Aquetong Spring Park: Aquetong Creek Water Quality, Fish, and Benthic Sampling

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 2000 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 middle of the formerly impounded area.

In the summer of 2017, Princeton Hydro conducted a survey of water quality and communities of fish and benthic macroinvertebrates. The study suggested that conditions were present that could support populations of brook trout, particularly cold summer water temperatures, sufficient dissolved oxygen concentrations, and a thriving macroinvertebrate community. In 2018, three events were conducted over the course of the year in which water quality and the general condition of the stream were assessed. Princeton Hydro also conducted a benthic macroinvertebrate survey during the summer event and a fisheries survey during the fall event. The benthic macroinvertebrate survey results were previously sent to the Township under separate cover.

The overall goal of this project was to assess the existing water quality conditions, fish, and benthic invertebrate communities upstream of the project site, specifically with regard to its potential to support a brook trout (*Salvelinus fontinalis*) fishery. Comparisons were also made between the 2018 data and that data collected in 2017 in order to assess any longitudinal changes occurring in the stream between the two monitoring years.

Methods

Three (3) stream surveys were conducted over the course of the 2018 growing season in order to collect water quality data and assess the general condition of the stream with discrete events in the spring, summer, and fall. Sampling was conducted at five (5) stations located along Aquetong Creek (Figure 1). Station 1 was located down-gradient of the breach, with this station serving as a reference station against which the upstream data was compared, as this station was never part of the former impoundment. Stations 2, 3, and 5 were sited along the mainstem Aquetong Creek upstream of the dam breach. Station 4 was located on the northern tributary within the footprint of the impoundment and downstream of Route 202. This distribution of stations is designed to foster evaluations along the Aquetong Creek, assess conditions within and outside the impoundment, and ascertain any impacts attributable to the Route 202 tributary. The following parameters were collected at each sampling site:

- ***In Situ* Water Quality Data:** Readings of temperature, dissolved oxygen concentration, specific conductivity, and pH were taken at each site using a calibrated multiprobe water quality meter. This data was also collected within the Ingham Spring pool.
- **Discrete Water Quality Data:** At each site, water samples were collected for the analysis of Nitrate-Nitrogen, Nitrite-Nitrogen, Total Kjeldahl Nitrogen, Total Nitrogen, Total Phosphorus (TP), and Total Suspended Solids. Water samples were analyzed by Environmental Compliance Monitoring, Inc. of Hillsborough, NJ.
- **Stream Discharge:** At each site, water velocities measurements were taken across the stream channel using a wading rod and Type AA (Price-type) flow meter. From this stream velocity data, total discharge was then calculated for each site.
- **Observational Data:** Additional notes were made regarding weather, changes to stream morphology, presence of fish and wildlife, riparian vegetation, and/or any other relevant observations made at each site.

In addition to these parameters, which were collected during every event, a benthic macroinvertebrate and fisheries survey were each conducted once in 2018. The fish community of each site was sampled on the 22nd of October. Sampling of the fishery involved the use of a backpack electrofishing unit. Three standardized passes of 100' reaches of the creek were conducted at each station. To maximize the return on the effort, a 50' bag seine was secured across the lower end and upper ends of each sampled reach prior to electrofishing. The nets helped capture any fish that may not have been collected by the dip netter working with the electrofisher. All collected fish were identified to species, measured (total length) and returned to the creek immediately following processing. The resulting fishery data was subjected to standard descriptive fishery statistical analyses (e.g. percent composition, dominance, catch per unit effort-CPUE, diversity, evenness, etc.). *In situ* water quality data was also sampled during this event.

Benthic macroinvertebrates were sampled during the summer event conducted in early July. At each sampling site, a D-net was used to sample various microhabitat types along an approximately 100' reach. This net was positioned on the stream bottom and the area immediately upstream of it was disturbed in order to dislodge any organisms present in the substrate. This was repeated several times per site, and all material collected was preserved in alcohol.

Benthic macroinvertebrate samples from each site were picked, identified, and enumerated in Princeton Hydro's in-house laboratory. For this process, each sample was spread homogenously across a pan. Even-

sized sections of the pan were assigned a value 1-9, and a random number generator was used to select a section from which to remove material. All individuals collected from the material in this section were identified to broad taxonomic group (typically order) and counted. The results of this benthic macroinvertebrate survey were previously sent to the Township under separate cover.

