SCIENCE ENGINEERING DESIGN

PRINCETON HYDRO

Mr. Christopher Garges, Township Manager
Solebury Township
3092 Sugan Road
P.O. Box 139
Solebury, PA, 18963

RE: Executive Summary - Aquetong Creek Ecologically-Based 2023 Water Quality Monitoring
Solebury Township, Bucks County, PA
Project #0388.014

February 14, 2024

Dear Mr. Garges,

Princeton Hydro is pleased to submit our 2023 report detailing the ecological condition of the Aquetong Creek, specifically as it applies to ongoing restoration within the Aquetong Creek Park. The following is an executive summary of our findings:

1. General observations suggested that the stream is doing well in regards to fish habitat. A potential barrier to upstream fish movement located near the previous location of the breaches dam now appears to be passable to fish.
2. An area of the stream that should be addressed is an approximately 3' headcut (small waterfall) approximately 300' downstream from the spring pool. This likely serves as a barrier to upstream fish movement.
3. Water quality in the mainstem of the Aquetong Creek is consistent with that found in previous years, including the stream's characteristic swift flows and stable cold temperatures.
4. Brook trout were sampled in higher numbers in 2023 than in the previous year. The reaches within the park yielded a total brook trout mass of approximately 21.5 lbs/acre, fulfilling conditions for a PA Class B Wild Brook Trout Stream.
5. Aquatic macroinvertebrate communities were largely consistent with those collected in previous years. Metrics calculated from this assessment suggest that the stream features relatively minimal ecological problems, ranking "good" or "very good". Amphipods (side-swimmers) were the dominant family found.
6. Overall, the stream continues to be in good ecological health given the timeline of the park's restoration efforts. In addition to continued monitoring in 2024 and the removal of the barrier to fish movement noted above, Princeton Hydro currently recommends conducting age-assessments on brook trout via scale collection and a more in-depth assessment of brook trout habitat.

We look forward to continuing to work with Solebury Township on the restoration of Aquetong Spring Park. If you have any questions or comments, please contact me directly at cmiko@princetonhydro.com or 908-237-5660.

Sincerely,

Chris L. Mikolajczyk
Senior Manager - Aquatics
Princeton Hydro, LLC

AQUETONG CREEK ECOLOGICALLY BASED WATER QUALITY MONITORING - 2023

SOLEBURY TOWNSHIP, BUCKS COUNTY, PA

FEBRUARY 2024

PREPARED FOR:

SOLEBURY TOWNSHIP
ATTN: CHRISTOPHER GARGES
TOWNSHIP MANAGER
3092 SUGAN ROAD
P.O. BOX 139
SOLEBURY, PENNSYLVANIA, 18963

PREPARED BY:

PRINCETON HYDRO, LLC
35 CLARK STREET, SUITE 200
TRENTON, NJ 08611
P.O. BOX 3689
TRENTON NJ 08629
(P): 908-237-5660

TABLE OF CONTENTS

INTRODUCTION

The Aquetong Creek restoration site is located in Solebury Township, Bucks County, PA, at the location of the former Aquetong Lake. Aquetong Lake was a 15-acre impoundment formed in 1870 by the construction of an earthen dam on Aquetong Creek. The main source of Aquetong Creek is Ingham Spring, an artesian spring formed at the contact of two geologic formations that flows at a rate of approximately 2,000 gallons per minute (GPM) (F.X. Browne, Inc., 2004). Aquetong Creek flows approximately 2.5 miles from Ingham Spring to its mouth at the Delaware River in New Hope, PA.

A 2004 study funded by Bucks County Trout Unlimited found that the impoundment was affecting downstream water quality, particularly water temperature (F.X. Browne, Inc., 2004). In 2015, the dam was breached with the goal of reducing thermal impacts on the creek and supporting a high-quality cold-water fishery in Aquetong Creek, while also avoiding the need for continued dam maintenance. With the dam breached and the lake drained, a meandering channel formed through the exposed former lakebed, connecting the upper and lower reaches of Aquetong Creek. Additionally, a small tributary flowing from the north under Route 202 now joins Aquetong Creek in the approximate center of the formerly impounded area.

In 2017 and 2018, Princeton Hydro conducted several monitoring events focusing on the downstream area closer to the dam breach, as well as upstream to the Ingham Spring and also within the northern tributary passing under Route 202. This monitoring concluded that conditions within the former lakebed were partially conducive to maintaining a brook trout (*Salvelinus fontinalis*) population as it pertains to temperature, dissolved oxygen, and available forage. However, the physical habitat still needed additional restoration to further increase the stability of streambanks and create more refuge habitat for trout. Another survey was conducted in 2019 focusing on the areas downstream of the breach to assess impacts of the removal of several ash trees within the park, and further surveys focusing on the original study area were conducted in the fall of 2020 and the growing seasons of 2021 and 2022.

In 2023, Princeton Hydro again conducted a survey of the ecological condition of the six (6) main sites within the study area. In addition, at the request of the Aquetong Watershed Association, two (2) sites outside of the initial study area previously monitored by the PADEP were also sampled. The overall goal of the 2023 study was to continue to assess current water quality conditions, fish, and benthic invertebrate communities within the project site. Comparisons were also made between the 2023 data and that data collected in previous years (where they apply) in order to assess any longitudinal changes occurring in the stream over time.

METHODS

As in previous years, six (6) points within the old lakebed and in areas downstream were sampled for water quality three (3) total times in 2023 (Figure 1). The downstream-most of these points is located near the eastern property line, while an additional site (ST1) is located approximately 450' downstream of the dam breach. ST2 is sited at the dam breach. ST2, ST3, and ST5 are all located along the mainstem of the Aquetong, while ST4 is located on a small tributary that enters the mainstem from the direction of Rt. 202. Two (2) additional sites were also sampled in 2022 and 2023, both near locations that have been previously sampled by the PADEP. One of these sites is located over 0.5 miles downstream of the dam breach and approximately 225 m downstream of Reeder Road (AW1). The other site is located along a northern branch of the Aquetong Creek at a reach that runs parallel to Creekside Drive (AW2). A map of locations is provided in Figure 1. A survey of the stream's macroinvertebrate and fisheries communities at each site was conducted on September 11th, 13th, and 15th, 2023.

IN-SITU AND STREAMFLOW DATA COLLECTION

At each location, Princeton Hydro scientists collected *in-situ* water quality data using an *In-situ* Aquatroll 500 calibrated multimeter water quality probe. This probe measured the following analytes:

- Temperature (°C)
- Dissolved Oxygen (concentration as mg/L and percent saturation as %)
- Specific Conductivity (µS/cm)
- pH (standard units)

Additionally, water velocity data was collected at several points along a cross-section at each station using a Marsh-McBirney, Inc. Flo-Mate™ Model 2000 Portable digital flowmeter and a wading rod. Total streamflow was calculated using water velocity, depth, and distance along the cross section collected at each point.

DISCRETE WATER QUALITY DATA COLLECTION

On each water quality sampling date, whole water samples were collected at each station and analyzed for the following:

- Total Phosphorus
- Total Nitrogen
- Total Suspended Solids

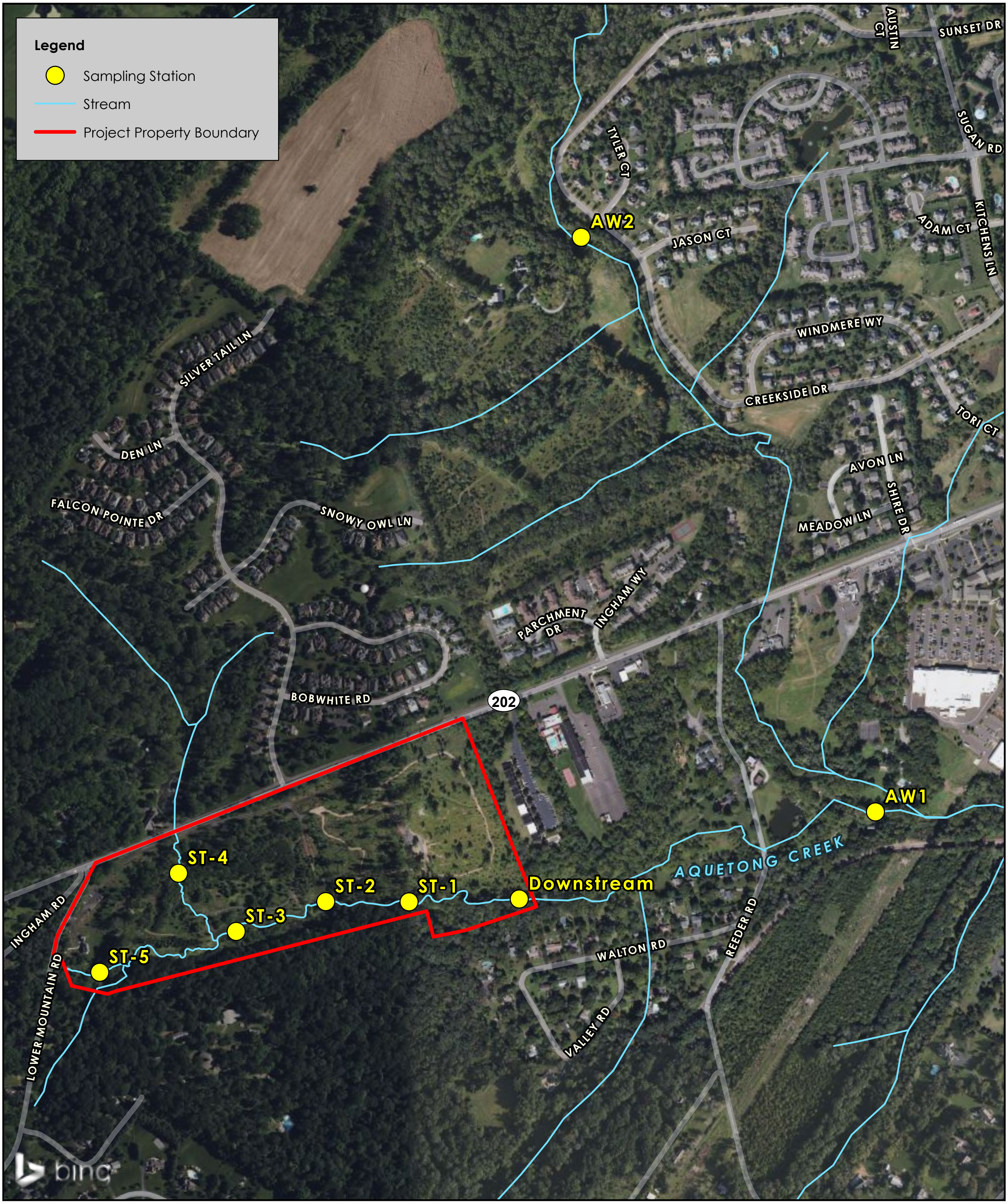
Following each sampling event, samples were delivered to Environmental Compliance Monitoring (ECM), a certified laboratory, for analysis.

