Township of Abington

Public Affairs Committee

John Spiegelman, Chair
Tom Bowman, Vice-Chair
Lori Schreiber
Jimmy DiPlacido
Peggy Myers

AGENDA

October 2, 2019
7:00 P.M.

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1. **CALL TO ORDER**

2. **ROLL CALL**

3. **CONSIDER APPROVAL OF MINUTES**

   a. Motion to approve Committee Meeting minutes of September 4, 2019

4. **PRESENTATION**
   a. Water Quality Improvement Plan – Lindsay Blanton

5. **UNFINISHED BUSINESS**

6. **NEW BUSINESS**

7. **PUBLIC COMMENT**

8. **ADJOURNMENT**

RESOLUTION
OF THE MANAGEMENT COMMITTEE
OF THE WISSAHICKON CLEAN WATER PARTNERSHIP
IN SUPPORT OF THE WATER QUALITY IMPROVEMENT PLAN
FOR THE WISSAHICKON CREEK WATERSHED

WHEREAS, thirteen municipalities in the Wissahickon Creek watershed representing roughly 99% of the land area in the watershed, the four wastewater treatment plant operators, and the Water Quality Advisory Team ("WQAT"), formed the Wissahickon Clean Water Partnership (the "Partnership") in 2016 through the adoption by ordinance of an Intergovernmental Agreement (IGA), and

WHEREAS, the Partnership was formed to develop a technically and scientifically sound alternative to the May 2015 Draft Total Phosphorous TMDL for the Wissahickon Creek (Draft TMDL) published in draft by the Environmental Protection Agency ("EPA" or the "Agency"), and

WHEREAS, the IGA established the Management Committee, consisting of one primary voting representative and one alternative representative per party to the IGA, each of whom have been appointed by their respective governing boards for purposes of implementing the IGA, and

WHEREAS, the Management Committee, with input and support from the WQAT, has undertaken the development of an alternative to the Draft TMDL in the form of a Water Quality Improvement Plan ("WQIP" or "Plan") for the Wissahickon Creek watershed based on a comprehensive analysis of water quality data collected throughout the watershed, and an evaluation of effective measures designed to improve water quality within the watershed.

NOW THEREFORE BE IT RESOLVED, that the Management Committee, in adopting this resolution, authorizes the submission of the draft WQIP to EPA and the Pennsylvania Department of Environmental Protection for review and comment.

Approved this ____ day of _____, 2019

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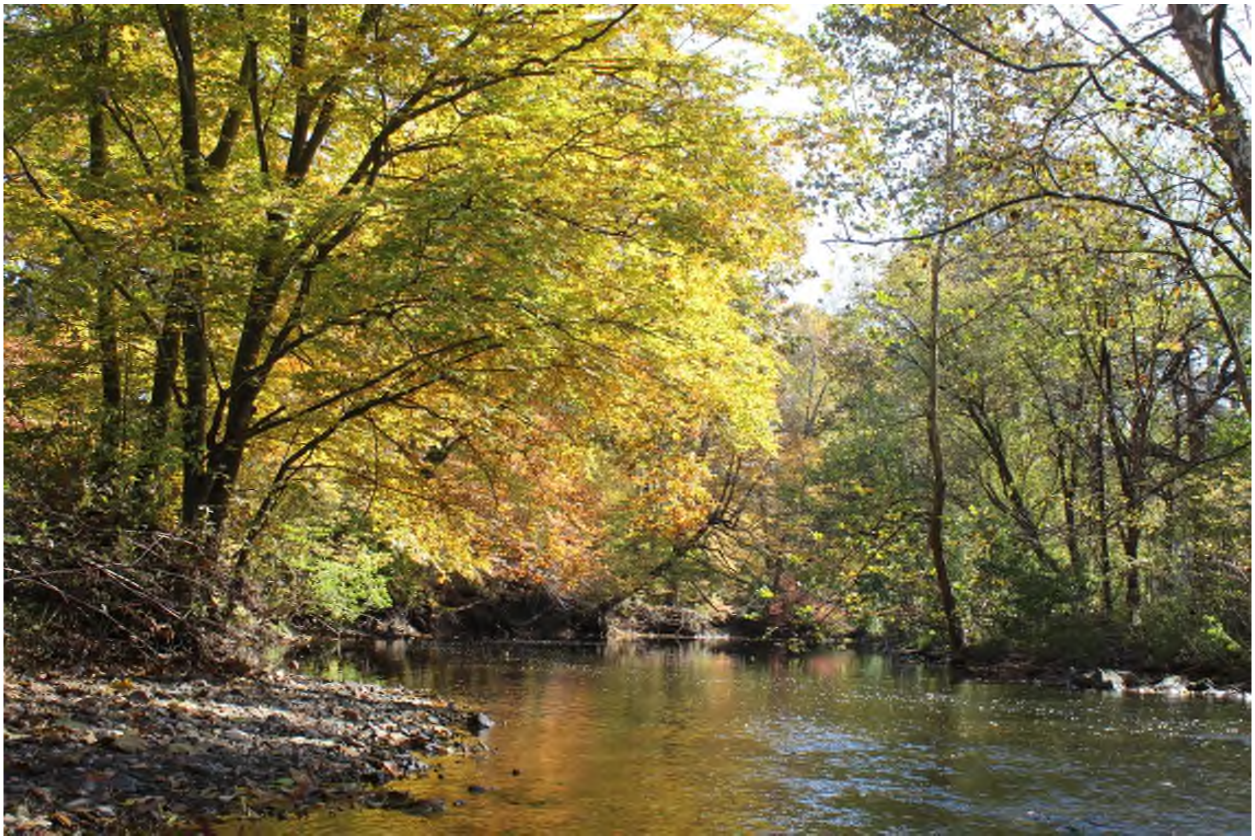
Mark Grey, Co-chair	Paul Leonard, Co-chair

Wissahickon Creek Water Quality Improvement Plan (WQIP)

A comprehensive plan to improve water quality in the Wissahickon Creek Watershed



September 2019

ACKNOWLEDGEMENTS

Wissahickon Clean Water Partnership

The Wissahickon Clean Water Partnership (WCWP or Partnership) is a coalition of 13 municipalities (representing 99% of the land area in the watershed) and operators of four wastewater treatment plants (WWTPs) in the Wissahickon Creek watershed. It was formed through an Intergovernmental Agreement (IGA), that established a process for the Partnership to collaborate with a Water Quality Advisory Team (WQAT) consisting of the Pennsylvania Environmental Council (PEC), Temple University, the Wissahickon Valley Watershed Association (WVWA), the University of Maryland Environmental Finance Center (EFC), and the Montgomery County Planning Commission for the development of a holistic watershed plan to improve water quality in the Wissahickon Creek.

Representatives of the 13 municipalities and four WWTPs make up the Partnership's Management Committee, which is supported by legal counsel from Manko, Gold, Katcher & Fox LLP, and technical services by Kleinfelder, Inc. The entities represented on the Management Committee are listed below:

Municipalities

Abington Township
Ambler Borough
Cheltenham Township
City of Philadelphia
Lansdale Borough
Lower Gwynedd Township
Montgomery Township
North Wales Borough
Springfield Township
Upper Dublin Township
Upper Gwynedd Township
Whitemarsh Township
Whitpain Township

Sewer Authorities/Wastewater Treatment Plants:

Abington Township WWTP
Ambler Borough WWTP
Upper Gwynedd Township WWTP
Upper Dublin WWTP (operated by Bucks County Water & Sewer Authority)

Water Quality Advisory Team

The roles and responsibilities of the WQAT are summarized below:Pennsylvania Environmental Council (overall coordination, funding coordination, documentation of process)
Temple University (gather and analyze data and develop and model scenarios)
Wissahickon Valley Watershed Association (public outreach and communication)
Environmental Finance Center, University of Maryland (funding opportunities, efficiencies and economic incentives)
Montgomery County Planning Commission (coordination and support of the Management Committee and the WQAT, and organizing meetings)

Funding

William Penn Foundation
Management Committee as provided by the IGA and amendments.

Additional Partners

Geosyntec Consultants, Inc. (WQIP Editor)
Environmental Protection Agency (EPA) Region 3
Pennsylvania Department of Environmental Protection (PADEP)

APPENDICES

Appendix 1: **Intergovernmental Agreement**
Appendix 2: **Municipal Fact Sheet**
Appendix 3: **Temple University Report on SWMM Model Development and Calibration for the Wissahickon Creek (October 22, 2018)**
Appendix 4: **Wissahickon Creek Act 167 Stormwater Management Plan**
Appendix 5: **July 2019 WQIP Update Letter from Marc Gold to EPA on behalf of the Management Committee and Letters of Support from WVWA, PEC, and Montgomery County Planning Commission**
Appendix 6: **Temple University Study for the WQIP**
Appendix 7: **Kleinfelder – Wissahickon Creek Water Quality Improvement Strategy (January 9, 2019)**
Appendix 8: **MS4 Community Plan Information**
Appendix 9: **Wastewater Treatment Plant Data**
Appendix 10: **Watershed BMP Project Inventory**
Appendix 11: **September 2017 Letter from Marc Gold to EPA on behalf of the WWTPs**

SECTION 1 Factual and Regulatory Background

This section provides background information that is essential to understanding the strategies proposed to be implemented under this Wissahickon Creek Water Quality Improvement Plan (WQIP), with a synopsis of the conditions that explains the holistic stormwater management approaches proposed in the WQIP, and discussed in greater detail in Section 3 below. It includes a description of the watershed; a discussion of the existing regulatory framework applicable to the analysis of effective measures for achieving water quality improvements in the watershed; and information about the Wissahickon Clean Water Partnership that was formed in response to the Draft Total Phosphorous TMDL for the Wissahickon Creek Watershed published by the United States Environmental Protection Agency (EPA) in 2015 (the Draft TMDL)[1]. It also includes a description of the purpose and goals of the WQIP, and a brief overview of the structure of the WQIP.

1.1 Wissahickon Creek Watershed

The Wissahickon Creek watershed is located in southeastern Pennsylvania, in Montgomery and Philadelphia Counties. The headwaters commence just below a parking lot in a large suburban mall. The mainstem flows approximately 27 miles before joining with the Schuylkill River in the City of Philadelphia. The watershed drains 64 square miles and spans portions of 16 municipalities. The municipalities range from small boroughs to larger townships to the City of Philadelphia. In 2010, an analysis of census data by watershed area estimated that nearly 222,000 people live in the Wissahickon Creek watershed (Table 1-1). Also noteworthy is the fact that five municipalities comprise over 70% of the watershed drainage area: Upper Dublin (18.9%), Philadelphia (16.8%), Lower Gwynedd (13%), Whitemarsh (12.9%), and Springfield (10.1%).

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[1] EPA (2015). Total Phosphorus TMDL for the Wissahickon Creek Watershed, Pennsylvania - Draft. May 20, 2015. www.epa.gov/tmdl/proposed-wissahickon-creek-phosphorus-tmdl , accessed February 1, 2019.

Municipality	**2010 Population in Watershed**	**2010 Census**	**Percent of Population in Watershed**
Abington Township	12,700	55,310	23.0%
Ambler Borough	6,417	6,417	100.0%
Cheltenham Township	500	36,793	1.4%
Horsham Township	100	26,147	0.4%
Lansdale Borough	3,800	16,269	23.4%
Lower Gwynedd Township	10,100	11,405	88.6%
Montgomery Township	3,500	24,790	14.1%
North Wales Borough	3,229	3,229	100.0%
Philadelphia County	112,100	1,526,006	7.3%
Springfield Township	18,400	19,418	94.8%
Upper Dublin Township	23,100	25,569	90.3%
Upper Gwynedd Township	9,600	15,552	61.7%
Upper Moreland Township	100	24,015	0.4%
Whitemarsh Township	9,800	17,349	56.5%
Whitpain Township	7,900	18,875	41.9%
Worcester Township	100	9,750	1.0%
Total	**221,446**	**1,836,894**	**12.1%**

Table 1-1 Population Estimates for the Wissahickon Creek Watershed. Sources: Census and 2014 Wissahickon Creek Act 167 Stormwater Management Plan. Philadelphia County and City of Philadelphia are congruous.

Throughout its history, the Wissahickon Creek watershed has undergone tremendous growth and urbanization. Its location within the Philadelphia metropolitan area made it attractive for development, especially between the 1950s through the 1980s. The pattern of growth has resulted in dense development in the center third of the watershed, with riparian areas along much of the lower and central main stem and portions of the northwestern headwaters protected as parks and preserves.

