White Clay Creek above Newark Source Water Assessment Plan

Draft December 7, 2019

Prepared for:

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1. Introduction

1.1. Objectives

This report is designed to identify potential sources of contamination in the 69-square mile White Clay Creek watershed in Delaware and Pennsylvania upstream from the City of Newark drinking water intake. Primary contaminants of concern include: (1) high levels of nutrients such as nitrogen and phosphorus from fertilizers and leaking septic systems that cause harmful algal blooms (HAB), (2) excessive bacteria from manure that deems the waters unswimmable and unpotable, and (3) elevated sediment loads from eroding topsoil and stream banks. The location and extent of potential contaminant sources are identified by examining stream water quality data collected by the U.S. Geological Survey, states of Delaware and Pennsylvania, and student research assistants and through land use/land cover mapping compiled by the GIS laboratory of University of Delaware Water Resources Center. Once the spatial extent of the potential contaminant sources is identified, investments in upstream best management practices (BMPs) can be programmed by the City of Newark in collaboration with Federal, State, and nonprofit sources of funding. The objectives of this report are to identify potential sources of contamination to the City of Newark water supply system in the upstream White Clay Creek watershed through analysis of:

- Population, land use, and agriculture trends
- Monitoring of salinity, pathogens, dissolved oxygen, phosphorus, nitrogen, and sediment.
- Stream bank and farm sediment fingerprinting

1.2. White Clay Creek at Newark

Established in 1990 at the site of the circa 1880 Curtis Paper Mill, the City of Newark Water Supply intake along the White Clay Creek can treat up to 5 mgd of drinking water during the summer peak or 2 to 3 mgd during normal demand periods. The treatment works draw raw water from the White Clay Creek at Dam No. 5 after the water flows ¾ of a mile down through a raceway and into a lagoon. The City of Newark can withdraw and treat up to 5 mgd from White Clay Creek. After screening large debris, the raw water flows into the treatment building for sedimentation, flocculation, san filtration, and disinfection before the treated water is pumped to elevated storage tanks for distribution to over 8,000 customers or over 30,000 people in the City of Newark. The City monitors basic parameters such as water temperature, pH, nutrients and will curtail withdrawals when the turbidity in the creek exceeds 10 to 20 NTUs due to potential for clogging of the treatment filters and risk of pathogens such as cryptosporidium and giardia that are associated with high sediment loads.

The 317 million gallon Newark Reservoir was constructed in 2005 and at a normal demand of 3 mgd has over 100 days of reserve storage capacity in the event of drought, high sediment flows, or spills upstream (Figure 1). The City of Newark can pump up to 18 mgd (six days of supply at

normal demand of 3 mgd) through 3,500 linear feet of a 24-inch pipeline from the storage lagoon at elev. 70 ft to the top of the reservoir at elev. 190 ft.

When creek withdrawals are curtailed as streamflow in White Clay Creek declines below the Delaware River Basin Commission regulated passby flow standard of 14 million gallons per day (mgd), the City releases relatively clear but untreated water from the Newark Reservoir (El. 190 ft msl) through a 3,500 ft long 24-inch ductile iron pipeline (Figure 2) back to the treatment plant (El. 70 ft msl) for distribution to 15,000 customers.

Figure 1. City of Newark surface water supply system along White Clay Creek.

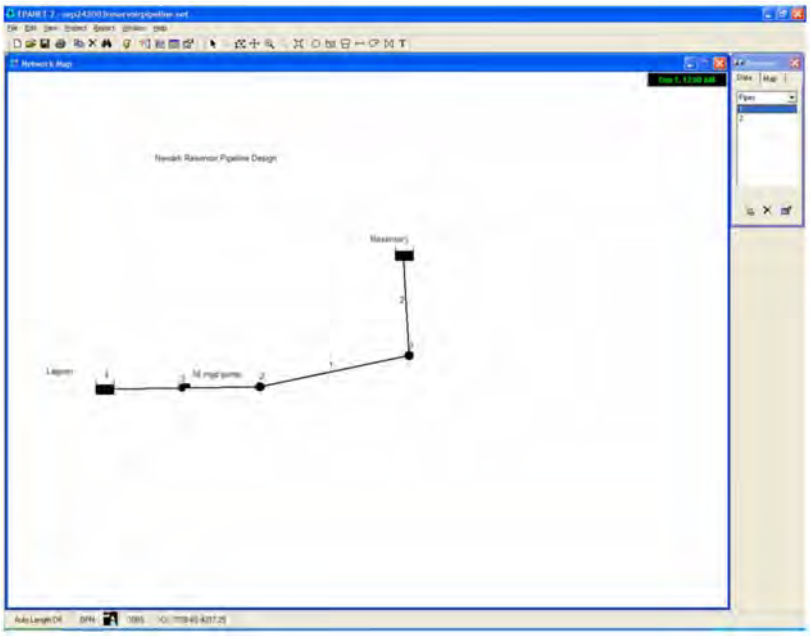
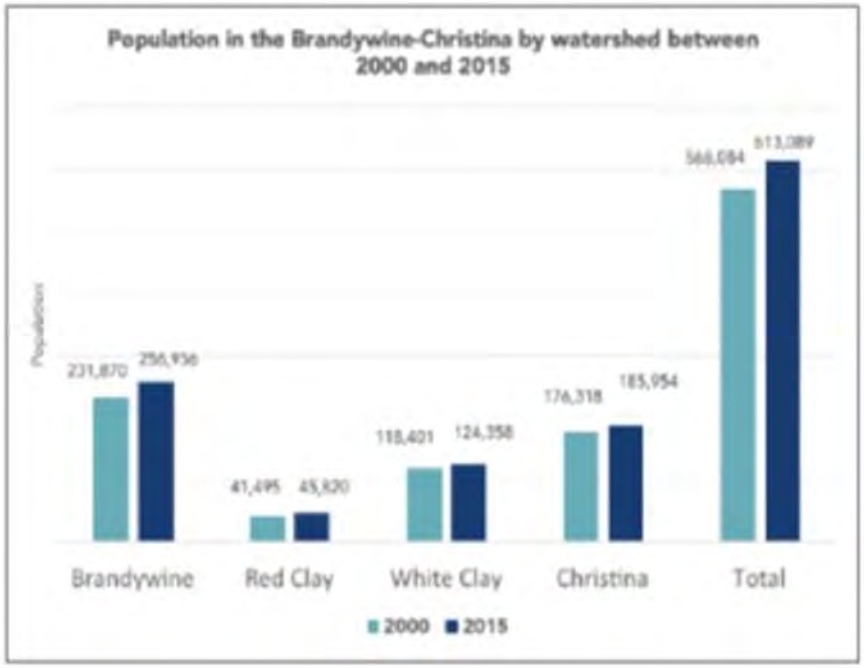


Figure 2. Newark Reservoir pipeline design

2. Watershed Characterization

2.1. Population

Population in the White Clay Creek watershed grew 5% or by 6,000 people from 118,401 in 2000 to 124,358 in 2015 (Figure 3). In the watershed, about 94,000 people (10% of the First State population) live in Delaware, 31,000 live in Pennsylvania, and 4 people live in Maryland.



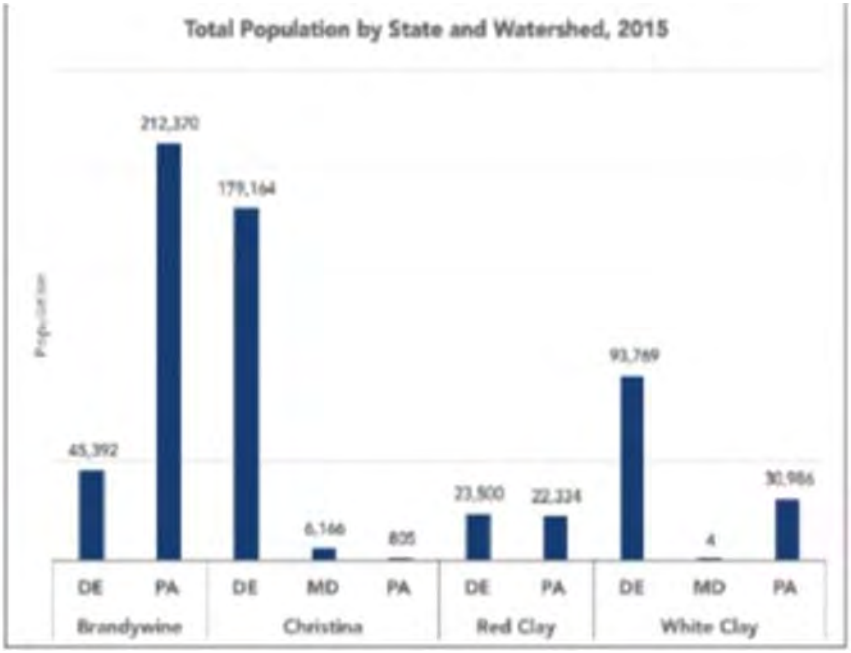


Figure 3. Population in the Brandywine Christina watershed (2015)

2.2. Precipitation/Flooding

Annual precipitation has been increased by 5 inches/year measured at Wilmington Airport since 1960 from 40 in/yr to 46 in/yr by 2015 (Figure 4). The largest floods in the watershed (Table 1 1) were Hurricane Floyd in September 1999 (>200-yr event), an unnamed superstorm in May 2014 (100-yr event), and Hurricane Irene in August 2011 (100-yr event). Peak floods have increased along the White Clay Creek near Newark USGS gage and no floods greater than 10,000 cfs (25-yr event) were recorded before 1988 but 5 floods greater than 10,000 cfs have been recorded since then in 1989, 1999 (Hurricane Floyd), 2003 (Tropical Storm Henri), 2011 (Hurricane Irene), and May 2014 a Nor-easterner (Figure 5).

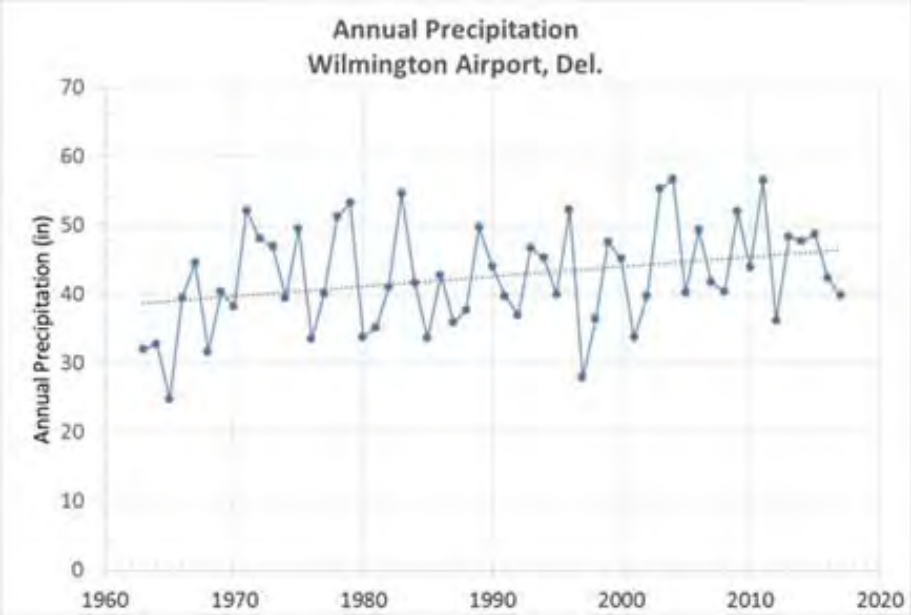


Figure 4. Annual precipitation at Wilmington Airport, Del.

Table 1. High flood events along White Clay Creek

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.

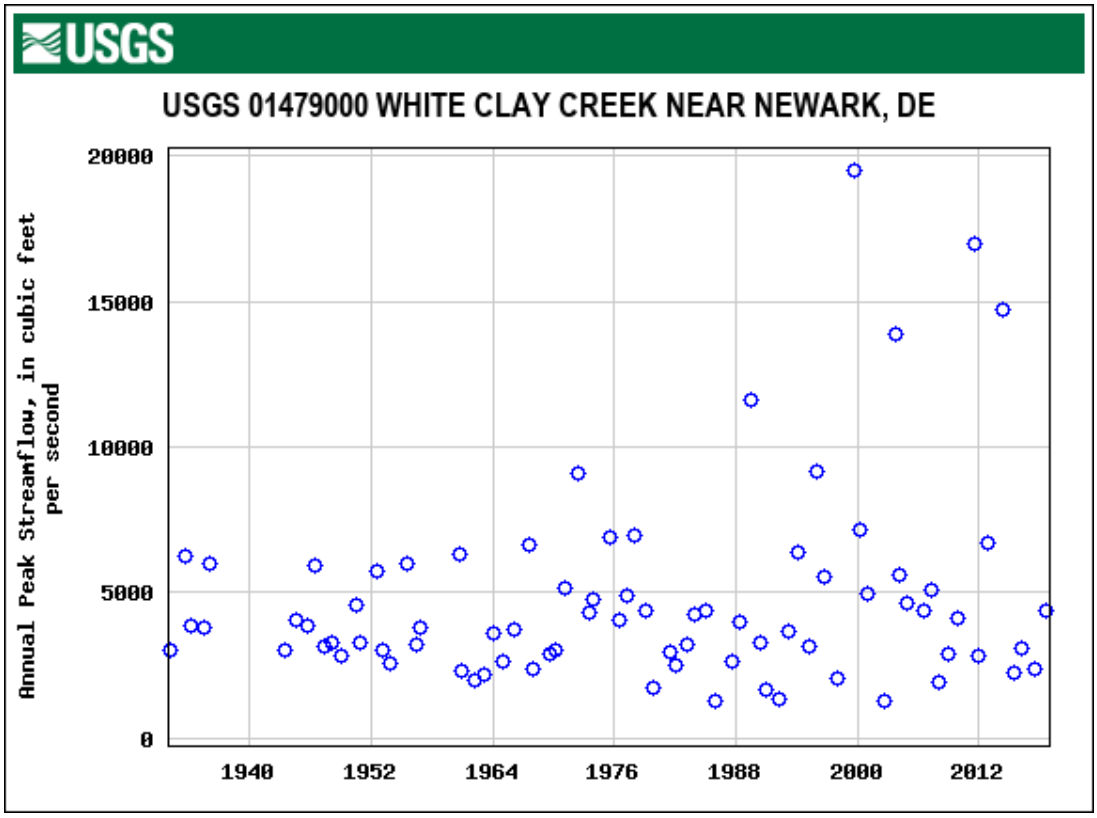


Figure 5. Annual peak streamflow in the White Clay Creek near Newark, DE.

2.3. Economic Value

The White Clay Creek watershed in Delaware and Pennsylvania supports $500 million in annual economic activity and $165 million in ecosystems services from habitat, and over 25,000 million jobs with $550 million in wages (Table 2).

Table 2. 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

2.4. Land Use

Land use in the White Clay Creek is trivided into 1/3 developed, 1/3 agriculture, and 1/3 forest/wetlands (Figure 6). Between 1996 and 2010, developed land grew by 4.6 square miles and was replaced by 1.2 square miles of forest/wetlands and 3.4 square miles of agriculture (Figure 7). Over 15 years, developed land grew by 200 acres/year and forest/wetland loss was 50 acres/year (38 football fields) and agriculture loss was 150 acres/year (115 football fields).

