2023 Tulpehocken Creek Watershed Association Annual Report

1. Executive Summary

A. Blue Marsh Lake

During the Summer of 2023, the Tulpehocken Creek Watershed Association (TCWA) focused our attention on learning about a key component of our watershed, Blue Marsh Lake. We researched available data utilizing Stroud's "Model My Watershed" (MMW) software. We also consulted with the Rangers at Blue Marsh Lake and obtained Keyhole Marker Language (KML) electronic files of Blue Marsh Lake lands and waterways. Combining these sources of information in Google Earth, as well as an Excel spreadsheet, we identified the thirteen main streams which feed the Blue Marsh Lake and set out to sample these streams and collect data on their water quality. See image on page 1 for the thirteen Sites' mapped locations.

We then compared the MMW nitrate and phosphate modeled concentrations for the thirteen streams with the test results we obtained. Summary of results are as follows:

Nitrates		
Location	From Stroud MMW (mg/L)	TCWA Measured (mg/L)
BMS1 Little Northkill Creek	4.1	1.0
BMS2 Northkill Creek	3.7	4.0, 2.0, 1.5, 1.0
BMS3 UT1 to Northkill Creek	4.2	No Flow
BMS4 UT2 to Northkill Creek	3.9	No Flow
BMS5 Tulpehocken Creek	12.8	6.5
BMS6 Power Mill Creek	3.6	4.0
BMS7 Licking Creek	3.5	5.0, 6.0
BMS8 UT Near Sheidy Rd	4.1	9.0
BMS9 UT Near Peacock Rd	4.5	5.5, 6.0
BMS10 Near Milestone Rd	5.5	8.0
BMS11 Spring Creek	4.0	7.0
BMS12 UT East of Brownsville	4.4	3.0
BMS13 UT Near Highland Rd	3.1	1.5

Table 1

Phosphates		
Location	From Stroud MMW (mg/L)	TCWA Measured (mg/L)
BMS1 Little Northkill Creek	0.2	0.1
BMS2 Northkill Creek	0.2	0.04, 0.08, 0.02, 0.05
BMS3 UT1 to Northkill Creek	0.3	No Flow
BMS4 UT2 to Northkill Creek	0.3	No Flow
BMS5 Tulpehocken Creek	0.9	0.3
BMS6 Power Mill Creek	0.3	0.3
BMS7 Licking Creek	0.3	0.3
BMS8 UT Near Sheidy Rd	0.3	0.1
BMS9 UT Near Peacock Rd	0.3	0.12 & 0.00
BMS10 Near Milestone Rd	0.3	0.1
BMS11 Spring Creek	0.3	0.1
BMS12 UT East of Brownsville	0.2	0.0
BMS13 UT Near Highland Rd	0.3	0.2

Table 2

See body of report for additional information.

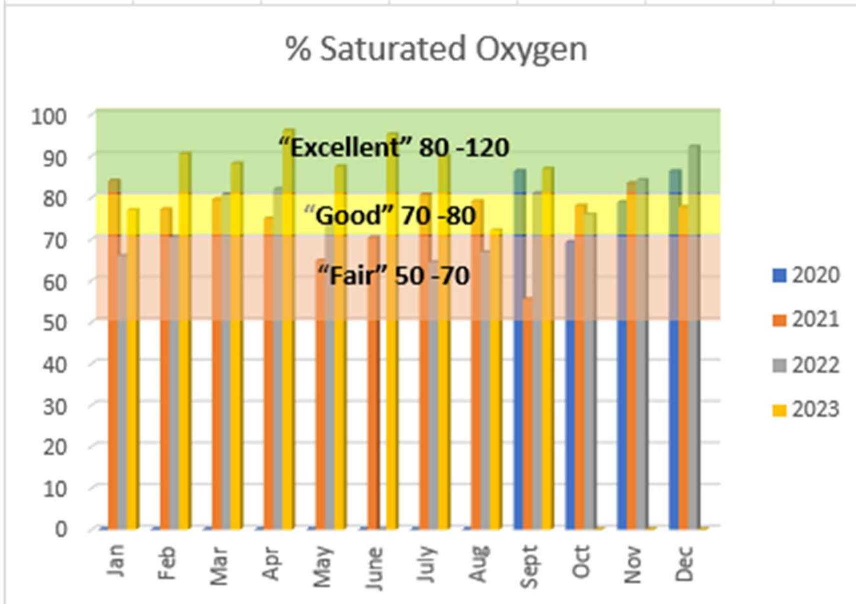
B. Cacoosing Creek – Downstream of the former Papermill Dam

In 2023, TCWA also continued our monthly testing of the Cacoosing Creek for the third consecutive year. The sampling point is located just upstream of the confluence with Tulpehocken Creek.

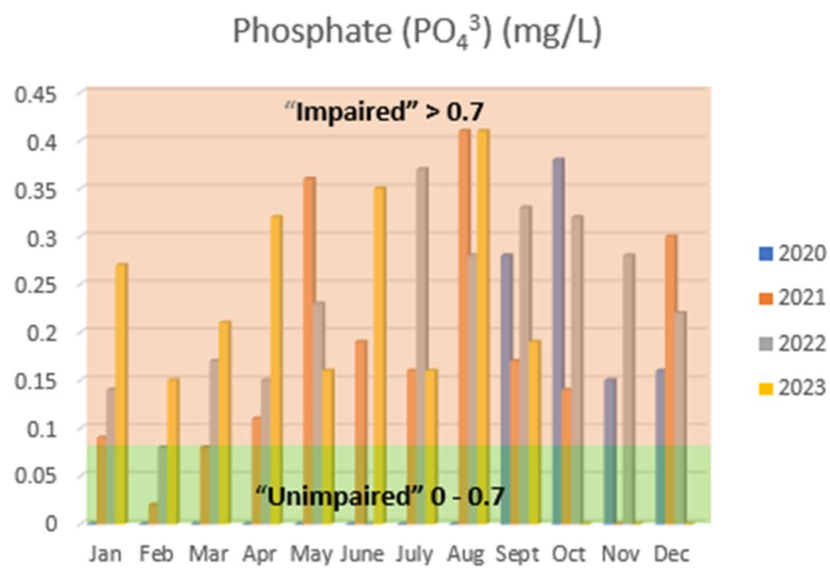
Over the three-year period, results indicate that for Dissolved Oxygen the levels of saturation were "Good" or "Excellent" for a majority of the tests. However, for Phosphate and Nitrate concentrations the levels indicate an "impaired" condition for a majority of the test results. See graphical representation of the results in the following images (Graphs 1 - 4).

The graphs were arranged on a month-by-month basis to discern if there were any recurring seasonal variations for the water quality attributes. Nitrate concentration was the only parameter that reached a similar level from year to year and that was in the month of May.

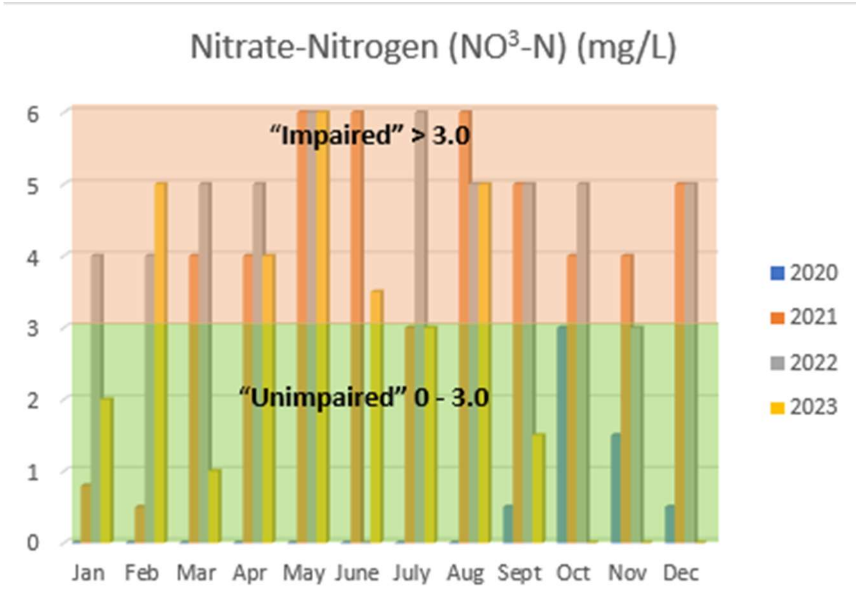
Another purpose of the long-term testing was to see if the Papermill Dam removal had a noticeable impact on the water quality. Although we did see some short-term response to the dam removal, no significant trends were observable during this time period.



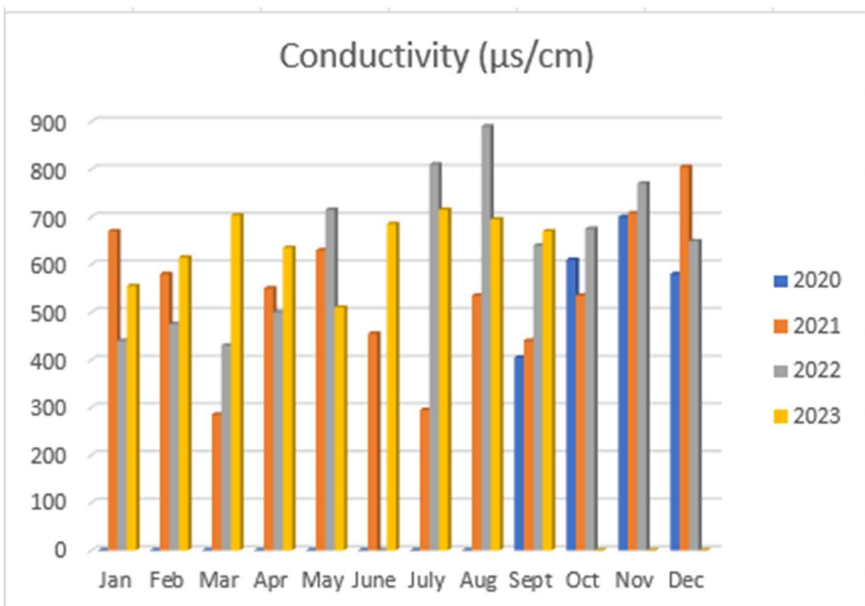
Graph 1. Monthly measured dissolved oxygen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.



Graph 2. Monthly measured phosphate levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.



Graph 3. Monthly measured nitrate-nitrogen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022



Graph 4. Monthly measured conductivity levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022

See the body of the report for additional information.

C. HOBO Data Logger Results

TCWA continued to collect stream temperature data from two HOBO data logger sensors installed in Licking Creek and the Little Cacoosing.

In regard to Licking Creek, there's an argument to be had that Licking Creek could be a candidate for redesignation either to Cold Water Fishery or maybe High Quality. The year-round temperature data looks excellent. However, macroinvertebrate Index of Biological Integrity (IBI) and fish community sampling would need to be done to meet PADEP's requirements for reclassification. TCWA is pursuing obtaining additional data from Stroud regarding IBI and fish sampling. See Appendix 8 for temperature data.

Data is being collected in the Little Cacoosing in an attempt to gauge the impact of a streamside rehabilitation project that started in August of 2022. The purpose of the project is to restore habitat and floodplains along 2,500 feet of Little Cacoosing in the Green Valley area of Lower Heidelberg Township. The temperature sensor is located in the stream immediately downstream of the project work. It will take more time before the recently installed vegetation grows sufficiently to affect the stream water temperature. See Appendix 8 for temperature data.

D. Follow-up of Recommendations from Previous Reports and Analysis of Additional Previous Watershed Wide Testing Results

TCWA Water Testing Results for 2022 suggested that Site 9 (Tulpehocken Creek at Stouchsburg Bridge) requires additional study. Also, Site 13 (Cacoosing Creek at Prendergast Rd) had high phosphate results and additional testing and analysis were required. Both suggestions have been followed through in 2023. See body of report for additional information.

As of October of 2023, TCWA has performed over 300 stream water quality tests since 2019. It was suggested that additional analysis be performed on this data. In 2023 additional analysis was performed. See body of report for additional information.

2. Blue Marsh Lake - Background Information

Blue Marsh Lake is a prominent reservoir located in Reading, Pennsylvania. Managed by the U.S. Army Corps of Engineers, the lake spans over 1,150 acres and offers a range of recreational activities, including boating, fishing, hiking, and picnicking. Despite its natural beauty and recreational appeal, Blue Marsh Lake has been facing significant environmental challenges related to nutrient pollution and algal blooms in recent years.

Nutrient pollution, often caused by excessive levels of nitrogen and phosphorus, has become a prevalent issue in many freshwater bodies across the United States. This issue affects water quality, aquatic ecosystems, and the safety of recreational activities. Blue Marsh Lake is no exception.

Nutrient pollution in Blue Marsh Lake primarily originates from various sources, including:

1. **Agricultural Runoff**: The surrounding area of Blue Marsh Lake has extensive agricultural activity. Runoff from farms can carry excess fertilizers containing nitrate and phosphate into the lake. From USGS's National Land Cover Database (2019), the land cover within the Tulpehocken Creek Watershed upstream of Blue Marsh lake is 41% cultivated crops and 15% pasture/hay.
2. **Wastewater Discharge**: Local wastewater treatment plants may release treated water into the lake via the streams that supply the lake. Although the plants employ multiple treatment systems, the effluent may still contain elevated levels of nutrients. There are 12 wastewater treatment/sewage treatment plants that discharge their effluent into streams that eventually feed into Blue Marsh Lake.
3. **Stormwater Runoff**: Urban areas near the lake contribute to nutrient pollution through stormwater runoff, which can carry pollutants, including nitrogen and phosphorus, into the lake. From USGS's National Land Cover Database (2019), the land cover within the Tulpehocken Creek Watershed upstream of Blue Marsh lake is approximately 14% developed land. In an attempt to control pollution from stormwater, Pennsylvania has instituted a Municipal Separate Storm Sewer System (MS4) program. Municipalities and other entities such as universities and prisons that meet certain standards must obtain NPDES permit coverage for discharges of stormwater from their municipal separate storm sewer systems (MS4s). The program is still developing.

The excessive nutrients entering Blue Marsh Lake have led to the development of algal blooms. Algal blooms occur when certain types of algae grow rapidly, often forming visible green, blue-green, or red scum on the water's surface. These blooms can have numerous negative impacts:

1. **Water Quality**: Algal blooms degrade water quality, making it unsuitable for recreational activities and sometimes affecting drinking water supply.
2. **Harm to Aquatic Life**: As algae die and decompose, they consume oxygen in the water, leading to oxygen depletion. This can harm fish and other aquatic organisms.
3. **Human Health Risks**: Some algae species produce toxins that pose health risks to humans and animals if ingested or exposed to the skin.
4. **Economic Impact**: The presence of algal blooms can deter tourists and negatively impact local businesses that rely on the lake for revenue.

To address nutrient pollution and algal blooms, Pennsylvania has set water quality standards and regulations. The Pennsylvania Department of Environmental Protection (PA DEP) has established mandated limits for nitrate and phosphate levels in lakes, including Blue Marsh Lake. These limits aim to control nutrient pollution and maintain the ecological health of the state's water bodies.

Pennsylvania's state mandates typically include:

1. **Total Maximum Daily Loads (TMDLs)**: TMDLs are calculated limits for specific pollutants in a water body to ensure that it meets water quality standards. In the case of Blue Marsh Lake, TMDLs would specify acceptable levels of nitrate and phosphate. More information on the TMDL program is available at

https://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/tmdl/TMDL_Slides.pdf

2. **Nutrient Management Programs**: The state may implement nutrient management programs to reduce nutrient runoff from agriculture and urban areas, thus controlling the sources of nutrient pollution. Additional information on this program is accessible at https://extension.psu.edu/programs/nutrient-management
3. **Wastewater Treatment Standards**: Pennsylvania enforces strict wastewater treatment standards to limit the discharge of nutrients into lakes and rivers. PA DEP wastewater information can be obtained at https://www.dep.pa.gov/Business/Water/CleanWater/WastewaterMgmt/Pages/default.aspx

3. Blue Marsh Lake – Review of Data and Future Plans

Table 3 combines the data extracted from MMW with the TCWA test results. The Stroud numbers are based on “average annual loads from 30 years of daily fluxes”. The last two columns in the table are from the TCWA water quality testing done in 2023 on these streams. See Appendix 4 for the full list of the data from these tests.

Looking at the data, the mainstem of Tulpehocken Creek is by far the most significant contributor of nutrients to BML. This is true in regard to concentration as well as volume with almost four million pounds of nitrate per year and over a quarter of a million pounds of phosphate. Spring Creek is the next largest contributor, but at rates of less than 10% of the Tulpehocken loads.

Location	From Stroud Model My Watershed					Conversion		Measured	
	Nitrate lb/yr	Phosphate lb/yr	Avg TN (mg/l)	Avg TP (mg/l)	cfs	gpd	lb/yr	TN (mg/L)	TP (mg/L)
BMS1 Little Northkill Creek	237,152	13,922	4.1	0.24	29.0	18,743,193	57,093,116,756	1.00	0.13
BMS2 Northkill Creek	176,126	10,551	3.7	0.22	24.2	15,640,871	47,643,221,569	4&2&1.5&1	.04&.08&.02&.05
BMS3 UT1 to Northkill Creek	13,599	937	4.2	0.29	1.7	1,072,886	3,268,088,752	No Flow	No Flow
BMS4 UT2 to Northkill Creek	9,680	727	3.9	0.29	1.3	820,823	2,500,284,768	No Flow	No Flow
BMS5 Tulpehocken Creek	3,720,280	264,787	12.8	0.91	147.0	95,008,599	289,403,040,108	6.50	0.25
BMS6 Power Mill Creek	26,722	2,114	3.6	0.28	3.8	2,475,394	7,540,228,868	4.00	0.25
BMS7 Licking Creek	31,166	2,552	3.5	0.28	4.6	2,940,742	8,957,713,146	5.0 & 6.0	0.34
BMS8 UT Near Sheidy Rd	27,281	1,856	4.1	0.28	3.3	2,158,699	6,575,552,068	9.00	0.05
BMS9 UT Near Peacock Rd	43,116	4,028	4.5	0.30	5.2	3,360,848	10,237,386,453	5.5 & 6.0	0.12 & 0.00
BMS10 Near Milestone Rd	28,607	2,734	5.5	0.38	4.5	2,889,037	8,800,214,893	8.00	0.11
BMS11 Spring Creek	326,607	23,316	4.0	0.29	41.4	26,738,134	81,446,284,145	7.00	0.11
BMS12 UT East of Brownsville	9,409	495	4.4	0.23	1.1	704,486	2,145,913,699	3.00	0.04
BMS13 UT Near Highland Rd	4,756	419	3.1	0.28	0.8	497,664	1,515,920,686	1.50	0.20
Total	4,654,501	328,438				173,051,377	527,126,965,911		

Table 3. Modeled and measured nitrate and phosphate loads for each of 13 tributaries to Blue Marsh Lake.

Comparing the TCWA measured values of the nutrient concentration (mg/L) to the MMW model concentrations, we get the following results (Table 4):

Location	Compare Measured Values to MMW Model	
	TN	TP
BMS1 Little Northkill Creek	24%	54%
BMS2 Northkill Creek	57%	18%
BMS3 UT1 to Northkill Creek	NA	NA
BMS4 UT2 to Northkill Creek	NA	NA
BMS5 Tulpehocken Creek	51%	27%
BMS6 Power Mill Creek	113%	89%
BMS7 Licking Creek	158%	121%
BMS8 UT Near Sheidy Rd	217%	18%
BMS9 UT Near Peacock Rd	128%	20%
BMS10 Near Milestone Rd	145%	29%
BMS11 Spring Creek	175%	38%
BMS12 UT East of Brownsville	69%	17%
BMS13 UT Near Highland Rd	48%	71%

Table 4, Comparison of total nitrogen (TN) and total phosphates (TP) measured by TCWA in summer 2023 to modeled average TN and TP from Model My Watershed for each of the 13 tributaries to Blue Marsh Lake.

The 2023 measured concentrations for nitrates showed a wide range of values as compared to the MMW modeled values with about half the measured values being lower than the modeled values and about half the measured values being higher. The average for all 13 comparisons is 108%.