Pre-1970s development within the Wissahickon Creek watershed typically did not take into account stormwater management controls. As these communities continued to develop and expand, some areas experienced high levels of flooding resulting in loss of property and in some cases, loss of life. Although stormwater management controls were put in place in later years, the controls initially focused on management of peak flows and storms. Water quality considerations were not among the priority considerations in designing and implementing stormwater controls until the late 1980s.

As of 2005, more than 50% of the Wissahickon Creek watershed was used for single- or multi-family residences. Population in both the suburban communities and the City of Philadelphia is expected to increase by approximately seven percent by 2040, requiring 5,800 new housing units. Commercial and industrial use comprise just under five percent of the watershed. Parking to support commercial, residential and community activities comprised an additional three percent of the land use. Woodland covers 17 percent of the watershed, agriculture seven percent, and recreational space occupies an additional eight percent. The remaining land use, ten percent, includes transportation, community services, water, utility operations, and vacant properties.

Even though the Wissahickon Creek faces ecological and water quality stresses that are directly linked to extensive urbanization, it is well-recognized that the watershed has many extraordinarily positive attributes that enhance the quality of life in the region. For example, the Wissahickon Creek watershed serves as a source of great aesthetic beauty, with a vast network of readily accessible trails surrounding the mainstem. These trails provide extraordinary recreational opportunities in and along the stream, including hiking, fishing, biking, jogging, and walking. The Pennsylvania Department of Conservation and Natural Resources has recognized the value of the watershed's trail system by naming Forbidden Drive, a five mile stretch along the Wissahickon Creek situated within the Wissahickon Valley Park, as the 2018 Pennsylvania Trail of the Year. These are among the features that led the WCWP and its collaborators to develop this forward-looking comprehensive WQIP as a TMDL alternative.

1.2 Water Quality Impairments and Total Maximum Daily Loads

The entire mainstem of the Wissahickon Creek and most of its tributaries have been identified by the Pennsylvania Department of Environmental Protection (PADEP or Department) as not supporting their designated aquatic life uses based on the results of PADEP's long-term benthic macroinvertebrate watershed sampling effort. PADEP identified segments of the Wissahickon Creek as impaired on Pennsylvania's Clean Water Act § 303(d) List in 1996, 1998, 2002, and 2016. Many of these segments have also been identified as impaired for nutrients and siltation.

In 2003, EPA established TMDLs to address nutrients, siltation, and low dissolved oxygen levels in the impaired segments of the Wissahickon Creek watershed (the 2003 Nutrient and Siltation TMDLs)[2]. Because Pennsylvania does not have specific numeric water quality criteria for nutrients or siltation, EPA selected an endpoint for the 2003 Nutrient and Siltation TMDLs based on a linkage between nutrient concentrations, dissolved oxygen concentrations, and biological activity in the streams. The 2003 Nutrient and Siltation TMDLs resulted in wasteload allocations (WLAs) for wastewater treatment plants (WWTPs) and the municipal separate storm sewer systems (MS4s) for several pollutants[3].

For the WWTPs, PADEP issued National Pollutant Discharge Elimination System (NPDES) permits that are consistent with the 2003 Nutrient and Siltation TMDLs that required significant treatment plant upgrades. Although WLAs for phosphorus were not assigned, the treatment plant upgrades indirectly resulted in improved phosphorus removal capabilities.

MS4 WLAs under the 2003 Nutrient and Siltation TMDLs are being addressed by the Pennsylvania Stormwater Management Act of 1978 (Act 167) and municipal MS4 permits. Act 167 requires preparation and adoption of stormwater management plans for each watershed to manage stormwater on a watershed basis. Peak rates for flood control are established to reduce erosion, preserve natural stormwater runoff regimes, and protect groundwater resources. PADEP-issued MS4 NPDES permits for

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[2] EPA (2003). Nutrient and Siltation TMDL Development for Wissahickon Creek, Pennsylvania. Final Report. October 2003.

[3] The 2003 Nutrient and Siltation TMDLs resulted in WWTP WLAs for ammonia nitrogen, nitrate-nitrite nitrogen, 5-day carbonaceous biological oxygen demand, and requirements to increase effluent dissolved oxygen concentrations to 7.0 milligrams per liter.

Philadelphia (2006) and the Small MS4s in the watershed (2013) to address the sediment WLAs in the Siltation TMDL. The MS4 permit renewal applications that were due to PADEP in 2018 for Small MS4s required TMDL Plans and Pollutant Reduction Plans (PRPs) to further reduce MS4 sediment loads.

In 2005, PADEP requested that EPA develop a TMDL with a total phosphorus endpoint of 0.24 milligrams per liter (mg/L). EPA conducted a study to establish total phosphorus endpoints for six watersheds in southeastern Pennsylvania, including the Wissahickon Creek watershed. EPA selected an endpoint of 0.04 mg/L for all six watersheds[4]. In 2015, EPA issued the Draft TMDL based on the premise that phosphorus is the primary cause of the low macroinvertebrate scores in the watershed.[5]

PADEP and the communities reviewed the Draft TMDL and other supporting information and provided comments to EPA. Of specific concern was the uncertainty associated with the Draft TMDL's stressor-response approach.[6] Analysis of macroinvertebrate index scores across a wide range of phosphorus concentrations showed that phosphorus levels could not be correlated with the measured aquatic life impairment in the watershed. This conclusion is illustrated by the fact that the significant phosphorus reductions achieved by the WWTPs pursuant to the 2003 Nutrient and Siltation TMDLs have not produced an observable improvement in macroinvertebrate bioassessment scores (Figure 1-1). Simply stated, reductions in point source phosphorus loads are not projected to improve IBI scores or reduce benthic algal growth.

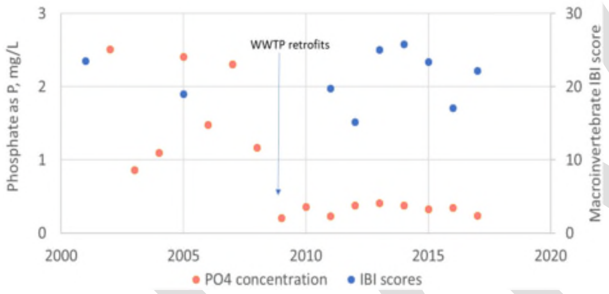

Figure 1-1 Measured phosphate (PO_4) and macroinvertebrate index of biological integrity (IBI) scores at the U.S. Geological Survey Fort Washington gage before and after WWTP retrofits.

Further, studies of the relationship between phosphorus and algae have shown that once phosphorus levels exceed a "threshold" level, algal growth is not constrained by phosphorus[7,8,9]. In addition to the absence of a phosphorus driver, phosphorus levels in the watershed cannot be reduced to the target level needed to restrain algal growth. Examples of why this numeric target cannot be achieved include:

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[4] EPA (2007). Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application. Prepared by Tetra Tech

[5] *See* infra Footnote 1.

[6] Jones, Benjamin W. Letter to Lenka Berlin, USEPA Region III. July 30, 2015. Wissahickon Creek TMDL. Manuscript.

[7] Thomann, R.V. and Mueller, J.A., 1987, Principles of Surface Water Quality Modeling and Control, Harper-Collins, New York

[8] Hill, et al. (2009) W.R. Hill, S.E. Fanta, and B.J. Roberts. Quantifying phosphorus and light effects in stream algae. (Limnol. Oceanogr., 54(1), 2009, 368–380)

[9] Goyette, J.O., Bennet, E.M. and Maranger R. (2018) Low buffering capacity and slow recovery of anthropogenic phosphorus pollution in watersheds. Nature Geoscience 11, 921-925.

- Total phosphorus levels in baseflow from the least impacted streams in the watershed are approximately 0.08 mg/L, essentially two times the proposed endpoint.

- Stormwater from urbanized areas generally contains total phosphorus levels of 0.2 to 0.4 mg/L; runoff in forested areas contains approximately 0.1-0.2 mg/L[10,11].

- WWTP effluent limits that would be required to achieve the WLAs for total phosphorus in the Draft TMDL ranged from 0.033 to 0.072 mg/L, which are levels beyond that typically required in municipal WWTPs and which cannot consistently be met in any WWTP even after the expenditure of significant capital and operating costs.

The combined WLAs (for WWTPs and MS4s) that would be imposed by the Draft TMDL are technologically unachievable.

Given the conclusion that the WLAs in the Draft TMDL will not improve water quality conditions in the Wissahickon Creek, the WCWP and its collaborators set out to define other feasible strategies that can be implemented to move toward achieving applicable water quality standards. Available studies have established that the degree of historical urbanization in the watershed is the single most important factor that influences benthic macroinvertebrate community structure.[12,13,14] Comprehensive and feasible strategies for minimizing the impacts of urbanization in the watershed were developed and are presented in the WQIP including stormwater BMPs and other projects that address (1) hydrologic (stream flow) changes; (2) riparian (streambank) degradation; (3) stream channel disturbances; (4) sedimentation; and (5) stormwater discharges.[15]

After the publication of the Draft TMDL in 2015, PADEP identified the Wissahickon Creek as a candidate for a TMDL alternative and included the stream under Category 5a (a designation supporting a TMDL alternative) in PADEP's 2016 Clean Water Act Section 303(d) List. PADEP's designation of the Wissahickon Creek as a candidate for a TMDL alternative was prompted by EPA's reassessment of the TMDL program, as reflected in the Long-Term Vision for Assessment, Restoration, and Protection Under the Clean Water Act Section 303(d) Program (December 2013).[16] EPA's Long-Term Vision framework recognizes the potential advantages of employing strategies that are tailored to meet the needs of a given watershed, with the possibility that site-specific measures provide immediate water quality benefits and added practicality for achieving the water quality goals of the Clean Water Act. Consistent

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[10] PADEP (2006). Pennsylvania Stormwater Best Management Practice Manual. Bureau of Watershed Management, Document 363-0300-002. December 30, 2006.

[11] Elliot, W.J., E. Brooks, D.E. Trauemer and M. Dobre. 2015. Extending WEPP Technology to Predict Fine Sediment and Phosphorus Delivery from Forested Hillslopes. Presented at the SEDHYD 2015 Interagency Conference. 19-23 April 2015. Reno, NV. 12 p.

[12] Walsh et al. (2005) C.J. Walsh, A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, R.P. Morgan (J. North Am. Benthol. Soc. 24(3):706-723) The Urban Stream Syndrome: Current Knowledge and the Search For A Cure. 2005.

[13] Steuer, J.J. (Urban Ecosyst DOI 10.1007/s11252-010-0131-x) A generalized watershed disturbance-invertebrate relation applicable in a range of environmental settings across the continental United States. 2010

[14] Moore, A.A. and M.A. Palmer (Ecological Applications, 15(4):1169–1177) Invertebrate Biodiversity in Agricultural and Urban Headwater Streams: Implications for Conservation and Management. 2005

[15] Barbour, et al. (2007), M.T. Barbour, M.J. Paul, D.W. Bressler, A.P. O'Dowd, V.H. Resh, E. Rankin. Bioassessment: A Tool for Managing Aquatic Life Uses for Urban Streams, Prepared for the Water Environment Research Foundation, Research Digest 01-WSM-3.

[16] EPA (2013). A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program. December 5, 2013. www.epa.gov/sites/production/files/2015-07/documents/vision_303d_program_dec_2013.pdf , accessed February 6, 2019.

with the Long-Term Vision framework, the WQIP has been developed to improve water quality in the Wissahickon Creek watershed by leveraging local interests and building upon a fresh, comprehensive understanding of the site-specific factors contributing to the ecological impairments of the Wissahickon Creek. The regulatory framework of a TMDL alternative provides an appropriate mechanism for the implementation of measures identified by the WCWP and its collaborators for improving water quality in the Wissahickon Creek.

1.3 Wissahickon Clean Water Partnership

Recognizing the challenges of improving ecological conditions in the face of high levels of urbanization, 13 municipalities and the four WWTPs formed the WCWP (*see* Figure 1-2) to develop a TMDL alternative through adoption of an Intergovernmental Agreement (IGA) (Appendix 1) that committed the municipalities and WWTPs to work collaboratively to improve overall ecological conditions.[17] The members of the Partnership unanimously extended the term of the IGA through the end of 2019 to ensure completion of this WQIP.

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[17] The three municipalities that make up the remaining one percent of the land area in watershed have voiced their support of the WCWP without having formally entered into the IGA.

