Water Quality Trends (1995-2024) in the Brandywine Christina Watershed at the DE/PA Stateline

June 14, 2025

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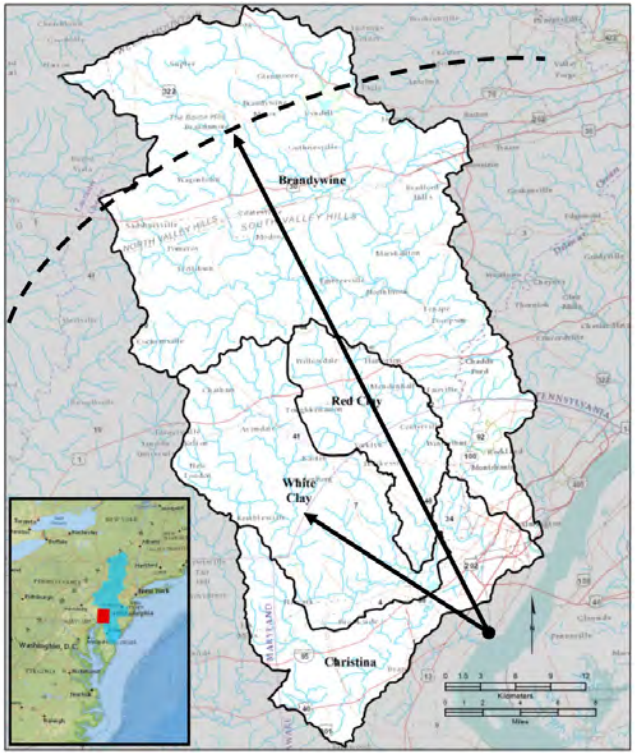
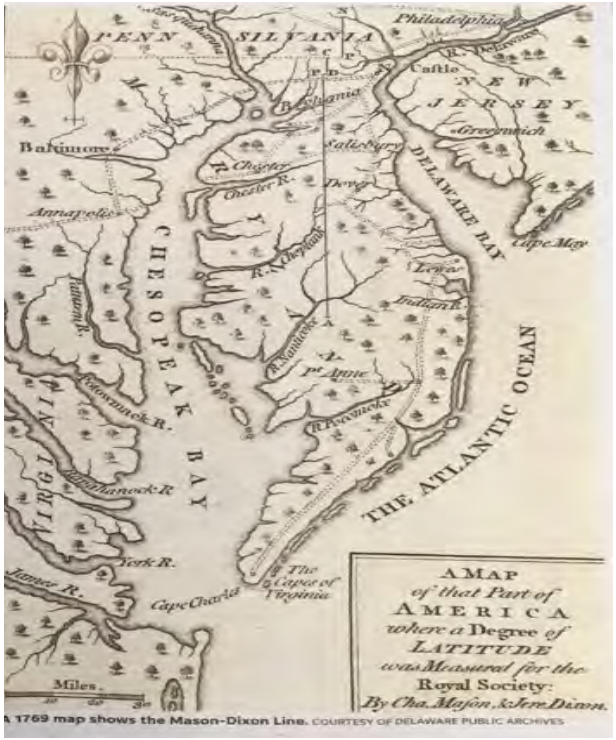
WATER
WATER, LIKE THE FOREST, IS A RENEWABLE RESOURCE. IT FALLS TO EARTH AS RAIN OR SNOW WHERE SOME OF IT SOAKS DEEP INTO UNDERGROUND STREAMS TO EMERGE LATER IN THE FORM OF SPRINGS. THE REMAINING WATER RUNS OFF THE LAND INTO STREAMS AND PONDS, EVENTUALLY REACHING THE OCEAN. AS THE WATER FLOWS ACROSS THE LAND, SOME OF IT EVAPORATES TO FALL AGAIN AS RAIN. LAND MANAGEMENT PRACTICES ON THE NATIONAL FORESTS PROTECT THE FLOW OF PURE WATER FROM THE FOREST.



In 1680, "The Duke of York wanted a circle of 20 or 30 miles drawn around New Castle."



1769 map shows the Mason-Dixon Line. COURTESY OF DELAWARE PUBLIC ARCHIVES

2017 CENSUS OF AGRICULTURE *County Profile*

Chester County
Pennsylvania

Total and Per Farm Overview, 2017 and change since 2012

	2017	% change since 2012
Number of farms	1,646	-5
Land in farms (acres)	150,514	-8
Average size of farm (acres)	91	-4
Total	($)	
Market value of products sold	712,468,000	+8
Government payments	1,775,000	+9
Farm-related income	19,948,000	-36
Total farm production expenses	542,936,000	-1
Net cash farm income	191,254,000	+34
Per farm average	($)	
Market value of products sold	432,848	+13
Government payments (average per farm receiving)	10,820	+82
Farm-related income	28,336	-32
Total farm production expenses	329,852	+4
Net cash farm income	116,193	+41

9 Percent of state agriculture sales

Share of Sales by Type (%)

Crops	80
Livestock, poultry, and products	20

Land in Farms by Use (%) [a]

Cropland	70
Pastureland	15
Woodland	9
Other	6

Acres irrigated: 1,191
1% of land in farms

Land Use Practices (% of farms)

No till	28
Reduced till	11
Intensive till	17
Cover crop	22

2017 CENSUS OF AGRICULTURE *County Profile*

Market Value of Agricultural Products Sold

	Sales ($1,000)	Rank in State [b]	Counties Producing Item	Rank in U.S. [b]	Counties Producing Item
Total	**712,468**	**2**	**67**	**53**	**3,077**
Crops	**570,929**	**1**	**67**	**25**	**3,073**
Grains, oilseeds, dry beans, dry peas	32,413	7	66	956	2,916
Tobacco	4,365	2	12	83	323
Cotton and cottonseed	-	-	-	-	647
Vegetables, melons, potatoes, sweet potatoes	6,266	7	67	294	2,821
Fruits, tree nuts, berries	1,845	12	66	338	2,748
Nursery, greenhouse, floriculture, sod	515,267	1	66	3	2,601
Cultivated Christmas trees, short rotation woody crops	605	14	64	69	1,384
Other crops and hay	10,166	10	66	245	3,040
Livestock, poultry, and products	**141,539**	**7**	**67**	**333**	**3,073**
Poultry and eggs	25,667	17	67	380	3,007
Cattle and calves	16,848	9	67	913	3,055
Milk from cows	82,808	5	63	99	1,892
Hogs and pigs	9,127	19	67	395	2,856
Sheep, goats, wool, mohair, milk	214	24	67	743	2,984
Horses, ponies, mules, burros, donkeys	5,881	2	63	24	2,970
Aquaculture	327	12	55	183	1,251
Other animals and animal products	667	9	67	239	2,878

Total Producers [c] **2,856**

Sex

Male	1,726
Female	1,130

Age

<35	429
35 – 64	1,645
65 and older	782

Race

American Indian/Alaska Native	3
Asian	12
Black or African American	15
Native Hawaiian/Pacific Islander	-
White	2,817
More than one race	9

Other characteristics

Hispanic, Latino, Spanish origin	80
With military service	169
New and beginning farmers	707

Percent of farms that:

Have internet access	74
Farm organically	3
Sell directly to consumers	13
Hire farm labor	43
Are family farms	96

Top Crops in Acres [d]

Forage (hay/haylage), all	35,439
Corn for grain	27,140
Soybeans for beans	15,567
Corn for silage or greenchop	8,323
Wheat for grain, all	5,121

Livestock Inventory (Dec 31, 2017)

Broilers and other meat-type chickens	297,852
Cattle and calves	47,499
Goats	1,390
Hogs and pigs	21,550
Horses and ponies	7,142
Layers	113,599
Pullets	335,713
Sheep and lambs	1,771
Turkeys	67,372

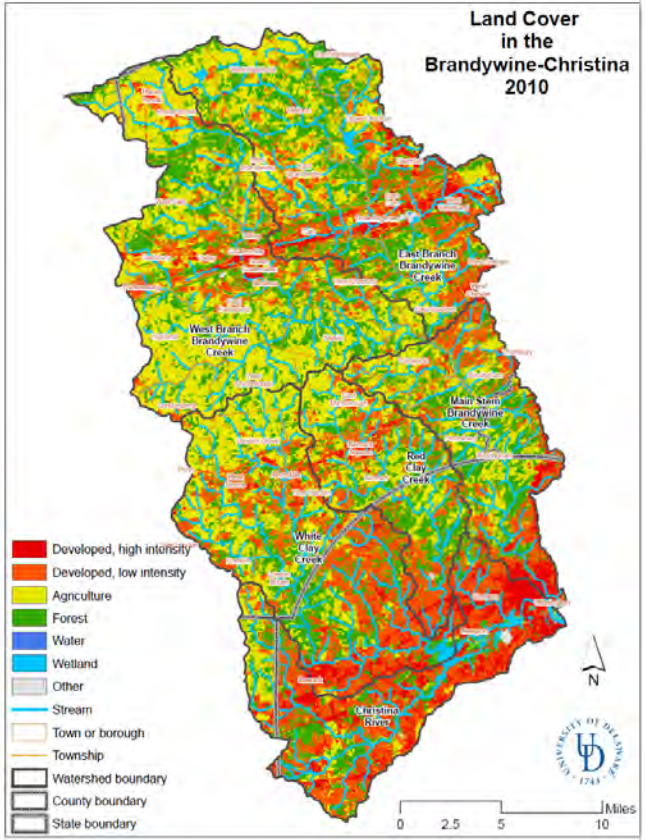
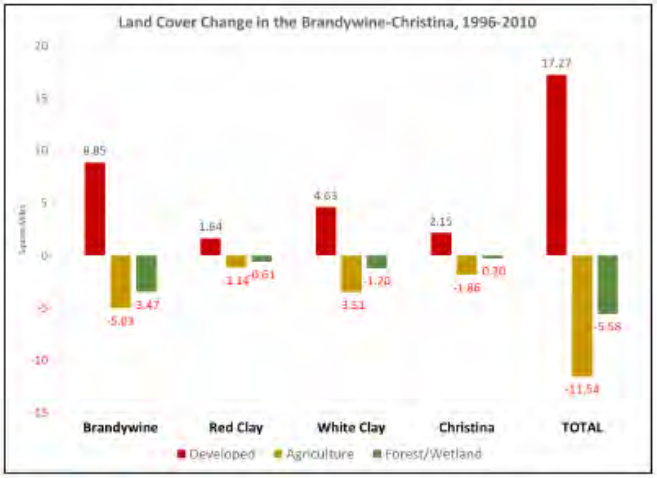
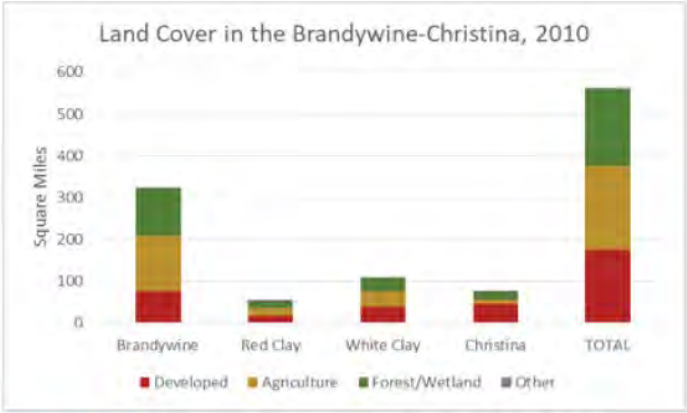
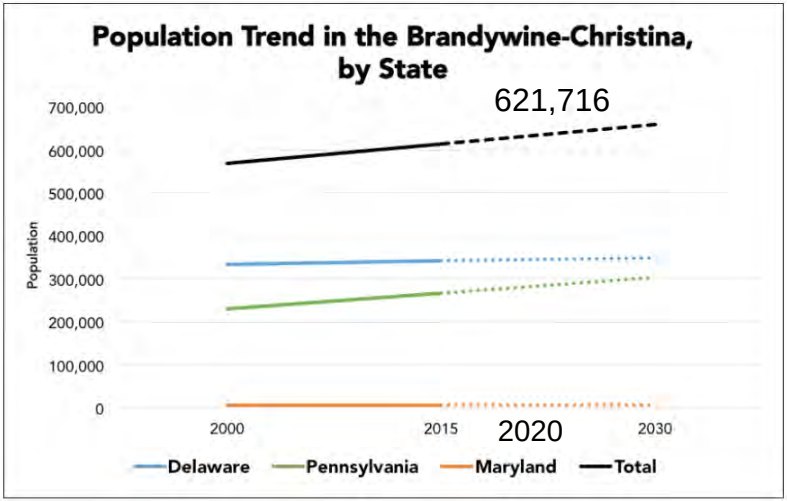


