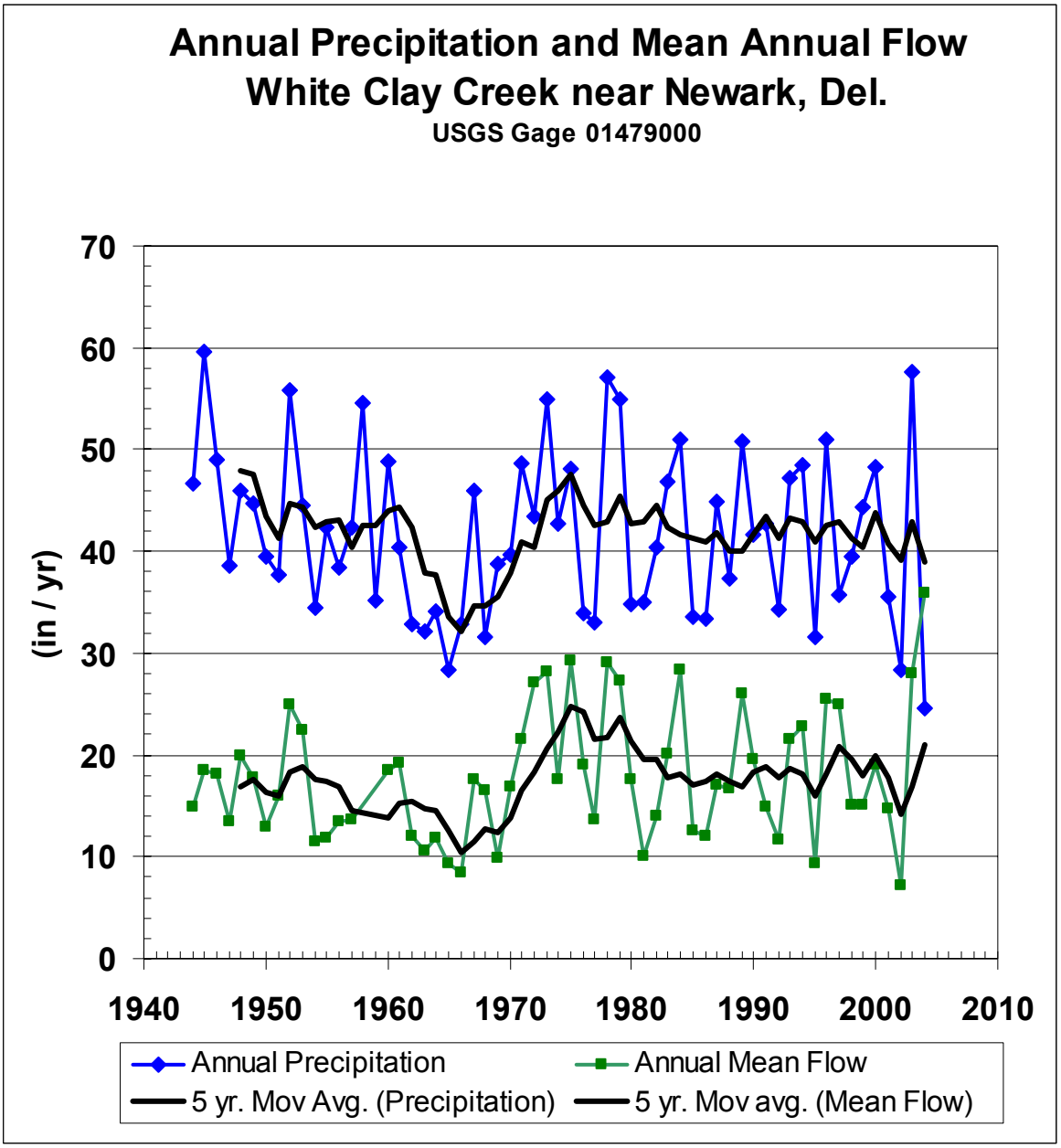
TREND

6. PRECIPITATION

Annual precipitation measured at the University of Delaware in Newark averages 41.5 inches per year, ranging from 28.3 inches during the drought of 2002 to 59.5 inches during 1945 (Figure 13). Precipitation as measured by a five-year moving average decreased during the early 1960s drought, increased during the wet 1970s, and has generally remained constant and just above 40 inches over the last two decades.

Mean annual flow in the White Clay Creek near Newark fluctuates based on precipitation and averages approximately 150 cubic feet per second (cfs) (20 inches per year) or half the average annual precipitation. This relationship indicates relatively plentiful groundwater recharge to stream base flow. Watersheds that are more urbanized than the White Clay Creek watershed have large amounts of impervious cover that reduce recharge resulting in mean annual flows that range from 10% to 25% of annual precipitation.

Figure 13. Annual precipitation and mean annual flow, along the White Clay Creek near Newark, 1944 to 2004.



7. STREAM FLOW

GRADE

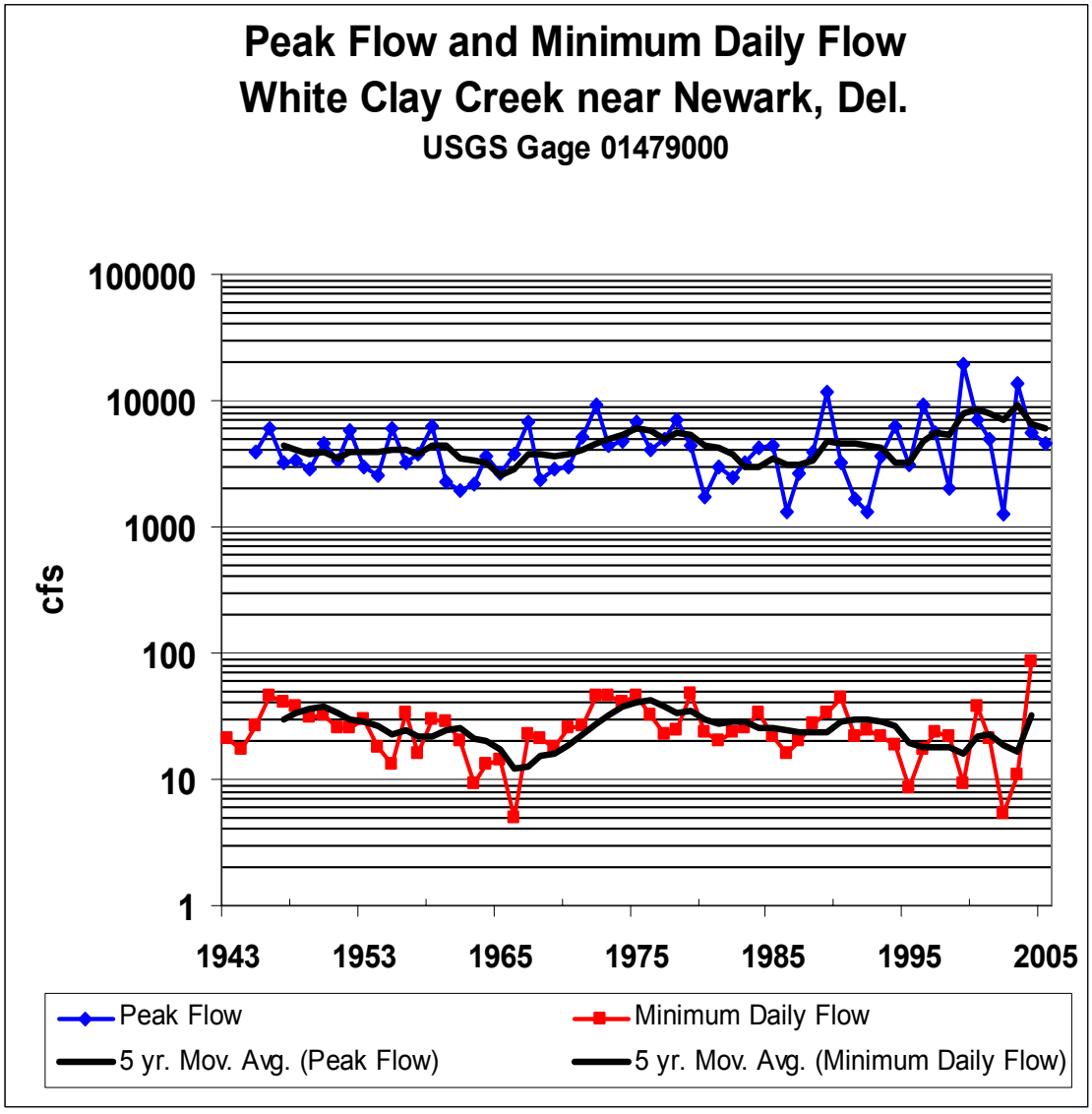
C

Fair

Hydrologic water budget theory holds that increased impervious cover may result in increased runoff and decreased recharge leading to larger and more frequent floods and lower base flows during drought. Peak stream flows along the White Clay Creek as measured by a five-year moving average have increased from 3,000 to 4,000 cfs prior to the 1970s to nearly 10,000 cfs since 2000 (Figure 14). Minimum low flows as measured by a five-year moving average have steadily decreased from 25 to 40 cfs between 1975 and 1995 to around 20 cfs between 1995 and 2005.

Stream flow data suggests that the White Clay Creek has experienced more frequent and intense floods and more severe droughts over the last couple of decades.

TREND



Warming of the atmosphere could result in more evaporation leading to increased flooding and drought flows in the water budget of the White Clay Creek watershed.

Figure 14. Peak flows and minimum daily flows along the White Clay Creek near Newark, 1943 to 2005.

8. GROUNDWATER

GRADE

B

Good

TREND

ND

Substantial groundwater resources exist within the White Clay Creek watershed providing a significant amount of potential drinking water for residents. The USGS estimates about 31.1 mgd of groundwater can be withdrawn from the watershed without affecting the once in every 25-year base flow in the White Clay Creek and its tributaries. During 1997 to 2000, groundwater withdrawals for water supply wells averaged 2.2 mgd, leaving 28.9 mgd (93% of the available resource) to be withdrawn without adversely affecting stream flows (Table 8). However, the increase in impervious surfaces that would likely accompany increases in withdrawals could have a significant negative impact on stream flows.