FISHERIES SURVEY

A survey of the fish communities at each site was conducted in mid-September 2023 using the backpack electrofishing method. During each sampling event, seine nets were placed in the upstream and downstream ends of the reach to prevent fish from moving into and out of the area to be sampled. A length of each reach was sampled three times, beginning at the downstream end of the reach. Captured fish were kept in a temporary holding vessel. After each electrofishing pass the fish were either immediately processed and released outside the sampling area or pooled for the three runs and subsequently processed and released to avoid recapture in the surveyed segment. All captured fish were identified to species, measured for total length, and returned to the stream immediately following measurement. Additionally, all brook trout were weighed using a small digital scale to obtain their approximate mass. The resulting data was analyzed for composition, catch per unit effort, Shannon's diversity, and evenness.

BENTHIC MACROINVERTEBRATE SAMPLING

During the September sampling event, the benthic macroinvertebrate community was sampled at each station using a D-net. Ten kicks or jabs were collected per station in various microhabitat types (e.g. riffles, coarse woody debris, aquatic vegetation) and compiled into a single sample. This sample was preserved with alcohol and analyzed in Princeton Hydro's in-house laboratory. A subsample of at least 50 organisms was picked from each sample, and each organism was identified to lowest practical taxon (typically family). The resulting data was used to calculate metrics such as %EPT, richness, diversity, and the family-level biotic index.



NOTES:
1. Stream sampling locations are approximate.
2. Property boundary is approximate.
3. Streams obtained from the Pennsylvania Spatial Data Access (PASDA) website: http://www.pasda.psu.edu/
4. Aerial imagery obtained through ArcGIS Online Bing Maps (C) 2021 Microsoft Corporation and its data suppliers.

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

FIGURE 1: ECOLOGICAL SURVEY SAMPLING STATIONS

AQUETONG CREEK RESTORATION PROJECT
AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com

RESULTS

GENERAL OBSERVATIONS

Conditions upstream of the dam have largely maintained their improved state in regard to streamside vegetation, sedimentation, and available habitat, however some individual areas still contain some fine sediment deposits. Adaptive management performed over the course of the last few years appear to have fostered preferred habitat for brook trout. As in the past, the stream features an abundance of aquatic vegetation, particularly watercress (*Nasturtium officinale*), aquatic moss (*Fontinalis sp.*), and horned pondweed (*Zannichellia palustris*). This vegetation provides excellent habitat for both fish and macroinvertebrates. A potential barrier to fish movement previously identified between sites ST1 and ST2 now appears largely passable to brook trout. Another potential barrier to fish movement that is still present was observed just downstream of ST5, presenting as a head-cut forming a relatively steep "ramp", measuring approximately 2.5-3' of vertical height. A study in 2004 by the US Department of the Interior concluded that a vertical height of over 1 meter is enough to prevent the upstream movement of most brook trout under 30 cm (~1') in length, if the plunge pool beneath is less than 10 cm in depth (Myrick and Kondratieff, 2004). Given the swiftness of flows in this area, and the taller height of this feature, this area may serve as a barrier to upstream movement for all brook trout, save for possibly some of the very large individuals.

The substrate for much of the stream is a combination of mixed cobble, gravel and silt. The majority of the stream reaches consist of a single channel, however there are several instances of split channels where flow is divided between several smaller channels. Additionally, there is a relative mix of sinuous and low sinuosity reaches of the stream, all consisting of a low slope. In some of the more pronounced meanders, specifically between ST2 and ST3, there are noticeable cut banks and point bars, formed through sediment deposition and erosion. There are examples present of pools, riffles, runs and glides which can create diverse habitat for stream biota.

IN-SITU AND FLOW DATA

As has been observed in past years, water temperatures in the mainstem of the Aquetong Creek remained very stable, varying by less than 2.0°C over the three events in the mainstem stations. Water in the Aquetong Creek typically exhibits cold temperatures, with a consistent exception being temperatures recorded in the Rt. 202 tributary (ST4). The two newer sampling stations also typically featured temperatures that differed from those within the initial study area. Along the mainstem within the Aquetong Spring Park, temperatures ranged from approximately 11.7°C to 13.0°C during the 2023 growing season. ST4, had the largest temperature variation with temperatures in May being 15.2 °C and reaching 25.6 °C in September. The higher temperatures are largely attributable to the upstream impoundment, north of Rt. 202, which feeds the tributary. AW1 had a smaller temperature range throughout the 2023 growing season with a low temperature of 13.0 °C in May and a high temperature of 16.5 °C in July. AW2 saw a low temperature of 15.6 °C in May and a high temperature of 22.5 °C in July. The increased temperatures at AW2 are most likely due to an impoundment above the station (Honey Hollow Pond) where stagnant water gets released into the stream.

Dissolved oxygen concentrations in the mainstem stations were similarly consistent and well within a preferable range, ranging from 89% to 104% throughout the 2023 growing season. ST4 had a closer range in DO with concentrations from 98% in September to 113% in May. AW1 and AW2 featured relatively consistent dissolved oxygen concentrations throughout the season, with measured values ranging from between 84% to 100% saturation. The consistent temperatures and dissolved oxygen concentrations that stayed within the preferred range in the park's boundaries are largely due to the groundwater input from the spring in the park. This along with strong flows allow for good mixing in the stream as you move farther from the spring. These measurements are largely consistent with temperature and dissolved oxygen measurements collected in previous surveys.

The mainstem's specific conductivity (SpC) within the Aquetong park was measured on average to be 424.9 µS/cm in May and only decreased slightly to an average of 425.5 µS/cm in July. Average conductivity inside the park increased to 432.5 µS/cm in September. These concentrations are very consistent and track with those obtained in 2021 and 2022. While these values are slightly elevated, it reflects the limestone geology of the watershed. As in past years, ST4 featured somewhat higher conductivity, averaging approximately 534.8 µS/cm throughout the growing season. These higher values likely reflect the denser development in that tributary's sub watershed. Sites AW1 and AW2 had the lowest recorded SpC of any of the sites with AW1 averaging 408.8 µS/cm and AW2 averaging 374.4 µS/cm.

As in previous years, pH values obtained from stations along the mainstem of the Aquetong ran slightly elevated, averaging 7.96 in May, 7.94 in July, and 7.97 in September. These alkaline values are likely due to local limestone geology, with the stream's origin at Ingham Spring. To a lesser extent, higher pH values may also in part be contributed by the abundance of plant life in the stream, as photosynthesis typically results in elevated pH. Similar to past years, pH tended to be slightly higher at ST4 averaging 8.09 throughout the growing season. AW1 and AW2 also had higher alkaline values. AW1 averaged 8.04 through the three sampling events and values were slightly increased to 8.07 at AW2 during the 2023 growing season.

Aquetong Creek *In-Situ* Data 5/19/2023						
Station	**Temperature °C**	**SpC µS/cm**	**DO mg/L**	**DO % %**	**pH s.u.**	**Flow CFS**
AW1	12.99	403.4	10.54	99.0	8.18	12.32
AW2	15.56	370.9	10.19	100.8	8.26	4.05
Downstream	12.26	412.98	10.92	100.95	8.1	7.37
ST1	12.44	427.8	10.78	100.1	8.09	6.27
ST2	12.48	428.7	10.83	100.7	8.05	7.38
ST3	12.16	429.1	10.60	97.6	7.89	7.07
ST4	15.15	545.8	11.48	113.5	8.41	0.33
ST5	11.56	426.2	9.90	90.2	7.66	6.01
Spring	12.15	421.0	6.96	64.2	7.56	-
Aquetong Creek *In-Situ* Data 7/31/2023						
AW1	16.49	404.6	9.03	92.6	7.97	11.71
AW2	22.05	364.7	7.49	85.2	8.02	3.22
Downstream	12.78	430.5	10.61	100.22	8.02	5.74
ST1	12.61	395.9	11.00	103.8	8.03	5.97
ST2	12.82	434.7	10.60	100.3	8.01	5.89
ST3	12.65	434.7	10.30	97.3	7.86	5.10
ST4	21.47	544.1	9.14	103.8	8.15	0.11
ST5	11.67	431.5	9.80	90.4	7.77	5.74
Spring	11.61	428.6	7.15	66.1	7.54	-
Aquetong Creek *In-Situ* Data 9/13/2023						
AW1	16.07	418.6	9.08	92.5	7.98	7.91
AW2	22.54	387.5	7.27	84.3	7.92	2.08
Downstream	12.75	433.52	10.68	101.04	8.08	4.78
ST1	12.58	434.6	10.77	101.7	8.05	4.75
ST2	13.01	433.5	10.58	100.9	8.02	5.86
ST3	12.32	435.8	10.43	97.8	7.97	3.91
ST4	25.55	514.7	8.03	98.5	7.7	0.25
ST5	11.9	425.1	9.67	89.8	7.75	6.60
Spring	11.79	428.3	6.94	64.4	7.94	-

Table 1: Aquetong Creek *In-Situ* Data 2023

As noted above, the mainstem of the Aquetong Creek is characterized by relatively swift, consistent flows. Of the mainstem stations, ST2 and ST3 typically featured some of the highest discharges. Flow did not vary much throughout the 2023 season in the mainstem of the stream. The average CFS on the mainstem slightly declined throughout the season which is expected with the seasonal precipitation. In May the mainstem averaged 6.82 CFS then slightly declined in July to average 5.58 CFS, and then averaged 5.46 CFS in September. ST4 showed a significantly lower discharge never going above 0.5 CFS. This is due to the origin of ST4 being a dammed pond with controlled discharge throughout the year. The Downstream station had flows that were mirrored ST1 throughout the season starting around 7.00 CFS in May and dropping to approximately 4. 76 CFS in September. AW1 had the highest discharges throughout the season starting at 12.32 CFS in May and dropping throughout the season to 7.91 CFS in September. AW2 had the second lowest flows throughout the year with 4.05 CFS being recorded in May, 3.22 CFS in July, and 2.08 CFS in September.

AW2 generally had minimal change in water depth and velocity for most of the channel transect during each of the monitoring events. AW1 flow velocities varied throughout the transect, with some emergent rocks creating eddy patterns of negative or reduced flow. Flow at the downstream station often was slightly bottlenecked by watercress along both banks and had a defined thalweg. ST1 often had decent depth and flow velocity resulting in one of the highest total discharges during each event. ST2 consistently had deeper water depths and slower flow velocities across the channel than other stations. The log steps and larger cobble substrate at station 3 resulted in variable flow velocities and discharge from event to event. ST4 is narrow, shallow and slow flowing; discharge was always the lowest at this station, consistent with previous years. ST5, similar to the downstream station, has a slightly bottlenecked flow pattern because of the prevalent watercress along both banks. Due to the small channel width, total discharge showed variation.