Results

Current Creek Condition

Since the summer of 2017, the mainstem of the Aquetong Creek has changed slightly, mostly due to erosion in the former lake bed. Site ST1's general morphology changed over the course of early 2018 from a slightly more sinuous channel to becoming relatively straight, possibly as a result of increased flows from a heavy rainstorm. The reach also featured increased amounts of large woody debris (LWD), which likely overtime will further influence channel morphology.

A notable change in 2018 was a perceived increase in fine sediments throughout site ST2 within the dam breach. While this site featured a largely gravel and cobble bottom in 2017, this microhabitat was infilled by 2018 and the coarser material embedded. This fine sediment was likely transported from areas within the old lakebed and settled to the stream bottom in this area due to generally lower water velocities. Continued erosion and subsequent deposition of sediment is likely to continue until sediments in the lakebed stabilize, in part of function of increasing vegetative cover. Additionally, the large populations of watercress (*Nasturtium officinale*) growing along both sides of this reach have significantly decreased, likely as a result of decreased suitable habitat. As this plant grew far into the channel in 2017, this presents a decrease of microhabitat for macroinvertebrates and fish populations. Noted in 2018 was a headcut, a vertical erosion feature within the channel, a few meters upstream of the dam breach that likely acted as a barrier to fish passage. By the end of the year, this feature had eroded and lessened in severity. While it is likely passable by many species of fish at this time (including Brook Trout), this feature should be closely monitored in coming years.

ST3 was similar morphologically in 2018 to its condition in 2017. This site features the highest water velocities, as well as a relatively narrow channel. Substrate in this reach consists largely of heavier clay from the old lake bottom with some cobble sparsely distributed throughout, although the upstream end features increased amounts of cobble. While the channel in the middle of this reach is relatively straight, both the upstream and downstream ends feature meanders.

The reach in ST4 is a tributary flowing from under Route 202, originating at a private pond directly on the opposite side of the highway. This reach features generally low flows, as well as steep, relatively unstable banks and soft substrate. Large amounts of organic matter are also often found in this reach. The upstream end of the reach features an approximately 3' drop from a culvert into a smaller plunge pool, followed by a concrete structure that conveys water into a large plunge pool. Vegetation along the easternside of the reach was recently partially cleared.

ST5 is characterized as the furthest upstream reach on the mainstem, less than 200 ft downstream of Ingham Spring. Conditions in this site have generally been observed in 2017 and 2018 to be the most suitable for brook trout habitat, with a gravel substrate, enough organic matter to provide structure and variation to the stream bottom, and sufficient flow straight from the spring. Watercress has also been observed to line both sides of the reach during both years. Since the survey conducted in 2017, operations have commenced to clear the invasive common reed (*Phragmites australis*) from an area along the left bank of the downstream end of the reach. Fostering the growth of native wetland species in this area will likely serve to further enhance the habitat quality of this reach. The downstream end of this reach features

a headcut significant enough to prevent upstream fish passage. This feature should be modified to allow better connectivity between this reach and areas downstream.

Water Quality and Flow

A summary of water quality and flow data is presented in Table 1. As observed in the summer of 2018, large differences were noted between the Route 202 tributary and the main stem of the creek. This tributary consistently featured higher water temperatures (over 10°C warmer in the spring and summer events) and higher specific conductivity than the main steam of the creek as well as minimal flows and dissolved oxygen concentrations lower than most of the other sites. pH levels at this station were also generally higher than those at other reaches during the Spring and Summer sampling events.

Discharge at most stations was highest during the fall sampling event due to the rain event the previous day. The highest discharge was consistently measured in ST3, a segment of the stream in the middle of the old lakebed with a relatively narrow channel and high water velocities. Increased flow at this station reflects the contributions of the northern tributary. Lower discharges at stations downstream may indicate a losing stream, one that loses flow to groundwater, but decreased measurement confidence at low velocity, shallow areas with obstructing vegetation or substrate is more likely the cause of the measured loss of flow. Site ST5, the reach closest to the spring, maintained fairly consistent discharge and temperature throughout the year (with the exception of one errant reading) due to the steady outflow from the spring itself and very few other inputs. Aside from those measured in ST4, the reach located on the Route 202 tributary, water temperatures remained cold, never exceeding 13.51°C. Cold summertime temperatures such as these indicate good thermal habitat for brook trout. It is notable that during the October fish sampling event, temperatures in the main stream remained close to those found throughout the rest of the monitoring period, while ST4 featured a lower temperature. This is likely due to the consistent discharge of groundwater in the mainstem which tends to be more thermally stable. Similarly, stations along the mainstem consistently featured well-saturated concentrations of dissolved oxygen, likely owing to the stream's cold temperatures and relatively high discharge.