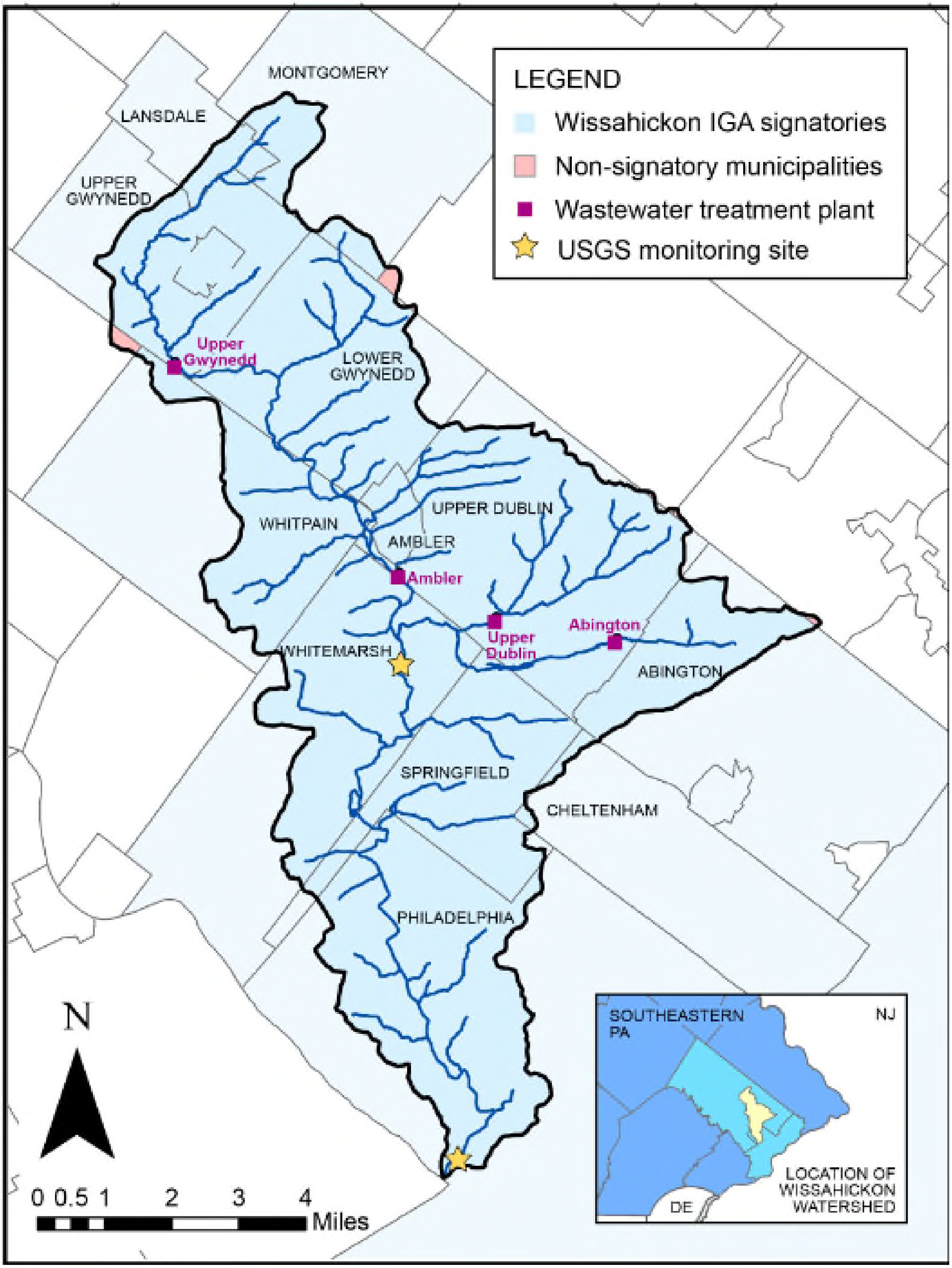

Figure 1-2 - Wissahickon Clean Water Partnership Municipalities and Wastewater Treatment Plants

Collaborative implementation of the IGA has enabled the WCWP to reduce the financial burden on the individual municipalities as they share resources and collective expertise from specialists in the field. For example, development of this WQIP enabled the leveraging of municipal funding with grant funding, most evident in the $1.3 million-dollar grant from the William Penn Foundation to the Pennsylvania Environmental Council (PEC) for instream monitoring, data collection, analysis and evaluation of options for developing strategies for a TMDL alternative. The municipalities collectively contributed $457,500 in matching funds for this effort. After the municipalities and the WWTPs signed the IGA and funding was secured through PEC from the William Penn Foundation, representatives from the WCWP met with PADEP and EPA to discuss an alternative to the Draft TMDL, consistent with PADEP's designation of the Wissahickon Creek under Category 5a in PADEP's 2016 Clean Water Act § 303(d) List.

This collaborative effort is unprecedented and earned the WCWP the 2019 Municipal Achievement Award from the Water Resources Association of the Delaware Basin. Additional information about the participating municipalities and their governance structures can be found in the Municipal Fact Sheet in Appendix 2.

1.4 Watershed Plan Purpose and Goals

The WQIP is intended to improve water quality conditions in the Wissahickon Creek watershed through implementation of an adaptive management approach to controlling stormwater flow rates and volumes that is supported by local stakeholders, inclusive of municipalities, WWTPs, and key environmental partners. This adaptive management plan will continually incorporate new data and information and identify new opportunities and actions to positively impact the watershed over time. As discussed in greater detail in Section 3, the measures established in this WQIP will be implemented over a time horizon of at least twenty years, a schedule that is reflective of the significant challenges to improving water quality in this highly urbanized watershed and the recognized need for iterative changes to the implementation measures over time. As a frame of reference, the WQIP was designed to generally conform with EPA's guidance on the preparation of watershed plans for improving water quality and EPA's handbook providing instruction for identification of critical source areas for implementation of BMPs and other measures to ultimately achieve water quality and quantity goals and objectives.[18]

The initial five-year phase of the WQIP includes significant commitments from the municipalities. A total of 91 BMP projects throughout the watershed, that are in addition to the projects identified in the municipalities' existing MS4 permits (*see* Table 3-1), have been identified for prioritization and consideration as part of the WQIP. Although not intended to be an exhaustive list, this list of projects represents potential opportunities that have been identified by the Management Committee and its collaborators to address the leading causes of water quality impairment. Consistent with the WQIP's adaptive management framework, the hydrologic model developed by Temple University, described in detail in Appendix 3, will be used as a tool for iterative decision-making and prioritization of targeted storm water management projects as the WQIP is implemented over time.

Section 3 also includes a discussion of the collaborative programs that will be initiated by the municipalities and WWTPs to leverage efficiencies by working together to identify and prioritize projects, programs, and policies that will lead to improvements in stream quality.

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[18] EPA (2018). Critical Source Area Identification and BMP Selection: Supplement to Watershed Planning Handbook. Office of Water: Nonpoint Source Control Branch. EPA 841-K-18-001, July 2018.

The WQIP also includes a series of tracking metrics and a comprehensive stream monitoring program for measuring progress implementing the identified stormwater BMPs and water quality improvements to the stream over time. As discussed in greater detail in Section 3.3, The tracking metrics include: (1) acres managed to control storm water impacts; (2) linear feet of stream restored and stream bank stabilized; (3) number of projects implemented; and (4) area of open space protected. Comprehensive water quality monitoring will be conducted periodically to confirm that the measures being implemented in accordance with the WQIP are having a positive impact, and to develop priorities for future actions. The WQIP also includes detailed reporting requirements to inform EPA, PADEP, and the public at large about the status of the projects and the progress that is being made through the implementation of the TMDL alternative.

SECTION 2 Watershed Characterization and Impairment Findings

2.1 The Watershed and its Supporters

The Wissahickon Creek watershed has many positive attributes notwithstanding the ecological impacts resulting from urbanization. Much of the mainstem benefits from wide, wooded stream corridors with dense tree canopy that provides shade and cooling, and wetlands. These features provide habitat, decrease flooding, reduce bank erosion, and maintain stream flows to sustain aquatic life during dry seasons. Healthy riparian vegetation intercepts and filters sediments in sheet and shallow subsurface flows.

Open space preservation in the Wissahickon Creek watershed dates back to the 1860s when Philadelphia developed the 1,800-acre Wissahickon Valley Park and established a large riparian buffer along the creek's east and west banks. The park begins at the border of Montgomery County and continues along the last 7 miles (11 km) of the Wissahickon Creek until its confluence with the Schuylkill River.

Based on a 2010 study conducted by Heritage Conservancy and funded by PADEP and the Montgomery County Planning Commission, 56% of the Wissahickon Creek watershed has tree cover on both sides, 25% has tree cover on one side, 14% has no tree cover on either side, and 6% has culverts or underground channels (Figure 2-1).[19] For Philadelphia, the statistics are more favorable, with 76% of the stream reach having tree cover on both sides. Tributaries in the city have less favorable canopy than the mainstem; Lorraine Run has only 50% canopy, as it runs through a golf course. Sandy Run headwaters also have low canopy with only 60% cover. The tributaries with the best cover are Prophecy Creek (93%) and Haines Run (92%). The survey found that riparian corridors provide shading to help reduce algae blooms, stabilize banks reducing erosion and siltation, and filter nutrients and sediment from overland flow. The large reaches of wooded buffer contribute to the health of the stream. The canopy cover maps identify potential locations for additional improvements including the headwaters and several golf courses.

The aesthetic beauty of the watershed, amid its urban and suburban setting, is recognized by the WCWP and others as providing important social benefits. A vast network of trails surrounds the creek, providing a high degree of public access (Figure 2-1). Recreational uses along the stream are common, including hiking, fishing, biking, walking, and jogging. This public access connects the residents to the watershed, reinforcing a culture of watershed stewardship.

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[19] Pennsylvania Spatial Data Access: The Pennsylvania Geospatial Data Clearinghouse. www.pasda.psu.edu/uci/DataSummary.aspx?dataset=36, accessed Feb. 13, 2019

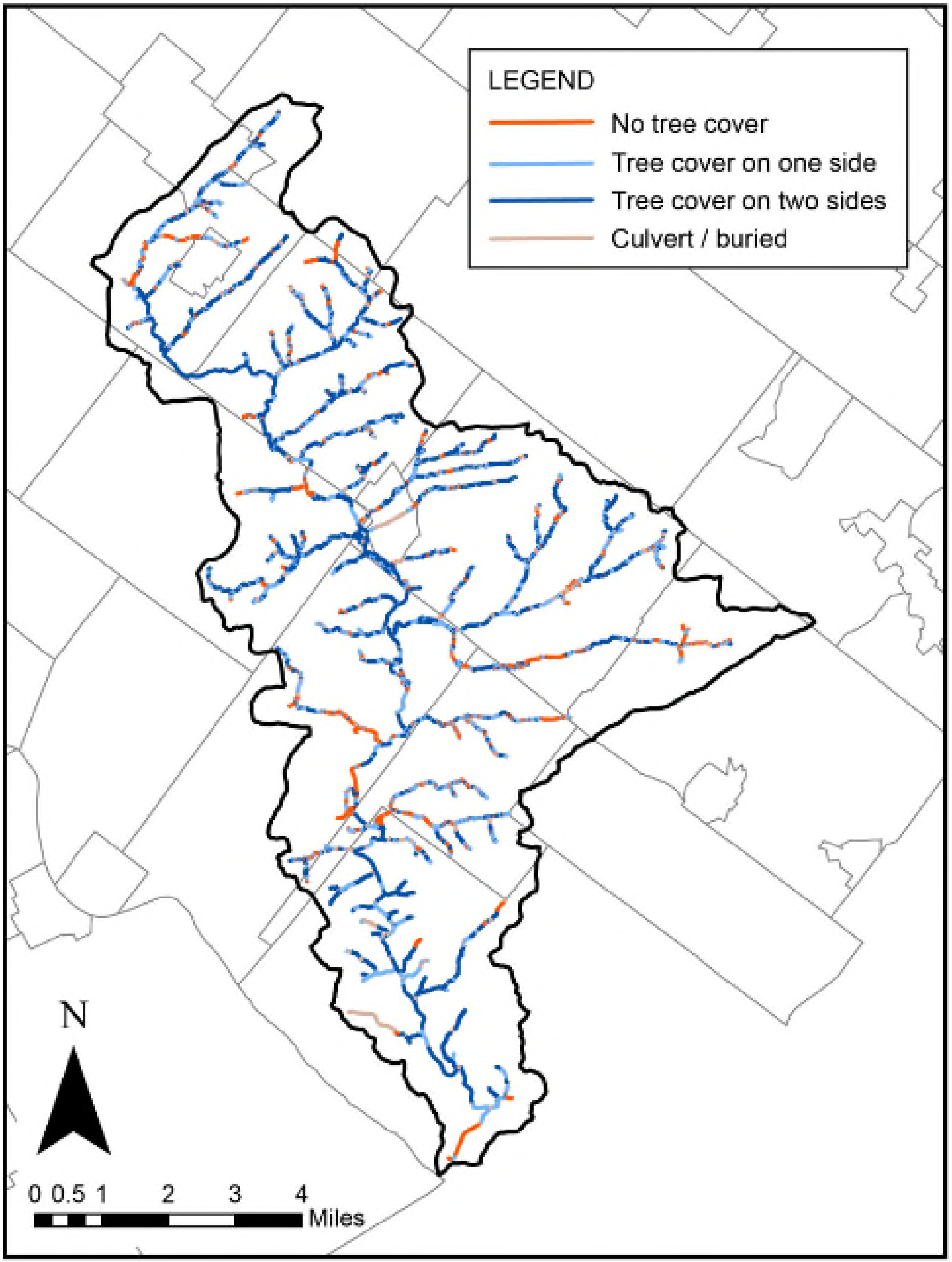

Figure 2-1 - Heritage Conservancy 2012 Riparian Buffer Assessment for Wissahickon Creek Watershed

Supporting the watershed's aesthetic beauty is an active network of watershed organizations and local environmental groups who raise awareness about the importance of improved water quality and will help to ensure that the goals of this WQIP are realized.[20] WVWA, Friends of the Wissahickon, Wissahickon Environmental Center, and Chestnut Hill Conservancy are a few of the organizations that provide resources and information to residents and municipalities in the watershed to help protect and steward the Wissahickon Creek. This robust cohort of organizations has contributed to a high level of environmental awareness and fluency among varied stakeholders in the watershed, which is crucial to the successful improvement of water quality in the Wissahickon Creek. Through continued and expanded engagement from watershed advocates as part of the WQIP, these groups will help to ensure that ecological conditions in the Wissahickon Creek continue to improve.