Figures displaying changes in *In-Situ* parameters in Stations ST1-5 over the past several years are provided in the Appendix.

COMPARISON TO WATER QUALITY CRITERIA

The collected data was also compared to the specific water quality criteria outlined in 25 Pa. Code § 93.7 where applicable. Of the various metrics described during this study, only three have directly comparable analogs in the technical regulations, including temperature, DO, and pH. The criteria and narratives provided below are applicable to Cold Water Fisheries (CWF).

Temperature: Maximum temperatures in the receiving water body resulting from heated waste sources regulated under Chapters 92a, 96 and other sources where temperature limits are necessary to protect designated and existing use.

Critical Use Period	°F
January 1-31	38
February 1-29	38
March 1-31	42
April 1-15	48
April 16-30	52
May 1-15	54
May 16-31	58
June 1-15	60
June 16-30	64
July 1-31	66
August 1-15	66
August 16-30	66
September 1-15	64
September 16-30	60
October 1-15	54
October 16-31	50
November 1-15	46
November 16-30	42
December 1-31	40

Table 2. Maximum temperature standards for Pennsylvania streams during several critical use periods. From 25 Pa. Code § 93.7

Dissolved Oxygen: For flowing waters, 7-day average 6.0 mg/L; minimum 5.0 mg/L. For naturally reproducing salmonid early life stages, 7-day average 9.0 mg/L; minimum 8.0 mg/L. Early life stage criteria applies from October 1 to May 31.

pH: From 6.0 to 9.0 inclusive.

In general, most of the sites stayed within PADEP compliance for applicable criteria. Starting with the temperature for CWF it is interesting to note that the standard has dual purposes, sustaining trout populations as well as protecting the temperature regime from heated discharges. The criteria are divided into discrete critical use periods throughout the year recognizing the expected seasonal changes in temperature.

As in 2022, the ST4 station exceeded the maximum temperature criteria for CWF during all events, with the September event showing an exceedance of approximately 18°F. As noted earlier, differing conditions in this reach, such as higher temperatures, are likely in part due to the upstream impoundment and the more developed nature of the tributary's watershed. AW2 was also outside of the compliance of CWF temperatures for all sampling events in 2023. This is most likely due to slowed flows due to congestion of the downstream portion of the sampling area and a more heavily developed watershed. The only other site that exceeded temperature criteria was AW1 during the September event. However, this was by less than 1°F and for only one event showing that there is still a cold water influence from the park to this area of the stream. None of the other sites that were located in the park exceeded CWF temperature criteria which is an example of groundwater influence from the spring located in the park. Temperature in the mainstem is clearly controlled by the spring and does not represent a departure from natural conditions nor thermal impairment. The spring is certainly one of the most outstanding such examples in southeastern Pennsylvania. As such, it is likely that should the need arise, site-specific criteria could be developed.

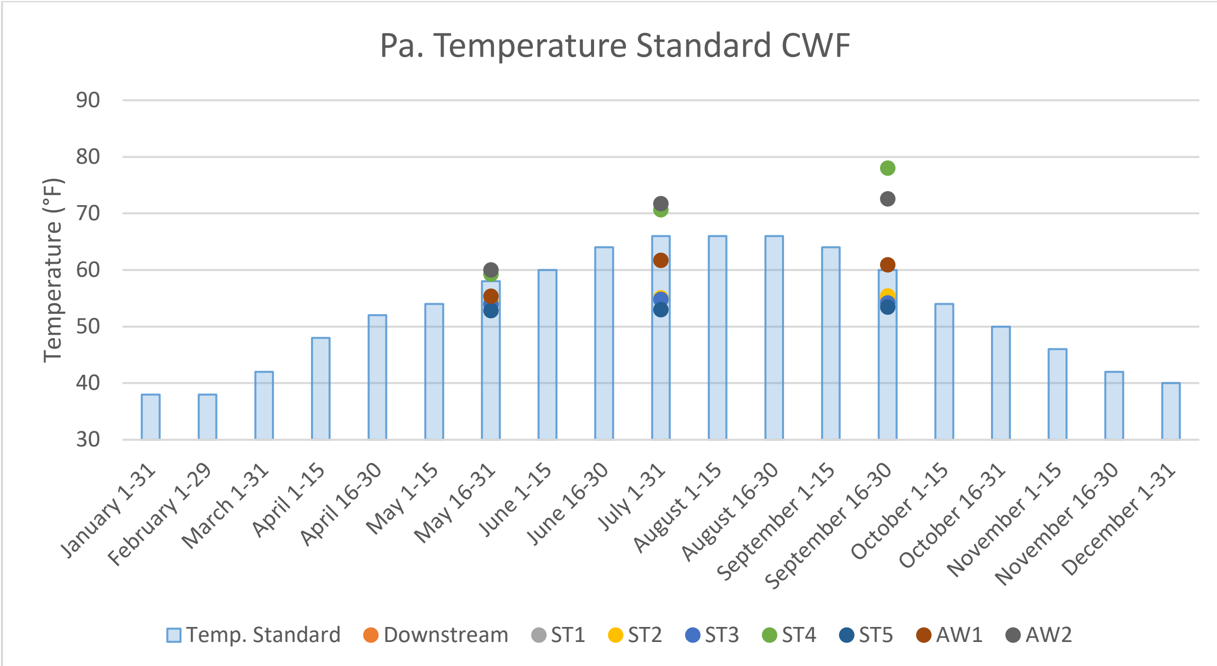


Figure 2: 2023 Water temperature data collected in Aquetong Creek compared to the Pennsylvania water temperature standard for CWF.

The DO criteria specify average and minimum values, with the objective of maintaining higher concentrations. Because young-of-year trout have been discovered onsite in past years, the criteria for early life stage (ELS) salmonids were explored in addition to the CWF criteria (Figure 3). In May all of the sites satisfied all criteria even for ELS trout which need more oxygen than larger fish. Consistently cool stream temperatures and energetic flow help maintain high DO concentrations throughout the year. Throughout the season, all stations remained above the threshold for a CWF which is likely due to high flow velocity. These flow patterns allow ripples to add oxygen to the stream throughout the sampled stretch. The only stations that fell below the ELS minimum requirements throughout the year were AW2 in July and both AW2 and ST4 in September. This is most likely due to the positioning of these locations and the stream topography in those areas.

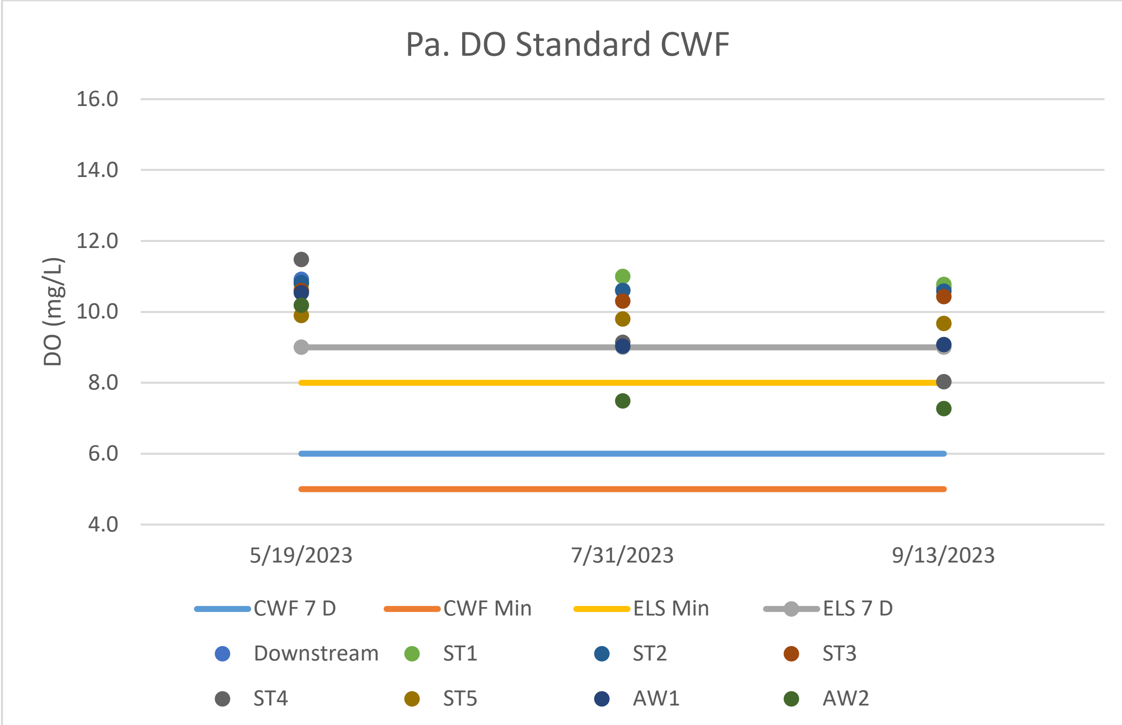


Figure 3: 2023 Dissolved oxygen data collected in Aquetong Creek compared to the Pennsylvania dissolved oxygen standards for CWF and ELS.

Lastly, pH was satisfied at all times at all stations and stayed with the limits of 6.0 to 9.0.

Overall, the mainstem stations were consistent with criteria for CWF, showing the high quality of the system.

DISCRETE WATER QUALITY DATA COLLECTION

Nutrients such as nitrogen and phosphorus influence growth of primary producers such as plants and algae, including periphyton and often indicate other organic pollutants. Total suspended solids are a measurement of sediment or other particulates. Phosphorus, an important nutrient for plant and algae life, was typically measured in relatively low amounts in the mainstem stations within the park, although some higher concentrations were measured occasionally (Table 3).

AW2 had the highest recorded phosphorus throughout the 2023 season with concentrations of 0.04 mg/L and 0.05 mg/L in May and July. Phosphorus declined to a more expected level in September concentrations 0.03 mg/L, while all of the concentrations were relatively low these were higher than what was recorded at the other stations on the stream. In May all stations except AW2 were recorded to have TP levels at either 0.01 mg/L or 0.02 mg/L which were well below recommended levels. In July all stations except AW2 averaged to be 0.02 mg/L which mirrored what was seen in 2022. In September the main stem statins all had nondetectable levels of phosphorus, while downstream and ST1 were recorded at 0.02 mg/L. There was a slight increase for ST4 and AW1 and AW2 all concentrations 0.03 mg/L.