Table 8. Groundwater availability in the White Clay Creek watershed.

Groundwater	**mgd**
Availability	31.1
Withdrawals	2.2
Amount Remaining	28.9

Table 9 summarizes data collected in 1998 on the groundwater withdrawals throughout the White Clay Creek watershed, including the total volume of groundwater withdrawn for public and individual water systems in each subwatershed. Withdrawals range from 0.01 mgd in the Middle Run subwatershed to 0.49 mgd in the Middle Branch White Clay Creek subwatershed. The total groundwater withdrawn in 1998 was 1.67 mgd.

Table 9. Groundwater withdrawals in the White Clay Creek in 1998. (source: Chester County Water Resources Authority, 2002)

White Clay Creek Subwatershed	**Groundwater Withdrawal (mgy)**	**Groundwater Withdrawal (mgd)**
West Branch	69	0.19
Middle Branch	177	0.49
Upper East Branch	149	0.41
Lower East Branch	163	0.45
Main Stem above Newark	21	0.01
Main Stem below Newark	13	0.04
Tidal White Clay Creek	3	0.01
Middle Run	2	0.01
Pike Creek	6	0.02
Mill Creek	14	0.04
Total	**617**	**1.67**

9. FLOODING

GRADE

D

Poor

TREND

In 2007, Duffield Associates developed a flow model for the White Clay Creek between the Christina River and the Kirkwood Highway Bridge and included:

- Larger flow rates reflect the trend of larger and more intense rainfall events in recent years, rather than conditions linked to development in the watershed.
- Approximately 106 principal structures (homes, apartments, commercial and industrial buildings) are in the 100-year floodplain in the study area.
- The Amtrak Railroad, CSX Railroad, Harmony Road, and Red Mill Road Bridges contribute to flood damages due to hydraulic inadequacies.
- Sediment and debris accumulations contribute to the hydraulic inadequacy of these bridges.

Since 1995, there have been several major flooding events including:

- Tropical Storm Floyd in September 1999, the flood of record along White Clay Creek, with flow rates that approximated the current FEMA 500-year discharge.
- Tropical Storm Henri on September 15, 2003, the third largest recorded flow rate along White Clay Creek (approximately equivalent the 50-year discharge).
- Tropical Storm Jeanne on September 18, 2004, which produced flows that approximated the 100-year discharge along White Clay Creek, based on a comparison of high water marks to predicted water surface elevations during flooding.

Historic rainfalls in northern Delaware that caused flooding in the White Clay Creek watershed included:

- May 1, 1947 — 4.2 in over 24 hours (a record at that time)
- July 1952 — 6.2 in over 24 hours (new record)
- September 12-13, 1960 — 5.6 in over 24 hours (Hurricane Donna)

Table 10 lists the flood frequency flows along the White Clay Creek at two locations, the White Clay Creek at Route 7 and the White Clay Creek below the Red Clay Creek.

Table 10. Flood frequency flows along the White Clay Creek.

Locations	**White Clay Creek at Route 7**	**White Clay Creek below Red Clay Creek**
Return Period (yrs)	Peak Flow Rate (cfs)	Peak Flow Rate (cfs)
10 years	7,600	10,200
50 years	13,000	18,000
100 years	15,600	21,100
500 years	23,100	31,500

GRADE

B

Good

10. DISSOLVED OXYGEN

According to data collected in the White Clay Creek watershed at the Chambers Rock Road and Stanton (Old Route 7 Bridge) stream monitoring stations, dissolved oxygen (DO) levels in the White Clay Creek decreased from 1970 to 1990 and improved since the early 1990s. Median DO levels for this time period are good at 10 parts per million (ppm), more than double Delaware's minimum water quality standard of 4 ppm (Figure 15).

TREND

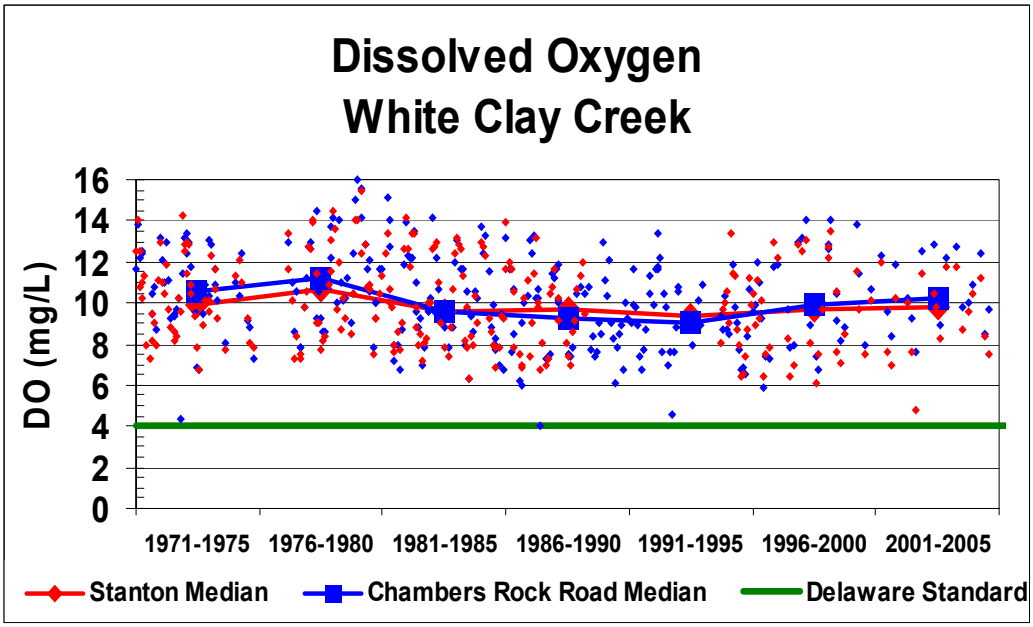
Since 1970

▼

Since 1990

▲

Figure 15. Dissolved oxygen along the White Clay Creek in Delaware 1971 to 2005. (source: DNREC)



11. PHOSPHORUS

GRADE

C

Fair

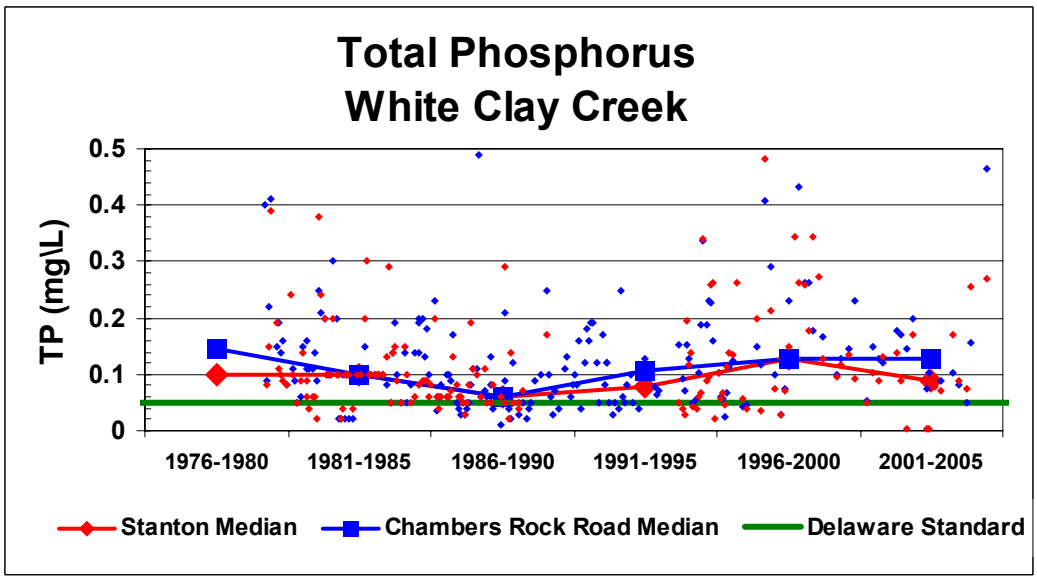
TREND

Since 1970

Since 1990

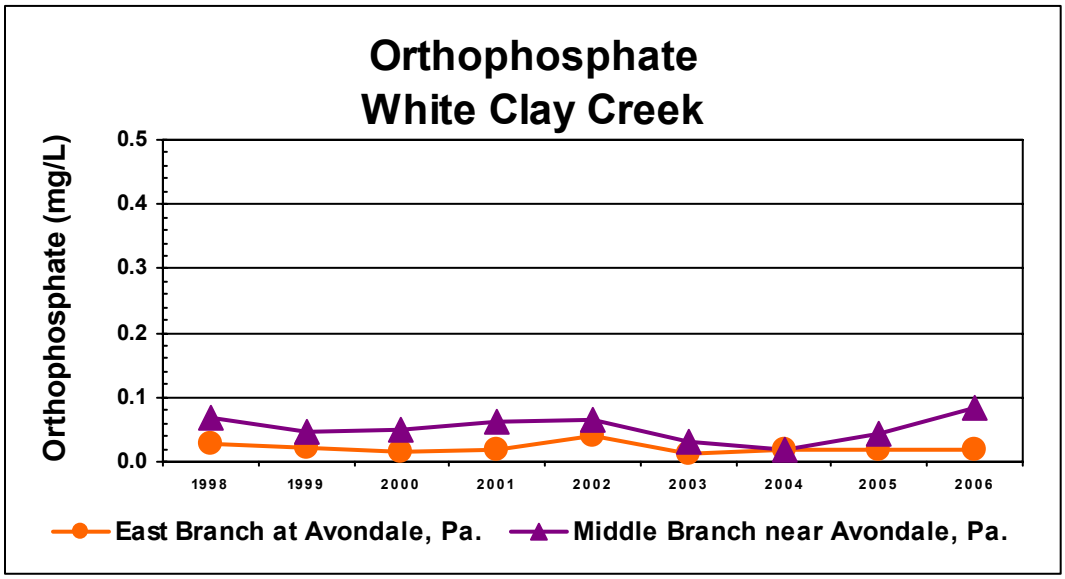
Total phosphorus (TP) levels in the White Clay Creek improved between the 1970s and early 1990s (Figure 16). Since the 1990s, TP levels are relatively constant. Median TP values are approximately 0.1 mg/L, fair , but still above the Delaware low target level of 0.05 mg/L.

