EnviroDIY in the Delaware River Basin

Informal summary monitoring results and station usage, successes/challenges, and recommendations

Description of document: The following contains *informal* summaries of some of the projects taking place in the Delaware River Basin using EnviroDIY monitoring stations equipped with CTD and Turbidity sensors. Stations are owned and managed by individual watershed groups and schools. Support has been provided by Stroud Water Research Center via the Delaware River Watershed Initiative. Summaries were voluntarily prepared by station owners/managers at the request of the Stroud Center. For more information contact dbressler@stroudcenter.org.

Organization: Brodhead Watershed Association; Station Manager: Edie Stevens; Stream/River: Forest Hills Run (http://monitormywatershed.org/sites/PKFH1S/)

This data logger was installed on May 21, 2018 but only began sending data remotely on October 18, 2019. Prior to that data, the site host, Bob Fendelander would manually pull the data card and download the data. For several months, he created charts to display on the BWA website, however, we only looked at the temperature data, as temperature has historically been a pollutant in Forest Hills Run. Forest Hills Run is listed as HQ-CWF in DEP regulations and has been listed as impaired for several years. The borough of Mt. Pocono's WWTP discharges to FHR as does that of the Mt Airy Resort and Casino.

When the data became available on the Monitor My Watershed website we immediately noticed the high conductivity readings at that site, in the 350-450 µS/cm range (Figure 1). We also observed that conductivity went down and temperature went up when water depth increased.

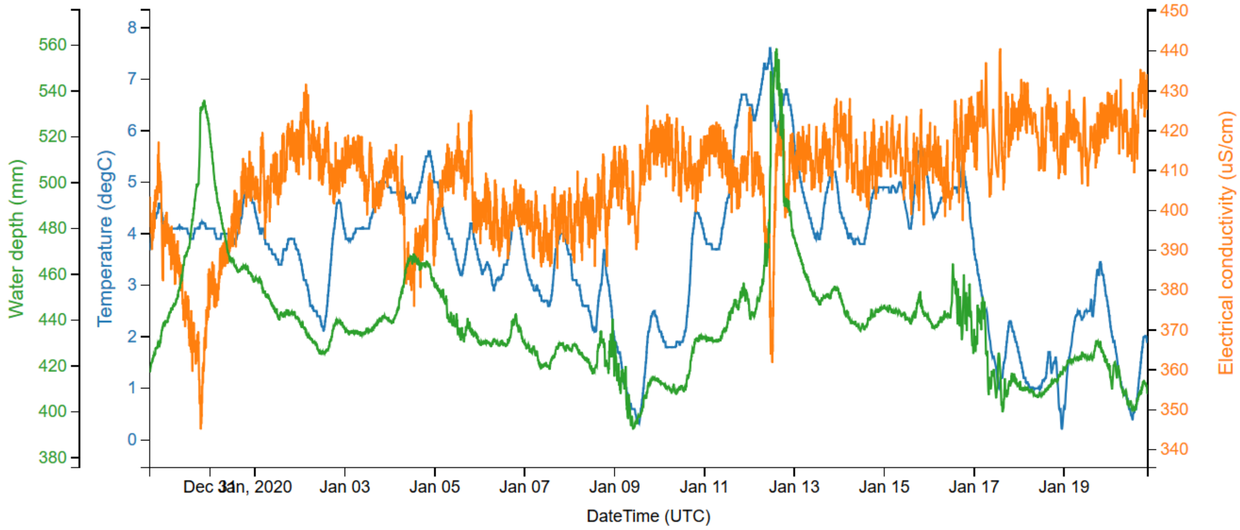


Figure 1. Data for EnviroDIY monitoring station on Forest Hills Run downstream of Mt Airy Resort. Data for Dec 20, 2019 – January 20, 2020.

As we investigated further, we analyzed logger data submitted by Mt Airy Resort to Paradise Township and BWA. The Township required Mt. Airy to provide this data as a condition of a conditional use permit granted to Mt. Airy to expand the resort. Mt Airy Resort has loggers positioned upstream and downstream of the resort and its associated discharge.We found that conductivity UPSTREAM of Mt. Airy (lake and discharge) was higher than downstream (in both cases, the data loggers are at the property boundaries)(Figure 2).

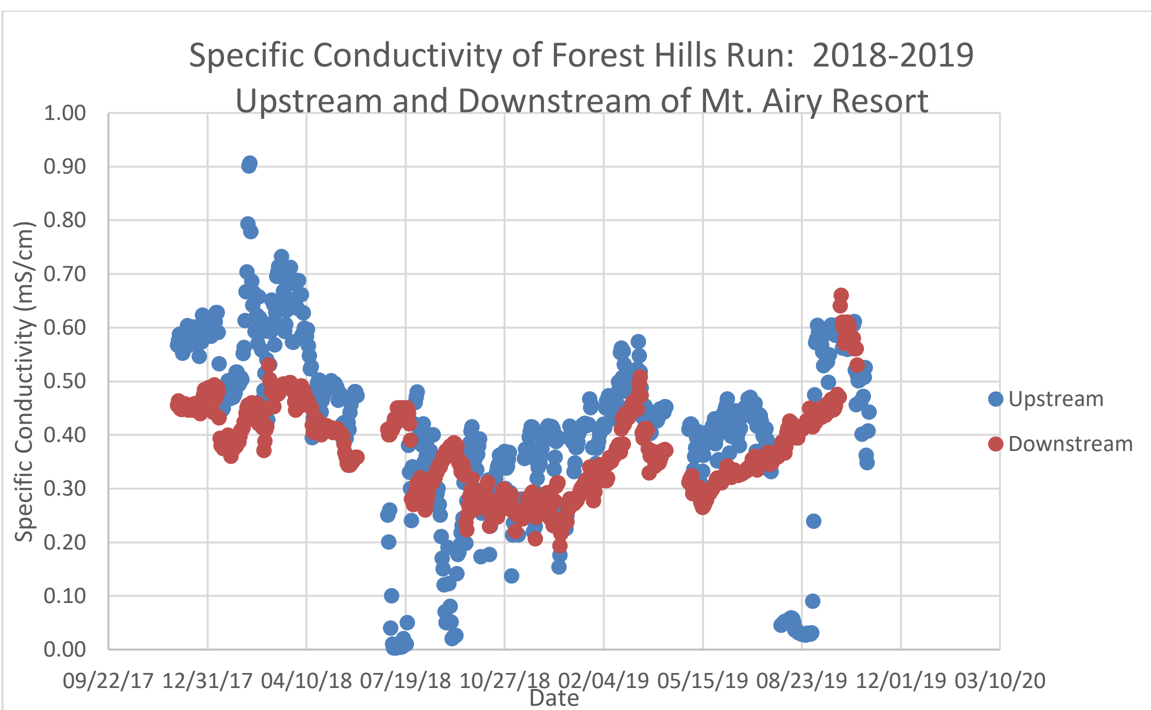


Figure 2. Data logger specific conductivity upstream and downstream of Mt Airy Resort discharge point (both points are upstream of the EnviroDIY monitoring station).

This caused us to look farther upstream, at data collected by the Mt. Pocono Municipal Authority (MPMA), owner/operator of the Mt. Pocono borough WWTP.

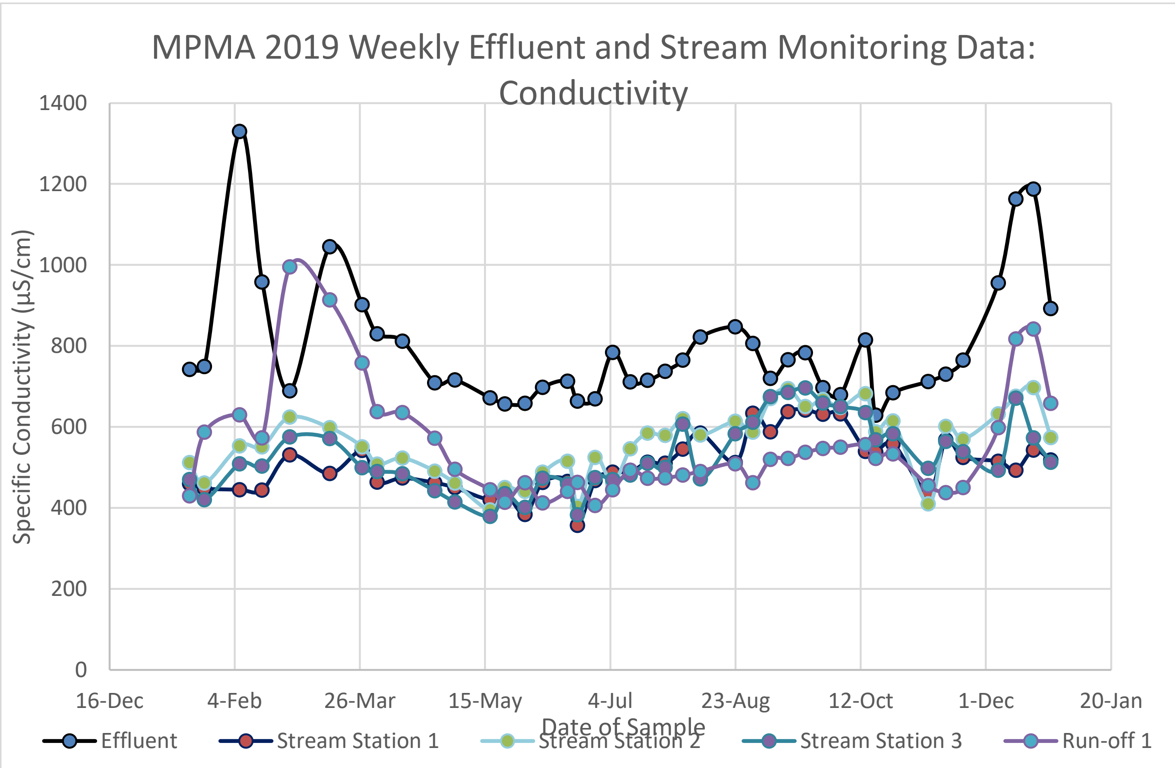
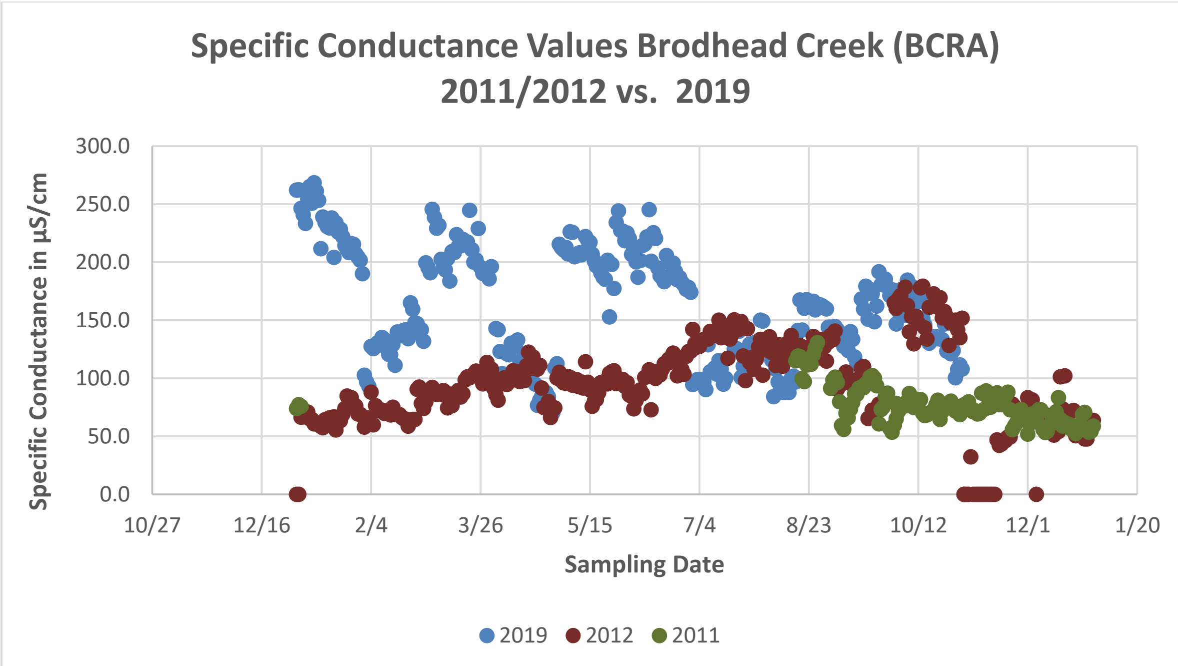


Figure 3. Specific conductivity in effluent, on-site runoff, and three stream stations (station 1 upstream of WWTP discharge, station 2 and 3 downstream).