As seen in previous years, total nitrogen concentrations in the mainstem of Aquetong Creek were elevated due to the groundwater influence from the spring. These concentrations ranged from 2.4 mg/L at the downstream site in July to 3.4 mg/L at ST5 in May. Such high nitrogen concentrations can be expected in streams such as Aquetong Creek where groundwater dominates flow, as groundwater typically contains higher concentrations of nitrogen than surface waters. As in past years, ST4 typically featured lower concentrations, yielding 0.67 mg/L in May and 0.30 mg/L in July and September. AW1 had average total nitrogen values ranging from 1.70 mg/L in September and 2.00 mg/L in May. AW2 had similar concentrations with values ranging from 0.80 mg/L in September to 1.41 mg/L in May.

Date	Station	TPO_4 mg/L	TSS mg/L	TN mg/L
5/18/2023	Downstream	0.01	ND<2	2.90
	ST1	0.01	ND<2	2.90
	ST2	0.01	ND<2	2.40
	ST3	0.02	ND<2	3.00
	ST4	0.02	ND<2	0.67
	ST5	0.01	ND<2	3.40
	AW1	0.02	ND<2	2.00
	AW2	0.04	5.0	1.41
7/31/2023	Downstream	0.02	5.0	2.40
	ST1	0.02	3.0	2.76
	ST2	0.02	2.0	2.70
	ST3	0.02	ND<2	2.60
	ST4	0.02	ND<2	0.30
	ST5	0.01	ND<2	2.60
	AW1	0.03	ND<2	1.86
	AW2	0.05	9.0	1.03
9/13/2023	Downstream	0.02	7.0	2.60
	ST1	0.02	ND<2	2.60
	ST2	ND<0.02	ND<2	2.60
	ST3	ND<0.02	3.0	2.70
	ST4	0.03	6.0	0.30
	ST5	ND<0.02	6.0	2.88
	AW1	0.03	5.0	1.70
	AW2	0.03	5.0	0.80
"ND" = Not detected at or above minimum detection limit				

Table 3: Aquetong Creek Discrete Water Quality Data 2023

Total suspended solids (TSS) concentrations varied throughout the study period, with generally low amounts measured at most sites for most of the study, but some sites averaging a higher amount of TSS. AW2 yielded the highest 2023 value of 9 mg/L in July, this was the same maximum TSS recorded in 2022. During the May sampling event most of the locations were recorded as undetectable. Only AW2 had a recordable amount of TSS with 5.0 mg/L. In July TSS was recorded at higher levels throughout the stream, but ST3, ST4, ST5, and AW1 were all below detectable values. The downstream station had a higher value of 5.0 mg/L while ST1 and ST2 were recorded as 3.0 mg/L and 2.0 mg/L respectively. During the July event AW2 had the highest recorded value of the year with 9.0 mg/L. During September only ST1 and ST2 had undetectable values, while ST3 was slightly elevated with a value of 3.0 mg/L. ST4 and ST5 were both recorded at 6.0 mg/L while AW1 and AW2 were both recorded at 5.0 mg/L. The downstream location had the highest concentration for that location of the season measured at 7.0 mg/L. Note that results labeled "ND <2.0" denote instances where the parameter was below detection limits. Changes in discrete water quality parameters over time are provided in the Appendix.

FISHERIES SURVEY

The fisheries community sampled in September 2023 was marked by a noticeable increase in brook trout numbers from 2022. In total, 359 fish were sampled between the eight (8) reaches of the stream, with seventeen (17) species being recorded. Stations ST 4 and AW1 had the highest numbers of fish with 155 and 64 fish respectively. Pumpkinseed (*Lepomis gibbosus*) were the most abundant species recorded, with a majority of these fish coming from the ST4 reach where 137 fish were recorded. The second most abundant species that was found was the Longnose dace (*Rhinichthys cataractae*) with 45 fish followed closely by the brook trout (Salvelinus fontinalis) which had 43 fish recorded. ST4 was the station with the most abundance of fish while the downstream only yielded two fish.

Shannon's diversity index, a measure of the general species diversity of a system, was calculated to be 1.32 for ST1-ST5, a slight decrease from 1.56 in 2022. ST2 had the highest diversity index with both brook trout and warm water species being collected. ST2 recorded the second highest number of brook trout with eleven (11) while also having centrarchid (sunfish and black bass) species in the reach. These warm water species may have migrated from upstream impoundments or from smaller ponds in the watershed.

As in past years, it should be noted that a majority of the fish sampled at ST4 were caught in the plunge pool immediately below Rt. 202. In 2023, most of the fish captured were pumpkin seeds with Green Sunfish (Lepomis cyanellus), Bluegill (Lepomis macrochirus), Creek Chubs (Semotilus atromaculatus) and Largemouth bass (Micropterus salmoides) being recorded in lesser numbers. Most of the fish in the pool have most likely migrated from the pond on the other side of Rt. 202. This may also be a point of origin for some sunfish obtained at reaches further downstream, although this cannot be confirmed. It also indicates that this feature is a barrier to upstream migration for all fish in this reach.

Lengths and masses of all brook trout collected are provided in Table 4. In 2023, 43 brook trout were sampled in the reaches within the Aquetong Spring Park, a marked increase from the 12 individuals captured in 2022. This however did not match the highest recorded number of 49 brook trout that was recorded in 2021. There was a healthy mix of trout in all size ranges recorded in this year's study. The average length of trout studied was 160.6 cm with an average weight of 71.9 grams. There were 19 brook trout captured that were classified as being young-of-the-year fish (Less than 150 mm) this is an increase from the 2 fish that were captured in the previous years study. These numbers suggest that greater numbers of young-of-the-year fish were able to remain in the stream over the winter season than in previous years. The two largest fish measured were 320 mm and 331 mm, suggesting that food and habitat are available to support these larger, older individuals. Even though the fish were not aged, the variation of age classes suggests good survival throughout the last few years. The large prevalence of aquatic macroinvertebrates present in the stream (mostly amphipods), a notable forage group for brook trout, also provides some evidence for this. Both hypotheses may be further explored with the aging of sampled fish in future fisheries assessments, usually by estimating ages using scale samples, which allows for live release of sampled fish.

Brook trout were weighed using a small digital scale to obtain mass in grams. A length-to-mass regression is provided in Figure 4. In total, brook trout biomass in sampled areas in September 2023 was measured to be approximately 3,018 grams, or approximately 6.65 lbs. When using the combined area of ST1-5 and the Downstream station, this correlates to approximately 21.5 lbs/acre. Again, this is an increase from the brook trout biomass collected in 2022. This fulfills conditions listed by the PFBC for Class B wild brook trout streams (total wild brook trout biomass of over 17.8 lbs./acre).

Figures displaying changes in brook trout densities and fisheries diversities over the course of past fisheries surveys are provided in the Appendix.

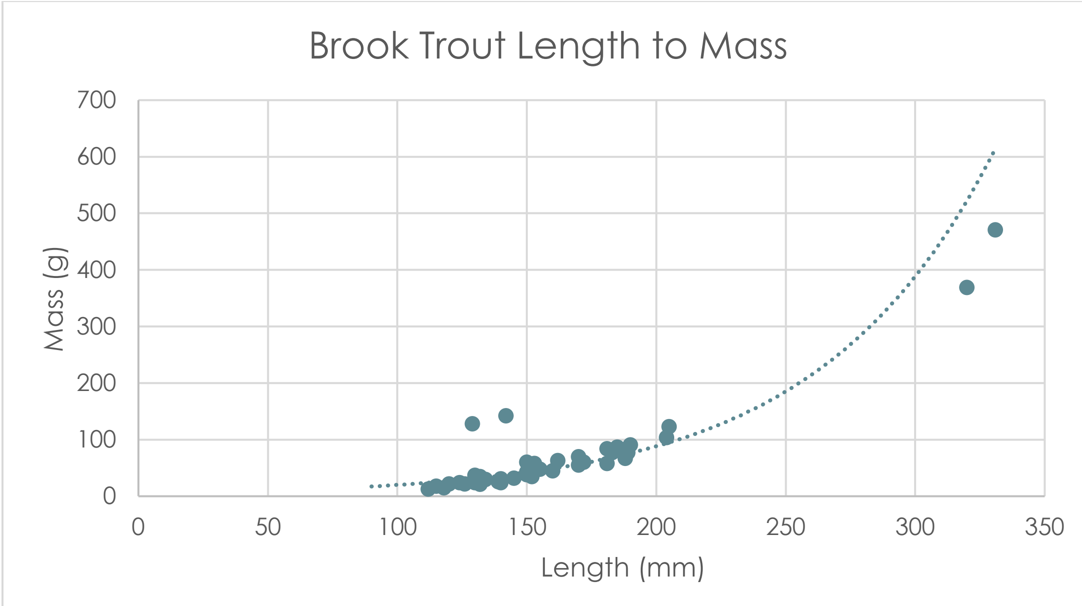


Figure 4: Length-to-mass regression for Brook Trout 2023

Reach	length (mm)	mass (g)
ST1	187	82
ST1	155	48
ST1	142	142
ST1	131	26
ST2	170	70
ST2	331	471
ST2	129	128
ST2	188	83
ST2	188	67
ST2	152	35
ST2	134	30
ST2	160	45
ST2	150	43
ST2	183	77
ST2	172	60
ST3	320	369
ST3	150	38
ST3	185	87
ST3	204	104
ST3	130	24
ST3	181	84
ST3	145	32
ST3	132	35
ST3	132	21
ST3	130	37
ST3	90	
ST3	126	22
ST3	139	26
ST3	124	24
ST3	205	123
ST3	153	58
ST3	120	22
ST3	189	77
ST3	140	31
ST3	150	60
ST3	170	55
ST3	112	13
ST3	162	63
ST5	190	91
ST5	115	18
ST5	140	24
ST5	181	58
ST5	118	15

Table 4: Weights and masses of brook trout sampled in 2023

Common Name	Downstream	ST1	ST2	ST3	ST4	ST5	AW1	AW2	Total	Relative Abundance (fish/acre)
American Eel	1		7	2			1	2	13	52.0
Banded Killifish								7	7	28.0
Black Crappie								1	1	4.0
Blacknose Dace							6		6	24.0
Bluegill			5		7		1	3	16	64.0
Brook Trout		4	11	23		5			43	171.9
Comely Shiner							1	1	2	8.0
Creek Chub			3		4		1		8	32.0
Fall Fish								3	3	12.0
Green Sunfish			1		6			1	8	32.0
Largemouth Bass			1		1			1	3	12.0
Longnose Dace	1		2				40	2	45	179.9
Margined Madtom								1	1	4.0
Pumpkinseed			10		137					587.7
Redbreast Sunfish								21	21	84.0
Tesselated Darter							14	4	18	72.0
White Sucker			11					6	17	68.0
Total abundance	2	4	51	25	155	5	64	53	359	1435.3
Richness (# Taxa)	2	1	9	2	5	1	7	13	17	
CPUE (fish/pass)	1.00	1.33	17.00	8.33	77.50	1.67	21.33	17.67	119.67	
Shannon's Diversity	0.69	0.00	2.17	0.28	0.43	0.00	1.11	2.02	2.06	
Evenness	1.00	-	1.12	0.40	0.27	-	0.57	0.79	0.73	

Table 5: Aquetong Creek Fishery Data 2023

BENTHIC MACROINVERTEBRATE SURVEY

Historically, the mainstem reaches of the Aquetong Creek have featured a large number of amphipods ("scuds" or "side-swimmers"; order Amphipoda, family Gammaridae), and this trend continued in 2023. This family made up at least half of the subsamples picked from many of the mainstem stations. Scuds tend to be common in and often dominate limestone stream systems. Likely as a product of different microhabitat types present in ST4, this reach's subsample was dominated by non-biting midge larvae (order Diptera, family Chironomidae) and velvet water bugs (order Hemiptera, family Hebridae). Chironomidae is a common and extremely diverse family that was also found in smaller numbers throughout almost all of the other reaches. Chironomids are able to withstand lesser water quality conditions than other families which is why they are found in such a wide range of stretches of the stream. It should be noted that this family contains many genera, and some genera are more tolerant of reduced conditions than others. Station AW1 was dominated by the net-spinning caddisflies (order Tricoptera, family Hydropsychidae), while AW2 both was dominated by the diminutive riffle beetle (order Coleoptera, family Elmidae). Both of these taxa are somewhat less tolerant of poor water quality conditions. A larger number of this taxa in a sample may indicate less-impacted water quality conditions.