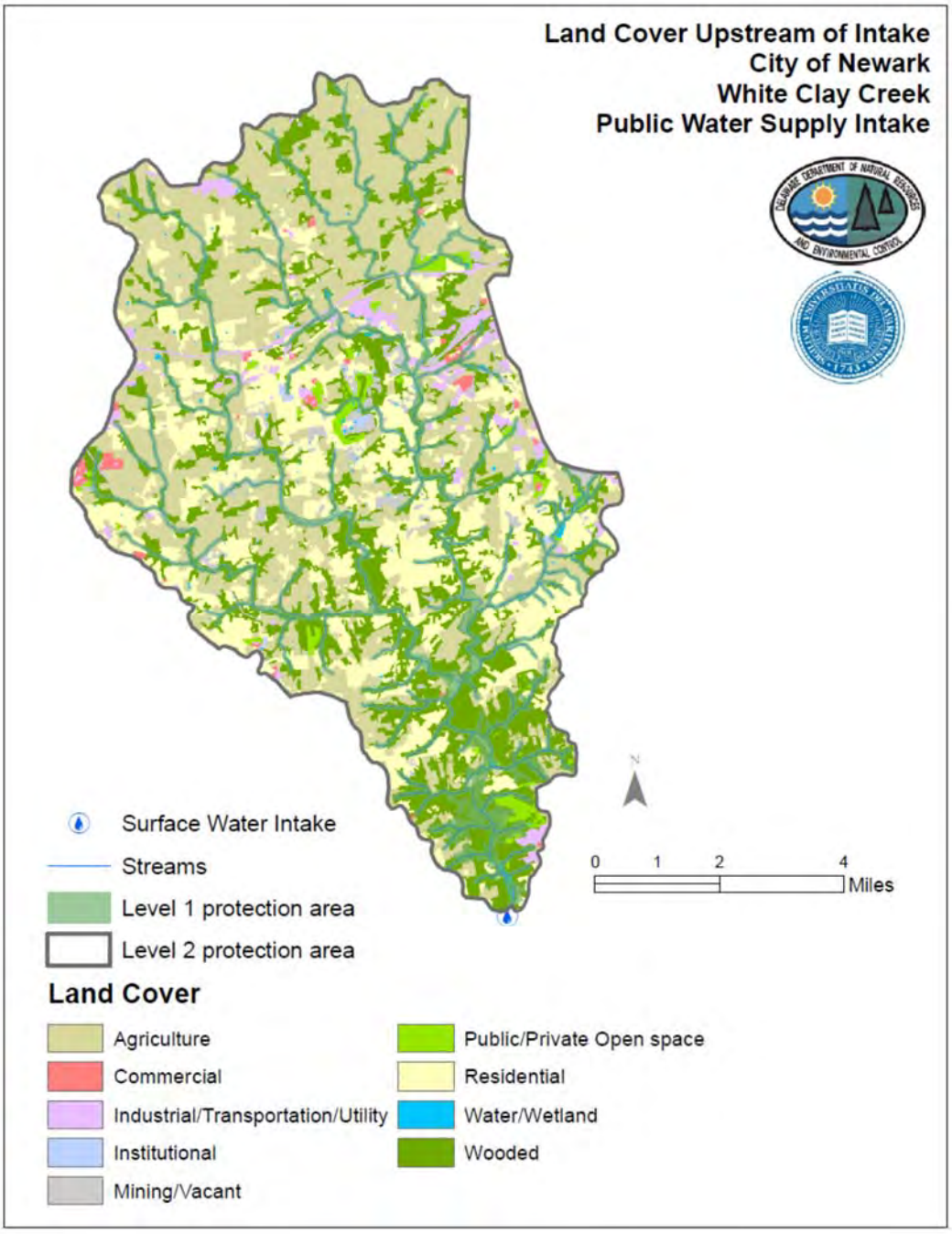


Figure 6. Land cover in White Clay Creek watershed upstream from City of Newark

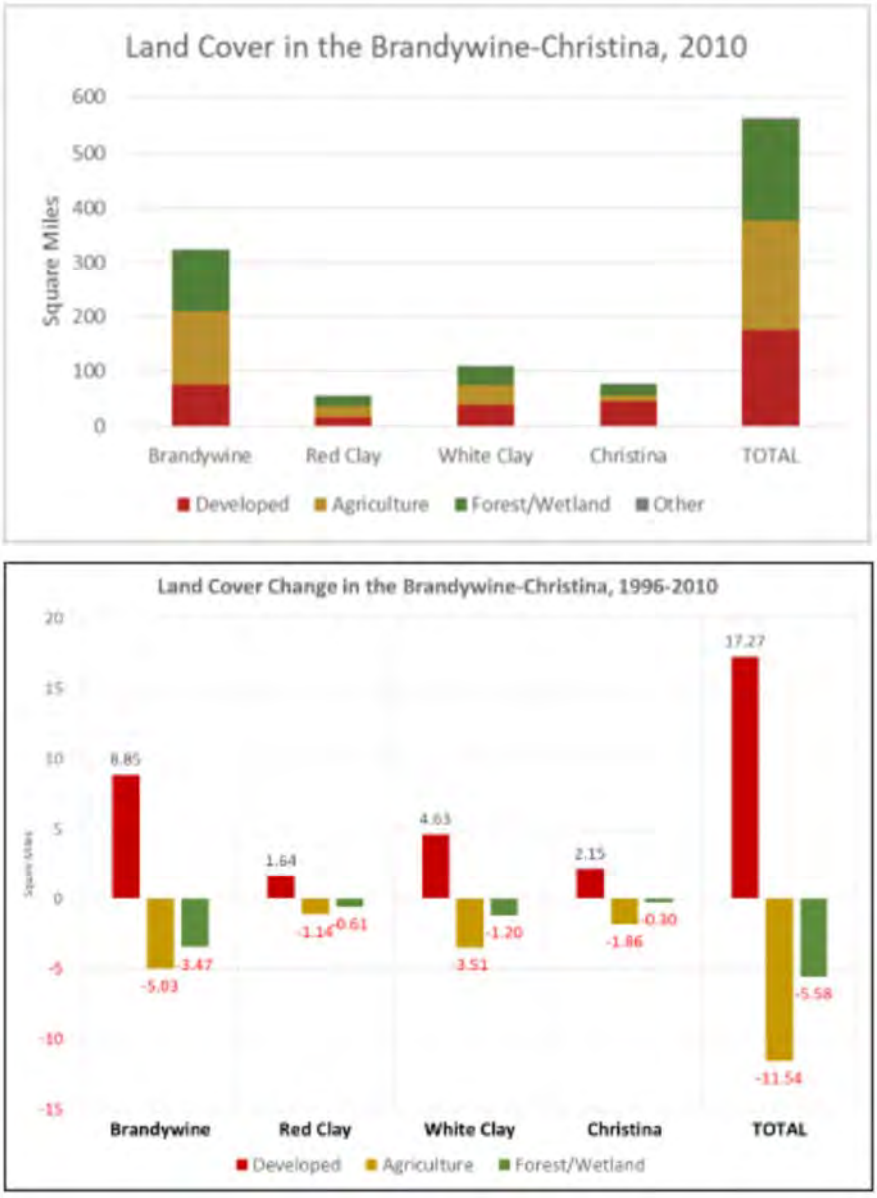


Figure 7. Land cover in the Brandywine-Christina watershed (1996-2010)

2.5. Agriculture

Up to 60% of the White Clay Creek watershed (especially in the headwaters) in Chester County, Pennsylvania is covered by agriculture (Figures 8 and 9). Chester County is Pennsylvania's second most valuable agricultural economy (after Lancaster County) and is ranked 1st in the US in nursery and green house sales. 1st in US in mushroom farming, 22nd in US in horse farming, 6th in PA n dairy and 7th in PA in row crops (Table 3). The essential challenge in managing the White Clay Creek watershed is how to sustain the substantial agricultural economy upstream in

Pennsylvania while ensuring clean drinking water supply the urban/suburban population downstream in Newark, Delaware.

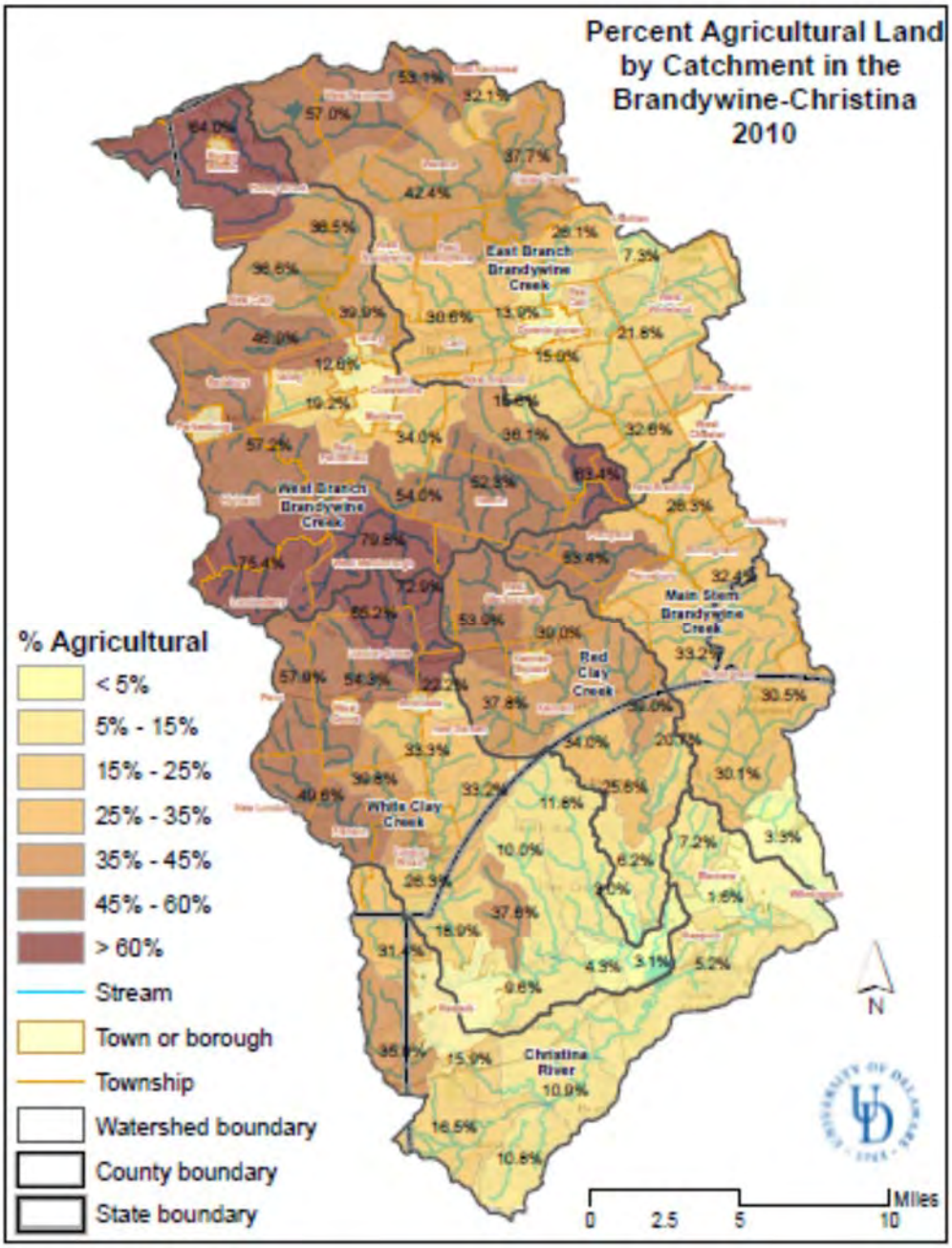


Figure 8. Agricultural land in the Brandywine Christina watershed

Table 3. Economic value of agricultural operations in Chester County, Pennsylvania (Chester County Agricultural Development Council, USDA National Agricultural Statistics Service)

Industry	Economic Value	Rank
Dairy farming	$73 million	6th in PA
Horse farming	$5.2 million	22nd in U.S.
Nursery, greenhouse, floriculture	$79 million	1st in U.S.
Row crops	$8.7 million	7th in PA
Mushroom farming	$412 million	1st in U.S.

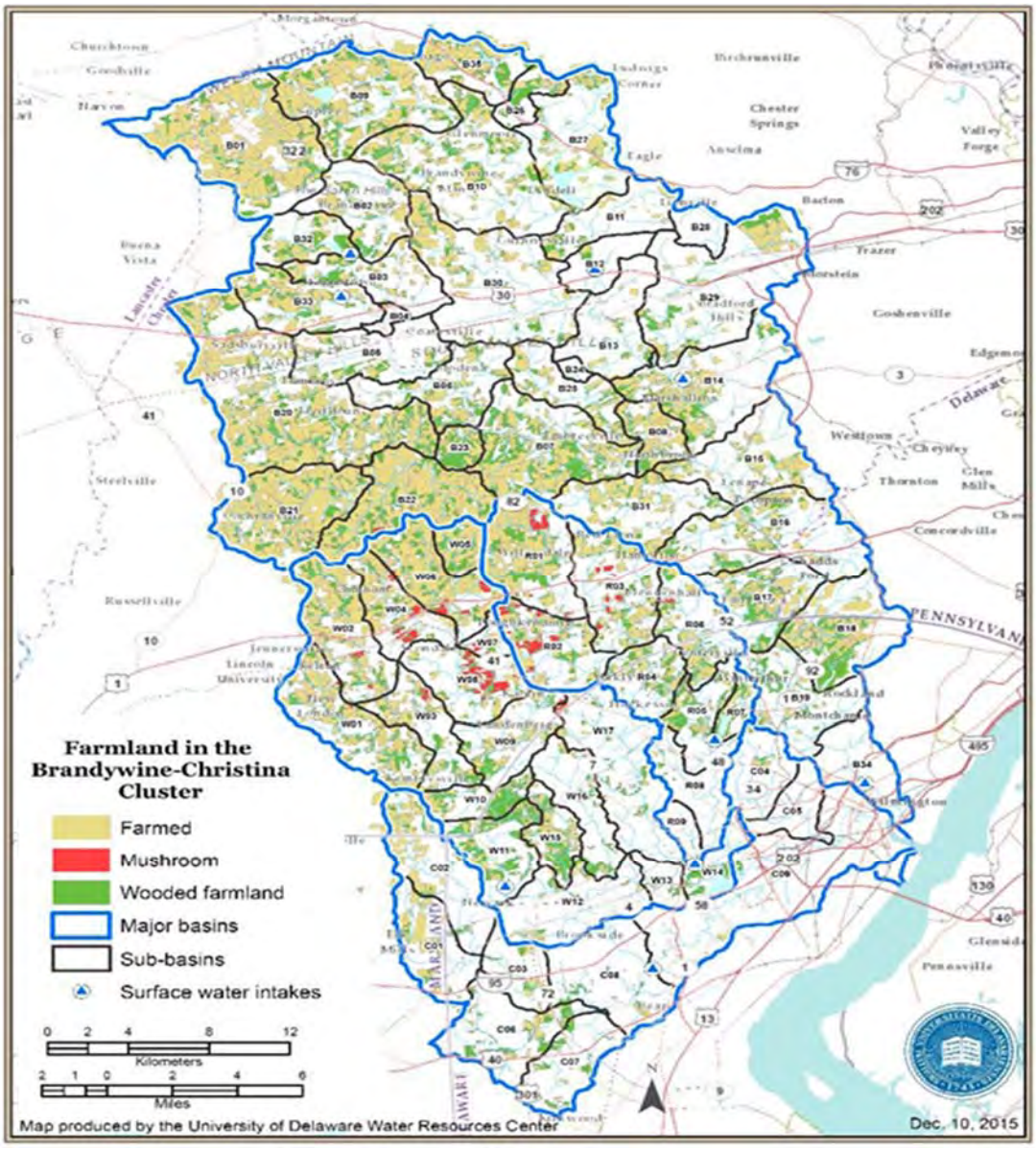


Figure 9. Farmland in the Brandywine Christina watershed

2.6. Farm Patterns

The East Branch headwaters of White Clay Creek are covered by a high density of horse farms and mushroom farms (Figure 10 and 11). The combination of high densities of cattle/dairy and horse farms (manure) coupled with downstream corn/soybean row crop and mushroom farms contribute high loads of pathogens, nitrogen, and sediment to the White Clay Creek that flows down from the East, Middle, and West branches to the Main Stem then to Newark, Delaware.

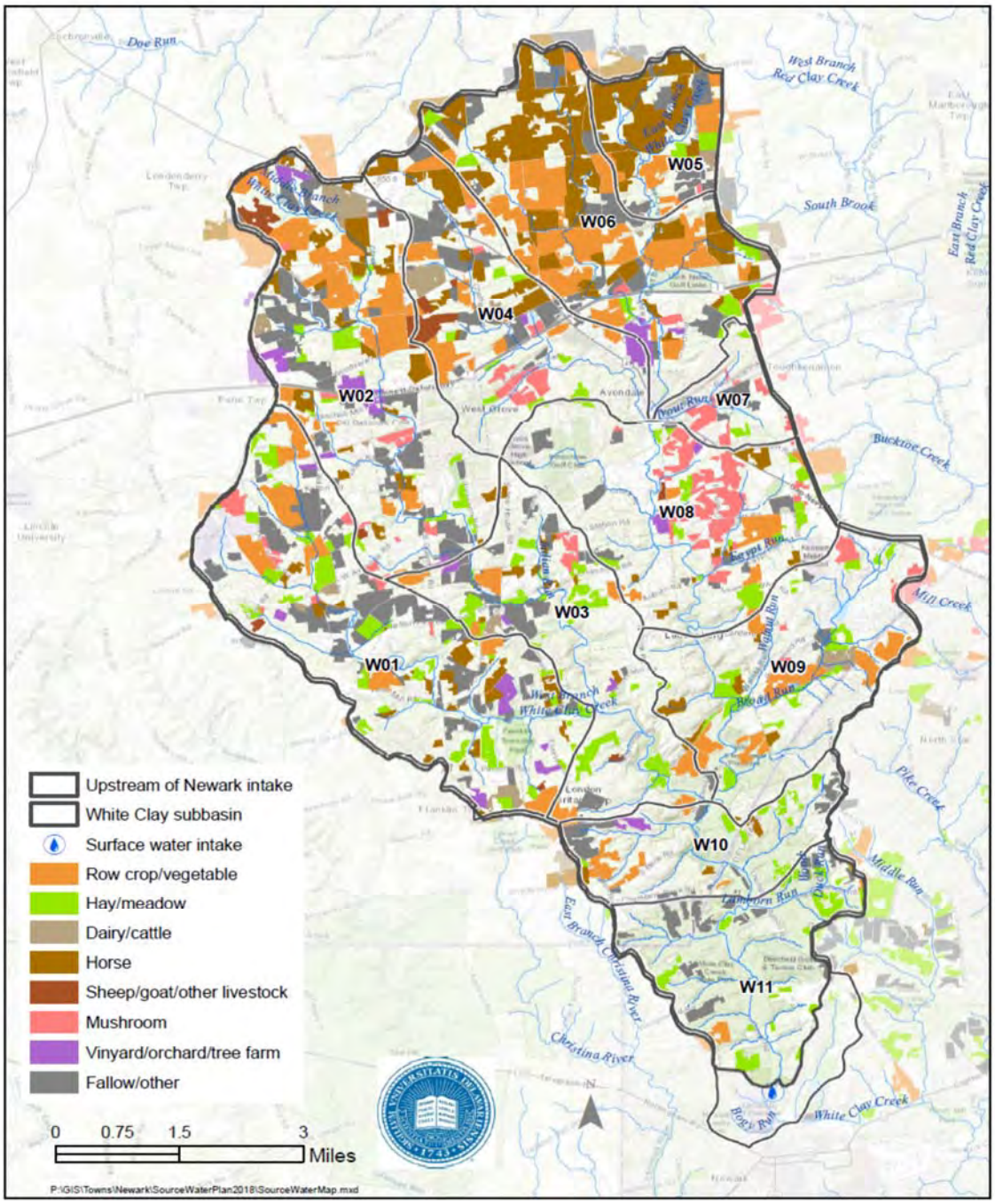


Figure 10. Farm patterns in the White Clay Creek above Newark watershed

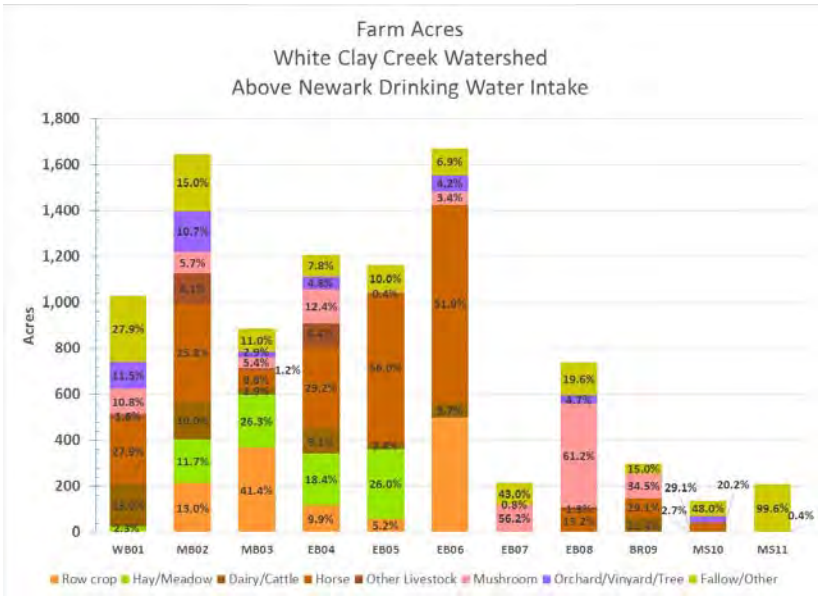


Figure 11. Farm acreage in White Clay Creek above Newark watershed

2.7. SRAT Modeling

The Academy of Natural Sciences SRAT model indicates high yields of nitrogen, phosphorus, and sediment flow from the headwaters into White Clay Creek (Figure 12.