Figure 16. Total phosphorus trends in the White Clay Creek in Delaware. (source: DNREC)



Pennsylvania DEP collects orthophosphate, a form commonly found in sewage, in the East Branch in Avondale and the Middle Branch near Avondale (Figure 17). Orthophosphate levels at the East Branch and the Middle Branch remained constant between 0 and 0.1 mg/L from 1998 to 2006, with a slight rise from 2000 to mid-2002. Levels slightly decreased from mid-2002 to 2005 and are increasing at the Middle Branch near Avondale station at the end of the sampling period from 2005 to 2006.

Figure 17. Orthophosphate levels in the White Clay Creek in Pennsylvania. (source: PADEP and USGS)



GRADE

D

Poor

TREND

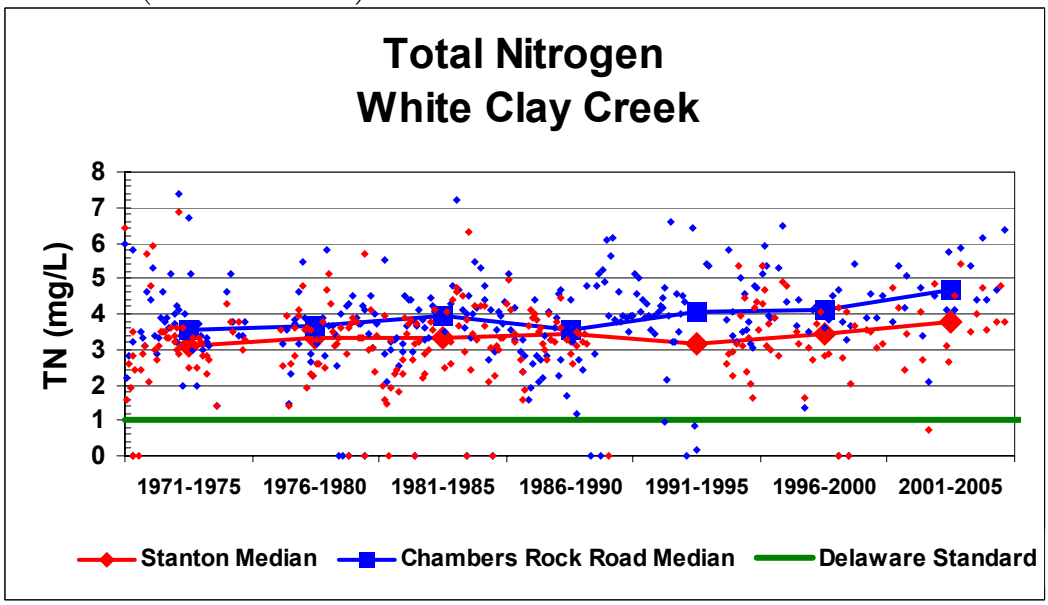
Since 1970

Since 1990

12. NITROGEN

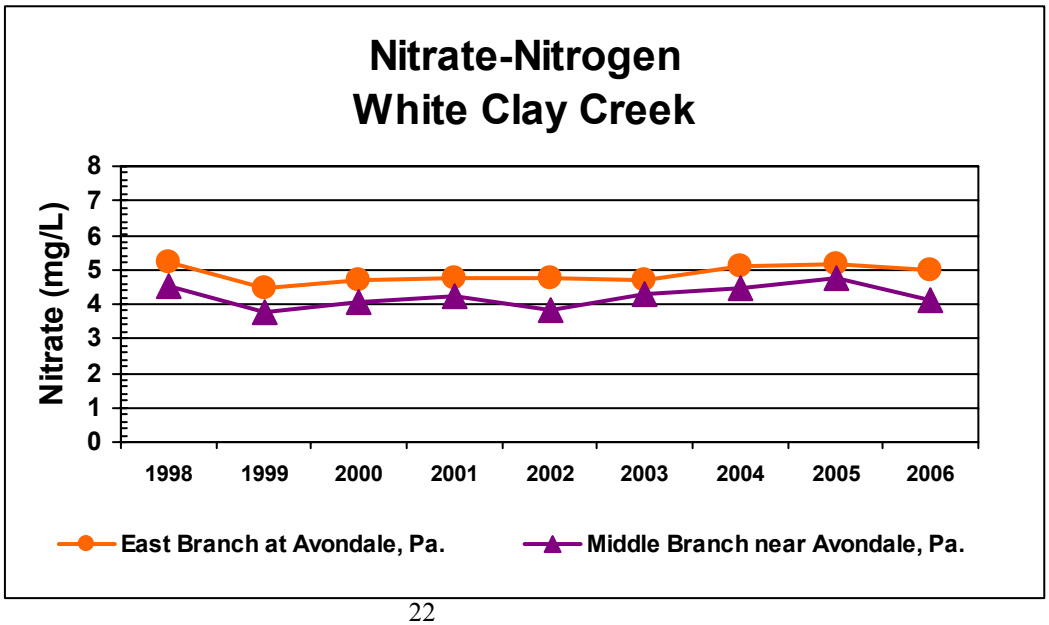
Total nitrogen (TN) levels along the White Clay Creek increased from 1971 to the mid-80s (Figure 18). In the mid-80s, a slight decrease occurred in TN levels; and in the early 90s, TN levels began to rise through 2005. Median TN levels are high ranging from 3.8 to 4.6 mg/L or 4 to 5 times the Delaware low target of 1.0 mg/L.

Figure 18. Total nitrogen trends in the White Clay Creek in Delaware. (source: DNREC)



The USGS collected nitrate-nitrogen, a form commonly found in plant decomposition, decay of human and animal waste, and fertilizer runoff , in the East Branch in Avondale and the Middle Branch near Avondale, from 1998 to 2006. Nitrate-nitrogen levels at both the East Branch and Middle Branch sampling locations have decreased slightly during this time period but remained high at 4 to 5 mg/L (Figure 19).

Figure 19. Nitrate-Nitrogen trends in the White Clay Creek in Pennsylvania. (source: PADEP and USGS)



13. SEDIMENT

GRADE

B

Good

Total suspended sediment (TSS) levels in the White Clay Creek have improved since 1971 and have remained relatively constant since 1990 (Figure 20). Delaware and Pennsylvania do not have sediment standards. By comparison against New Jersey's sediment standard of 40 mg/L, median TSS levels in the White Clay Creek are low at 6 to 8 mg/L. The Chester County and New Castle County Conservation Districts have implemented soil erosion and sediment control programs for agriculture and new construction that have resulted in decreased sediment loads.

TREND

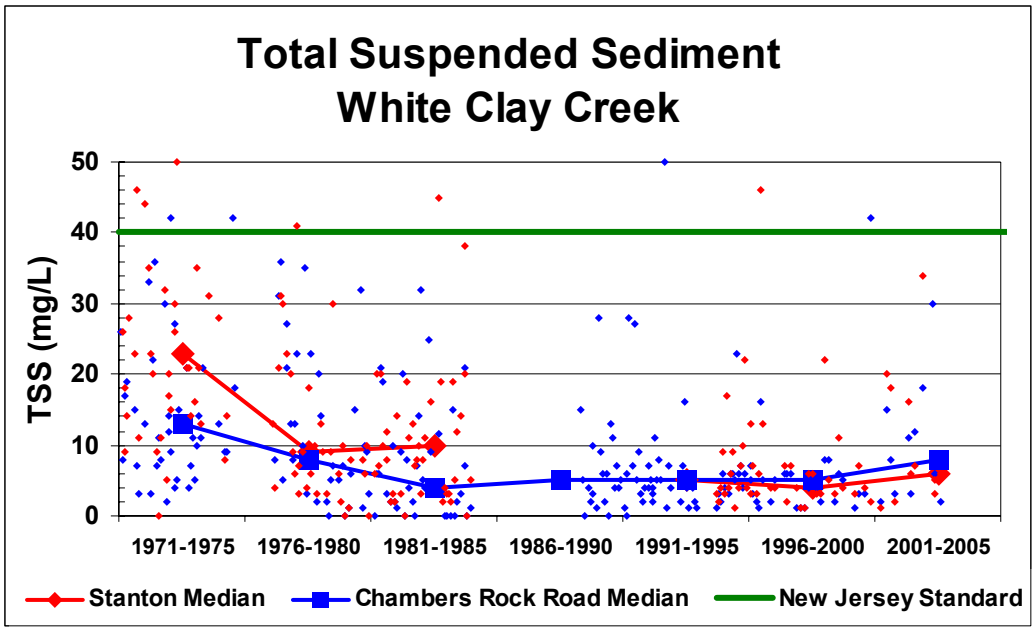
Since 1970

▲

Since 1990

●

Figure 20. Total suspended sediment trends in the White Clay Creek in Delaware. (source: DNREC)



