

Characterization of an Urban Stream for Stormwater Control: A Baseline Study on the Campus of Penn State Harrisburg

Christina Y.S. Siu, Katherine H. Baker, Shirley E. Clark
Penn State Harrisburg, School of Science, Engineering, and Technology
Middletown, PA

Corresponding Author: Christina Y.S. Siu, cys106@psu.edu

Natural streams subjected to anthropogenic activities such as urban runoff, encroachment, or modification of the stream channel exhibit characteristics that may indicate compromised stream health. These problems are manifested by changes in a stream's surroundings and the organisms associated with the stream. Urban stormwater runoff is a major contributor to anthropogenic change. Impervious surfaces affect urban runoff by contributing pollutants from the surfaces themselves as well as creating a rapid drainage pathway for the water and pollutants. Non-porous surfaces also affect the hydrologic cycle due to the reduction in natural infiltration. The runoff from post-urbanized streams typically has greater volumes and peak flow rates. In addition, the runoff hydrograph is typically high in volume and runs quickly into receiving waters, usually resulting in degradation of both urban streamwater and habitat quality. An urban stream, located on the campus of Penn State Harrisburg in Middletown, PA, was assessed temporally and spatially at the headwaters, midstream, and downstream from September 2005 – March 2006 to determine the health of the stream. Historical data for the stream does not exist; therefore, the physiochemical, biological, and habitat observations from this research form baseline data for the stream. It is critically important for future research to investigate the health of the stream prior to the next episode of development on the campus. A full report of this research can be found in Siu (2006), available through the Penn State University library.

Due to the small size of the stream (less than one mile in length and its width approximately 4-18 feet depending on stream location) and its urbanized nature, the stream's water source comes from a combination of precipitation, subsurface flow, and stormwater drainage from urban campus runoff. The headwaters flow continuously throughout the year, most likely fed by water flowing into the stormwater collection pipes from the surrounding areas and natural stream flow. Midstream and downstream sections of the stream are more affected by environmental variables such as solar radiation due to the lack of streamside vegetative cover. The stream will usually become dry during the mid to late summer months. Streambanks are steep and eroded; pipes (some sewage) and remnants of pipes are scattered across or along the stream; banks are armored at the entrance of the campus and state route PA 230. An assessment of the streambank stability is being undertaken by Ruth Sitler (whose paper is included in these proceedings).

A total of fourteen chemical and biological parameters were tested at four different stream sites. Two sites were located at the headwaters (named Foam and Headwates),

one approximately halfway down the stream length (Midstream), and one at the intersection of the campus entrance and PA 230 (Downstream). The metrics tested were ammonia, chemical oxygen demand (COD), chlorophyll α , conductivity, detergent (anionic), dissolved oxygen (DO), fluoride, nitrate, phosphate, pH, primary productivity, total dissolved solids (TDS), total suspended solids (TSS), and turbidity. Visual-based habitat assessments were performed as well, based on U.S. EPA's *Rapid Bioassessment Protocol* (Barbour *et al.* 1999). Algae and macroinvertebrates were sampled sporadically due to the stream's ephemeral nature. The effects of specific factors on stream characteristics were examined in this study. These factors included (1) seasonal variability, (2) base/stormflow variability, and (3) the amount of rainfall in a given storm event. Observations of the presence of foam at the stream's headwaters allowed inference of water quality degradation. The presence of steep and exposed stream banks may result in erosional/sedimentation problems and associated high levels of turbidity, conductivity, dissolved solids, and suspended solids. Sufficient samples were collected to investigate the impact of dry-weather and immediately-post-storm flows on the stream health.