WVWA, a community leader in providing environmental education for the citizens who reside in the watershed since 1957, plays a particularly important role for the watershed community, including:

- Support to municipalities on public education and programs, planning projects for water quality improvement, and preserving open space for water quality improvement;
- Public lectures about environmental issues;
- Training for residents regarding implementation of green stormwater infrastructure on their private properties;
- Workshops and support for large landowners to implement best management practices on their private properties;
- Extensive student education programs on water quality science and monitoring;
- Ongoing training for a group of citizen scientists monitoring the Wissahickon Creek and its tributaries; and
- Annual creek clean ups, removing hundreds of pounds of trash, debris, and tires from the Wissahickon and surrounding trails.

There are nine Environmental Advisory Councils (EACs) in the Wissahickon Watershed who contribute to watershed education through the following activities:

- Green stormwater infrastructure workshops;
- Informational articles shared with residents through municipal newsletters, websites, or social media accounts;

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[20] Grant, L. and Langpap, C. (2018) Private provision of public goods by environmental groups, *Proceedings of the National Academy of Sciences* (stating that that "the presence of water groups in a watershed resulted in improved water quality and higher proportions of swimmable and fishable water bodies") DOI: 10.1073/pnas.1805336115

- Public education offerings at municipal events (tabling at community fairs, schools, recycling events);

- Educational resources and tools for residents and businesses to assist them in pollution reduction activities; and

- Grants to support implementation of residential and public property stormwater enhancement/management projects such as rain gardens, rain barrels, and flow through planters.

This history of educational services has created a knowledgeable constituency of residents, businesses, municipal staff, and elected officials to make informed decisions about planning for improving water quality and ecological conditions in the watershed.

Despite the many positive features of the watershed, there are unalterable hydrologic, geographic, and land-use realities that make the task of improving ecological conditions in the Wissahickon Creek challenging and that require a coordinated, collaborative response. For example, seventy-four percent (74%) of the watershed is urbanized; twenty-seven percent (27%) is impervious; and twenty-four percent (24%)[21] is semi-pervious. The negative impacts of urbanization on stream biological health ("urban stream syndrome") are well documented[22]. These impacts include altered hydrology, degraded riparian habitat, stream degradation from channelization and culverts, and increased erosion and sedimentation. The hydrology of the Wissahickon Creek is also influenced by limestone quarries such as Plymouth Meeting Quarry (formerly known as Corson Quarry). While the quarry is an important source of water for Lorraine Run, the dewatering effect associated with it can lower groundwater levels and reduce baseflow in the stream.

Numerous road crossings (Figure 2-2) with culverts and bridges also increase velocities by forcing stream flow through narrow channels. Each crossing represents a potentially significant stressor to the stream due to channelization, hydraulic impacts, and stormwater impacts. As part of an infrastructure survey stream walk conducted for the Wissahickon Creek Watershed Comprehensive Characterization Report, PWD identified 315 bridges and 163 culverts in the watershed, the vast majority (~80%) of which cross streams. The 2014 Wissahickon Creek Watershed Act 167 Plan (Act 167 Plan)[23] estimated that 34 of the 370 bridges and culverts assessed for the Act 167 Plan have inadequate capacity and would be overtopped by a 1-year design storm (2.75 inches of rain). A copy of the Act 167 Plan is included with this WQIP at Appendix 4.

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[21] University of Vermont Spatial Analysis Laboratory. (2013). High-Resolution Land Cover, Commonwealth of Pennsylvania, Chesapeake Bay Watershed and Delaware River Basin, 2013. Burlington.

[22] Walsh et al. (2005) C.J. Walsh, A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, R.P. Morgan (J. North Am. Benthol. Soc. 24(3):706-723) The Urban Stream Syndrome: Current Knowledge and the Search For A Cure. 2005.

[23] Center for Sustainable Communities, Temple University and Newell Tereska & Mackay Engineering (2014). Wissahickon Creek Act 167 Plan, Fromuth, R. (Ed.). April 2014 (revised November 2014) www.montcopa.org/2264/Wissahickon-Creek-Watershed-Act-167-Plan , accessed Feb. 9, 2019.

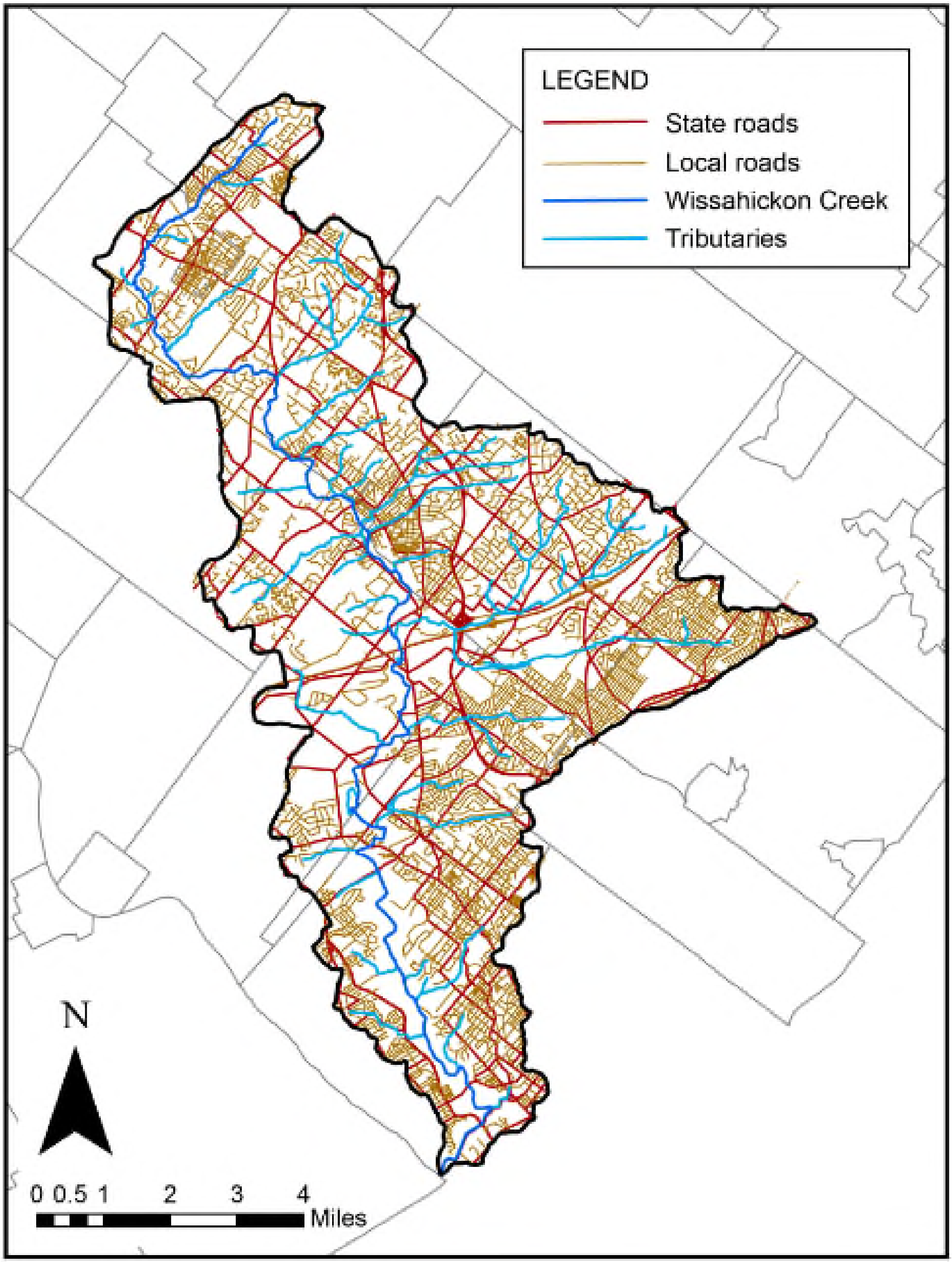

Figure 2-2 - Road Crossings

2.2 General Findings from the Watershed Evaluation

In Pennsylvania's 2016 Integrated Water Quality Monitoring and Assessment Report setting forth the Commonwealth's Clean Water Act § 303(d) list, the Pennsylvania Department of Environmental Protection (PADEP) determined that approximately 87 miles (140 kilometers) of the Wissahickon Creek and its tributaries do not meet their designated aquatic life uses.[24] This includes Pine Run and tributaries; Sandy Run and tributaries; and Trewellyn Creek and tributaries. Only Prophecy Creek is attaining its aquatic life use.

As part of the development of the WQIP, an assessment of the Wissahickon Creek watershed was performed to holistically assess the cause of impairment in the stream. This effort included a comprehensive sampling plan administered by Temple University that resulted in the collection of more than two years of new data that significantly expands upon the historical dataset for the Wissahickon Creek. Additionally, Kleinfelder, the technical consultant for the Management Committee, performed an independent watershed assessment based on the robust historic dataset for the Wissahickon Creek and the data collected by Temple through its study for the WQIP.

Both the Temple study for the WQIP and the Kleinfelder assessment[25] revealed that total phosphorus is not the primary cause of aquatic life impairment at this time. Instead, the available data show that storm water flows (both rate and volume) in the highly urbanized Wissahickon Creek watershed are the primary drivers of macroinvertebrate disruption, and efforts to reduce total phosphorus will produce no measurable impact on water quality, if ever and certainly not until stormwater improvements throughout the watershed are implemented. This fundamental conclusion based on the unalterable urban realities of the watershed is the central underpinning of the WQIP and the strategies for improving water quality conditions in the stream. Details of the Temple study for the WQIP can be found in Appendix 6. The Kleinfelder assessment can be found in Appendix 7.

Primary production (conversion of light energy to biomass) in aquatic systems is performed by one or more of these broad categories of producers: phytoplankton (suspended algae); rooted aquatic plants; and periphyton (algae attached to rocks and other substrates). There is no evidence that phytoplankton accumulate to any significant degree in the Wissahickon Creek or its tributaries, and plants appear to be mostly insignificant. Periphyton therefore account for most of the primary production. However, the periphyton densities in the Wissahickon Creek are consistent with other urban streams and do not rise to nuisance levels.

Flow and dissolved oxygen are monitored continuously by the United States Geological Survey (USGS) at two locations on the mainstem. These locations are (1) near the Wissahickon Creek confluence with the Schuylkill River at Ridge Avenue (USGS 01474000), and (2) just downstream of Sandy Run at Skippack Pike, commonly referred to as the Fort Washington gauge (USGS 01473900). Flow and dissolved oxygen were also measured during the Temple Study for the WQIP at two locations. *See* Appendix 6. Diurnal

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[24] Pennsylvania Department of Environmental Programs (PADEP) (2018). 2016 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report: Clean Water Act Section 305(b) Report and 303(d) List. Jan. 10, 2018 http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4168, accessed February 5, 2019.