The 2023 measured concentrations for phosphates revealed that most of the measured values were considerably lower than the values found in the MMW model with the exception being Licking Creek. The average for all 13 comparisons is 46%.

A study performed by the United States Department of Agriculture (USDA) published in April 1992 titled “Agricultural Nonpoint Source Evaluation for the Tulpehocken Creek Watershed" stated, “The watershed evaluation consists of implementing 100 contracts with participants having serious agricultural pollution problems”. The Executive Summary of the report noted, “A 5-year implementation program with financial aid and technical assistance would reduce the nutrient pollution of the streams by about 32 percent”. (USDA, 1992). TCWA did find evidence that almost $1 million dollars were spent to implement the nutrient pollution reduction program between 1998 and 2001 (Archives, 1998). And the government and private sector have continued to invest in attempts to reduce nonpoint source as well as point source nutrient concentrations in our waterways. So, we would hope to see a reduction in the concentration of nutrients.

Based on our limited testing in 2023, phosphate concentrations in a majority of the streams feeding Blue Marsh Lake appear to be at a lower level today as compared to the 30-year average. However, nitrate levels appear to be higher on six of the streams tested when compared to the 30-year average.

As noted in our previous reports, discrete chemical testing only provides an extremely limited view of the nutrient concentration and properties of a stream. Projections based on limited sampling will have questionable accuracy. As can be seen from our previous testing results over a three-year period, albeit only one test per year, results vary significantly in many of the streams for most of the locations tested. (TCWA, 2020, 2021, 2022). Monthly monitoring, which TCWA is continuing to do on Cacoosing Creek, provides a better indication of stream water quality and may eventually display seasonal variability, possibly leading to identifying causes of quality change. Continuous monitoring is the only way of getting an accurate picture of stream properties, such as the quantity of nitrates and phosphates being carried by a stream.

As science begins to have a more comprehensive understanding of the impact of nutrients in our waterways, we see that the “acceptable” concentrations continue to change. TCWA in our past reports referenced the following table from Izaak Walton League of America “Chemical Monitoring Data Form for Stream Monitors” which references M.K. Mitchell and W. B. Stapp, Field Manual for Water Quality Monitoring.

WATER QUALITY SUMMATION for Chemical Tests				
	Excellent	**Good**	**Fair**	**Poor**
Dissolved Oxygen (% Saturation)	80-120	70-80 120-140	50-70 >140	<50
pH (units)	7.0-7.5	6.5-7.0 7.5-8.5	5.5-6.5 8.5-9.0	<5.5 >9.0
Chloride (Cl) (mg/L)	0-20	20-50	50-250	>250
Reactive Phosphate (PO_4X^3) (mg/L)	0-0.2	0.2-0.5	0.5-2.0	>2.0
Nitrate (NO_3) (mg/L)	0-3	3-5	5-10	>10
Transparency (cm)	>65.0	65.0-35.0	35.0-15.5	<15.5

Table 5. Water quality ranges identified by the Izaak Walton League of America for stream monitoring chemical tests.

More recently, we have found lower thresholds from Stroud Wiki watershed knowledge base, water quantity and quality models (https://wikiwatershed.org/knowledge-base/water-quantity-and-quality-models/#stream-reach-assessment-tool-overview)

From Wikiwatershed: “Pollutant Thresholds

Provided below is a table that presents some “threshold” values for nutrients and sediment that are intended to help determine whether a given watershed or stream segment might be impaired with respect to water quality. It must be understood, however, that these values are provided for guidance purposes only, and that actual impairments may vary based on many factors that interact at any given location. In the case of the values from Sheeder and Evans, both loading rate and in-stream concentration values are given. **These latter values are to be interpreted as approximate "breakpoints" between impaired and unimpaired watersheds that were based on an analysis of observed stream data for 29 watersheds in Pennsylvania**. The in-stream concentration values developed by USEPA and NJDEP, on the other hand, represent "targets" that each agency believes should be met to ensure unimpaired conditions within the general region of the Delaware River Basin. In the case of the USEPA values, a range is given for TN and TP due to the fact that values were developed for different ecoregions across the U.S, and the Delaware River Basin covers two of these regions.

From the table, it can be seen that a threshold value of 0.1 mg/l seems appropriate for TP. Although the values range considerably for TN, it should be noted, as described earlier, that the value for TP is usually more important due to the fact that it is the limiting nutrient for most streams in the Delaware River Basin. In the case of TSS, NJDEP has set different threshold values for TSS depending upon whether the streams do or do not support trout." (Sheeder, 2004)

Yields and Concentration Thresholds

Source	TN	TP	TSS
Sheeder and Evans	13.0 kg/ha (14.6 lb/ac)	0.30 kg/ha (0.34 lb/ac)	785 kg/ha (882 lb/ac)
Sheeder and Evans	3.0 mg/L	0.07 mg/L	197 mg/L
USEPA	0.07-1.0 mg/L	0.006-0.1 mg/L	–
NJDEP	10.0 mg/L	0.1 mg/L	25-40 mg/L (trout vs. non-trout)

**Note the actual nitrogen values given in Sheeder and Evans are for inorganic N only and are lower than those shown in the table above. The values shown above have been adjusted upwards to account for organic N as well. Also note that the TN values for NJDEP are for nitrate-N only. In this case, the value appears to be based on the national 10 mg/L drinking water standard rather than ecological or nutrient enrichment factors.*

For nitrates, both the values from MMW as well as our measured values, a majority of the streams have concentrations that exceed the Sheeder and Evans thresholds.

Although, based on our 2023 tests, phosphates appear to be lower for most streams when we compare these numbers to the MMW values, a majority of the streams still have concentrations that exceed the Sheeder and Evans thresholds.

In regard to tightening of limits on nutrient concentrations, to control eutrophication the USEPA has established **a recommended limit of 0.05 mg/L for total phosphates in streams that enter lakes** and 0.1 mg/L for total phosphorus in flowing waters (USEPA, 1986). These are even lower than the Sheeder numbers and compared to most of our test measurements, are ½ or ¼ the measured values.

With these numbers in mind, it is apparent that more must be done to reduce the amount of nutrients in Blue Marsh Lake. The attempt at limiting the nutrients getting into the streams may be meeting with some limited success, however, it may be time to look into efforts to filter the excessive nutrients from the stream before they dump into the lake or even after they are in the lake.

One approach to filtration could be the use of freshwater mussels. According to the Partnership for the Delaware Estuary (www.DelawareEstuary.org), one adult mussel filters up to 10 gallons of water per day. Although that may seem like a lot, when you look at Table 3 above and see that over 173 million gallons of water enter Blue Marsh Lake per day, that would be a lot of mussels! However, if we focus on some of the smaller streams that enter the lake in areas where algal blooms are more prevalent, such as Licking Creek, a pilot project set up in that area may show some positive results.

Another approach is through the use of Phytoremediation. "Duckweeds have potential uses for low-cost wastewater treatment and efficient removal of excess N and P. It has been estimated that duckweed can accumulate up to 9.1 t/ha/year of total N and 0.8 t/ha/year of total P in their biomass. … high rates of removal were also demonstrated with duckweed growing on sewage water and wastewater from a hog farm. Moreover, 98% removal of N and P from pig-farm effluent has been achieved. This was accompanied by a significant increase in the level of dissolved oxygen and the production of duckweed biomass with 35% crude protein." (Zhou, 2023). Similar to the mussels, this would not solve the problem in and of itself, but it could be another tool in the toolbox to begin addressing this problem.

Another method employing vegetation is FWI. According to Princeton Hydro, "Installing Floating Wetland Islands (FWI) is a low-cost, effective green infrastructure solution used to mitigate phosphorus and nitrogen stormwater pollution often emanating from highly developed communities and/or agricultural lands…Once the islands are anchored in the lake, the plants thrive and grow, extending their root systems through the mat and absorbing and removing excess nutrients from the water column such as phosphorus and nitrogen…. The installation of FWIs in Belcher's Creek will immediately address nutrients in the water before it enters Greenwood Lake and help decrease total phosphorus loading. In turn this will help reduce HABs, improve water quality throughout the Greenwood Lake watershed, and create important habitat for beneficial aquatic, insect, bird, and wildlife species." (Princeton Hydro, 2020).

For 2024, TCWA plans to continue to work with Blue Marsh Lake staff monitoring the waters as well as investigating and working with possible solutions to the HABs problem.

4. Cacoosing Creek - Background Information

From the *Coldwater Conservation Plan for the Cacoosing Creek Watershed*, "The Cacoosing Creek is listed as a Cold-Water Fishery –Migratory Fish (MF) due to the presence of the American eel (*Anguilla rostrata*) under its Pennsylvania Chapter 93

Designated Use. Adversely, the Little Cacoosing is designated as a Warm Water Fishery. There is a 2.5-mile stretch of the Cacoosing Creek located from Wernersville Road (T668) and north of State Route 422 that is listed as Class-A Wild Brown Trout Fishery by the [Pennsylvania Fish and Boat Commission] PFBC. Additionally, the Cacoosing Creek is designated as a Natural Reproduction Trout Stream from its headwaters to its confluence with the Tulpehocken. The designation provides Exception Value (EV) protection to all wetlands located within the watershed, including the wetlands associated with the Little Cacoosing which does not have any designated trout water classifications by the PFBC."

"Protected uses of the Cacoosing Creek Watershed include Aquatic Life and Recreation. However, the Cacoosing Creek watershed was surveyed under the PADEP's Statewide Surface Water Assessment Program, which resulted in over 25 miles of stream being determined as impaired with sediment, nutrients, and pathogens, and not meeting its Designated Use."

"Nutrients - Sources of nutrients from agricultural runoff to streams can have varying pathways, but in general can occur from animal concentration areas (barnyards, feed lots, loafing areas, etc.) and the overapplication of manure or commercial fertilizers. The conversion of nitrogen into nitrite (NO-2) and ammonia (NH3) can be lethal to most aquatic organisms while excess nitrate (NO_3) in water supplies can be harmful to human health. Nitrates cause exponential growth in brackish and saltwater plants, algae, and phytoplankton. The eventual death of these organisms and breakdown, cause reduced dissolved oxygen to hypoxic levels, creating a dead zone for most organisms. In freshwater systems, these plant communities respond in similar fashion to an abundance of Phosphorus or phosphate (PO_4^{3-}). Unlike nitrogen which is highly soluble, phosphate is mostly insoluble and clings to sediments, and can be introduced to surface water through soil erosion." (Berks County Conservation District, 2019).

The Conservation Plan also states, "In May of 2018, an assessment of the Cacoosing Creek Watershed was conducted."

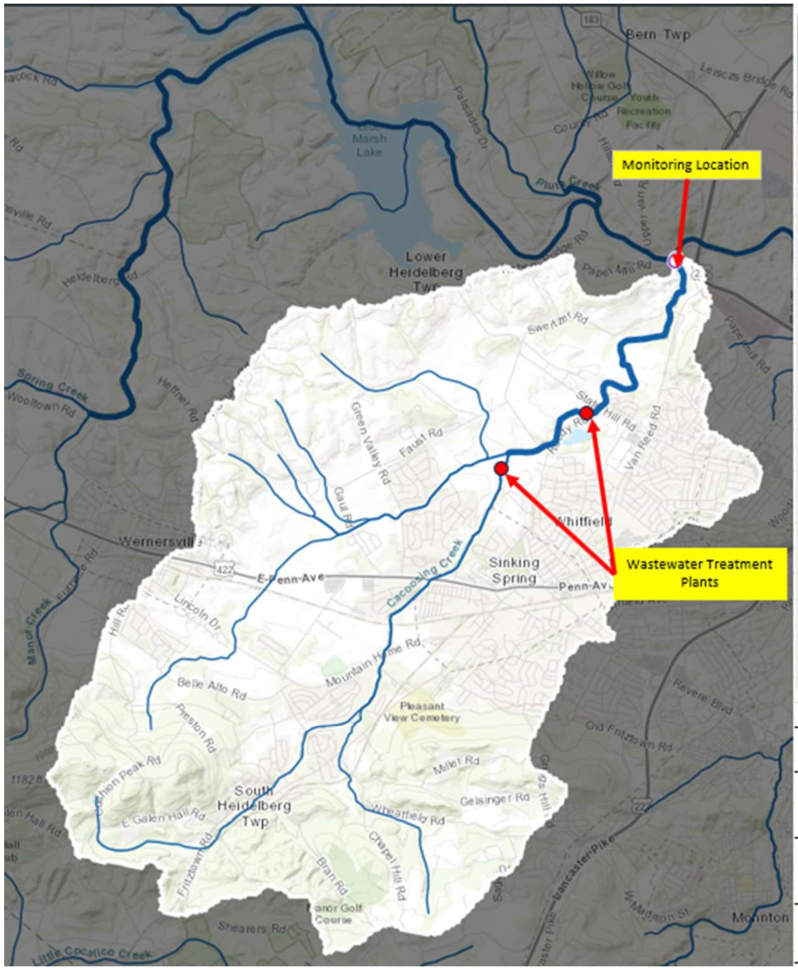
The results were as follows. Site CW001 is data from the Plan which corresponds to the site where TCWA is monitoring. See Table 6 below for comparison.

Site	Alkalinity	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous as P (mg/L)	pH
CW001	160	560	9.6	3.53	0.08	7.31
Papermill 2020 – 2023 Averages	NA	599	8.6	3.8	0.07	7.93

Table 6. Water quality test results for Cacoosing Creek from the BCCD (top row) in 2018 and TCWA (bottom row) from 2020 to 2023.

See Appendix 6 for a table with all TCWA Cacoosing Papermill tests shown.

Based on information obtained from Stroud's Model My Watershed, the Cacoosing Creek watershed is twenty-two square miles in area and contains 21 miles of streams. See map of watershed below.



Map 1

Model My Watershed

Cacoosing Creek | Details

Current Conditions | Export GMS

Hydrology | Water Quality

Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. ✔ Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	8,352,239.4	189,052.3	17,502.2
Loading Rates (lb/ac)	600.13	13.58	1.26
Mean Annual Concentration (mg/L)	144.51	3.27	0.30
Mean Low-Flow Concentration (mg/L)	550.65	4.29	1.26

Mean Flow: 925,796,130 (ft³/year) and 29.36 (ft³/s)

NPDES Code	City	Discharge (mgd)	TN Load (lb/yr)	TP Load (lb/yr)
PA0028649	Lower Heidelberg Twp	0.477	219.337	1,827.89
PA0043052	Lower Heidelberg Twp	1.038	365.569	1,827.89
Total For Area of Interest		1.515	584.907	3,655.78

Table 7

Stroud data shows Cacoosing Creek with an average mean annual concentration of nitrates equal to 3.27 mg/L and an average of 0.30 mg/L of phosphates (Table 7). The average stream volumetric flow rate is 29 cubic feet per second The creek drains into the Tulpehocken Creek downstream of Blue Marsh Lake. The water quality of the creek has been tested on a monthly basis by TCWA since September 15, 2020. See Map 1 above for monitoring location. See Appendix 6 for a table containing all 3 years of data. Note that Table 6 above shows an average nitrate measurement for all testing of 3.8 mg/L and for the phosphate the average is 0.22 mg/L. These values are fairly close to Stroud's Model values of 3.27 mg/L and 0.30 mg/L respectively.

Another significant feature of the creek is that it receives effluent from two wastewater treatment plants. See Map 1 above for location of these plants.

TCWA has been focusing on testing at this location, just upstream of the confluence with the Tulpehocken Creek, due to the fact that there was a dam scheduled for removal. The dam was located about 500 feet upstream of the confluence with the Tulpehocken Creek. It had been in place since 1825 when it was constructed to provide power to the Van Reed Papermill. The dam was removed in July 2022.

5. Cacoosing Creek - – Review of Data and Future Plans

Graphs 2 and 3 in the Executive Summary of this report show that the phosphate and nitrate concentrations exceed what would result in an "impaired" classification a majority of the time. Some work has been done by the Berks County Conservation District on installing riparian buffers and keeping livestock out of the creek in this sub watershed. We are hoping to see improvements in nutrient concentrations over time as a result of these efforts.

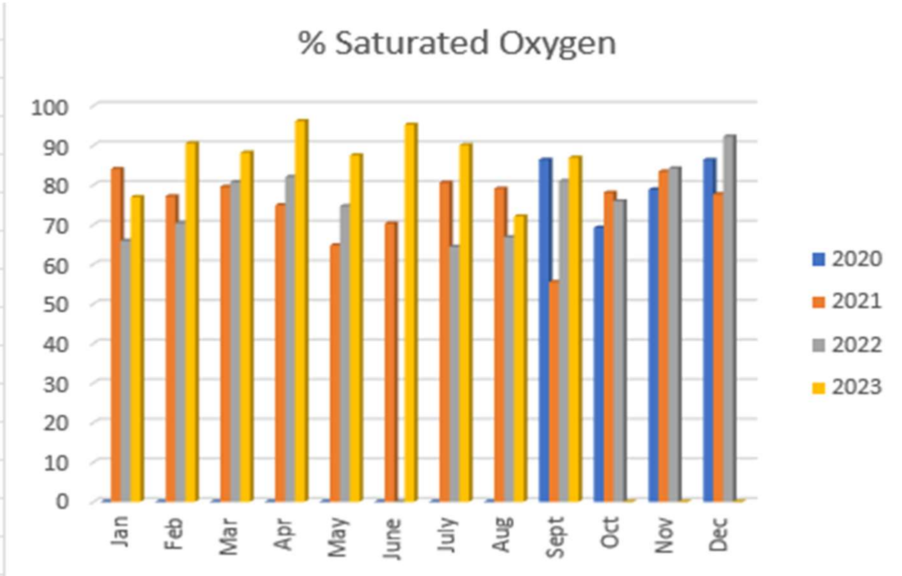
There continues to be residential development in the watershed. The local townships have fairly strong stormwater ordinances and riparian buffer requirements. Hopefully this will help control future contaminants from entering the waters. But there is still a long way to go before phosphate concentrations get down to a 0.07 mg/L level.

Based on the numbers in Stroud's MMW, the nitrate contribution from the wastewater treatment plants in the watershed is less than 1% of the total. However, the phosphate contribution from the plants is 20%. We have seen test results with phosphate readings as high as 0.41 mg/L (average was 0.22 mg/L) during times of drought when the effluent from the wastewater plants made up a significant portion of the stream volumetric flow. See Appendix 6 for a complete set of test data.

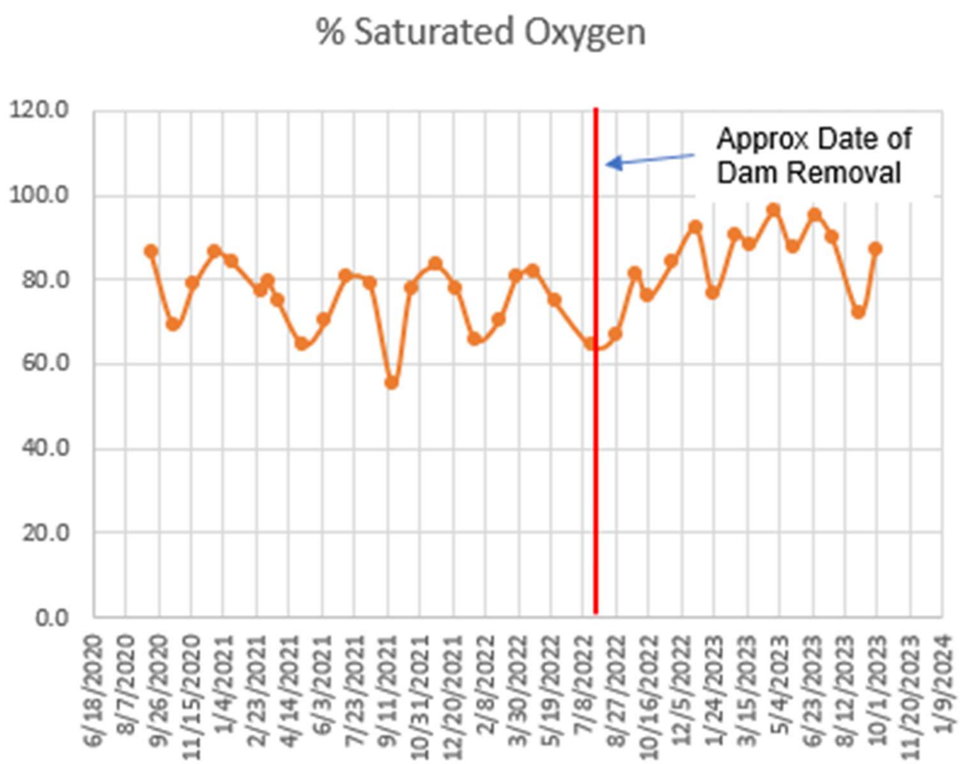
Looking at a comparison of the "after dam removal" measurements (July of 2022) compared to the "before dam removal" in the plotted data presented in Graphs 5 and 6 below, here are some observations.