The Ingham Spring pool consistently featured the lowest temperatures and the lowest dissolved oxygen concentrations. Both of these can be explained as a product of the groundwater origin of the pool's inflow. This allows for only minimal mixing of atmospheric oxygen between the origin of the flow and the pool's outlet.

Dissolved 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 is a measurement of sediment or other particulates. Phosphorus concentrations measured high in the spring event, likely due to an influx of organic material from the watershed carried by spring rains and meltwater. These were detected to be much lower during the summer event, before increasing again slightly in ST1, ST2, and ST4 in September. This may be the result of a wet late-summer season increasing organic inputs into the stream. Total nitrogen concentrations remained high throughout the season, which can be expected in systems where groundwater dominates flow, as groundwater nitrogen concentrations tend to be much higher than surface waters. Total suspended solids were not detected at any of the stream sites during the spring sampling event. While they were still detected to be relatively low during the summer event, ST1 featured a large increase, suggesting an upstream input of sediment, either from runoff or stream bank scouring near this site. Total suspended solid concentration increased for the other

stream sites in September, a result of recent heavy rains. A high concentration was obtained from ST4 during this sampling event, likely due to either erosion/scouring of its banks or runoff from Route 202.

Table 1. Discrete water quality data for Aquetong Creek on three dates in 2018.

Date	Sample Station	Total Nitrogen (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Total Kjeldahl Nitrogen-N (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
5/7/2018	St1	4.4	4.4	0.002	ND <0.16	0.05	ND <3
	St2	4.6	4.6	0.002	ND <0.16	0.05	ND <3
	St3	3.9	3.9	0.004	ND <0.16	0.07	ND <3
	St4	0.6	0.6	0.012	ND <0.16	0.06	ND <3
	St5	4.8	4.8	0.003	ND <0.16	0.05	ND <3
Date	**Sample Station**	**Total Nitrogen (mg/L)**	**Nitrate-N (mg/L)**	**Nitrite-N (mg/L)**	**Total Kjeldahl Nitrogen-N (mg/L)**	**Total Phosphorus (mg/L)**	**Total Suspended Solids (mg/L)**
7/2/2018	St1	2.8	2.8	0.003	ND<0.16	0.02	25
	St2	2.8	2.8	0.003	ND<0.16	ND<0.01	5
	St3	3.5	3.5	0.002	ND<0.16	ND<0.01	4
	St4	0.3	0.3	0.023	ND<0.16	ND<0.01	6
	St5	3.2	3.2	ND<0.002	ND<0.16	0.02	5
Date	**Sample Station**	**Total Nitrogen (mg/L)**	**Nitrate-N (mg/L)**	**Nitrite-N (mg/L)**	**Total Kjeldahl Nitrogen-N (mg/L)**	**Total Phosphorus (mg/L)**	**Total Suspended Solids (mg/L)**
9/27/2018	St1	3.6	3.6	0.002	ND<0.16	0.04	17
	St2	3.5	3.5	0.003	ND<0.16	0.03	6
	St3	3.4	3.4	0.002	ND<0.16	0.01	9
	St4	0.8	0.8	0.012	ND<0.16	0.06	19
	St5	3.8	3.8	ND<0.002	ND<0.16	0.01	7

Biotic Assessment

Table 2 summarizes fisheries data collected during 2018. Since 2017, overall species richness for the entire stream system has increased, with the addition of two shiner species, creek chubs (*Semotilus atromaculatus*), and bluegill sunfish (*Lepomis macrochirus*). The only species sampled in 2017 that was not observed in 2018 was the tessellated darter (*Etheostoma olmstedi*). All sites featured an overall increase in fish abundance, including sites ST3 and ST4, at which no fish were caught in 2017. In the case of ST4, it should be noted that almost all of the fish sampled were captured in the two plunge pools at the upstream end of the reach, which was not sampled in 2017. This reach featured an assemblage consisting entirely of sunfish species (*Lepomis sp.*) which likely originated at the pond on the other side of Route 202.

