# AQUETONG CREEK ECOLOGICALLY-BASED WATER QUALITY MONITORING - 2021

## SOLEBURY TOWNSHIP, BUCKS COUNTY, PA

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# 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 within the northern tributary passing under Route 202. This monitoring concluded that conditions within the former lake bed 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 in order to assess impacts of the removal of several ash trees within the park.

The overall goal of this project in fall 2020 and the growing season of 2021 was to continue to assess current water quality conditions, fish, and benthic invertebrate communities within the project site, particularly as further restoration efforts have been made in the study area. Comparisons were also made between the 2020-2021 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 points within the old lake bed and in areas downstream were sampled for water quality once in October 2020 and three times in 2021 (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 main stem of the Aquetong, while ST4 is located on a small tributary that enters the mainstem from the direction of Rt. 202. 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 October 13th and 14th, 2021.

### *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

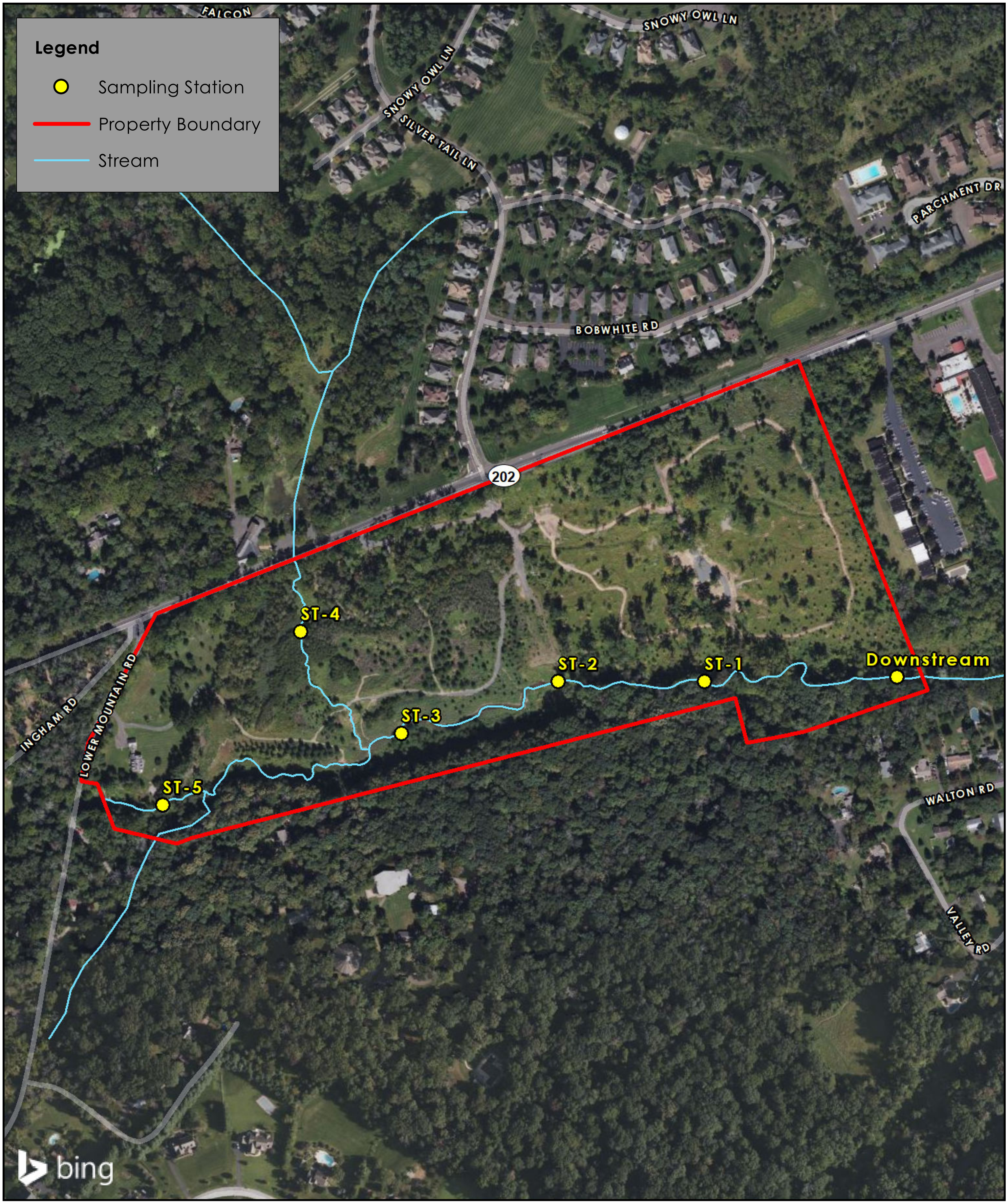
Following each sampling event, samples were delivered to Environmental Compliance Monitoring (ECM), a certified laboratory, for analysis.