FIGURE 5-1 Land cover in the Brandywine-Christina watershed, based on 2010 NOAA CSC C-CAP.







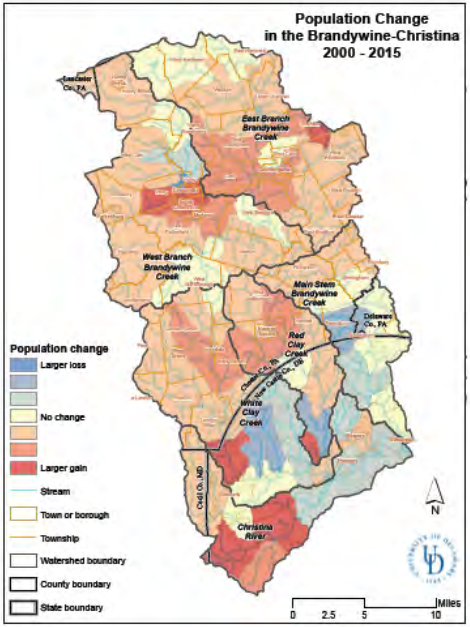
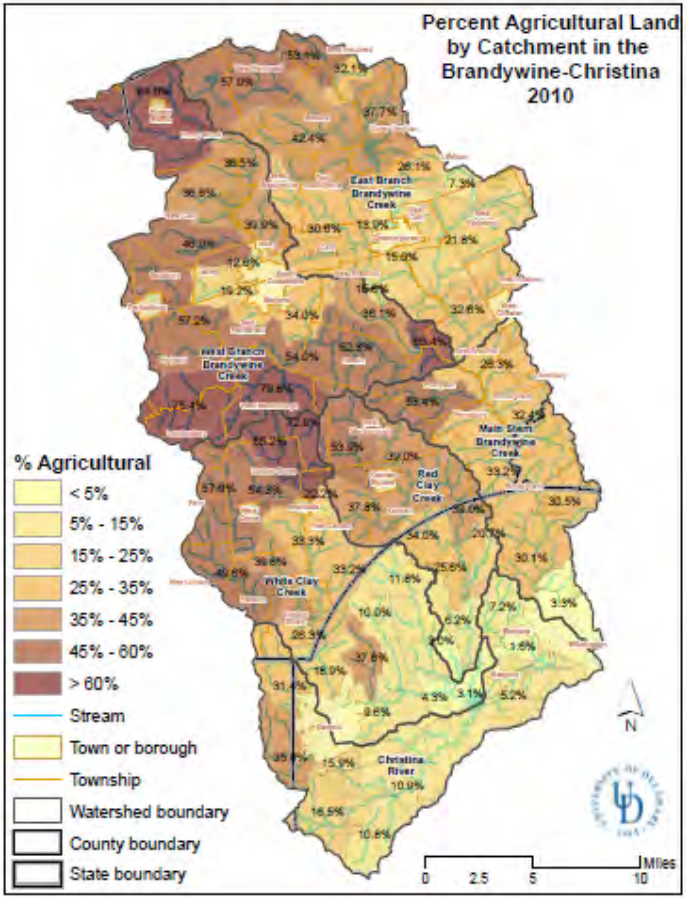
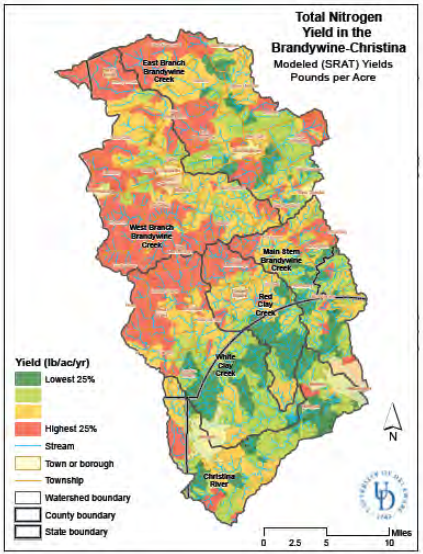


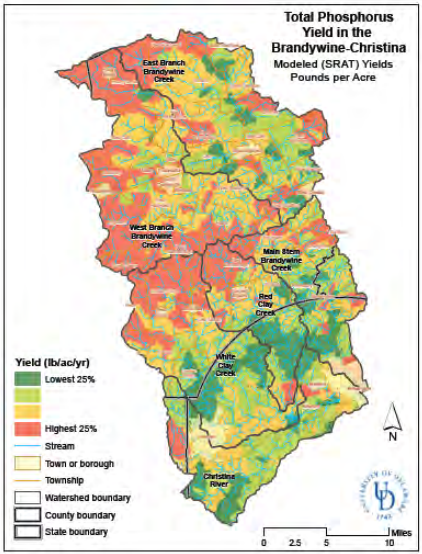
Figure 2-9 Population change by sub-watershed in the Brandywine-Christina watershed, between 2000 and 2015. (US Census Bureau)

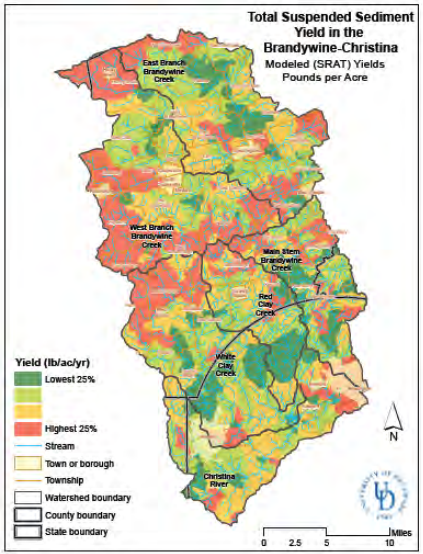
Pop. 2010	Pop. 2020	Change 2010-2020	% Change 2010-2020
599,441	621,716	22,275	4%



Up to 60% of the watershed is agriculture.