For % Saturated Oxygen, Graph 6 shows the value beginning to rise after July and continuing to increase to levels higher than previous years for most of the test results.

Dams often slow down the flow of water in rivers, creating reservoirs with reduced water movement. When dams are removed, the increased flow can help oxygenate the water through aeration. Faster-moving water tends to have higher oxygen levels.



Graph 5. Monthly measured dissolved oxygen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.



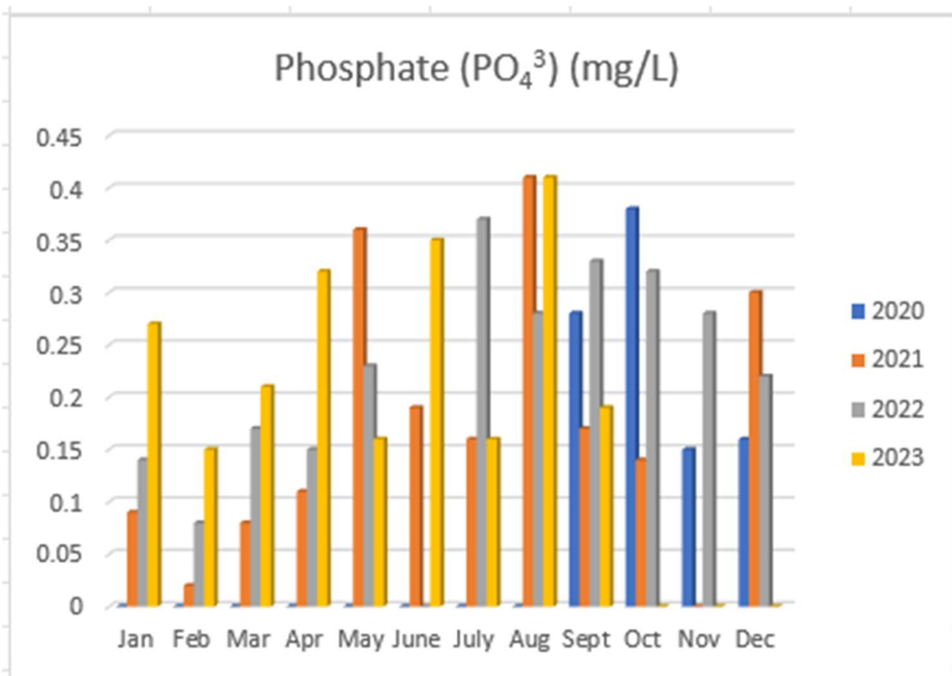
Graph 6. Monthly measured dissolved oxygen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

In regard to the phosphate levels, in Graph 8 it appears that the levels did not drop down to the lower values seen prior to the dam removal. However, more data is needed to confirm if this is a long-term effect.

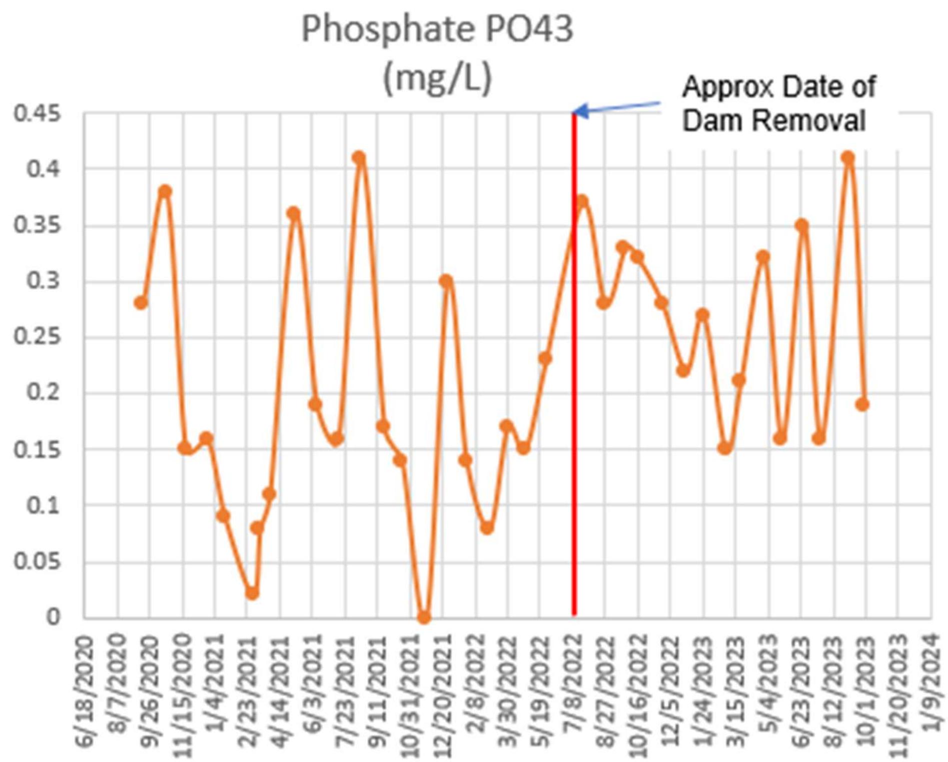
Dams accumulate sediments behind them over time, which can contain nutrients like phosphates. When a dam is removed, these sediments can be mobilized and transported downstream, potentially leading to an initial increase in phosphate concentrations immediately after removal.

Also, the removal of a dam can alter the natural flow and nutrient cycling of a river. This can impact the sources and sinks of phosphates in the ecosystem, potentially leading to changes in phosphate concentrations.

Since we were only monitoring once a month, this discrete measurement approach often misses high and low concentrations. See Appendix 7 for an example of discrete versus continuous measurements.

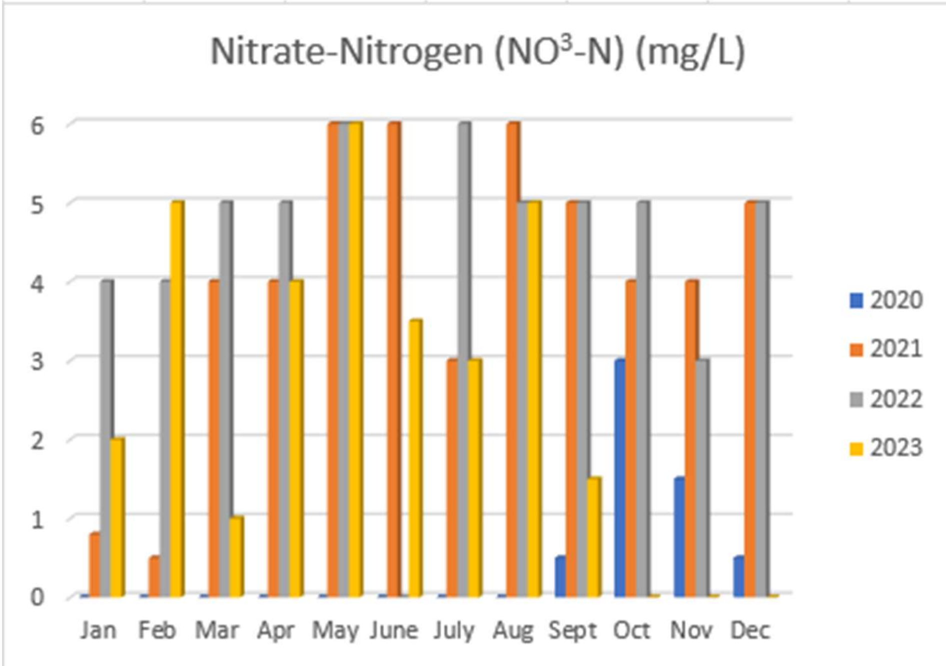


Graph 7. Monthly measured phosphate levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

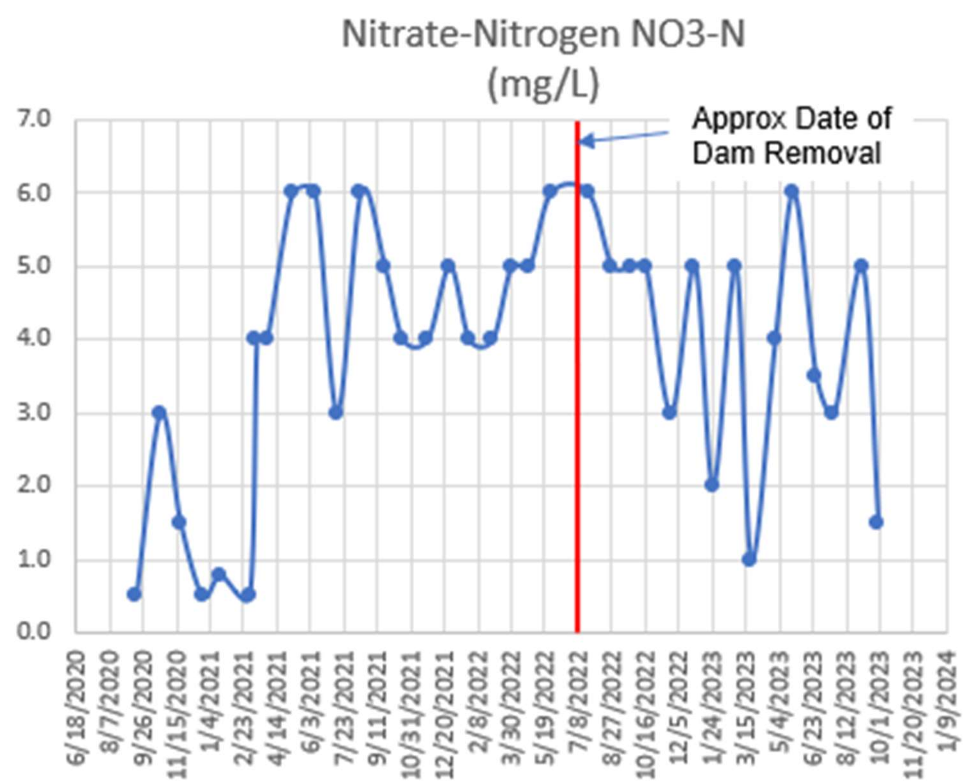


Graph 8. Monthly measured phosphate levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

Looking at Graph 10, the nitrate measurements had no obvious long-term change from before to after the dam removal. The comments made above in regard to dam removal and impact on phosphate concentrations also apply to nitrates. There was a spike in July compared to previous years, but it was lower in August. The measurements taken in the month of May consistently have shown the highest concentrations, which may be related to the application of fertilizer as almost 20% of the watershed is in cultivated crops and over 10% is in hay.

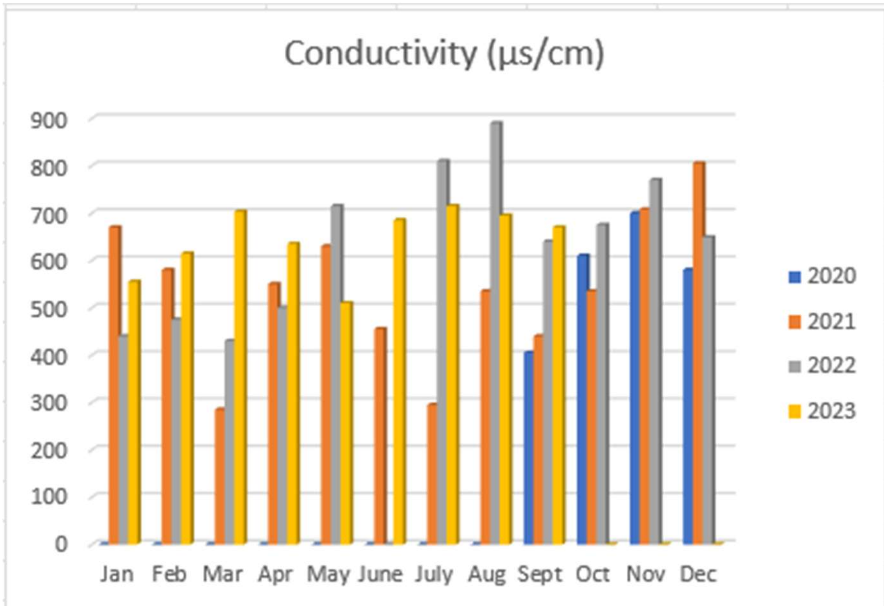


Graph 9. Monthly measured nitrate-nitrogen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

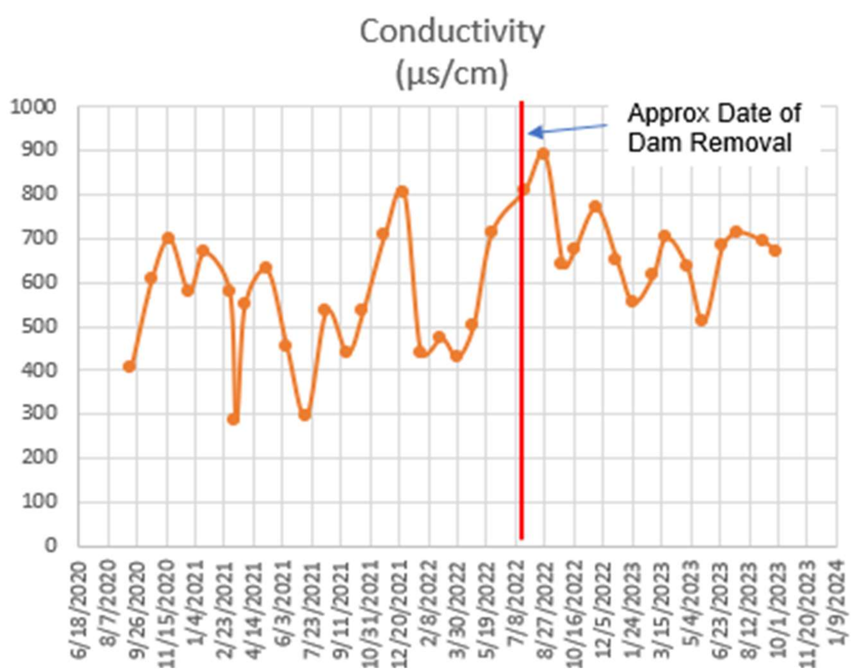


Graph 10. Monthly measured nitrate-nitrogen levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

For conductivity, Graph 12, similar to the phosphate measurements, it appears that the levels did not drop down to the lower values seen prior to the dam removal. However, more data is needed to confirm if this is a long-term effect.. There was a spike in July and August 2022 compared to previous years.

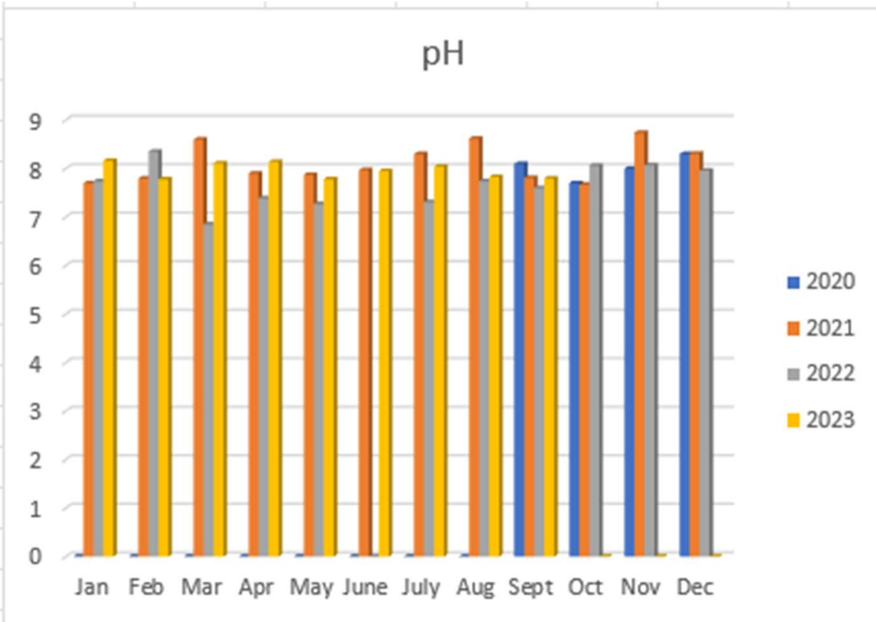


Graph 11. Monthly measured conductivity levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

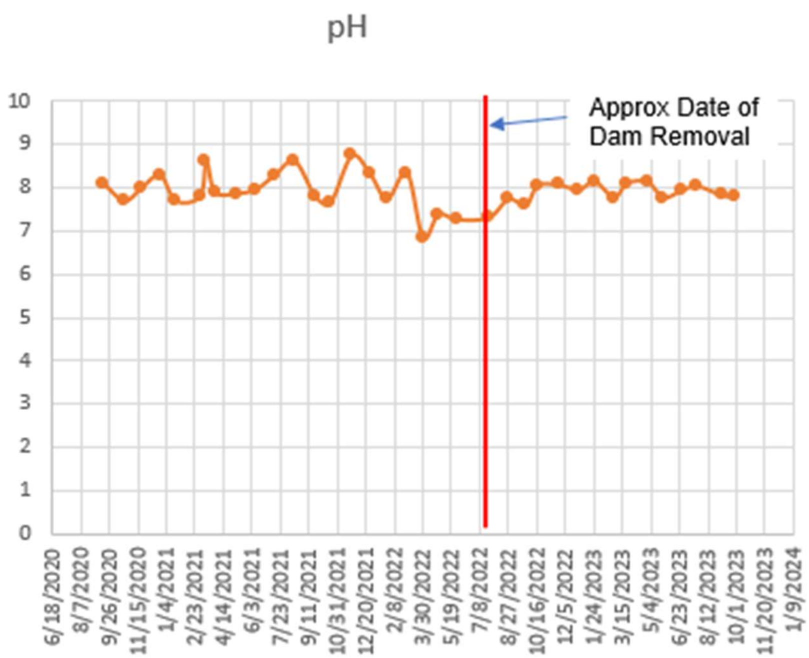


Graph 12. Monthly measured conductivity levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

In Graph 14, the pH measurement showed a slight decrease in July 2022, but no noticeable trend in the "after dam removal" measurements compared to the "before dam removal" measurements other than there seems to be a tighter band of values.



Graph 13. Monthly measured pH levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.



Graph 14. Monthly measured pH levels on Cacoosing Creek downstream of the Papermill Dam site from 2020-2023. The dam was removed in July 2022.

TCWA intends to continue the monthly water testing downstream of the former dam site.

6. Watershed Wide Testing Data - Review of Data and Future Plans

TCWA Water Testing Results 2022 stated “In addition to the above observations, Site 9 (Tulpehocken Creek at Stouchsburg Bridge) requires additional study, as the % Saturated Oxygen is well into the “Poor” category, and it has tested “Poor” all three years. More frequent sampling of this site began in late 2021 and will continue given these annual results”. (TCWA, 2022). Additional tests were performed during the later part of 2022 with the results showing % Saturation levels back in the “Excellent” category. See Table 8 below.

	Testing Organization	Site Name	Latitude	Longitude	Elev (M)	Date	Air Temp C	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen
9	TCWA 2020 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	8/1/2020	21.8	30	5.7	60.8
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	8/10/2021	23.5	-	2.6	28.5
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	8/16/2021	27.6	-	-	-
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	11/7/2021	13.6		8.8	78.7
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	1/6/2022	1.8		11.6	93.4
	TCWA 2021 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	3/5/2022	3.9		10	79.9
	TCWA 2022 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	8/3/2022	20.5		5.6	61.0
	TCWA 2022 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	9/24/2022	18.4		10	101.7
	TCWA 2022 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	11/26/2022	14.6		11	95.4
	TCWA 2023 Site 9	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	10/10/2023	15.5	40	8.5	82.4
	USDA 9, SW 21	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	7/9/1991	26.7	-	11.8	142.8
	BCCD 5, SW 21	Tulpehocken Creek at Stouchsburg Bridge	40.373264	-76.218307	112	7/12/1990	-	-	-	-

Table 8. Dissolved oxygen levels at Site 9 on the mainstem of the Tulpehocken Creek at the Stouchsburg Bridge, immediately downstream of the confluence with Mill Creek in Marion Township, Berks County.