As in 2017, site ST2 featured the highest overall abundance of fish and the highest richness, featuring 7 different species. While brook trout were not found at this site in 2018, 4 individuals were sampled at ST5,

and additional individuals were observed upstream of this reach. These fish were overall smaller than brook trout sampled in 2017, with a maximum length of 180 mm or about 7 inches, and an average length of 137.25 mm, compared to an average length of 220 mm in 2017. Using a Pennsylvania-specific mass-length model,.the total biomass of brook trout sampled was 0.31 lbs., or approximately 2.83 lbs. per acre sampled. Based on the data collected during the survey, this segment of Aquetong Creek does not currently satisfy PFBC Class A Brook Trout stream criteria (total wild brook trout biomass of at least 26.7 lbs/acre, PADEP 2017). The stream could, however, be a candidate for a Class D Wild Trout stream classification (Total Wild trout biomass of more than 0 lbs/acre and less than 10 lbs/acre, Nihart - PFBC, 2017). Most of the stream currently provides optimal temperature, flow, and water quality regimes for riverine brook trout populations, however, in most of the stream, bottom substrate, cover, stream bank condition, and pool-riffle ratios are currently not optimal (Raleigh, 1982). The brook trout numbers and size structure sampled in October mark a departure from a survey performed earlier in 2018, in which the Aquetong Watershed Association found large numbers of brook trout fry in the stream. Large numbers of these fry may have moved downstream as a result of the multiple heavy rain events that occurred over the summer. This may be remedied by adding structure to foster juvenile habitat. Because the fish community was not sampled in its entirety throughout the park, it is possible that additional brook trout adults and/or fry may be present in unsampled areas.

Table 3 summarizes the benthic invertebrate community data. Amphipods (scuds) were the dominant invertebrate at most stations, with the Route 202 tributary being dominated instead by true flies (order Diptera). Both richness and percentage of EPT taxa (individuals from the orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies)) decreased in ST1, ST2, and ST3. This may reflect reduced habitat complexity due to sedimentation of the stream bottom or loss of aquatic vegetation (both of which were observed in ST2). Invertebrates in these three orders are typically sensitive to negative changes in habitat and water quality, and a decrease between the two years indicates that these sites have become impacted in some way. However, it should be noted that, while not collected as part of a benthic survey, ST1 was observed to contain large numbers of mayfly larvae (order Ephemeroptera) during the spring sampling event, suggesting that EPT taxa may have only been seasonally low during the 2018 survey. Despite conditions indicative of an impacted stream site, ST4 featured the highest richness of any of the stream sites in both 2018 and 2017, possibly as a result of the higher amounts of organic and woody debris. It should be noted, however, that while more sensitive taxa were present in the sample, the assemblage consisted largely of less tolerant organisms, particularly fly larvae (order Diptera)

Conclusions

Brook trout populations in the upper reaches of the Aquetong Creek appear to be increasing, as evidenced by the increased number of these fish sampled in 2018. These fish exhibit lower weights (in a small sample size), however, and the stream did not yield a high enough biomass of brook trout to be ranked as a Class-A Brook Trout Stream by Pennsylvania's criteria. As noted above, the stream features habitat characteristics that are supportive of a brook trout population, particularly in regards to temperature, flow, and water quality. In order to obtain a higher habitat suitability index (HSI) rating (an estimation of how suitable the stream is for sustaining a brook trout population), Aquetong Creek requires further improvements (Raleigh, 1982).