14. BACTERIA

GRADE

Chambers Rock

C

Fair

Stanton

D

Poor

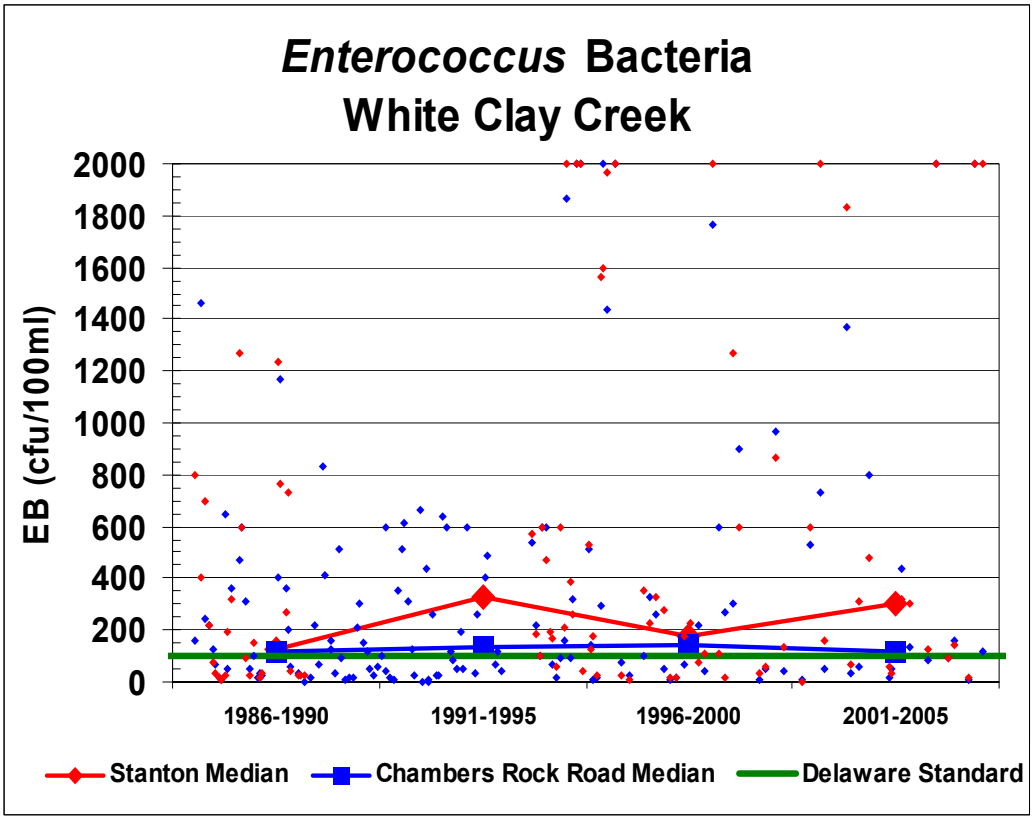
TREND

Chambers Rock Since 1990

Stanton Since 1990

Delaware uses *Enterococcus* bacteria as the bacterial indicator in the state's water quality sampling for pathogen standards. Bacteria levels along the White Clay Creek have remained constant and even declined slightly since 1990 at the Stanton monitoring station and remained constant at the Chambers Rock Road station just downstream from the state line (Figure 21). Median bacteria levels are poor at the Stanton station and exceed the Delaware water quality standard of 100 colony-forming units per milliliter (cfu) by a factor of 3. Median bacteria levels at the Chambers Rock Road station in the White Clay Creek State Park above Newark are better and just exceed the 100 cfu standard.

Figure 21. *Enterococcus* bacteria in the White Clay Creek in Delaware. (source: DNREC)



15. MACROINVERTEBRATES

GRADE

C/D

Fair to Poor

TREND

ND

Macroinvertebrates are excellent tools to assess environmental conditions. The biometric Macroinvertebrate Aggregated Index for Streams (MAIS) is used by the Stroud Water Research Center (SWRC) in their assessment of stream condition at 16 locations throughout the White Clay Creek watershed based on stream watch data from 2003 to 2005.

A MAIS Score is a single multimetric value of 0 to 20, with the higher scores indicating higher quality. A site with a MAIS Score of 13.1-20 was classified as "Good," 6.1–13 was "Fair," and 0–6 was "Poor." Macroinvertebrates were collected in late March in 2003, 2004, and 2005 at all 16 sites except 2 sampling sites: WCC 23 (samples collected only in 2003 and 2005) and WCC 25 (samples collected only in 2005). The location of each sampling site and the sampling ID number is shown in Figure 22.

MAIS Scores from White Clay Creek classified only one site (WCC 11) as "Good." Six sites are on the lower half of "Fair" and nine sites are classified as "Poor." Across all three groups, the best conditions are in the upstream headwater sites, although somewhat degraded in the headwaters of the Middle and West Branches. In Figure 22, the red dots depict the sites with a "Poor" rating, the yellow dots depict the sites with a "Fair" rating, and the blue dot depicts the site with a "Good" rating. This is also reflected in the graph in Figure 22.

Among the 16 sites, 94% of the sites sampled in the White Clay Creek scored "Fair" (38%) or "Poor" (56%), indicating that chemical and/or physical conditions have degraded enough that approximately 30% to >70% of the pollution-sensitive species are no longer found in some reaches of the stream. Figure 23 shows the average MAIS scores from the samples collected on the White Clay Creek from 2003 to 2005. The macroinvertebrate assemblages in the "Fair" and "Poor" sites had moderately high or highly modified macroinvertebrate assemblages. The data analysis found that several of these sites support pollution-tolerant macroinvertebrates, with some sites having an increased abundance, while there has been a significant reduction or elimination of pollution sensitive macroinvertebrates.

The classification for each site varies among the three years sampled. This variability may be due to a combination of natural and anthropogenic conditions and events. Estimates of average conditions in the White Clay Creek based on three years of data are clearly more representative than a single year of data. Figure 23 shows the yearly means (2003 to 2005) for the MAIS scores for the White Clay Creek. Several of the sites classified as "Fair" and "Poor" fluctuate between these two categories on an annual basis, but none of the sites changed from "Poor" to "Good" or "Good" to "Poor."

Figure 24 represents a comparison between the MAIS scores of the White Clay Creek and the Schuylkill River watershed, which lies northeast of the White Clay Creek watershed. The Schuylkill River watershed is highly urbanized and is heavily impacted by agriculture and acid mine drainage. This comparison clearly shows a greater proportion of sites classified as "Good" in the Schuylkill River and a greater proportion of sites classified as "Poor" in the White Clay Creek.

Figure 22. Sampling sites and MAIS scores in the White Clay Creek watershed, 2003 to 2005. (source: Stroud Water Research Center, 2008)

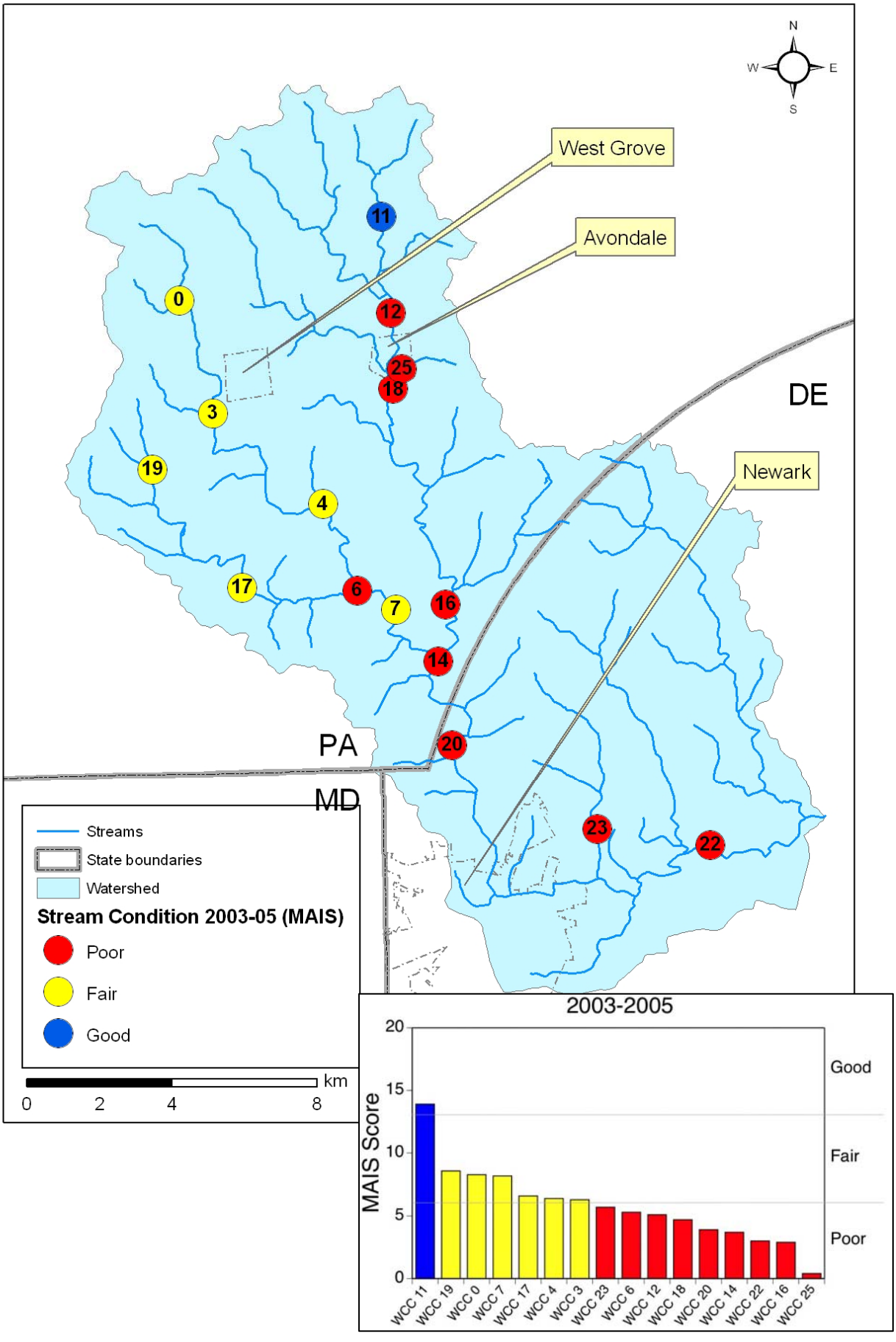


Figure 23. Yearly means (2003 to 2005) of the MAIS scores on the White Clay Creek. (source: Stroud Water Research Center, 2008)