“Site 13 (Cacoosing Creek at Prendergast Rd), based on the 2022 TCW-wide testing results, had the highest phosphate measurement of all twenty-three Sites with a reading of 0.39 mg/L measured on 8/14/2022.” (TCWA, 2022). This Site is very close to the Cacoosing Creek Papermill Dam test site which was already discussed in the section labeled “Cacoosing Creek – Downstream of the former Papermill Dam” above. What was concluded in the 2022 Report was “…that the wastewater treatment plants, at least for this past August, contributed a majority of the Phosphate to the Cacoosing Creek.”. As noted above, this was probably due to the drought conditions.

Considering that the phosphate levels continue to be high for this Site, and the two wastewater treatment plants discharge directly into this stream, TCWA is in the process of testing the waters directly upstream and downstream of these plants to collect additional data. We will also be sending samples collected up and downstream of these locations to a State certified lab at the Academy of Natural Sciences (ANS) to further substantiate our findings. To control eutrophication, the USEPA has established a recommended limit of 0.05 mg/L for total phosphates in streams that enter lakes and 0.1 mg/L for total phosphorus in flowing waters (U.S. Environmental Protection Agency, 1986). The levels in the Cacoosing at the site of the former Papermill dam are far in excess of these recommended levels. TCWA will issue a report on our findings once we receive lab testing data from ANS.

As of October of 2023, TCWA has performed over 300 stream water quality tests since 2019. We have taken a close look at this data and recently took monthly averages from Sites where we have performed at least 6 tests to see if there were any obvious trends:

- The % saturation oxygen decreases slightly in the summer months.
- The pH numbers decline from May to August.
- The chloride has a peak in the middle of April and again in mid-September.
- Nitrates rise in mid-March and again in mid-May.
- Phosphate peaks in the beginning of June and in the beginning of August.
- Conductivity is a roller coaster with continuous peaks and valleys.

See Appendix 9 for graphs of Monthly Average Data as well as the source data for the averages.

7. What's Next?

For 2024 we plan on continuing our collaboration with Berks Nature, the Berks County Conservation District and Blue Marsh Lake to assist them with collecting water quality data.

As noted in previous reports, the vast majority of nutrients and sediment washed into streams are picked up by deluges from severe storms that occur on relatively few days of the year. Maybe testing a handful of the TCW sites after serious storms to get a sense of environmental impact would provide worthwhile data for the Delaware River watershed. But we need to develop a strategy to be able to do this quickly and safely.

Stream discharge rates may also have a significant impact on water chemistry and its response to rainfall is complex. We would need a continuous water depth measuring device, such as Stroud's Mayfly, coupled with a cross section of the stream, to determine discharge rates for our monitoring sites. In 2023 BCCD loaned us their flow measuring device. We collected data for one instance in time for the UT to Plum where the Mayfly is installed but need to repeat the test.

Groundwater also impacts stream chemistry and may be a factor in prolonging elevated nutrient levels after significant rain or during times of low stream discharge rates. Groundwater chemistry may be available for the TCW from USGS studies. Also, if we coordinate another "Test Your Well Water" activity with Berks Nature, using test strips we can check for nitrates and phosphates as well as the coliform testing we normally perform.

TCWA should develop a test schedule to continue our high level of stream monitoring.

Tulpehocken Creek Watershed Association (TCWA) Information

Learn more about the TCWA by visiting our website at:

https://berksnature.org/tulpehocken-creek-watershed-association/

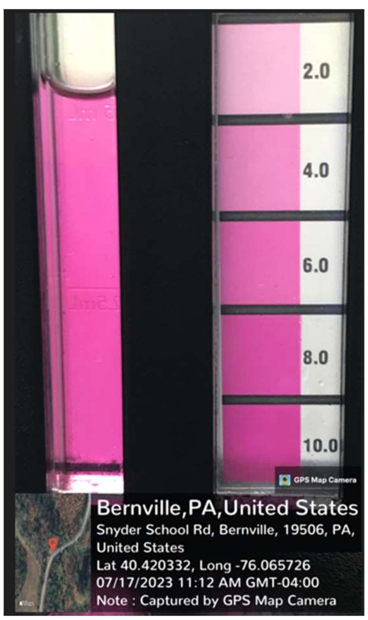
Methodology for Water Testing

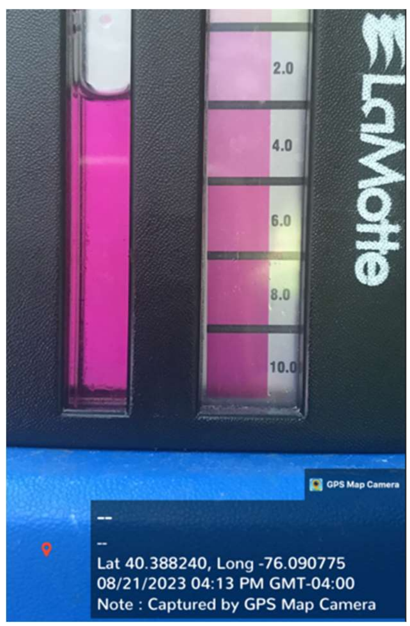
The water quality testing was conducted by three separate groups, each with their own testing equipment composed of the same model LaMotte and Hanna test kits. A majority of the people conducting the tests were the same group that conducted similar testing in 2020, 2021 and 2022.

All the chemicals in the three kits were fresh and confirmed to not have reached the expiration date.

In an attempt to limit the influence of rainfall on the 2023 tests, we set a criterion of not testing within three days of a daily rainfall exceeding 0.5 inches. Based on stream flow responses to rainfall from USGS data for the Schuylkill River at Berne as well as Mayfly data from streams in Berks County, it appears that the effect of heavy rainfall on the stream flow subsides within a few hours after the rain event. However, based on other test data, the impact on nutrient levels may last a bit longer. See Appendix 2.

As we had noted in previous reports, the challenging part of the testing is the Nitrogen test which requires the matching of the color of the test sample to the LaMotte Octa-Slide 2 Viewer. The shades of the color on the slide gradient from 6.0 to 10.0 are not much different, so there is a bit of subjectiveness to color matching the sample with the Octa-Slide visual color comparison.





		40.374639, -76.222358 10/10/2023
BMS07 Licking Creek	BMS09 Peacock Bridge	Tulpehocken Creek
5 ppm	6 ppm	8 ppm

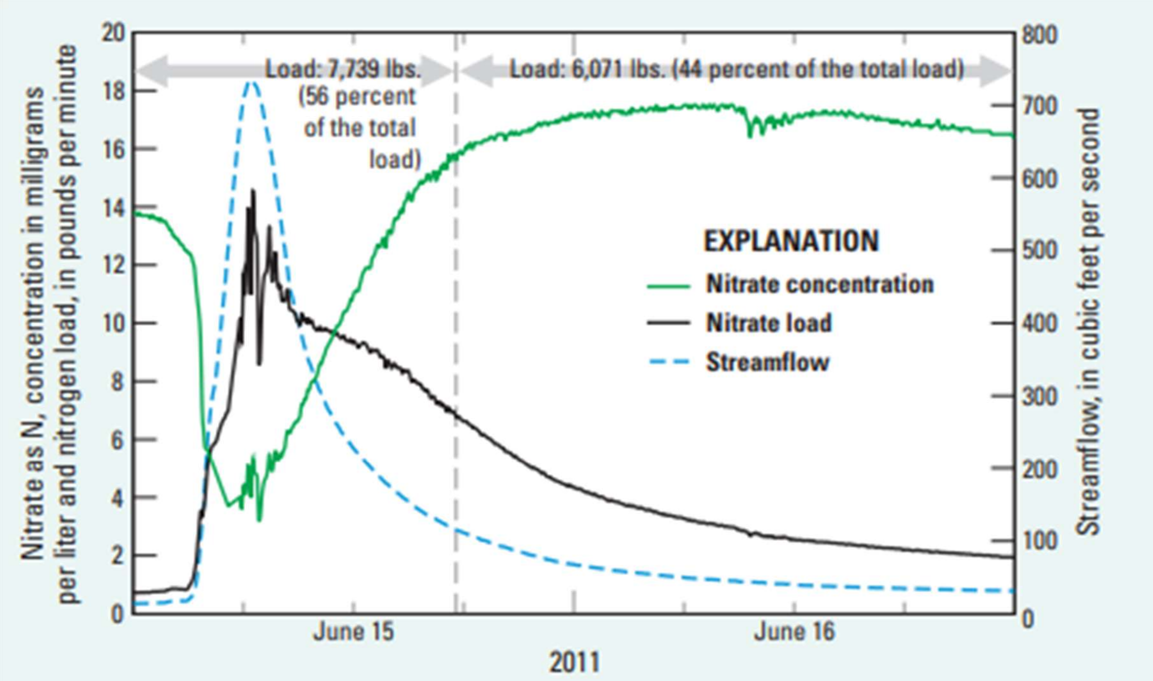


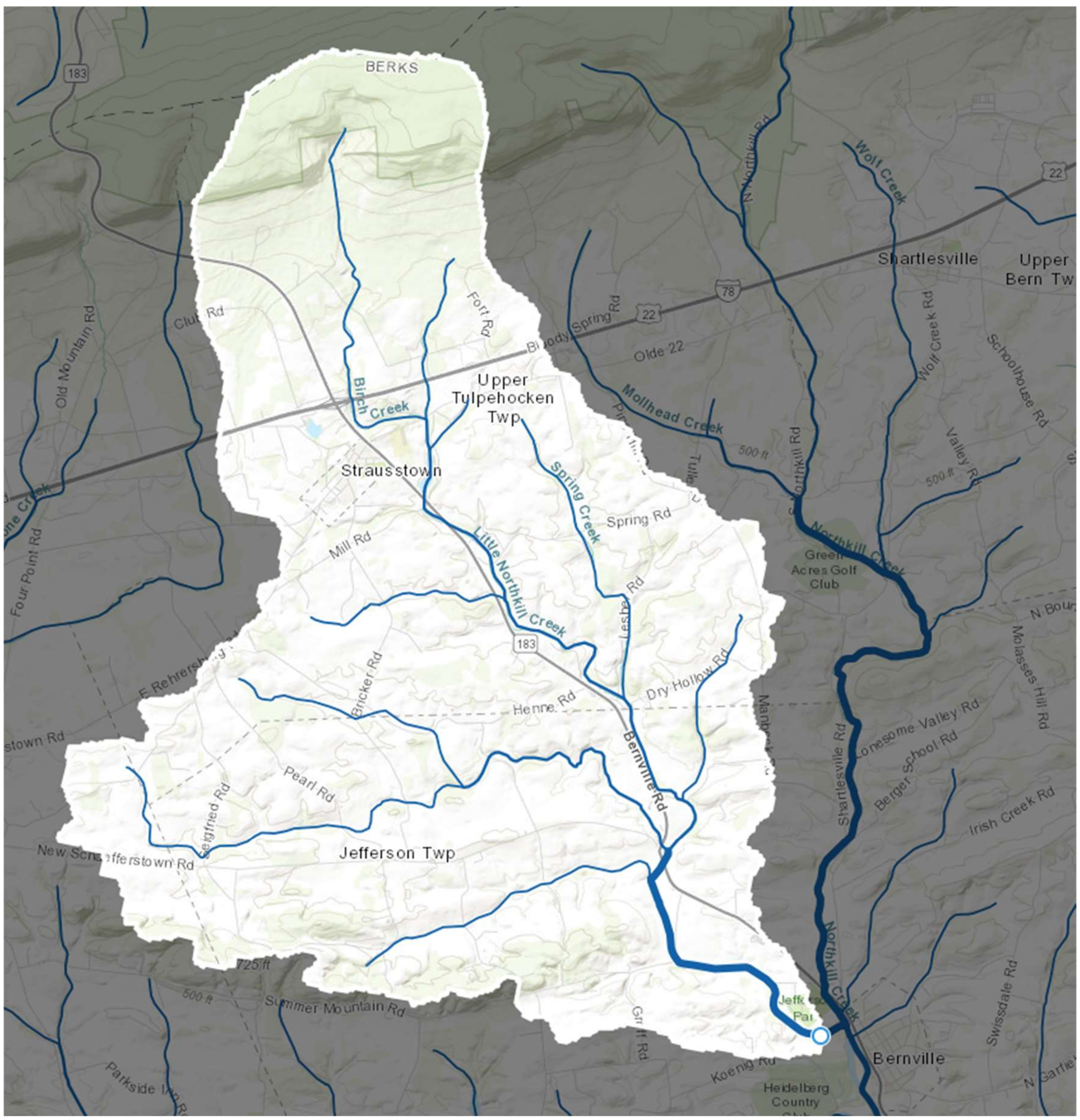
Figure 4. Continuous nitrate concentrations can lead to better understanding of nitrate transport during storm events. This example from Kickapoo Creek at Ireland Grove Road near Bloomington, Illinois, shows the inverse relation between streamflow and nitrate concentration, and the spike in the nitrate load (mass of nitrate during a given time in pounds per minute (lb/min)) to the stream during the storm event. Based on continuous nitrate and discharge measurements, more than half of the event nitrate load occurred within 15 hours from the initial storm event on June 15, 2011.

Studies have shown that nitrate concentration in streams is affected by streamflow and, although initially depressed, elevated nitrate concentrations may last for a few days after an increase in streamflow. See Graph 6 below illustrating the longevity of nitrate concentration increase due to bump up in streamflow. Of course, different sized streams and different shaped watersheds will impact this relationship. (USGS, 2013)

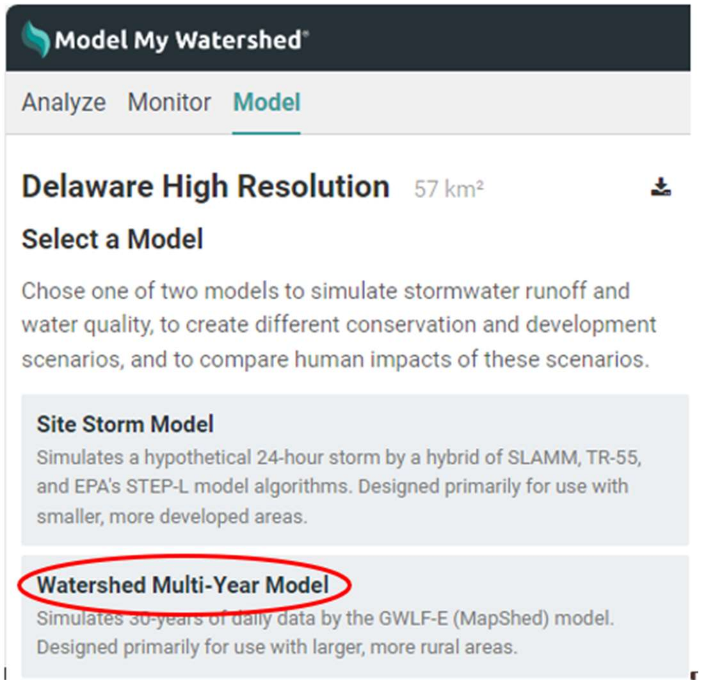
Methodology for Obtaining Data from Stroud Model My Watershed

The method for deriving the data from MMW to determine the concentration of nitrate and phosphate was as follows:

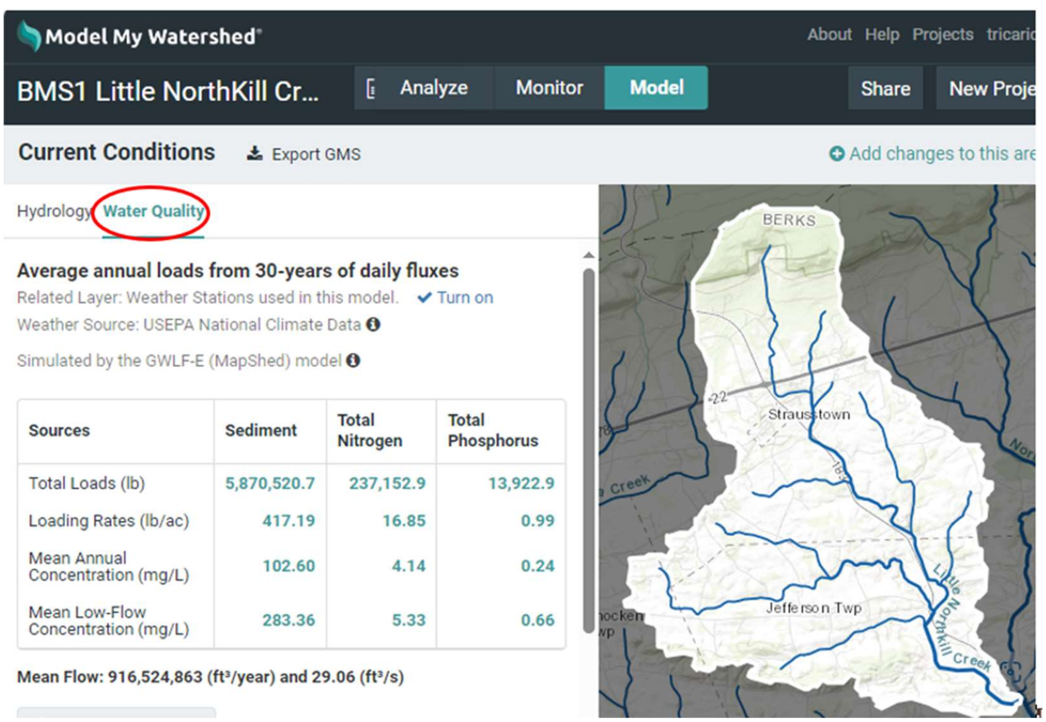
The Model My Watershed software was opened, and the watershed associated with each of the thirteen streams was automatically delineated by selecting a point on the stream close to where it enters the Blue Marsh Lake. For example, see the watershed delineated for BMS1 Little Northkill Creek in the illustration below. The circle in the bottom right corner of the highlighted watershed represents the exit point of the watershed.



Once the software defined the watershed, the “Model” tab was selected from the top menu and then the Watershed Multi-Year Model was selected from the window.



From the next screen, the “Water Quality” tab at the top of the page was selected and the following screen appeared.



Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	5,870,520.7	237,152.9	13,922.9
Loading Rates (lb/ac)	417.19	16.85	0.99
Mean Annual Concentration (mg/L)	102.60	4.14	0.24
Mean Low-Flow Concentration (mg/L)	283.36	5.33	0.66

To better understand the meaning of the title above “Average annual loads from 30-years of daily fluxes”, USGS provides the following definitions “In the context of contaminant transport, the term “flux” refers to the rate of mass transport (reported in units of mass/time), whereas the term “load” typically refers to the amount of mass transported (reported in units of mass) and “yield” refers to the amount of mass transported per unit area (reported in units of mass/area). Flux is calculated as the product of concentration and stream flow and a unit conversion factor”.

The table, “Average annual loads from 30-years of daily fluxes”, on the previous page provides total lbs of Nitrate and Phosphate for that watershed, along with the mean annual concentration (in mg/L) for the Total Nitrogen and Total Phosphorous. A similar approach was used for all thirteen sections. .

Bear in mind that the data from MMW is based on a model. MMW technical documentation states “The core watershed multi-year simulation model used in MMW and MapShed (GWLF-E) is an enhanced version of the Generalized Watershed Loading Function (GWLF) model first developed by researchers at Cornell University … and tested extensively in the U.S. and elsewhere.” Also, the technical documentation states that the software model “… provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads and allows for the inclusion of point source discharge data.” So, this is modeled data, not based on ongoing testing of the water.

See Appendix 5 for similar data for all thirteen sites studied.