[25] Counsel for the Partnership originally shared a copy of the Kleinfelder assessment with the WQIP update letter that was sent to EPA Region III on July 18, 2019. *See* Gold, Marc E. (2019). Letter to Jenifer Fields, Wissahickon Creek TMDL Alternative. July 18, 2019. A copy of the July 18, 2019 letter along with letters of support from the Wissahickon Valley Watershed Association, the Pennsylvania Environmental Council, and the Montgomery County Planning Commission can be found in Appendix 5.

variations in dissolved oxygen ("swings") provide a relative indication of productivity. These swings are caused by primary producers pumping dissolved oxygen into the water column during the day (from photosynthesis) and depleting oxygen at night (from respiration and decomposition).

We have found that the potential link between phosphorus and aquatic life impairments is through the direct stimulation of excessive plant growth, which impacts diurnal dissolved oxygen and can lead to indirect impacts on benthic aquatic life. Phosphorus is elevated in most streams in the Wissahickon Creek watershed. In addition, algal (periphyton) density and growth rate (productivity) are high at many locations throughout the watershed. However, reducing phosphorus loads to the Wissahickon Creek watershed would not decrease algal productivity.

Phosphorus levels in the Wissahickon Creek watershed cannot be reduced to levels that will restrain algal growth. The algal growth rate exhibits a threshold-type response, and that threshold occurs at a very low concentration of available phosphorus.[26] As a result, only small amounts of phosphorus are needed to support maximum periphyton growth rates. The study performed for EPA Region 3 and used to establish a recommended instream endpoint of 0.040 milligrams per liter (mg/L) total phosphorus cited the range of "algal growth saturation" at 0.025 to 0.050 mg/L available phosphorus.[27] Additional phosphorus above the saturation level will not result in higher algal growth rates. Conversely, algal growth rates will not decrease unless the available phosphorus is below the "algal growth saturation" levels.

Conditions in Prophecy Creek were used to help inform the selection of the three strategies to improve water quality in the Wissahickon recommended in the WQIP. There are no point sources discharging to Prophecy Creek and it is considered the least impacted by urbanization. A substantial portion of the sub-watershed drains Prophecy Creek Park and Briar Hill Preserve. The entire length of Prophecy Creek also benefits from an intact riparian corridor with mostly dense canopy, and the creek is crossed by only a few roads. PWD's 2005 evaluation of the Wissahickon Creek watershed[28] noted that Prophecy Creek exhibits the best resident fishery community in the entire watershed. Prophecy Creek therefore provides the best reference condition in the watershed. Phosphorus levels in Prophecy Creek were measured quarterly over a one-year period by Temple University; two of those quarterly samples captured baseflow conditions, which average 0.071 mg/L dissolved phosphorus. These levels are nearly identical to phosphorus levels observed in other areas of the Wissahickon Creek watershed upstream of the influence of point sources. Thus, the available phosphorus concentrations in baseflow, even in the most unimpacted areas of the watershed, exceeds the range of algal growth saturation and the EPA-proposed target of 0.04 mg/L total phosphorus in the Draft TMDL.

Based on these observations and a comprehensive assessment of the potential factors contributing to the aquatic life impairment in the Wissahickon Creek watershed, an evaluation of ongoing efforts to address urbanization-related stormwater impacts in the watershed, and informed by the hydrologic model projections discussed in Appendix 3, this WQIP recommends the following three types of measures for improving water quality in the Wissahickon Creek:

- **Additional Stormwater Management Measures** represent the principal means available to restore a more natural hydrologic regime to the Wissahickon Creek by decreasing runoff rates

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[26] *See* infra Footnote 8.

[27] Paul and Zheng, 2007, Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application. Report prepared by Tetra Tech for the U.S. Environmental Protection Agency, Region III, November 2007.

[28] PWD (2007). Wissahickon Creek Watershed Comprehensive Characterization Report. January 2007.

and volumes and enhancing baseflow. Stormwater management measures can directly improve stream corridors and mitigate riparian degradation. Improvements to stream crossings can directly alleviate stream channel disturbances. Stormwater management directly affects sediment loads and therefore mitigates siltation. In addition, it can reduce peak stream flows and decrease instream erosion. Addressing hydrologic impacts may also mitigate other stressors affecting aquatic life.

- **Riparian Improvements** lessen riparian degradation and hydrologic impacts while reducing the load of sediment impacting the stream. Riparian improvements also extend canopy, which limits light availability and directly reduces the potential for algal growth.

- **Instream Restoration** mitigates channel disturbances and reduces sedimentation by decreasing instream erosion.

Section 3 of the WQIP presents the ambitious commitments of the WCWP to collectively implement projects keyed to these recommended strategies throughout the Wissahickon Creek watershed.

The WQIP does not recommend WWTP upgrades to further reduce phosphorus loads at this time because such measures will not help restore aquatic life until a more natural hydrology is established in the Wissahickon Creek watershed, something that may take decades to achieve. Additionally, reducing phosphorus loads from treatment plants would impose secondary environmental costs, principally increased use of chemicals and increased sludge production and disposal costs. Consideration of additional improvements at the WWTPs as part of the TMDL alternative should be deferred until the measures recommended in this WQIP are implemented and the water quality benefits from these measures are evaluated.

2.3 Evaluation of Ongoing Efforts to Manage Stormwater

In light of the conclusions derived from the comprehensive stream assessment described in Appendices 6 and 7 that rates of stormwater volume and flow linked to urbanization are the primary cause of water quality impairments in the stream, the existing efforts of the MS4s and WWTPs that discharge to the Wissahickon Creek and its tributaries were assessed to provide an understanding of baseline conditions in the watershed and to define additional efforts to improve ecological conditions in the stream. While the existing efforts by the MS4s and WWTPs generally described in this section are significant, the assessment revealed that additional efforts to manage stormwater are needed to improve ecological conditions in the stream, particularly the establishment of additional stormwater BMPs throughout the watershed. *See* Section 3 for additional detail.

2.3.1 Municipal Efforts to Address Stormwater

Act 167 requires municipalities to develop comprehensive stormwater management programs and to manage stormwater programs for local development. Municipalities may also be required to manage stormwater pursuant to their MS4 permits, which generally require the employment of stormwater BMPs and the development of Pollutant Reduction Plans (PRPs)[29] and/or plans to meet any TMDL-based WLAs. The municipalities in the Wissahickon Creek watershed are already addressing sediment and

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[29] Pollutant Reduction Plans (PRPs) are required if a TMDL has not been developed or the permittee has not been assigned a specific wasteload allocation (WLA) in a TMDL.

nutrient pollution in stormwater to meet the requirements of the Nutrient and Siltation TMDL[30]. Some of the municipalities have decided to address their full WLAs for nutrients and sediments, while others have chosen to reduce their existing loads by 10%, as permitted under PADEP's MS4 permitting framework.

For the development of this WQIP, the 13 municipalities' MS4-related plans were reviewed, including a representative sample of community plans and annual reports that were prepared under the MS4 program. A general summary of the municipal plans and annual reports that were reviewed can be found in Appendix 8. The review indicated that the municipalities already have undertaken significant work to reduce stormwater impacts in the watershed since the establishment of the 2003 Nutrient and Siltation TMDLs, as further described below.

To achieve their required goals under the MS4 permitting program and the 2003 Nutrient and Siltation TMDLs, the municipalities are implementing stormwater BMPs, including retrofits of existing BMPs and installing new BMPs. BMP installation requires resources for planning, siting, design, and construction. Pursuant to their MS4 permits, each municipality is reporting on the status of its BMP inventory, an activity that becomes more involved as new BMPs are implemented.

Stormwater BMPs also require regular maintenance to ensure that they continue to function as designed. This requires resources to train municipal staff in proper operations and maintenance, develop systems to monitor continued effectiveness of BMPs, correct deficiencies, and report on BMP inspection and status.

Table 2-1 outlines the number, locations, and types of BMP each municipality has proposed to implement in order to meet its obligations under the 2003 Nutrient and Siltation TMDLs. Many of the proposed BMPs fall into two categories: stormwater basin retrofits and streambank restoration. These are important commitments that will continue to require considerable attention and resources.

In addition to BMPs, the MS4 program requires the municipalities to provide community education and outreach with respect to stormwater management. The 13 municipalities have established a robust set of public education and outreach programs that provide various means of providing relevant information to their residents. The current public education and outreach programs for a representative sample of the Wissahickon Creek watershed municipalities are summarized in Table 2-2. The existing framework serves as a useful starting point for the municipalities to coordinate efforts and share resources as they administer the stormwater BMPs on a watershed basis, in accordance with this WQIP.

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[30] *See* infra Footnote 2.

Table 2-1 – Proposed BMPs in PRP and TMDL Plans

Municipality	Proposed BMPs under permit	Characterization of Proposed Best Management Practices
Abington Township	10	Sandy Run Stream Bank Stabilization Project; Madison Avenue Meadow Construction; Roychester Park Rain Garden; Roychester Riparian Buffer Restoration; Roychester Park Bioretention/Infiltration Trench; Roychester Park Infiltration Berms/Retentive Grading; Evergreen Manor Park Infiltration Basin; Grove Park Stream Restoration; Ardsley Wildlife Sanctuary Streambank Stabilization and Basin.
Ambler Borough	2	Potential BMPs include street sweeping, inlet filter inserts, and streambank restoration.
Cheltenham Township	2	Street sweeping, private redevelopment, Caroll Brooke Park Swale, Glasgow, Inc./ Caroll Brooke Park Raingarden, Caroll Avenue stormwater conveyance channels improvements, Carroll Avenue BMP, Church Road and Willow Grove Avenue stormwater conveyance facility improvement, Route 309 Offset Road improvements, Cresheim trail BMP
Lansdale Borough	NA	Existing BMPs meet load reduction requirements.
Lower Gwynedd Township	4	3 basin retrofits; Streambank Restoration
Montgomery Township	8	Riparian buffer restoration; floodplain restoration; 5 basin naturalizations
North Wales Borough	2	Diversion of parking lot runoff of 1.22 acres to rain garden and 0.36 acres of residential site draining to infiltration bed.
Philadelphia	NA	Existing BMPs meet load reduction requirements
Springfield Township	NA	Existing BMPs meet load reduction requirements
Upper Dublin Township	2	Township-wide temporal basin discharge coordination to reduce flow variability in the stream; reduction of road salt to reduce levels of chloride and conductivity in the stream.
Upper Gwynedd Township	1	Wissahickon Creek streambank restoration with WVWA.
Whitemarsh Township	6	Rain barrel distribution, street sweeping, tree-planting
Whitpain Township	10	7 basin retrofit BMPs and 3 streambank restoration and stabilization projects

Table 2-2 – Representative Sample of Existing MS4 Public Education and Outreach Programs

Activity	Abington Township	Ambler Borough	Lansdale Borough	Lower Gwynedd Township	Montgomery Township	North Wales Borough	Philadelphia	Upper Gwynedd Township
Distribute information via municipal newsletter	●	●	●	●	●	●	●	●
Distribute information via community calendar	●							
Distribute information via municipal website	●	●	●	●	●	●	●	●
Distribute information via local newspaper								●
Distribute information via social media		●	●			●	●	
Distribute information to local businesses					●		●	
Provide information at municipal facilities	●	●				●	●	●
Provide stormwater education materials to contractors				●		●	●	
Swimming pool water discharge guidelines						●	●	●
Educational signage water quality project site					●			●
Homeowners Guide to Stormwater BMP Maintenance - article						●		
When it Rains it Drains - pamphlet						●		
Please Don't Feed the Geese - article						●		
Help make Community a Shade Better		●						
Community workshops (rain barrels, rain gardens, etc.)	●	●		●	●	●	●	
Seedling shade tree distribution					●			
New resident welcome packets					●			
Displays/Presentations at community events	●	●	●	●			●	
Storm drain stenciling	●			●			●	
Recruit community members to assist	●						●	
Sought public input on ordinances, SOPs, PRPs, and TMDL plans	●	●	●	●	●	●	●	●
Sought public input on capital improvements	●						●	
Partner with local schools	●					●	●	
Tree planting							●	●
Information meetings regarding stream restoration projects							●	●
Stream clean-up days				●		●	●	

2.3.2 Wastewater Treatment Plants

The WWTPs in the watershed have been upgraded since the 2003 Nutrient and Siltation TMDLs to improve their phosphorus removal capabilities. Methods for removal include addition of magnetite, aluminum, ferric chloride, and polymers. The WWTPs engaged in further phosphorus removal optimization during the development of the WQIP and provided progress reports on those efforts to EPA in December 2017, May 2018, December 2018, and May 2019. The efforts undertaken by the WWTPs during the WQIP development process demonstrate that three of the WWTPs are able to meet a seasonal average of 0.5 mg/L of orthophosphate.