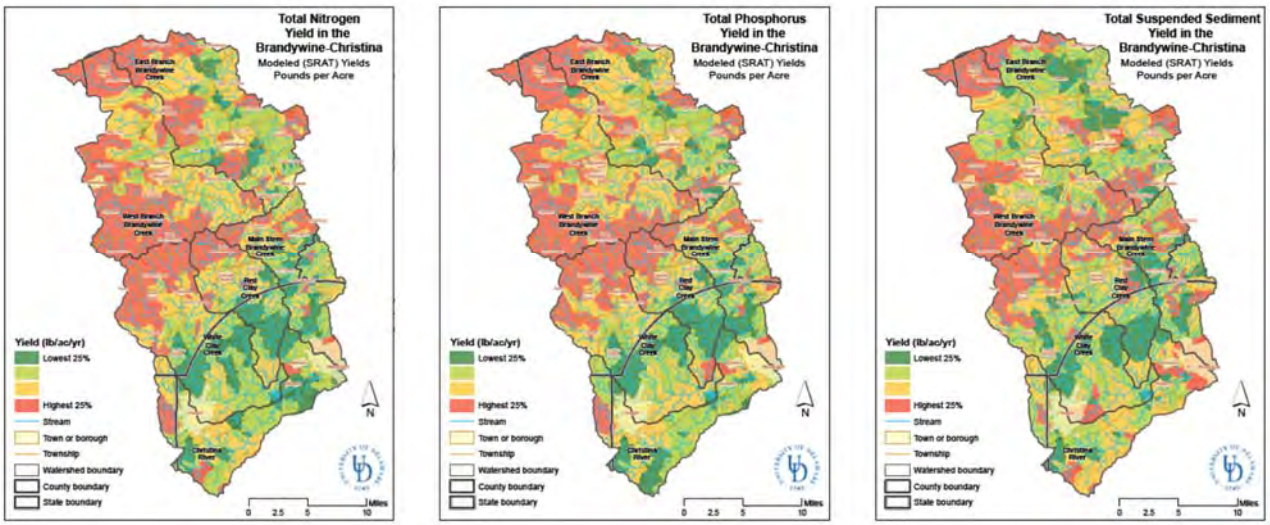


Figure 12. Total pollutant yield in the Brandywine Christina watershed

3. Water Quality

3.1. Monitoring

Since 1970, the DNREC has monitored stream water quality once a month at the White Clay Creek at Chambers Rock Road station (105131) just below the DE-PA stateline (Figure 14).

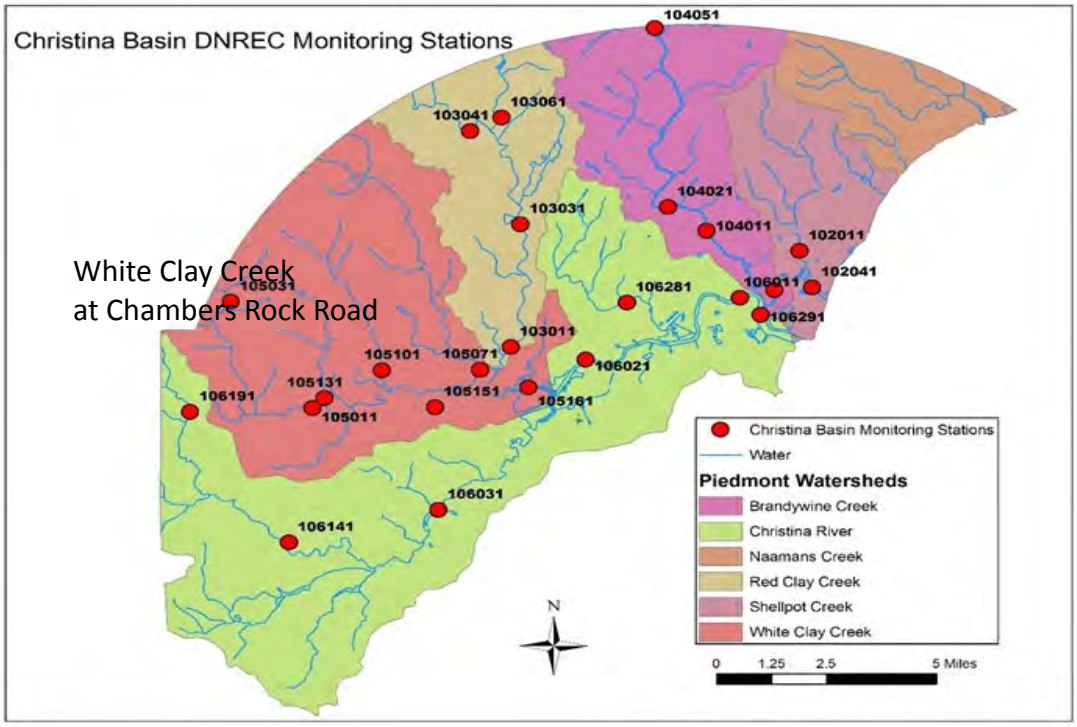


Figure 14. Delaware DNREC stream water quality monitoring stations.

The DNREC stream water quality monitoring network samples the visible pollutants such as dissolved oxygen, enterococcus bacteria, total phosphorus, total nitrogen, and total suspended sediment to compare water quality to Delaware fishable and swimmable water quality standards and goals (Table 4)

Table 4. Delaware stream water quality criteria

Parameter	Criteria	Goal
Dissolved Oxygen	4.0 mg/l	Fishable
Enterococcus Bacteria	100 col./100 ml	Swimmable
Total Phosphorus	0.05-0.10 mg/l	TMDL Target
Total Nitrogen	1.0-2.0 mg/l	TMDL Target
Total Susp. Sediment	20 mg/l	DE Inland Bays

Research students at the University of Delaware Water Resources Center established a water quality monitoring network (Figure 15) in the White Clay Creek watershed in Chester County,

Pennsylvania at Main Stem (MS), East Branch (EB), Middle Branch (MB), West Branch (WB), and Broad Run (BR).

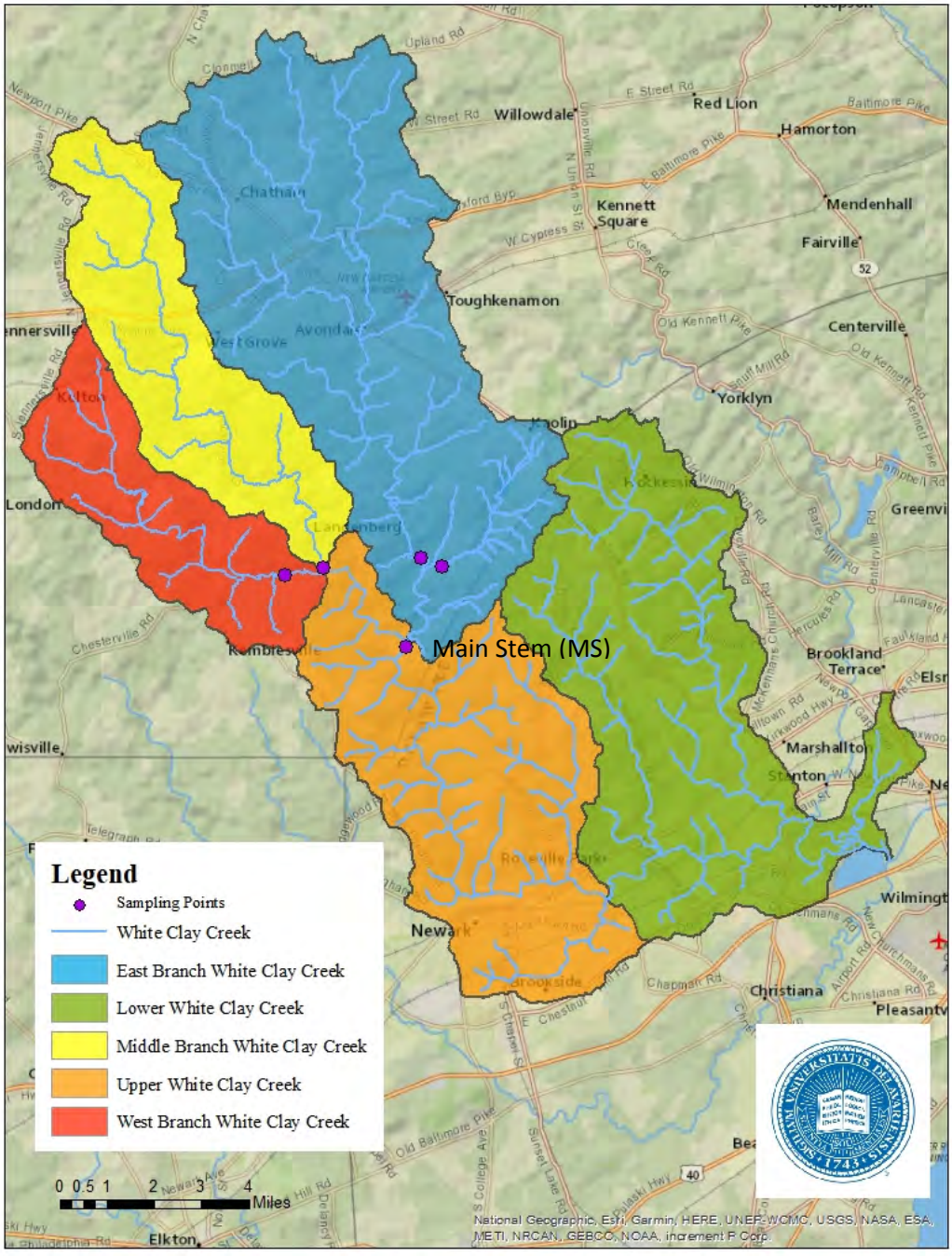


Figure 15. Stream monitoring stations along White Clay Creek.

3.2. Salinity/Chlorides

Salinity is inching up to 100 mg/l of chlorides in the White Clay Creek, up from 75 mg/l recorded in 2000 (Figure 16). Chlorides are converted by multiplying salinity by 0.2. Elevated chloride levels are thought to be due to increases in road salt use by highway department coupled with increased concentration built up in groundwater over the last decade and a half. The EPA has established a secondary drinking water standard for chlorides at 250 mg/l.

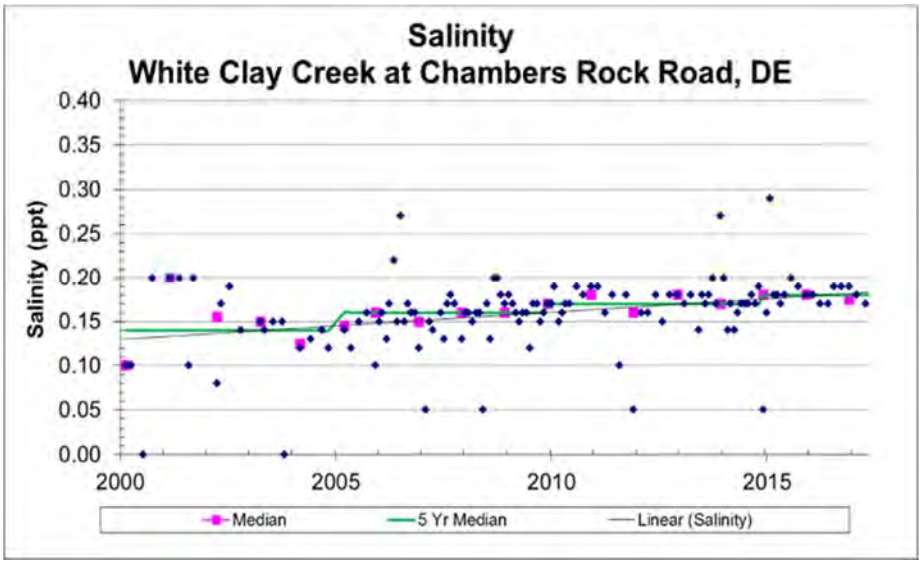


Figure 16. Salinity along White Clay Creek at Chambers Rock Road, Delaware.

The University of Delaware Water Resources Center established a conductivity monitoring network at 21 sites in the White Clay Creek watershed in Delaware and Pennsylvania (Figure 17). Chloride (Cl) concentration can be estimated from conductivity (SC) measurements according to the following equation: $Cl = (SC - 310)(0.28)$. The highest median conductivity levels were detected in the urban Cool Run downstream from Newark, Delaware and Loch Nairn golf course north of Avondale, Pennsylvania and the lowest levels were detected in the forested Middle Run watershed in Delaware and South Bank watershed in Pennsylvania (Figure 1).