	Testing Organization	Site Name	Latitude	Longitude	Elev (M)	Date	Air Temp C	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Nitrate NO_3- (mg/L)	Phosphate PO_4^3 (mg/L)	Phosphorus PO_4-P (mg/L)	pH	Water Temp (C)	Conductivity (μs)	Water Transparency (cm)
BMS1	TCWA 2023	Little Northkill Creek 100' upstream of Northl	40.435806	-76.116755	89.3	8/14/2023	21.8		7.2	80.3	1.0	4.4	0.13	0.04	7.6	20.7	245	110
BMS2	TCWA 2023	Northkill Creek Bernville 100' upstream of Litt	40.439652	-76.119637	89.7	3/21/2021	10.2		10.4	87.6	4.0	17.6	0.04	0.01	7.3	7.9	125	115
BMS2	TCWA 2023	Northkill Creek Bernville 100' upstream of Litt	40.439652	-76.119637	89.7	8/2/2021	21.6		7.8	87.6	2.0	8.8	0.08	0.0	8.64	21.1	155	115.0
BMS2	TCWA 2023	Northkill Creek Bernville 100' upstream of Litt	40.439652	-76.119637	89.7	8/1/2022	24.4		7.8	88.7	1.5	0.0	0.02	0.0	8.59	21.7	255	105.0
BMS2	TCWA 2023	Northkill Creek Bernville 100' upstream of Litt	40.439652	-76.119637	89.7	8/14/2023	20.9		7.6	84.4	1.0	4.4	0.05	0.0	7.79	20.5	220	112.0
~~BMS3~~	~~TCWA 2023~~	~~UT1 to Northkill Creek Detention pond OF~~	~~40.438185~~	~~-76.116402~~														
~~BMS4~~	~~TCWA 2023~~	~~UT2 to Northkill Creek Detention pond OF~~	~~40.435601~~	~~-76.114251~~														
BMS5	TCWA 2023	Tulpehocken Creek (Bernville)	40.422546	-76.124262	90	9/6/2023	36.8	40	7.2	90.9	6.5	28.6	0.25	0.08	8.09	27.3	510	110
BMS6	TCWA 2023	Power Mill Creek	40.418641	-76.086966	89	7/17/2023	31.7	20	8	88.7	4.0	17.6	0.25	0.08	7.67	20.4	175	100
BMS7	TCWA 2023	Licking Creek	40.420442	-76.065309	96	7/17/2023	31.1	28	8.5	91.4	5.0	22.0	0.34	0.11	7.81	18.9	335	95
BMS7	TCWA 2023	Licking Creek	40.420442	-76.065309	96	8/15/2023	27.8	38	8.8	93.5	6.0	26.4	0.05	0.02	7.44	18.3	395	115
BMS8	TCWA 2023	UT near Sheidy Rd	40.401848	-76.112385	98	9/6/2023	30.1	30	7.2	80.0	9.0	39.6	0.24	0.08	7.72	20.5	405	-
BMS9	TCWA 2023	UT near Peacock Rd	40.387949	-76.090522	89	8/8/2023	23.5	28	7.8	84.2	5.5	24.2	0.12	0.04	7.88	19.1	305	100
BMS9	TCWA 2023	UT near Peacock Rd	40.387949	-76.090522	89	8/21/2023	33.9	30	8	90.8	6.0	26.4	0.00	0.00	7.45	21.6	345	110
BMS10	TCWA 2023	UT near Milestone Rd	40.371329	-76.088813	95	8/18/2023	24.7		6.2	71.6	8.0	35.2	0.11	0.04	8.29	22.5	435	100
BMS11	TCWA 2023	Spring Creek	40.370158	-76.081139	90	7/23/2023	25.4		8.1	89.9	7.0	30.8	0.11	0.04	8.62	20.5	490	118
BMS12	TCWA 2023	UT east of Brownsville	40.370416	-76.07658	100	7/23/2023	23.6		7	79.4	3.0	13.2	0.04	0.01	8.04	21.6	280	118
BMS13	TCWA 2023	UT near Highland Rd at Old Dry Road Farm	40.370137	-76.060188	107	8/18/2023	26.5		6.3	69.3	1.5	6.6	0.20	0.07	8.37	20.0	185	118

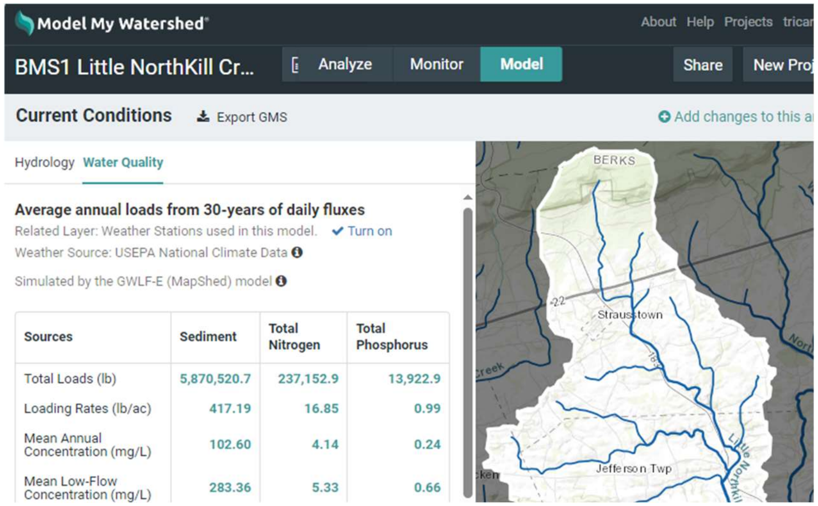
WATER QUALITY SUMMATION for Chemical Tests

	Excellent	Good	Fair	Poor
Dissolved Oxygen (% Saturation)	80-120	70-80 120-140	50-70 >140	<50
pH (units)	7.0-7.5	6.5-7.0 7.5-8.5	5.5-6.5 8.5-9.0	<5.5 >9.0
Chloride (Cl) (mg/L)	0-20	20-50	50-250	>250
Reactive Phosphate (PO_4X^3) (mg/L)	0-0.2	0.2-0.5	0.5-2.0	>2.0
Nitrate (NO_3) (mg/L)	0-3	3-5	5-10	>10
Transparency (cm)	>65.0	65.0-35.0	35.0-15.5	<15.5

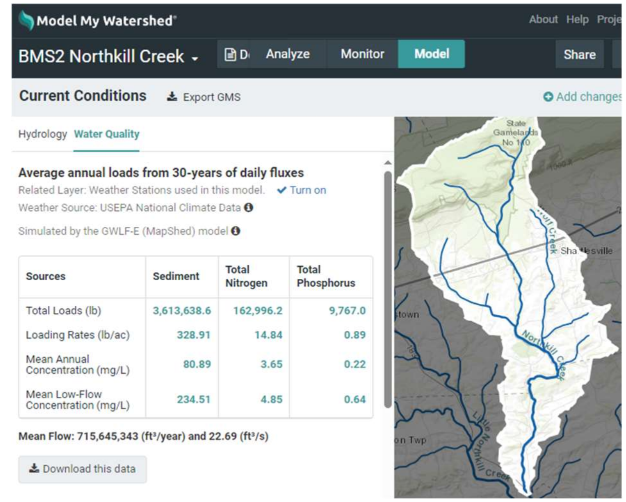
Source = Izaak Walton League

Excellant
Good
Fair
Poor

Note - Per Delaware Riverkeepers study relating to Nitrates and Phosphates
A recent study of nutrient impacts on Pennsylvania stream biology indicated that the thresholds for these two parameters are 2.01 and 0.07 mg/l respectively, above which stream biology is negatively impacted

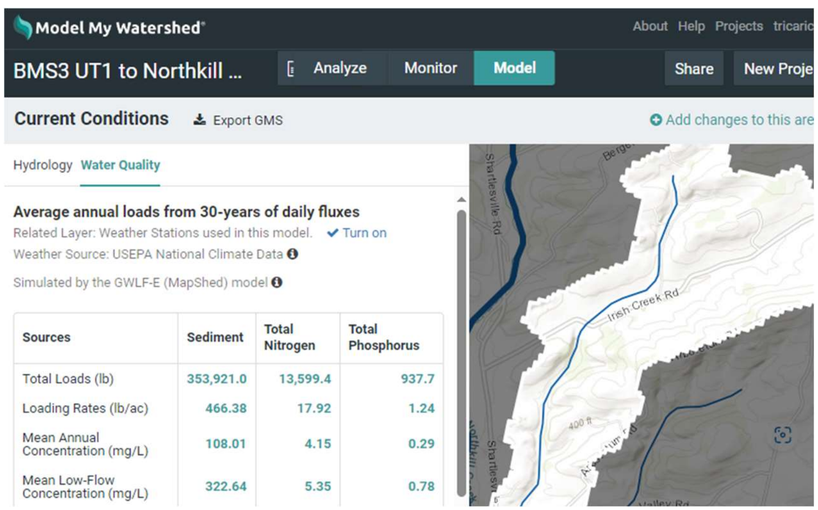


Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	5,870,520.7	237,152.9	13,922.9
Loading Rates (lb/ac)	417.19	16.85	0.99
Mean Annual Concentration (mg/L)	102.60	4.14	0.24
Mean Low-Flow Concentration (mg/L)	283.36	5.33	0.66

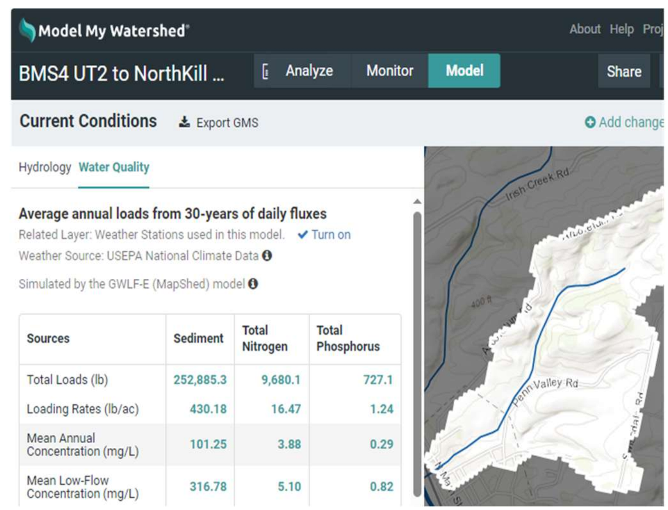


Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	3,613,638.6	162,996.2	9,767.0
Loading Rates (lb/ac)	328.91	14.84	0.89
Mean Annual Concentration (mg/L)	80.89	3.65	0.22
Mean Low-Flow Concentration (mg/L)	234.51	4.85	0.64

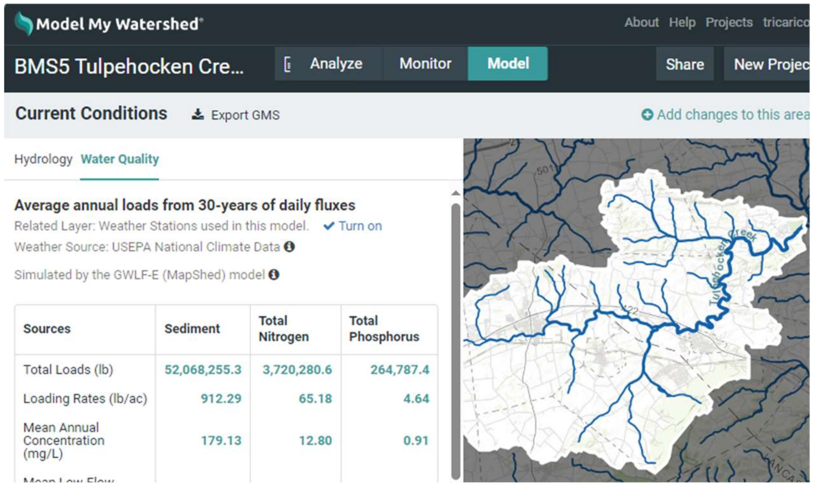
Mean Flow: 715,645,343 (ft^3/year) and 22.69 (ft^3/s)



Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	353,921.0	13,599.4	937.7
Loading Rates (lb/ac)	466.38	17.92	1.24
Mean Annual Concentration (mg/L)	108.01	4.15	0.29
Mean Low-Flow Concentration (mg/L)	322.64	5.35	0.78



Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	252,885.3	9,680.1	727.1
Loading Rates (lb/ac)	430.18	16.47	1.24
Mean Annual Concentration (mg/L)	101.25	3.88	0.29
Mean Low-Flow Concentration (mg/L)	316.78	5.10	0.82



Model My Watershed
BMS5 Tulpehocken Cre...

Current Conditions

Hydrology Water Quality

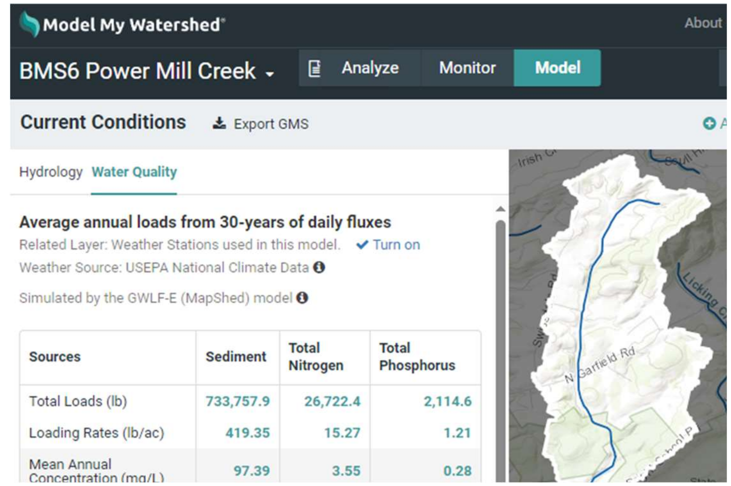
Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	52,068,255.3	3,720,280.6	264,787.4
Loading Rates (lb/ac)	912.29	65.18	4.64
Mean Annual Concentration (mg/L)	179.13	12.80	0.91



Model My Watershed
BMS6 Power Mill Creek

Current Conditions

Hydrology Water Quality

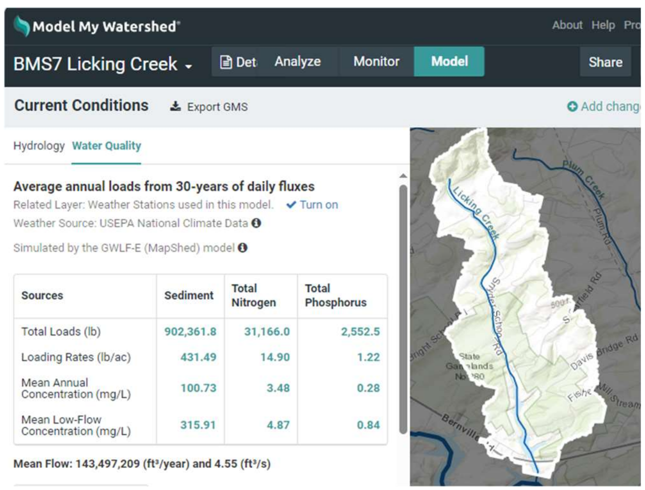
Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	733,757.9	26,722.4	2,114.6
Loading Rates (lb/ac)	419.35	15.27	1.21
Mean Annual Concentration (mg/L)	97.39	3.55	0.28



Model My Watershed
BMS7 Licking Creek

Current Conditions

Hydrology Water Quality

Average annual loads from 30-years of daily fluxes

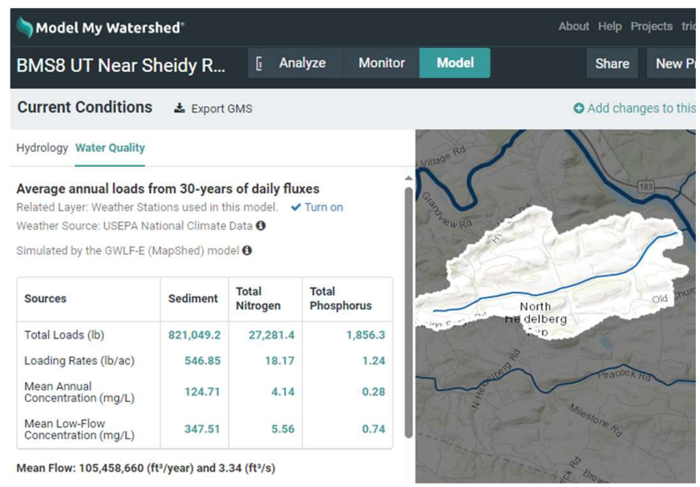
Related Layer: Weather Stations used in this model. Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	902,361.8	31,166.0	2,552.5
Loading Rates (lb/ac)	431.49	14.90	1.22
Mean Annual Concentration (mg/L)	100.73	3.48	0.28
Mean Low-Flow Concentration (mg/L)	315.91	4.87	0.84

Mean Flow: 143,497,209 (ft³/year) and 4.55 (ft³/s)



Model My Watershed
BMS8 UT Near Sheidy R...

Current Conditions

Hydrology Water Quality

Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	821,049.2	27,281.4	1,856.3
Loading Rates (lb/ac)	546.85	18.17	1.24
Mean Annual Concentration (mg/L)	124.71	4.14	0.28
Mean Low-Flow Concentration (mg/L)	347.51	5.56	0.74

Mean Flow: 105,458,660 (ft³/year) and 3.34 (ft³/s)

Model My Watershed

BMS9 UT Near Peacock... Details

Current Conditions Export GMS

Hydrology **Water Quality**

Average annual loads from 30-years of daily fluxes

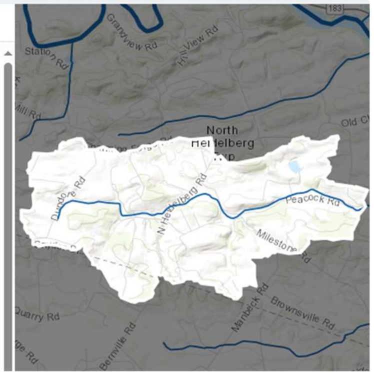
Related Layer: Weather Stations used in this model. ✓ Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,501,017.2	45,836.0	3,072.6
Loading Rates (lb/ac)	618.95	18.90	1.27
Mean Annual Concentration (mg/L)	146.37	4.47	0.30
Mean Low-Flow Concentration (mg/L)	424.46	5.96	0.82

Mean Flow: 164,265,118 (ft³/year) and 5.21 (ft³/s)



Model My Watershed

BMS10 Near Milestone ... Details

Current Conditions Export GMS

Hydrology **Water Quality**

Average annual loads from 30-years of daily fluxes

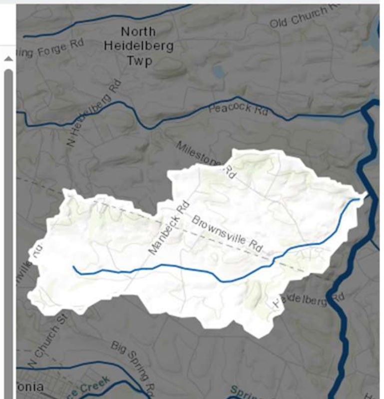
Related Layer: Weather Stations used in this model. ✓ Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,822,713.6	48,405.5	3,386.8
Loading Rates (lb/ac)	928.18	24.65	1.72
Mean Annual Concentration (mg/L)	206.97	5.50	0.38
Mean Low-Flow Concentration (mg/L)	592.92	7.33	1.02

Mean Flow: 141,069,305 (ft³/year) and 4.47 (ft³/s)



Model My Watershed

BMS11 Spring Creek Details

Current Conditions Export GMS

Hydrology **Water Quality**

Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. ✓ Turn on

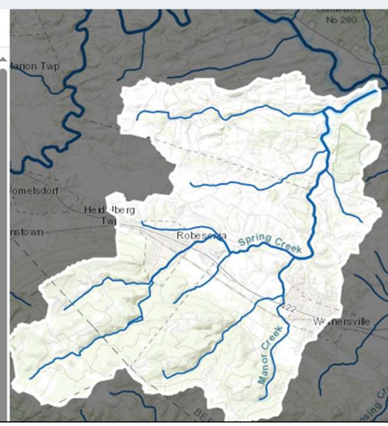
Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	8,586,411.3	326,607.8	23,316.0
Loading Rates (lb/ac)	435.40	16.56	1.18
Mean Annual Concentration (mg/L)	105.43	4.01	0.29
Mean Low-Flow Concentration (mg/L)	559.80	6.82	1.32

Mean Flow: 1,304,572,457 (ft³/year) and 41.37 (ft³/s)

Download this data



Model My Watershed

BMS12 UT East of Brow... Details

Current Conditions Export GMS

Hydrology **Water Quality**

Average annual loads from 30-years of daily fluxes

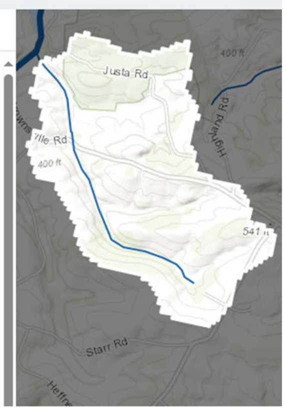
Related Layer: Weather Stations used in this model. ✓ Turn on

Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	153,912.6	9,409.1	495.5
Loading Rates (lb/ac)	291.33	17.81	0.94
Mean Annual Concentration (mg/L)	71.46	4.37	0.23
Mean Low-Flow Concentration (mg/L)	240.28	5.27	0.70

Mean Flow: 34,500,722 (ft³/year) and 1.09 (ft³/s)



Model My Watershed®

BMS13 UT Near Highla...