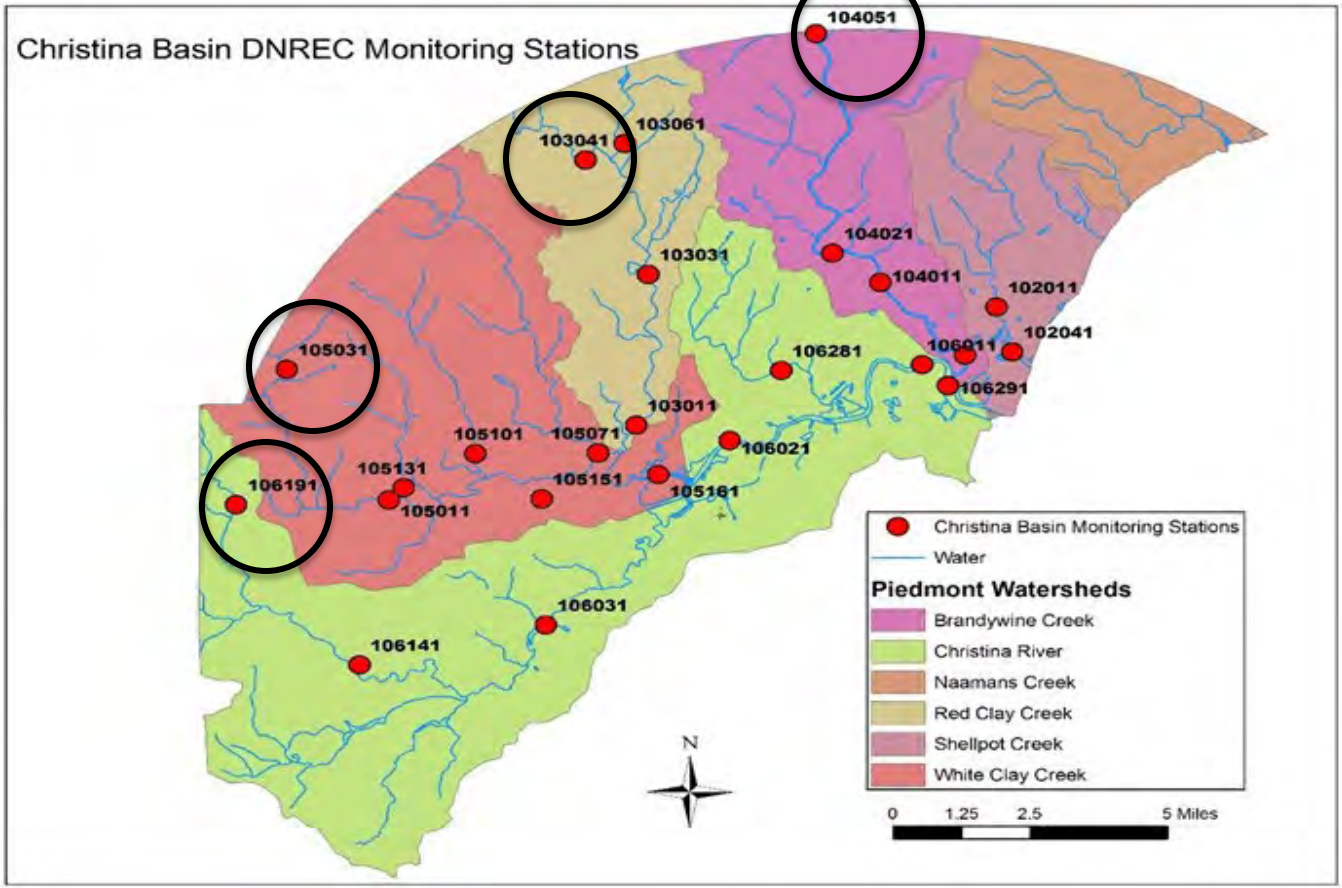


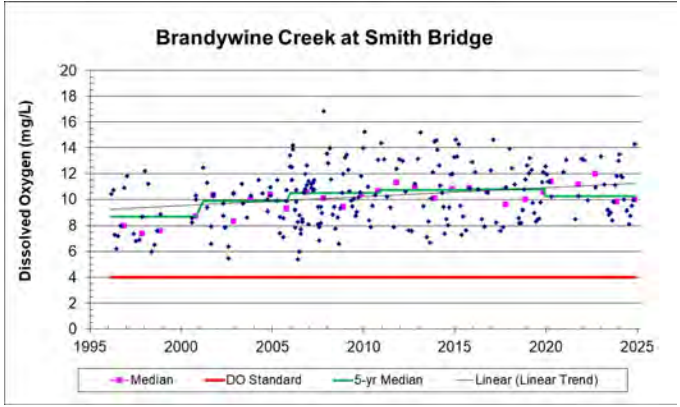


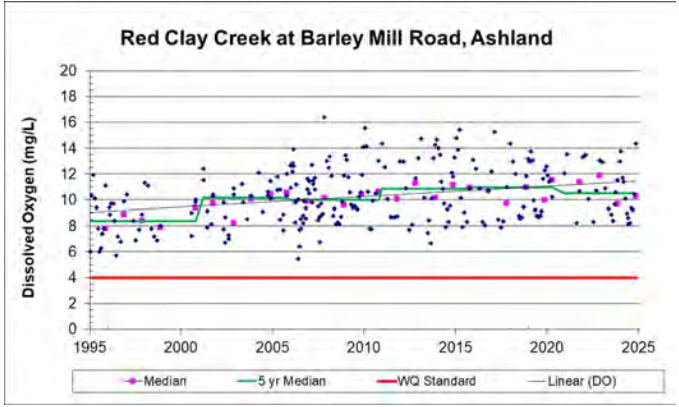
THE ANS SRAT model shows high yield of N, P, and TSS from the headwaters.

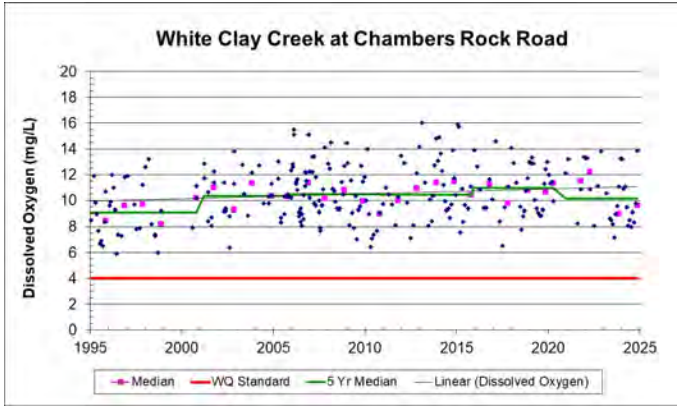
Delaware Stream Water Quality Criteria

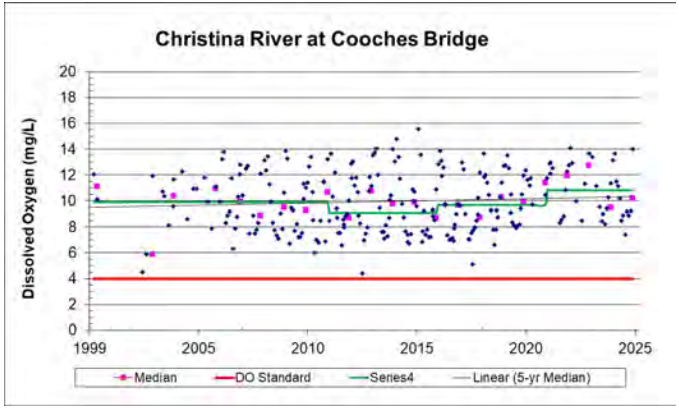
Dissolved Oxygen	4.0 mg/l	Fishable
Enterococcus Bacteria	180 col./100 ml	Swimmable
Total Phosphorus	0.05-0.10 mg/l	TMDL Target
Total Nitrogen	1.0-2.0 mg/l	TMDL Target
Total Susp. Sediment	5-20 mg/l	DE Inland Bays


Christina Basin DNREC Monitoring Stations
104051
103041
103061
104021
103031
104011
102011
102041
105031
106281
106011
106291
103011
105101
105071
106021
105131
106191
105151
105161
105011
106031
106141
N
Christina Basin Monitoring Stations
Water
Piedmont Watersheds
Brandywine Creek
Christina River
Naamans Creek
Red Clay Creek
Shellpot Creek
White Clay Creek
0
1.25
2.5
5 Miles

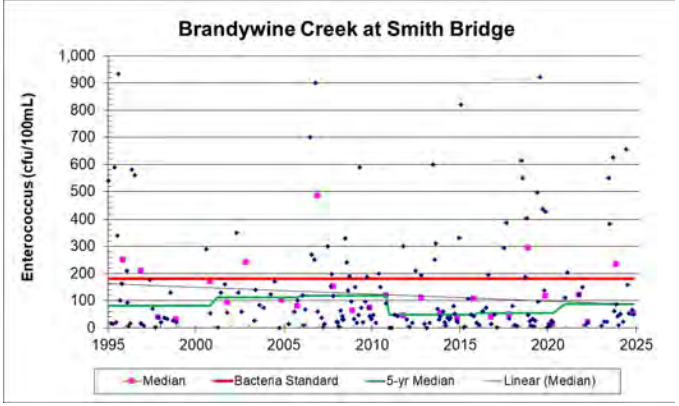


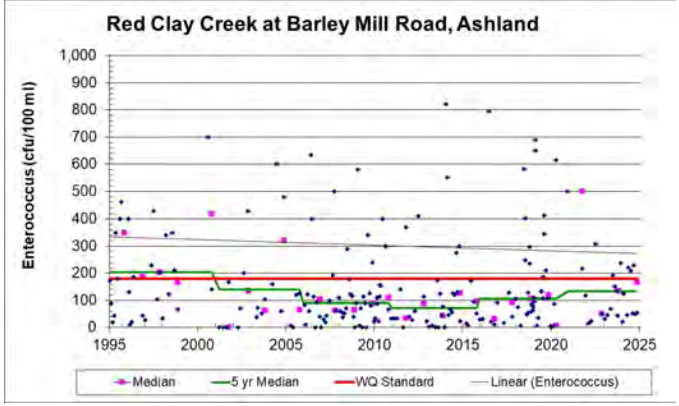


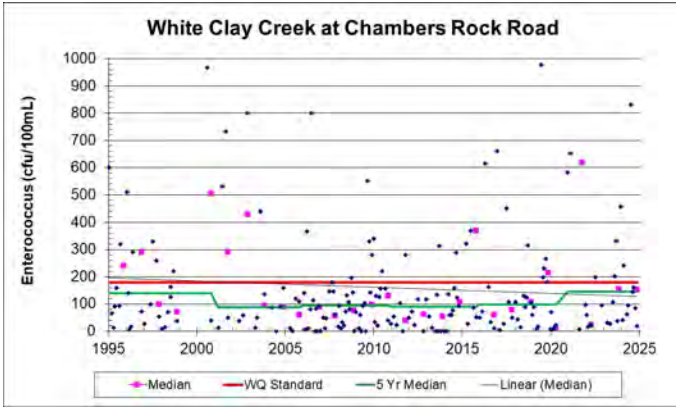


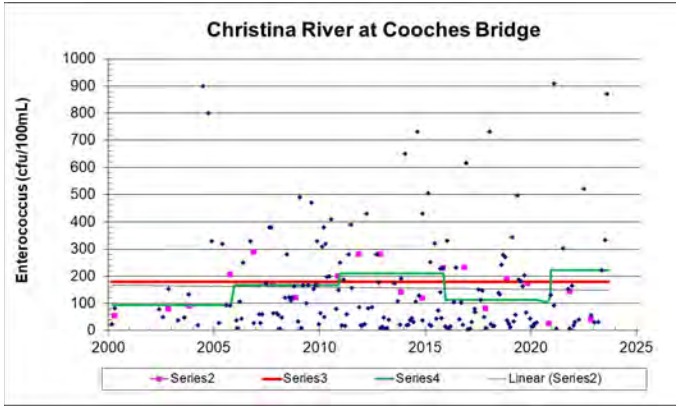


DO increased by 2 mg/l since 1995 along the Brandywine, Red Clay, White Clay and is well above the 4 mg/l fishable standard.