Of all the metrics tested, the results of the following contaminants raised some concern. Nutrients, specifically nitrate and phosphate, are more of a concern for this specific waterbody than other stream characteristics. Nitrate and phosphate were assumed to originate from lawn runoff (of fertilizers) from the stream's surrounding area and similar concentrations for nitrate and phosphate were expected for each sampling site. Results showed nitrate occurred highest at the headwaters. This may indicate a nitrate source upstream of where the stream daylight. Also, the area surrounding the majority of the stream length is grassed open space, routinely mowed and fertilized. Grass clippings remain on the mowed area and often times, the clippings fall/are mowed into the stream. Seasonal or within season variability of nutrients may reflect mowing. Plant decay will also release nitrate into the stream, which is demonstrated during autumn when tree leaves begin to fall, landing into the stream. Nitrate concentrations were evaluated high seasonally and increased through the seasons (summer: 2.8 mg/L, autumn: 3.8 mg/L, winter 3.8 mg/L). Algal blooms appeared to dominate in the winter months. When algae are present in the stream, it takes up available nitrate and should lower nitrate concentrations. But, as the algae die off and decay, this nitrate is released back into the stream, resulting in higher nitrate concentrations. This probably resulted in the increased amount and frequency of algae observed in the stream, a perpetuating system until a large storm flushes everything out. Also, precipitation may re-dissolve nitrate out of soils. Highest nitrate concentrations coincided with higher rainfall amounts (>5 inches). Storm flow for nitrate showed more variability in concentrations, possibly overwhelming any statistically significant differences. Nitrate showed a gradual decrease in concentration along the stream from headwater to downstream during both base and storm flows.

Phosphate, though, showed an inverse relationship to nitrate. Higher concentrations were seen in the summer and decreased through the seasons (summer: 0.6 mg/L, autumn: 0.25 mg/L, winter: 0.12 mg/L). Phosphate also illustrated an increase in concentration with increasing rainfall, once rainfall depth exceeded 0.1 inches.

However, unlike nitrate, concentrations occurred highest at 0-0.1 inches and may be significantly different from the remaining rainfall ranges. Phosphate decreased in concentration in the downstream direction during base flow and showed greater site variability at base flow than storm flow. Conversely, during storm flow, concentrations increased from foam (approximately 0.2 mg/L) to midstream (0.3 mg/L) and then decreased at downstream (approximately 0.25 mg/L). Sources for these two nutrients may differ, since the results showed an unexpected inverse relationship. Hypothetically, the site could be leaking at the midstream or downstream collection site where sewage pipes exist, thus, not affect upstream. The leak would cause phosphate concentrations to increase at either site or both.

Ammonia concentrations were even lower. Notable conclusions could only be made on rainfall amounts affecting this nutrient. More data is needed to ascertain seasonal differences. Differences were not found between sampling sites. Though sampling sites did not show significant differences among each other for either base or storm flow, ammonia concentration ranges differed. Midstream at dry flow showed more similarity to foam and midstream during storm flow than to the other sampling sites at dry flow. Greater ammonia concentrations occurred at base flow than storm flow, except at the midstream sampling site. Ammonia at this site was similar at both base and storm flow. Storm flow concentrations (0.02-0.08 mg/L) were about one-half to one-third lower than base flow concentrations (0.025-0.12 mg/L) for some sampling sites. The amount of rainfall affected ammonia concentrations – decreasing in concentration with increasing rainfall, probably an indication of dilution from precipitation. A greater range and concentration occurred in rainfall amounts of 0-0.1 inches and were significantly different from rainfall amounts greater than 0.1 inches. Measurements of nine different sampling days were either zero, not detected, or below the analytical limit of 0.02 mg/L for one or more sampling sites. On many of these days, all four sampling sites were either not detected or zero. The number of zeros and non-detects may contribute to the variability of ammonia for this stream. It is possible that ammonia was converted to nitrate and nitrite, which could explain increased nitrate concentrations. A possible source of ammonia is sewage. There is a possibility that a source occurs at the headwaters and ammonia is diluted by the time it reaches the midstream sampling site. A different source may feed the downstream sampling site since downstream concentrations increased compared to midstream.

Other areas of concern are the lack of overstory vegetative cover along the midstream and downstream sections of the stream and the lack of species diversity and individuals among aquatic organisms observed. Summer temperatures along with the lack of overstory cover exacerbate living conditions in in-stream habitats. More importantly, the ephemeral nature of the stream stresses its inhabitants. Both biomass and diversity of macroinvertebrates were low, further illustrating the impaired nature of the stream.