Details

Analyze

Current Conditions

Export GMS

Hydrology Water Quality

Average annual loads from 30-years of daily fluxes

Related Layer: Weather Stations used in this model. Turn on

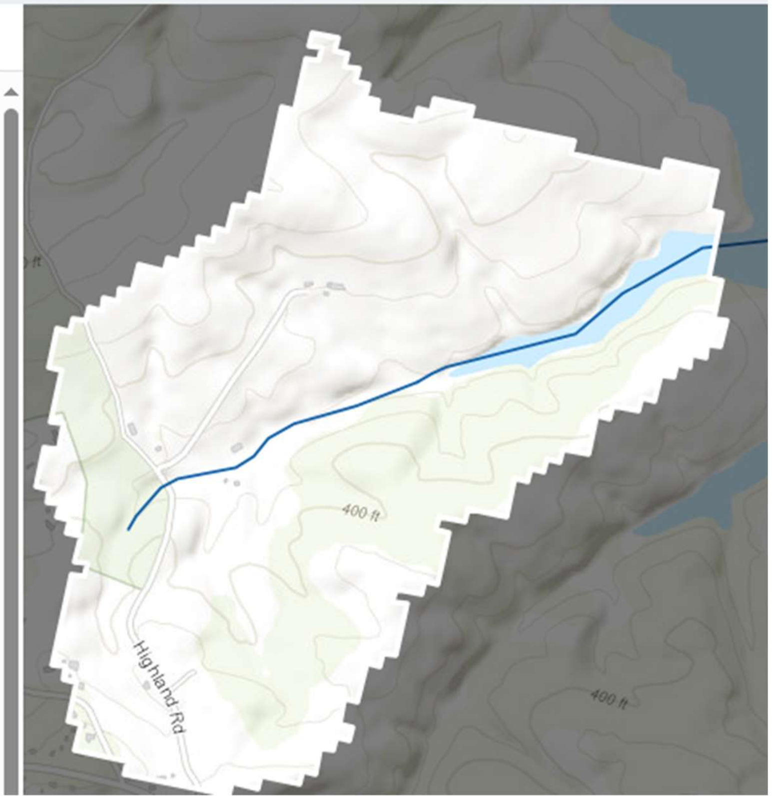
Weather Source: USEPA National Climate Data

Simulated by the GWLF-E (MapShed) model

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	158,513.4	4,756.1	419.4
Loading Rates (lb/ac)	434.02	13.02	1.15
Mean Annual Concentration (mg/L)	104.31	3.13	0.28
Mean Low-Flow Concentration (mg/L)	329.16	4.44	0.83

Mean Flow: 24,341,218 (ft³/year) and 0.77 (ft³/s)

Download this data



Date	Year	Month	Air Temp C	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Nitrate NO_3^- (mg/L)	Phosphate PO_4^3 (mg/L)	Phosphorus PO_4-P (mg/L)	pH	Water Temp (C)	Conductivity (µs/cm)	Water Transparency (cm)
9/15/2020	2020	Sept	14.9	-	9	86.3	0.5	2.2	0.28	0.09	8.1	13.5	405	115
10/21/2020	2020	Oct	16.8	-	7.2	69.2	3.0	13.2	0.38	0.12	7.7	13.6	610	115
11/20/2020	2020	Nov	15.9	-	8.6	78.9	1.5	6.6	0.15	0.05	8	11.5	700	114
12/23/2020	2020	Dec	4.8	-	10.4	86.3	0.5	2.2	0.16	0.05	8.3	7.3	580	115
1/19/2021	2021	Jan	5	-	10	84.0	0.8	3.5	0.09	0.03	7.7	7.8	670	115
3/3/2021	2021	Feb	9.4	-	9.6	77.1	0.5	2.2	0.02	0.01	7.8	6	580	54
3/14/2021	2021	Mar	14.6	-	9	79.5	4.0	17.6	0.08	0.03	8.6	9.9	285	-
3/29/2021	2021	Apr	7.7	-	8.6	74.9	4.0	17.6	0.11	0.04	7.9	9.3	550	115
5/6/2021	2021	May	16.5	-	6.8	64.8	6.0	26.4	0.36	0.12	7.87	13.2	630	115
6/9/2021	2021	Jun	27.6	-	6.6	70.3	6.0	26.4	0.19	0.06	7.97	18.4	455	115
7/12/2021	2021	Jul	27.6	-	7.3	80.6	3.0	13.2	0.16	0.05	8.3	20.2	295	36
8/16/2021	2021	Aug	23.3	-	7.6	79.1	6.0	26.4	0.41	0.13	8.62	17.3	535	115
9/21/2021	2021	Sep	21.7	-	5.6	55.5	5.0	22.0	0.17	0.06	7.81	15	440	115
10/18/2021	2021	Oct	13.2	-	8.3	78.0	4.0	17.6	0.14	0.05	7.67	12.6	535	115
11/24/2021	2021	Nov	4	-	10	83.4	4.0	17.6	0	0.00	8.74	7.5	708	115
12/27/2021	2021	Dec	3.4	-	9.2	77.7	5.0	22.0	0.3	0.10	8.31	8	805	115
1/25/2022	2022	Jan	2.4	-	8	65.9	4.0	17.6	0.14	0.05	7.74	7	440	115
3/1/2022	2022	Feb	6.2	-	8.5	70.4	4.0	17.6	0.08	0.03	8.35	7.2	475	115
3/29/2022	2022	Mar	4.2	-	10	80.8	5.0	22.0	0.17	0.06	6.85	6.2	430	115
4/25/2022	2022	Apr	12.3	-	8.8	82.0	5.0	22.0	0.15	0.05	7.39	12.2	500	115
5/27/2022	2022	May	20.9	-	7.6	74.7	6.0	26.4	0.23	0.08	7.27	14.6	715	115
7/22/2022	2022	Jul	23	-	6.2	64.4	6.0	26.4	0.37	0.12	7.31	17.2	810	115
8/26/2022	2022	Aug	24	-	6.6	66.8	5.0	22.0	0.28	0.09	7.74	16	890	115
9/26/2022	2022	Sep	21.6	84	8	81.0	5.0	22.0	0.33	0.11	7.6	16	640	115
10/16/2022	2022	Oct	20	88	8.2	75.9	5.0	22.0	0.32	0.10	8.06	11.9	675	100
11/22/2022	2022	Nov	9.7		9.8	84.2	3.0	13.2	0.28	0.09	8.07	8.7	770	115
12/28/2022	2022	Dec	3.4	80	11	92.2	5.0	22.0	0.22	0.07	7.96	7.7	649	60
1/24/2023	2023	Jan	4.9		9.2	76.9	2.0	8.8	0.27	0.09	8.16	7.6	555	115
2/27/2023	2023	Feb	7.3	80	10.8	90.5	5.0	22.0	0.15	0.05	7.78	7.7	615	115
3/22/2023	2023	Mar	10.7		10	88.2	1.0	4.4	0.21	0.07	8.11	9.8	703	115
4/27/2023	2023	Apr	14.7	80	10	96.1	4.0	17.6	0.32	0.10	8.14	13.6	635	110
5/25/2023	2023	May	14.6		9.0	87.5	6.0	26.4	0.16	0.05	7.78	14.1	510	115
6/27/2023	2023	Jun	20.5	80	9.0	95.2	3.5	15.4	0.35	0.11	7.95	18.1	685	115
7/24/2023	2023	Jul	26.2		8.8	90.1	3.0	13.2	0.16	0.05	8.04	16.5	715	115
9/4/2023	2023	Aug	21.5	84	7	72.1	5.0	22.0	0.41	0.13	7.83	16.8	695	75
9/28/2023	2023	Sep	15.7		9	86.9	1.5	6.6	0.19	0.06	7.8	13.8	670	115
Average over the past three years				82	8.6	79.1	3.8	16.8	0.22	0.07	7.93	12.05	599	108

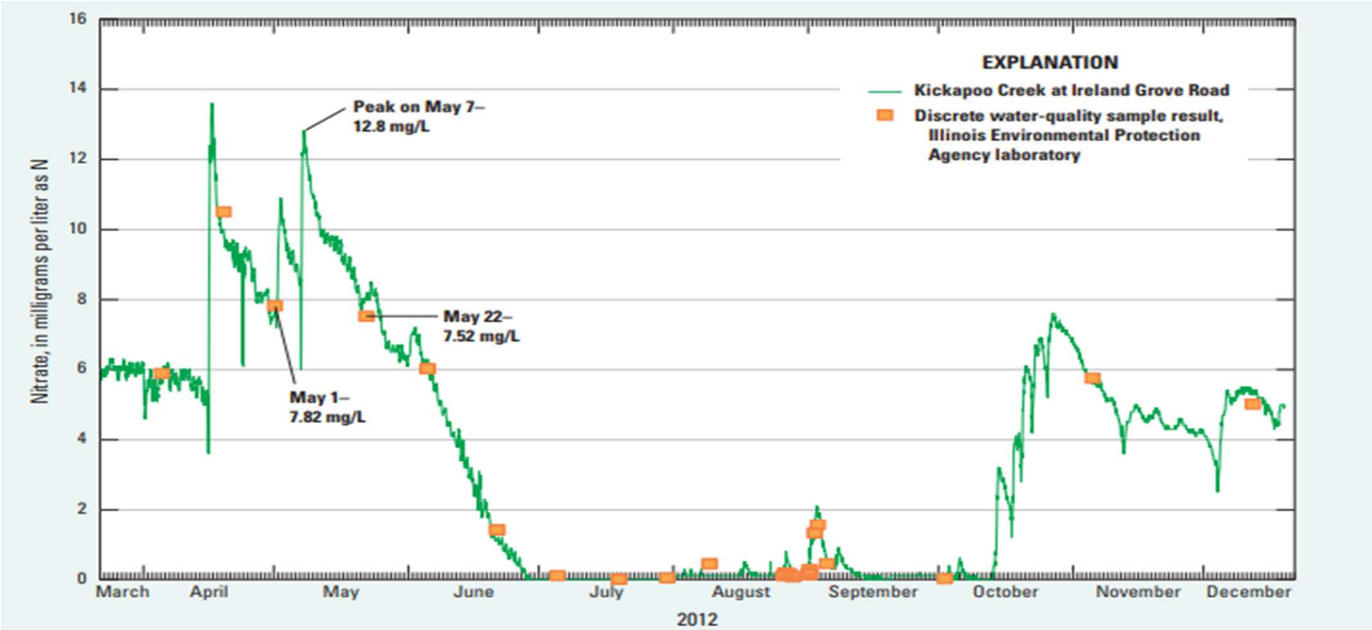
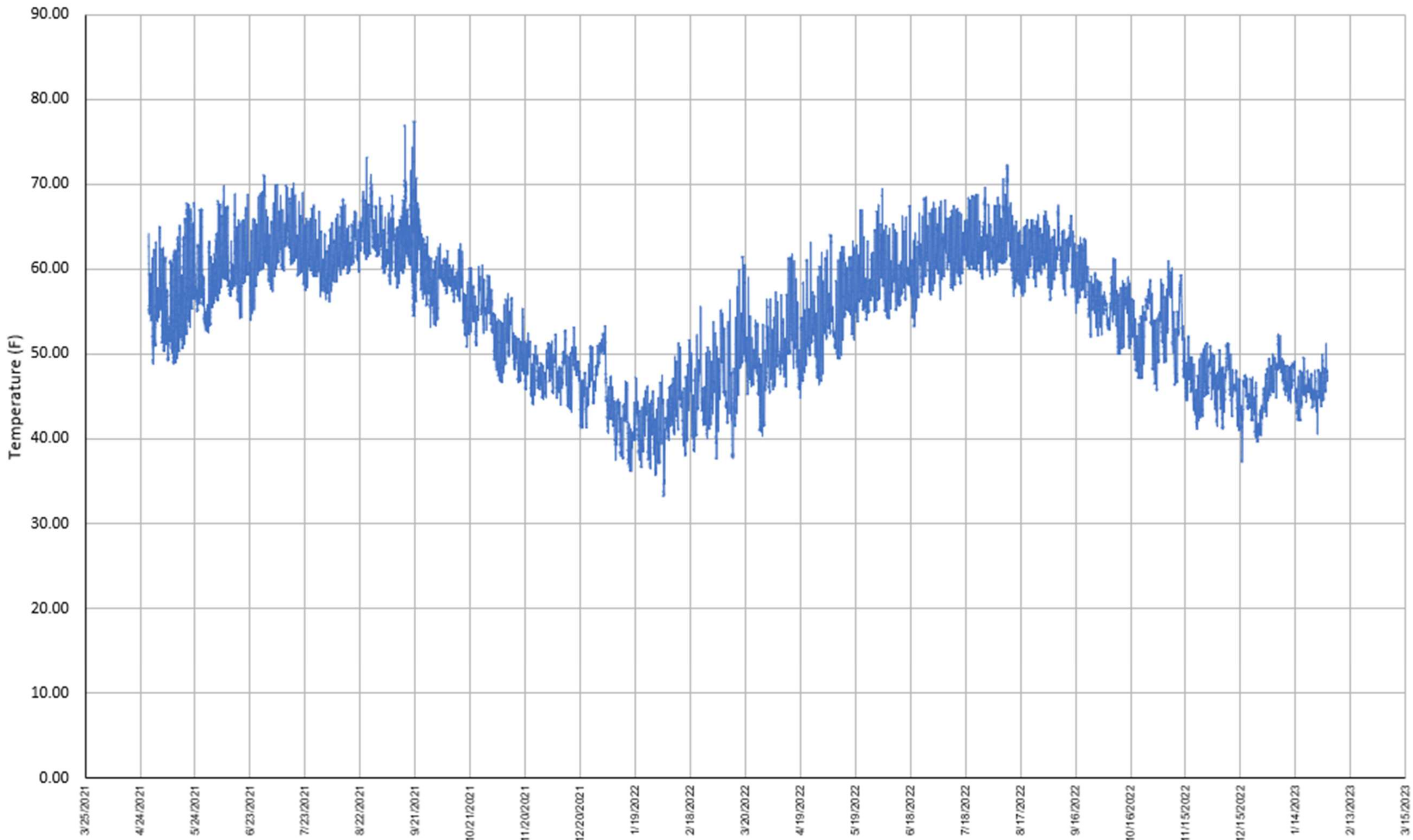
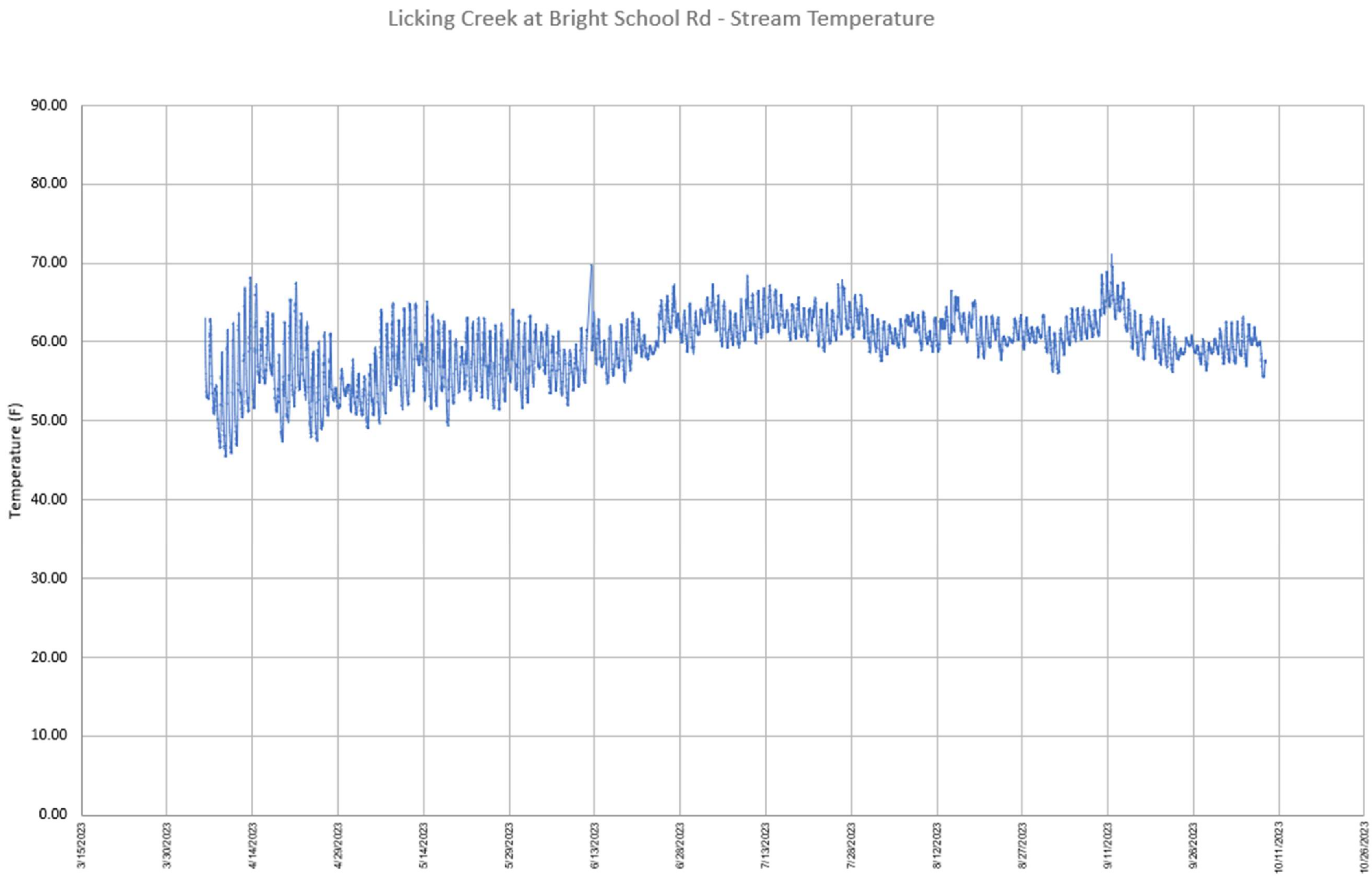


Figure 3. Continuous nitrate monitoring captures spikes in nitrate concentration that would not be evident by periodic laboratory samples. The graph of continuous nitrate concentration from Kickapoo Creek at Ireland Grove Road near Bloomington, Illinois, shows the relation between discrete water-quality samples and continuous data. The continuous data pick up peaks in nitrate concentrations that are not evident in the discrete samples. The peak of 12.8 milligrams per liter (mg/L) as N between a discrete sample collected on May 1, 2012 (7.82 mg/L), and May 22, 2012 (7.52 mg/L), would have been missed without the continuous data collection. When nitrate is a concern in drinking water or the accurate calculation of load is needed, the identification of the peak concentration is important for managing the water quality.