### *FISHERIES SURVEY*

A survey of the fish communities at each site were conducted in mid-October, 2021 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. An approximately 200' 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 in order 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 October 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, undercut banks) 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.




File: P:\0388\Projects\038801 1\GIS\MXD\Stream_Sampling_Locations.mxd, 1/17/2022, Drawn by bsmith, Copyright Princeton Hydro, LLC.

NOTES:
1. Stream sampling locations are approximate.
2. Property boundary is approximate.
3. Aerial imagery obtained through ArcGIS Online Bing Maps (C) 2021 Microsoft Corporation and its data suppliers.

0 200 400 Feet

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 improved in regards 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. Compared to previous years, many areas are less incised than previously observed, which should allow for increased floodplain connectivity. 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. Following Hurricane Ida, some changes to the stream in regards to restoration efforts were observed. In particular, the pool adjacent to the dam breach (ST2) that was manipulated so as to create wetland habitat extending from both sides of the stream had become partially blown-out, resulting in a loss of width to this wetland area (the width of the main channel has largely remained relatively consistent). Additionally, a head-cut of approximately 1' in height was created in the channel between this pool and the footbridge downstream. 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). Based on this, this feature is likely not a total barrier to upstream movement for larger brook trout; however, smaller brook trout, as well as some other fish species, may not be able to pass through this feature in an upstream direction. Another potential barrier to fish movement was observed just downstream of ST5, presenting as a head-cut forming a relatively steep "ramp", measuring approximately 2.5-3' of vertical height. 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.

## *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 four events in the mainstem stations. Water in the Aquetong Creek typically exhibits cold temperatures, with the only consistent exception being temperatures recorded in the Rt. 202 tributary (ST4). Along the mainstem, temperatures ranged from approximately 11.8°C to 13.4°C. ST4, however, displayed a larger temperature range, measuring approximately 15.7°C in October 2020 and 25.1°C in July 2021. The higher temperatures are largely attributable to the upstream impoundment, north of Rt. 202, which feeds the tributary. Dissolved oxygen concentrations in the mainstem stations were similarly consistent and well within a preferable range, largely ranging from approximately 91% to 115% saturation. Again, ST4 displayed a larger variation than this, measuring approximately 59.9% saturation during the May event and 122.9% during the July event. The consistent temperatures and dissolved oxygen concentrations within the preferred range throughout the season in the mainstem of the stream are largely products of the stream's origin as groundwater discharged via the spring and high flow velocities, which allow for continuous mixing with atmospheric oxygen. This is consistent with temperature and dissolved oxygen measurements collected in previous surveys.

The mainstem's specific conductivity (SpC) was measured on average to be approximately 424.2 µS/cm in October 2020 before slightly dropping to 414.7 µS/cm in the mainstem stations in late May 2021 when flows were higher. Conductivity increased to 446.3 µs/cm in July 2021 before dropping slightly to 440.8 µg/L in October 2021. These readings are very consistent and track with those obtained in 2018. While these values are slightly elevated, it reflects the limestone geology of the watershed. ST4 featured somewhat higher conductivity readings, averaging approximately 570.0 µg/L over the course of the study. These higher values likely reflect the denser development in that tributary's subwatershed.