Suspended solids and dissolved ions are less of a concern, unlike most urban streams where sedimentation/erosion causes major concern. Turbidity was inversely related to rainfall, the opposite of the typical trend found in urban streams. Initially, the constant presence of foam was thought to adversely affect the water quality of the stream.

Tests for detergent showed less than one ppm present. The attempt to determine the source of the foam seen at the headwater was inconclusive. The test kit may not analyze for other categories/types of surfactants available commercially. Another possibility is that the foam is naturally occurring. Thus, further analysis is needed to determine whether the foam is indeed from synthetic chemicals or from nature. Stream sampling and testing should continue through spring and summer, possibly uncovering further seasonal or other trends not found during this study. First flush effects should be considered as well. This study did not examine first flush effects which could elucidate the chemical components present based on pipe and stream location, also allowing for the study of the fate and transport of these constituents.

To some extent, this local stream does not have the poor water quality similar to other urban streams. Concentrations for the various physiochemical characteristics analyzed were much lower than concentrations typically observed in urban streams. The stream is small and ephemeral in nature. As a result, impacts from development can be seen more readily and the negative consequences magnified. For example, if erosion control is not properly implemented pre-construction and erosion occurs during construction for a campus project that is near the stream, then the eroded sediment will be transported into the stream. This eroded sediment will affect DO, stream temperature, turbidity, TSS, and TDS. Stream biota will also be affected. This excess sediment can cover microhabitats (losing shelter and breeding grounds), clog gills of fish and macroinvertebrates, and damage or destroy the aesthetic quality of the stream. Factors such as rainfall and season demonstrate some effect on these characteristics. It appears the lower and higher amounts of rainfall had the most effect on concentrations, compared to rainfall amounts in between (0.1-1.5 inches). Sampling site has less of an effect on stream quality except for measures like DO and temperature. In addition, the stream's ephemeral nature stresses the aquatic organisms that inhabit the stream.

Prior to this study, historical in-stream data for the unnamed stream near the main entrance of Penn State Harrisburg did not exist. The results of the study will be used as reference data for assessing future impacts to the stream, especially during the anticipated future campus development. Future campus impacts will further degrade the stream if considerations such as stormwater management throughout the phases of construction are not planned and implemented correctly or thoroughly. Campus development activities need to consider what will and can occur during all phases of construction (pre-, during, post-) and its impacts to receiving waters. Tying in stormwater management of the new infrastructure to the existing stormwater control plan is important as well. Another important phase that is not often implemented is the monitoring of the stormwater control system and its impacts on receiving waters. Short-term monitoring (1-2 years) is typical. However, long-term monitoring is recommended. Problems may not develop or be seen until 5, 10, 20 or more years into the future.

Depending on the development plans of PSH, if one of its foci is to create areas for students and faculty to enjoy, ideas for stream improvement can be coupled with recreation space. A riparian buffer of a minimum of five feet can be implemented on

both banks of the stream. Outside this buffer zone, park benches or other sitting structures can be placed along the stream. This area should contain pervious cover, otherwise runoff may further impact the stream system. Native trees that will not drink in all the streamwater should be planted along the stream bank, giving much needed shade to the stream, stabilizing the ground, aiding in erosion control and water filtration, and also renewing soil porosity.

Urban development and maintaining a healthy stream ecosystem are jointly possible when the potential impacts to stream ecology and morphology are taken into consideration in the planning stages. There is not a reason why urban projects cannot be implemented and not negatively impact receiving waters if careful, thorough, and thoughtful planning takes place prior to construction.

References

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. (1999). *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition*. EPA 841-B-99-002. United States Environmental Protection Agency and Office of Water, Washington, D.C.

Siu, C.Y.S. (2006). *Characterization of an urban stream for stormwater control: a baseline study on the campus of Penn State Harrisburg*. Masters of Science, Environmental Pollution Control. Penn State Harrisburg, Middletown, PA.