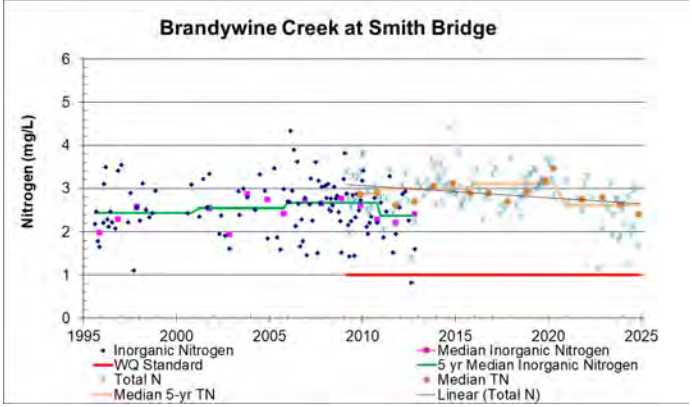


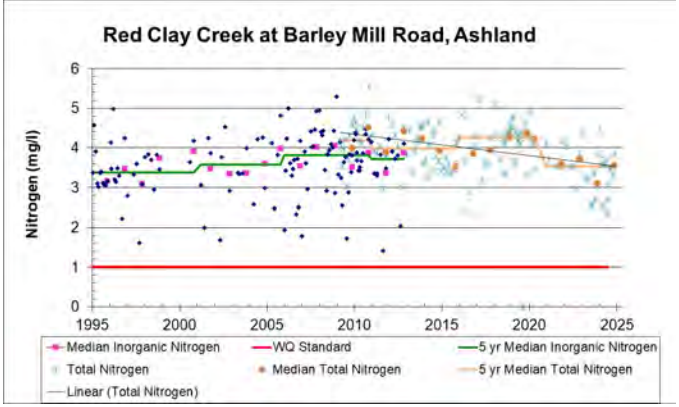


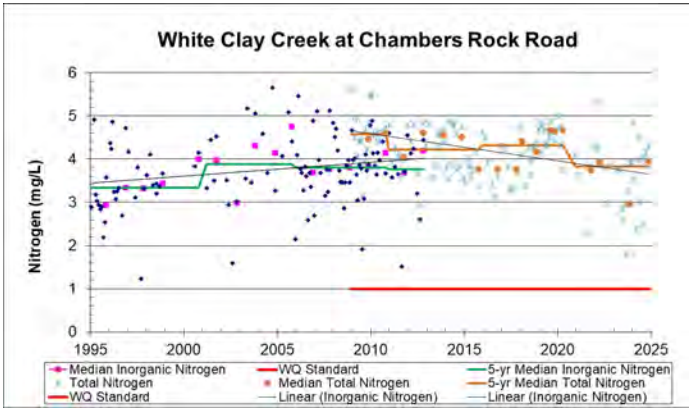


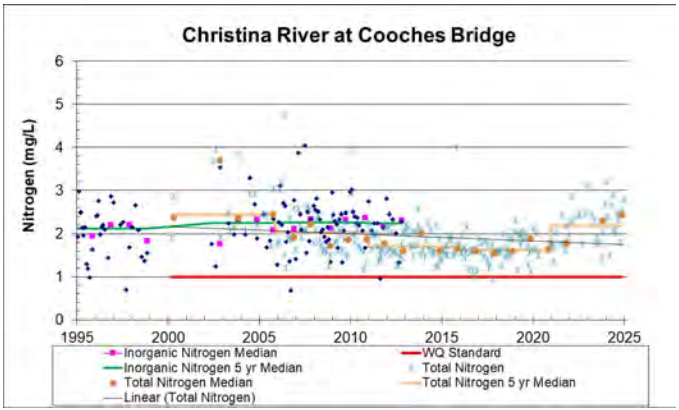


Bacteria increased a bit in the Brandywine, Red Clay, White Clay; streams are swimmable 2/3 of the time, 5 to 7 days after storms.

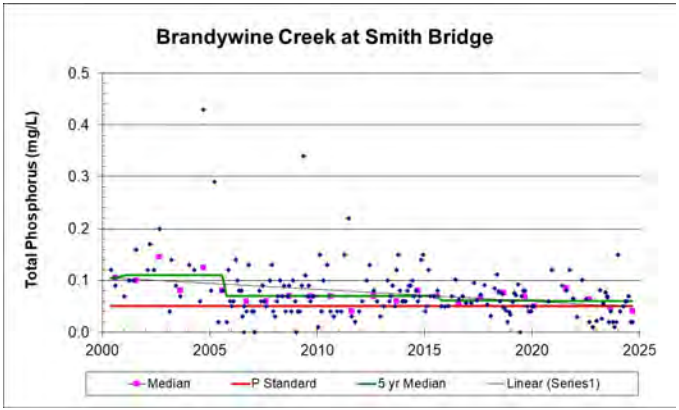


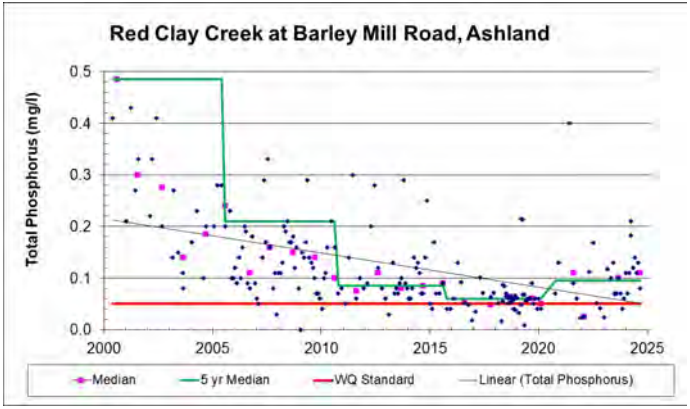


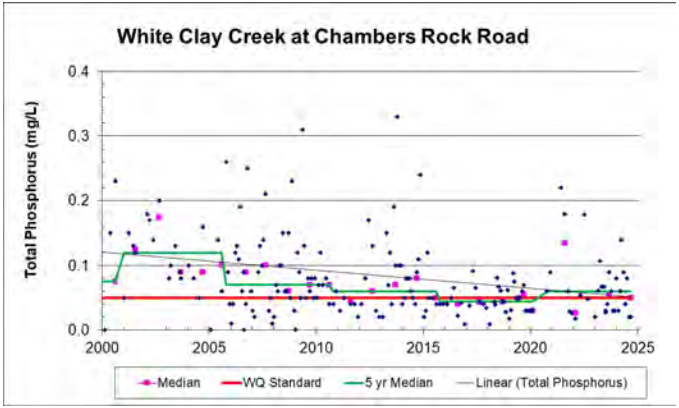


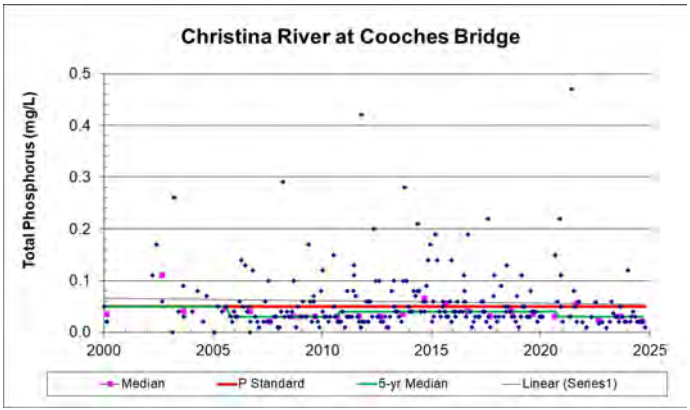


Nitrogen is 2 to 4 times greater than the TMDL target but leveled off and even declined over the last decade except in the Christina

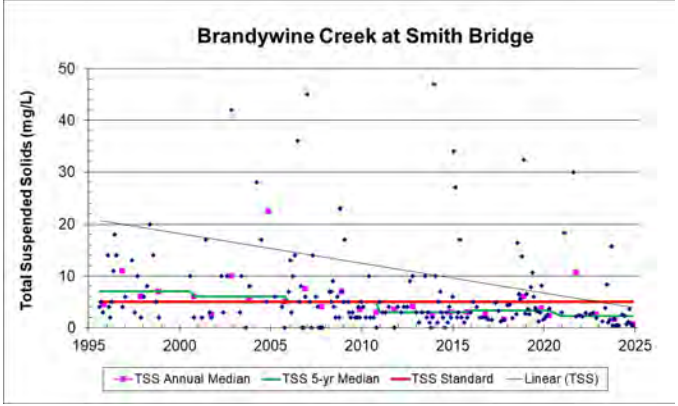


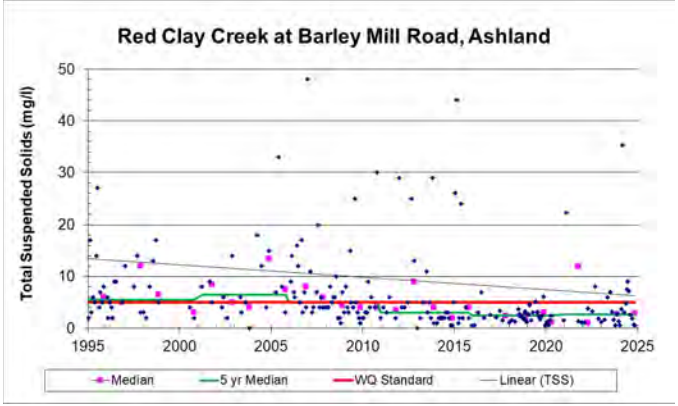


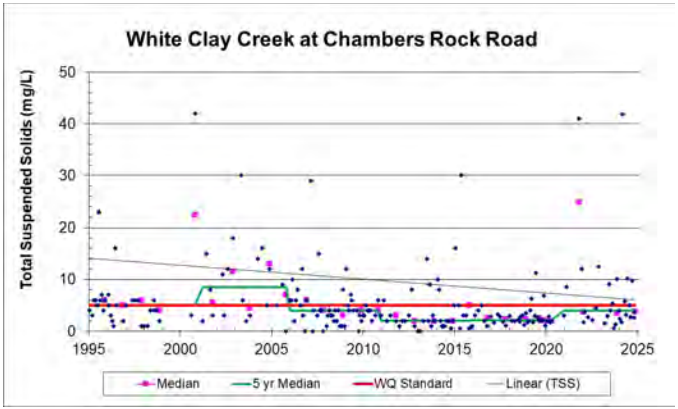


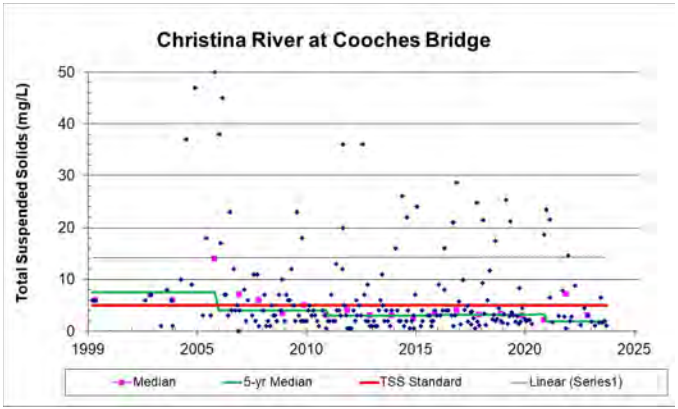


Phosphorus has markedly declined to the 0.05 mg/l TMDL target level.