As in previous years, pH values obtained from stations along the mainstem of the Aquetong ran somewhat high, averaging approximately 7.79 in October 20210, 7.85 in May 2021, 7.94 in July 2021, and 7.73 in October 2021. These alkaline values are likely due to local geology, with the stream's origin at Ingham Spring reflecting the limestone geology. 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. pH tended to be slightly higher at ST4 particularly later in the year, which again is attributable to high levels of primary production and photosynthesis in the upstream pond.

| Station | Temperature °C | SpC µS/cm | DO mg/L | DO % % | pH s.u. | Flow CFS |
|---|---|---|---|---|---|---|
| **Aquetong Creek *In-Situ* Data 10/21/20** | | | | | | |
| Downstream | 12.09 | 425.0 | 11.84 | 110.3 | 7.98 | 5.07 |
| ST1 | 12.09 | 426.0 | 11.53 | 115.3 | 7.77 | 4.01 |
| ST2 | 12.08 | 426.0 | 11.94 | 111.0 | 7.77 | 4.71 |
| ST3 | 12.04 | 425.0 | 11.23 | 104.4 | 7.77 | 4.45 |
| ST4 | 15.68 | 586.0 | 10.57 | 106.5 | 8.09 | 0.10 |
| ST5 | 11.83 | 419.0 | 10.65 | 98.6 | 7.66 | 4.21 |
| Spring | 11.75 | 419.0 | 9.44 | 85.7 | 7.84 | N/A |
| **Aquetong Creek *In-Situ* Data 5/27/21** | | | | | | |
| Downstream | 12.96 | 417.9 | 10.69 | 101.5 | 7.82 | 6.25 |
| ST1 | 13.07 | 417.3 | 10.67 | 101.6 | 8.03 | 6.20 |
| ST2 | 13.37 | 416.2 | 10.76 | 102.8 | 7.98 | 5.171 |
| ST3 | 12.63 | 416.5 | 10.31 | 97.2 | 8.01 | 6.52 |
| ST4 | 22.08 | 599.1 | 5.21 | 59.9 | 7.81 | 0.10 |
| ST5 | 11.98 | 405.5 | 9.85 | 91.9 | 7.39 | 5.54 |
| Spring | 11.93 | 409.6 | 7.27 | 67.3 | 7.66 | N/A |
| **Aquetong Creek *In-Situ* Data 7/21/21** | | | | | | |
| Downstream | 12.94 | 446.2 | 10.97 | 109.6 | 7.97 | 5.50 |
| ST1 | 12.98 | 448.2 | 11.10 | 105.7 | 8.13 | 5.16 |
| ST2 | 13.04 | 445.4 | 11.20 | 107.0 | 8.03 | 4.667 |
| ST3 | 12.64 | 444.3 | 10.62 | 100.6 | 7.86 | 5.77 |
| ST4 | 25.13 | 568.8 | 10.06 | 122.9 | 8.31 | 0.06 |
| ST5 | 11.91 | 447.3 | 10.04 | 93.3 | 7.72 | 4.68 |
| Spring | 11.66 | 445.0 | 7.87 | 72.7 | 7.45 | N/A |
| **Aquetong Creek *In-Situ* Data 10/14/21** | | | | | | |
| Downstream | 11.91 | 441.8 | 11.02 | 102.1 | 7.78 | 5.14 |
| ST1 | 12.16 | 441.8 | 10.91 | 101.8 | 7.98 | 5.15 |
| ST2 | 12.28 | 440.7 | 11.44 | 107.0 | 7.65 | 5.77 |
| ST3 | 11.93 | 448.5 | 10.71 | 99.3 | 7.83 | 4.93 |
| ST4 | 18.94 | 605.3 | 9.75 | 105.3 | 8.08 | 0.10 |
| ST5 | 11.79 | 431.1 | 9.83 | 90.9 | 7.42 | 5.32 |
| Spring | 11.79 | 438.4 | 7.03 | 65.1 | 7.34 | N/A |