Information from this document illustrates the potential for discrete chemical testing not accurately reflecting the nitrate concentration. Note the 12.8 mg/L on May 7 is significantly higher (64%) than the discrete test results on May 1 (7.82 mg/L) and the discrete test on May 22 (7.52 mg/L). (USGS, 2013)

Licking Creek at Bright School Rd - Stream Temperature




Licking Creek at Bright School Rd - Stream Temperature
Temperature (F)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
3/15/2023
3/30/2023
4/14/2023
4/29/2023
5/14/2023
5/29/2023
6/13/2023
6/28/2023
7/13/2023
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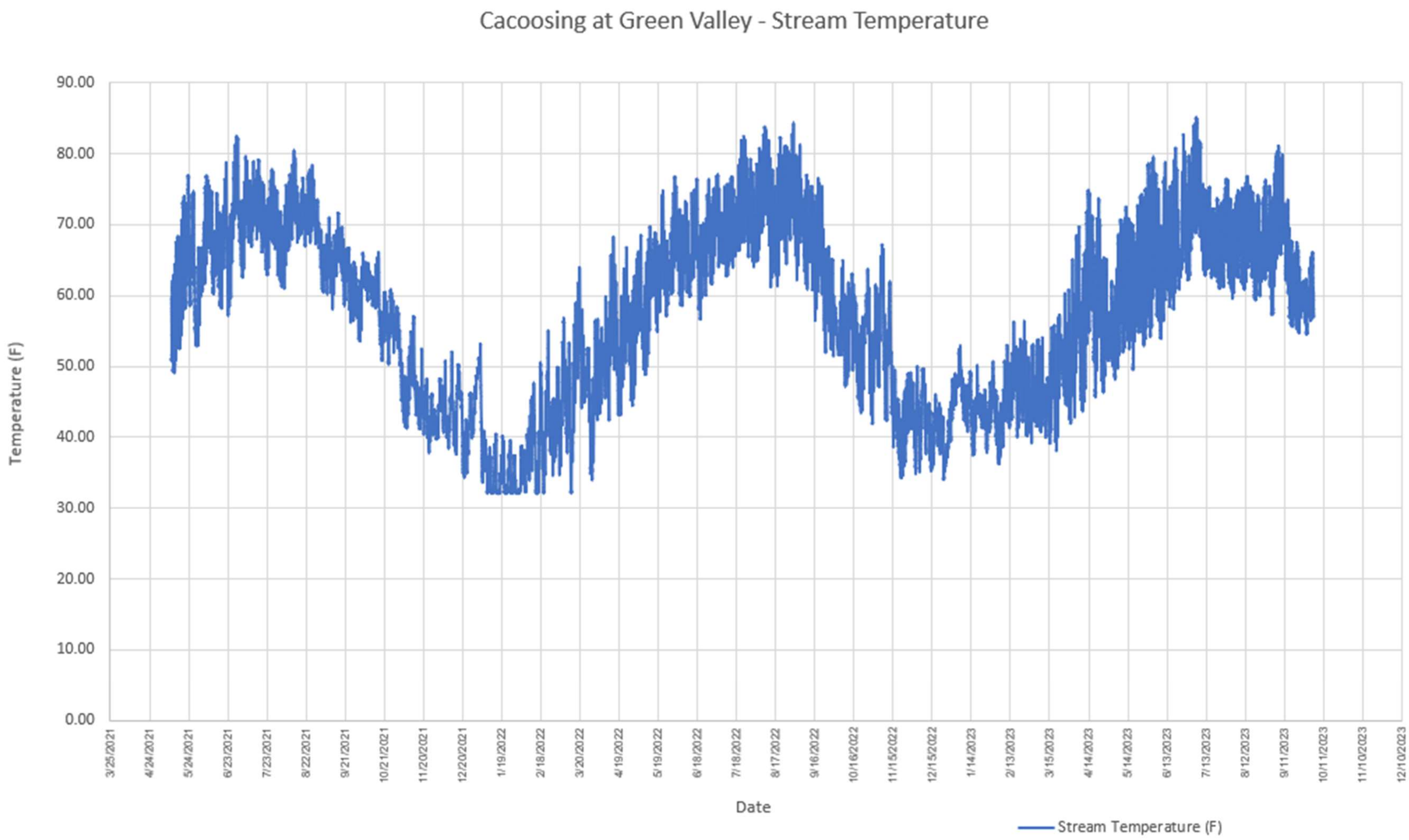
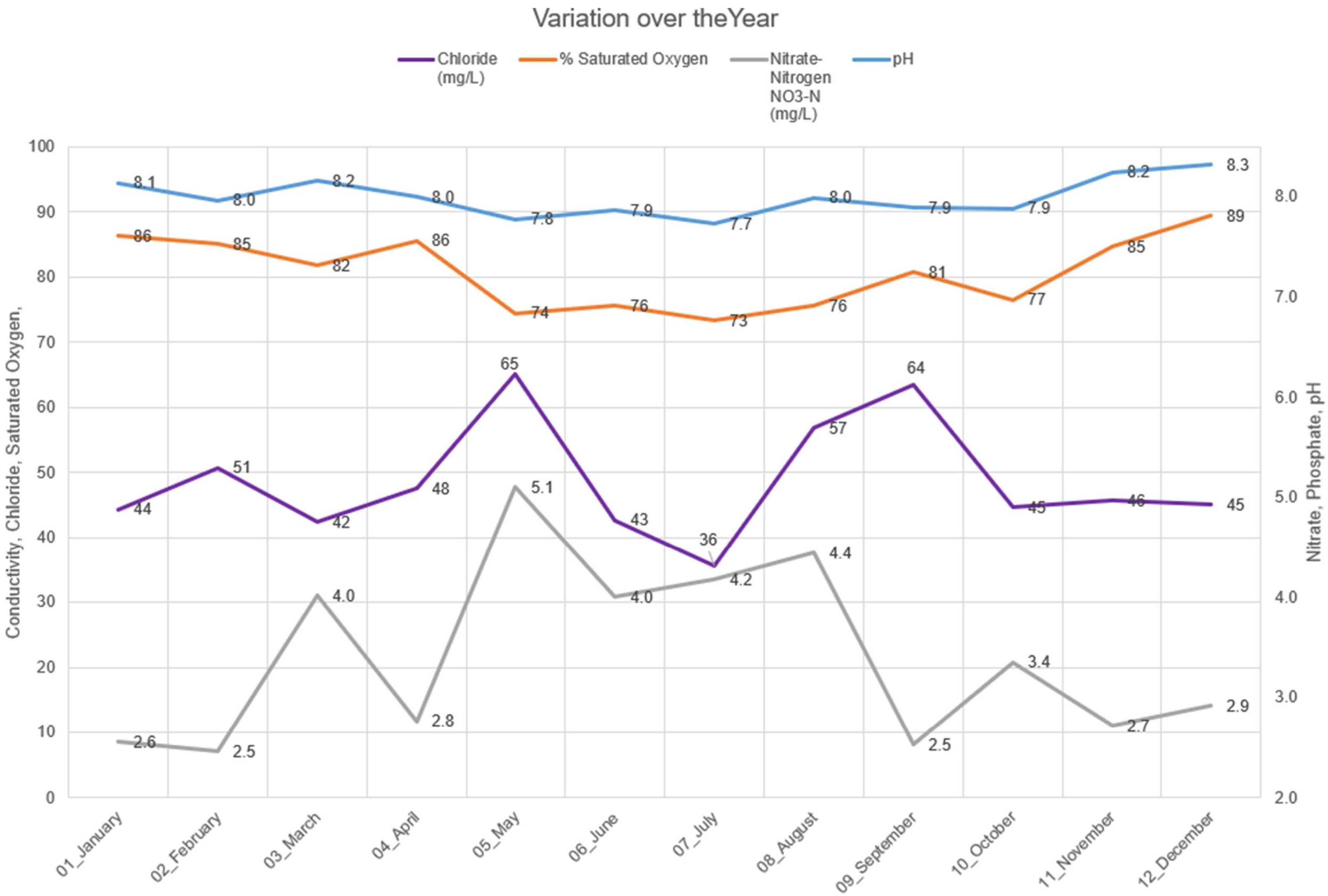
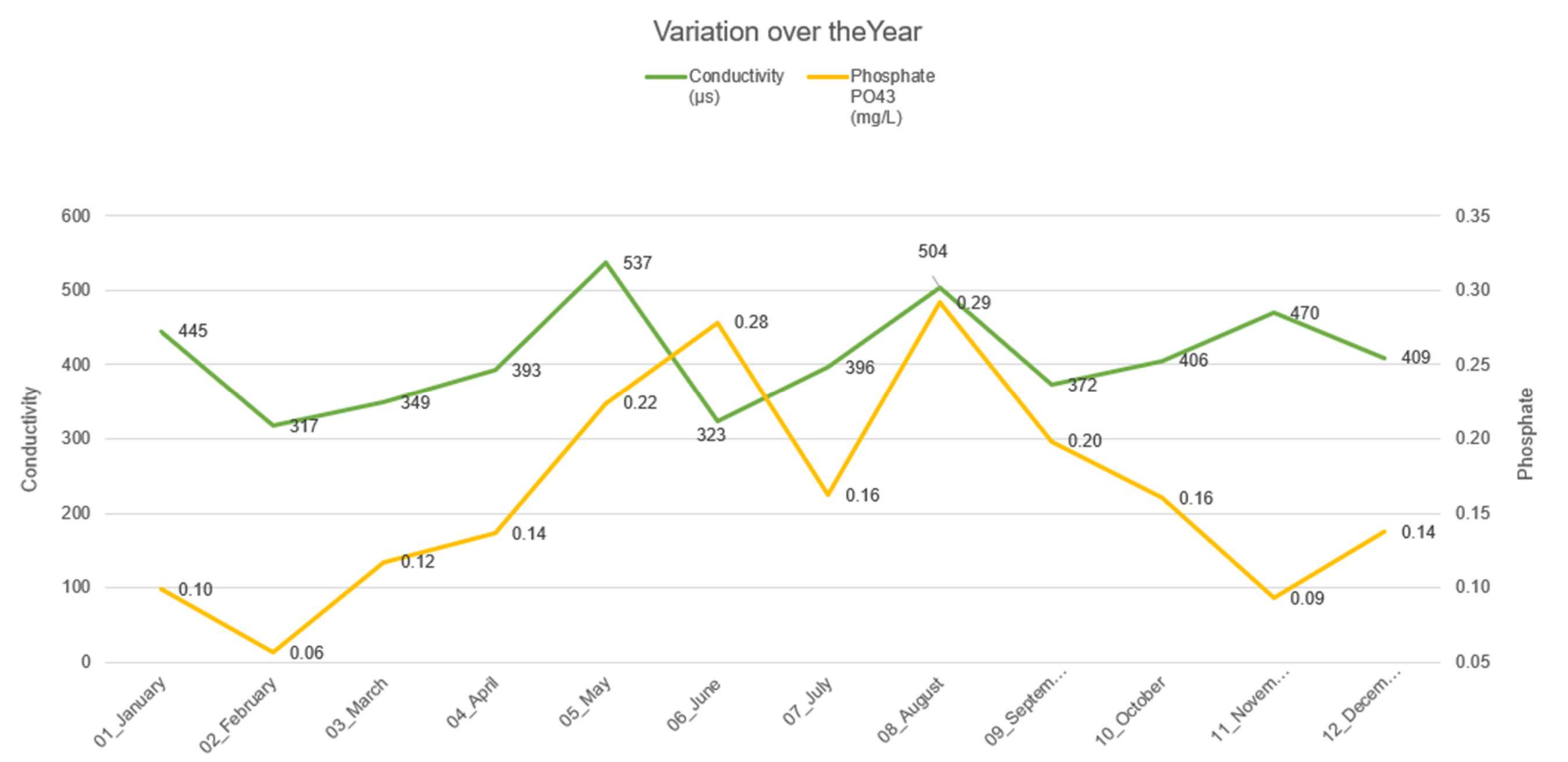
8/12/2023
8/27/2023
9/11/2023
9/26/2023
10/11/2023
10/26/2023


Cacoosing at Green Valley - Stream Temperature
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Temperature (F)
3/25/2021
4/24/2021
5/24/2021
6/23/2021
7/23/2021
8/22/2021
9/21/2021
10/21/2021
11/20/2021
12/20/2021
1/19/2022
2/18/2022
3/20/2022
4/19/2022
5/19/2022
6/18/2022
7/18/2022
8/17/2022
9/16/2022
10/16/2022
11/15/2022
12/15/2022
1/14/2023
2/13/2023
3/15/2023
4/14/2023
5/14/2023
6/13/2023
7/13/2023
8/12/2023
9/11/2023
10/11/2023
11/10/2023
12/10/2023
Date
Stream Temperature (F)


Variation over theYear
Chloride (mg/L)
% Saturated Oxygen
Nitrate-Nitrogen NO3-N (mg/L)
pH
Conductivity, Chloride, Saturated Oxygen,
Nitrate, Phosphate, pH
01_January
02_February
03_March
04_April
05_May
06_June
07_July
08_August
09_September
10_October
11_November
12_December


Variation over theYear
Conductivity (µs)
Phosphate PO43 (mg/L)
Conductivity
Phosphate
600
500
400
300
200
100
0
0.35
0.30
0.25
0.20
0.15
0.10
0.05
445
317
349
393
537
323
396
504
372
406
470
409
0.10
0.06
0.12
0.14
0.22
0.28
0.16
0.29
0.20
0.16
0.09
0.14
01_January
02_February
03_March
04_April
05_May
06_June
07_July
08_August
09_Septem...
10_October
11_Novem...
12_Decem...

Site Name	Date		Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^{3} (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Cacoosing Dam Upstream	29-Apr	April	60	10.6	92.8	0.1	0.10	7.8	515	100
Cacoosing Dam Upstream	April-22	April	60	8	75.9	4.0	0.34	7.82	600	110
Cacoosing Dam Downstream	April-21	April	-	8.6	74.9	4.0	0.11	7.9	550	115
Cacoosing Dam Downstream	April-22	April	-	8.8	82.0	5.0	0.15	7.39	500	115
County Rd Dam	April-22	April	40	9.7	90.4	5.0	0.05	8.45	215	105
Plum & Tully Confluence	April-19	April	-	10	88.6	2.0	0.19	8.1	-	98
UT to Plum Run (near Mayfly Sensor MSPL2S)	April-21	April	30	10	94.7	0.5	0.00	8	210	105
Furnace Creek by Church Street	April-22	April		8.3	85.1	1.5	0.15	8.5	160	112
		01_January	44.333333	10.73636364	86.2970366	2.55	0.09909091	8.1363636	445	109
Cacoosing Dam Upstream	August-21	August	80	6.8	71.8	4.0	0.36	7.66	580	100
Cacoosing Creek 1 (Dam Removed)	August-22	August	90	7.4	76.9	5.0	0.26	7.92	715	110
Cacoosing Dam Downstream	August-21	August	-	7.6	79.1	6.0	0.41	8.62	535	115
Cacoosing Creek 2 (Dam Removed)	August-22	August	-	6.6	66.8	5.0	0.28	7.74	890	115
Plum & Tully Confluence	August-21	August	60	8.6	96.1	4.0	0.99	8	425	110
Licking Creek	August-21	August	24	7.8	82.9	7.0	0.13	7.9	310	85
Tulpehocken Creek at Stouchsburg Bridge	August-20	August	30	5.7	60.8	1.8	0.08	8.03	580	98
Tulpehocken Creek at Stouchsburg Bridge	August-21	August	-	-	-	10.0	-	-	-	-
Tulpehocken Creek at Stouchsburg Bridge	August-22	August		5.6	61.0	4.0	0.18	8.23	585	115
Furnace Creek by Church Street	August-21	August	-	7.9	80.7	1.6	0.07	7.81	210	112
Furnace Creek by Church Street	August-22	August		7	79.6	0.5	0.16	7.99	205	115
		02_February	50.666667	10.92	85.0893862	2.46	0.056	7.962	317	85.6
Cacoosing Dam Upstream	December-20	December	-	11	92.9	0.3	0.13	8.1	590	105
Cacoosing Dam Upstream	December-21	December	80	7.8	65.4	5.0	0.26	7.98	640	110
Cacoosing Dam Downstream	December-20	December	-	10.4	86.3	0.5	0.16	8.3	580	115
Cacoosing Dam Downstream	December-21	December	-	9.2	77.7	5.0	0.3	8.31	805	115
Cacoosing Creek 2 (Dam Removed)	December-22	December	80	11	92.2	5.0	0.22	7.96	649	60
County Rd Dam	December-19	December	-	13	101.8	0.3	0.05	8.3	270	102
County Rd Dam	December-21	December	32	11.8	96.0	4.0	0.00	8.6	290	105
County Rd Dam	December-22	December	30	12.2	94.6	3.0	0.08	8.55	255	110
Plum & Tully Confluence	December-19	December	-	11.4	88.6	1.5	0.12	7.9	492	60
Plum & Tully Confluence	December-21	December	42	12.6	111.1	4.0	0.38	8.54	440	110
Plum & Tully Confluence	December-22	December	40	11	88.4	3.0	0.29	8.38	345	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-19	December	-	12	87.0	3.0	0.00	8.9	195	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-21	December	36	11.6	93.9	2.0	0.00	8.46	250	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-22	December	35	12	93.7	2.0	0.00	8.06	235	120
Licking Creek	December-22	December	30	10	78.1	5.0	0.10	8.12	325	110
Furnace Creek by Church Street	December-21	December	-	10	82.2	3.0	0.11	8.7	190	113

Site Name	Date		Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^{3} (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
		03_March	42.333333	9.458333333	81.7482545	4.0166667	0.11727273	8.1575	348.9166667	96.87
Cacoosing Dam Upstream	February-21	February	62	10.6	83.9	0.3	0.02	7.4	450	65
Cacoosing Dam Downstream	February-21	February	-	9.6	77.1	0.5	0.02	7.8	580	54
UT to Plum Run (near Mayfly Sensor MSPL2S)	February-20	February	20	11.2	90.4	4.0	0.00	8.1	200	97
UT to Plum Run (near Mayfly Sensor MSPL2S)	February-22	February	70	13	93.5	5.0	0.06	7.92	185	100
Furnace Creek by Church Street	February-22	February	-	10.2	80.5	2.5	0.18	8.59	170	112
		04_April	47.5	9.25	85.5404961	2.7625	0.13625	7.995	392.8571429	107.5375
Cacoosing Dam Upstream	January-21	January	64	10	83.6	0.5	0.00	7.9	610	105
Cacoosing Dam Upstream	January-22	January	80	9.2	73.7	4.0	0.19	8.07	500	110
Cacoosing Dam Downstream	January-21	January	-	10	84.0	0.8	0.09	7.7	670	115
Cacoosing Dam Downstream	January-22	January	-	8	65.9	4.0	0.14	7.74	440	115
Cacoosing Creek 2 (Dam Removed)	January-23	January		9.2	76.9	2.0	0.27	8.16	555	115
County Rd Dam	January-21	January	32	12	91.6	0.5	0.00	8.2	410	105
Plum & Tully Confluence	January-21	January	40	13	106.0	0.5	0.12	8.2	380	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	January-21	January	30	13.5	103.0	0.3	0.03	8.3	215	105
Licking Creek	January-23	January	20	10	85.1	6.0	0.13	7.62	305	100
Tulpehocken Creek at Stouchsburg Bridge	January-22	January		11.6	93.4	7.0	0.07	8.98	625	112
Furnace Creek by Church Street	January-22	January	-	11.6	86.0	2.5	0.05	8.63	185	112
		05_May	65	7.56	74.4049804	5.1	0.224	7.778	537	107.4
Cacoosing Dam Upstream	July-21	July	40	5.2	57.9	2.5	0.22	7.7	365	30
Cacoosing Creek 1 (Dam Removed)	July-22	July	74	6.3	67.2	5.0	0.34	7.68	725	110
Cacoosing Dam Downstream	July-21	July	-	7.3	80.6	3.0	0.16	8.3	295	36
Cacoosing Creek 2 (Dam Removed)	July-22	July	-	6.2	64.4	6.0	0.37	7.31	810	115
Plum & Tully Confluence	July-19	July	-	7.1	74.0	2.0	0.21	7.3	397	17
Licking Creek	July-20	July	20	6.5	70.5	5.0	0.02	8.14	280	65
Licking Creek	July-21	July	28	7	77.0	10.0	0.08	7.4	410	80
Licking Creek	July-22	July	20	8.5	88.5	7.0	0.00	7.62	400	95
Furnace Creek by Church Street	July-20	July	31	6.6	72.7	0.8	0.08	8.05	130	100
Furnace Creek by Church Street	July-22	July		7.2	80.3	0.5	0.14	7.8	150	75
		06_June	42.666667	6.9	75.5940077	4	0.27833333	7.866	323.3333333	109.3333333
Cacoosing Dam Upstream	June-21	June	60	6	64.4	5.0	0.27	7.37	590	95
Cacoosing Dam Downstream	June-21	June	-	6.6	70.3	6.0	0.19	7.97	455	115