Station	Density per ft²	Taxa Richness	Dominant Taxa	Shannon's Diversity	Evenness	% EPT Taxa	Family Biotic Index
Downstream	333.6	13	Amphipoda, Gammeridae (Scuds)	1.70	0.66	7.55	4.50
ST1	249.6	11	Amphipoda, Gammeridae (Scuds)	1.28	0.53	8.65	4.13
ST2	367.2	13	Amphipoda, Gammeridae (Scuds)	1.60	0.64	10.46	4.83
ST3	650.4	17	Amphipoda, Gammeridae (Scuds)	1.14	0.41	8.30	4.18
ST4	55.2	12	Diptera, Chironomidae (Non-biting Midges) and Hemiptera, Hebridae (Velvet Water Bugs)	2.24	0.90	0.00	4.50
ST5	195.6	8	Amphipoda, Gammeridae (Scuds)	1.04	0.50	22.09	3.90
AW1	344.4	18	Tricoptera, Hydropsychidae (Net-Spinning Caddisflies)	2.34	0.81	53.66	4.29
AW2	499.2	17	Coleoptera, Elmidae (Riffle Beetles)	1.93	0.70	20.67	4.08

Table 6: Benthic Macroinvertebrate Data 2023

Table 6 and Figures 5-7 display metrics pertaining to the benthic macroinvertebrates collected at each site. Note that these are calculated from the subsample collected for each sample. Using Hilsonhoff's family-level biotic index, sites that were sampled during this survey all measured in the "good" or "very good" categories (3.90-4.83). The mainstream sites ranged from a value of 3.90 at ST5 while the higher end of the range was 4.83 at ST2. Station AW1 had a family tolerance value of 4.29 and AW2 was recorded at 4.08 both being in the "good" category. Shannon's diversity index was also calculated from these sampling events, with station AW1 yielding the highest value of 2.34, suggesting the highest level of diversity among the sites. Station ST5 featured the lowest diversity index at 2.34. Overall, the values in the mainstream of the stream showed relatively high diversity in the macroinvertebrate community. Percentages of EPT taxa (Ephemeroptera - mayflies, Plecoptera - stoneflies, and Tricoptera - caddisflies), a group of relatively sensitive taxa, were also calculated in order to assess ecological function of the stream and its ability to provide habitat to these sensitive taxa. An increase in % EPT taxa over time may suggest an overall increase in ecological function and habitat quality. AW1 had the highest percentage of EPT species at 53% due to the high numbers of mayflies and caddisflies observed in the subsample. Station ST4 featured the lowest percentage of EPT taxa, with no organisms in these orders being detected in the sample. This may reflect the habitat quality of the area sampled, which largely features warmer water temperatures and increased amounts of sediment. Most of the mainstem stations fell between 7.5% and 22%, suggesting moderate habitat quality and ecological function. It should be noted that this metric may have been driven downwards in many of the mainstem locations due to the high abundance of scuds, which typically represented a large percentage of the total organisms collected in these samples.

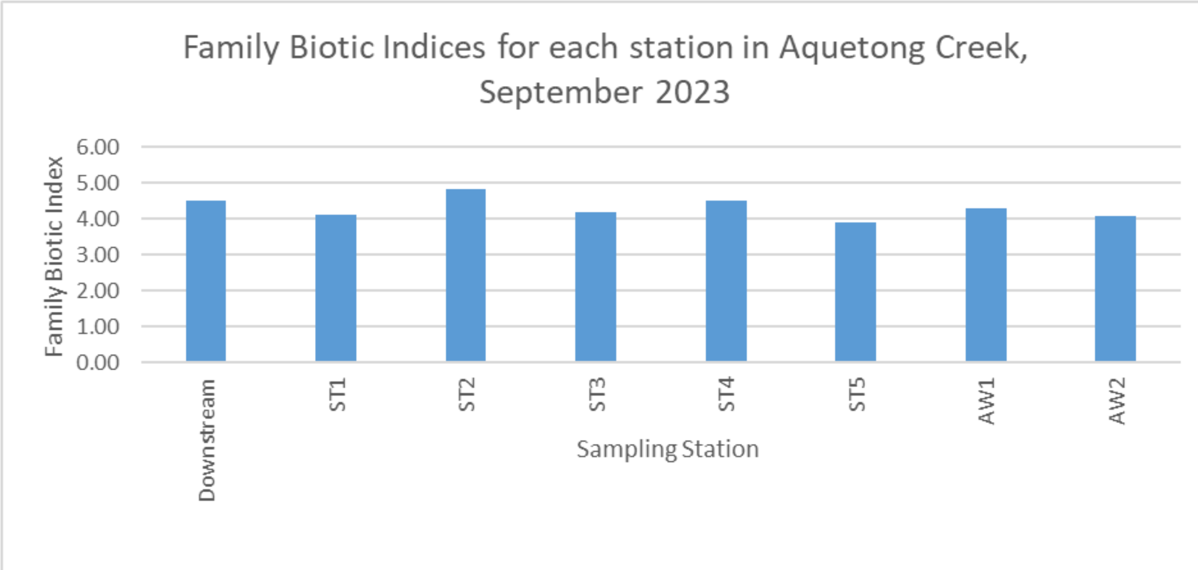


Figure 5: Hilsenhoff's Family Biotic Indices for 8 stations in the Aquetong Creek watershed

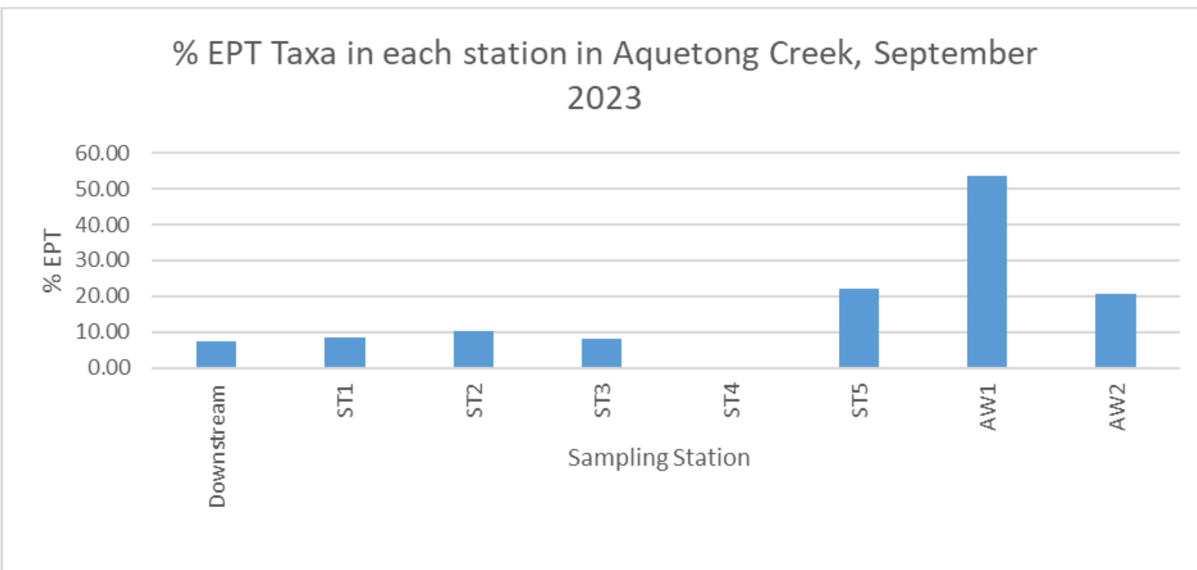


Figure 6: Percentage of samples comprising individuals from the orders Ephemeroptera, Plecoptera, and Trichoptera