**Table 1: Aquetong Creek *In-Situ* Data 2020-2021**

As noted above, the mainstem of the Aquetong Creek is characterized by relatively swift, consistent flows. Over the course of the study period, the downstream station and ST3 averaged the highest discharges, likely reflecting groundwater gains upstream of these stations as well as the confluence with the tributary, however the departure is low relative to the other mainstem stations. ST4, which features a shallower and narrower channel, as well as a different point of origin from the mainstem, featured significantly less discharge than any of the other sites.

### *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 Fishes (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.

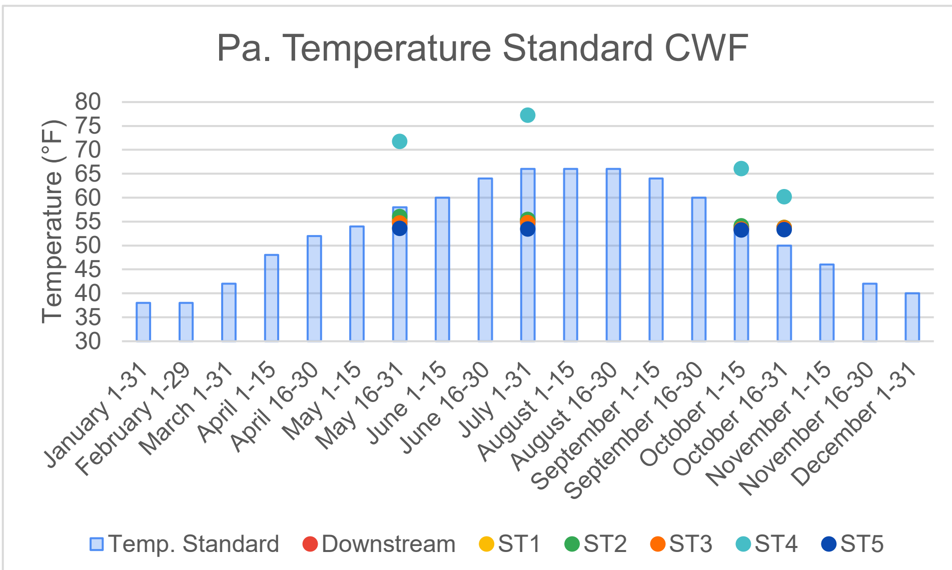
| Critical Use Period | °F |
|---|---|
| January 1-31 | 38 |
| February 1-29 | 38 |
| March 1-31 | 42 |
| April 1-15 | 48 |
| April 16-30 | 52 |
| May 1-15 | 54 |
| May 16-31 | 58 |
| June 1-15 | 60 |
| June 16-30 | 64 |
| July 1-31 | 66 |
| August 1-15 | 66 |
| August 16-30 | 66 |
| September 1-15 | 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**