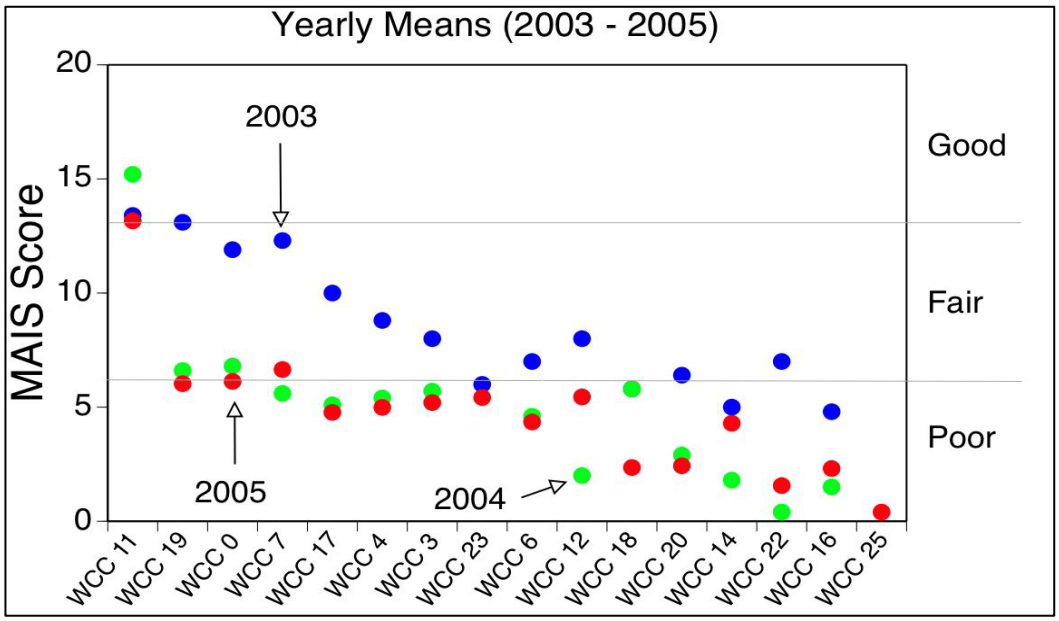
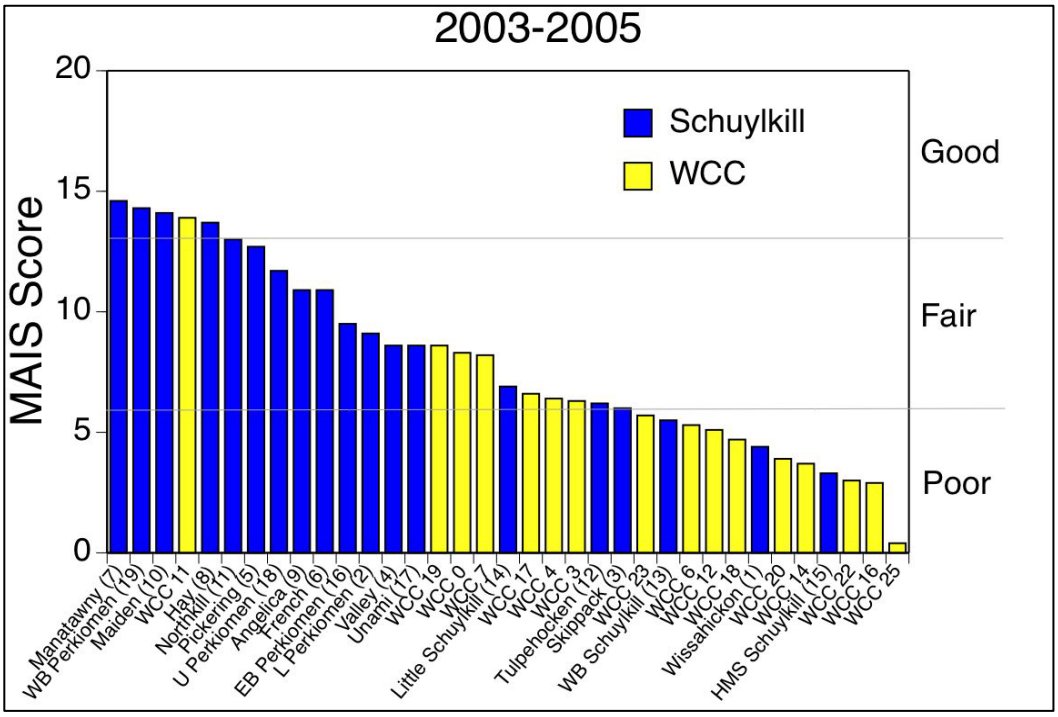


Figure 24. MAIS scores for the Schuylkill River and White Clay Creek, 2003 to 2005. (source: Stroud Water Research Center, 2008)



16. IMPAIRED STREAMS

GRADE

D

Poor

TREND

ND

The *State of Delaware Surface Water Quality Standards* (as amended July 11, 2004), designates streams in the White Clay Creek watershed for the following uses:

- Public, agricultural, and industrial water supply.
- Primary and secondary contact recreation.
- Fish, aquatic life, and wildlife.
- Cold water fish (put and take).
- Waters of exceptional recreational or ecological significance (ERES).

Chapter 93 of the *Pennsylvania Water Quality Standards* designates streams in the White Clay Creek watershed for the following uses:

- Potable, industrial, and livestock water supply.
- Irrigation.
- Water contact sports and aesthetics.
- Boating and fishing.
- Wildlife water supply.
- Trout stocking and warm water fishes.
- Cold water and migratory fishes.
- High quality (HQ) and exceptional value (EV) waters.

Due to excess nutrients and bacteria, and high DO, certain streams currently do not meet their designated uses. As a result, the USEPA has named a large portion of the streams in the White Clay Creek watershed as impaired. Approximately 89 miles or 64% of 139 stream miles in the White Clay Creek are rated as impaired by the USEPA using data supplied by Delaware's DNREC and the PADEP (Figure 26).

As a result of the degraded water quality in these streams, the USEPA has set total maximum daily loads (TMDLs) for the impaired segments of the White Clay Creek. Figure 25 shows the proportion of reductions necessary for TN, TP, and bacteria, *Enterococci* bacteria (Del.) and fecal coliform (Pa.), in the subwatersheds. The TMDL lists TN, TP, and bacteria load reductions that must be met to meet the state's stream water quality standards.

Figure 25. TMDL reductions for the White Clay Creek watershed.

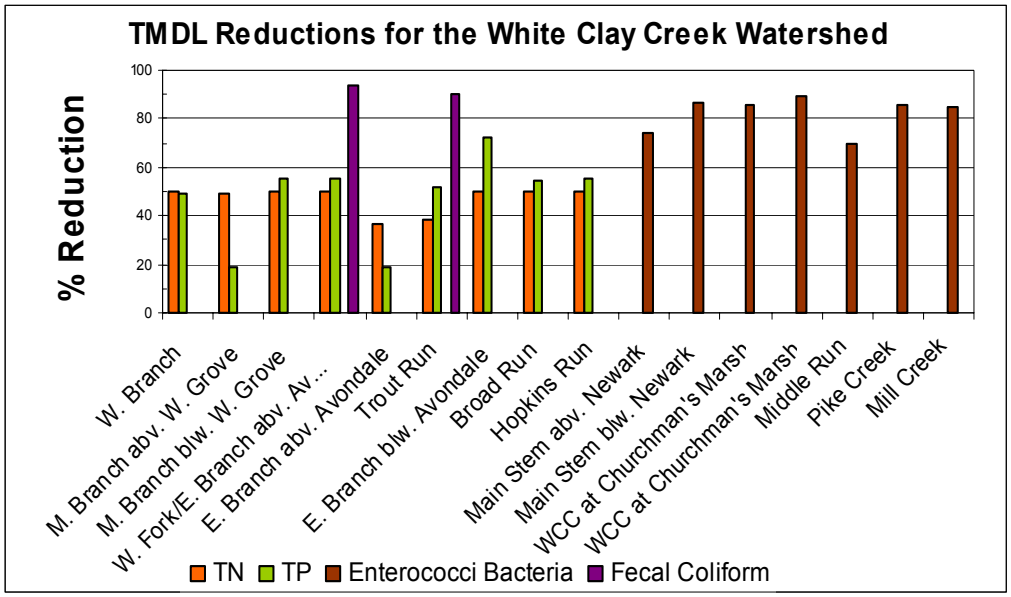
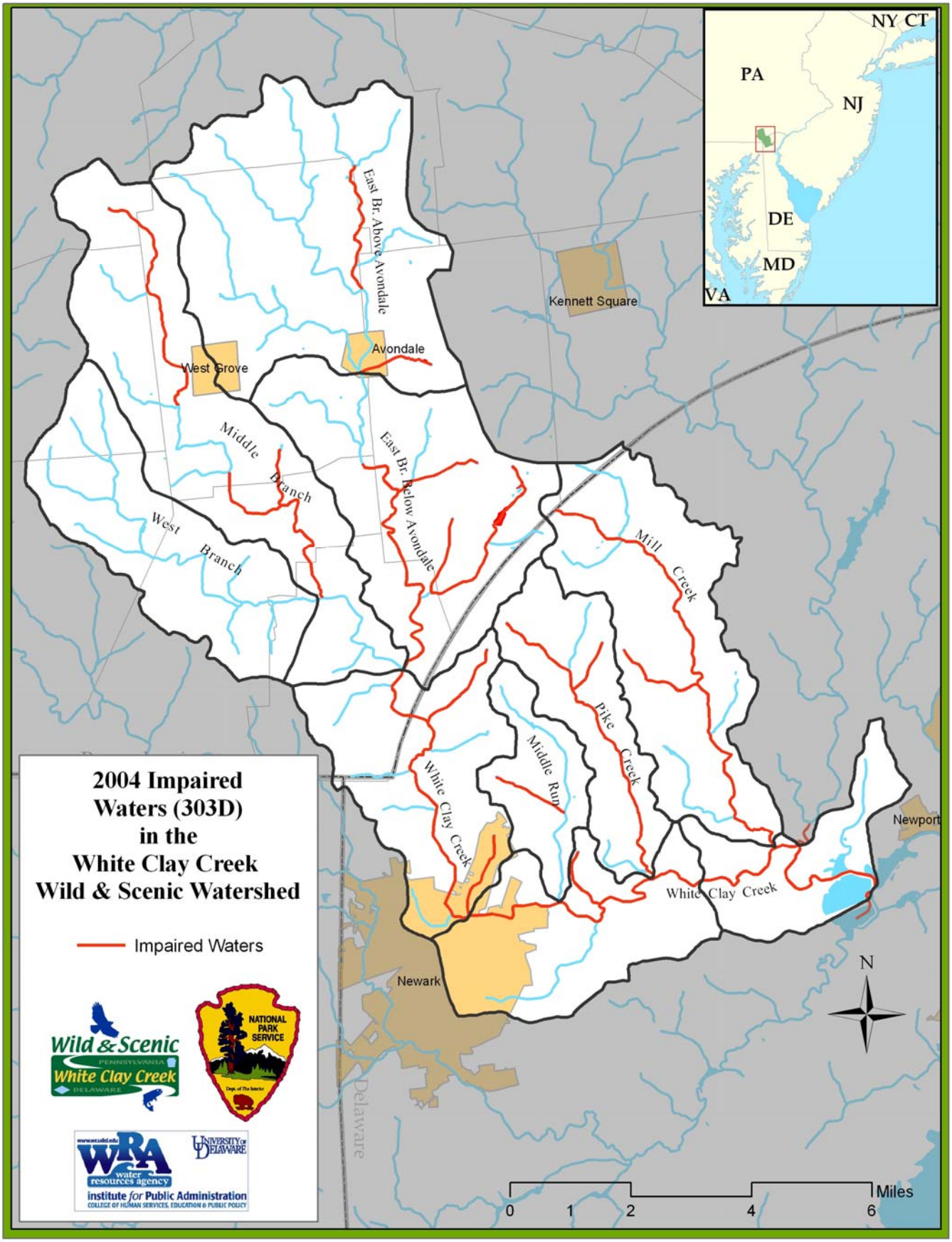