The lack of bioassessment response in the watershed based on the results of the data evaluation, combined with the cost of chemical addition and related increases in sludge disposal, suggest that additional phosphorus reduction efforts by the WWTPs would not be productive at this time. Instead, efforts should be directed at activities that will further the implementation of the WQIP, including:

- Participation in the coordinated monitoring plan described in Section 3;
- Targeted stormwater projects on WWTP property;
- Regional collaboration regarding planning and coordination efforts; and
- Periodic re-assessment of the value of additional nutrient removal

For additional information about the assessment of the efforts from the four WWTPs, please refer to Appendix 9.

2.4 Evaluation of Stormwater Alternatives

The recommended improvement measures in the WQIP have been informed by hydrologic modeling that was performed by Temple University as part of the WQIP study. Temple University developed a hydrologic model of the Wissahickon Creek watershed to provide a tool to assess the impact of future changes in land use, stormwater controls, and other alternatives designed to improve the water quality of the creek. The model is a predictive tool that can be used to assess theoretically the effectiveness of proposed alternatives.

Rainfall runoff processes were modeled using PCSWMM Version 7.1.2480[31] This is a proprietary platform that utilizes the EPA supported Storm Water Management Model (SWMM) engine and incorporates an ArcGIS interface to improve data input and provide additional output analysis capabilities. The model combines hydrology, hydraulics, and water quality into a single, well documented, model. The model has a vast user community and has been used in thousands of studies to examine the impact of stormwater controls on runoff quantity and quality. Additional information on model input parameters, data sources used in this project, and modeling scenarios used to evaluate stormwater alternatives is provided in Appendix 3.

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[31] CHI Water, PCSSWMM 7,1,2480, October 31, 2107. https://www.pcswmm.com/Downloads/PCSWMM

SECTION 3 WQIP Implementation, Monitoring, and Reporting

The Water Quality Improvement Plan (WQIP) includes measures that are designed to improve conditions in the Wissahickon Creek and its tributaries in an effort to meet water quality standards in the future. This section of the WQIP presents the measures that the 13 municipalities with municipal separate storm sewer systems (MS4s) and the operators of the four wastewater treatment plants (WWTPs) will implement to address aquatic life impairments in the Wissahickon Creek watershed, in conjunction with regional partners, including the Wissahickon Valley Watershed Association (WVWA). The implementation strategies described in this section are predicated on an adaptive management approach that is intended to improve water quality conditions in the Wissahickon Creek watershed in an iterative and holistic manner.

The framework for these commitments is a collaborative strategy for integrating projects, policies, and programs to improve water quality conditions over time, and provides a process to sustain the prioritization and implementation of measures in an effort to improve water quality in the Wissahickon Creek watershed. Implementation of the WQIP is contemplated to take 20 years or more before water quality standards can be expected to be achieved, with five-year phases allowing for ongoing assessment and refinement of the control measures and strategies.

WQIP implementation will be a collaborative effort among the municipalities and WWTPs, and other regional partners like WVWA. The adaptive management approach embodied in the WQIP recognizes that changes in the science, economy, or support from others (such as private landowners) may create new opportunities. Consequently, as part of the WQIP, the members are committed to working together to adapt to changing circumstances.

3.1 Improvement Strategies

The improvement strategies that will be implemented by the WCWP municipalities as part of the WQIP fall into three main categories discussed in greater detail in this section: (1) projects; (2) programs; and (3) policies. Additionally, the four WWTPs remain committed to assisting with WQIP implementation despite the fact that further reductions in phosphorus discharges from the WWTPs are not the focus of the WQIP based on the updated analysis of the causes of impairment. The specific commitments of the WWTPs are discussed in Section 3.1.1.4.

3.1.1 Projects

Projects to be implemented as part of the WQIP are designed to make progress in achieving the common goal of improving conditions in the watershed. The projects will be coordinated and collectedly prioritized, when appropriate, to achieve consistency throughout the Wissahickon Creek watershed and to leverage available experience and optimal project siting. The partners in the WQIP will implement projects that include:

- Comprehensive identification and tracking of BMPs on public and private land (consistent amongst municipalities);
- Installation of BMPs on targeted tax-exempt properties by third parties;

- Additional installation of riparian buffers on appropriate sites;
- Identification and implementation of stream restoration and bank stabilization BMPs at culverts, bridge crossings, and other areas where infrastructure protection is needed.

As part of the WQIP, the WCWP developed a comprehensive inventory of candidate stormwater management projects, available at Appendix 10. Sources reviewed to develop the inventory include: the 2014 Wissahickon Creek Watershed Act 167 Plan (Act 167 Plan), municipal PRPs, 2003 Nutrient and Siltation TMDL plans, sewershed and outfall mapping, desktop analysis of the watershed, and input provided during discussions with individual municipalities between October 2016 and March 2017.

Projects identified through the Act 167 Plan were vetted with the respective municipalities to determine feasibility for implementation. The inventory in Appendix 10 includes the following categories of candidate projects: stormwater basin retrofits; conversion of existing stormwater detention basins to infiltration basins; stream bank stabilization and channel restoration; riparian buffers; floodplain restoration/storage; native habitat creation; and green stormwater infrastructure such as rain gardens. Projects determined to be potentially feasible were included in the inventory database.

A review of sewershed and outfall maps for each municipality that participated in the focused discussions was completed to determine possible locations where the storm sewer system could be intercepted and directed through a stormwater best management practice (BMP). The result of this detailed research is a database of roughly 190 sites throughout the watershed identified as project opportunities and/or suitable land. Figure 3-1 provides a summary of the projects by type. About 60% of the projects have not been previously identified. Half of these projects are on private land, which requires continued public education efforts, incentives, and partnerships for successful implementation.

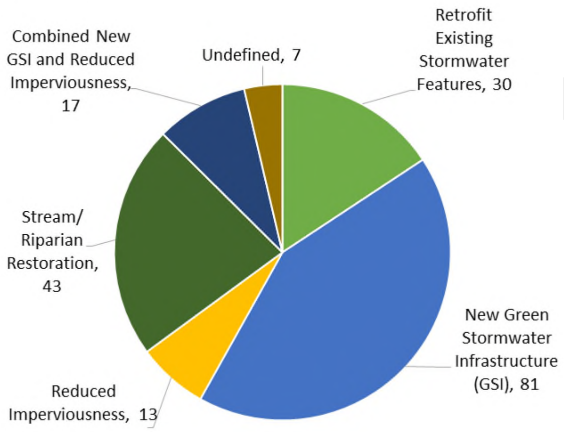

Figure 3-1 – WCWP Stormwater Project Inventory by Project Type. Numbers reflect the number of projects (total = 191).

The stormwater projects included as part of the municipalities' MS4 programs constitute a subset of all projects identified in the inventory. Therefore, the non-MS4 projects in Appendix 10 will provide stream quality benefits beyond those outlined in the municipalities' existing MS4 PRP/TMDL implementation plans. Included among the non-MS4 projects on the inventory list are 91 total projects presented in Table 3-1 that will be evaluated and prioritized for implementation over term of the WQIP. Clearly, this collaborative effort offers greater potential for progress than individual actions.

Table 3-1: Summary of Wissahickon Creek Watershed Non-PRP/TMDL Projects

Municipality	Projects	Ownership: Public	Ownership: Private	BMP Type: Retrofit	BMP Type: New GSI	BMP Type: Impervious Reduction	BMP Type: Stream, riparian Restoration	BMP Type: Unknown
Abington	5	4	1		5			
Ambler	4	3	1		4			
Cheltenham	3		3		3			
Lansdale	4	2	2		3	1	1	1
Lower Gwynedd	11	4	7	5	4		3	1
Montgomery	4	2	2		1		1	2
North Wales	10	7	3		8	1	1	
Springfield	12	9	3	5	4		3	
Upper Dublin	11	7	4	7	5		2	
Upper Gwynedd	5	3	2	4	1			
Whitemarsh	3	2	1	1	1		1	
Whitpain	3		3	3				
Philadelphia	16	10	6	11			5	
Total*	91	53	38	36	39	2	17	4

*Note: Some projects include multiple practices.

Terms: BMP – Best Management Practice; GSI – Green Stormwater Infrastructure

3.1.2 Programs

The program elements of the WQIP will be performed jointly by the municipal participants and provide for the sharing of resources. The individual roles and responsibilities associated with these programs will be detailed in the IGA, although some programs are expected to commence before the IGA is finalized. The programs include plans to:

- Conduct water quality monitoring and modeling to evaluate alternatives and measure and report on progress (*see* Section 3.2);
- Develop a shared coordination and progress reporting structure;
- Develop a program to help ensure proper operation and maintenance of stormwater BMPs;
- Execute a collaborative funding mechanism for project implementation;
- Encourage installation of BMPs on tax exempt properties;
- Develop a program to identify and implement stream restoration and stabilization BMPs at culverts, bridge crossings, and other areas where infrastructure protection is needed;
- Create a plan to assess riparian buffer opportunities, prioritize identified opportunities, and adopt implementation plans;
- Design a riparian buffer protection strategy using private property easements and stewardship;
- Implement private landowner "small" BMPs through a watershed-wide residential stormwater management program modeled on PWD's Rain Check program; and
- Coordinate public education, outreach, and engagement to further implementation of the WQIP with support from WVWA.

3.1.3 Policies

In addition to the projects and programs discussed above, the municipalities are encouraged to adopt policies in their respective communities that will:

- Ensure any stormwater ordinance enacted in accordance with the Act 167 Plan maximizes water quality benefits, incentivizes compliance, and provides for enforcement if necessary;
- Review subdivision and zoning ordinances and amend as appropriate to limit the creation of new impervious surfaces during development and redevelopment;
- Prioritize protection of high-quality riparian areas;
- Encourage additional tree canopy and cover protection;

- Encourage property owners to reduce impervious areas and/or implement green infrastructure solutions;

- Adopt new open space protection programs to preserve or enhance forested areas and protect existing pervious parcels; and

- Identify and prioritize opportunities to add additional protected open space throughout the watershed.

3.1.4 WWTPs

In December 2017, counsel for the WCWP submitted a letter to EPA on behalf of the WWTPs describing numerous efforts they would undertake while development of this WQIP proceeded (*see* Appendix 11),[32] including:

1) Facility Optimization - The WWTPs attempted to reduce phosphorus-related discharges by fifty percent of the maximum limits set forth in their NPDES permits during WQIP planning. The WWTPs entered into this effort despite knowing that it was unlikely that phosphorus discharges could be lowered enough to improve IBI scores or prevent algae blooms in the creek.

2) Report Progress - The WWTPs have provided semi-annual progress reports to EPA beginning in December 2017.

3) Feasibility Analysis - The WWTPs evaluated feasible phosphorus removal targets and strategies that would be subsequently refined taking into account the WQIP findings.

4) Feasibility Analysis Report - After the WQIP is accepted by EPA and PADEP, the WWTPs will prepare and submit a summary of their individual feasibility analyses within 180 days of the agencies' acceptance of the WQIP and confirmation of continued interest in the TMDL alternative.

The WWTPs satisfied the first three items. Despite the clear conclusion that stormwater rate and flows are the primary causes of stream impairment in the watershed, the WWTPs nevertheless will continue with facility optimization and will submit the feasibility analysis reports during the initial phase of WQIP implementation after approval of the TMDL alternative by EPA and PADEP.

In addition, the WWTPs have committed to providing funding for a portion of WQIP administration and to paying for the cost of a new USGS gauge on Sandy Run near the Abington WWTP (above the Upper Dublin WWTP), or at Bethlehem Pike near the confluence with the mainstem, as discussed in detail in Section 3.2, below. They also will evaluate whether stormwater BMPs can be implemented at their facilities.

3.2 Monitoring and Modeling Program

The monitoring and modeling program discussed in this section will provide a mechanism to evaluate stream quality improvements in the watershed resulting from implementation of the WQIP. The

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[32] Gold, Marc E. (2017). Letter to Evelyn MacKnight, Wissahickon Creek Alternative TMDL. September 19, 2017.

program will offer the opportunity for ecological trend analysis of macroinvertebrate assemblages and evaluation of changes in water quality and other ecological metrics over time. Additionally, the modeling program will serve as a tool to assist the WCWP evaluate and prioritize potential future BMP projects.