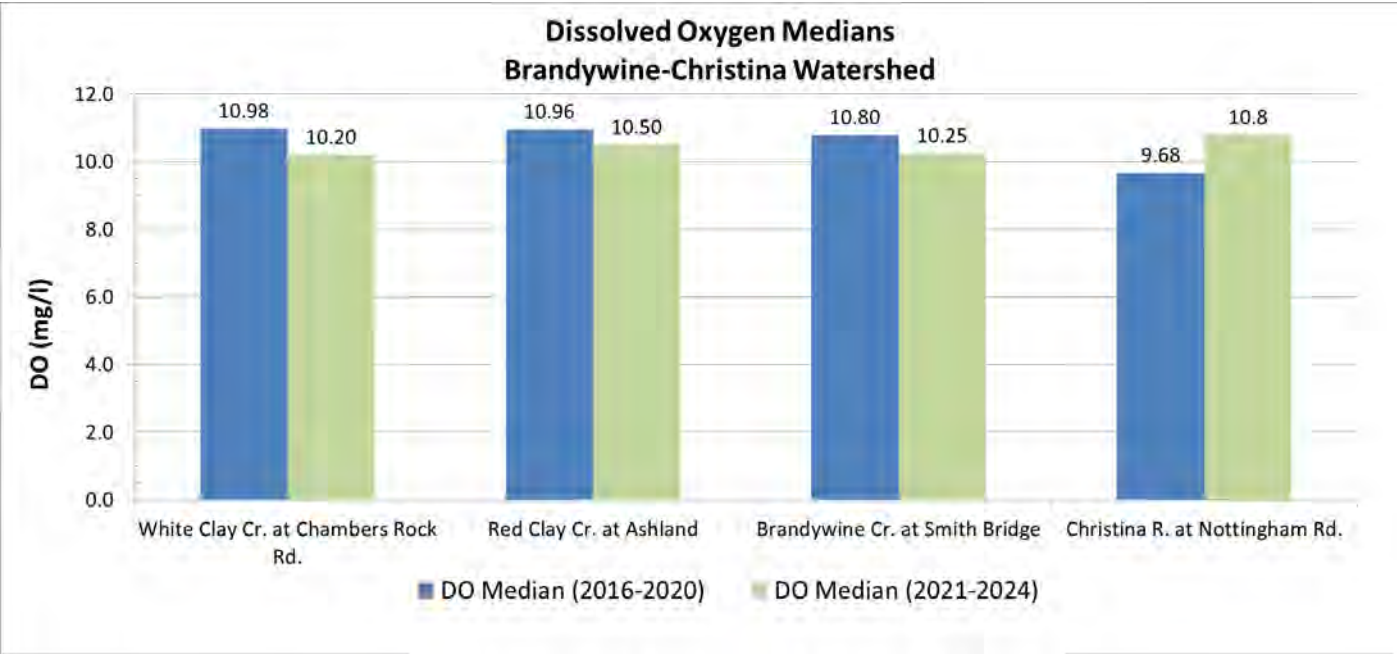


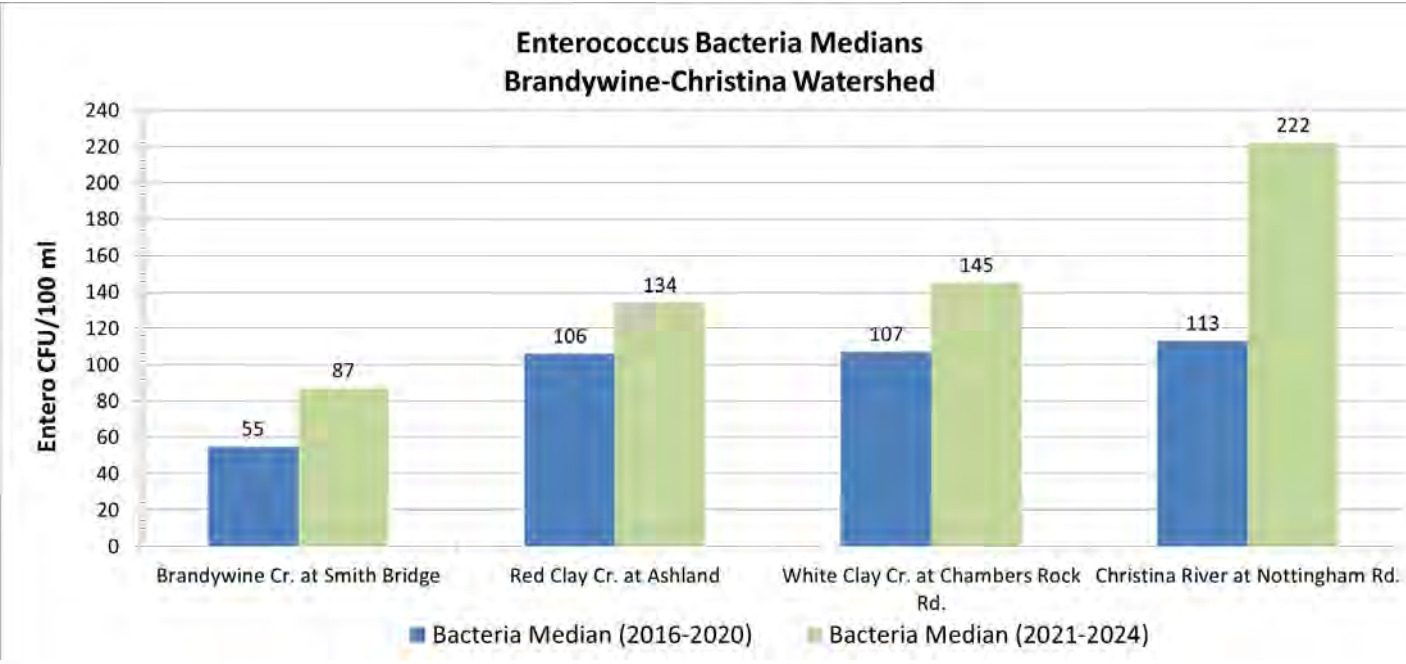


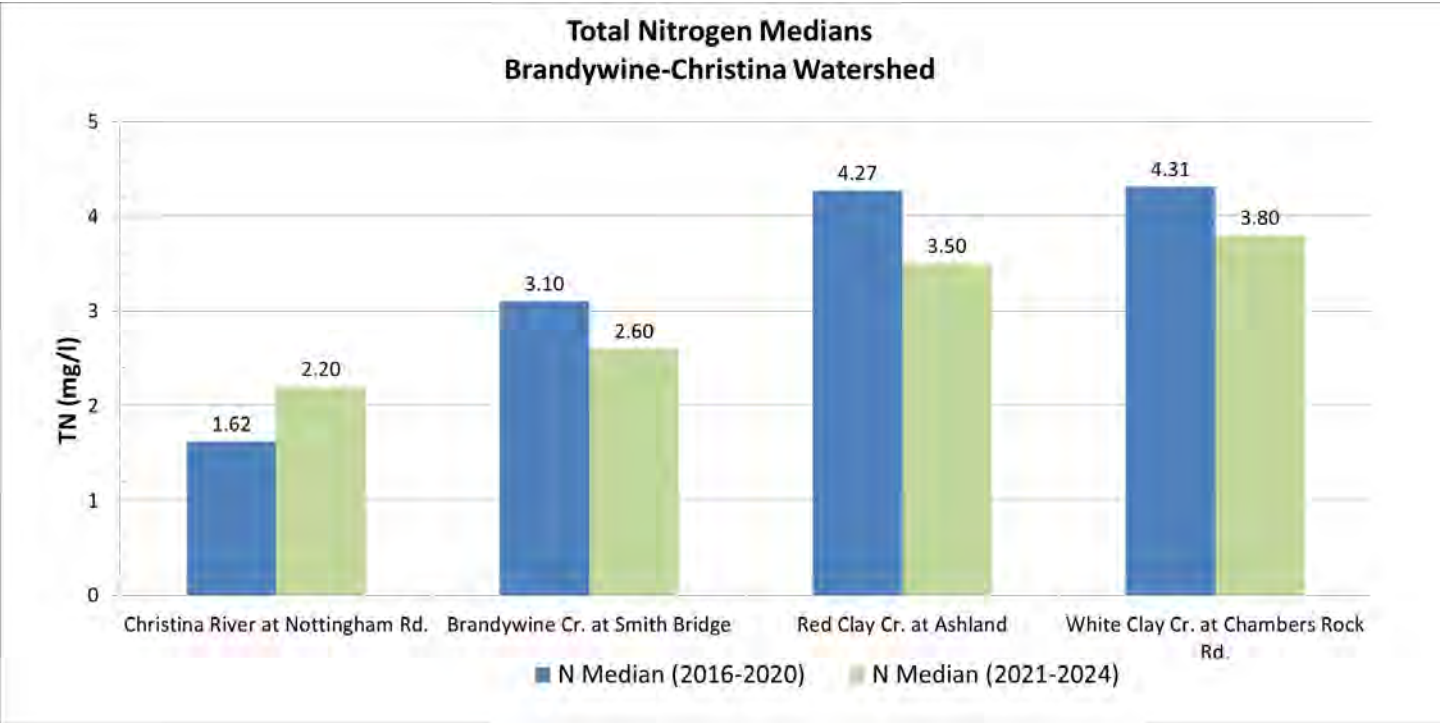


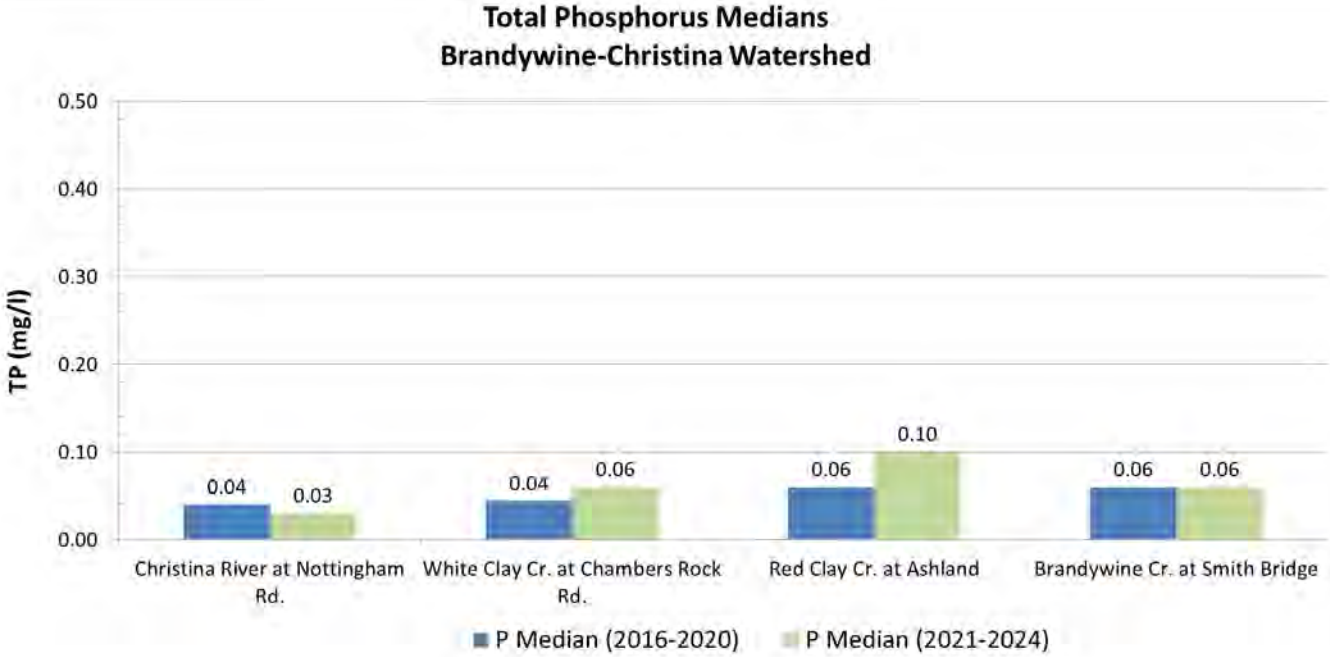


Sediment levels have declined but are still high during storms.