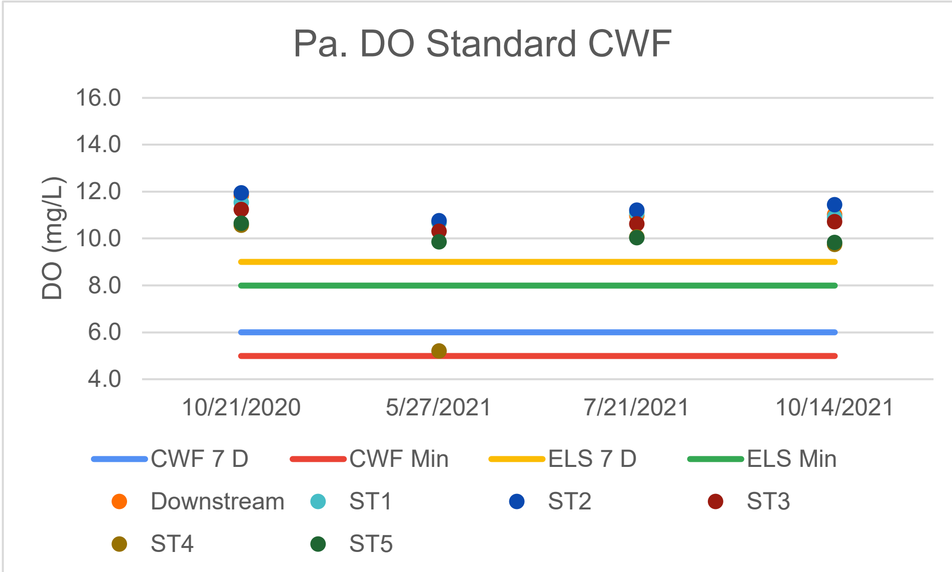
Dissolved Oxygen: For flowing waters, 7-day average 6.0 mg/L; minimum 5.0 mg/L. For naturally reproducing salmonid early life stages, 7-day average 9.0 mg/L; minimum 8.0 mg/L. Early life stage criteria applies from October 1 to May 31.

pH: From 6.0 to 9.0 inclusive.

In general, the site shows compliance with the applicable criteria. Starting with the temperature criteria 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. First, the northern tributary, ST4, never met the criteria. In fact, through the four critical use periods that were sampled, the temperature exceedance ranged from approximately 10.0 to 14.0°F. As indicated before, the high temperatures in this tributary reflect the upstream impoundment and other thermal impacts related to development of that subwatershed. The mainstem stations fared much better. During the late May, July, and early October critical use periods, all five of those stations were below the maximum criteria (Figure 2). In fact, during July, perhaps the most thermally stressful period, on average the five stations were 11.1°F lower than the criterion. During the late October critical use period all five mainstem stations were above the temperature criterion. While this is above the standard, the temperature remains well below any thermal stressor to salmonids, and the dominance of brook trout in the fishery as well as documented recruitment indicate superior suitability for trout. 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.




The DO criteria specify average and minimum values, with the objective of maintaining higher concentrations. Because young-of-year trout were discovered onsite, the criteria for early life stage (ELS) salmonids were explored in addition to the CWF criteria (Figure 3). All five of the mainstem stations satisfied all applicable criteria, even for ELS (although this is only properly applied from October through May). As described above, consistently cool temperatures and energetic streamflow help maintain high DO concentrations throughout the year. ST4 was again the only outlier. During three of the events, it satisfied the standards, but fell below and contravened three of the criteria, with the exception of CWF minimum, in late May. DO is not steady at this station, and shows a pattern typically associated with eutrophic waterbodies, which again points to its origin in the upstream impoundment. In the early spring DO was fairly low, reflecting oxygen depression in the pond as well as relatively high temperatures. While the standards are based on seven-day averages, there is no reason to expect given the steady flows and stable thermal regime of the mainstem that DO varies significantly in the short-term with the possible exception of storm events.




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, although some higher concentrations were measured occasionally (Table 2). In October of 2020, the downstream station yielded an elevated concentration of 0.06 mg/L and while higher than typically measured is still low. During 2021, the mainstem of the stream usually maintained concentrations of between 0.01 and 0.04 mg/L, while ST4 consistently yielded slightly higher concentrations of 0.04-0.05 mg/L, although October of 2020 saw a lower concentration of 0.03 mg/L at this site. These were somewhat consistent with values measured in 2018.