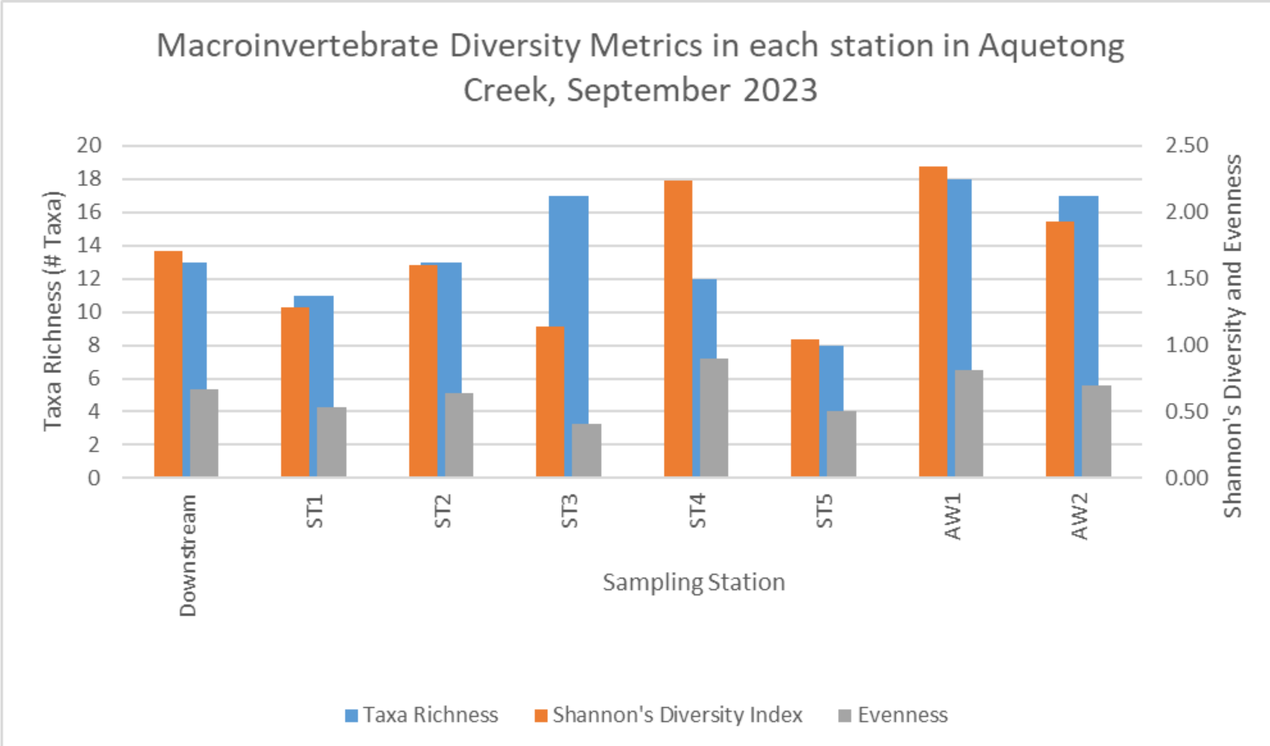


Figure 7: Aquatic Macroinvertebrate diversity metrics for 8 stations in the Aquetong Creek watershed

RECOMMENDATIONS

Based on the observations and measurements made during the 2023 monitoring of the Aquetong Creek, Princeton Hydro proposes the following recommendations:

BROOK TROUT HABITAT SUITABILITY INDEX

One of the goals for the Aquetong Creek Park is the establishment of a viable population of naturally reproducing brook trout. In order to facilitate this, Princeton Hydro recommends a full habitat assessment of the stream in accordance with the parameters used in the brook trout habitat suitability index (HSI, Raleigh, 1982). This index features a collection of several habitat metrics and their optimal ranges for different brook trout life stages (e.g. breeding habitat, habitat for larvae and fry, etc.). Many of these metrics within the Aquetong Creek can be obtained while conducting the usual annual stream monitoring, although some of them require taking measurements during certain times of year (e.g. assessing minimum winter temperatures, as this influences larvae survival). By collecting such data on the Aquetong Creek, the exact elements in which the stream needs improvement as they relate to brook trout habitat can be further ascertained. It should be noted, however, that a favorable HSI index for a stream does not necessarily guarantee a high brook trout biomass. This would need to be accompanied with fish surveys such as those that have been conducted in the present study to assess the continued impacts of restoration efforts on the standing stock of brook trout in the stream. Princeton Hydro recommends this assessment occur in 2024 to 2025.

REMOVAL OF BARRIERS TO FISH PASSAGE

As discussed above, an area immediately downstream of station ST5 was observed in the study area with a rapid change in grade that may be impassable to upstream movement by some fish. Princeton Hydro strongly recommends that this location be addressed, as barriers to fish movement may prevent fish from returning to areas upstream after downstream movement, reducing the populations upstream. This will be particularly important in maintaining brook trout populations. The same has been noted in the riverine surveys (provided under separate cover) with regard to PADEP stream restoration permit reporting requirements.

AGE ASSESSMENT OF BROOK TROUT

As noted above, there is a degree of uncertainty as to the age and growth rate of some of the smaller and mid-sized brook trout collected in the Aquetong Creek, although the variation in lengths and masses strongly suggests the presence of more than one age class. This can be assessed by collecting scales from each brook trout sampled and assessing them under magnification. While other methods of aging fish also exist, many of them (such as the assessment of otoliths) require that fish be euthanized. Collection of scales, however, is a relatively simple process that causes minimal stress to the fish being assessed and allows for assessed fish to be released. Age data can be paired with length data to produce age-length regressions similar to the length-weight regression performed in 2021-2023. If desired, Princeton Hydro can perform scale assessments on brook trout during future fisheries assessments under a new task.

CONTINUED GENERAL MONITORING IN 2024

Princeton Hydro recommends the continued monitoring of the Aquetong Creek in order to assess the effectiveness of continued restoration efforts and the status of the stream's brook trout population. A monitoring event for 2024 should largely follow the same methodology used in 2020-2023. This involves the continued sampling of fish and macroinvertebrates at least once a year in either the Spring or Fall seasons, to assess how changes to the stream and habitat affect these populations and, in particular, if brook trout populations are reproducing.

REFERENCES

Climate Information for Management and Operational Decisions (CLIMOD2) system. National Weather Service Cooperative Weather Station DOYLESTOWN AIRPORT (54786 WBAN). October 2022. Northeast Regional Climate Center, Cornell University. http://climod2.nrcc.cornell.edu/.

F.X. Browne, Inc. 2004. Ingham Spring Dam Removal Study.

Hartman, K.J., and J.P. Hakala. 2006. Relationships between Fine Sediment and Brook Trout Recruitment in Forested Headwater Streams. Journal of Freshwater Ecology, 21:2, pp. 215-230.

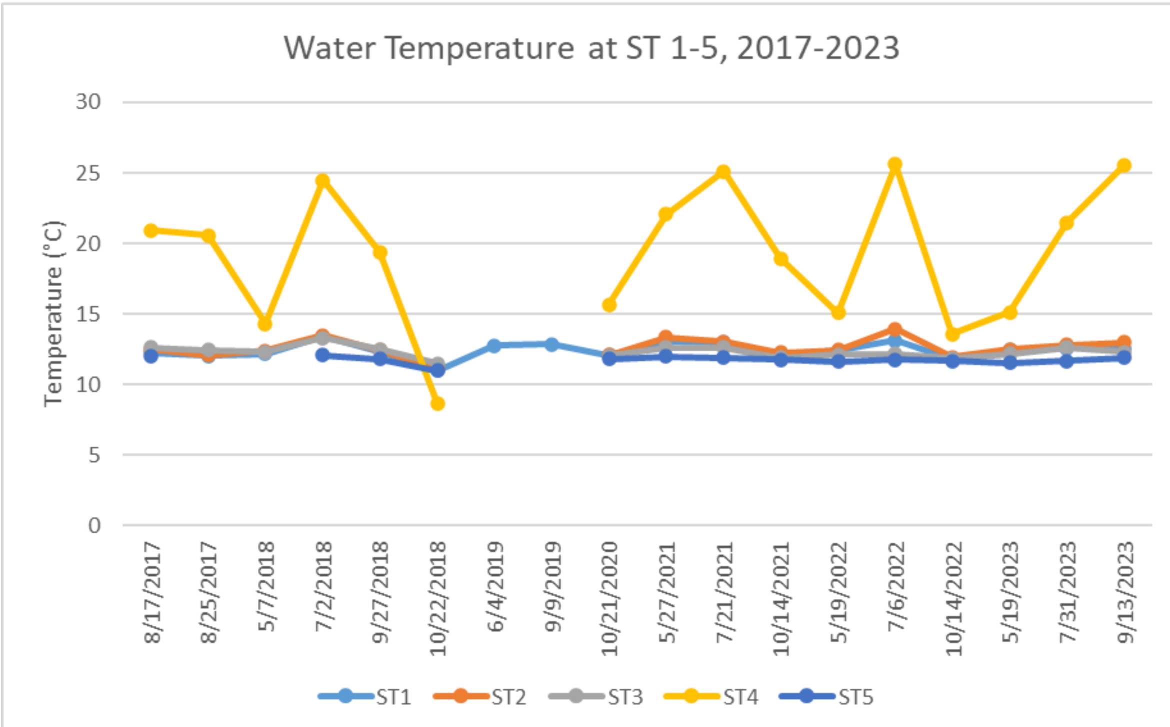
Hilsenhoff, W.L. 1988. Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index. Journal of the North American Benthological Society, 7:1 pp. 65-68.

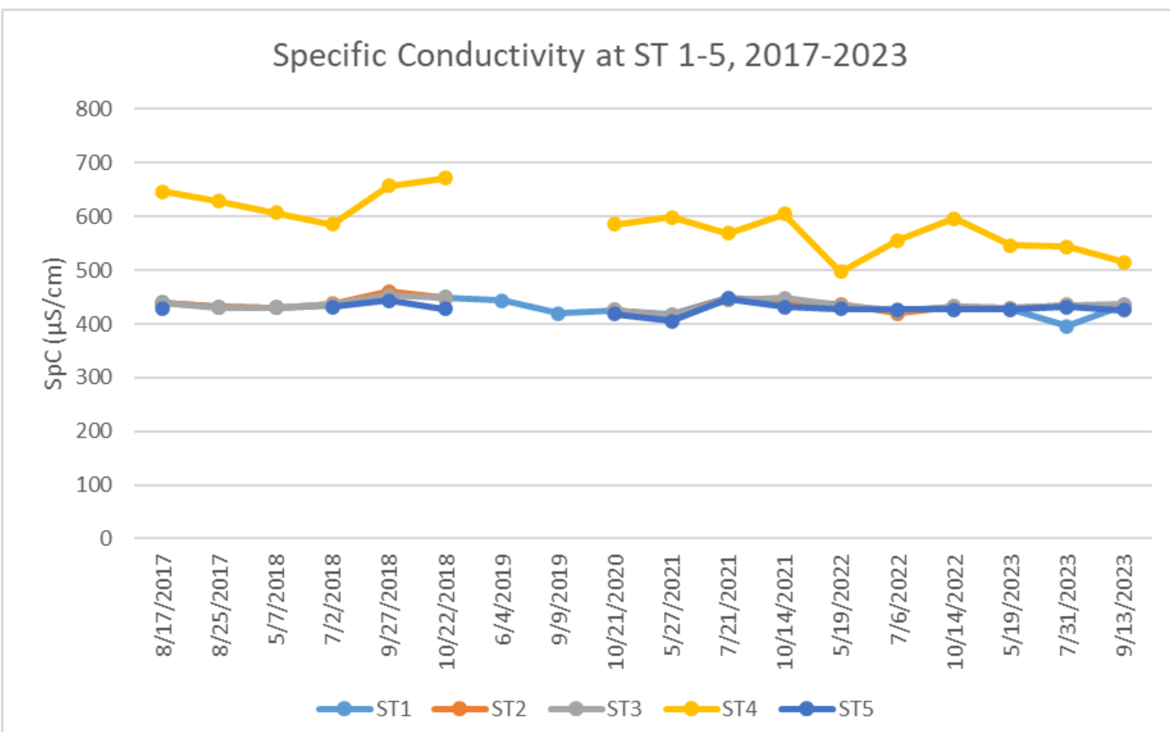
Myrick, C., and M. Kondratieff. 2004. An evaluation of a potential barrier to the upstream movement of brook trout in Rocky Mountain national Park, Colorado. United States Department of the Interior, National Park Service, Water Resources Division. Technical Report NPS/NRWRD/NRTR-2005/337.