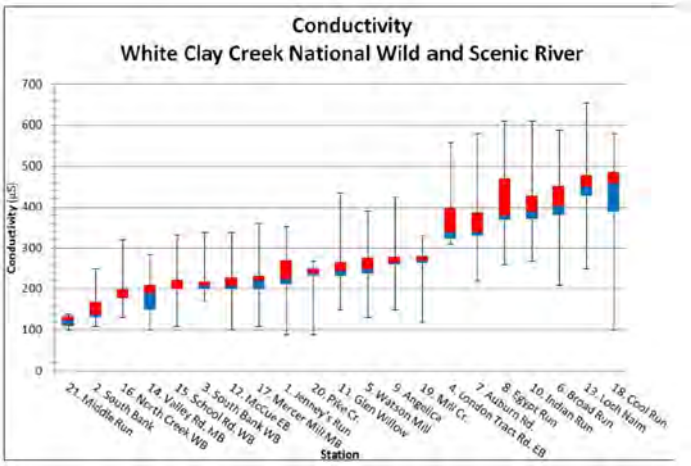


Figure 18. Conductivity monitoring sites in the White Clay Creek watershed

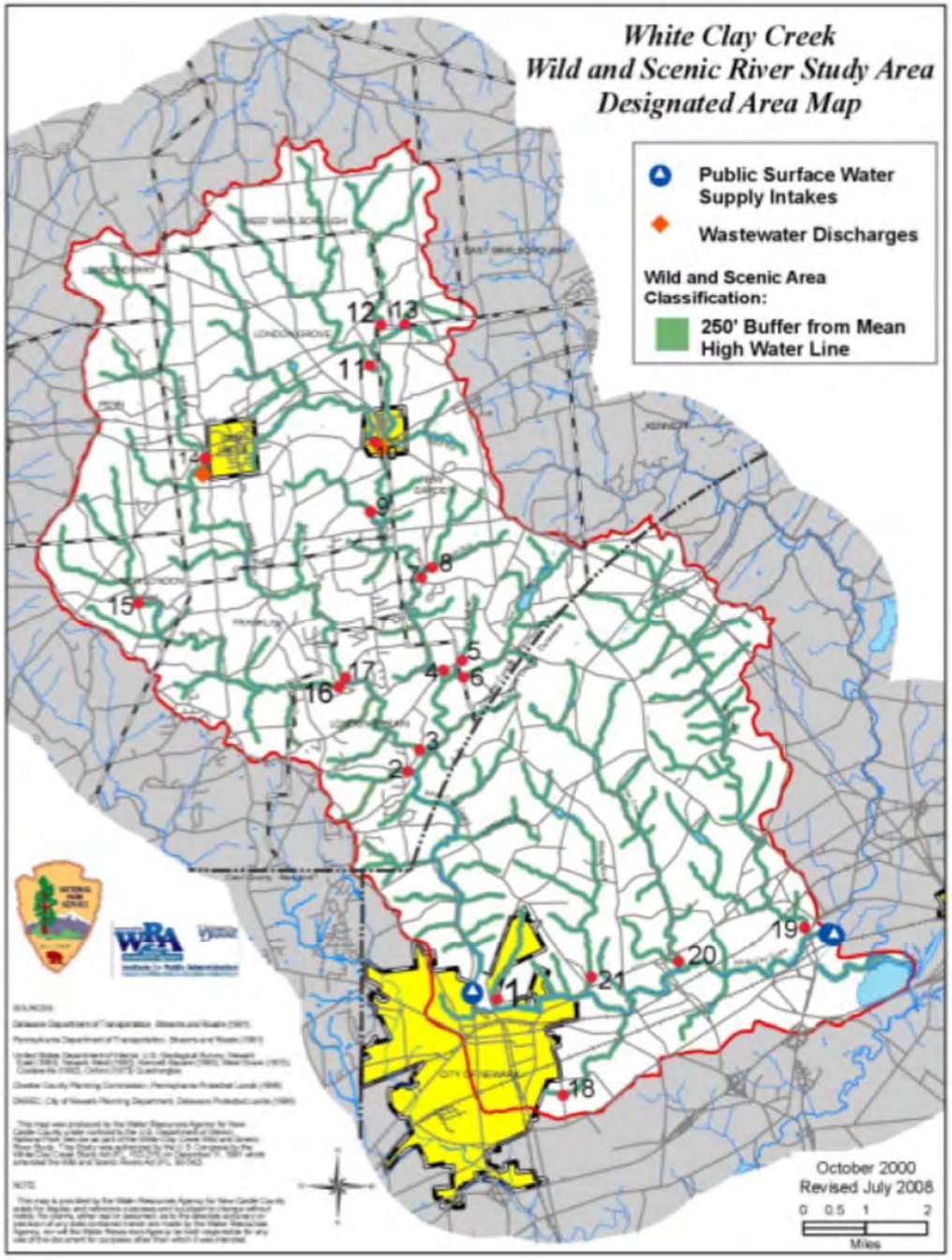


Figure 18. Conductivity monitoring sites in the White Clay Creek watershed

2.3. Dissolved Oxygen

Dissolved oxygen measured in White Clay Creek at Chambers Rock Road at the DE/PA stateline has increased by 2 mg/l since 1995 and is well above the 4 mg/l fishable standard (Figure 19).

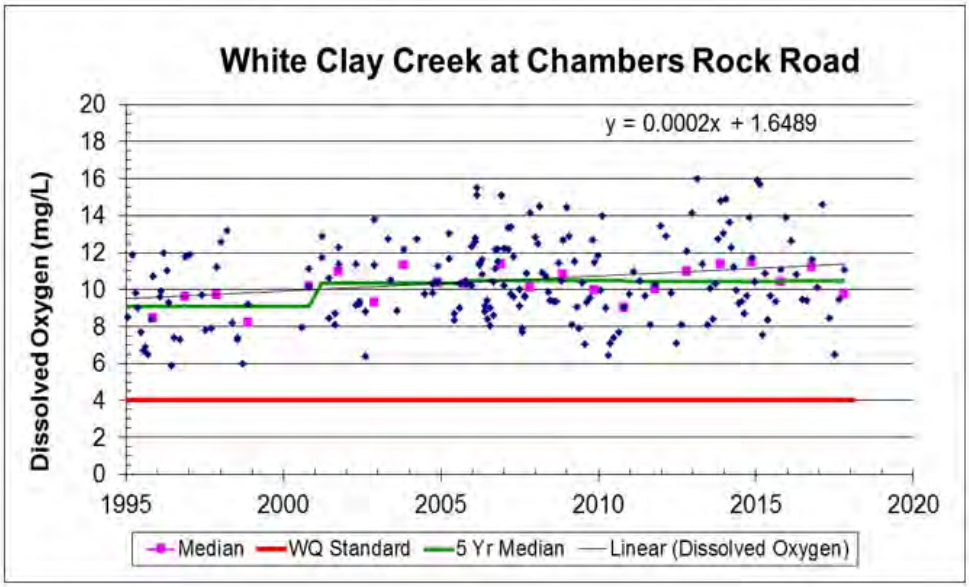


Figure 19. Dissolved oxygen along White Clay Creek at Chambers Rock Road, Delaware

2.4. Bacteria

Enterococcus bacteria levels are declining and White Clay Creek meets the Delaware swimmable standard of 100 cfu/100 ml 3 to 5 days after storms (Figure 20). The White Clay Creek is not swimmable due to high bacteria levels in the couple of days following storms.

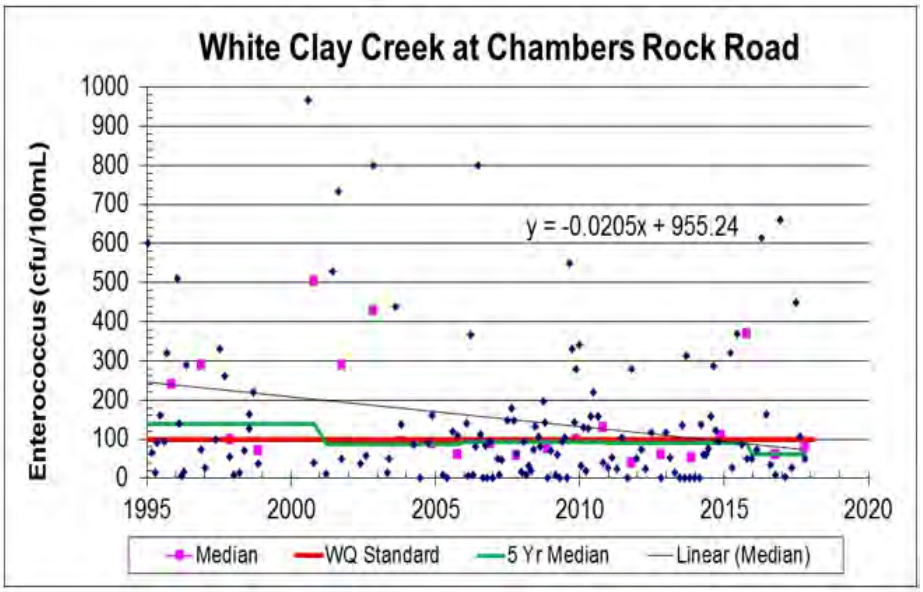


Figure 20. Enterococcus bacteria along White Clay Creek at Chambers Rock Road, Delaware

2.5. Phosphorus

Due to ban on phosphate detergent, farm best management practices, and phosphorus removal installed at Avondale and West Grove wastewater treatment plants in Pennsylvania, phosphorus

has declined since 1995 to at or below the 0.05 mg/l target level set by the Delaware DNREC (Figure 21). Should the phosphorus decline below 0.05 mg/l continue for at least 5 consecutive years, then the DNREC may consider delisting the White Clay Creek as impaired for phosphorus (Figure 22).

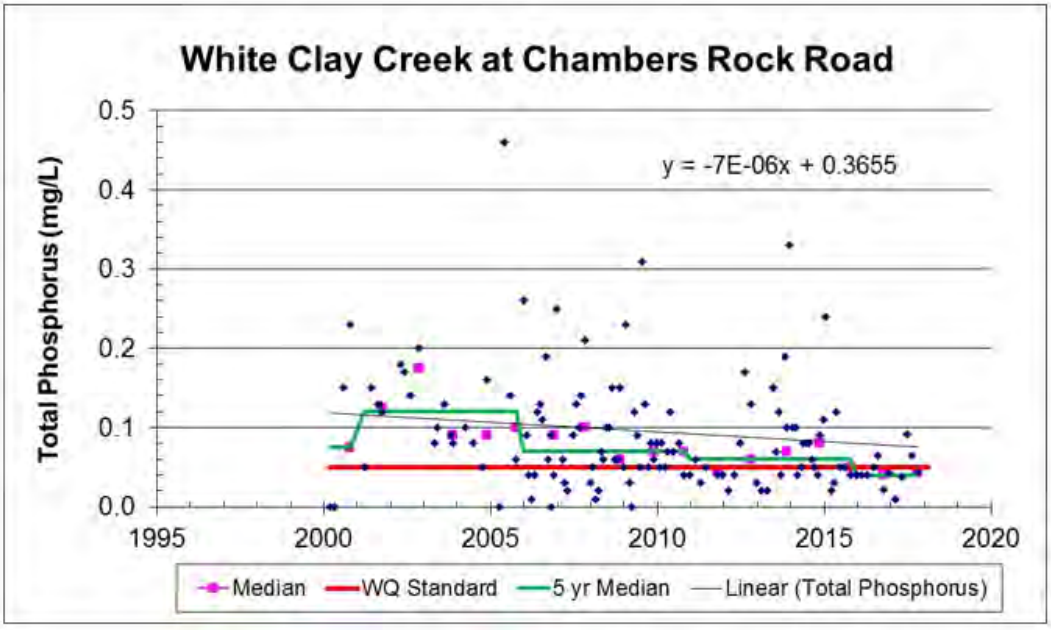


Figure 21. Total phosphorus along White Clay Creek at Chambers Rock Road, Delaware.

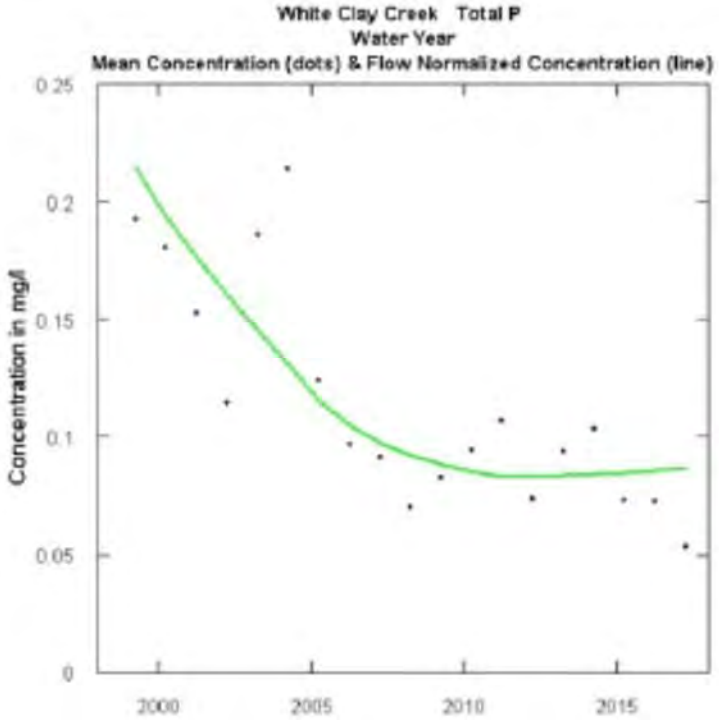


Figure 22. Total phosphorus along the White Clay Creek at Chambers Rock Road, Delaware

2.6. Nitrogen

High nitrogen levels in White Clay Creek are a crux issue and are a concern to the City of Newark downstream. Nitrogen levels at White Clay Creek near Strickersville, PA and just downstream at Chambers Rock Road in Delaware are 4 to 5 times higher than the TMDL target of 1 mg/l but have declined over the last 5 to 10 years (Figure 23). Total nitrogen has declined from 4 mg/l in 2000 to 3 mg/l by 2018 (Figure 24 and 25). Nitrogen levels are higher in the East Branch than Middle Branch, West Branch, and Main Stem of White Clay Creek (Figure 26 and Table 5). High nitrate nitrogen levels have been measured along tributaries of White Clay Creek (Figures 27 and 28) at Broad Run (4 to 5 mg/l), Egypt Run (11 mg/l), Hickory Hill Mill Creek (5 mg/l), and Middle Run (2 to 4 mg/l)

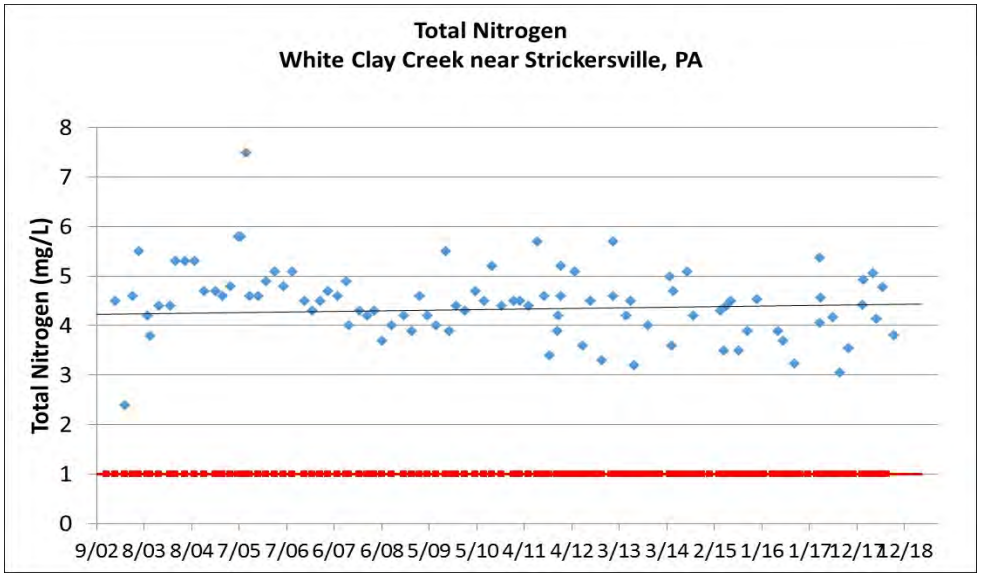


Figure 23. Total nitrogen along the White Clay Creek near Strickersville, Pennsylvania.

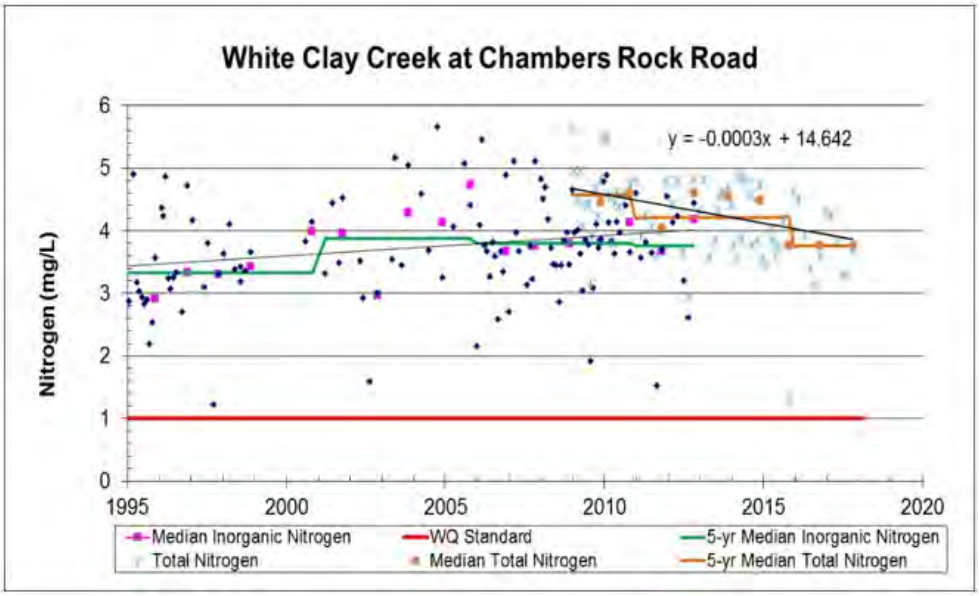


Figure 24. Nitrogen measured along White Clay Creek at Chambers Rock Road, Delaware

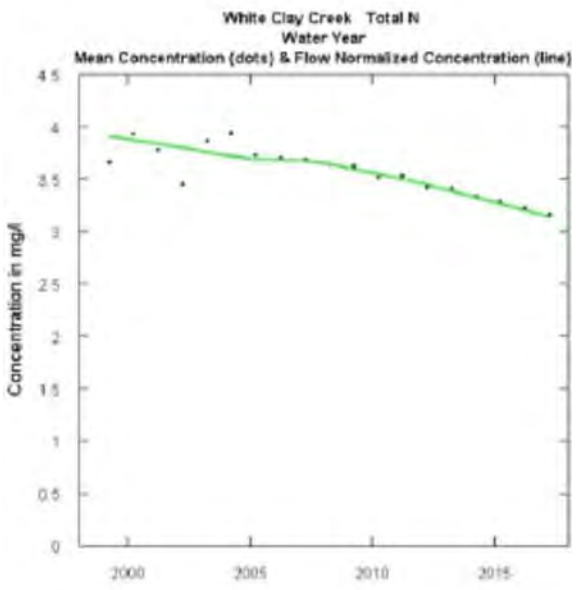


Figure 25. Total nitrogen trend along White Clay Creek at Chambers Rock Road, Delaware

Table 5. Total nitrogen trend along White Clay Creek at Chambers Rock Road, Delaware