As in previous years, total nitrogen concentrations along the mainstem of the Aquetong Creek were generally somewhat high, ranging from 2.7 mg/L at the downstream site in May 2021 to approximately 5.1 mg/L at ST5 during July 2021. Such high nitrogen concentrations can be expected in streams such as the Aquetong Creek where groundwater dominates flow, as groundwater typically contains higher concentrations of nitrogen than surface waters. ST4 typically featured much lower concentrations, ranging from 0.37 mg/L in October 2020 to 1.1 mg/L in October 2021; again, this may reflect uptake of nitrogen in the upstream impoundment. Total suspended solids (TSS) varied widely throughout the study period, with generally low amounts measured at most sites for most of the study, but higher spikes being measured during some individual events. ST4 in particular yielded higher concentrations (10 – 34 mg/L) during the 2021 season but were below the detectable concentration of 2 mg/L in October 2021. Station ST3 also yielded a higher concentration of 10 mg/L in May of 2021, probably reflecting at least in part the elevated loads from the northern tributary, before dropping to 2 mg/L and less in subsequent events. The study conducted in 2018 similarly usually featured relatively low values with occasional large spikes in TSS. Discrete water quality data for the full study is provided in Table 3. Note that results labeled "ND <2.0" denote instances where the parameter was below detection limits.

| Date | Station | $TPO_4$ mg/L | TSS mg/L | TN mg/L |
|---|---|---|---|---|
| 10/21/2020 | Downstream | 0.06 | 6.0 | 3.80 |
| | ST1 | 0.02 | 2.0 | 3.70 |
| | ST2 | 0.03 | 2.0 | 4.00 |
| | ST3 | 0.02 | 3.0 | 3.90 |
| | ST4 | 0.03 | ND<2.0 | 0.37 |
| | ST5 | 0.02 | 2.0 | 3.90 |
| 5/27/2021 | Downstream | 0.02 | ND <2.0 | 2.70 |
| | ST1 | 0.01 | 3.0 | 2.74 |
| | ST2 | 0.02 | ND<2.0 | 2.97 |
| | ST3 | 0.02 | 10.0 | 3.07 |
| | ST4 | 0.04 | 11.0 | 0.77 |
| | ST5 | 0.02 | 7.0 | 3.16 |
| 7/21/2021 | Downstream | 0.02 | 4.0 | 3.19 |
| | ST1 | 0.02 | ND<2.0 | 3.26 |
| | ST2 | 0.02 | ND<2.0 | 3.55 |
| | ST3 | 0.02 | 2.0 | 3.49 |
| | ST4 | 0.05 | 34.0 | 0.42 |
| | ST5 | 0.02 | ND<2.0 | 5.09 |
| 10/14/2021 | Downstream | 0.02 | ND<2.0 | 3.50 |
| | ST1 | 0.01 | ND<2.0 | 3.40 |
| | ST2 | 0.01 | ND<2.0 | 3.40 |
| | ST3 | 0.01 | ND<2.0 | 3.70 |
| | ST4 | 0.05 | 10.0 | 1.10 |
| | ST5 | 0.04 | 8.0 | 4.40 |

### *FISHERIES SURVEY*

The fisheries community sampled in October of 2021 was marked by large increase in brook trout numbers and were the most frequently caught species. In total, 102 fish were sampled between the 6 reaches, with 9 different species of fish being represented. As noted, brook trout were the most frequently sampled species, with pumpkinseed (*Lepomis gibbosus*) also being relatively common. Shannon's diversity index, a measure of the general species diversity of a system, was calculated to be 1.34 for ST1 – ST5, lower than the value of 1.9 obtained in 2018. This is likely due to the higher prevalence of brook trout. This metric saw at least a slight decrease at each of the main stations on the mainstem. ST4 however saw a slight increase in diversity.

It should be noted that a majority of the fish sampled at ST4 were caught in the plunge pool immediately below Rt. 202. Most of these fish, a mix of centrarchids (sunfish), likely migrated to this area 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.