Dissolved Oxygen Medians
Brandywine-Christina Watershed
DO (mg/l)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10.98
10.20
10.96
10.50
10.80
10.25
9.68
10.8
White Clay Cr. at Chambers Rock Rd.
Red Clay Cr. at Ashland
Brandywine Cr. at Smith Bridge
Christina R. at Nottingham Rd.
DO Median (2016-2020)
DO Median (2021-2024)


Enterococcus Bacteria Medians
Brandywine-Christina Watershed
Entero CFU/100 ml
240
220
200
180
160
140
120
100
80
60
40
20
0
55
87
106
134
107
145
113
222
Brandywine Cr. at Smith Bridge
Red Clay Cr. at Ashland
White Clay Cr. at Chambers Rock Rd.
Christina River at Nottingham Rd.
Bacteria Median (2016-2020)
Bacteria Median (2021-2024)


Total Nitrogen Medians
Brandywine-Christina Watershed
TN (mg/l)
5
4
3
2
1
0
1.62
2.20
3.10
2.60
4.27
3.50
4.31
3.80
Christina River at Nottingham Rd.
Brandywine Cr. at Smith Bridge
Red Clay Cr. at Ashland
White Clay Cr. at Chambers Rock Rd.
N Median (2016-2020)
N Median (2021-2024)


Total Phosphorus Medians
Brandywine-Christina Watershed
TP (mg/l)
0.50
0.40
0.30
0.20
0.10
0.00
0.04
0.03
0.04
0.06
0.06
0.10
0.06
0.06
Christina River at Nottingham Rd.
White Clay Cr. at Chambers Rock Rd.
Red Clay Cr. at Ashland
Brandywine Cr. at Smith Bridge
P Median (2016-2020)
P Median (2021-2024)

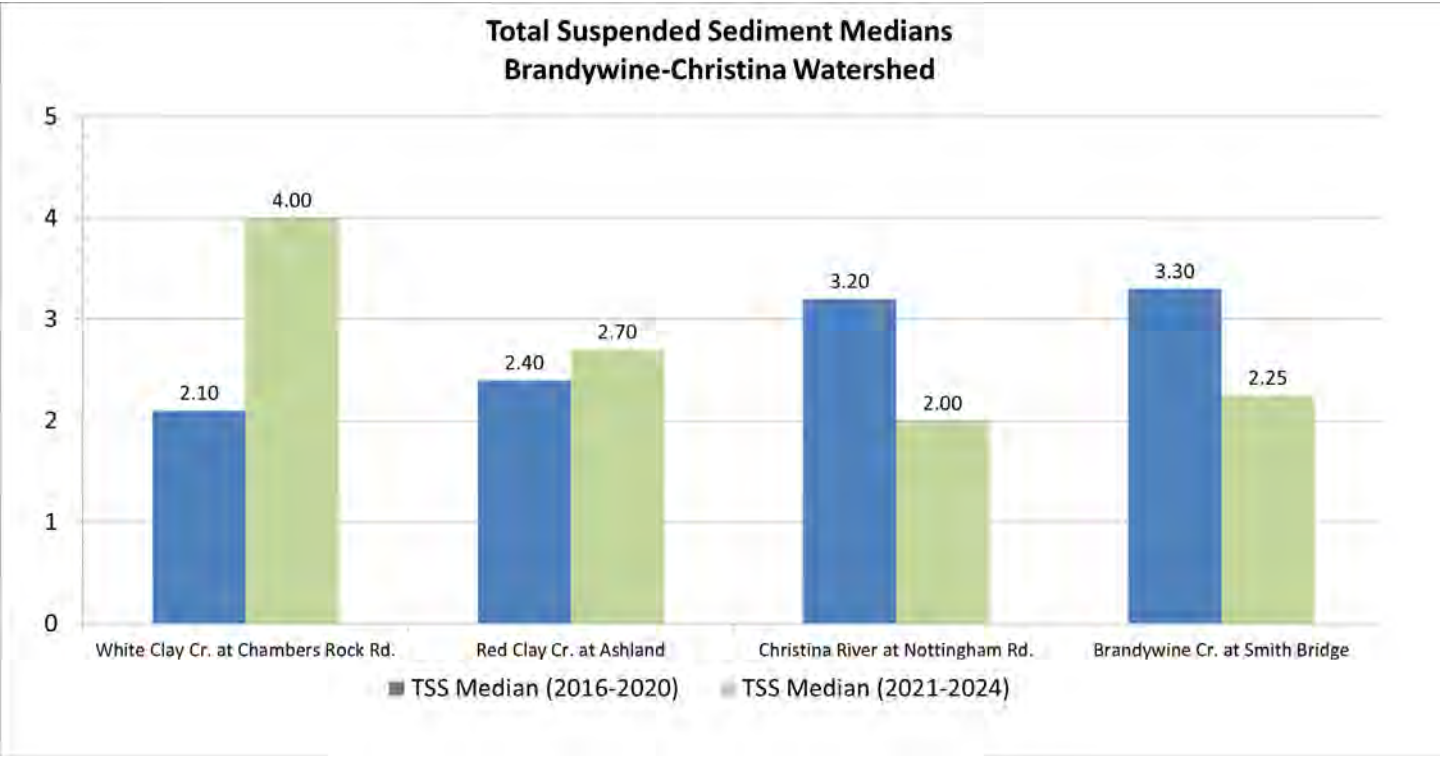

Total Suspended Sediment Medians
Brandywine-Christina Watershed
5
4
3
2
1
0
4.00
2.10
2.70
2.40
3.20
2.00
3.30
2.25
White Clay Cr. at Chambers Rock Rd.
Red Clay Cr. at Ashland
Christina River at Nottingham Rd.
Brandywine Cr. at Smith Bridge
TSS Median (2016-2020)
TSS Median (2021-2024)

Table 2. Trend Analysis Results for TN and TP Concentrations at the C1 Monitoring Sites

C1 Site ID	Location description	Period (water year)	Estimated TN Change (mg/l)	Estimated TP Change (mg/l)	TN Trend*	TP Trend*
103031	Red Clay Creek at Lancaster Pike (Rt. 48)	1999 - 2019	-0.07	-0.177	~~~	↓
104021	Brandywine Creek at New Bridge Rd. (Rd. 279)	1999 - 2019	-0.19	-0.070	↓	↓
105151	White Clay Creek at Delaware Park Blvd.	1999 - 2019	-0.63	-0.142	↓	↓
106141	Christina River at Sunset Lake Rd. (Rt. 72)	1999 - 2019	-0.83	-0.026	↓	↓

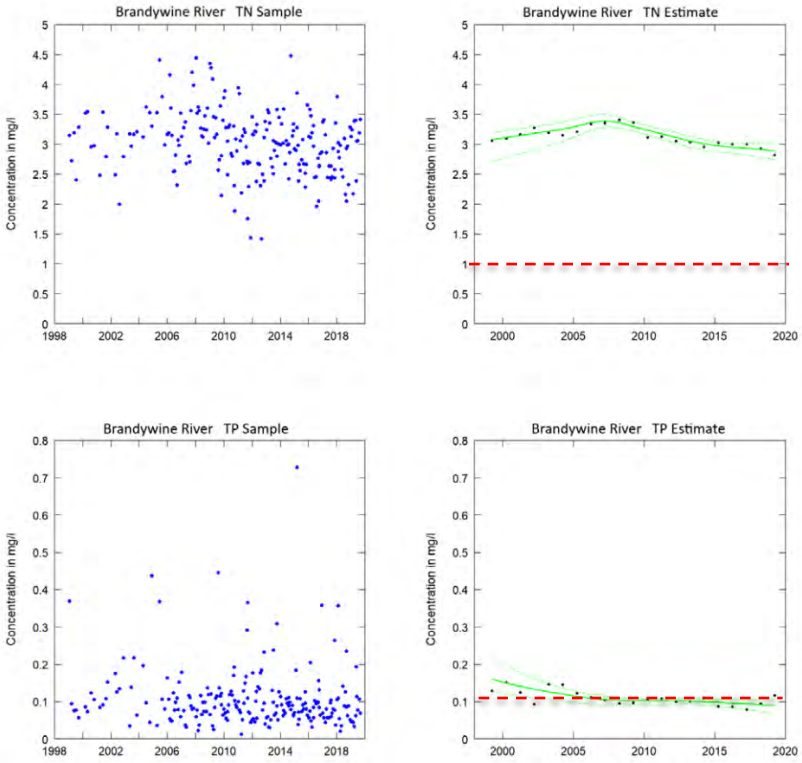


Figure 7. TN and TP sample concentrations (blue dots) at Brandywine River at New Bridge Road (site ID 104021), estimated annual mean (black dots) and flow normalized concentrations (green lines) with 90% confidence intervals (green dotted lines)

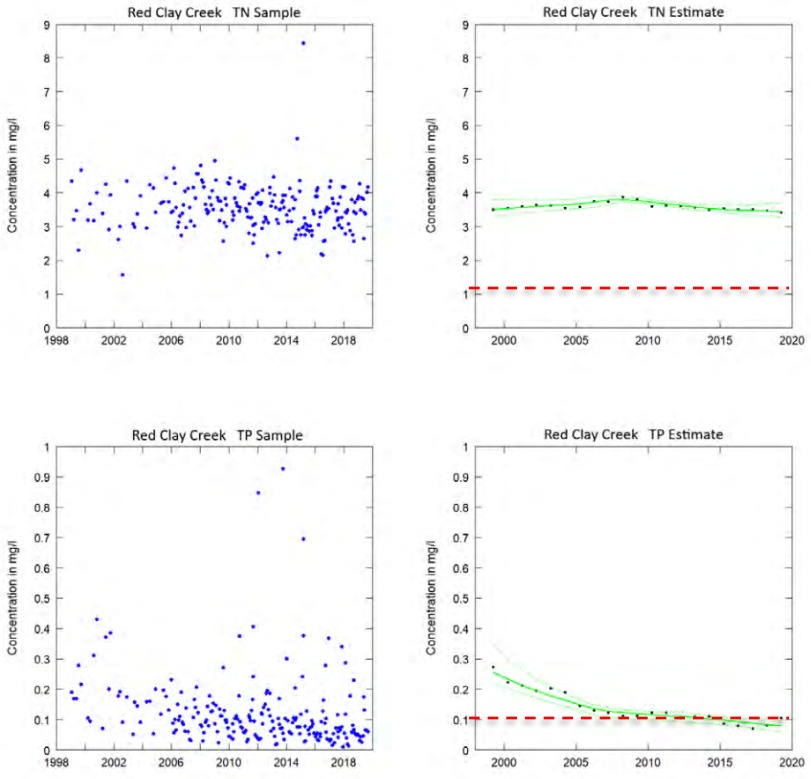


Figure 6. TN and TP sample concentrations (blue dots) at Red Clay Creek at Lancaster Pike (site ID 103031), estimated annual mean (black dots) and flow normalized concentrations (green lines) with 90% confidence intervals (green dotted lines)