MPMA staff, throughout 2019, collected grab samples from their treated effluent, a site on their property with runoff from the borough, and the stream at three locations (above the discharge, below the discharge and farther downstream).   We graphed that data, and found conductivity is high in the stream at all three locations, the treated effluent is still higher, and the runoff generally close to stream conductivity with peaks in February and December, perhaps relating to storm events and road deicing.

Additionally, we received conductivity data from Brodhead Creek Regional Authority (BCRA), water supplier on Brodhead Creek. The BCRA has been taking grab samples of the Brodhead Creek at their intake location for several years.   Conductivity is rising over time, including in summer months, which may indicate long term accumulation of road salt and de-icers in soils that leach into nearby streams throughout the year, not just during the winter (Figure 4).



Finally, we purchased handheld conductivity meters and recruited volunteers to take conductivity readings throughout the watershed. Todd Burns monitors several headwaters sites, Mike Stein measures several sites on Forest Hills Run, and Rich Cramer and Rick Croll monitor several sites in the lower watershed. Trout Unlimited volunteers may monitor additional sites.

Several things became obvious: Yankee Run, a headwaters stream that originates at a busy intersection in Mt. Pocono tested high 600-625 µS/cm , all other headwaters, mean 100-250 µS/cm.

Forest Hills Run showed increasing conductivity from downstream to upstream, with the highest reading ABOVE the WWTP discharge (only one test date however).

None of the sites in the lower watershed were above 300 µS/cm, and generally are below 200 µS/cm.

NEXT STEPS: We need to learn more about conductivity in our watershed. Is there a build-up of chlorides in groundwater, causing high conductivity in some streams throughout the year? What ions are present in some streams that are causing high conductivity there, but not in other streams?

We will continue to monitor with hand-held meters, and chloride test strips; however, we have applied for a grant to pay for certified lab testing to determine what specific ions are present and their respective concentrations. This information would help us narrow our search for the causes of such high specific conductance in some headwaters streams.

Organization: Schuylkill River Greenways; Station Manager: Sarah Crothers, Tim Fenchel; Stream/River: Schuylkill River (http://monitormywatershed.org/sites/MSSR2S/)

Teaching and informing new users, other watershed groups, and schools on how these stations and data can be used

We've worked with high school students from The Hill School. They are able to work with us in the field and gain an understanding of river health but they are also able to work in their schools and with their teachers during class time by having the real-time updated data at their fingertips. Learning about the Schuylkill River does not stop once they leave the field.

What we've learned about our watershed

Our sensor has connected us to the Schuylkill River in a way that we were not connected before. Because of our sensor we pay attention to cfs, temperature, turbidity, and conductivity 100% more than we have in the past.

Monitoring

We are looking to move our sensor to a more central location for our staff and volunteers. But the volunteers who were trained by Stroud are reliable and very interested in this work. We are very fortunate to have them as support for our sensor. We have used the sensor as both a source to verify data and a reason to take data measurements by hand with high school students. Our Mayfly sensor helps root our work in science and enables us communicate river science to the community in a deeper way.

Continuous data and data analysis

We have data on a section of the Schuylkill River that we have not had in the past. It is reliable, continuous, and constantly updated, providing a real-time snapshot of the River.

It has had very little issues with quality control, data accuracy and precision. Only depth and its place on the river bank has affected the sensor data.

Personnel, volunteers, organizing, etc.

Volunteers are excited to work with the equipment. It helps them feel like their data is more valid and useful and they have a means to check their hand-collected data. The Mayfly sensor has also spurred a larger research project among four centers along the Schuylkill River that possess a Mayfly on their local river section and have begun to take more data with volunteers. We are in the beginning stages of locally sharing our data internally with each center and our sensors continue to inform our research. We hope to be able to make conclusions from our research and communicate the health of the Schuylkill River to the public, using our sensors as a way to continue to communicate future findings with the public and allowing them to access the real-time reporting.

<u>Technology, sensors, troubleshooting, maintenance/management, etc.</u>

Stroud has been wonderful with troubleshooting and helping us stay on top of maintenance and management of the sensor. Our volunteers play a critical role in the maintenance of it and checking in on the equipment.

<u>Information/data sharing, communication, and curation/storage</u>

We now have a little over a year's worth of data and we hope to continue to collect the data and use it to find answers to research questions.

<u>Education and engagement</u>

We are able to engage local students and volunteers in a very new way that we have not in the past. We use the sensor and its capabilities to explain river science in another way to adult program participants. We are currently building a research project with a lot of community engagement and the sensor and its data spurred this work.

Organization: The Nature Conservancy Stream Stewards, Delaware/Pennsylvania; Station Manager: Jeff Chambers, Kim Hachadoorian; Stream/River: Rocky Run and others (http://monitormywatershed.org/sites/ROCK_US3/)

Based on Mayfly sensor data from Upper Rocky Run, we have learned that Upper Rocky runs with very high conductivity year round, and suffers from extreme conductivity spikes related to salt laden runoff from road brining in winter months. In an attempt to understand the cause of the high conductivity, we have undertaken a reconnaissance of Upper Rocky upstream of the FSNHP. Through water samples of outfalls taken in a section of the stream confined in a concrete conduit, several very high conductivity sources were identified. Based on data from the Mayfly sensors and laboratory analyses of the samples, a report was submitted to New Castle County, DE authorities. Upon further investigation by the county, at least one of the outfalls was traced to a misconnected underground conduit, resulting in direct discharge of heavily polluted water into Upper Rocky. As a result of the investigation, the pollution source was capped.

This investigation has been published in The Nature Conservancy's Newsletter. Also, I have been invited to discuss these findings in a Keynote speech to the Wilmington Trail Club (WTC) Annual Dinner in April 2020. This is an opportunity to educate WTC members about watershed issues in Northern Delaware. The Nature Conservancy's Stream Stewards program, and Stroud Water Research Center. As a result of my involvement in the Stream Stewards, I have also been invited to discuss water quality issues in two lecture series at the University of Delaware's Osher Lifelong Learning Institute.

Organization: The Nature Conservancy, Delaware/Pennsylvania; Station Manager: Kim Hachadoorian; Stream/River: Rocky Run, Hurricane Run, Beaver

Creek, Palmer Run, Ramsey Run (http://monitormywatershed.org/sites/HURR_US2/)

Using Mayfly Sensor stations developed by The Stroud Center has been invaluable for achieving the goals of our Stream Stewards Watershed Stewardship program. The data collected by Stream Stewards citizen scientist volunteers is contributing to science-based management of the land in and around the park to improve and protect water quality in Brandywine Creek. Stream Stewards participants gain a first-hand understanding of the threats to our waterways and the ways in which scientific information can help to address these problems.

Engaging in this work has led many volunteers to become more active in other watershed stewardship activities, such as advocacy, public outreach and education. One volunteer, Jeff Chambers, began teaching a course on Water at the UD Osher Lifelong Learning Institute, and he will be delivering a keynote address about his water quality monitoring work at the upcoming Wilmington Trail Club's annual dinner. Another volunteer, Rob Tuttle, developed a program for data analysis and visualization. Other volunteers, like Chuck Wagner, have been attending public hearings, to use what they have learned as Stream Stewards to advocate for their local watershed. As a result of their work with the sensor stations, volunteer have become true ambassadors for watershed protection.

Because of our partnership with First State National Historical Park, where the sensor stations are located, we have been able to provide evidence of the high water quality in the streams that are contained within the park boundaries. This underscores both the importance of protecting these high quality streams and also the impact of proper land management and maintaining forested banks. Having sensor stations in a National Park also provides the opportunity to raise awareness among park visitors about the importance of data collection and using science to guide management and decision-making around natural resource protection. We intend to incorporate the citizen science work with the sensors into interpretive signage and programming in cooperation with the National Park staff.

Organization: Wallkill River Watershed Management Group; Station Manager: Kristine Rogers; Stream/River: Paulins Kill (http://monitormywatershed.org/sites/NHPK9S/)

<u>Where the Wallkill River Watershed Management Group plans to go with use of the data</u>

The sensor data will be used to help our organization track if any water quality improvements can be observed from stormwater BMP installation on the community college campus. Last summer, the Wallkill River Watershed Management Group received a NFWF grant that included funding for the installation of porous pavement parking lots, tree trenches, rain gardens/bioswales, and tree and shrub planting within the SCCC stormwater detention basins. Project installation is set to begin this spring-summer and will hopefully allow the Wallkill River Watershed Management Group to track whether or not the stormwater best management practices reduced flashiness and pollutant inputs to the Paulins Kill River headwaters.

Ongoing challenges

Volunteer capacity and SCCC professor commitment to this effort have restricted the effectiveness that the sensor station installation is resulting in on campus. Due to the fact that I work in a small, 3-person organization and wear multiple hats, with the sensor station monitoring being only a tiny aspect of the grant writing, reporting, communication, educational event organizing, and meeting facilitation that I do, I feel that the ultimate educational opportunities of our sensor station have not been reached. The SCCC science professors have not wanted to incorporate in-depth analysis of the sensor station read-outs into the classroom, which means the burden has been on me to keep the process and student involvement going. I have typically had first-year environmental science students assisting with the maintenance of the sensor, but they have only wanted to get directly involved in the process during the semester that they have the environmental science class in order to fulfill their service learning requirements for the course. Volunteer turnover has remained a continuous battle at SCCC and remains my most difficult struggle for keeping the educational component of the program going.

Possible future directions

Since I don't have a science background, I have trouble identifying/interpreting trends in the data. Perhaps, every other year, Stroud staff members can examine the data for each of the sensor stations within the Delaware Basin and send an individualized report to the sensor station manager about the high-level patterns and trends that are being observed as a result of the continuous data collection. This sort of report would be beneficial for non-science majors to convey the important take-aways from the continuous data collection. Such information could easily be shared with students, volunteers, municipal officials, and organizational board members in order to convey information about stream impairments and take action at the municipal policy level to enact local ordinance change. In the future, I see the Delaware sensor station network really being used to inform and strengthen local environmental policy. If the manager of the sensor station works for an organization that does not become involved in municipal politics, the water quality data summation from Stroud can be shared with our statewide cluster partners (like ANJEC) whose sole mission is to work for change at the municipal level. In my opinion, the sensor station network is not working to its full potential unless the scientific data is being used to change the hearts and minds of people living within the watershed and helping to create legislative policies that can be used to strength local ordinances and practices.

Organization: Penn State Master Watershed Stewards; Station Manager: Carol Armstrong; Stream/River: Pickering Creek (http://monitormywatershed.org/sites/SHPK5S/; http://monitormywatershed.org/sites/SHPK6S/)

The Pickering watershed has its European history dating back to the 17th century. It was the territory of the Lenni Lenape people who were the first to inhabit the beautiful highland woods that filled the watershed. However, in the late 1600s, the British King Charles II repaid a debt and granted land to

William Penn. The creek was named after Charles Pickering, to whom William Penn granted 5,383 acres along the creek where Mr. Pickering mistakenly thought there was silver. The Pickering is impounded just downstream from one of the EnviroDIY sensor stations into the Pickering Creek Reservoir where it is a source of drinking water for many relatively old communities. According to the Dept. of Environmental Protection (DEP), it is subject to the point and non-point stormwater runoff from communities with high human impacts from treated sewage, untreated sewage, cars/tires, salt, plastic debris, industrial facilities, agricultural runoff, above ground storage tanks, landfills, and spills and accidents (PSW-Pickering Creek Intake: Public Summary).

The stream I have collected the most data on is the Pickering Creek of northeastern Chester County. It was straightened and buried underground in places for roads and farms long ago, and further modified as the population increased. It has the PA Turnpike along the southern portion of the west half of the watershed, and stretches as far west as Rt 100 and Lionville; it goes almost as far north as Birchrunville; to the east, most of the watershed is in Charlestown Township. The runoff comes from Schuylkill, Charlestown, East Pikeland, West Pikeland, West Vincent, and Uwchland Townships.