Monitoring Site ID	Site Description	Data used start year	Data used end year	Concentration change from 2008-2017 (mg/l)	Improving/ Worsening Trend
103031	Red Clay Creek at Lancaster Pike (Rt. 48)	1999	2017	-0.43	Improving
104021	Brandywine Creek at New Bridge Rd. (Rd. 279)	1999	2017	-0.53	Improving
105151	White Clay Creek at Delaware Park Blvd.	1999	2017	-0.50	Improving
106141	Christina River at Sunset Lake Rd. (Rt. 72)	1999	2017	-0.47	Improving

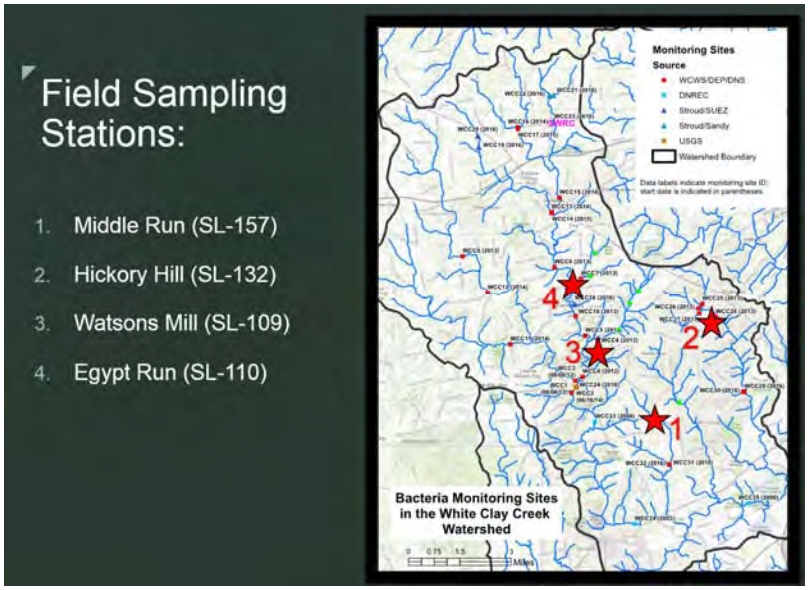


Figure 26. Field sampling stations along tributaries of White Clay Creek

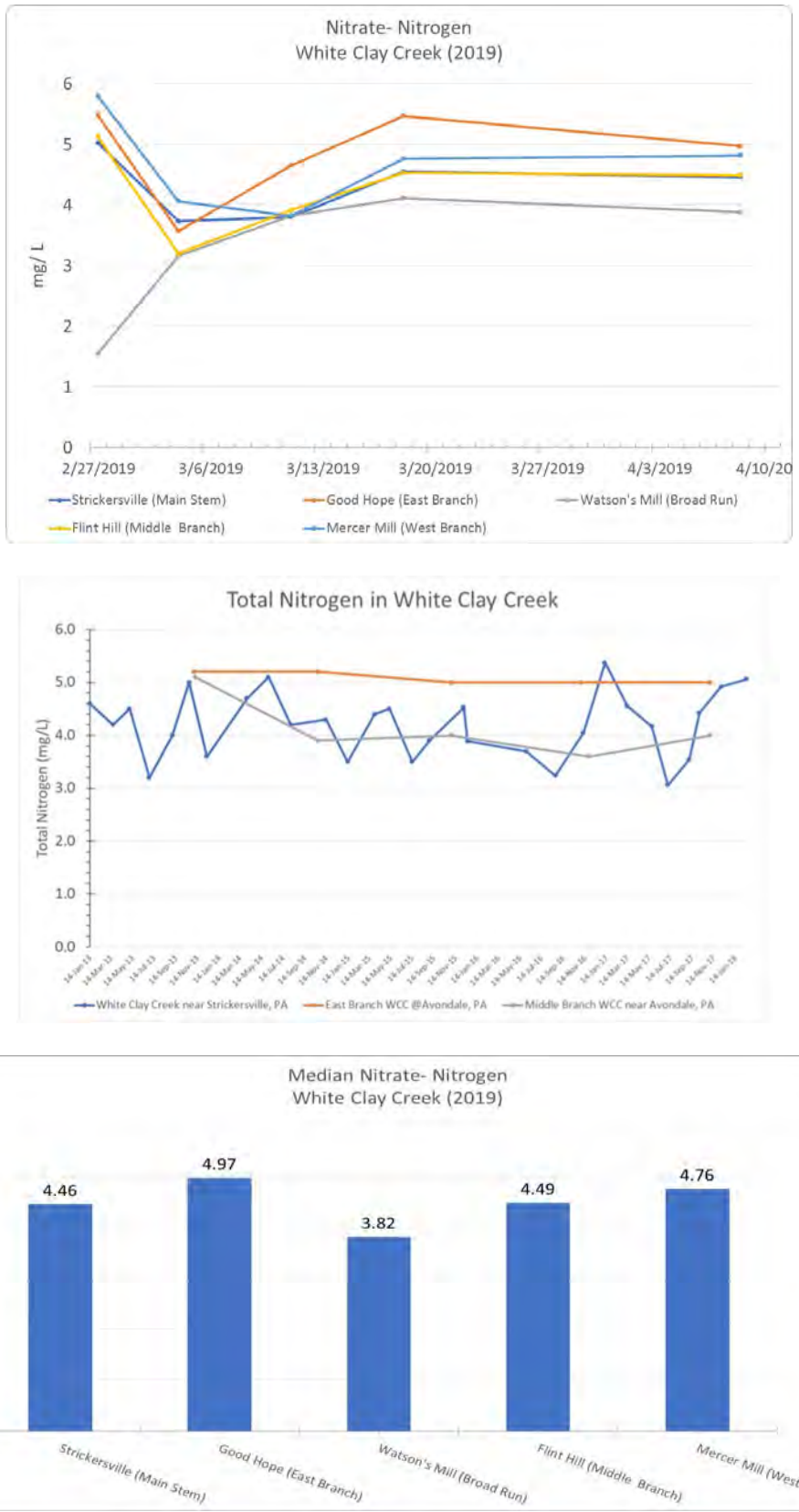
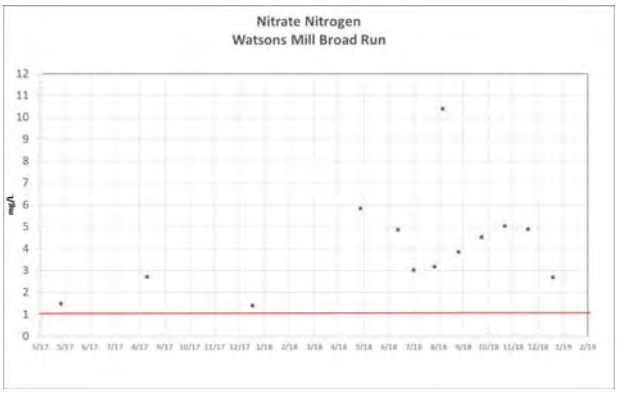
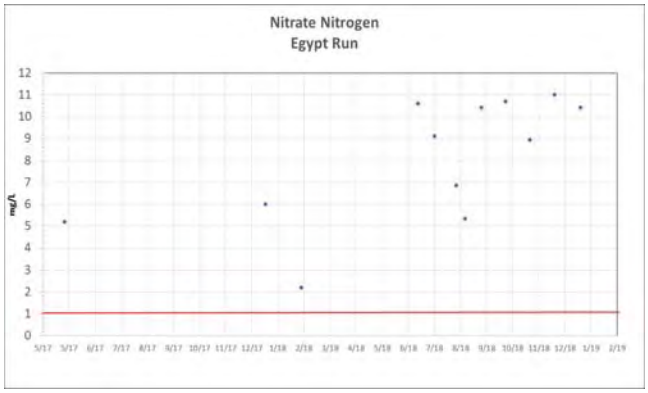
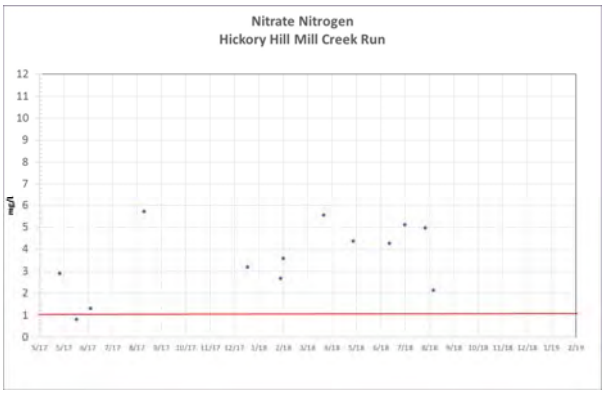


Figure 27. Nitrogen measured in the branches and main stem of White Clay Creek







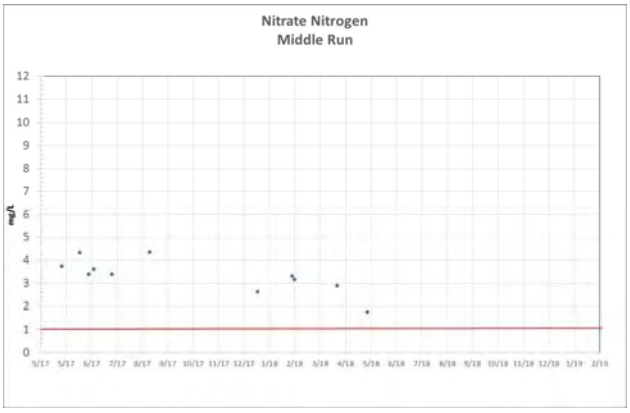


Figure 28. Nitrate nitrogen monitored along White Clay Creek tributaries

3.7. Turbidity

The City of Newark curtails water treatment withdrawals when turbidity exceeds 20 FNU along White Clay Creek. Measured at the White Clay Creek near Strickersville USGS gage along the Main Stem in Pennsylvania about 5 miles upstream from Newark in Delaware, turbidity exceeds 20 FNU about 10 to 30 days per year between 2011 and 2019 (Figure 29). The highest turbidity levels of 21 stations monitored by the University of Delaware Water Resources Center were recorded at Mercer Mill Run, Indian Run, and Valley Road. (Figure 30).

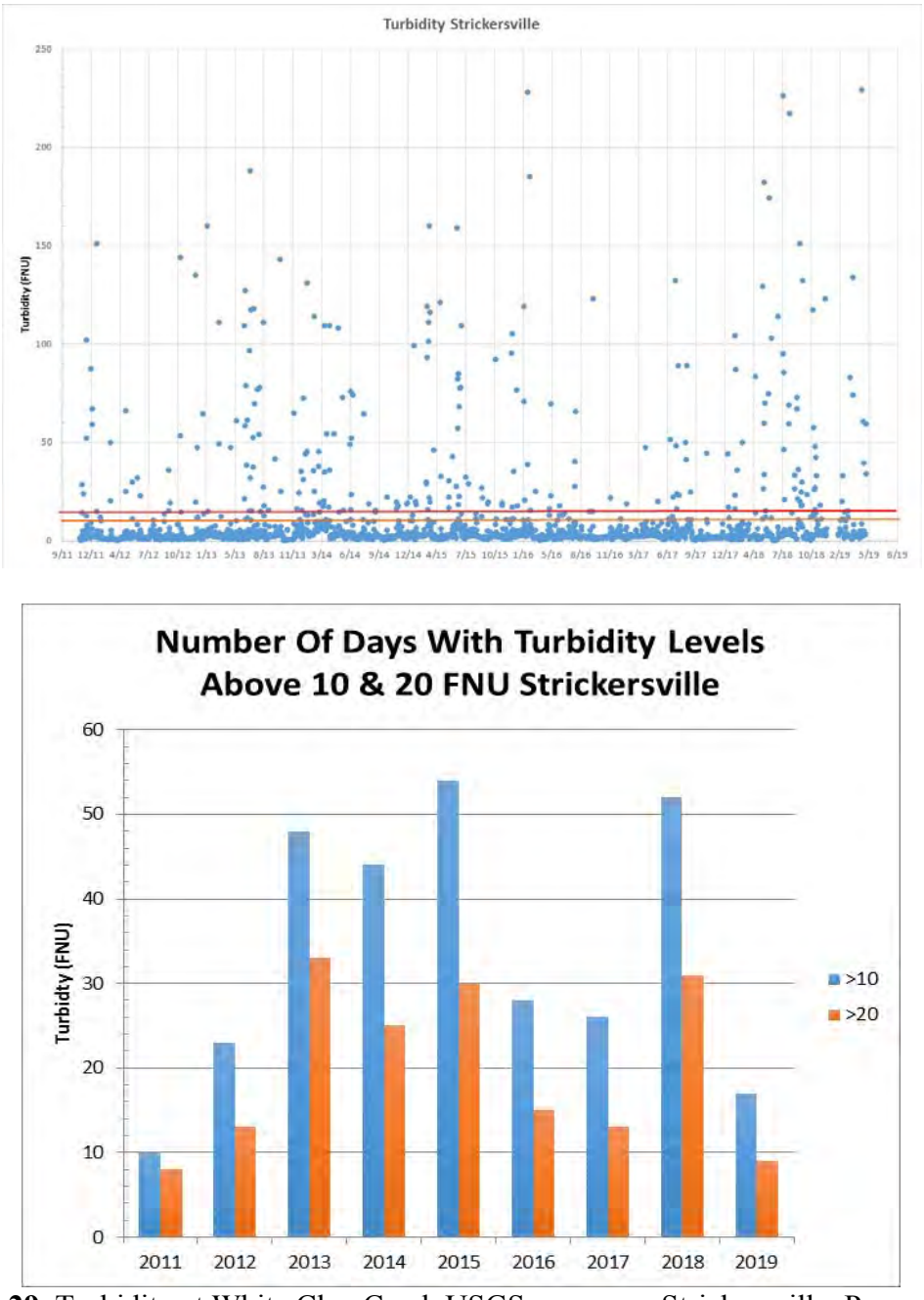


Figure 29. Turbidity at White Clay Creek USGS gage near Strickersville, Pennsylvania

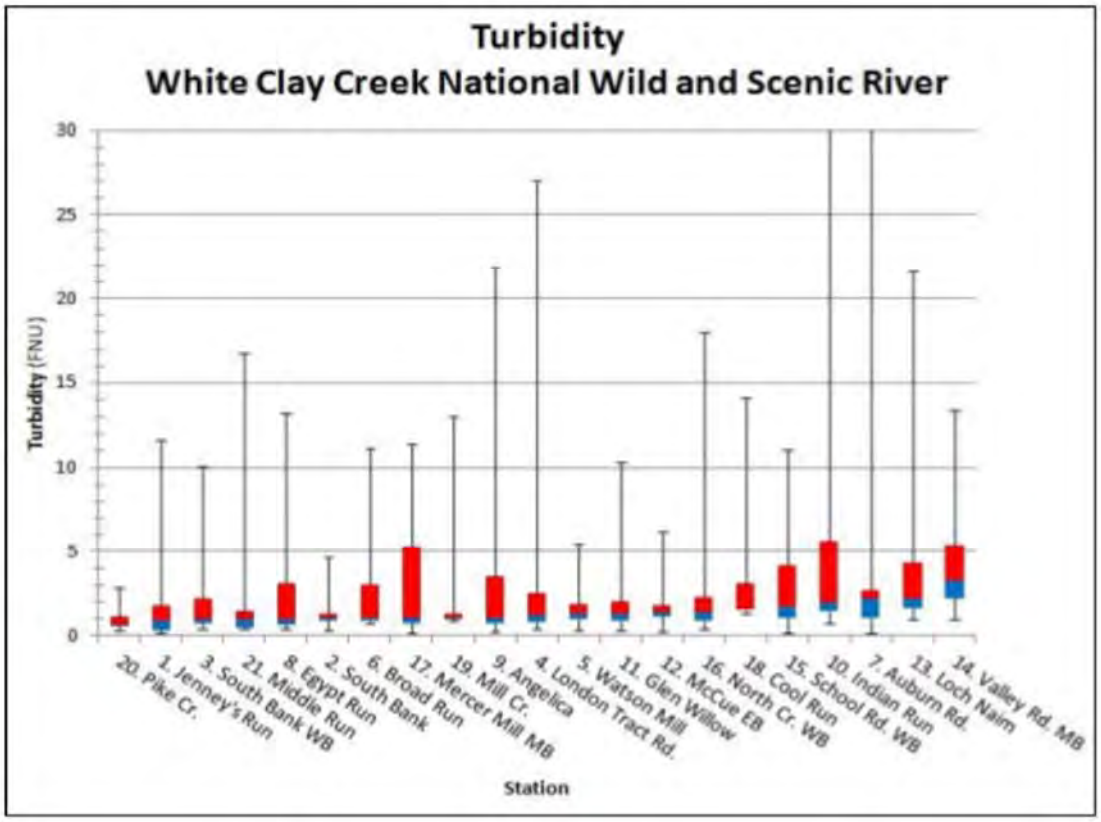


Figure 30. Turbidity White Clay Creek National Wild and Scenic River

3.8. Sediment

Sediment levels measured along White Clay Creek at Chambers Rock Road at the DE/PA stateline have declined but are still high during and just after storms and high flow events (Figure 26). Suspended sediment loads recorded at the White Clay Creek at Strickersville just upstream from the DE/PA stateline are measureable higher than loads recorded in the east and west branches of Brandywine Creek (Figure 27). High sediment levels were recorded along Mill Run and Egypt Run in Pennsylvania (Figure 28). Turbidity (T), a measure of water clarity, is closely related to total suspended sediment (TSS) though the following relationship (Figure 29) where:

$TSS = 3.2(T) - 42.5.$

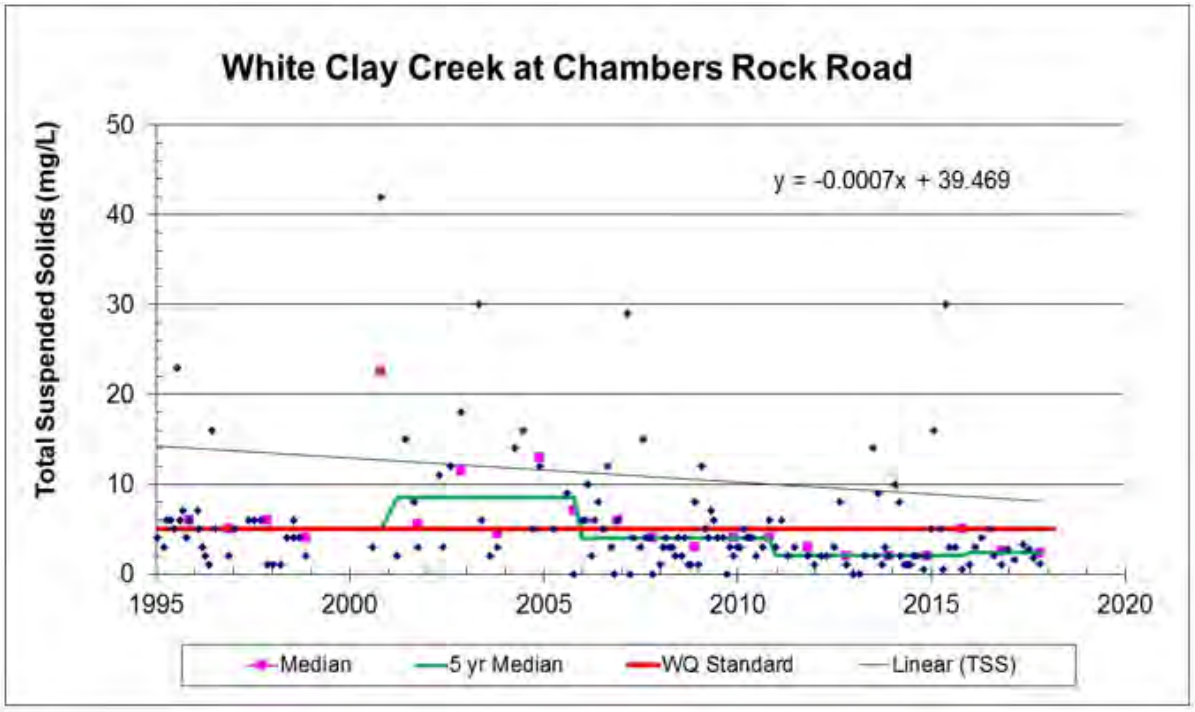


Figure 26. Sediment levels along White Clay Creek at Chambers Rock Road, Delaware

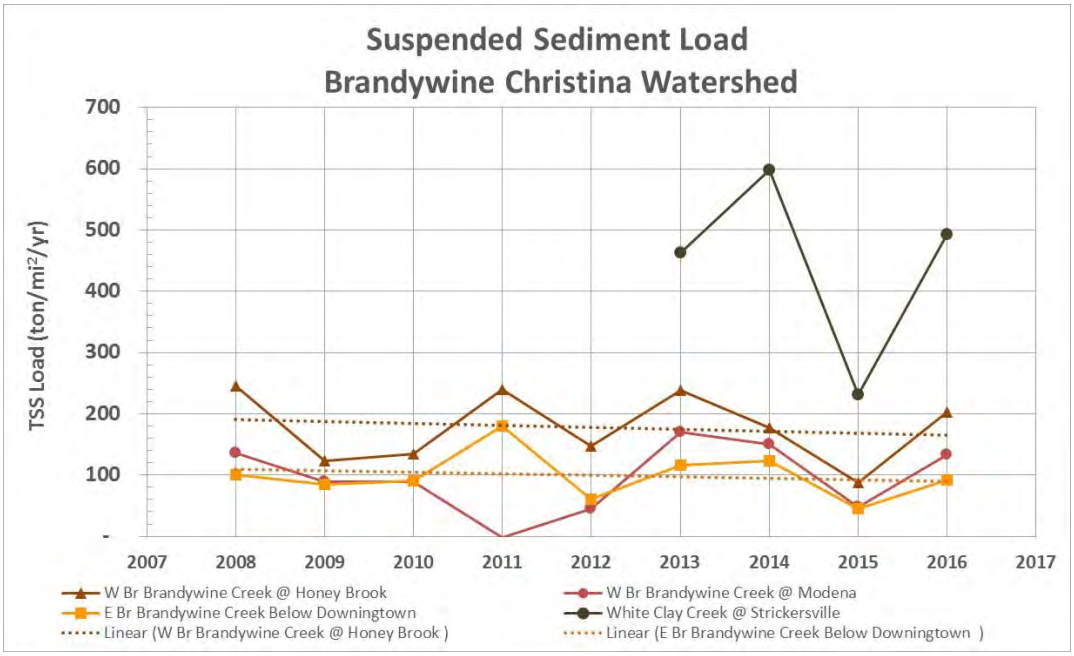


Figure 27. Suspended sediment loads in the Brandywine Christina watershed since 2008.

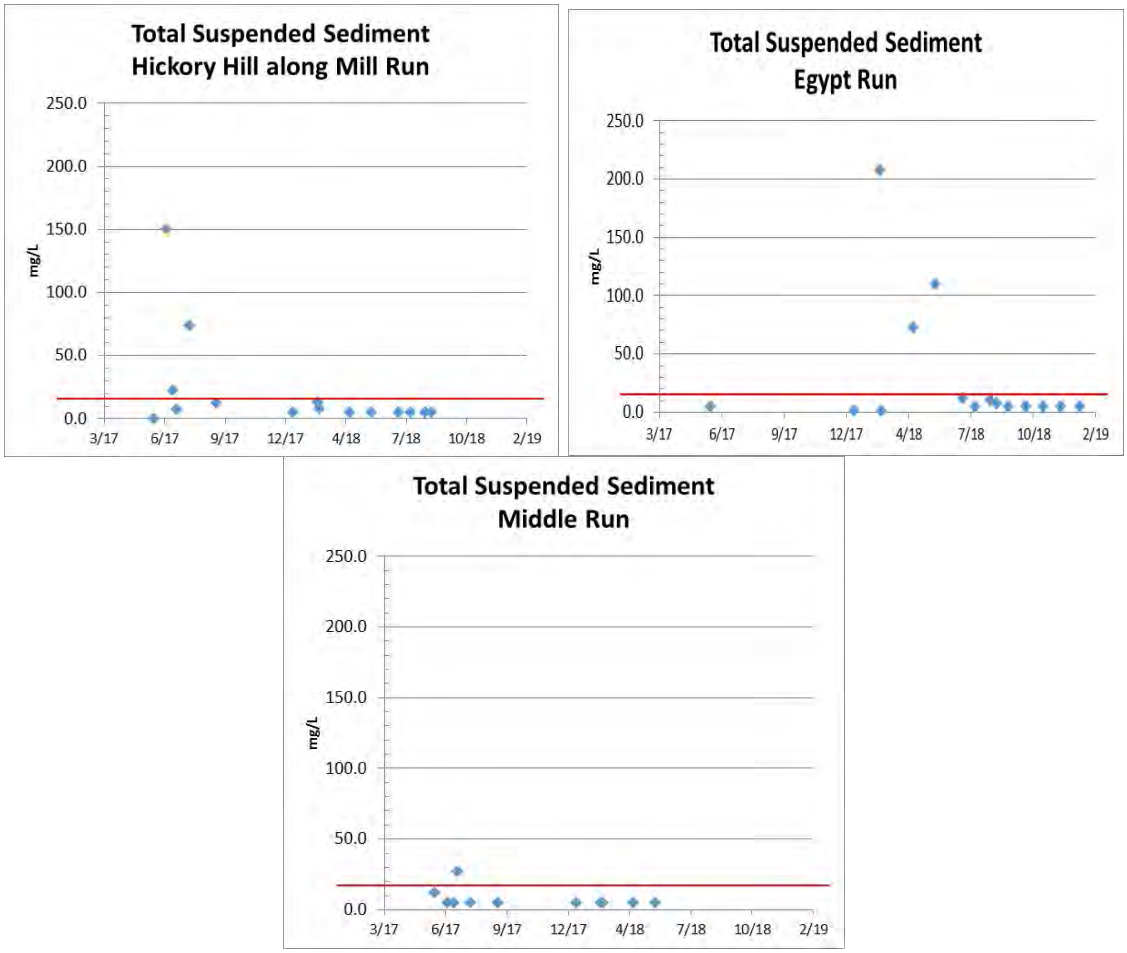


Figure 28. Total suspended sediment measured Mill Run, Egypt Run, and Middle Run

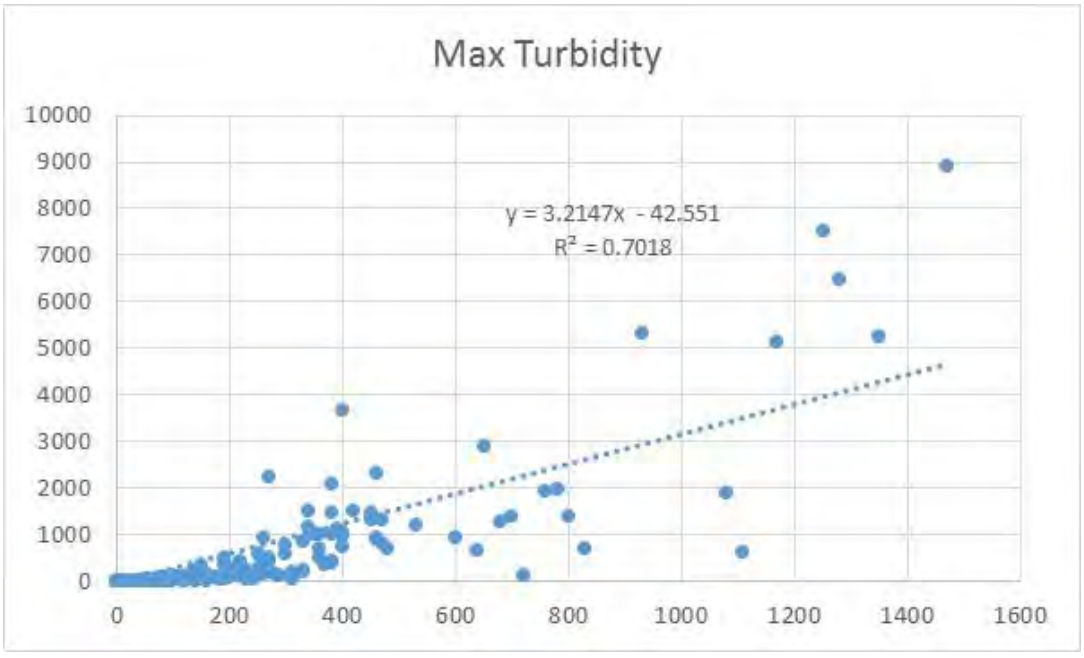


Figure 29. Turbidity vs. suspended sediment along White Clay Creek at Strickersville, PA

3.9. Sediment Fingerprint

To identify the source of high turbidity and sediment loads, University of Delaware research students sampled soils at farms and streambanks along the East Branch, Middle Branch, West Branch, and Main Stem of White Clay Creek on March 4, March 11, March 18, and April 8, 2019. Soil samples were collected and transported to the UD soil laboratory at the College of Agriculture and Natural Resources for sieve analysis and classification of soil texture. The analysis indicates that the texture of the soils from both locations are similar ranging from 60% - 80% fine sand in farm topsoil and stream bank soil (Figures 30 and 31 and Table 6 and 7).

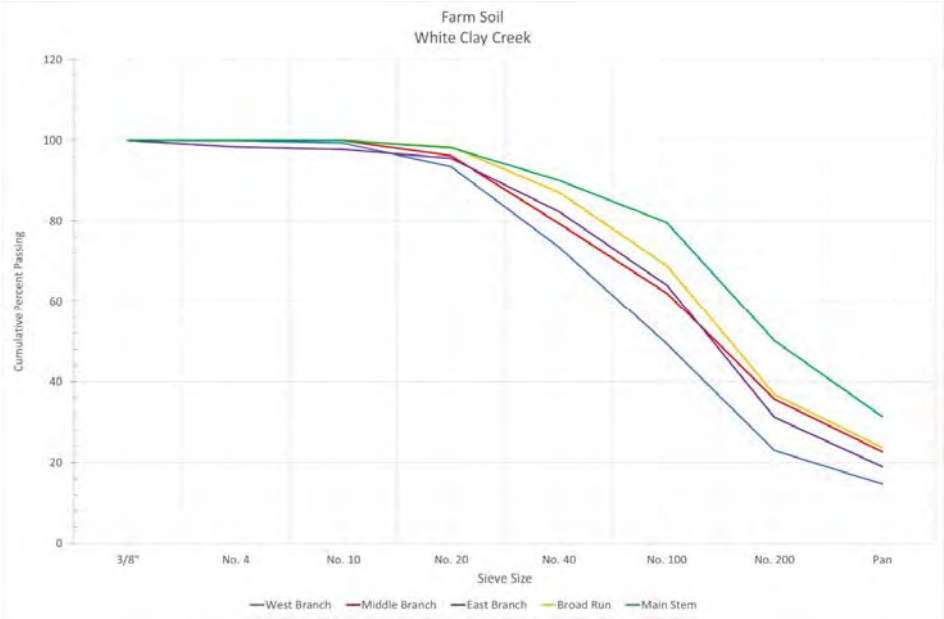


Figure 30. Farm soil textural class along White Clay Creek

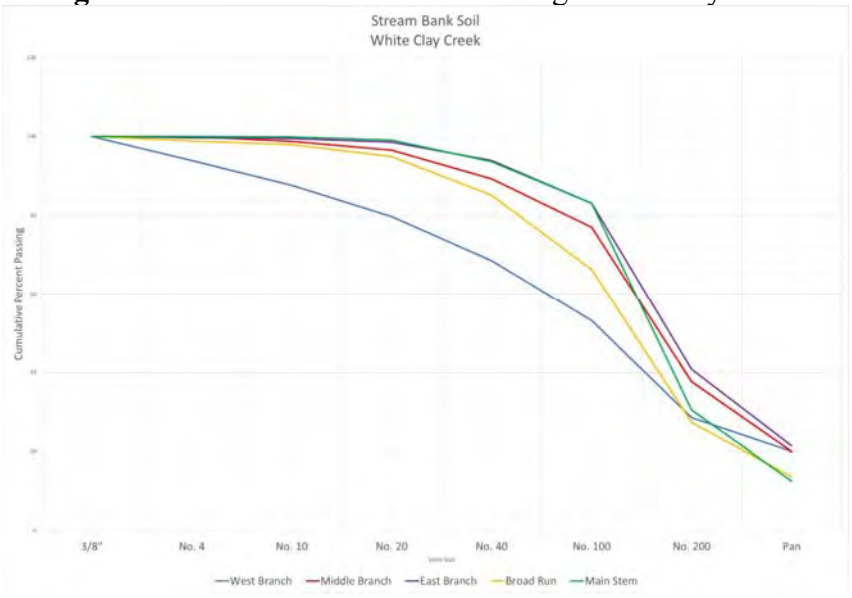


Figure 31. Streambank soil textural class along White Clay Creek

Table 6. Soil textural class along White Clay Creek (March 18, 2019)

	Good Hope Stream	Good Hope Farm	Flint Hill Stream	Flint Hill Farm	Stricklerville Stream	Stricklerville Farm	Mercer Mill Stream	Mercer Mill Farm	Watson Mill Stream	Watson Mill Farm
Textural Class	Sandy loam	Loam	Sand	Sand	Loamy sand	Loam	Sandy loam	Silt loam	Loamy sand	Silt loam
Sand (%)	59	51	93	88	84	51	70	39	78	43
Silt (%)	35	41	5	10	14	39	26	51	20	51
Clay (%)	6	8	2	2	2	10	4	10	2	6

Table 7. Soil textural class along White Clay Creek (April 8, 2019)

	Good Hope Stream	Good Hope Farm	Flint Hill Stream	Flint Hill Farm	Stricklerville Stream	Stricklerville Farm	Mercer Mill Stream	Mercer Mill Farm	Watson Mill Stream	Watson Mill Farm
Textural Class	Sandy loam	Loam	Sand	Loamy sand	Loamy sand	Loam	Sandy loam	Silt loam	Sandy loam	Silt loam
Sand (%)	62	42	88	87	86	48	66	35	66	34
Silt (%)	30	46	7	9	9	40	24	51	24	54
Clay (%)	8	12	5	4	5	12	10	14	10	12