3.2.1 Water Quality Monitoring

The Philadelphia Water Department (PWD) will administer the WQIP's monitoring plan on behalf of the WCWP, as described below. Additionally, the WWTPs will fund the establishment and annual operation of a new USGS continuous stream flow gauge on Sandy Run near the Abington WWTP (above the Upper Dublin WWTP), or at Bethlehem Pike near the confluence with the mainstem.

PWD presently conducts comprehensive water quality monitoring in the Wissahickon Creek watershed and provided a substantial amount of the data that was used in this analysis. As part of the WQIP, PWD will continue to partner with the USGS and WVWA to operate and maintain continuous streamflow and seasonal water quality monitoring (March through November) at the Fort Washington and Ridge Avenue USGS gauging stations. Parameters monitored at those stations include gauge height, discharge, temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. PWD also will continue to collect dry weather grab samples on a quarterly basis at the Fort Washington and Ridge Avenue USGS gauge stations and will also begin grab sampling at the new USGS station. The grab sampling allows for the assessment of trends over time and contributes to a long-term record of water quality changes as restoration projects are completed. The grab samples are analyzed for ammonia, fecal coliform, specific conductance, *E. coli*, nitrate, orthophosphate (PO_4), DO, pH, total phosphorus (TP), temperature, and turbidity. These data help characterize water quality and are analyzed in a similar fashion as the samples collected at the stream gauges.

As part of the source water protection program, PWD collects monthly water quality grab samples at Ridge Avenue. This program is independent of the quarterly dry weather sampling and will continue pursuant to the WQIP. Parameters include alkalinity, ammonia, chloride, *E. coli*, fecal coliform, flow, hardness, nitrate, PO_4, pH, silica, specific conductance, TSS, and turbidity.

PWD's wadeable streams assessment program also will continue. This program is semi-probabilistic and includes 25 samples collected annually to assess physical habitat and benthic macroinvertebrate communities in area watersheds. Sampling occurs each year at the two USGS gauges. Additionally, a targeted basin is chosen for sampling from among Philadelphia's five major watersheds. Approximately 20% of samples (~5 samples) are collected from randomly selected sites, some of which may be in the Wissahickon Creek watershed. The Wissahickon and Pennypack Creeks are subdivided into mainstem and tributary sampling locations that are sampled intensely by PWD on roughly five-year cycles. The next PWD Wissahickon Creek watershed-wide tributary macroinvertebrate and habitat assessment is scheduled for spring 2022 (11 sites). This will be followed, in 2023, by mainstem assessments (12 sites).

The results of PWD's WQIP monitoring effort will be included within the periodic reports that the WCWP will submit to EPA and PADEP, as further described in Section 3.4, below.

The monitoring plan for the Wissahickon Creek watershed will provide the WCWP with a contemporaneous understanding of how implementation of the projects, programs, and policies implemented as part of the WQIP will contribute to ecological improvements in the stream over time. As implementation of the WQIP progresses, the WCWP will consider additional data needs as understanding of the factors contributing to water quality impairments in the stream may evolve over time.

3.2.2 Use of SWMM Model

The SWMM model described in Appendix 3 can be used on an ongoing basis as a tool to predict the impact of potential stormwater BMP projects and estimate the progress toward improved water quality in the Wissahickon Creek watershed. The SWMM model can also be used to evaluate placement and design of future projects on an individual as well as cumulative basis. This evaluation can include impacts to surface runoff volume and quality as well as impacts to instream water quality. Funding for these efforts in the Wissahickon Creek watershed is being provided through 2020 by the William Penn Foundation to Temple University as part of their support for the Delaware River Watershed Initiative and is not included as part of the WQIP monitoring programs.

3.3 Implementation Metrics

The following metrics will be used to track implementation progress on an annual basis. These metrics allow for clear tracking of the implementation of the BMPs that have been developed for the WQIP.

1. Overall number of BMPs implemented pursuant to the WQIP.

2. Increases in area treated by BMPs.

3. Increases in linear feet of stream restoration and bank stabilization.

4. Increases in protected open space.

Tracking and reporting of these of metrics will facilitate an adaptive management approach to address aquatic life use impairments in the Wissahickon Creek watershed.

3.3.1 Metric Keyed to Land Area Treated

For purposes of the WQIP, “Area Treated” is defined as:

> *an area measured in acres managed via stormwater BMPs to control the volume and peak flow rate of stormwater in accordance with the Pennsylvania Stormwater Management Act of 1978 (Act 167) stormwater ordinances (Montgomery County portion of watershed) or the City of Philadelphia’s stormwater regulations (Philadelphia portion of watershed). This definition applies to new development, re-development, and also areas that are retrofitted with stormwater BMPs to limit the volume and peak flow rate of stormwater runoff. Due to site conditions, it may be possible that certain BMPs are able to for improved stormwater volume and peak flow rate control. In these cases, the area treated metric will be increased based on the ratio of the volume and flow rates actually treated by the BMP relative to the volume and flow rates prescribed in regulations or ordinances. The maximum area treated credit will be capped at the 24-hour 1-year design storm as defined in NOAA Atlas 14 Volume 2 (2.73 in.) (Bonnin, et al 2006). Conversely, it may be possible that certain BMPs*

> *are unable to fully meet the requirements of stormwater ordinances and regulations. In these cases, the area treated metric will be adjusted (i.e., decreased) based on the ratio of the volume and flow rates actually treated by the BMP relative to the volume and flow rates prescribed in regulations or ordinances.*

The Area Treated metric is well-suited to measure the progress and success of WQIP implementation because it is:

- **Measurable**: Baseline data available to understand progress from current conditions;
- **Inclusive**: Allows for holistic assessment of the impacts of individual projects;
- **Trackable**: Can be quantified by existing tools; and
- **Relatable to Water Quality Improvements**: The SWMM Model suggests that for each 1% of area treated, there is a similar decline in peak rate flows which is linked to other parameters including runoff volume reduction increased infiltration and removal of pollutants.

The WQIP presents a total area-treated aspirational goal of 9,385 acres (using 2003 as the base year) within 20 years after the WQIP is adopted as a TMDL alternative, which represents approximately 24% of the watershed area. It is important to understand that there are many factors that may ultimately prevent the attainment of this aspirational goal, including private ownership of land well-suited for priority BMP projects; limited project funding; engineering challenges; and agency permitting to name just a few. The WCWP has an interest in tracking progress within the projected 20-year implementation timetable and formulated for its own purpose tentative interim goals on five-year intervals as a management tool as follows: 15% of total new acreage by year 5; 40% by year 10; 65% by year 15; and 100% by year 20. The interim goals reflect accelerated implementation in later years and will provide opportunities for the WCWP and its collaborators to adjust and adapt implementation priorities throughout the various phases of WQIP implementation.

3.3.2 Additional Metrics

In addition to tracking the number of stormwater BMPs that are implemented and the area treated metric described above, the WCWP will implement additional measures as part of the WQIP (projects, programs and policies) to enhance watershed restoration and improve water quality conditions within the watershed. These measures also contribute to stream quality improvements but cannot be converted to an area treated metric. In particular, several **stream restoration opportunities** are listed with the potential to improve over 9,600 linear feet (1.8 stream miles) of instream habitat. These projects typically take longer to plan and construct, require more permitting and are more difficult to schedule, as their implementation and ultimate success are dependent upon how well the stream responds to other measures.

The **protection and conservation of priority open space** in the watershed will also continue. The existing total protected open space for the watershed is 6,341 acres. Both the Montgomery County Planning Commission and WVWA have documented about 4,000 acres of unprotected open space in the watershed. WVWA has identified approximately 1,600 acres of that total for targeted protection based on several criteria including location along waterways, connectivity to other open space areas and alignment with municipal and county programs.

The proposed WQIP implementation goals, and target metrics for the 20-year plan are summarized in Table 3-2.

Table 3-2: Wissahickon Watershed - Proposed WQIP Metrics

Name	Measures included in Area Treated Definition	Definition	Aspirational Goal (20 yr plan)	Interim Tracking Goals	Water Quality Link	How determined
Area Treated		Area measured in acres managed via a stormwater BMPs to limit the volume and peak flow rate of stormwater runoff *	9,385 acres from existing base year of 2003	15% of total new acreage yr 5; 40% of total by yr 10, 65% by year 15; 100% by yr 20.	Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
	Impervious area removed and/or replaced with pervious feature	Area measured in sf of impervious surface converted to other pervious surface or removal of impervious paving & conversion to meadow	N/A - Rolls up to area treated metric		Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
	Tree canopy/riparian buffers	Increased acres of riparian buffers and increased canopy cover implemented in compliance with PA DEP guidance.	N/A - Rolls up to area treated metric		Reduction in peak flows, removal of pollutants	Projects completed, inspected and reported.
	Green Stormwater Infrastructure: basin retrofits, rain gardens, bioswales, green roofs, & others where area managed can be calculated.	Drainage area managed by GSI measure constructed per PA DEP guidance	N/A - Rolls up to area treated metric		Reduction in peak rate flows; Reduction in runoff volume; removal of pollutants; increased infiltration	Projects completed, inspected and reported.

Stream Restoration		Linear feet of stream restoration via DEP MS4 accredited practice	up to 9,600 LF from projects listed in Table 5.1	as appropriate	Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
Increased Protected Open Space^		Protect and increase dedicated open space along riparian areas or part of the MS4 drainage area. Includes areas converted from existing development to open space (e.g. buyout of flood prone structures)	1,600 Acres^^	as appropriate	Reduction in peak flows, removal of pollutants, retain infiltration value	Acres preserved/eased (purchase, gift, easement granted, conservation development)

Note: Of the 9,385 acres, MS4 PRP credits account for 3,281 acres, 660 acres of which includes new projects and 2,621 acres of which are credited through existing projects constructed since 2003.

* Area treated also includes features that are retrofitted to reduce runoff and peak flows according to the area treated metric described in section 3.3.1.

^Total protected open space per WVWA & MCPC data for Wissahickon Creek: 6,341 Acres

^^Total priority open space opportunities as identified by WVWA 2018 study: 1600 Acres

3.4 Proposed Implementation Schedule

The WQIP is intended to be implemented in a phased approach to afford opportunities for periodic re-evaluation, prioritization and modification. Each phase is intended to span a five-year period and provide an opportunity to assess implementation of the WQIP projects, programs, and policies, and make adjustments as necessary for each subsequent phase. The WQIP contemplates a minimum of four phases, with features of each phase as follows:

Phase 1 Years 1-5	• Amend and execute the IGA, plan, adopt policies, implement initial BMP projects, monitor, report
Phase 2 Years 5-10	• Collaborate, implement BMPs, monitor, **adapt**.
Phase 3 Years 11-15	• Same as Phase 2, **adapt.**
Phase 4 Years 16-20	• Same as Phase 3; evaluate new WWTP upgrades and investments, **adapt**.

Phase 1

The initial five-year phase of the WQIP includes the following tasks:

- Develop and enter into a new IGA, as described in Section 3.6 below, to be renewed every five years – Years 1 through 3.
- Implement the monitoring program – Years 1 through 5. It is contemplated that the monitoring program will commence before the IGA is finalized.
- Commence planning, design, and implementation of the projects listed Table 3-1 – Years 4 through 5. Though the process to implement the projects identified in Table 3-1 will commence after the IGA is finalized, the municipalities will assess other opportunities to improve the Wissahickon Creek prior to execution of the IGA.
- Develop and adopt policies and programs for mitigating stormwater impacts in the watershed – Years 1 through 5. Certain programs will commence only after the IGA is finalized.
- Update the SWMM model with the data collected as part of the monitoring program – Years 3 through 5.

Additional Phases

The subsequent phases of the WQIP will:

- Continue with the monitoring and reporting framework applicable during the first phase.
- Continue with implementation of the BMP projects identified in Table 3-1, as well as identify other potential projects throughout the watershed using information from the monitoring and modeling programs.
- Evaluate the ongoing effectiveness of WQIP implementation and make adjustments as needed.

3.5 Reporting

Periodic reporting to EPA, PADEP and the public is an integral part of the WQIP after it is approved. Based on the elements of the plan, reports will be submitted in accordance with the following schedule:

- Semi-annual reports as to the status of the new IGA until the IGA is in place
- Annual reports including (1) description of progress implementing BMP projects during each reporting period; (2) policies and programs adopted during each reporting period; (3) results of monitoring undertaken during each reporting period; and (4) accounting of progress towards tracking metrics/goals.

3.6 The Value of Continued Collaboration

Continuing a collaborative watershed-based approach, as contemplated by this WQIP, will provide substantial water quality benefits. Given the water-quality challenges facing the watershed related to urbanization and stormwater management, sustained collective action over time has a higher likelihood of resulting in improved stream quality conditions in the watershed than any individual actions taken by a municipality or WWTP.