Model My Watershed (ModMW), reveals that upstream of thePickering Reservoir in Schuylkill Township Pickering Creek has a total length of 75.26 km, with 50% as a first order stream, 29% as a second order stream, and 17% as a third order stream, flowing into the Schuylkill River. However, it should be noted that this summary from ModMW uses medium resolution stream coverages so many of the small headwater tributaries are not included. According to the ModMW 2011 land use data, little remains in agricultural areas (8.7%). The watershed comprises 27.21 km2, and the largest portion of the watershed is deciduous forest (32.5%); high and medium density development is 2.8%, low density is 4.5%, and developed open space is 16.1%. Pasture and cultivated crops are the other predominant use at 28.7%. These proportions may have changed significantly since the 2011 with numerous residential and commercial developments having taken place over the last decade.

The Pickering sensor station site at Montgomery School is incised as it runs straight past old farms and Rte. 113 which was built up above the right bank of the stream, and active scouring is seen on both banks. The banks have remained relatively stable as the School built several detention basins to prevent flooding of school buildings (school founded in 1915), which has caused the stream to rarely ever reach its flood plain. The downstream Pickering sensor station at the Phoenixville YMCA is much broader, about 70 feet at the sensor station, but broader above and below that point. The banks are shallower, although the right bank is also limited by Creek Road, about 150 feet from the stream and thus it is a deeper bank and shows much sign of scouring. The left bank is shallow. Both banks often reach the flood plain during a heavy rain.

Both streams are actively managed, and data from the stations have been used by the American Eel (Anguilla Rostrata) research study being conducted by Erik Silldorff, Richard Horwitz, David Lieb, and Heather Galbraith, with the goals of reducing the invasive crayfish species, bringing back the native crayfish, and increasing other biodiversity. Neither site was deemed suitable for release of 100 American eels of varied ages, but different sections of the headwaters only about a mile upstream were chosen as healthy aquatic environments for the releases, and where some native crayfish had been found. Evidence of invasive crayfish can be seen at both the Montgomery School and YMCA sensor station sites, along with Asian clams, blue herons, kingfishers, fox, deer, and native wildflowers.

Maintaining a sensor station and managing the sensors and programmable Mayfly microprocessor boards are critical for the purpose of getting usable data from the sensor station. Active management of the sensor stations included cleaning when turbidity reaches a level above that naturally expected either during base flow or storm flow. Base turbidity was identified when the station was installed, and used as a benchmark for fouling of the sensors. Regular management also included observation of the battery and identification of problems that could disrupt the battery's functioning and damage the Mayfly board. A problem that occurred one summer was nesting ants inside the Pelican box, which could not be cleaned with chemicals and which required manual removal of the ants; fortunately, their activity did not damage the station, which can happen if there is a delay in detecting them. Thus it is important to examine inside the Pelican box that houses the station modules and antenna regularly. Another problem occurred when moisture was frequently getting into the box, probably due to bolts that had subtly loosened, and thus cables entering the box should also be checked. The moisture led to a damaged battery. Batteries can lose power if they become unsynchronized with the solar panel, leading to much draw on the battery at times, appearing as repeated frequent big changes in high and low voltage that is not typical. During maintenance visits, cables should be observed for breaks or tears, which most often occur in some sites due to animal activity, but which did not occur at the Pickering sites. (The exception was a break in a sensor wire inside a cable that was not visible externally, and was only identified when an engineer went through systematic trouble shooting of the failed sensor.)

Some sites foul very easily, such as the broad downstream Pickering reach, where a great deal of debris flushes downstream during storms, including trees and large branches, and large stones or small boulders. Also, so much cobble flushed down during the record strong storms of 2018 that it built up in the middle of the stream, so that it changed a broadly distributed set of currents into two main currents along the left and right banks. Another maintenance problem at these sites is aquatic mineralization of the turbidity and CTD sensors so that the turbidity sensor's optic window was blackened and could not function correctly, and the sensor had to be replaced. Although the CTD slot was also blackened, as were the steel rods and cables, it did not damage the pressure transducer or electrodes. Any of these problems could compromise the accuracy of the sensor data, especially turbidity and conductivity. Furthermore, the position of the antenna away from the microprocessor board, the cleanness of the solar panel, the position of the memory card that is inserted into the Mayfly, and the cleaning of the sensors (debris, sediment, algae) are critical for gaining and saving usable data that is relatively complete and accurate.

Another important function is quality control measurements of station data that are collected at least quarterly. These are human controlled measurements of water depth, of conductivity meter with a hand-held meter, hand-held temperature probe, and of any other chemical metric with an externally implemented meter to compare with the in-stream online sensors. My experience in examining conductivity with a Hanna conductivity meter on a monthly basis for 1.5 years is that data drift might occur as seen by comparing the hand-held instrument with the online sensors (that are of a higher quality). The hand-held meters must be calibrated before use at intervals recommended by the manufacturer. Such drift appeared to occur after almost a year of use, and was tested with various procedures to assess whether the Hanna meter was giving accurate measurements. The field measurements suggested that the Hanna was slightly diverging from the in-stream sensor in a negative direction over time. Assessments of its accuracy in calibration, measurement of the standard, and measurement of distilled water showed more variability than expected in the Hanna's readings. This suggested that it was likely less accurate than the in-stream sensors (Meter Group and Campbell Scientific).

Readying the data for analyses requires extensive work to collect enough data to calculate the volume of water and velocity at the range of storm stream stages at the sensor station site. Data should continue to be collected in order to provide redundant data all along the stream stage. In the downstream Pickering site, we have collected 30 data sets mainly using the neutral buoyant object method (NBO). During storm events, the stream currents becomes very deep and swift, and are too dangerous to navigate with a flow meter during a storm, and measurements would be very difficult to make for the same reasons. At the upstream Pickering station, we have collect 19 data sets using NBO. More data is needed to build the discharge curves at both sites. Using a flow meter is considered more accurate but is difficult to do in streams when the streams exceed one meter in depth. The highest depth at which discharge measurements and grab samples were taken at both sites was 1.43 meters; at the narrower incised upstream site the total discharge was 13.25 meters3/second, and at the wider downstream site the total discharge was 35.40 meters3/second. Grab samples have been collected at both sites, allowing us to build the chloride:conductivity and TSS:turbidity curves. Due to the great deal of variability that occurs in the material moving through a major stream during a strong storm event, some correction and selection of the data must be done in order to find meaningful relationships. Once this work is done, then the discharge volume/velocity data can be applied to the chloride:conductivity and TSS:turbidity regressions, in order to measure how much chloride and how much total suspended solids are moving through the stream during a selected storm.

Although the equipment, station and sensor management, sampling, and analyses are not done frequently enough or at a professional level needed for regulatory use or comparison, the data can contribute to understanding the effects of storms, changes over time, and comparison of sites and their surrounding land uses for the purposes of educating local governments, businesses, schools, and residents. I hope to build enough information about the downstream Pickering station to engage the YMCA to understand the importance of best practices in managing uncovered salt piles in winter, and to increase their sense of value of the stream flowing through their property, especially for educating their facilities personnel and children's programs. I have conducted a monthly measurement of conductivity and temperature in the runs and tributaries on the YMCA property to learn which areas of human use are contributing most to conductivity which is elevated in this stream about 200 uS/cm above natural levels (by comparison with a spring on a small horse farm that seeps into the Pickering). I hope to continue to map the sources of pollution coming into the Pickering at the YMCA from old housing developments, roads, and three public schools. I plan to learn whether macroinvertebrate sampling at the stream site is possible, as another comparative measurement of the outflow points into the Pickering tributaries.

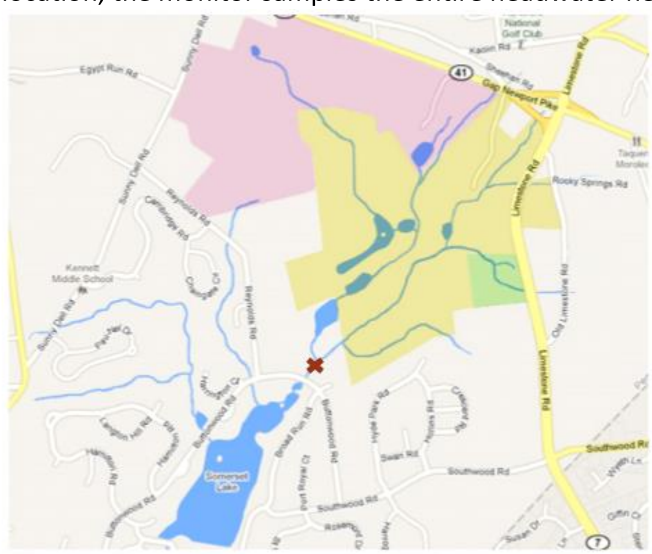
Data is being shared with many stakeholders, including a watershed science coordinator with Green Valley Watershed Association, middle school teachers at both sites, science team working on the American Eel study, the YMCA, the PennState Ext. Master Watershed Steward program, and the Stroud Water Research Center. Observations of unprotected salt piles was shared with Schuylkill Township, who reported it to the Clean Water Operations of the DEP. The facilities personnel have not sufficiently protected this salt source, and it is leaching through the soil, moving downstream toward the stream. Exploratory measurements show elevated conductivity at the stream edge near the salt pile, though the sources of salt are not just from this pile but from decades of salting the roads and driveways at the YMCA and near state and local roads.

Organization: Watershed Hydrological Analysis Team/Somerset Lake Watershed Committee; Station Manager: Dave Yake, Marion Waggoner, Bill Ward; Broad Run (http://monitormywatershed.org/sites/BCBR1S/, but not online)

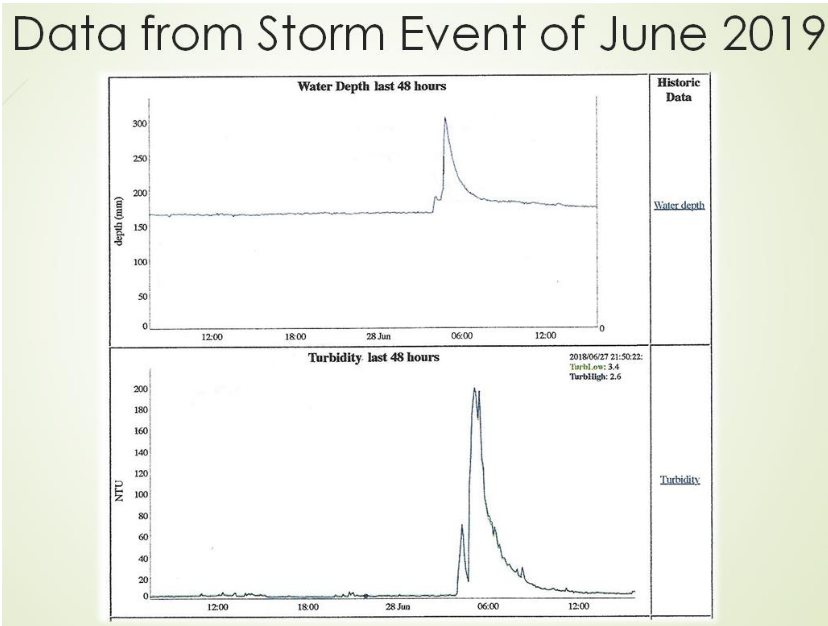
This is summary of a presentation we made to the New Garden Township Board of Supervisors on Jan. 21, 2020. It describes how we used our stream monitor (SL177). The most important point is our conclusion that the data from the monitor provide a tool to detect changes in watershed quality. This is to alert the township supervisors about J.P. Morgan/Chase, who have just announced plans to build a mixed residential/commercial development in our Broad Run watershed.

Presentation to the New Garden Township Board of Supervisors on January 21, 2020

This overview illustrates the headwaters of Broad Run, shown as a network of blue lines. Branches of the network originate in the St. Anthony's property (yellow area), in the J.P. Morgan site (pink area), and in the former township dump (green area). The stream monitor is located here (red X) just before Broad Run passes under Buttonwood Rd. and enters Somerset Lake, on property owned by Stan Lukoff. In this location, the monitor samples the entire headwater network of Broad Run.