When examining the stream using a simplified 8-point habitat model, the mainstem of the upper Aquetong Creek fulfills 4 of the 8 points of an optimum habitat. These are a cold average and maximum

summer water temperature, a relatively stable flow regime, and good water quality (Raleigh, 1982). Areas where the Aquetong Creek does not meet optimal habitat standards are in its pool-riffle ratio (optimally 1:1), the vegetation and stability of the stream's banks, the amount of the overall stream area that provides adequate cover (optimally 25% or more), and rocky substrate that is free of siltation. Furthermore, the stream channel has been observed to contain headcuts that likely serve as a barrier to upstream movement by brook trout. Part of the reason for these shortcomings is likely due to the relatively recent breaching of the Aquetong Lake dam. The former area of the lake, while becoming increasingly vegetated since the breaching of the dam, is still not sufficient to provide adequate cover or entirely stabilize stream banks. Additionally, much of the stream channel still features clay and sediment from the original lake bottom. Further restoration efforts will occur in 2019 to control soil erosion and sediment and to continue the reestablishment of native vegetation within the immediate watershed. Future surveys of the stream's fish communities should yield increased numbers of brook trout as restoration work continues on the stream.

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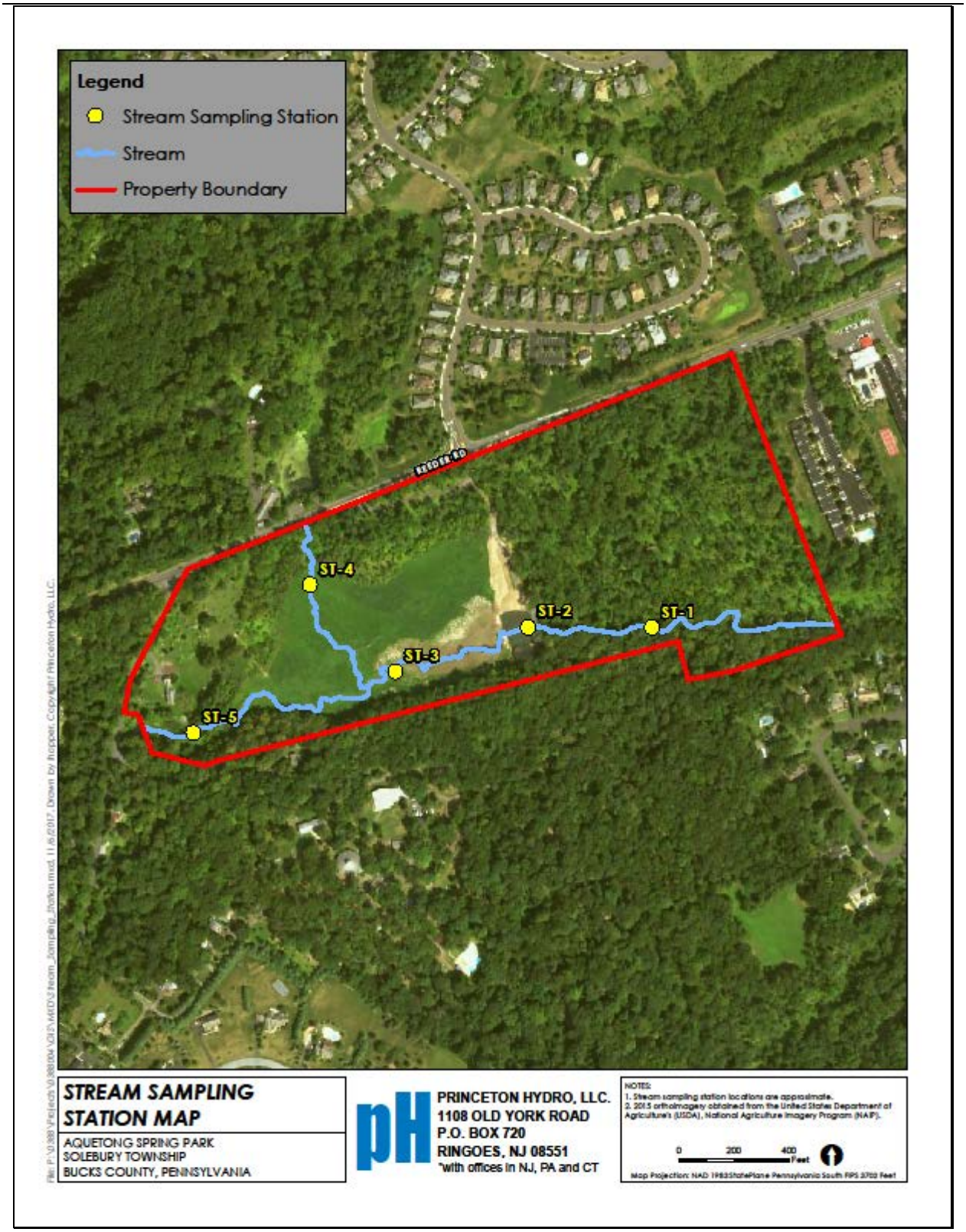

Figure 1. Map of Sampling locations along Aquetong Creek.