Figure 26. Impaired streams in the White Clay Creek watershed.
(source: USEPA, 2004)



17. BIRDS

GRADE

B

Good

TREND

ND

The White Clay Creek watershed is the habitat of many bird species and several that are on the Delaware endangered species list, including:

- Brown Creeper
- Bald Eagle
- Pied-billed Grebe
- Northern Harrier
- Cooper's Hawk
- Black-crowned Night-Heron
- Yellow-crowned Night-Heron
- Northern Parula
- Short-eared Owl
- Black Rail
- Upland Sandpiper
- Loggerhead Shrike
- Black Skimmer
- Henslow's Sparrow
- Cerulean Warbler
- Hooded Warbler
- Swainson's Warbler
- Red-headed Woodpecker
- Sedge Wren

Derek Stoner, Anas Biodiversity Consulting, conducted two bird surveys in the White Clay Creek watershed between July and October 2007. These surveys were conducted on two properties in Franklin Township, Pennsylvania, on the Middle and West Branches in the White Clay Creek watershed. Table 11 summarizes the species observed on each property.

In total, 21 hours of surveying effort on the 29-acre property on the Middle Branch yielded observations of 68 species of birds over the course of four months. Thirty-two hours of surveying effort on the 81-acre property on the West Branch yielded observations of 108 species of birds over the course of four months. For this area of southeastern Pennsylvania, these represent an excellent total for relatively small parcels of forest. Birds are perhaps the best (and most visible) indicator of the quality of habitat on a parcel of land, and the observations made in this survey indicate that the properties on the Middle and West Branches are highly valuable and rich woodlands worthy of protection and conservation efforts.

Table 11. Bird species observed in the White Clay Creek watershed on the Middle and West Branches. (source: Derek Stoner, 2008)

Species	Property		Species	Property		Species	Property		Species	Property	
	Middle Branch	West Branch		Middle Branch	West Branch		Middle Branch	West Branch		Middle Branch	West Branch
Great Blue Heron		X	Acadian Fly-catcher	X	X	Golden-crowned Kinglet		X	Yellow-breasted Chat		X
Green Heron		X	Easter Wood-peewee	X	X	Ruby-crowned Kinglet	X	X	Yellow-rumped Warbler		X
Black Vulture	X	X	Eastern King-bird	X	X	Blue-gray Gnatcatcher		X	Scarlet Tanager	X	X
Turkey Vulture	X	X	Eastern Phoebe	X	X	American Robin	X	X	Chipping Sparrow		X
Canada Goose	X	X	Great Crested Flycatcher	X	X	Eastern Blue-bird		X	Dark-eyed Junco	X	X
Mallard		X	Least Fly-catcher		X	Hermit Thrush		X	Eastern Towhee	X	X
Wood Duck		X	Willow Fly-catcher		X	Swainson's Thrush	X		Field Sparrow		X
American Kestral		X	Blue-headed Vireo	X		Veery	X	X	Fox Sparrow		X
Cooper's Hawk*	X	X	Philadelphia Vireo		X	Wood Thrush	X	X	Song Sparrow	X	X
Red-tailed Hawk	X	X	Red-eyed Vireo	X	X	Brown Thrasher		X	Swamp Sparrow		X
Sharp-shinned Hawk	X	X	Warbling Vireo	X	X	Gray Catbird	X	X	White-crowned Sparrow		X
Killdeer		X	White-eyed Vireo		X	Northern Mockingbird		X	White-throated Sparrow	X	X
Ring-billed Gull		X	Yellow-throated Vireo		X	European Starling		X	Blue Grosbeak		X
Mourning Dove	X	X	American Crow	X	X	Cedar Wax-wing		X	Indigo Bunting	X	X
Rock Dove		X	Blue Jay	X	X	American Redstart	X	X	Northern Cardinal	X	X
Black-billed Cuckoo		X	Fish Crow	X	X	Black-and-white Warbler	X	X	Rose-breasted Grosbeak	X	X
Yellow-billed Cuckoo	X	X	Barn Swallow		X	Black-throated Blue Warbler	X		Baltimore Oriole	X	X
Eastern Screech-owl	X	X	Purple Martin		X	Black-throated Green Warbler	X	X	Brown-headed Cowbird	X	X
Great-horned Owl	X	X	Tree Swallow	X	X	Chestnut-sided Warbler	X	X	Common Gackle	X	X
Chimney Swift		X	Black-capped Chickadee	X	X	Common Yellowthroat		X	Eastern Meadow-lark		X
Ruby-throated Hummingbird	X	X	Carolina Chickadee	X	X	Louisiana Waterthrush	X	X	Orchard Oriole		X
Belted King-fisher		X	Tufted Tit-mouse	X	X	Magnolia Warbler	X	X	Red-winged Blackbird		X
Downy Wood-pecker	X	X	Red-breasted Nuthatch	X	X	Northern Parula*	X	X	American Gold-finch	X	X
Hairy Wood-pecker	X	X	White-breasted Nuthatch		X	Ovenbird	X	X	House Finch	X	X
Northern Flicker	X	X	Brown Creeper	X	X	Palm Warbler	X		Purple Finch	X	X
Pileated Woodpecker	X	X	Carolina Wren	X	X	Prairie Warbler		X	House Sparrow		X
Red-bellied Woodpecker	X	X	House Wren	X	X	Tennessee Warbler		X			
Yellow-bellied Sapsucker	X	X	Winter Wren	X	X	Yellow Warbler		X			

*= Species present on the Delaware Endangered Species List.

GRADE

B

Good

TREND

18. FISH

The White Clay Creek watershed is home to over two dozen species of fish. Numerous studies in the watershed throughout the 1990s have found evidence of these fish. For example Table 12 summarizes the number and location of 20 fish species identified in electroshock fishery surveys conducted along the White Clay Creek in 1996.

In addition, according to the *Water Supply Plan, Supplemental Environmental Studies, Spring 1996* the following fish were detected in the lower White Clay Creek at Churchman's Marsh:

- Striped Bass
- American Eel
- White Perch
- Gizzard Shad

Ichthyoplankton—eggs and larvae of fish—were detected in the lower White Clay Creek at Churchman's Marsh in 1996:

- Alewife
- Striped Bass
- White Perch
- Gizzard Shad

According to the *Phase 2, 7Q10 Assessment Sampling (*Fall 1995) the following fish were detected in the White Clay Creek near Stanton (at United Water's surface water withdrawal):

- Alewife
- Blueback Herring
- Largemouth Bass
- Yellow Perch
- American Eel
- Sea Lamprey
- Small Mouth Bass

More recent sampling at the White Clay Creek near Newark found the following fish species:

- American Eel
- Sea Lamprey
- Largemouth Bass
- Smallmouth

While fishermen also report that shad were caught in the White Clay Creek in April and May, 2003.

Table 12. Fishery surveys along the White Clay Creek in 1996.
(source: Metcalf and Eddy)

Date of Sampling	**June 6**	**June 6**	**June 7**	**June 28**
Location	**WCA**	**WCB**	**TT**	**CK**
Seconds Shocked	**2319**	**3232**	**1585**	**815**
Common Name	**Number of Fish**			
American Eel	4	8	3	4
Am. Brook Lamprey	7	1	2	
Margined Madtom		2		
White Sucker	69	54	40	4
Rosyside Dace		65	88	59
Satinfin Shiner	24	23	1	1
Cutlips Minnow	6	11		
Common Shiner	15	35	23	
Spottail Shiner	3	14		
Swallowtail Shiner	38	15		
Bluntnose Minnow	2	1	1	
Blacknose Dace	23	23	42	48
Longnose Dace	1	52		
Creek Chub	21	14	28	21
Tesselated Darter	44	31		1
Rainbow Trout		1		
Rock Bass		4		
Redbreast Sunfish	1			
Pumpkinseed	1			
Bluegill	1		2	
Total Fish	**260**	**354**	**230**	**138**
Number of Species	**16**	**17**	**10**	**7**
TT - Thompson Station Tributary				
CK - Corner Ketch Tributary				
WCA - White Clay Creek at Hopkins Bridge				
WCB - White Clay Creek below confluence of Thompson Station Tributary				