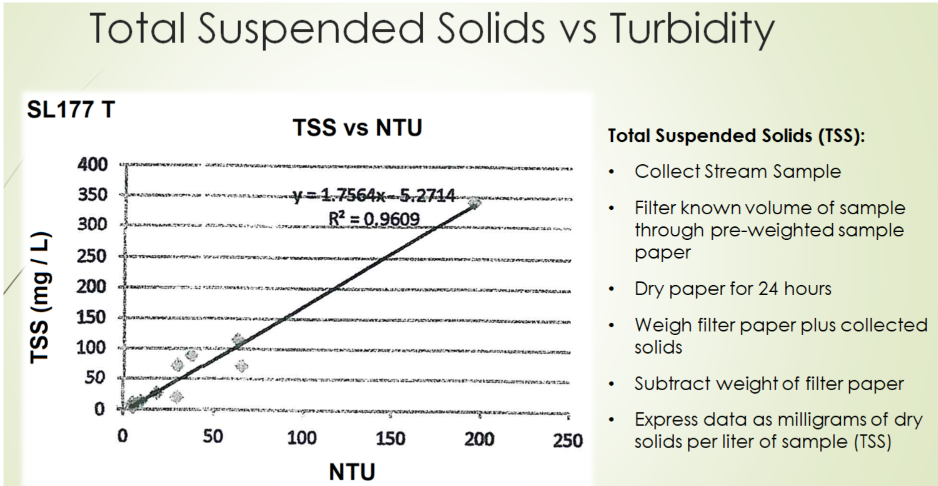
Here are data from a rain event on June 28, 2019. The upper panel shows stream depth as a function of time on the X-axis. Prior to the start of rain, Broad Run was at its typical base flow of 6". When the rain started around 4 AM, stream depth quickly doubled to 12", then recovered fairly quickly. This was a moderate rain event. We have seen heavy rains elevate stream depth at this site to almost 3 feet.



The turbidity sensor (lower panel), whose data are expressed in Nephalometric Turbidity Units (NTU), tracked quite closely with changes in stream depth. The most recent 48 hrs are routinely displayed, but the data are archived, so we can revisit past rain events if necessary. Our hope was that with sufficient data we might be able reliably to correlate these NTU data with actual sediment load into Somerset Lake. But the lake doesn't fill with NTUs, it fills with dirt. So initially we had to measure sediment loads directly.

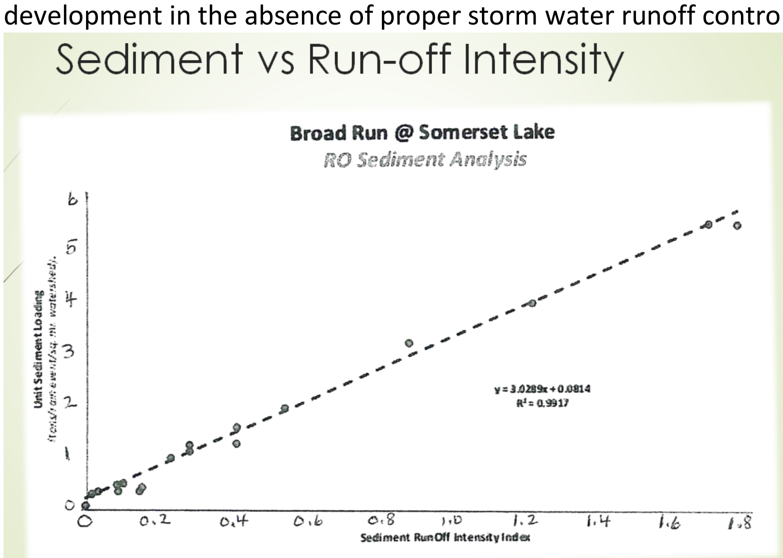
And the way we do that is by measuring Total Suspended Solids (TSS). We collect a stream sample, filter a known volume of sample through a pre-weighed filter paper, and dry the paper for 24 hrs. Then we reweigh the filter paper containing the collected solids, subtract the weight of the paper, and express the data as mg of dry solids per liter of original sample. It's Science putting a number on how muddy the stream looks. For quick reference, if TSS is less than 10, the stream looks clear. If TSS is in the hundreds, the stream is definitely turbid. And if TSS is in the thousands, Broad Run looks like it is carrying liquid mud. That has happened several times in the past 18 months.

The figure on the left demonstrates some of our initial data comparing NTU from the monitor's turbidity sensor on the X-axis, with TSS values from our laboratory on the Y-axis, in stream samples collected at known times on the turbidity curve. Stroud identifies our monitor as SL177. We were encouraged by these initial data. There appeared to be a reasonable linear correlation between NTU and TSS. We wondered if the monitor could reliably tell us the sediment load, without having to actually measure TSS all the time. But our optimism quickly faded as we encountered major rain events. Once TSS exceeded 400 mg/L, the turbidity sensor began to give spurious results. And TSS can reach 5-10 times the level. Heavy sediment loads foul the turbidity sensor's window, and NTU data jump all over the place. We needed to find a more reliable way for the stream monitor to tell us what TSS was over the entire spectrum of rain events, not just the minor ones.



One possibility was the stream depth sensor, which produced reliable data at all times. Our colleagues Dave Yake and Marion Waggoner looked carefully at archived stream depth data from 18 rain events for which good TSS data existed. They developed an analytical model based on three features of the stream depth curves. First, how steep was the initial rise of the depth curve? This reflects the intensity of the rainfall. Second, how deep did the stream ultimately get? This reflects the total rain amount. And third, what was the shape of the recovery curve as Broad Run returned to base flow? This reflects the duration of the rain event.

Using these data, Yake and Waggoner developed a Runoff Intensity Index, shown here on the X-axis of this last slide, plotted against total sediment load per rain event, based on TSS data from the laboratory on the Y-axis. Each data point represents an individual rain event. Several interesting conclusions emerge from this figure. First, there is remarkable agreement between the runoff model and the field data. A second, and for us an alarming, feature of this figure is that significant rain events can deposit 5-6 tons of sediment into Somerset Lake, per event. That needs to change. The final point worth noting about this curve is that its precision will allow us to detect changes in the watershed, with respect to soil erosion. If watershed quality improves, as we are working hard to ensure, this curve will become flatter. If, on the other hand, watershed quality deteriorates, for example as a result of land development in the absence of proper storm water runoff control, this curve will get steeper.



In conclusion, the stream monitor you funded in 2018 has provided valuable information about how the Broad Run watershed responds to rain events. Perhaps more importantly, the monitor provides a tool to detect future changes in watershed quality. Your support made this possible, and we thank you.

Organization: Valley Forge Trout Unlimited; Station Manager: Al Renzi; Stream/River: Valley Creek (http://monitormywatershed.org/sites/SHVC1S/)

Title of the project

The Valley Creek Monitoring Project, located at the former Knickerbocker Landfill site in East Whiteland Township, Chester County, PA

Environmental Need

Protect the Valley Creek Watershed, an EV and Class "A" wild trout fishery, and address the threats posed by upcoming development at the former Knickerbocker Landfill.

The focus of this project is a continuation of our chapter's efforts to monitor and maintain the health and vitality of Valley Creek (VC) for the wild brown trout that inhabit it in the face of the continuing development of the creek's watershed. Valley Creek is designated as an Exceptional Value(EV) Stream as well as a Class "A" wild trout fishery. Valley Creek is located in Chester County PA and is a tributary of the Schuylkill River.

The overarching focus of this effort is to meet the goals of the Health Waters Initiative, which is to protect the aquatic systems and watersheds of Pennsylvania, including the Valley Creek watershed. This project is designed to curtail threats that are projected to lessen the integrity of Valley Creek an Exceptional Value stream and Class "A" Wild Trout fishery.

The health of Valley Creek is of critical importance since 6 million people live within the Philadelphia metropolitan area. The head waters are located in the south and north ridges of the western part of the Great Valley. The creek flows east through East Whiteland and Tredyffrin townships and finally through Valley Forge National Historical Park (VFNHP) passing Washington's HQ before entering the Schuylkill River. The conservation impact has both regional and national implications. Currently, the water shed is estimated to be over 20% impervious surface.

A development project is being proposed in East Whiteland Township for the construction of housing and commercial space on the site of the former Knickerbocker Landfill, which is located in the western end of the Great Valley close to the headwaters of Valley Creek. This site was an active landfill for many years and part of the development site is in the 100 year flood plain, has significant slope areas greater than 25% and has wetlands adjacent to it. Since Valley Creek and tributaries flow along and across this site, we are concerned about how this development could affect the health of the Valley Creek watershed, including the Valley Creek waters traversing Valley Forge National Historic Park.

Development of this site could potentially create significant runoff and pollution that would affect Valley Creek, an EV stream and Class "A" Wild Trout Fishery, that currently contains wild brown trout. There are no stream monitoring devices in this area that could help us determine any adverse events in Valley Creek. These are all potential risk factors, and emphasize the importance of a stream monitoring system.

Project Goals

We will use the Stroud Water Research Center (SWRC) developed EnviroDIY Mayfly Sensor Stations, an electrofishing study and an VFTU member driven baseline macro study to establish a baseline physical and biological assessment of the stream in the development area, that then can be used to measure changes to the health of the stream. We will also conduct targeted monitoring visits before, during, and after storms to evaluate sediment transport and hydrology in relation to the development. We will partner with Stroud Water Research Center for this project.

Current Experience as of 2/10/2020

One of our keys goals in initiating this project is to educate and engage the VFTU membership on stream ecology, monitoring and data collection and how this can help drive decision-making before, during and after the development process. We are creating a VFTU Stream Team that will take ownership of the loggers and will be important for making this project a success.

The initial install occurred on September 26th. At that time, members of Valley Forge Trout Unlimited, an East Whiteland Township supervisor and staff from Stroud were present to install the logger. Stroud representatives provided detailed explanation of the installation process and equipment. Maintenance and recordkeeping was reviewed as well.

The first few months of operation of the logger has involved general maintenance of the unit. At this time, we have one of two loggers installed. We are using the first install to learn the basic operation and function of the unit. We have undertaken maintenance visits every one to two weeks depending on the integrity of the data that we can view on-line. In particular, our main concern has been with the turbidity sensor, since this seems to become covered with algae within a short period of time. Also, when the logger was first installed, we discovered that the battery was not functioning properly, so Stroud replaced the solar panel with a larger panel. Since that time, there has been no problems with battery function.

On February 1st, a total of eight VFTU members were in attendance to review QC operations for the logger that will be undertaken every quarter. Additionally, the necessary paperwork and digital data entry was reviewed and the opportunity to have questions answered was welcome.

Our recent efforts have focused on learning the logger, data entry and understanding how to maintain the equipment. Our next set of goals for 2020 will be to conduct targeted monitoring visits before, during, and after storms to evaluate sediment transport and hydrology continue our QC quarterly assessments, complete a VFTU member-driven baseline macro study of Valley Creek and install the second data logger downstream from the proposed development site. This set of goals will serve as a good baseline for further data analysis in 2021.