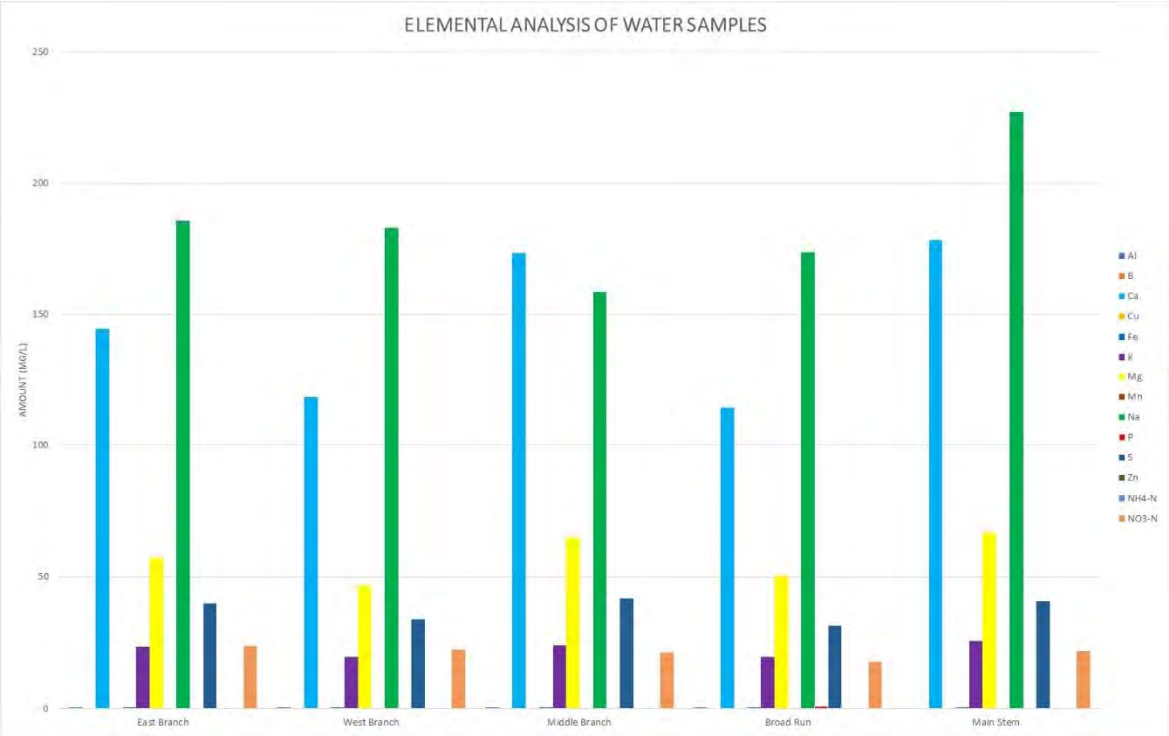


Figure 33. Elemental analysis of water samples along tributaries of White Clay Creek

4. Water Policy Implications

4.1. Total Maximum Daily Load (TMDL)

The City of Newark is one of 60 municipalities in the Brandywine Christina watershed (Figure 34) required by the Environmental Protectrion Agency to implent Total Maximum Daily Loads under the terms of a Municipal Separate Stormsewer (MS4) National Pollution Discharge Elimination System (NPDES) permit by the Fedarl Clean Water Act. The State of Pennsylvania is required to reduce sediment, nitrogen, and phosphorus by 26-70%, 28%, and 73% respectively in the White Clay Creek warershed at the DE/PA stateline (Table 8). Sediment loads in the Pennsylvania portion of White Clay Creek watershed upstream from Newark are to be reduced by 26% to 70% depending on the subwatershed (Table 9)

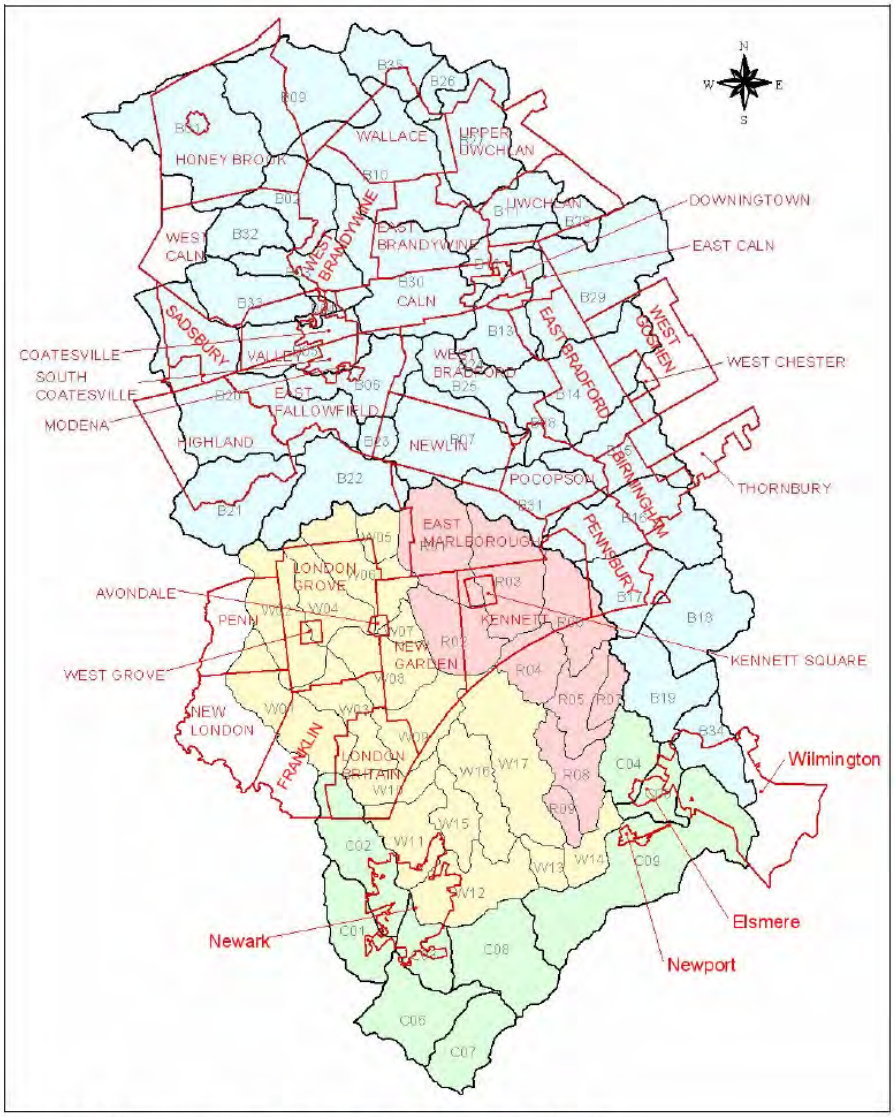


Figure 2-2. Municipalities with MS4 permits in Christina River Basin

Figure 1. Municipalities with MS4 NPDES permits in the Brandywine Christina watershed

Table 8. High flow nonpoint source TMDL reductions in the Brandywine Christina watershed

Watershed	% Reduction			
at PA-DE line:	**E. Bacteria**	**Sediment**	**Total N**	**Total P**
Brandywine Creek	93%	16 – 60%	46%	41%
Red Clay Creek	58%	45 – 52%	31%	40%
White Clay Creek	70%	26 – 70%	28%	73%
Christina River (at MD-DE line)	58%		73%	48%
in DE:				
Brandywine Creek	88 - 94%		16%	36%
Red Clay Creek	29 – 89%		49%	54%
White Clay Creek	66 – 89%			
Christina River	61 – 91%		6%	9%

Table 9. Annual allocations for White Clay Creek watershed sediment TMDL

Subbasin	Baseline Load (ton/yr)			TMDL Allocation (ton/yr)					Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	LA	MOS	TMDL	
White Clay Creek									
W01	0.30	5353.56	5353.87	0.30	2940.17	-	154.76	3095.23	42.2%
W02	11.42	7999.18	8010.60	11.42	2283.47	449.21	144.43	2888.53	63.9%
W03	0.00	3168.54	3168.54	0.00	1825.04	-	96.05	1921.10	39.4%
W04	0.00	5187.94	5187.94	0.00	1722.66	58.57	94.49	1875.72	63.8%
W06	2.83	8114.08	8116.92	2.83	1795.34	667.6	129.78	2595.55	68.0%
W07	2.97	1414.61	1417.58	2.97	393.60	-	20.87	417.44	70.6%
W08	2.19	4606.80	4609.00	2.19	2146.83	-	113.11	2262.13	50.9%
W09	0.05	2808.89	2808.95	0.05	1968.74	-	103.62	2072.42	26.2%

4.2. Harmful Algal Bloom (HAB)

A combination of high nitrogen laden water (> 3 mg/l) from White Clay Creek (Figure 1) and high summer water temperatures that exceed 83 deg F (Figure 35) contribute to harmful algal blooms (HAB) in Newark Reservoir cancelling triathlons and rendering reservoir drinking water unpotable (Figure 3).

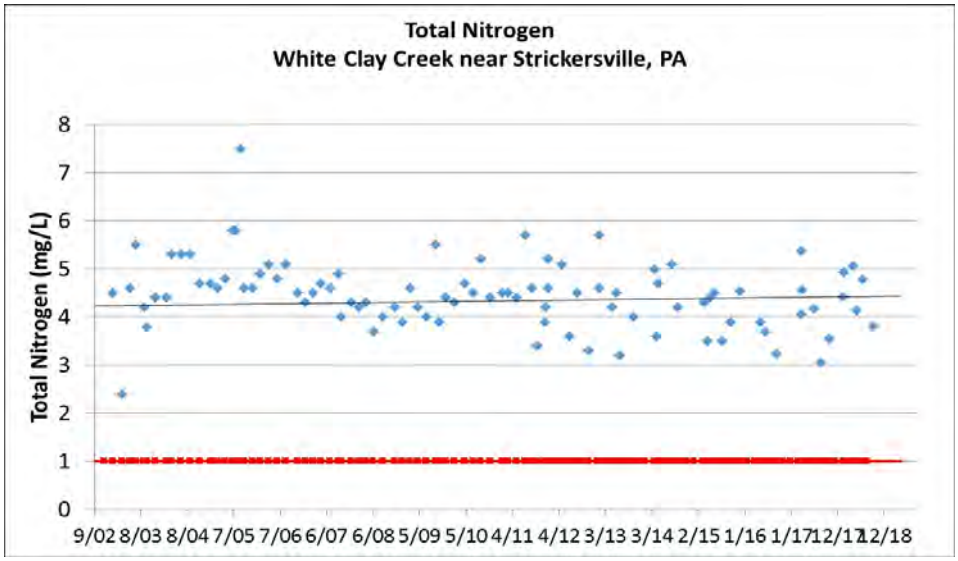


Figure 35. Total nitrogen along the White Clay Creek near Strickersville, Pennsylvania.

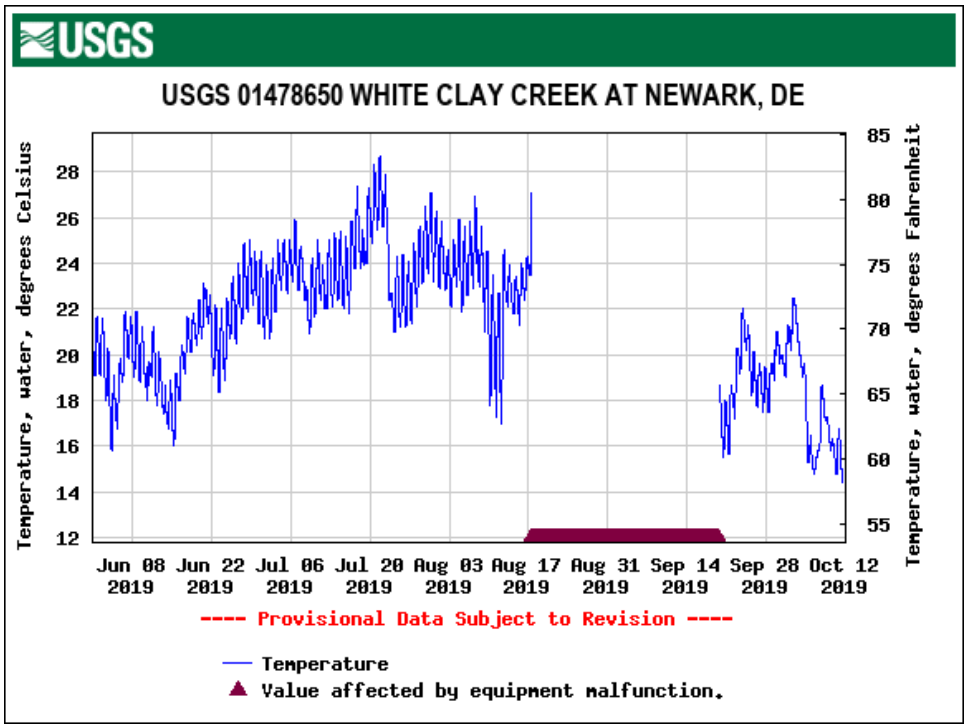


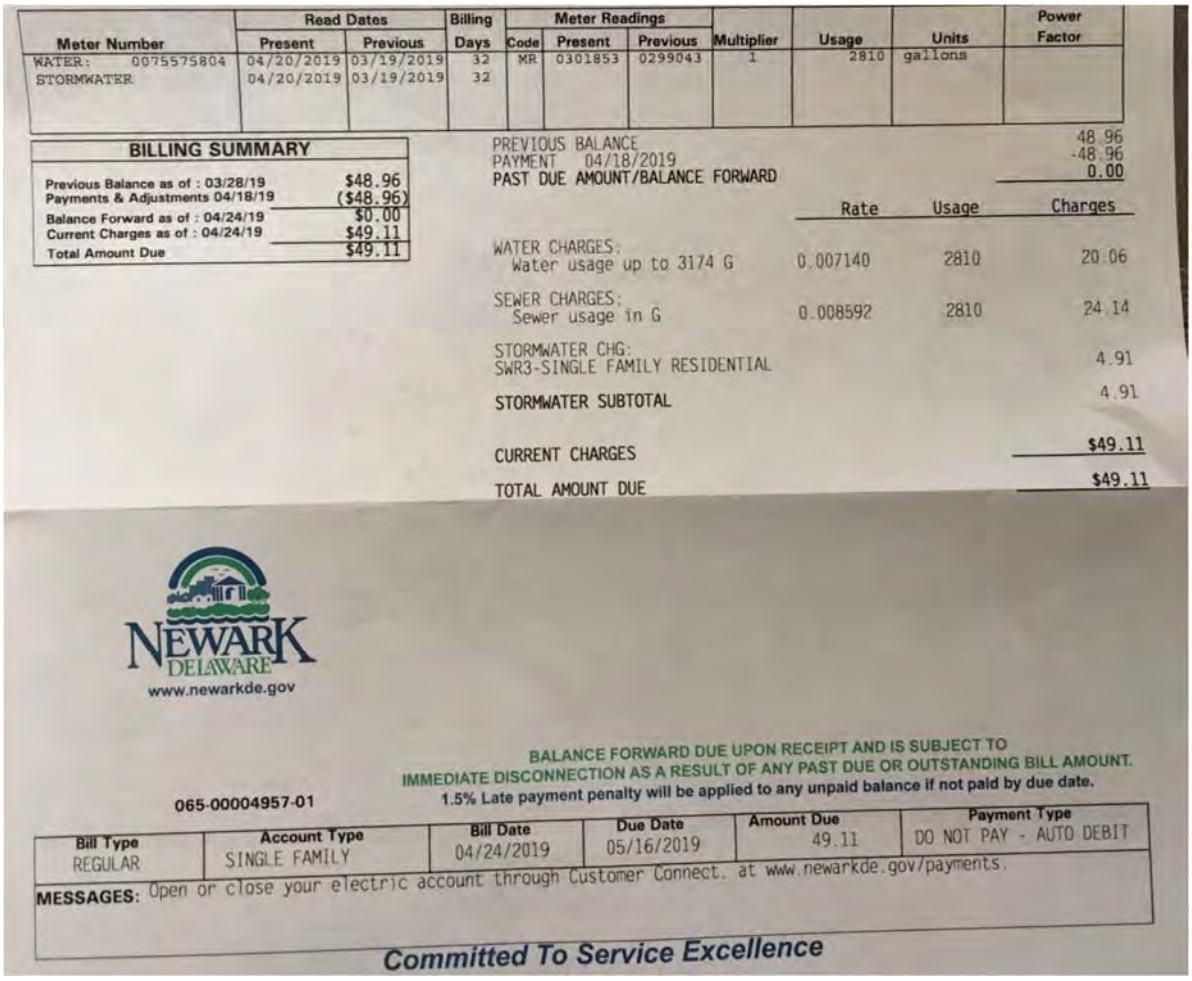
Figure 36. Water temperature recorded at White Clay Creek at Newark USGS gage during 2019

Newark Reservoir in 2017 was plagued with a blue-green algae bloom. *(Photo: Jennifer Corbett, The News Journal)*

Figure 37. Harmful algal bloom in Newark Reservoir observed in August 2017

4.3. Stormwater Utility Fund

In 2017, City Council approved a stormwater utility fee by 4-2 vote. The average monthly fee for a 1/4 to 1/3-acre residential parcel is $4.91 (Figure 38). Revenue from the stormwater utility fee can be invested upstream to reduce pollution in the White Clay Creek which is a drinking water source for the City of Newark.