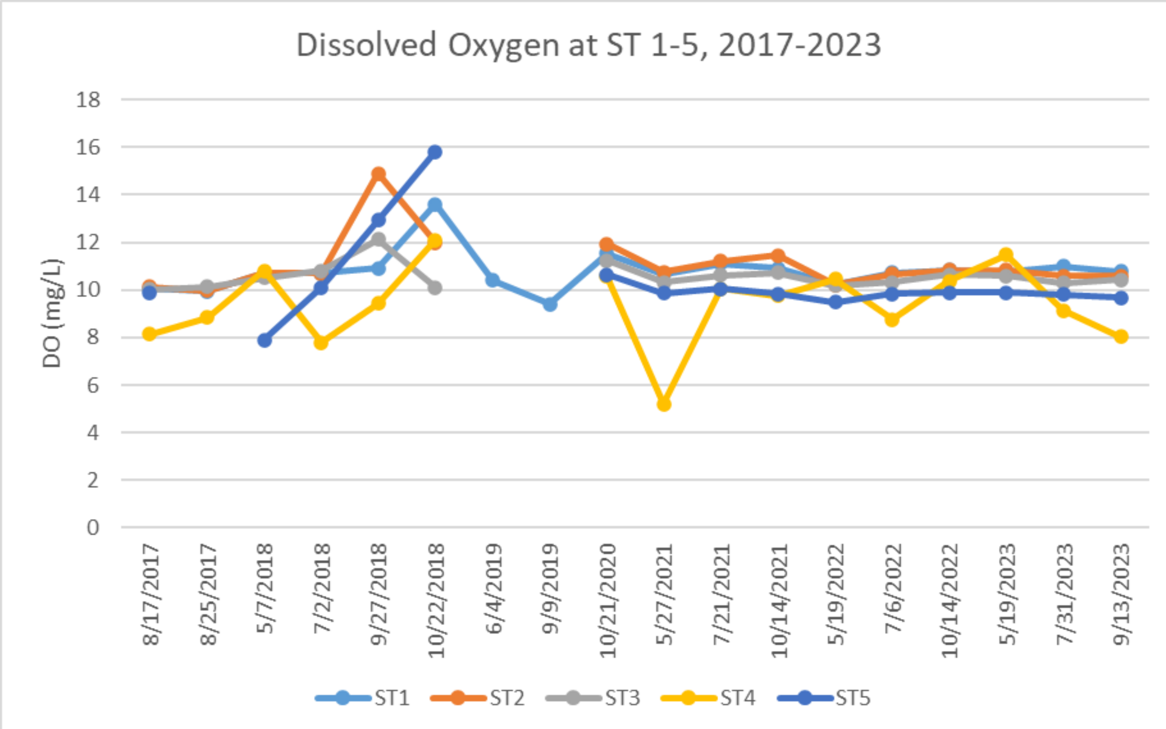
Pennsylvania Fish & Boat Commission. 2022. Operational Guidelines for the Management of Trout Fisheries in Pennsylvania Waters. Bureau of Fisheries, Division of Fisheries Management. 5th Edition.

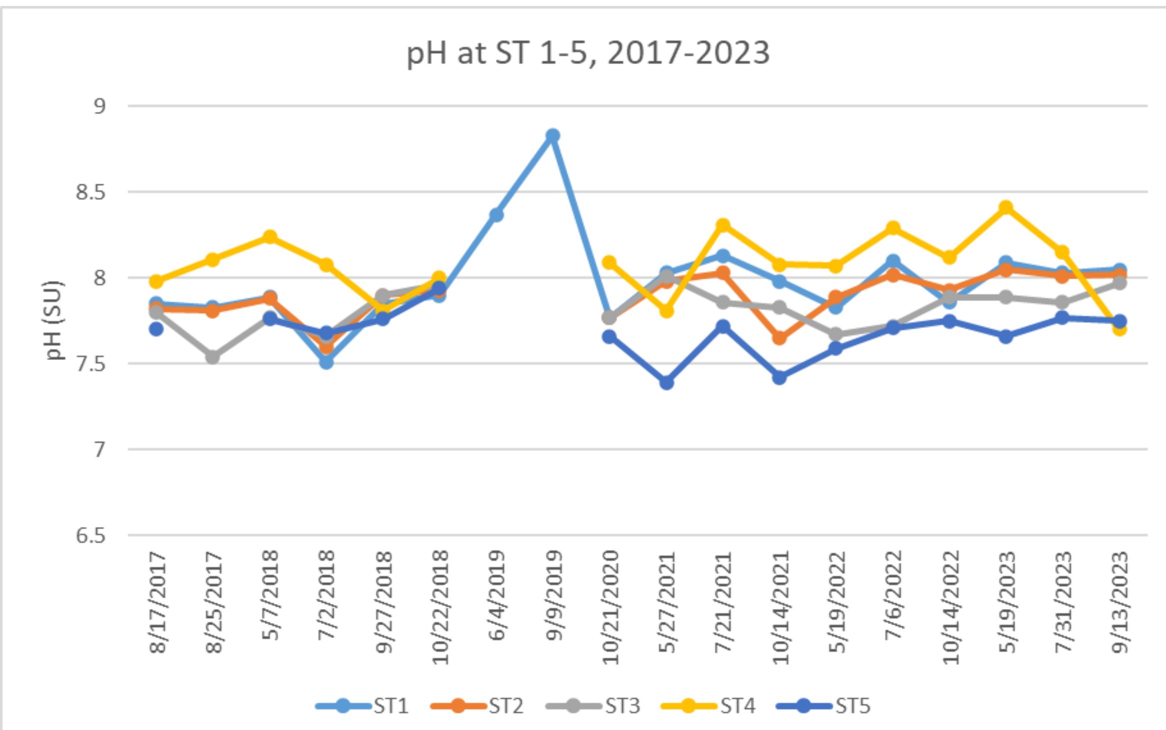
Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.24. 42 pp.

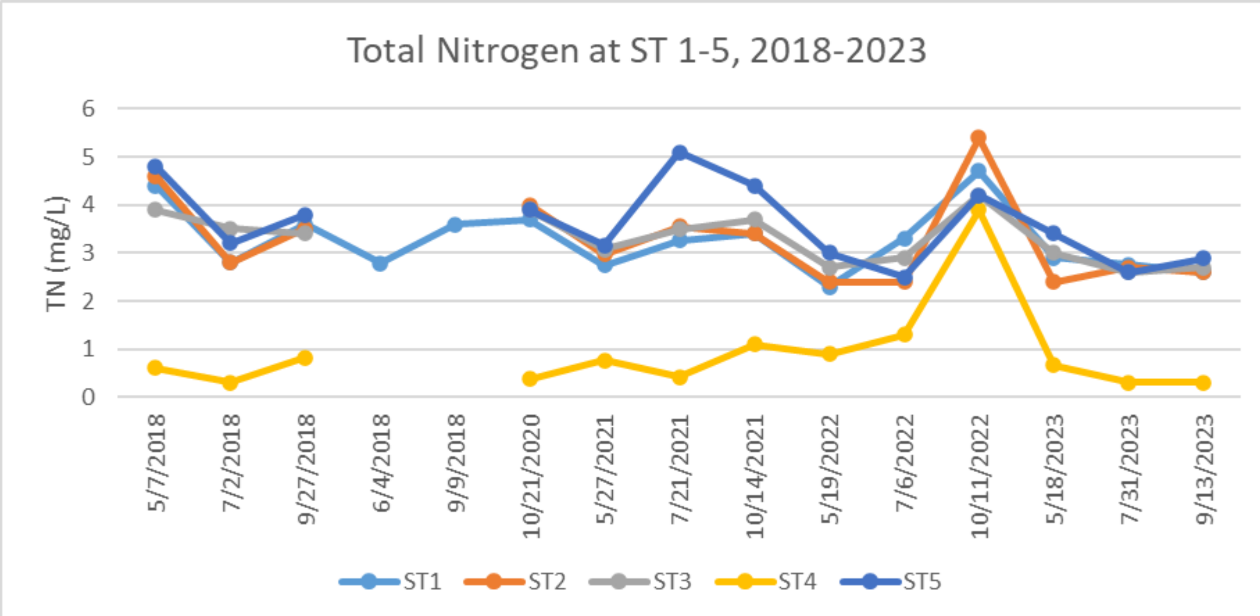
APPENDIX
HISTORIC WATER QUALITY AND FISHERIES TRENDS IN STATIONS ST1-5

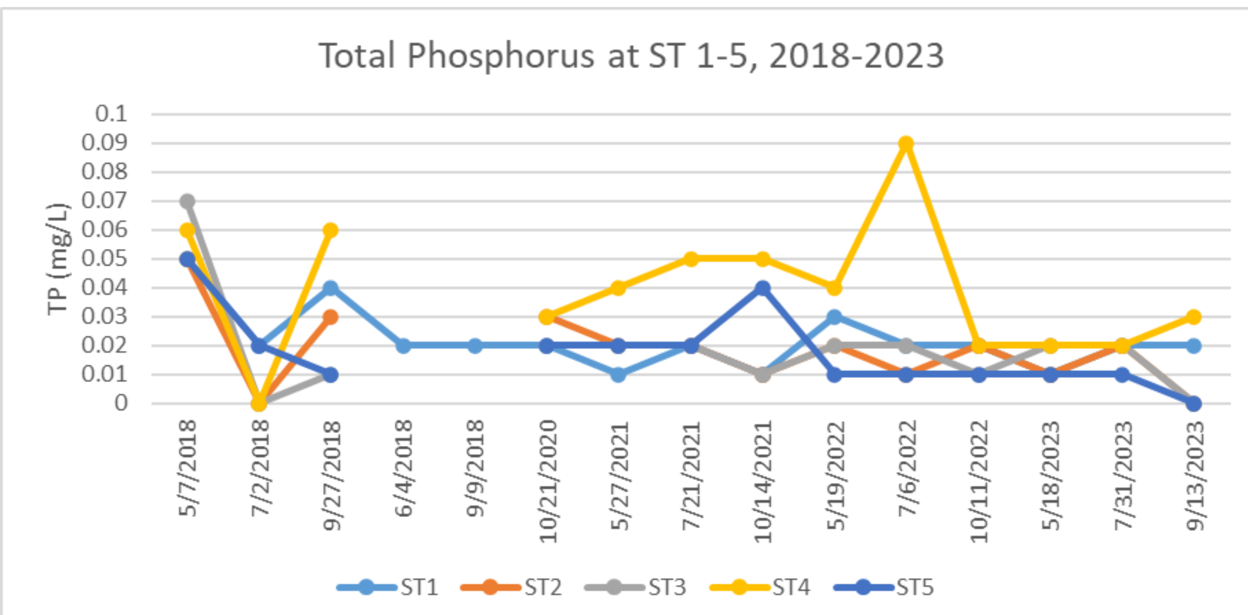

Water Temperature at ST 1-5, 2017-2023
Temperature (°C)
30
25
20
15
10
5
0
8/17/2017
8/25/2017
5/7/2018
7/2/2018
9/27/2018
10/22/2018
6/4/2019
9/9/2019
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/14/2022
5/19/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5