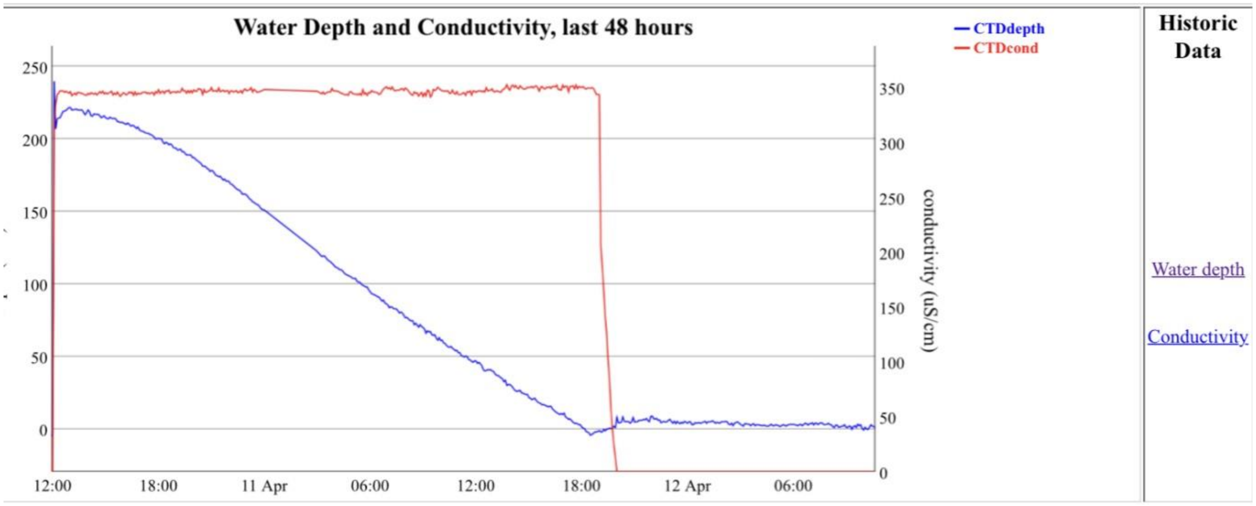
Data interpretation

During the course of our activities in learning the function of the data logger, we did have the opportunity to review our data output versus other loggers nearby in the Pickering Creek. The Pickering is a freestone creek and is classified as an HQ stream. Valley Creek is a limestone creek and is classified as EV. In reviewing one of the loggers in the Pickering Creek watershed, it was notable that the temperatures appear to be lower in the winter and higher in the summer than the corresponding temperatures in Valley Creek. In addition, the conductivity in Valley Creek is considerably and consistently higher than Pickering Creek. We think this heightened conductivity and temperature difference in Valley Creek is most probably due to the limestone and in-spring nature of the watershed. We also take note that there are at least at this point significant turbidity differences with the Pickering baseline turbidity being higher than Valley Creek. We believe that this may be due to the fact that the Pickering logger is installed in a tributary of Pickering which may account for higher turbidity readings. Given the short-term nature of our data at this time, we can use these data to further inform our monitoring efforts and exemplifies the importance and uniqueness of each watershed we inhabit.

Organization: Primrose Creek Watershed Association; Station Manager: Francis Collings; Stream/River: Primrose Creek (http://monitormywatershed.org/sites/PUPC2S/; http://monitormywatershed.org/sites/PUPC3S/)

What PCWA has learned about our watershed in the Stroud EnviroDIY Mayfly Era.

We knew that Primrose Creek's main channel is bisected by a huge limestone quarry. What we learned is that the upper and lower reaches have very different values for baseline parameters in depth, conductivity and air and water temperature. The two sensors monitoring our creek every 5 minutes, 24 hours, 365 days and has made us aware of the ongoing and sudden changes in both reaches of the Primrose Creek. Using a newly installed Primrose Hotline , PCWA community can observe and respond to night and day, day to day, weather, wet and dry periods along with natural (sinkhole) and manmade(illegal dumping) events.



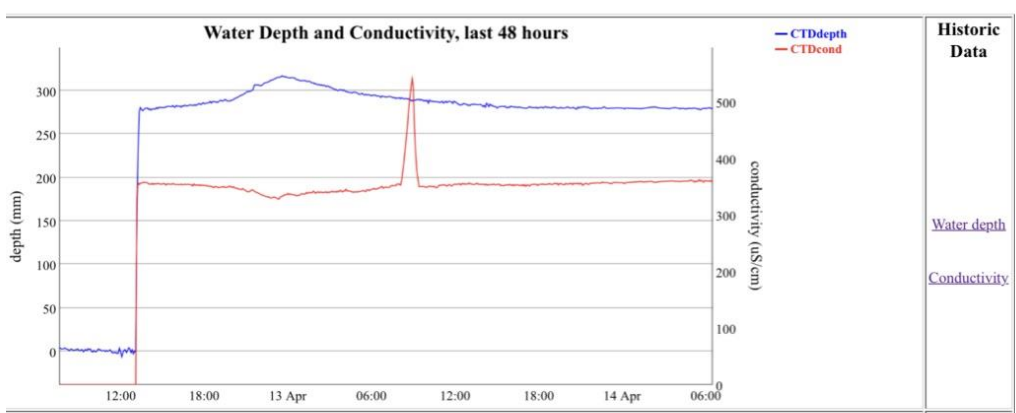
SL158 Turbidity/CTD Logger

This is data from logger SL158.
The logger is equipped with a Decagon CTD which measures water conductivity, temperature, and depth.

Show all data in the database as table or as CSV text
Get raw CSV text file

Latest readings:

At 2019-04-14 06:30:47 EST:
CTD Depth= 280.3mm, CTD Temp= 15.5 degreesC, CTD Conductivity= 360.7 uS/cm
Board Temp= 12 degreesC; Battery= 4.06 volts

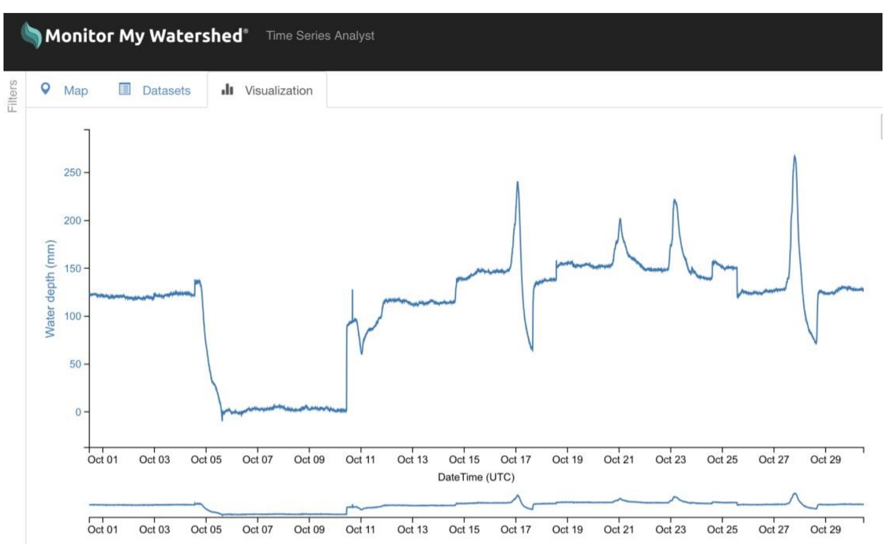


A sinkhole opens up in Primrose Creek April 10, 2019 on Solebury School campus.
Red copper sulfate stream dumping by resident recorded/reported to the DEP 4-15-19

We have learned that our stream and stream ecology is vastly different in water quality between the upstream and downstream stations. Biannual data sets are recorded by the sensors and supported by ground truth and pollution tolerance index (PTI) macro-invertebrate surveys conducted by high school classes.

Having the ability to monitor a continuous data record and data analysis displays in the new Monitor My Watershed online format, assists in identifying cause and effect when big questions are raised about the conditions of the Primrose watershed.

PCWA is light years ahead of our old kit subjective monitoring. The new sensors en-courage our monitoring team members to follow quality control, data accuracy, precision standards and practices.



EnviroDIY

Attracting personnel, volunteers, and organizing is still the biggest challenge to our association.

Wanted! STREAM STEWARDS

Congratulations to All at Stroud! Due to the excellent continued educational and technical support by the entire faculty of Stroud, the task of pre-service orientation, in-stallation, and troubleshooting the technology, sensors, maintenance/management continues a high level.

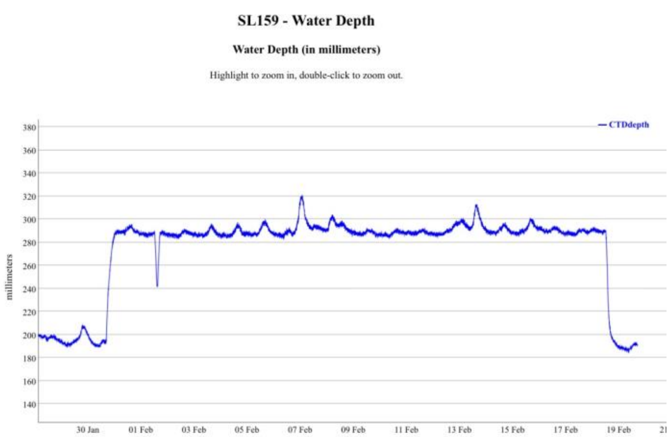
Because of the excellent efforts of the Stroud support staff, Information/data sharing, communication, and curation/storage are extremely accessible when needed.

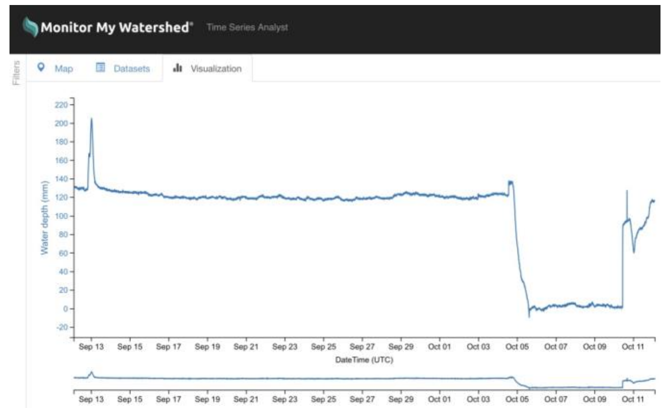
Interwoven with Stroud support and sharing, education "Schooling" Watershed 102 and other environmental support workshops and personnel engagement by the Stroud staff are frequent, ongoing and freshly delivered by first class scientists.

Primrose ? Creek ? at Phillips Mill ?

What did the data tell you that you that you didn't know before?

The NHCS quarry was not keeping its responsibility to maintain constant stream flow of 500,000 cubic feet per day. Due to “mechanical” failures and inept management, the lower reach of the Primrose was flooded with 1,500,000 cubic feet per day for 19 rainy February days and no pumping for 5 days during a hot and dry October.





What we didn’t know was the Primrose watershed’s overall big picture”

Stream pirating caused by accelerated sinkhole formation in the upper reach’s stream channel leads to the precarious depletion of water and stress on macro-invertebrates, and the hydrostatic depression of the local aquifer and community household water wells.

Conductivity data spike analysis confirms the point source dumping and overflow of toxic chemicals by residential and municipal sources. Namely; copper sulfate, animal manure, fertilizers and road salt.

The above narratives show how PCWA's collaboration with Stroud results in "AEE"… Action, Engagement and Education for our PCWA volunteers, area Bucks County schools and well water users in and beyond the Primrose Watershed.

Primrose Creek Watershed Association, supplementary email from Francis Collins, March 11, 2020:

Most importantly you have to have a reason for why you want real time water monitoring.

The reason that the Primrose Creek watershed association has been testing water was that we wanted to know what was affecting water quality and quantity above and below the quarry in our bisected creek.

We wanted to be able to share that data with all of the residents whose water wells were impacted by drop in the water table in the 1.5 mile radius cone of depression around the New Hope Crushed Stone Quarry.

In 2013 our initial water monitoring (4 year effort) involved a team of volunteers sampling once or twice a month at two locations with a scientific "cookbook" Lamotte kit and manual. https://www.lamotte.com/en/

At the end of this four year phase we came to the conclusion that our data was woefully sparse and inaccurate to be of any value to the association members, home owners and township supervisors.

We also agreed that the biggest investment in the cost of water monitoring testing is the investment in time by the "boots in the stream" volunteer testers. We searched for a data logger device that could substitute for "boots in the stream" but balked at the prohibitive costs... And lack of support after installation.

https://www.globaltestsupply.com/brands/hobo-data-loggers/level-water-indicator

The breakthrough "Ah Ha moment" came when our education and monitoring team members attended the Delaware Watershed Congress in Pottstown and joined the workshop of the Stroud Enviro DIY Mayfly sensor project. We observed that once deployed, the mayfly sensor would record every five minutes every 24 hours. It would send the data via cellular connection to the Web. What we would have is a real time display of what was going on in the creek.

What has been going on?

In the two years that we have been monitoring we have correlated many watershed stressors and anomalies of suspicious water depth changes, caused by the formation of sinkholes and the breakdown of quarry pumping. We have been able to monitor residents who have dumped toxic substances and periodic road salt and manure intrusions.