Table 2. In-situ water quality monitoring and flow data for Aquetong Creek on four dates in 2018.

Date	Sample Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Specific Conductivity (µs/cm)	Discharge (cfs)
5/7/2018	St1	12.2	10.7	103.5	7.89	430.1	4.83
	St2	12.4	10.7	104.2	7.88	430.3	3.49
	St3	12.3	10.5	102.2	7.77	429.9	8.36
	St4	14.3	10.8	109.6	8.24	606.6	0.34
	St5	26.7	7.9	102.3	7.76	-	4.53
	Pool	11.8	7.1	68.2	7.36	419.3	-

Date	Sample Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Specific Conductivity (µs/cm)	Discharge (cfs)
7/2/2018	St1	13.4	10.7	102.9	7.51	0.435	4.17
	St2	13.5	10.7	102.4	7.60	0.437	5.25
	St3	13.3	10.8	103.5	7.66	0.436	6.41
	St4	24.5	7.8	93.3	8.08	0.586	0.23
	St5	12.1	10.1	93.9	7.68	0.431	4.47
	Pool	12.0	6.5	60.8	7.84	0.433	-

Date	Sample Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Specific Conductivity (µs/cm)	Discharge (cfs)
9/27/2018	St1	12.4	10.9	101.4	7.85	0.459	5.12
	St2	12.5	14.9	138.8	7.90	0.460	6.06
	St3	12.5	12.1	113.2	7.90	0.453	7.77
	St4	19.4	9.4	101.8	7.81	0.657	0.28
	St5	11.8	129.2	116.9	7.76	0.444	5.08
	Pool	11.7	7.4	68.0	7.76	0.441	-

Date	Sample Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Specific Conductivity (µs/cm)	Discharge (cfs)
10/22/2018	St1	11.0	13.6	121.6	7.90	0.449	-
	St2	11.2	12.0	109.0	7.93	0.448	-
	St3	11.5	10.1	91.9	7.96	0.450	-
	St4	8.7	12.1	102.3	8.00	0.671	-
	St5	11.0	15.8	143.2	7.94	0.428	-
	Pool	11.6	9.5	85.5	7.92	0.433	-

Table 3. Summary of Bioassessment with fish community data.

Fish sampled in Aquetong Creek, October 2018								
Common Name	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Total**	**Relative Abundance (# per acre sampled)**	**Relative Abundance (# per hectare sampled)**
American Eel	3	8	1	-	2	14	130	321
Black Nose Dace	1	4	-	-	-	5	46	115
Brook Trout	-	-	-	-	4	4	37	92
Green Sunfish	3	2	1	2	-	8	74	183
Largemouth Bass	-	4	-	-	-	4	37	92
Pumpkinseed Sunfish	-	1	-	**12**	-	13	120	298
Bluegill Sunfish	4	16	2	**11**	-	33	306	756
Creek Chub	2	2	-	-	-	4	37	92
Common Shiner	-	-	1	-	-	1	9	23
Spottail Shiner	1	-	-	-	-	1	9	23
White Sucker	-	-	1	-	-	1	9	23
Abundance	14	37	6	**25**	6	88	815	2015
Richness (# of taxa)	6	7	5	**3**	2	11	-	-
Evenness	0.93	0.82	0.91	**0.83**	0.92	0.79	-	-

Table 4. Summary of Bioassessment with benthic invertebrate community data. EPT species are organisms that are indicative of stream quality and include individuals from the orders Ephemeroptera, Plecoptera, and Tricoptera.

Benthic Invertebrates for Aquetong Creek, July 2018					
Station	**Relative Abundance**	**Richness (# of taxa)**	**Evenness**	**Dominant taxa**	**% EPT species**
ST1	77	5	0.39	Amphipoda	1.3%
ST2	50	5	0.63	Amphipoda	4.0%
ST3	50	3	0.72	Amphipoda	4.0%
ST4	196	11	0.39	Diptera	8.16%
ST5	116	7	0.52	Amphipoda	8.62%