19. TROUT STREAMS

GRADE

B

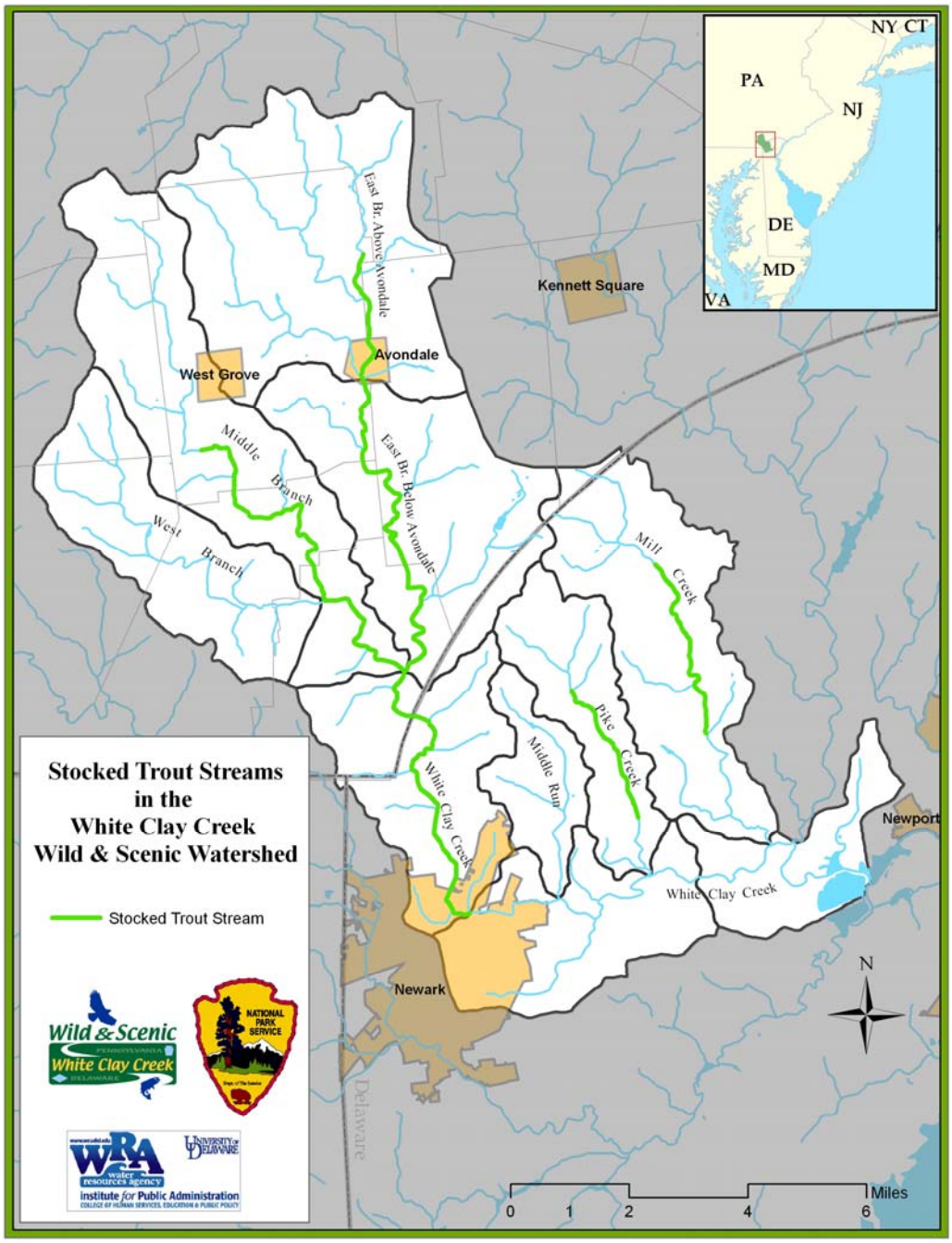
Good

TREND

ND

PADEP and the Pennsylvania Fish and Boat Commission stock 20.5 miles of trout streams along the Middle and East Branches of the White Clay Creek. DNREC stocks 13.0 miles of put and take trout streams along the White Clay Creek above Newark, Pike Creek, and Mill Creek , which are three of the only six trout streams in Delaware. Figure 27 shows the location of the stocked trout streams in the White Clay Creek watershed.

Figure 27. Stocked trout streams in the White Clay Creek watershed.



20. FISH CONSUMPTION ADVISORIES

GRADE

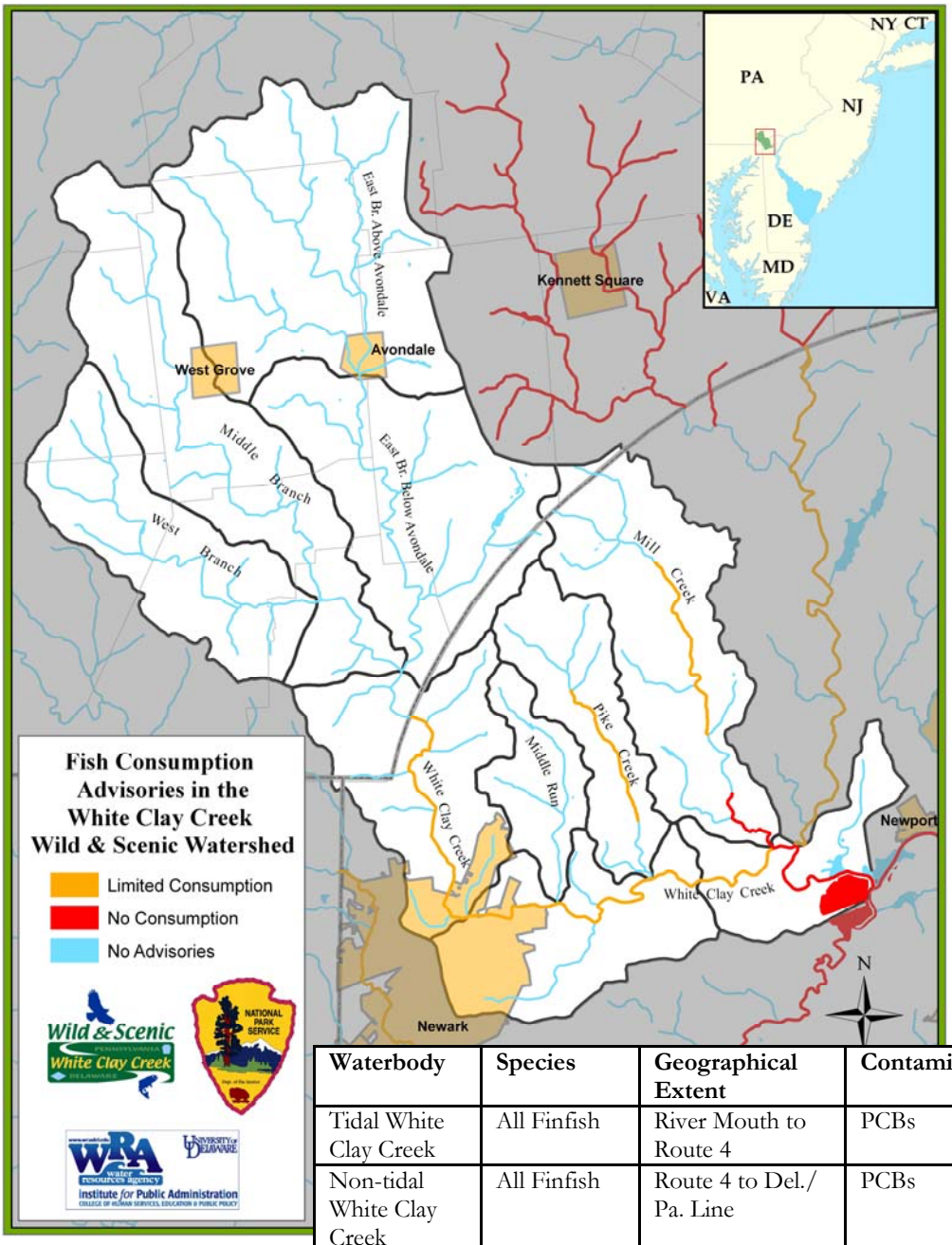
C

Fair

Approximately 25.9 miles of streams in the White Clay Creek watershed have full or partial fish consumption advisories as posted by the PADEP and DNREC. Specific segments of the tidal White Clay Creek, non-tidal White Clay Creek, and designated trout streams in the Delaware portion of the White Clay Creek have fish consumption advisories on all finfish and stocked trout due to PCBs. Figure 28 maps the locations of the streams with fish consumption advisories throughout the entire watershed.

TREND

Figure 28. Fish consumption advisories in the White Clay Creek watershed.



Waterbody	Species	Geographical Extent	Contaminants	Advice
Tidal White Clay Creek	All Finfish	River Mouth to Route 4	PCBs	No Consumption
Non-tidal White Clay Creek	All Finfish	Route 4 to Del./ Pa. Line	PCBs	No More Than One Meal Per Month
Designated Trout Streams	Stocked Trout	White Clay Creek above Newark, Pike Creek, and Mill Creek	PCBs	No More Than One Meal Per Month

21. FISH PASSAGE (DAMS)

GRADE

C

Fair

TREND

Seven dams along almost 13 miles of the Delaware portion of the White Clay Creek impede the migration of anadromous fish such as shad and striped bass (Table 13). Figure 29 depicts the location, height, and elevation of each of the seven dams in the Delaware portion of the White Clay Creek watershed that present a barrier to fish passage and migration. In addition to the seven dams in Delaware, the PADEP regulates several additional dams, and the National Inventory of Dams identified five dams along the White Clay Creek.

The White Clay Creek National Wild and Scenic Rivers Program Management Committee, Brandywine Conservancy, and University of Delaware's IPA-WRA are working with DNREC Division of Fish and Wildlife to evaluate the feasibility of removing dams or installing fish ladders and rock ramps to restore fish passage along the White Clay Creek.