Students have been able to correlate these stressors with macro invertebrates population studies that show marked differences in upstream and downstream water quality.

We now have the township supervisors undivided attention. We monitor air and water temperature, water depth, and conductivity for the detection of volatile dumpings and intrusion by highly conductive chemicals. These are important to monitor for the safety of drinking water for residents, students, farm animals and wild life.

Take a look for yourself at our sensors in real time.

Upstream at Solebury School

http://monitormywatershed.org/sites/PUPC2S/

Downstream at Phillips Mill

http://monitormywatershed.org/sites/PUPC3S/

I would just like to say that the Mayfly is a bargain if you consider that a single hand held YSI multi meter and probe can cost as much as

That YSI multimeter would not monitor the creek every five minutes 24 hours of every day.

https://www.ysi.com/
I would say that the Mayfly is a bargain if you consider that one station that is online can be monitored by every single resident in the watershed by going to **monitor my watershed.**

https://monitormywatershed.org/

I would say that it is a bargain if you consider that one station can be your organization's keystone to an educational environmental outreach program in any school or interested member in your watershed.

To answer the question about a budget…Consider what Dave Bressler and Stroud are offering…

Education and monitoring it can be disseminated on the web to all the residents in your watershed. The most important things Stroud is offering… Education and monitoring it can be disseminated on the web to all the residents in your watershed. The cost is about one brand new MacBook $1300 with a $100 per year cell bill and $500 in the bank for contingency repairs.

Please ask any questions and by the way....

Wet Booters Larry Hampt, Carol Cope and I will gladly take you on a wet boot walk to introduce you to our sensors.

Organization: Great Marsh Institute; Station Manager: Jim Moore; Stream/River: Marsh Creek (http://monitormywatershed.org/sites/BCMC3S/; http://monitormywatershed.org/sites/BCMC4S/

Great Marsh Environmental Study

This is a broad based study on the effects of various inputs to the outgoing water quality of Marsh Creek. These inputs comprise precipitation, storm water runoff, and agricultural runoff/infiltration.

We currently have 8 sensor stations; two are the Stroud mayfly stations (BCMC3S and BCMC4S) and six are the low-cost EC sensor stations (GMI_EC#n) which we developed around the Mayfly data logger. The two BCMC stations are located on the main stem of Marsh Creek and the six GMI stations are located on various tributaries into the Great Marsh watershed. The locations are shown on a GE image in figure 1.

GMI_EC2#2 is located in a dry ditch which was caused by runoff from the Pennsylvania Turnpike. A picture of this sensor station is shown in figure 2. It consists of a dam with a V-shaped cutout to measure flow volume using a camera that is triggered by conductivity. The camera is idle during non-storm times because the conductivity will be close to zero or zero. During a storm event the water will rise in this dam and trigger a trail camera when the EC is greater than 50 µS. As long as there is water in the dam the camera will take one picture per data upload interval which is currently set for five minutes.

There was a storm event on the morning of Feb 7 with a total rainfall of 2" and a maximum rate or 2"/hr. Figure 3 shows data from five of the GMI EC sensor stations and figure 5 shows the data for the same time frame from the two Mayfly Decagon sensor stations. The camera images during the heaviest rainfall where made into a time lapse movie clip. This was the first storm event where the station worked as planned. However, a few design changes where indicated which include reconfiguring the location of the EC probe so as to be able to seal the catch basin. The water currently leaks out where the anchor stake is located which compromises any estimate of total volume during a storm event. With this sealed the water will need to be removed with a syphon to reset the station for the next weather event.

Observations/Questions:

- I expected the storm water runoff would have a much higher EC than the 70 µS maximum observed at GMI_EC2. Since the weather was warm there was no salt or brine treatment and oil and other automotive drippings may not contribute to ionic levels that would cause a rise in EC.
- The high volume of water on Feb 7 caused the EC probe at GMI_EC5 (see fig 4) to get buried in stream sediment which caused a drop from a typical EC of 180 µS to ~100 µS. When the probe was repositioned on Feb 16 the EC returned to normal base line values. I assume that since the sediment, which was mostly sand, is non-conductive this would cause a drop in the average conductivity in the sensing port hence lower EC readings.
- GMI_EC3 and 4 typically have base line EC's of 40 to 60 µS whereas the conductivity readings for GMI_EC5,6,and 1 have conductivities between 180 and 300 µS. Could this difference be attributed to a forested buffer vs farm fields (see Fig 1)?
- The large periodic spikes of conductivity recorded at GMI_EC1 (see fig 6) do not seem to be correlated with storm events and are characterized with a consistently fast rise time. The source of this warrants further investigation.

Organization: White Clay Wild and Scenic; Station Manager: Shane Morgan; Stream/River: Broad Run, Egypt Run, Mill Creek, UT Middle Run (http://monitormywatershed.org/sites/BCWC10S/, not online; http://monitormywatershed.org/sites/BCWC9S/, not online; http://monitormywatershed.org/sites/BCMC2S/; http://monitormywatershed.org/sites/BCMR1S/)

What we've learned about:

- Our watershed(s) I would say it's reinforced how flashy our headwater streams are. In that storm events move through very quickly (i.e. sediment slugs, conductivity spikes from snow melts, etc.)

- Monitoring – it takes A LOT of time and patience to curate the data and keep tabs on those collecting the data and managing the stations. Perhaps the hardest part was determining how to organize the data so that it could be used in other systems like R and google data studio (which is still a work in progress).

- Continuous data and data analysis – again – it's a lot of information. Being organized is super important – even in terms of labeling the files in a systematic way so they are easy to find. I haven't done much with analysis yet – but I am working on it. Right now it has really been just looking at what we are seeing and then comparing it to state standards or goals. Also – comparing data among sites with different land uses. Mushroom heavy area has extremely high nitrates, more developed residential area we sometimes see unexplainable conductivity spikes (not from snow melt) and higher OP levels, the more natural, wooded site has the lowest nutrient levels (but still some spikes here and there. I think I need more time with the continuous data analysis –for depth and temperature, but the trends do seem to follow what you would expect seasonally. Over time I think water temperature will be of more interest.
- Quality control, data accuracy and precision – not mine finest suit. We do clean the sensors twice a month (sometimes not as clean as I would like, but it's difficult and stuff builds up on the probes which I don't like to lift out of the water since it is hard to put the pin again. With grab samples we take duplicates each quarter to test the lab, with the staff gage we follow the manual Stroud put together, although I got a late start on that. We've had to move our sensors because of the shallow nature of some of our creeks and the bed movement they tend to get buried once in a while. I try to remove data where there are readings that make no sense (for instance -9999), but the best thing has been the capability of visualizing it and see where the data looks off, then taking a closer look when you see those oddities.
- Personnel, volunteers, organizing, etc. – I decided to use two student interns (grad students from UD) this way I have consistent help. I also have a few very intelligent, very capable retirees who help out quite a bit with troubleshooting and data management.
- Technology, sensors, troubleshooting, maintenance/management, etc. – This isn't so bad simply because of all the help that is out there. Obviously – a ton of help from Stroud with this, Shannon in particularly. I just reach out when I see something off and she either goes out to take a look or explains to me what I need to do (like exchanging a battery pack).
- Information/data sharing, communication, and curation/storage – This is a work in progress. As I mentioned, I have a brilliant, retired software engineer who helps tremendously in this area. I have shared the data with DNREC for their 303b report and noted that two streams that were delisted for nutrients in 2012 appear to still have impairments from our data collection. We are now starting to talk with River Network to learn how we can better integrate R with an online dashboard so that our data can be readily access to the public. Both programs are integrating all of the data we collect, not just the data from the sensors themselves.
- Education and engagement – At this point I've published a few articles in township newsletters and the National Park Service River Currents newsletter, our annual reports and website. I've also used the data in conversations with township managers, engineers and supervisors to discuss problem areas. The newsletter articles were mainly on conductivity and how it relates to rain and snow depending on the time of year and we correlated it with the grab samples for CL concentrations. We also produce reports at one station for DelDOT to use at a location that they are interested in doing some road repairs in conjunction with a restoration project.

<u>What did the data tell you that you didn't know before?</u>

- This is a tricky one for me. I think the most informative and education piece is the conductivity. The turbidity probe is finicky and tends to foul easily, but it does show how stormwater effects certain reaches more than others. I think water temperature will be important to look at in the long term. Most important to me – is the grab samples. We've learned that all of our sites are impaired for nutrients, but Nitrogen is the main one and at one location we have levels greater than the drinking water standard 10ppm. I spoke to the manager about this to see if he knew the property owner near the sensor since it could be a nice place to plant some trees to maybe suck up some of the Nitrogen (these levels are at baseflow) and we are working on it. The other site of interest is a relatively new one in an urbanized area (no ag). The data is still new from there but the data is showing that the CL levels there are higher than other sites. The sensor near the proposed restoration site hasn't shown any real need to do restoration. It is the cleanest of all our sites (in terms of meeting standards) and the turbidity levels there seem to be low compared to the others so it wouldn't be a priority site (again my opinion). I mentioned our comments to DNREC about the two delisted streams and I shared our data with the environmental scientist for DNREC so this data may get them to take a closer look.

Bottom line is I use this data to back up what I speak about all the time. Having real time data, as well as grab samples from several monitoring sites in the watershed allows me to back up what I'm saying when I am speaking about the impacts of stormwater. So, to me it is a very good educational tool. I'm hoping to see some long-term trends over time. Hopefully for the better so I can tell that story too.

Finally, I applied for a grant with USGS this February to have them look at our data and do an analysis. This would allow them to publish our data onto their online Sciencebase-catalog so that it can be cited by USGS and other researchers. I'm hoping they can also help me determine a grading threshold for the White Clay so that I can more easily communicate to the general public about our water quality and what it means besides just being impaired.

Organization: Bartram's Garden (letter to PA DEP); Station Manager: Chloe Wang; Stream/River: Schuylkill River

We are a group of volunteers, high school interns, and staff who support public boating and fishing programs at Bartram's Garden Community Boathouse. We have been collecting water quality data over the past two years, and we write to you to provide our data for consideration in the assessment of Pennsylvania's water quality.

As a result of controls on many industrial point sources of pollution along the Schuylkill River, the vast improvement in water quality over the last few decades has made it feasible for people to safely access and enjoy this public waterway. However, the tidal portion of the Schuylkill is still subjected to frequent and persistent inputs of pollution, with direct impact on our program safety, from the approximately 40 combined sewer overflow discharge points that empty raw sewage into the river during many rain events. Our policy is to cancel public boating within 24 hours of rainfall of a quarter-inch or more, though we have sometimes been more conservative because the Philadelphia Water Department's CSOCast web site has indicated in the past that overflows can be triggered by as little as a tenth of an inch of rain. This cancellation policy is determined to be protective of our guests based on our understanding of the interactions of weather, tides, bacterial counts, and other parameters. This understanding is limited by a lack of historical water quality data below Fairmount Dam, in the section of the river affected by CSOs. As far as we are aware, the USGS and Philadelphia Water Department only have sensors installed above the dam and thus do not document effects of CSOs. We also understand that DEP and DRBC have not assessed bacterial counts on the tidal Schuylkill, because this segment is not designated by the state for water contact, and is designated by DRBC for secondary contact recreation.

Seeing the lack of existing data as a constraint to our programming as well as an opportunity for community science to meaningfully contribute, Bartram's Garden River Programs staff decided to start collecting our own data and have been doing so over the last two years. In June 2018, we partnered with Stroud Water Research Center to install a Mayfly continuous monitoring sensor station that includes a CTD, turbidity sensor, and dissolved oxygen sensor, which collect readings every five minutes. In consultation with Stroud, Bartram's staff also designed protocols (see attachments) for active data collection by volunteers and interns.

We have just completed our first full season of active data collection from May to October 2019. A subset of Boathouse volunteers participated in this water quality monitoring program, collecting water samples weekly and testing levels of *E. coli*, phosphate, and nitrate. Additionally, during their six-week summer intensive, the high school River Crew interns tested for *E. coli* on other days of the week. Both volunteers and interns also measured pH, electrical conductivity, and water temperature using a handheld probe. Probe measurements and samples are collected from the Bartram's Garden dock, on the west bank of the tidal Schuylkill. All of these data have been recorded alongside sensor and rain gauge data from corresponding time points.