Meter Number	Read Dates: Present	Read Dates: Previous	Billing Days	Meter Readings: Code	Meter Readings: Present	Meter Readings: Previous	Multiplier	Usage	Units	Power Factor
WATER: 0075575804	04/20/2019	03/19/2019	32	MR	0301853	0299043	1	2810	gallons	
STORMWATER	04/20/2019	03/19/2019	32							

BILLING SUMMARY

Previous Balance as of : 03/28/19	$48.96
Payments & Adjustments 04/18/19	($48.96)
Balance Forward as of : 04/24/19	$0.00
Current Charges as of : 04/24/19	$49.11
Total Amount Due	$49.11

PREVIOUS BALANCE			48.96
PAYMENT 04/18/2019			-48.96
PAST DUE AMOUNT/BALANCE FORWARD			0.00
	Rate	Usage	Charges
WATER CHARGES: Water usage up to 3174 G	0.007140	2810	20.06
SEWER CHARGES: Sewer usage in G	0.008592	2810	24.14
STORMWATER CHG: SWR3-SINGLE FAMILY RESIDENTIAL			4.91
STORMWATER SUBTOTAL			4.91
CURRENT CHARGES			$49.11
TOTAL AMOUNT DUE			$49.11

NEWARK DELAWARE
www.newarkde.gov

BALANCE FORWARD DUE UPON RECEIPT AND IS SUBJECT TO IMMEDIATE DISCONNECTION AS A RESULT OF ANY PAST DUE OR OUTSTANDING BILL AMOUNT.
1.5% Late payment penalty will be applied to any unpaid balance if not paid by due date.

065-00004957-01

Bill Type	Account Type	Bill Date	Due Date	Amount Due	Payment Type
REGULAR	SINGLE FAMILY	04/24/2019	05/16/2019	49.11	DO NOT PAY - AUTO DEBIT

MESSAGES: Open or close your electric account through Customer Connect. at www.newarkde.gov/payments.

Committed To Service Excellence

Figure 38. Typical residential stormwater utility bill in the City of Newark, DE

4.4. Watershed Cluster Focus Areas

The Brandywine Christina Watershed Cluster supported by the William Penn Foundation is supporting investment in the Phase II focus areas in the headwaters of the Brandywine, Red Clay, and White Clay creeks (Figure 13).

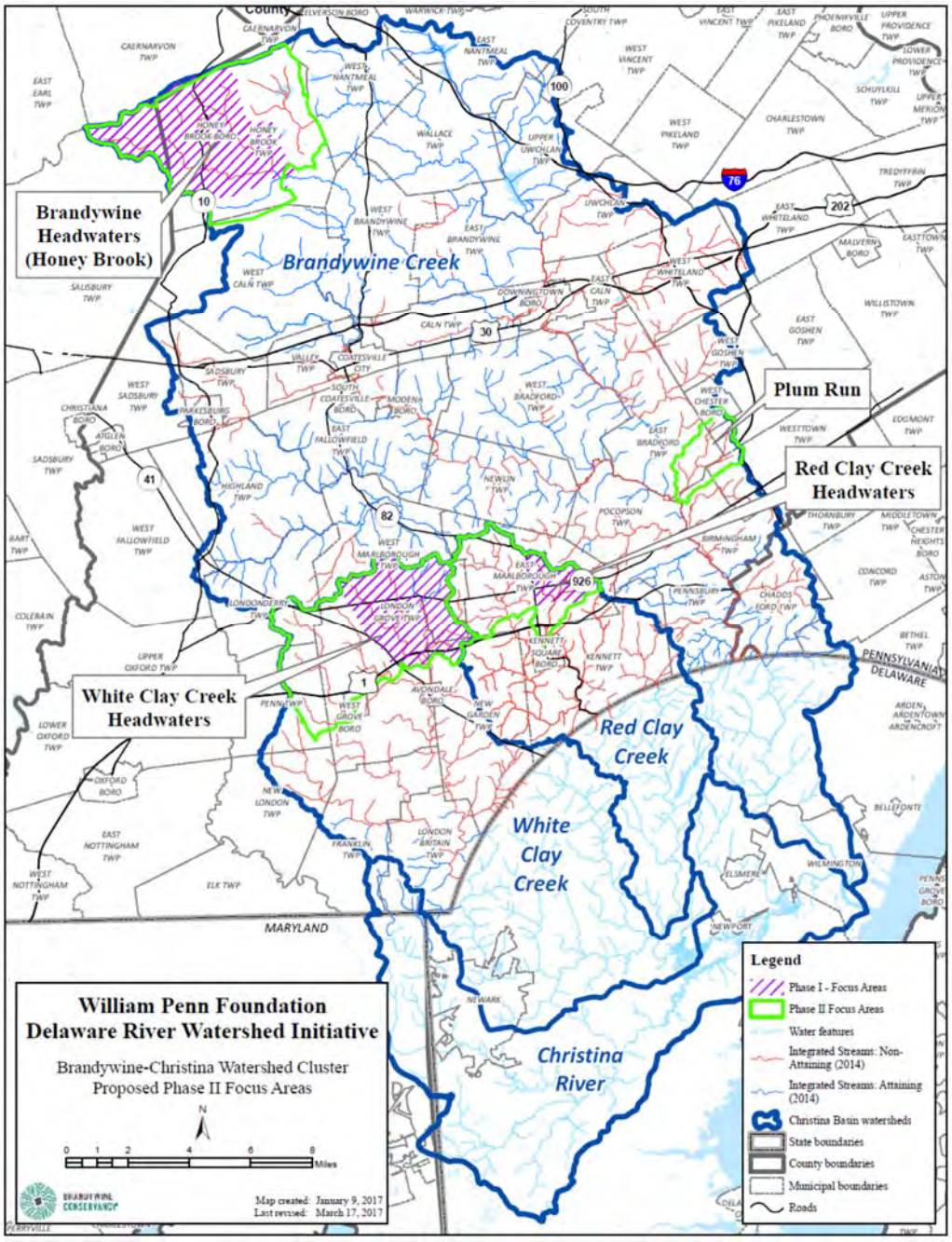


Figure 13. Brandywine Christina Watershed Cluster Phase II Focus Areas.

4.5. Open Space

Open space investment by the City of Newark and State, county, and local governments in the White Clay Creek watershed grew from 12,000 acres (19 mi^2) in 2005 to 20,000 acres (31 mi^2) in 2015 (Figure 39).

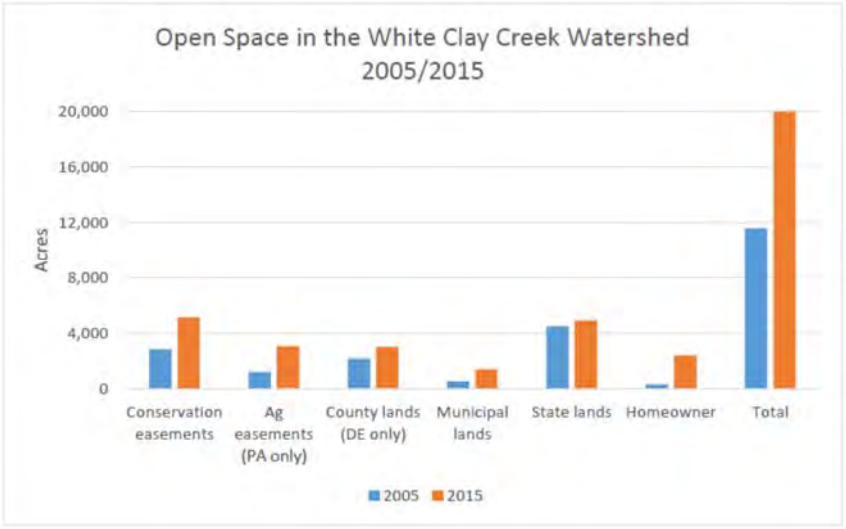


Figure 39. Open space preservation in the White Clay Creek watershed

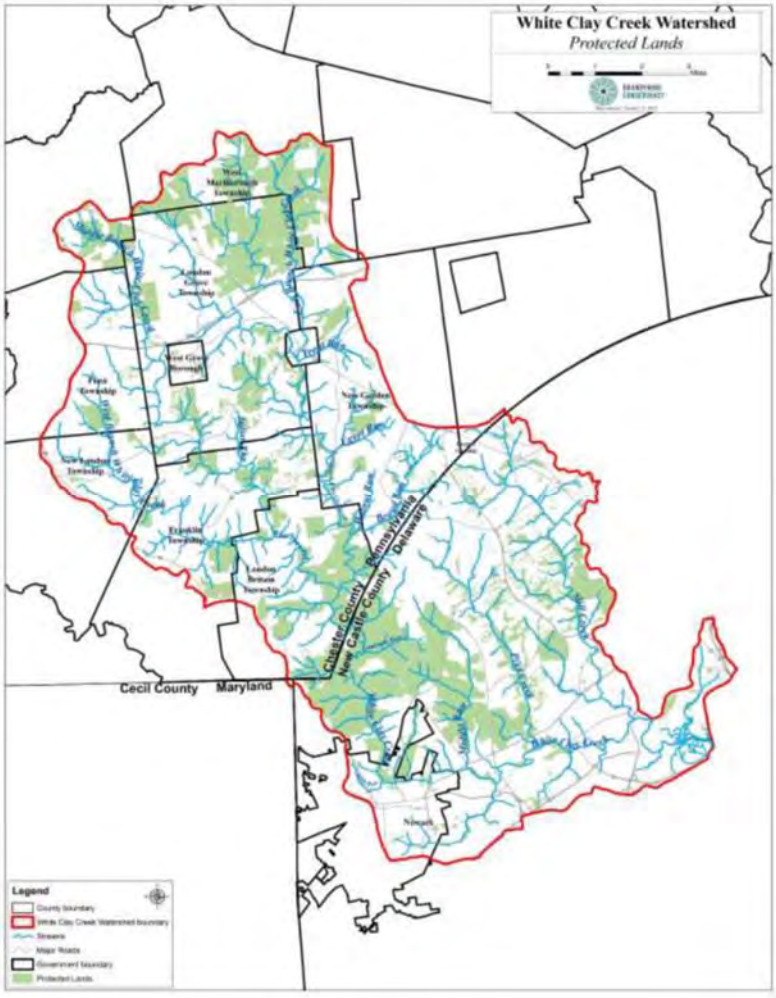


Figure 40. Open space preservation in the White Clay Creek watershed

5. Conclusions/Recommendations

5.1. Conclusions

The crux challenge in supplying clean drinking water to the City of Newark from the 70 mi^2 White Clay Creek watershed are high loads of sediment and nitrogen that flow down into Delaware from eroded stream banks and fields in Pennsylvania. The essential experiment in managing the White Clay Creek watershed is how to sustain the substantial agricultural economy upstream in Chester County, Pennsylvania while supplying clean drinking water to the urban/suburban population downstream in Newark, Delaware.

1. **White Clay Creek:** The Newark water intake along White Clay Creek can treat up to 5 million gallons per day (mgd) to deliver to 8,000 customers or 30,000 people in/around the City. Water from White Clay Creek is pumped to the 317 million gallon Newark Reservoir constructed in 2005 that at normal demand (3 mgd) has 100 days of reserve storage.

2. **Population:** Population in the White Clay Creek watershed grew 5% or by 6,000 people from 118,401 in 2000 to 124,358 in 2015 with 94,000 people (10% of the First State population) live in Delaware, 31,000 live in Pennsylvania, and 4 people live in Maryland.

3. **Precipitation/Floods:** Peak floods >10,000 cfs with high sediment/nitrogen have increased since 1988 as annual precipitation grew by 5 inches since 1960 to 46 inches per year.

4. **Economics:** The White Clay watershed in DE/PA supports $500 million in annual economic activity, $165 million in ecosystem services, and 25,000 jobs w/ $550 million wages.

5. **Land Use:** Between 1996 and 2010, developed watershed land grew by 4.6 mi^2 (200 ac/yr) that replaced 1.2 mi^2 of forest/wetlands (50 ac/yr) and 3.4 mi^2 of agriculture (150 ac/yr).

6. **Agriculture:** Up to 60% of the White Clay watershed headwaters in PA is agriculture. Chester County is the Keystone State's 2nd most valuable agricultural economy (after Lancaster) and ranked 1st in the US in nursery and green house sales. 1st in US in mushroom farming, 22nd in US in horse farming, 6th in PA in dairy and 7th in PA in row crops.

7. **Farm Patterns:** The East, Branch, Middle Branch, and West Branch headwaters of White Clay Creek are covered by many horse and cattle/dairy farms that coupled with downstream corn/soybean row crop and mushroom farms contribute to high loads of pathogens, nitrogen, and sediment that flow down the Main Stem of White Clay Creek to Newark, Delaware.

8. **SRAT Modeling:** The Academy of Natural Sciences SRAT model indicates high yields of nitrogen, phosphorus, and sediment flow from the headwaters into White Clay Creek.

9. **STORET Water Quality Monitoring:** Since 1970, DNREC has monitored water quality once a month at White Clay Creek at Chambers Rock Road just below the DE-PA stateline.

10. **Salinity/Chlorides**: Salinity is inching up to 100 mg/l of chlorides in White Clay Creek, up from 75 mg/l in 2000. The EPA secondary drinking water standard is 250 mg/l. Elevated chlorides are from winter road salt by highway departments.

11. **Dissolved Oxygen:** DO in White Clay Creek at Chambers Rock Road at the DE/PA stateline has increased by 2 mg/l since 1995 and is well above the 4 mg/l fishable standard.

12. **Bacteria:** Enterococcus bacteria levels are declining. White Clay Creek meets the DE swimmable standard (100 cfu/100 ml) a week after storms but not during storms.

13. **Phosphorus:** Has declined since 1995 to the 0.05 mg/l target level set by Delaware and the DNREC may consider delisting the White Clay Creek as impaired for phosphorus.

14. **Nitrogen:** Nitrogen in White Clay Creek near Strickersville, PA and Chambers Rock Road, DE are 4 to 5 times higher than the DNREC TMDL target of 1 mg/l but have declined over the last decade. Nitrogen is higher in the East Branch than Middle Branch, West Branch, and Main Stem of White Clay Creek. High nitrate nitrogen is found in Broad Run (4 - 5 mg/l), Egypt Run (11 mg/l), Hickory Hill Mill Creek (5 mg/l), and Middle Run (2 - 4 mg/l).

15. Turbidity: At White Clay Creek near Strickersville, PA turbidity exceeds 20 FNU about 10 to 30 days per year between 2011 and 2019. At 20 FNU the City of Newark will curtail withdrawals at the White Clay Creek water intake and draw water from the reservoir.

16. Sediment: Sediment at White Clay Creek at Chambers Rock Road has declined but still high after storms. Sediment loads in White Clay Creek are higher than in Brandywine Creek. Turbidity (T) is related to sediment though the equation: TSS = 3.2(T) – 42.5.

17. Sediment Fingerprint: University of Delaware research students sampled soils along White Clay Creek on March 4, March 11, March 18, and April 8, 2019 and found the texture of soils from streambanks and farm topsoil are similar ranging from 60% - 80% fine sand.

18. Total Maximum Daily Load (TMDL): Pennsylvania is required by the TMDL to reduce sediment, nitrogen, and phosphorus by 26-70%, 28%, and 73% respectively in the White Clay Creek watershed at the DE/PA stateline.

19. Harmful Algal Bloom (HAB): High nitrogen laden water (> 3 mg/l) from White Clay Creek and high summer water temperatures (>83 deg F) contribute to harmful algal blooms (HAB) in Newark Reservoir cancelling triathlons and rendering reservoir drinking water unpotable.

20. Stormwater Utility: In 2017, City Council approved a stormwater utility by a 4-2 vote resulting in an average monthly fee for a 1/4 to 1/3 acre residential parcel of $4.91. Revenue can be invested upstream to reduce pollution in White Clay Creek and protect drinking water.

21. Watershed Focus Areas: The Brandywine-Christina Cluster supported by William Penn Foundation invests in Phase II focus areas in Brandywine, Red Clay, White Clay headwaters.

22. Open Space: Open space investment by Newark and State and local governments in the White Clay watershed grew from 12,000 acres in 2005 to 20,000 acres (31 mi^2) in 2015.

5.2. Recommendations

The City of Newark in Delaware should utilize revenue from the stormwater utility and working with partners invest in sediment and nitrogen reduction programs in the headwaters of White Clay Creek in Chester County, Pennsylvania though the following measures:

1. **Watershed Partnerships:** Work in concert with the Counties (New Castle County and Chester County Water Resources Authority), Conservation Districts (Chester County and New Castle County), White Clay Creek Wild and Scenic River Management Committee, and William Penn Foundation Brandywine Christina Watershed Cluster Partners (Brandywine Conservancy, Brandywine Red Clay Alliance, Stroud Water Research Center, Natural Lands, and the Nature Conservancy.

2. **Stream Restoration:** Focus on stream restoration programs along 2 miles per year in the East Branch headwaters of White Clay Creek.

3. **Horse Farms:** Invest in new barns, pasture management, and manure handling facilities at 5 farms/yr in the East Branch headwaters of White Clay Creek.

4. **Cattle/Dairy Farms:** Invest in new barns, pasture management, and manure handling facilities at 5 farms/yr in the Middle Branch and Broad Run headwaters of White Clay Creek.

5. **Corn/Soybean Row Crops:** Invest in cover crop, reforestation, and stream buffer planting at at 5 farms/yr in the West Branch headwaters of White Clay Creek.

6. **Mushroom Farms:** Invest to place all mushroom composting and growing operations indoors or under roof in the East Branch White Clay Creek.

7. **Watershed Advocacy**: Gently nudge the upstream cleanup of the White Clay Creek watershed by citing public health benefits of clean, plentiful drinking water for Newark residents and then go on to cite the legal requirements of the Federal Clean Water Act and Safe Drinking Water Act. Reserve legal action though the bounty provisions of the Clean Water Act as the action of very last resort.