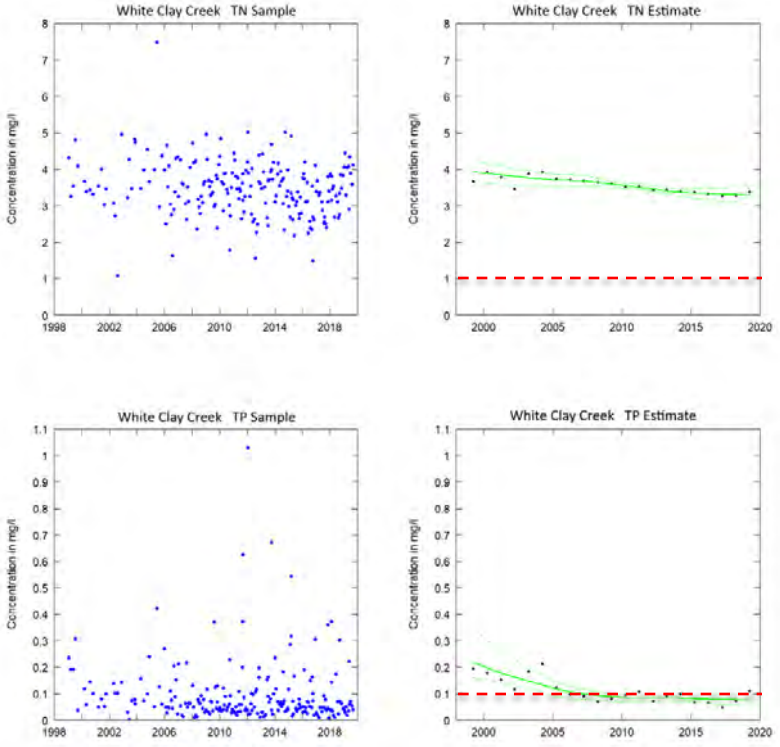


Figure 8. TN and TP sample concentrations (blue dots) at White Clay Creek at DE Park Boulevard (site ID 105151), estimated annual mean (black dots) and flow normalized concentrations (green lines) with 90% confidence intervals (green dotted lines)

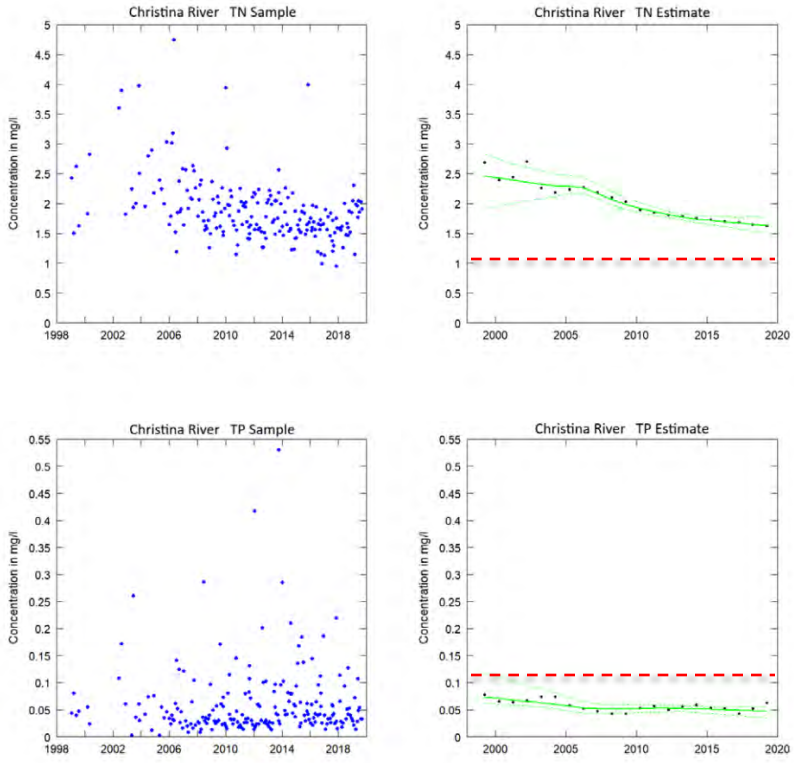
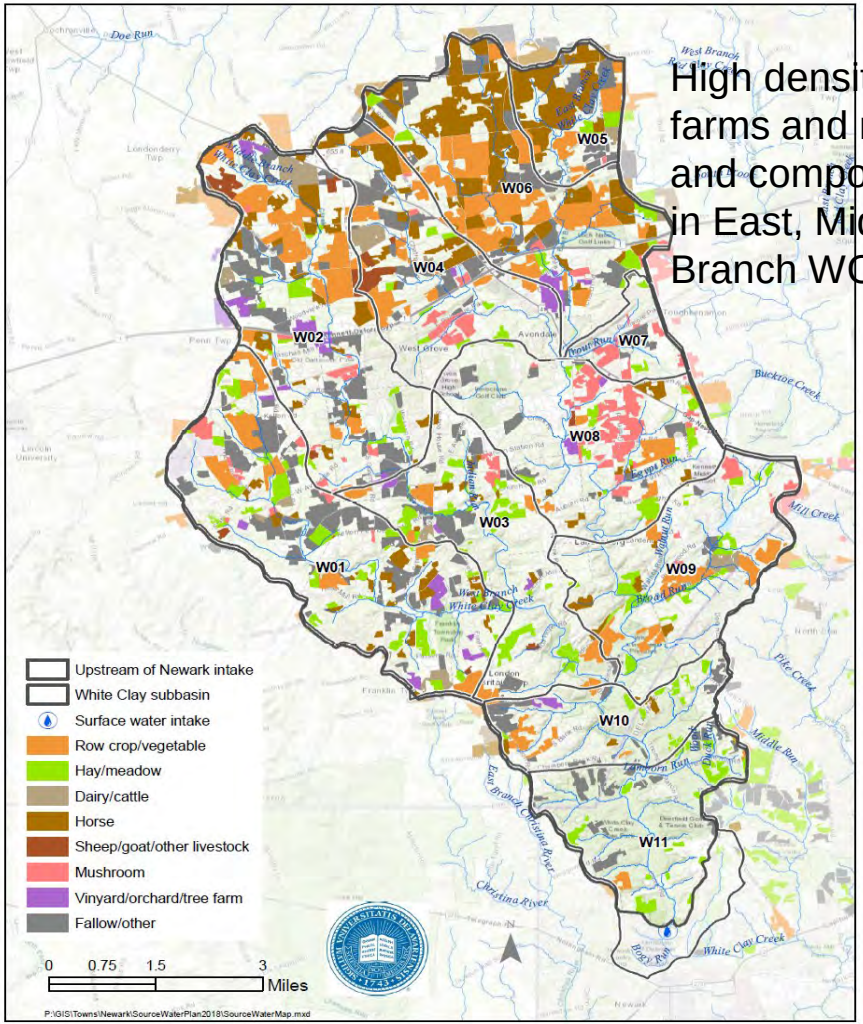
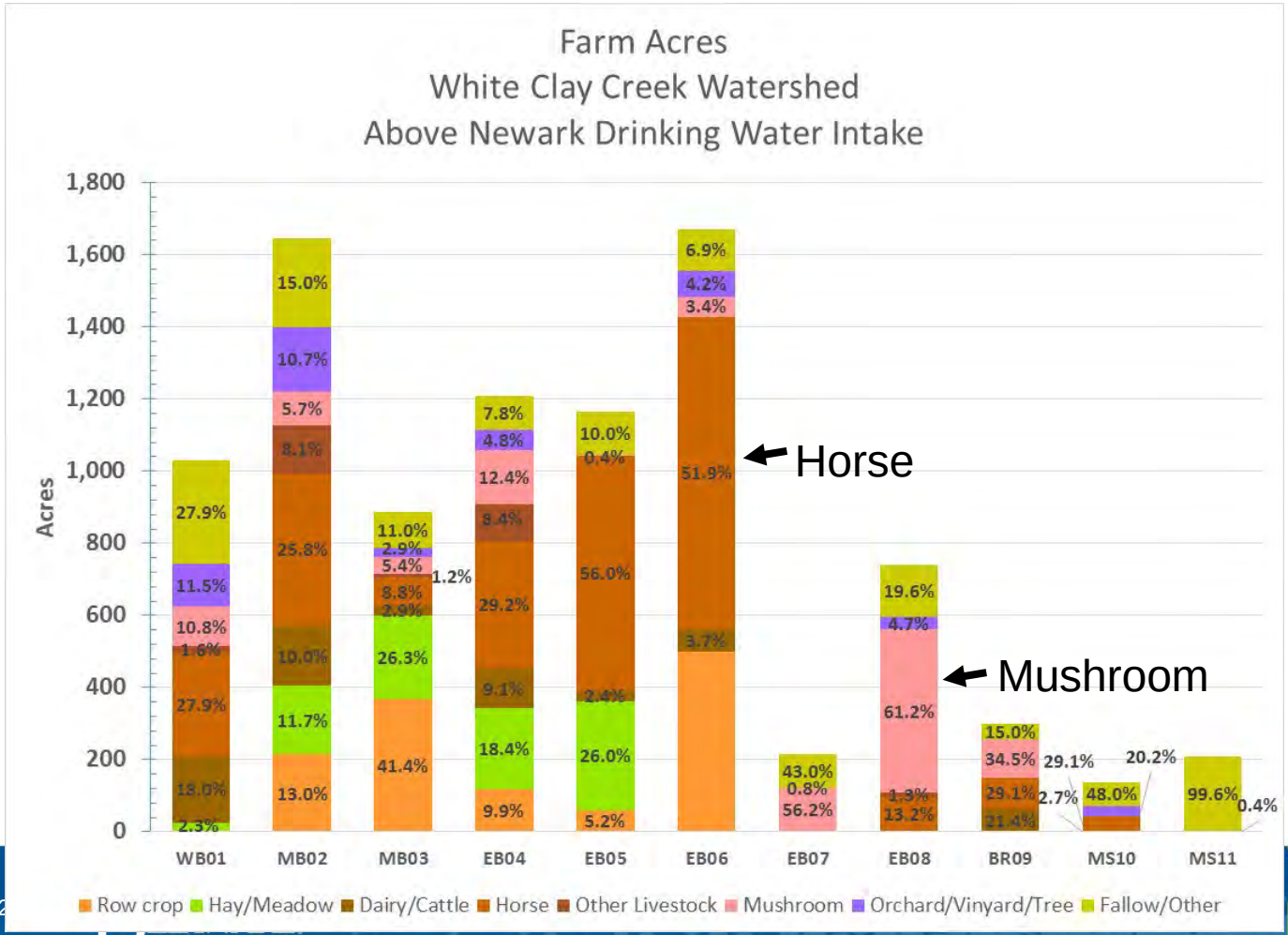