Data

Raw data actively collected by volunteers and interns in 2019 is provided as an attachment. For your convenience, here are links to raw data that are continually updated online:

Summary of findings we wish to highlight:

The Bartram's Garden Community Boathouse program aims to offer safe, easy access to the tidal Schuylkill River for members of the public. Since safety is our primary concern, the tracking of rainfall and bacteria levels helps inform our cancellation policy. We take a conservative approach and follow the EPA guidelines for primary contact recreation—rather than secondary contact—because of the water exposure inherent in the use of sit-on-top kayaks, and because of the risk of capsizing. Indeed, kayaking is increasingly considered as a primary contact activity due to the chance of immersion and incidental water ingestion, which is heightened when participants are inexperienced.[1]

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[1] See e.g. Philadelphia Water Department, Philly River Cast: A Daily Forecast of the Schuylkill River Water Quality in Philadelphia, http://www.phillyrivercast.org/Nav_definition.aspx (including kayaking as a primary contact use). See also EPA, Watershed Academy, Introduction to the Clean Water Act,

Table 1. Recommended 2012 RWQC.

Criteria Elements	Estimated Illness Rate (NGI): 36 per 1,000 primary contact recreators			Estimated Illness Rate (NGI): 32 per 1,000 primary contact recreators	
	Magnitude			Magnitude	
Indicator	GM (cfu/100 mL)[a]	STV (cfu/100 mL)[a]	OR	GM (cfu/100 mL)[a]	STV (cfu/100 mL)[a]
Enterococci – marine and fresh	35	130		30	110
OR					
E. coli – fresh	126	410		100	320
Duration and Frequency: The waterbody GM should not be greater than the selected GM magnitude in any 30-day interval. There should not be greater than a ten percent excursion frequency of the selected STV magnitude in the same 30-day interval.					

[a] EPA recommends using EPA Method 1600 (U.S. EPA, 2002a) to measure culturable enterococci, or another equivalent method that measures culturable enterococci and using EPA Method 1603 (U.S. EPA, 2002b) to measure culturable *E. coli*, or any other equivalent method that measures culturable *E. coli*.

Chart from EPA publication Recreational Water Quality Data, Office of Water 820-F-12-058, p.6.

There are approximately 40 combined sewer outfalls on the tidal Schuylkill River, so we err on the side of caution after rain and regularly suspend boating. To support our decision, in 2019 we collected data on *E. coli* levels (Figures 1,2). These bacterial tests take 24 hours to culture, so we were not able to use them for scheduling decisions on the day of planned programming. Instead, we hope to use our combined data including rainfall, *E. coli*, and other variables to devise a reliable predictive model to keep our visitors safe from high bacteria counts in the river.

We are aware of DEP's plan to begin using *E. coli* rather than fecal coliform for its water contact criterion for May–September, but until the Triennial Review is approved by EPA, DEP continues to use fecal coliform as indicator bacteria year round. Thus, our measurements cannot be directly compared to current DEP or DRBC criteria, but our practices align with EPA guidelines for freshwater and position us proactively for DEP's shift from fecal coliform to *E. coli* for the time frame relevant to our visitors.

Our measurement of *E. coli* found a large range over the season, from 0 to over 7,000 CFU/100ml, and variability from day to day (Figures 1–3). That variability was evident even with low rainfall amounts (Figure 4), so rainfall alone did not account for *E. coli* levels above the EPA guideline. We plan to collect more data to develop a reliable model; some experimentation with multiple regressions yielded promising potential for a predictive, multi-variable model.

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https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1990 (including kayaking as a primary contact activity and noting that "Obviously, it can be difficult to draw distinct lines between these different activities, because the extent of exposure can be affected by factors such as the skill of the recreationist and weather conditions.").

We are also concerned about our findings of water temperature and dissolved oxygen (DO) levels in violation of DEP criteria for warm water fish (WWF), and the implications for river health. Temperature measurements from our sensor station have, on multiple occasions, exceeded WWF criteria (Figure 5), and this season we saw DO fall below the WWF minimum of 5.0 mg/L assigned by DEP (Figure 6). DO levels appear to be meeting DRBC criteria (seasonal averages of at least 6.5 mg/L and 24-hour averages of at least 3.5 mg/L), though with instantaneous minima as low as 3.4 mg/L. It is confusing to navigate the relationship between DEP and DRBC criteria in cases such as this, in which DEP defers to DRBC for a segment where DEP criteria still apply. We believe additional monitoring by DEP and/or DRBC would be helpful to better understanding water quality in the tidal Schuylkill, but there needs to be a clearly articulated approach to assessment when two agencies have authority.

Summary

We appreciate the work that DEP and DRBC put in to keep our waterways healthy. However, we need more support from your end. Currently, we understand your focus of assessment has been entirely on aquatic life, but we are submitting these data and information on our program to demonstrate that there is more to the river than just aquatic life, and we need you to look deeper into the river's health. There are other important factors to consider.

As mentioned above, DEP and DRBC have not assessed bacterial counts on the tidal Schuylkill. We submit our consistently high river program attendance, as well as the popularity of our site for personal boating and fishing, as evidence that water recreation is an existing use of the waterway and therefore warrants protection under the Clean Water Act. We thus see the need for an update to DEP's designated uses for the tidal Schuylkill River, if not the entire segment that currently encompasses the tidal Schuylkill. We offer the following suggestions to make DEP and DRBC standards better reflect and protect existing uses and improve consistency between the two agencies:

1. DEP should designate the tidal Schuylkill for water contact in accordance with its existing use.
2. Likewise, DRBC should update its designation of this segment from secondary to primary contact to more accurately reflect the risk of immersion and ingestion inherent in Bartram's Garden program activities (i.e., kayaking) and other forms of water contact we observe (e.g., paddleboarding, canoeing, jet skiing) as discussed above; see footnote 2.
3. DEP and DRBC should update bacterial criteria for water contact from fecal coliform to *E. coli* **year-round**.
4. DEP should assess the tidal Schuylkill for water contact and its existing warm water fish designation. The blanket "aquatic life" use that is currently assessed in this segment is inadequate and does not include assessment of the parameters that define WWF criteria. Our data point to exceedances of these criteria that call into question whether the segment can be considered "attaining" for all aquatic life. Based on assessment, the status of the tidal Schuylkill with respect to water contact and warm water fish should be listed in DEP's next Integrated Report. A TMDL should be developed to address any impairments and protect recreators.
5. DRBC should also monitor the tidal Schuylkill for the Stream Quality Objectives listed for Zone 4 and submit this data to DEP.

Because people use the river, DEP and DRBC need to make sure the environment is suitable for human interaction. Since CSOs are a significant source of pollution to the water, DEP and DRBC should look into their impacts on users. Our testing has indicated issues, but we ask you to conduct additional tests. Ensuring protective water quality should not fall entirely on the shoulders of civilians.

Figures

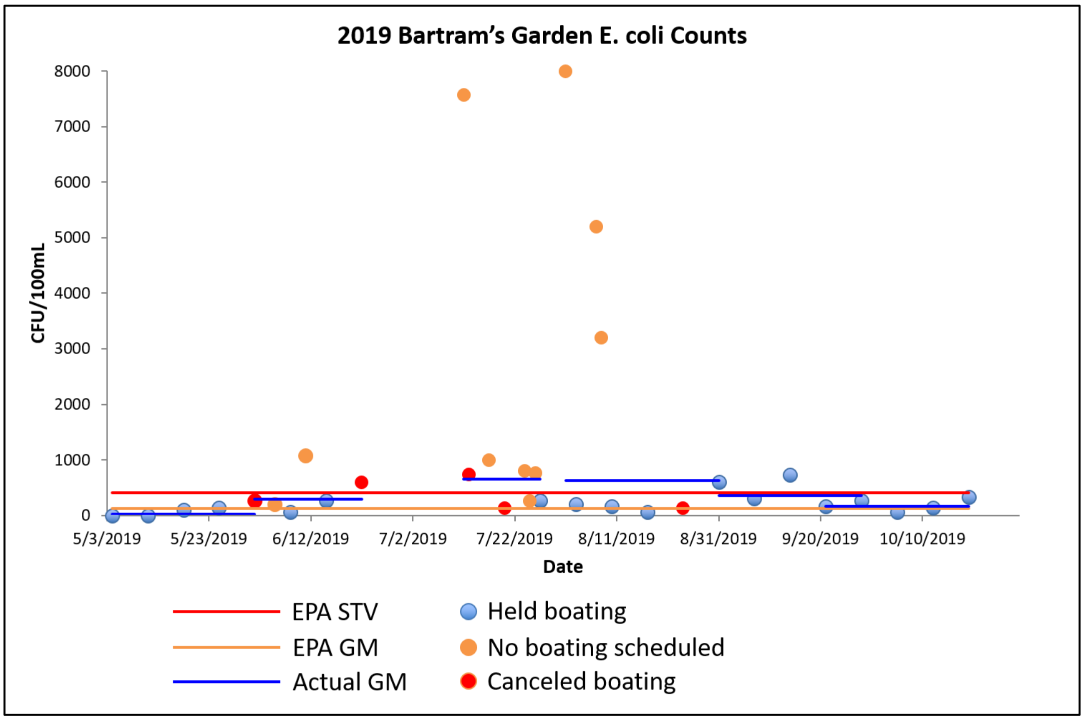

Figure 1. *E. coli* readings taken this season. Orange and red lines are EPA recommended geometric mean and statistical threshold value, blue lines are actual calculated monthly geometric means. Note that the result for the highest point on this plot was actually "too numerous to count," but it is represented here as 8000 CFU/100mL. Cancellations were made for various reasons, not limited to rainfall.

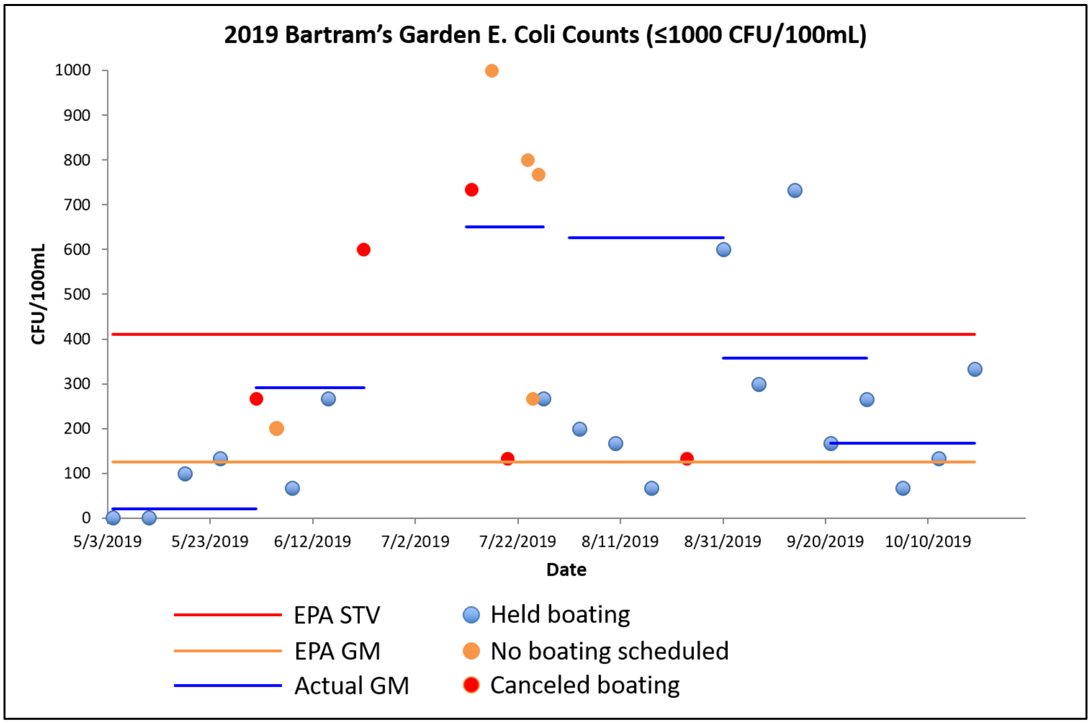

Figure 2. *E. coli* readings taken this season, only including readings ≤1000 CFU/100mL to better visualize the low range.