Brook trout were weighed using a small digital scale to obtain mass in grams. Pairing this data with length data allowed for the development of a length-weight regression. Figure 4 below displays the results of this analysis. The equation displayed on the chart below can be used during future studies and by anglers to obtain an estimate of brook trout mass (*y*) by substituting *x* with a specimen's length in millimeters. In total, brook trout biomass in sampled areas in October of 2021 was measured to be approximately 2,919 grams, or approximately 6.45 lbs. This correlated to approximately 33.8 lbs of brook trout per acre of stream. This is a massive increase from estimates obtained from previous surveys and suggests a thriving brook trout population is present in the stream. Should this population be found to maintain itself without further stocking efforts, the Aquetong Creek within the study area may be classifiable as a Pennsylvania Class A Wild Trout Waters.

| Common Name | Downstream | ST1 | ST2 | ST3 | ST4 | ST5 | Total | Relative Abundance (fish/acre ) |
|---|---|---|---|---|---|---|---|---|
| American Eel | - | 1 | - | - | 1 | 3 | 5 | 20.3 |
| Bluegill | - | - | - | - | 1 | - | 1 | 4.1 |
| Brook Trout | - | 2 | 17 | 21 | - | 9 | 49 | 199.1 |
| Creek Chub | 2 | - | 3 | - | 2 | - | 7 | 28.4 |
| Green Sunfish | - | - | - | - | 1 | - | 1 | 4.1 |
| Largemouth Bass | - | - | - | - | 2 | - | 2 | 8.1 |
| Longnose Dace | 3 | - | - | - | - | - | 3 | 12.2 |
| Pumpkinseed | - | 1 | 11 | 4 | 11 | - | 27 | 109.7 |
| White Sucker | 2 | - | 3 | - | 2 | - | 7 | 28.4 |
| Total abundance | 7 | 4 | 34 | 25 | 20 | 12 | 102 | 414.5 |
| Richness (# Taxa) | 3 | 3 | 4 | 2 | 7 | 2 | 9 | - |
| CPUE (fish/pass) | 3.50 | 1.33 | 11.33 | 8.33 | 10.00 | 4.00 | 6.38 | - |
| Shannon's Diversity | 1.08 | 1.04 | 1.14 | 0.44 | 1.47 | 0.56 | 1.49 | - |
| Evenness | 0.98 | 0.95 | 0.82 | 0.63 | 0.75 | 0.81 | 0.68 | - |