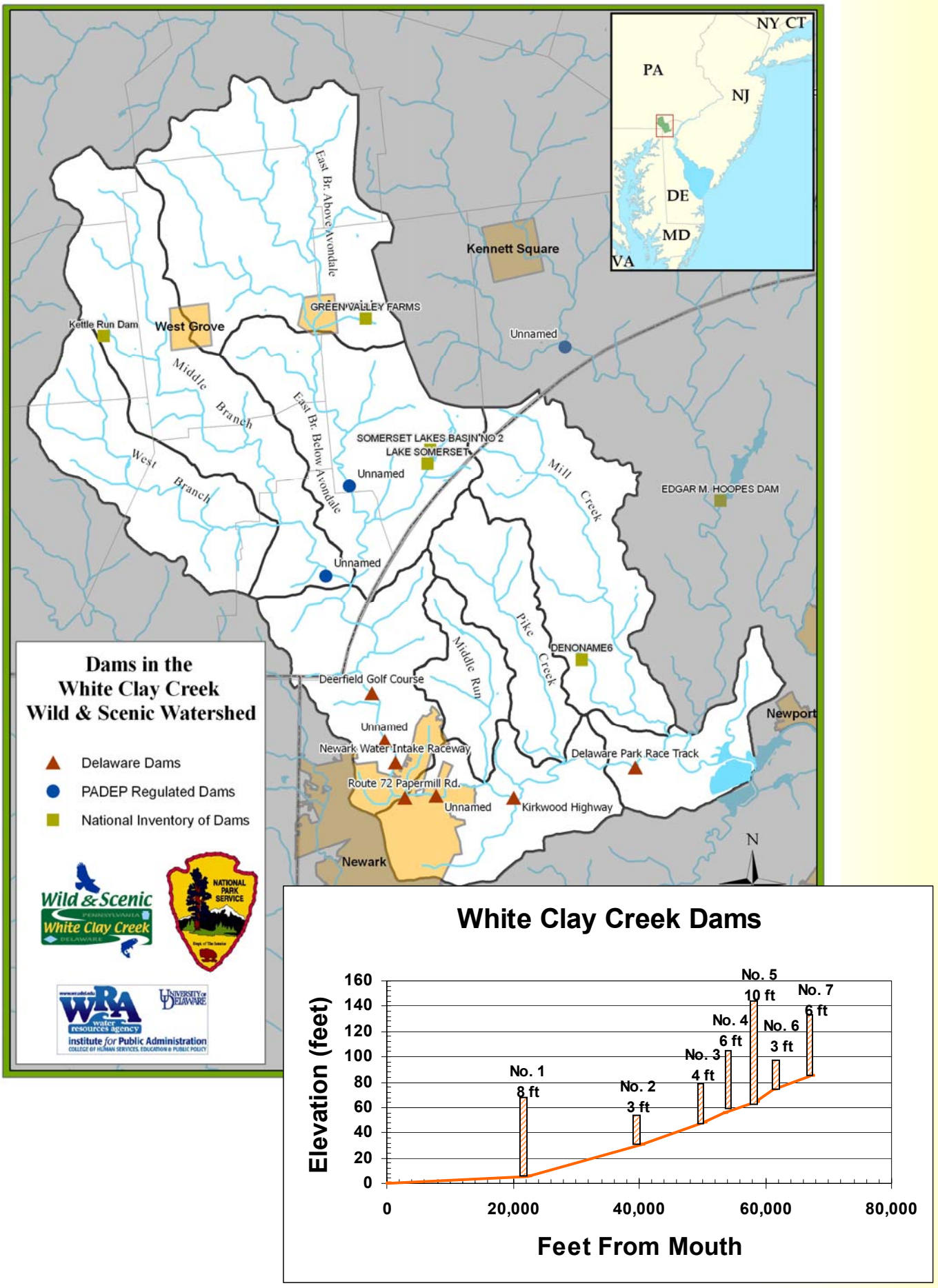
Table 13. Dams along the White Clay Creek in Delaware.
(source: FEMA Flood Insurance Study)

Dam	Feet above Mouth	Height of Dam (ft)
No. 1 (Del. Park. Race Track)	22,300	8
No. 2 (Kirkwood Highway)	40,200	3
No. 3	50,000	4
No. 4 (Route 72 Paper Mill Road)	53,300	6
No. 5 (Newark Water Intake)	58,400	10
No. 6	61,300	3
No. 7 (Deerfield Golf Course)	67,000	6

Numerous historical mill dam sites are present on the White Clay Creek. Preliminary research conducted by David Hawk identifies almost 70 mill sites, most of which had their own dams at one time. Although most of these dams are completely gone, the remains of a few of these dams are left and may impede fish passage. Below is a photo of a still-standing dam on the East Branch of the White Clay Creek just south of Landenberg, Pennsylvania. It was one of four dams that powered the mills of Landenberg.

Photo Credit: David Hawk

Figure 29. Dams in the White Clay Creek watershed.



RECOMMENDATIONS

The White Clay Creek Wild and Scenic Watershed Management Committee should consider implementing the following recommendations that emanate from the report card:

Landscape

1. Population – Update the population estimates for the White Clay Creek watershed based on the upcoming 2010 U.S. Census.

2. Forests – 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.

3. Open Space – Continue the geometric growth in protected lands by acquiring public open space, parks, and private conservation easements.

4. Riparian Buffers – Install buffers on the 209.1 stream miles where there are opportunities to plant buffers.

5. 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.

Hydrology

6. Precipitation – Install a real time precipitation gage at the USGS stream gage White Clay Creek near Newark.

7. Stream Flow – Mitigate increased high flows and decreased low flows though green technology storm water best management practices, encourage recharge of runoff, and minimize impervious cover.

8. Groundwater – 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.

9. 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-year floodplain.

Water Quality

10. Dissolved Oxygen
11. Phosphorus
12. Nitrogen
13. Sediment
14. Bacteria

Continue water quality improvements by installing agriculture conservation projects and fixing leaking septic systems, and particularly reduce 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.

Habitat

15. Macroinvertebrates – Continue annual sampling by the Stroud Water Research Center to establish trends.

16. 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 that are prepared every two years (2008 and 2010).

17. Birds – Conduct annual abundance surveys on the two properties in Franklin Township to establish trends in bird populations.

18. Fish – 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.

19. Trout Streams – Tabulate the annual totals in trout stamps issued in the White Clay Creek watershed as an assessment of trout fishing popularity.

20. Fish Advisories – Annually remap the stream miles under Delaware and Pennsylvania fish consumption advisories in the White Clay Creek watershed.

21. Fish Passages (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.

WHITE CLAY CREEK REPORT CARD

Indicator	Commentary	Grade	Trend	
LANDSCAPE				
1. Population	The White Clay Creek watershed population has doubled from over 60,000 in 1970 to nearly 120,000 by 2000 and could exceed 130,000 by 2010.	C	▼	
2. Forest	Forests decreased from 33% of the watershed in 1990 to 30% by 2000. For a net loss of 3 mi².	C	▼	
3. Open Space	Public open space in the Del./Pa. White Clay Creek Preserve grew from 24 acres in 1968 to over 5,000 acres by 2005.	A	▲	
4. Riparian Buffers	Over 625 stream miles are buffered (either full or partial) in the White Clay Creek watershed with 209 stream miles available for buffering.	B	ND	
5. Impervious Cover	Impervious cover increased from 15% in 1990 to 20% by 2005, 1% every two years, and could reach 22% by 2010. Impervious cover is low above Newark.	B/D	▼	
HYDROLOGY				
6. Precipitation	Annual precipitation averages 41 inches and has remained constant over the last two decades. Mean annual flow averages half of the annual precipitation, a healthy recharge ratio.	B	●	
7. Stream Flow	Peak flows increased from 3,000 to 4,000 cfs before 1970 to 10,000 cfs since 2000. Low flows declined from 20 to 30 cfs before 1995 to below 20 cfs since then.	C	▼	
8. Groundwater	By 2000, 31.1 mgd of groundwater was available and 2.2 mgd was withdrawn through wells, leaving 28.9 mgd (93%) of the groundwater resource available.	B	ND	
9. Flooding	106 structures are in the 100-year floodplain of the White Clay Creek and four bridges are prone to flood damage. Greater than 50-year flood events occurred in 1999, 2003, and 2004.	D	▼	
WATER QUALITY			1970/80	Since 1990
10. Dissolved Oxygen	DO levels have improved since 1990. Median DO is 10 ppm, or more than double the Delaware Water Quality standard, and never drops near the minimum standard.	B	▼	▲
11. Phosphorus	TP improved since 1970 and constant since 1990. Median TP is fair, but above the Del. 0.05 mg/L target. Orthophosphate rose at the Middle Branch site and fell at the East Branch site.	C	▲	●
12. Nitrogen	TN ratings are degrading and poor with levels 4 to 5 times the Del. target kevel of 1.0 ppm. Nitrate Nitrogen levels degrading at both PA sampling stations.	D	▼	▼
13. Sediment	TSS levels improved since 1970 and are constant since 1990. Median TSS levels low at 6 to 8 ppm, significantly less than the NJ water quality standard of 40 mg/l.	B	▲	●
14. Bacteria	At Chambers Rock Road, bacteria has been constant since 1990, just above the Del. 100 cfu standard. At Stanton, bacteria is high (3 times the standard of 100 cfu), but constant since 1990.	C/D	●	●
HABITAT				
15. Macroinvertebrates	MAIS ratings are fair and poor with the West and Middle Branches rated fair and the East Branch and Mainstem rated poor. Only one site upstream from Avondale is rated good.	C/D	ND	
16. Impaired Streams	Over 89 miles or 64% of 139 stream miles in the White Clay Creek watershed are rated impaired by the USEPA for bacteria, nutrients (N and P), and low DO.	D	ND	
17. Birds	Nineteen endangered bird species nests in the White Clay Creek watershed and 110 bird species were sighted in a 2007 survey on two properties in Franklin Township.	B	ND	
18. Fish	The White Clay Creek watershed is habitat for over two dozen freshwater and salt water fish including striped bass, American shad, alewife, trout, and smallmouth bass.	B	●	
19. Trout Streams	PADEP/DNREC stock 33 miles of trout streams in the White Clay Creek watershed including the only fly fishing reach and three of the only six trout streams in Del.	B	ND	
20. Fish Consumption Advisories	PADEP and DNREC imposed full or partial fish consumption advisories along 26 miles of streams in the White Clay Creek watershed due to PCBs.	C	●	
21. Fish Passage (Dams)	Fifteen dams in the White Clay Creek watershed, 7 in Delaware, impede fish migration. Feasibility studies are underway for dam removal or fish ladders and rock ramps.	C	▲	

Trend: ▲ **Improving,** ● **Constant,** ▼ **Degrading, ND Not enough data to determine a trend.**
Grade: A = Excellent, B = Good, C = Fair, D = Poor, F = Very Poor, I = insufficient data.

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