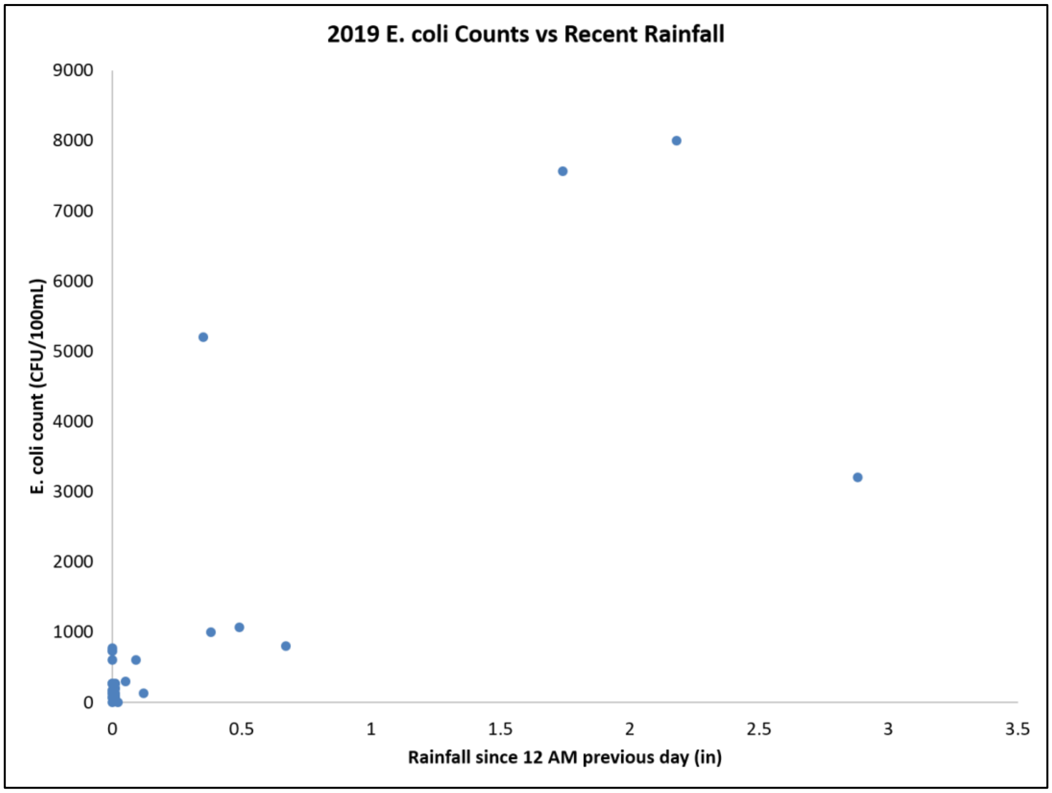

Figure 3. 2019 *E. coli* counts plotted against rainfall measured by rain gauge since 12 AM the previous day.

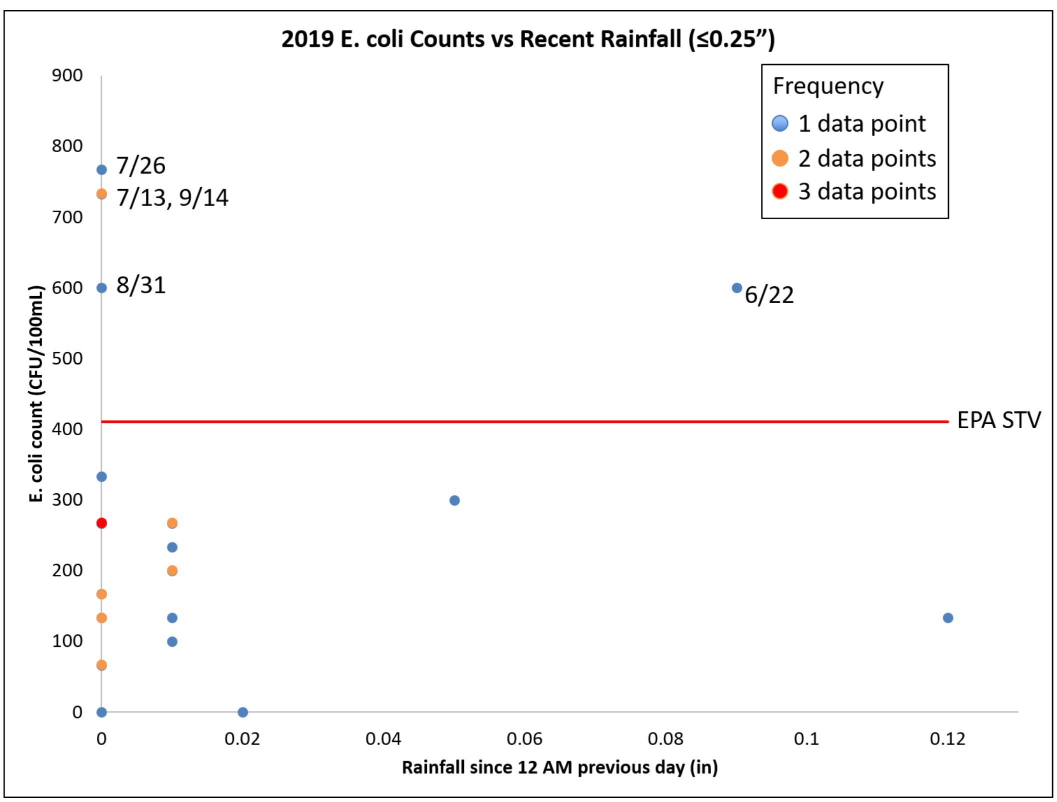

Figure 4. 2019 *E. coli* counts plotted against rainfall measured by rain gauge since 12 AM the previous day, only including rainfall ≤0.25" to better visualize the low range and with colors indicating frequency of repeated values. The 6/22 and 7/13 samples were taken within a week of heavy flooding. On 7/26 there had been heavy rain 3 and 4 days prior. 8/31 and 9/14 were not preceded by heavy rain or flooding.

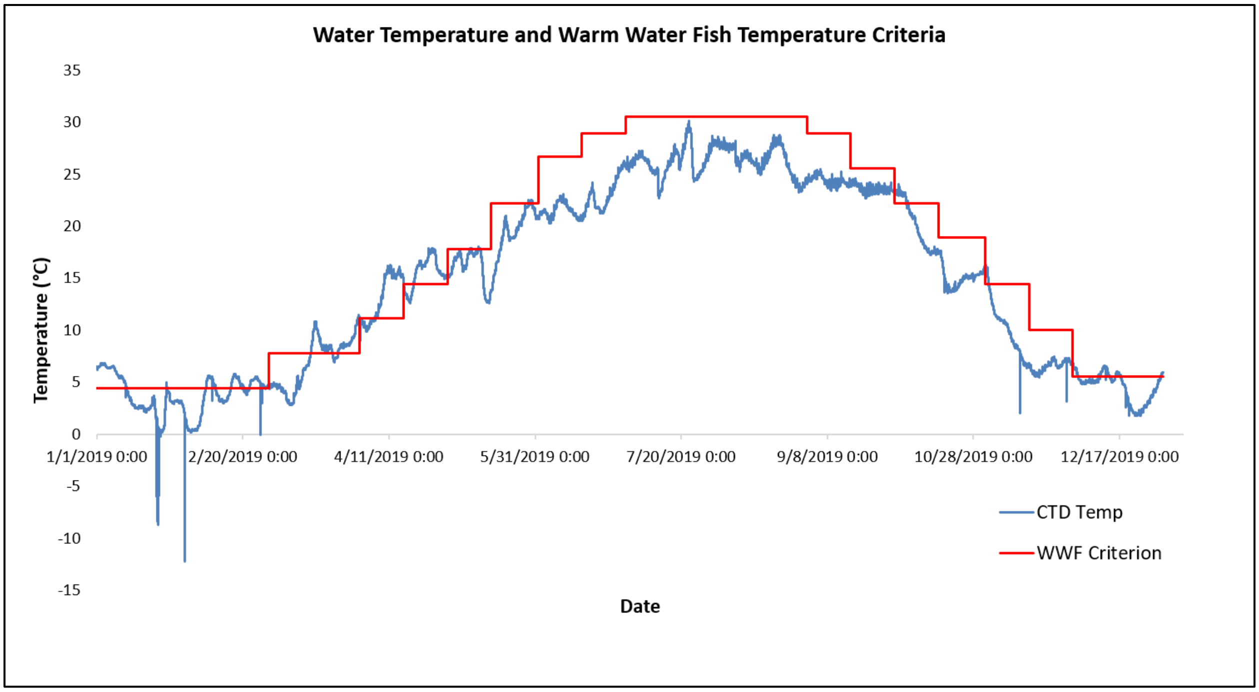

Figure 5. Continuous water temperature data measured by CTD, plotted with WWF temperature criteria. Temperature spikes below 0 degrees C correspond to exceptionally low tide events when water level fell below sensors.

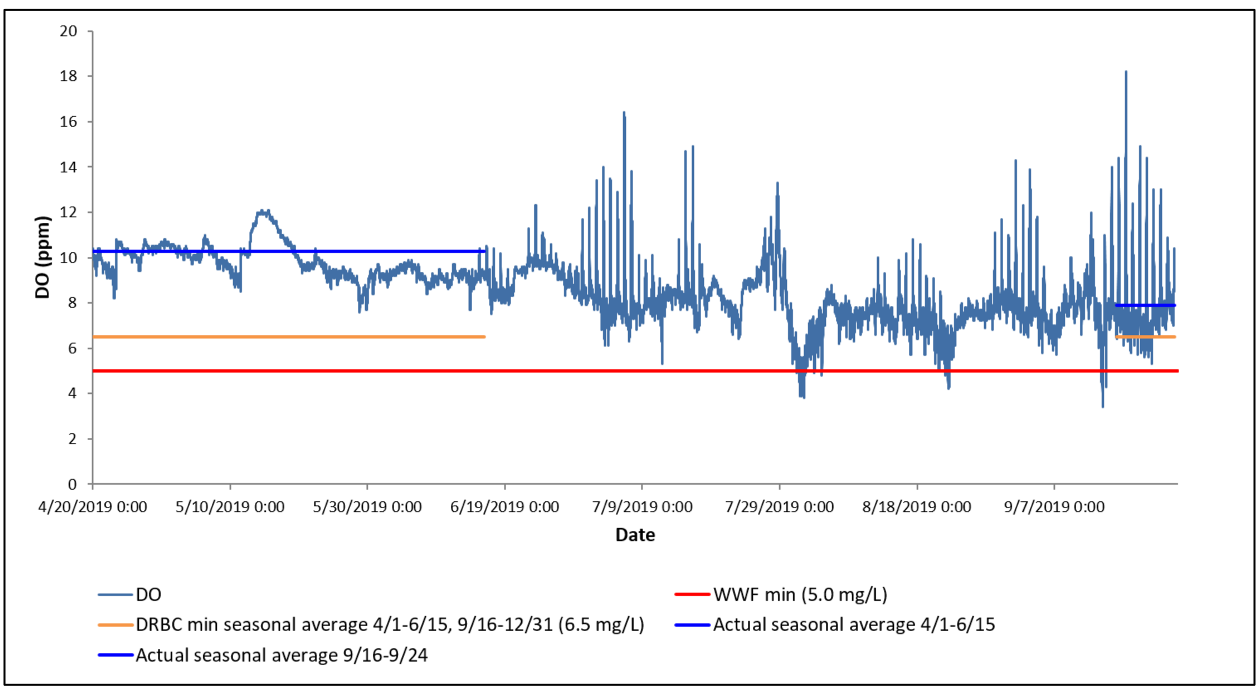

Figure 6. Continuous dissolved oxygen concentration measured by DO sensor, plotted with WWF DO minimum (5.0 mg/L), DRBC minimum seasonal average for 4/1 to 6/15 and 9/16 to 12/31 (6.5 mg/L), and actual averages

calculated from sensor data for 4/1/19 to 6/15/19 and 9/16/19 to 9/24/19 (DO sensor data has been unusable since 9/24/19).