**Table 4: Aquetong Creek Fishery Data 2021**

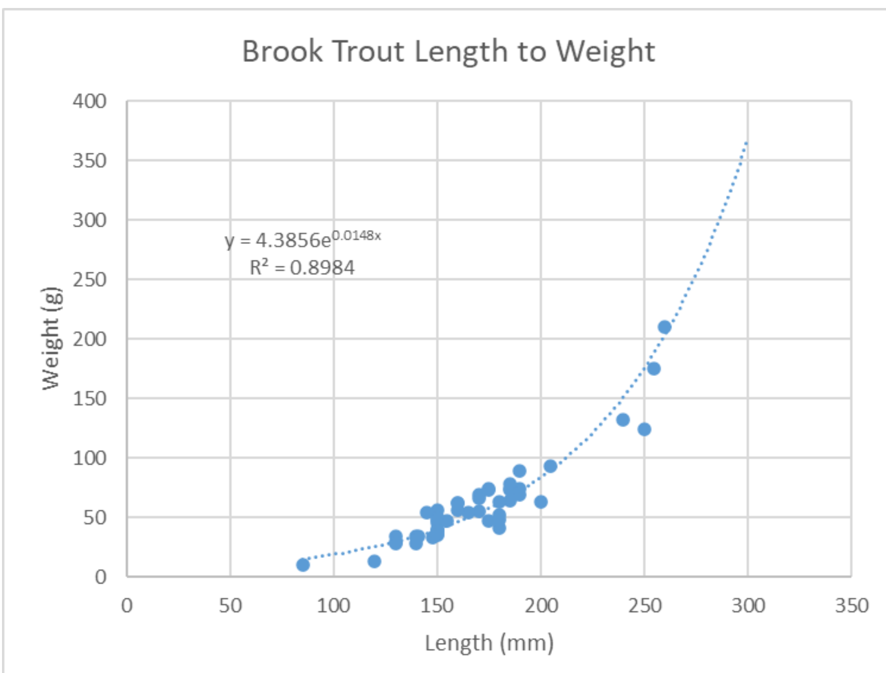



**Figure 4: Length-to-Mass regression for Brook Trout**

### *BENTHIC MACROINVERTEBRATE SURVEY*

Historically, Aquetong Creek has featured a large number of scuds (order Amphipoda, family Gammaridae), and this trend continued in October 2021. This family made up approximately 75% of the subsamples picked from many of the mainstem stations, with the family representing over 90% of ST3's assemblage. Scuds tend to be common in and often dominate limestone stream systems. It should be noted that while the dominant taxa in the downstream station, Gammaridae only comprised 40% of this reach's assemblage. Additionally, ST4's subsample only contained a single individual from this taxon, with the dominant taxon instead being black flies (Order Diptera, family Simuliidae). This is likely due to the different habitat that is found in this reach, although black flies were found in smaller numbers in many of the mainstem samples as well.

| Station | Density per ft² | Taxa Richness | Dominant Taxa | Shannon's Diversity | Evenness | % EPT Taxa | Family Biotic Index |
|---|---|---|---|---|---|---|---|
| Downstream | 120.0 | 12 | Amphipoda, Gammeridae (Scuds) | 1.89 | 0.76 | 23.00 | 4.66 |
| ST1 | 68.4 | 6 | Amphipoda, Gammeridae (Scuds) | 0.91 | 0.51 | 3.51 | 4.11 |
| ST2 | 244.8 | 9 | Amphipoda, Gammeridae (Scuds) | 0.93 | 0.48 | 13.73 | 4.35 |
| ST3 | 187.2 | 6 | Amphipoda, Gammeridae (Scuds) | 0.30 | 0.19 | 1.92 | 4.04 |
| ST4 | 139.3 | 11 | Diptera, Simuliidae (Black Flies) | 1.27 | 0.58 | 0.00 | 5.75 |
| ST5 | 43.2 | 11 | Amphipoda, Gammeridae (Scuds) | 1.09 | 0.48 | 5.56 | 4.29 |

**Table 5: Benthic Macroinvertebrate Data 2021**

Table 5 displays 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 along the mainstem were calculated to largely yield values between approximately 4.0 and 4.7, classifying most of these sites as "Very Good" or "Good" in respect to organic pollution. ST4 yielded a value of 5.75, which correlates to "Fair" and approaches "Fairly Poor", indicating an increased amount of pollution and/or habitat degradation. The high abundance of scuds compared to other species present in most of the mainstem sites resulted in Shannon's Diversity scores of less than 1.0 for many of these sites. The percentage of EPT (Ephemeroptera - mayflies, Plecoptera - stoneflies, and Tricoptera - caddisflies), a group of relatively sensitive taxa, was relatively low for most of the sites, although these organisms made up almost 25% of the assemblage at the downstream station. ST2 also saw an increase in percentage of EPT taxa since 2018, although each survey occurred at different times of the year, potentially impacting what organisms would be present.

## RECOMMENDATIONS

Based on the observations and measurements made during the 2020-2021 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 areas 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 large 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 2022 or 2023, after the habitat restoration construction projects have had time to establish.

### *REMOVAL OF BARRIERS TO FISH PASSAGE*

As discussed above, two areas were observed in the study area with rapid changes in grade that may be impassable to upstream movement by some fish. These areas are in or adjacent to ST2 and ST5. Princeton Hydro strongly recommends that these areas 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.

### *CONTINUED GENERAL MONITORING IN 2022*

Princeton Hydro recommends the continued monitoring of the Aquetong Creek in order to assess the effectivity of continued restoration efforts and the status of the stream's brook trout population. A monitoring event for 2022 should largely follow the same methodology used in 2020-2021. This involves the continued sampling of fish and macroinvertebrates at least once a year in either the Spring or Fall seasons, in order to assess how changes to the stream and habitat affect these populations and, in particular, if brook trout populations are reproducing.

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