Figure 9. TN and TP sample concentrations (blue dots) at Christina River at Sunset Lake Road (site ID 106141), estimated annual mean (black dots) and flow normalized concentrations (green lines) with 90% confidence intervals (green dotted lines)

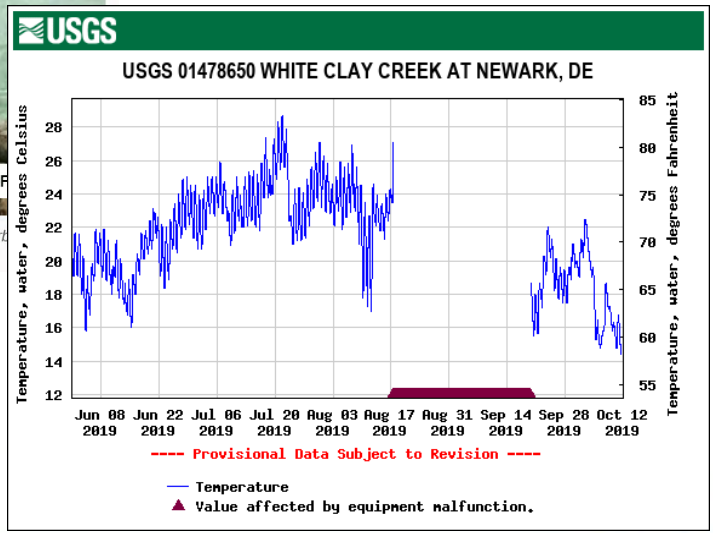


High density of horse farms and mushroom and compost operations in East, Middle, West Branch WCC.


Farm Acres
White Clay Creek Watershed
Above Newark Drinking Water Intake
Acres
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
WB01
MB02
MB03
EB04
EB05
EB06
EB07
EB08
BR09
MS10
MS11
27.9%
11.5%
10.8%
1.6%
27.9%
18.0%
2.3%
15.0%
10.7%
5.7%
8.1%
25.8%
10.0%
11.7%
13.0%
11.0%
2.9%
5.4%
1.2%
8.8%
2.9%
26.3%
41.4%
7.8%
4.8%
12.4%
8.4%
29.2%
9.1%
18.4%
9.9%
10.0%
0.4%
56.0%
2.4%
26.0%
5.2%
6.9%
4.2%
3.4%
51.9%
3.7%
43.0%
0.8%
56.2%
19.6%
4.7%
61.2%
1.3%
13.2%
15.0%
34.5%
29.1%
21.4%
29.1%
2.7%
48.0%
20.2%
99.6%
0.4%
Horse
Mushroom
Row crop
Hay/Meadow
Dairy/Cattle
Horse
Other Livestock
Mushroom
Orchard/Vinyard/Tree
Fallow/Other

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

High nitrogen and high summer temps contribute to harmful algal blooms in Newark Reservoir cancelling triathlons and rendering drinking water unpotable.



Executive Summary

1. Newark maintains a stormwater system in the Christina/White Clay watersheds with 60 miles of sewers, 200 miles of curb/gutter, 3000 catch basins, 34 stormwater ponds, & 500 floodplain acres.

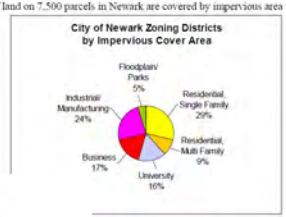
2. The City proposes to adopt a stormwater utility as a dedicated funding source to recover $1.6 million annually for operation of stormwater, water quality, and floodplain programs largely required by Federal and State laws and regulations.

3. The goals of the Newark stormwater program are to: (a) prevent/reduce flood and stormwater problems, (b) improve water quality, (c) decrease pollutant loads to City drinking water sources.

4. Stormwater utility advantages include: (a) treats stormwater as a utility resource (like drinking water) instead of waste stream, (b) equitable by stormwater contribution from impervious roof and pavement, (c) accrued to tax paying & tax exempt properties - both contribute stormwater runoff.

5. There are more than 500 stormwater utilities throughout the USA:
- The average stormwater fee for a single family home was $3.67 per month.
- College town monthly residential fees: $1.50 (Burlington, VT), $3.43 (Orono, ME), $14.26 (Ft. Collins, CO).
- USEPA survey in mid-Atlantic, residential stormwater fees range from $2 to $40 per quarter.
- Wilmington and Philadelphia monthly residential fees are $3.03 and $10.80, respectively.

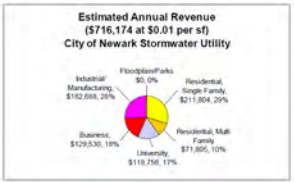
6. About 34% of land on 7,500 parcels in Newark are covered by impervious area with breakdown:



e family residential parcels in Newark is 4,000 sf which is
l (ERU).

utility in the City of Newark would range from:
mpervious cover ($3.33 per month single family residential), to
impervious cover ($6.75 per month single family residential).

City of Newark 2



9. The following table lists possible options for a City of Newark stormwater utility fee:

Designation	Option 1 ($0.01/sf) Stormwater Fee	Option 2 ($0.02/sf) Stormwater Fee
Residential, One-family, detached, semidetached	$3.33 monthly	$6.75 monthly
Multifamily Residential, University, Business, Manufacturing, Industrial, Office	$10.00/1000 sf monthly	$20.00/1000 sf monthly
Open floodway district (undeveloped)	No building permitted	No building permitted
Parkland, Roads/streets, Railroads, City – owned land, City – leased parking facilities	Exempt	Exempt
Projected Annual Revenue	**$716,174**	**$1,432,348**

10. The City and WRA should initiate a public education program to inform property owners about the benefits of a stormwater utility to reduce flooding/stormwater problems and improve water quality:
- Meet with commercial properties that generate high stormwater runoff and (2) tax exempt properties.
- Establish a stormwater utility website.
- Create a stormwater utility brochure to be sent to all customers before initial billing.

11. Municipalities are authorized to form a stormwater utility in Chapter 40, Title 7, Delaware Code.

12. The City should consider the water/sewer/electric or property assessment billing systems to assess the stormwater fee with the latter being the preferred mechanism.

13. City Council should consider adopting a stormwater utility ordinance to recover annual costs of stormwater services provided to parcel owners with ordinance effective date January 1, 2010.

University of Delaware
College of Human Services, Education & Public Policy
Institute for Public Administration

August 19, 2009

Mr. Kyle Sonnenberg, City Manager
Mr. Rich Lapointe, Public Works Director
City of Newark
220 Elkton Road
Newark, DE 19711

RE: Stormwater Utility Feasibility Report

Dear Mr. Sonnenberg and Mr. Lapointe:

Enclosed is our revised report summarizing the feasibility of a stormwater utility for the City of Newark. The purpose of the stormwater utility is to equitably fund the City's stormwater programs to reduce flooding and stormwater problems and improve water quality. ***In Newark, stormwater is drinking water.*** Many of these City programs are conducted in accordance with Federal/State laws like the Clean Water Act and Del. Stormwater and Sediment Control Regulations. Delaware municipalities are authorized to form stormwater utilities under Chapter 40, Title 7 of Delaware Code. Many college towns of similar character have successfully implemented stormwater utilities as dedicated and sustainable funding of stormwater, water quality, and floodplain management programs.

Based on a statistical GIS analysis of parcels and zoning districts and annual rates of $0.01 to $0.02 per square foot of impervious area, the stormwater utility would generate $716,000 to $1,432,000 per year for the City stormwater budget. The gross impervious cover of 7,500 parcels within 8.0 sq mi of the City is 34% (minus roads/railroads). At a penny per sf rate, the flat fee for single family residential parcels would be $3.33 per month and nonresidential fees would be $10.00 per 1000 sf per month. At two pennies per sf, the fee for single family residential would be $6.75 per month and nonresidential fees would be $20.00 per 1000 sf per month. The study includes a draft ordinance for considerati---

This report incorporates additional information presented at last night's City Council workshop.

Please do not hesitate to contact us at 302-831-4929 or jerryk@udel.edu.

Warmly;

Gerald J. Kauffman P. E.
Director

Andrew Homsey
GIS Manager

Cc: Roy Lopata, Newark Planning Department
Roy Simonson, Newark Water Department
Dennis McFarland, Newark Finance Departm

In 2009 UD submitted the first stormwater utility feasibility report to the City of Newark.

Newark council approves monthly stormwater fee

Charge is equivalent to 7 percent tax hike for average resident

By Josh Shannon jshannon@chespub.com Oct 10, 2017 9

The stormwater fee approved Monday will raise $1.4 million each year to improve stormwater facilities around the city. SUBMITTED PHOTO

Capping years of discussion, city council on Monday approved a plan to charge every landowner in the city a monthly fee to fund upgrades to the stormwater system.

Starting in January, homeowners will pay between $1.77 and $5.31 each month, which for the average resident is akin to a 7 percent tax increase, officials said.

The proposal passed 4-2, with opposing votes from Councilmen Stu Markham and Mark Morehead, who both said they support the idea in principle but had unresolved concerns. Councilman Luke Chapman was absent.

Supporters of the measure acknowledged it's not perfect but believed it was time to move forward.

Latest e-Edition More Issues

Meter Number	Read Dates Present	Previous	Billing Days	Meter Readings Code	Present	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

	Rate	Usage	Charges
PREVIOUS BALANCE			48.96
PAYMENT 04/18/2019			-48.96
PAST DUE AMOUNT/BALANCE FORWARD			0.00
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

In 2017, City Council approved stormwater utility by 4-2 vote. Average monthly resident fee = $4.91. Revenue can be invested upstream.