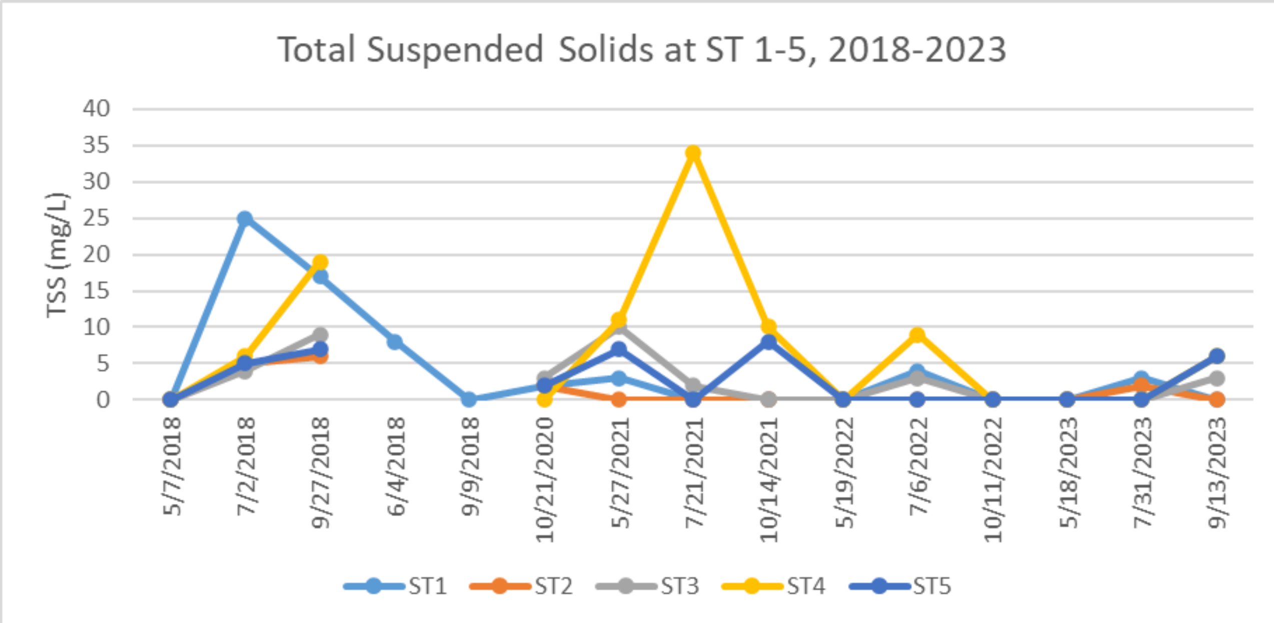

Specific Conductivity at ST 1-5, 2017-2023
SpC (µS/cm)
800
700
600
500
400
300
200
100
0
8/17/2017
8/25/2017
5/7/2018
7/2/2018
9/27/2018
10/22/2018
6/4/2019
9/9/2019
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/14/2022
5/19/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5

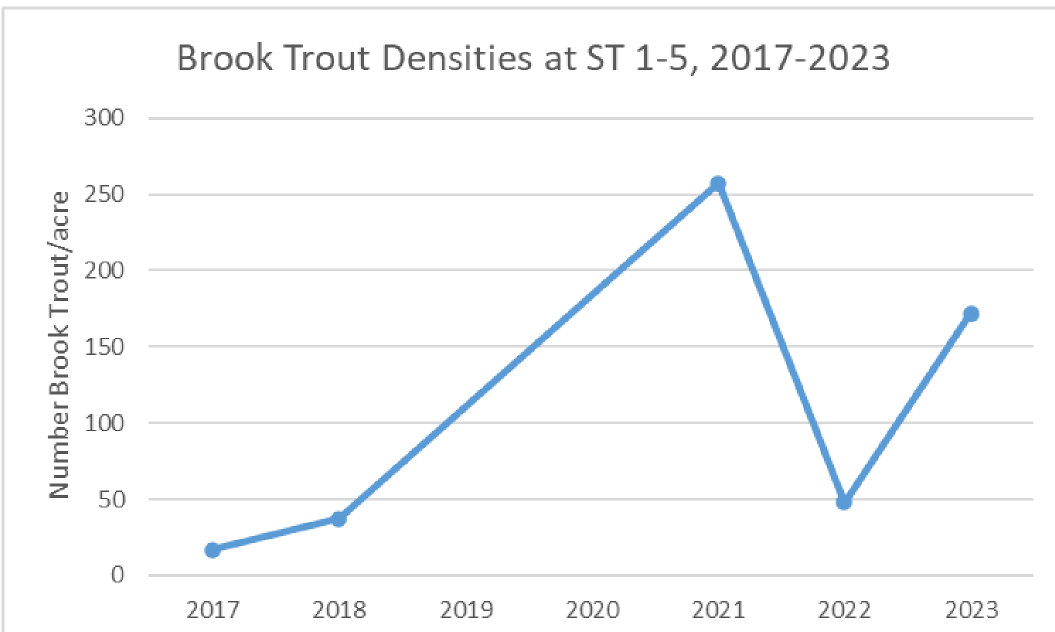

Dissolved Oxygen at ST 1-5, 2017-2023
DO (mg/L)
18
16
14
12
10
8
6
4
2
0
8/17/2017
8/25/2017
5/7/2018
7/2/2018
9/27/2018
10/22/2018
6/4/2019
9/9/2019
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/14/2022
5/19/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5

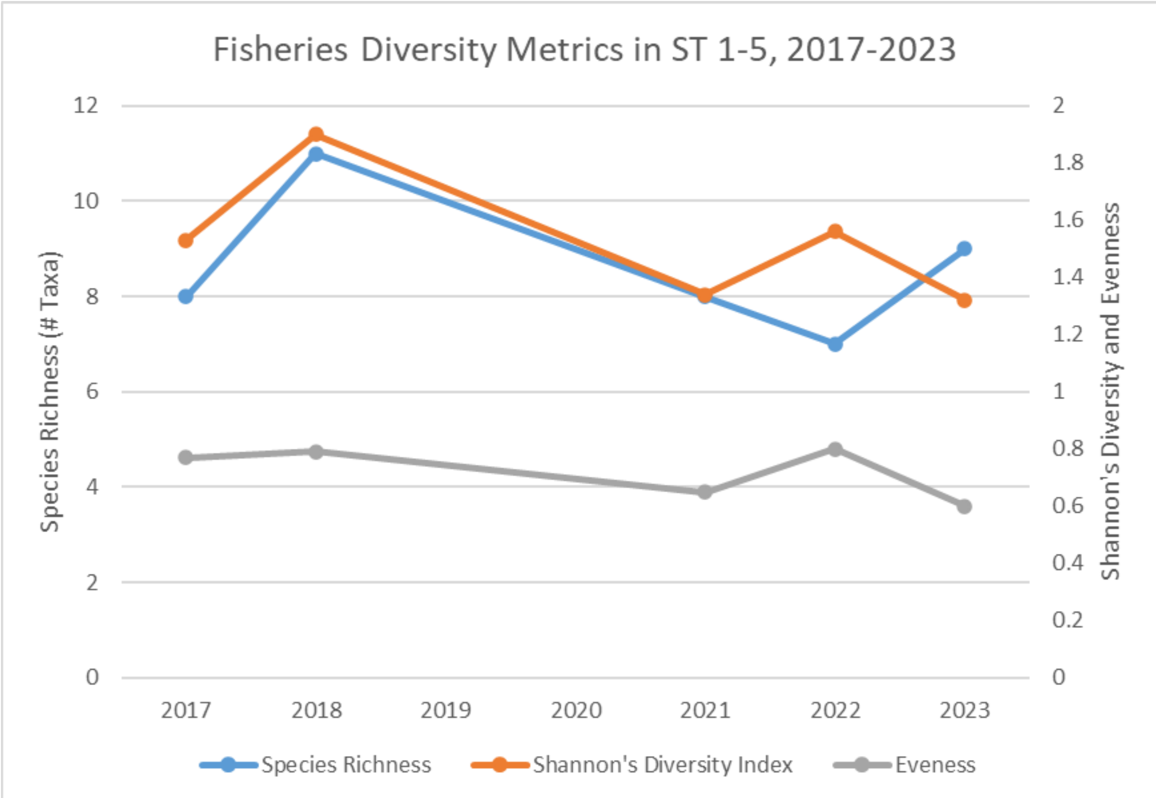

pH at ST 1-5, 2017-2023
pH (SU)
9
8.5
8
7.5
7
6.5
8/17/2017
8/25/2017
5/7/2018
7/2/2018
9/27/2018
10/22/2018
6/4/2019
9/9/2019
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/14/2022
5/19/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5


Total Nitrogen at ST 1-5, 2018-2023
TN (mg/L)
6
5
4
3
2
1
0
5/7/2018
7/2/2018
9/27/2018
6/4/2018
9/9/2018
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/11/2022
5/18/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5


Total Phosphorus at ST 1-5, 2018-2023
TP (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/7/2018
7/2/2018
9/27/2018
6/4/2018
9/9/2018
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/11/2022
5/18/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5


Total Suspended Solids at ST 1-5, 2018-2023
TSS (mg/L)
40
35
30
25
20
15
10
5
0
5/7/2018
7/2/2018
9/27/2018
6/4/2018
9/9/2018
10/21/2020
5/27/2021
7/21/2021
10/14/2021
5/19/2022
7/6/2022
10/11/2022
5/18/2023
7/31/2023
9/13/2023
ST1
ST2
ST3
ST4
ST5


Brook Trout Densities at ST 1-5, 2017-2023
Number Brook Trout/acre
300
250
200
150
100
50
0
2017
2018
2019
2020
2021
2022
2023


Fisheries Diversity Metrics in ST 1-5, 2017-2023
Species Richness (# Taxa)
Shannon's Diversity and Evenness
0
2
4
6
8
10
12
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2017
2018
2019
2020
2021
2022
2023
Species Richness
Shannon's Diversity Index
Eveness