Site Name	Date		Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^3 (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Plum & Tully Confluence	June-20	June	38	5.4	57.5	4.0	1.04	-	325	120
UT to Plum Run (near Mayfly Sensor MSPL2S)	June-22	June	30	8	87.1	2.5	0.00	7.96	220	100
Furnace Creek by Church Street	June-21	June	-	8	94.1	0.35?	0.09	7.75	185	111
Furnace Creek by Church Street	June-22	June		7.4	80.2	2.5	0.08	8.28	165	115
		07_July	35.5	6.79	73.293816	4.175	0.162	7.73	396.2	72.27
Cacoosing Dam Upstream	March-21	March		12	108.0	2.0	0.14	8.8	435	-
Cacoosing Dam Upstream	March-22	March	70	9.5	78.1	3.0	0.14	8.04	470	115
Cacoosing Dam Upstream	March-22	March	70	10	79.3	5.0	0.27	7.74	610	115
Cacoosing Dam Downstream	March-21	March	-	9	79.5	4.0	0.08	8.6	285	-
Cacoosing Dam Downstream	March-22	March	-	8.5	70.4	4.0	0.08	8.35	475	115
County Rd Dam	March-19	March	-	7.6	65.0	3.7	-	8.5	257	58
County Rd Dam	March-20	March	30	9.3	84.5	3.0	0.00	7.5	220	35
Plum & Tully Confluence	March-20	March	20	10	91.9	4.0	0.00	7.7	160	97
Plum & Tully Confluence	March-22	March	44	9.2	88.8	5.0	0.26	7.96	330	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	March-20	March	20	9.4	84.4	3.0	0.00	8	145	100
Tulpehocken Creek at Stouchsburg Bridge	March-22	March		10	79.9	9.0	0.09	8.32	625	112
Furnace Creek by Church Street	March-22	March		9	71.0	2.5	0.23	8.38	175	112
		08_August	56.8	7.1	75.5524313	4.4409091	0.292	7.99	503.5	107.5
Cacoosing Dam Upstream	May-21	May	70	8	76.1	6.0	0.25	7.52	575	80
Cacoosing Dam Upstream	May-22	May	60	6.8	68.3	5.0	0.18	7.6	610	115
Cacoosing Dam Downstream	May-21	May	-	6.8	64.8	6.0	0.36	7.87	630	115
Cacoosing Dam Downstream	May-22	May	-	7.6	74.7	6.0	0.23	7.27	715	115
Furnace Creek by Church Street	May-22	May		8.6	88.2	2.5	0.10	8.63	155	112
		09_September	63.5	8.033333333	80.6632887	2.5272727	0.19818182	7.8872727	372.2727273	89.06363636
Cacoosing Dam Upstream	November-20	November	68	10.6	97.2	1.5	0.13	8	660	110
Cacoosing Dam Upstream	November-21	November	70	8.8	72.3	3.0	0.11	7.88	560	105
Cacoosing Dam Downstream	November-20	November	-	8.6	78.9	1.5	0.15	8	700	114
Cacoosing Dam Downstream	November-21	November	-	10	83.4	4.0	0	8.74	708	115
Cacoosing Creek 2 (Dam Removed)	November-22	November		9.8	84.2	3.0	0.28	8.07	770	115
County Rd Dam	November-19	November	-	10.2	85.5	0.3	0.00	8.3	260	85
County Rd Dam	November-21	November	28	10.5	86.3	3.0	0.00	8.1	240	105
Plum & Tully Confluence	November-21	November	38	9.6	83.8	4.0	0.16	8.04	290	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	November-21	November	24	11.2	90.7	3.0	0.00	8.05	210	105

Site Name	Date		Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^{3} (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Tulpehocken Creek at Stouchsburg Bridge	November-21	November		8.8	78.7	8.0	0.11	8.56	650	112
Tulpehocken Creek at Stouchsburg Bridge	November-22	November		11	95.4	0.3	0.04	8.71	620	118
Furnace Creek by Church Street	November-21	November	-	9.6	78.1	3.5	0.12	8.12	250	112
Furnace Creek by Church Street	November-22	November		10.6	85.8	0.3	0.11	8.65	195	118
		10_October	44.571429	7.875	76.5196273	3.35	0.16	7.8846154	405.6153846	108.8333333
Cacoosing Dam Upstream	October-20	October	-	6.4	62.6	2.0	0.26	7.6	615	107
Cacoosing Dam Upstream	October-21	October	66	7.2	67.8	3.5	0.23	7.97	590	110
Cacoosing Dam Downstream	October-20	October	-	7.2	69.2	3.0	0.38	7.7	610	115
Cacoosing Dam Downstream	October-21	October	-	8.3	78.0	4.0	0.14	7.67	535	115
Cacoosing Creek 2 (Dam Removed)	October-22	October	88	8.2	75.9	5.0	0.32	8.06	675	100
County Rd Dam	October-21	October	28	6.8	71.5	4.0	0.00	8.1	320	85
Plum & Tully Confluence	October-21	October	42	7.8	80.7	4.0	0.24	7.8	405	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-19	October	-	-	-	0.3	0.02	7.2	313	-
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-21	October	30	8	81.7	3.0	0.05	8.05	270	115
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-22	October	38	9.2	85.1	2.0	0.00	8.24	245	120
Licking Creek	October-21	October	20	7.8	81.8	10.0	0.05	7.9	345	100
Furnace Creek by Church Street	October-21	October	-	8.2	79.7	2.5	0.18	7.94	175	112
Furnace Creek by Church Street	October-22	October		9.4	84.0	0.3	0.21	8.27	175	117
		11_November	45.6	9.946153846	84.6338826	2.7153846	0.09307692	8.2476923	470.2307692	109.1538462
Cacoosing Dam Upstream	September-20	September	80	8.3	80.7	1.5	0.27	8.1	395	97
Cacoosing Dam Upstream	September-21	September	60	7.4	74.8	5.0	0.12	7.93	500	105
Cacoosing Dam Downstream	September-20	September	-	9	86.3	0.5	0.28	8.1	405	115
Cacoosing Dam Downstream	September-21	September	-	5.6	55.5	5.0	0.17	7.81	440	115
Cacoosing Creek 2 (Dam Removed)	September-22	September	84	8	81.0	5.0	0.33	7.6	640	115
County Rd Dam	September-19	September	-	6.9	73.3	1.0	0.01	8.4	327	57
Plum & Tully Confluence	September-19	September	-	8.3	86.6	0.3	0.58	6.5	258	114
UT to Plum Run (near Mayfly Sensor MSPL2S)	September-22	September	30		-	7.0	0.04	7.68	265	30
Tulpehocken Creek at Stouchsburg Bridge	September-22	September		10	101.7	1.5	0.08	8.55	565	115
Furnace Creek by Church Street	September-21	September	-	-	-	0.8	0.13	7.74	90	2
Furnace Creek by Church Street	September-22	September		8.8	86.1	0.3	0.17	8.35	210	115
		12_December	45	11.0625	89.366361	2.9125	0.1375	8.3225	409.4375	103.75

Site Name	Date	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^3 (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Cacoosing Dam Upstream	September-20	80	8.3	80.7	1.5	0.27	8.1	395	97
Cacoosing Dam Upstream	October-20	-	6.4	62.6	2.0	0.26	7.6	615	107
Cacoosing Dam Upstream	November-20	68	10.6	97.2	1.5	0.13	8	660	110
Cacoosing Dam Upstream	December-20	-	11	92.9	0.3	0.13	8.1	590	105
Cacoosing Dam Upstream	January-21	64	10	83.6	0.5	0.00	7.9	610	105
Cacoosing Dam Upstream	February-21	62	10.6	83.9	0.3	0.02	7.4	450	65
Cacoosing Dam Upstream	March-21		12	108.0	2.0	0.14	8.8	435	-
Cacoosing Dam Upstream	April-21	60	10.6	92.8	0.1	0.10	7.8	515	100
Cacoosing Dam Upstream	May-21	70	8	76.1	6.0	0.25	7.52	575	80
Cacoosing Dam Upstream	June-21	60	6	64.4	5.0	0.27	7.37	590	95
Cacoosing Dam Upstream	July-21	40	5.2	57.9	2.5	0.22	7.7	365	30
Cacoosing Dam Upstream	August-21	80	6.8	71.8	4.0	0.36	7.66	580	100
Cacoosing Dam Upstream	September-21	60	7.4	74.8	5.0	0.12	7.93	500	105
Cacoosing Dam Upstream	October-21	66	7.2	67.8	3.5	0.23	7.97	590	110
Cacoosing Dam Upstream	November-21	70	8.8	72.3	3.0	0.11	7.88	560	105
Cacoosing Dam Upstream	December-21	80	7.8	65.4	5.0	0.26	7.98	640	110
Cacoosing Dam Upstream	January-22	80	9.2	73.7	4.0	0.19	8.07	500	110
Cacoosing Dam Upstream	March-22	70	9.5	78.1	3.0	0.14	8.04	470	115
Cacoosing Dam Upstream	March-22	70	10	79.3	5.0	0.27	7.74	610	115
Cacoosing Dam Upstream	April-22	60	8	75.9	4.0	0.34	7.82	600	110
Cacoosing Dam Upstream	May-22	60	6.8	68.3	5.0	0.18	7.6	610	115
Cacoosing Creek 1 (Dam Removed)	July-22	74	6.3	67.2	5.0	0.34	7.68	725	110
Cacoosing Creek 1 (Dam Removed)	August-22	90	7.4	76.9	5.0	0.26	7.92	715	110
Cacoosing Dam Downstream	September-20	-	9	86.3	0.5	0.28	8.1	405	115
Cacoosing Dam Downstream	October-20	-	7.2	69.2	3.0	0.38	7.7	610	115
Cacoosing Dam Downstream	November-20	-	8.6	78.9	1.5	0.15	8	700	114
Cacoosing Dam Downstream	December-20	-	10.4	86.3	0.5	0.16	8.3	580	115
Cacoosing Dam Downstream	January-21	-	10	84.0	0.8	0.09	7.7	670	115
Cacoosing Dam Downstream	February-21	-	9.6	77.1	0.5	0.02	7.8	580	54
Cacoosing Dam Downstream	March-21	-	9	79.5	4.0	0.08	8.6	285	-
Cacoosing Dam Downstream	April-21	-	8.6	74.9	4.0	0.11	7.9	550	115
Cacoosing Dam Downstream	May-21	-	6.8	64.8	6.0	0.36	7.87	630	115
Cacoosing Dam Downstream	June-21	-	6.6	70.3	6.0	0.19	7.97	455	115
Cacoosing Dam Downstream	July-21	-	7.3	80.6	3.0	0.16	8.3	295	36
Cacoosing Dam Downstream	August-21	-	7.6	79.1	6.0	0.41	8.62	535	115
Cacoosing Dam Downstream	September-21	-	5.6	55.5	5.0	0.17	7.81	440	115
Cacoosing Dam Downstream	October-21	-	8.3	78.0	4.0	0.14	7.67	535	115

Site Name	Date	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^3 (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Cacoosing Dam Downstream	November-21	-	10	83.4	4.0	0	8.74	708	115
Cacoosing Dam Downstream	December-21	-	9.2	77.7	5.0	0.3	8.31	805	115
Cacoosing Dam Downstream	January-22	-	8	65.9	4.0	0.14	7.74	440	115
Cacoosing Dam Downstream	March-22	-	8.5	70.4	4.0	0.08	8.35	475	115
Cacoosing Dam Downstream	April-22	-	8.8	82.0	5.0	0.15	7.39	500	115
Cacoosing Dam Downstream	May-22	-	7.6	74.7	6.0	0.23	7.27	715	115
Cacoosing Creek 2 (Dam Removed)	July-22	-	6.2	64.4	6.0	0.37	7.31	810	115
Cacoosing Creek 2 (Dam Removed)	August-22	-	6.6	66.8	5.0	0.28	7.74	890	115
Cacoosing Creek 2 (Dam Removed)	September-22	84	8	81.0	5.0	0.33	7.6	640	115
Cacoosing Creek 2 (Dam Removed)	October-22	88	8.2	75.9	5.0	0.32	8.06	675	100
Cacoosing Creek 2 (Dam Removed)	November-22		9.8	84.2	3.0	0.28	8.07	770	115
Cacoosing Creek 2 (Dam Removed)	December-22	80	11	92.2	5.0	0.22	7.96	649	60
Cacoosing Creek 2 (Dam Removed)	January-23		9.2	76.9	2.0	0.27	8.16	555	115
County Rd Dam	March-19	-	7.6	65.0	3.7	-	8.5	257	58
County Rd Dam	September-19	-	6.9	73.3	1.0	0.01	8.4	327	57
County Rd Dam	November-19	-	10.2	85.5	0.3	0.00	8.3	260	85
County Rd Dam	December-19	-	13	101.8	0.3	0.05	8.3	270	102
County Rd Dam	March-20	30	9.3	84.5	3.0	0.00	7.5	220	35
County Rd Dam	January-21	32	12	91.6	0.5	0.00	8.2	410	105
County Rd Dam	October-21	28	6.8	71.5	4.0	0.00	8.1	320	85
County Rd Dam	November-21	28	10.5	86.3	3.0	0.00	8.1	240	105
County Rd Dam	December-21	32	11.8	96.0	4.0	0.00	8.6	290	105
County Rd Dam	April-22	40	9.7	90.4	5.0	0.05	8.45	215	105
County Rd Dam	December-22	30	12.2	94.6	3.0	0.08	8.55	255	110
Plum & Tully Confluence	April-19	-	10	88.6	2.0	0.19	8.1	-	98
Plum & Tully Confluence	July-19	-	7.1	74.0	2.0	0.21	7.3	397	17
Plum & Tully Confluence	September-19	-	8.3	86.6	0.3	0.58	6.5	258	114
Plum & Tully Confluence	December-19	-	11.4	88.6	1.5	0.12	7.9	492	60
Plum & Tully Confluence	March-20	20	10	91.9	4.0	0.00	7.7	160	97
Plum & Tully Confluence	June-20	38	5.4	57.5	4.0	1.04	-	325	120
Plum & Tully Confluence	January-21	40	13	106.0	0.5	0.12	8.2	380	105
Plum & Tully Confluence	August-21	60	8.6	96.1	4.0	0.99	8	425	110
Plum & Tully Confluence	October-21	42	7.8	80.7	4.0	0.24	7.8	405	110
Plum & Tully Confluence	November-21	38	9.6	83.8	4.0	0.16	8.04	290	105
Plum & Tully Confluence	December-21	42	12.6	111.1	4.0	0.38	8.54	440	110
Plum & Tully Confluence	March-22	44	9.2	88.8	5.0	0.26	7.96	330	110

Site Name	Date	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^3 (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Plum & Tully Confluence	December-22	40	11	88.4	3.0	0.29	8.38	345	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-19	-	-	-	0.3	0.02	7.2	313	-
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-19	-	12	87.0	3.0	0.00	8.9	195	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	February-20	20	11.2	90.4	4.0	0.00	8.1	200	97
UT to Plum Run (near Mayfly Sensor MSPL2S)	March-20	20	9.4	84.4	3.0	0.00	8	145	100
UT to Plum Run (near Mayfly Sensor MSPL2S)	January-21	30	13.5	103.0	0.3	0.03	8.3	215	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	April-21	30	10	94.7	0.5	0.00	8	210	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-21	30	8	81.7	3.0	0.05	8.05	270	115
UT to Plum Run (near Mayfly Sensor MSPL2S)	November-21	24	11.2	90.7	3.0	0.00	8.05	210	105
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-21	36	11.6	93.9	2.0	0.00	8.46	250	110
UT to Plum Run (near Mayfly Sensor MSPL2S)	February-22	70	13	93.5	5.0	0.06	7.92	185	100
UT to Plum Run (near Mayfly Sensor MSPL2S)	June-22	30	8	87.1	2.5	0.00	7.96	220	100
UT to Plum Run (near Mayfly Sensor MSPL2S)	September-22	30		-	7.0	0.04	7.68	265	30
UT to Plum Run (near Mayfly Sensor MSPL2S)	October-22	38	9.2	85.1	2.0	0.00	8.24	245	120
UT to Plum Run (near Mayfly Sensor MSPL2S)	December-22	35	12	93.7	2.0	0.00	8.06	235	120
Licking Creek	July-20	20	6.5	70.5	5.0	0.02	8.14	280	65
Licking Creek	July-21	28	7	77.0	10.0	0.08	7.4	410	80
Licking Creek	August-21	24	7.8	82.9	7.0	0.13	7.9	310	85
Licking Creek	October-21	20	7.8	81.8	10.0	0.05	7.9	345	100
Licking Creek	July-22	20	8.5	88.5	7.0	0.00	7.62	400	95
Licking Creek	December-22	30	10	78.1	5.0	0.10	8.12	325	110
Licking Creek	January-23	20	10	85.1	6.0	0.13	7.62	305	100
Tulpehocken Creek at Stouchsburg Bridge	August-20	30	5.7	60.8	1.8	0.08	8.03	580	98
Tulpehocken Creek at Stouchsburg Bridge	August-21	-	-	-	10.0	-	-	-	-
Tulpehocken Creek at Stouchsburg Bridge	November-21		8.8	78.7	8.0	0.11	8.56	650	112
Tulpehocken Creek at Stouchsburg Bridge	January-22		11.6	93.4	7.0	0.07	8.98	625	112
Tulpehocken Creek at Stouchsburg Bridge	March-22		10	79.9	9.0	0.09	8.32	625	112
Tulpehocken Creek at Stouchsburg Bridge	August-22		5.6	61.0	4.0	0.18	8.23	585	115
Tulpehocken Creek at Stouchsburg Bridge	September-22		10	101.7	1.5	0.08	8.55	565	115
Tulpehocken Creek at Stouchsburg Bridge	November-22		11	95.4	0.3	0.04	8.71	620	118
Furnace Creek by Church Street	July-20	31	6.6	72.7	0.8	0.08	8.05	130	100
Furnace Creek by Church Street	June-21	-	8	94.1	0.35?	0.09	7.75	185	111
Furnace Creek by Church Street	August-21	-	7.9	80.7	1.6	0.07	7.81	210	112
Furnace Creek by Church Street	September-21	-	-	-	0.8	0.13	7.74	90	2
Furnace Creek by Church Street	October-21	-	8.2	79.7	2.5	0.18	7.94	175	112

Site Name	Date	Chloride (mg/L)	Dissolved oxygen (mg/L)	% Saturated Oxygen	Nitrate-Nitrogen NO3-N (mg/L)	Phosphate PO_4^3 (mg/L)	pH	Conductivity (µs)	Water Transparency (cm)
Furnace Creek by Church Street	November-21	-	9.6	78.1	3.5	0.12	8.12	250	112
Furnace Creek by Church Street	December-21	-	10	82.2	3.0	0.11	8.7	190	113
Furnace Creek by Church Street	January-22	-	11.6	86.0	2.5	0.05	8.63	185	112
Furnace Creek by Church Street	February-22	-	10.2	80.5	2.5	0.18	8.59	170	112
Furnace Creek by Church Street	March-22		9	71.0	2.5	0.23	8.38	175	112
Furnace Creek by Church Street	April-22		8.3	85.1	1.5	0.15	8.5	160	112
Furnace Creek by Church Street	May-22		8.6	88.2	2.5	0.10	8.63	155	112
Furnace Creek by Church Street	June-22		7.4	80.2	2.5	0.08	8.28	165	115
Furnace Creek by Church Street	July-22		7.2	80.3	0.5	0.14	7.8	150	75
Furnace Creek by Church Street	August-22		7	79.6	0.5	0.16	7.99	205	115
Furnace Creek by Church Street	September-22		8.8	86.1	0.3	0.17	8.35	210	115
Furnace Creek by Church Street	October-22		9.4	84.0	0.3	0.21	8.27	175	117
Furnace Creek by Church Street	November-22		10.6	85.8	0.3	0.11	8.65	195	118

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