By building on the existing Management Committee structure of the WCWP and entering into a new IGA, the municipalities and WWTPs will be able to maximize water quality improvements related to watershed-wide planning and implementation of the stormwater management activities described in the WQIP. This collaborative structure will allow for the deployment of a holistic asset management strategy to track system operations and schedule regular maintenance of stormwater BMPs that will provide substantial benefit to the watershed when compared to the current approaches for managing stormwater pursuant to individual MS4 permits. Likewise, continuing a strong, coordinated monitoring program will allow the members of the WCWP to adjust the plan if the data suggests modification of the WQIP would be more beneficial for improvement of conditions in the stream.

The IGA that the WCWP members intend to enter into during the first phase of WQIP implementation will outline the governing structure for the collaboration, activities to be jointly funded, and funding mechanisms. Sources of funding for contributions from individual municipalities would be up to each municipality but could include general fund revenue, fees-in-lieu, capital fund revenue, bond funds, and stormwater fees. The IGA will likely continue with a Management Committee that has been effective during the WQIP development process. Going forward, the Management Committee has identified a set of preliminary activities for continued collaboration. Leads for these activities have been identified as described below:

- Administration and Reporting – Montgomery County Planning Commission through a community planning assistance contract with the municipal partners.

- Public Education and Private Landowner Programming – Wissahickon Valley Watershed Association through a contract with the municipal partners.

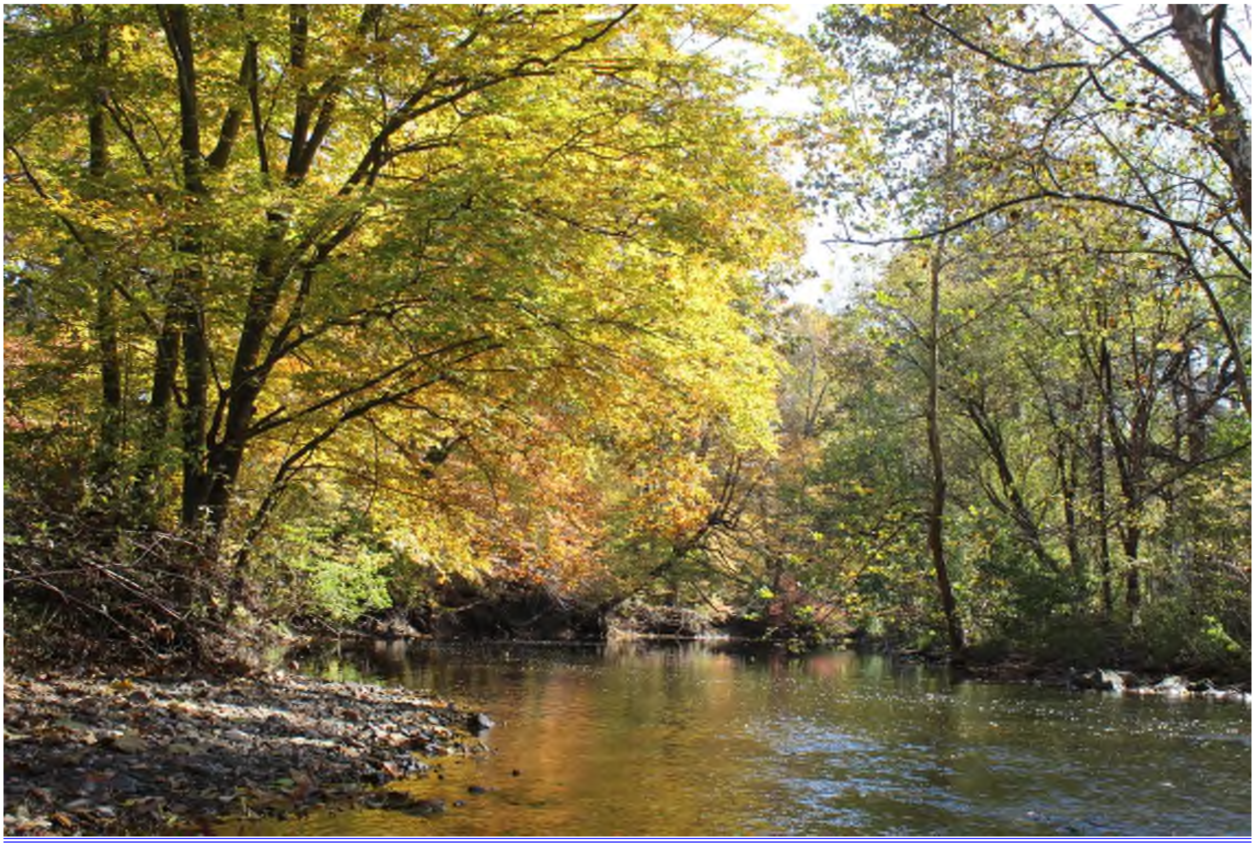
- Monitoring and Modeling – The Philadelphia Water Department will implement the monitoring and modeling program described above, work that it values at $200,000.

From a financing perspective, a strong collaborative structure in the Wissahickon Creek watershed will enable the municipalities to maximize the power of leveraging available resources. Combining resources across municipalities provides for greater potential to provide matching funds that may increase the potential of the WCWP to secure higher grant awards. In addition, grant funders often seek out collaborations because they know that investing in collaborations increases the likelihood of achieving economies of scale.

Continuation of the collaboration among the members of the WCWP also will strengthen applications for funding of stormwater and nonpoint source pollution prevention projects to PENNVEST, among others, who is dedicated to helping achieve both environmental improvements and economic development in Pennsylvania communities.

Wissahickon Creek Water Quality Improvement Plan (WQIP)

A comprehensive plan to improve water quality in the Wissahickon Creek Watershed



September 2019

ACKNOWLEDGEMENTS

Wissahickon Clean Water Partnership

The Wissahickon Clean Water Partnership (WCWP or Partnership) is a coalition of 13 municipalities (representing 99% of the land area in the watershed) and operators of four wastewater treatment plants (WWTPs) in the Wissahickon Creek watershed. It was formed through an Intergovernmental Agreement (IGA), ~~which committed~~ that established a process for the Partnership to collaborate with a Water Quality Advisory Team (WQAT) consisting of the Pennsylvania Environmental Council (PEC), Temple University, the Wissahickon Valley Watershed Association (WVWA), the University of Maryland Environmental Finance Center (EFC), and the Montgomery County Planning Commission for the development of a holistic watershed plan to improve water quality in the Wissahickon Creek.

Representatives of the 13 municipalities and four WWTPs make up the Partnership's Management Committee, which is supported by legal counsel from Manko, Gold, Katcher & Fox LLP, and technical services by Kleinfelder, Inc. The entities represented on the Management Committee are listed below:

Municipalities
Abington Township
Ambler Borough
Cheltenham Township
City of Philadelphia
Lansdale Borough
Lower Gwynedd Township
Montgomery Township
North Wales Borough
Springfield Township
Upper Dublin Township
Upper Gwynedd Township
Whitemarsh Township
Whitpain Township

Sewer Authorities/Wastewater Treatment Plants:
Abington Township WWTP
Ambler Borough WWTP
Upper Gwynedd Township WWTP
Upper Dublin WWTP (operated by Bucks County Water & Sewer Authority)

Water Quality Advisory Team

The roles and responsibilities of the WQAT are summarized ~~below:~~below:Pennsylvania Environmental Council (overall coordination, funding coordination, documentation of process)
Temple University (gather and analyze data and develop and model scenarios)
Wissahickon Valley Watershed Association (public outreach and ~~communicate progress~~communication)
Environmental Finance Center, University of Maryland (funding opportunities, efficiencies and economic incentives)
Montgomery County Planning Commission (coordination and support of the Management Committee and the WQAT, and organizing meetings)

~~Water Quality Monitoring~~

~~Environmental monitoring was conducted by a team including Dr. Laura Toran (Principal Investigator), Dr. Sarah Ledford (postdoctoral research associate), and Chelsea Kanaley (master's student) of Temple University. Temple was also responsible for the analytical work supporting the technical conclusions in the WQIP.~~

Funding

William Penn Foundation

Management Committee as provided by the IGA and amendments.

Additional Partners

Geosyntec Consultants, Inc. (WQIP Editor)
Environmental Protection Agency (EPA) Region 3
Pennsylvania Department of Environmental Protection (PADEP)

~~Cover~~

~~Map shows impervious surfaces in the watershed: Dark purple are impervious surfaces such as roads and buildings (27% of area) and light purple includes semi-pervious surfaces such as lawns (24% of area)~~

APPENDICES

Appendix 1:	**~~2016~~ Intergovernmental Agreement ~~and 2019 Extension~~**
Appendix 2:	**Municipal Fact Sheet**
Appendix 3:	**Temple University ~~Hydrologic Modeling Report & Scenarios~~ Report on SWMM Model Development and Calibration for the Wissahickon Creek (October 22, 2018)**
Appendix 4:	**Wissahickon Creek Act 167 Stormwater Management Plan**
Appendix 5:	**July 2019 WQIP Update Letter from Marc Gold to EPA on behalf of the Management Committee and Letters of Support from WVWA, PEC, and Montgomery County Planning Commission**
Appendix 6:	**Temple University Study for the WQIP ~~Assessment Report (Insert Date)~~**
Appendix 7:	**Kleinfelder ~~Report~~ – Wissahickon Creek Water Quality Improvement Strategy (January 9, 2019)**
Appendix 8:	**MS4 ~~Municipal~~ Community Plan Information**
Appendix 9:	**Wastewater Treatment Plant Data**
Appendix 10:	**Watershed BMP Project Inventory**
Appendix 11:	**September 2017 Letter from Marc Gold to EPA ~~Re:~~ on behalf of the WWTPs**

SECTION 1 Factual and Regulatory Background

This section provides background information that is essential to understanding the strategies proposed to be implemented under this Wissahickon Creek Water Quality Improvement Plan (WQIP), with a synopsis of the conditions that explains the holistic stormwater management approaches proposed in the WQIP, and discussed in greater detail in Section 3 below. It includes a description of the watershed; a discussion of the existing regulatory framework applicable to the analysis of effective measures for achieving water quality improvements in the watershed; and information about the Wissahickon Clean Water Partnership that was formed in response to the Draft Total Phosphorous TMDL for the Wissahickon Creek Watershed published by the United States Environmental Protection Agency (EPA) in 2015 (the Draft TMDL)[1]. It also includes a description of the purpose and goals of the WQIP, and a brief overview of the structure of the WQIP.

1.1 Wissahickon Creek Watershed

The Wissahickon Creek watershed is located in southeastern Pennsylvania, in Montgomery and Philadelphia Counties. The headwaters commence just below a parking lot in a large suburban mall. The mainstem flows approximately 27 miles before joining with the Schuylkill River in the City of Philadelphia. The watershed drains 64 square miles and spans portions of 16 municipalities. The municipalities range from small boroughs to larger townships to the City of Philadelphia. In 2010, an analysis of ~~Census~~ census data by watershed area estimated that nearly 222,000 people live in the Wissahickon Creek watershed (Table 1-1). Also noteworthy is the fact that five municipalities comprise over 70% of the watershed drainage area: Upper Dublin (18.9%), Philadelphia (16.8%), Lower Gwynedd (13%), Whitemarsh (12.9%), and Springfield (10.1%).

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[1] EPA (2015). Total Phosphorus TMDL for the Wissahickon Creek Watershed, Pennsylvania - Draft. May 20, 2015. www.epa.gov/tmdl/proposed-wissahickon-creek-phosphorus-tmdl , accessed February 1, 2019.

Municipality	2010 Population in Watershed	2010 Census	Percent of Population in Watershed
Abington Township	12,700	55,310	23.0%
Ambler Borough	6,417	6,417	100.0%
Cheltenham Township	500	36,793	1.4%
Horsham Township	100	26,147	0.4%
Lansdale Borough	3,800	16,269	23.4%
Lower Gwynedd Township	10,100	11,405	88.6%
Montgomery Township	3,500	24,790	14.1%
North Wales Borough	3,229	3,229	100.0%
Philadelphia County	112,100	1,526,006	7.3%
Springfield Township	18,400	19,418	94.8%
Upper Dublin Township	23,100	25,569	90.3%
Upper Gwynedd Township	9,600	15,552	61.7%
Upper Moreland Township	100	24,015	0.4%
Whitemarsh Township	9,800	17,349	56.5%
Whitpain Township	7,900	18,875	41.9%
Worcester Township	100	9,750	1.0%
Total	**221,446**	**1,836,894**	**12.1%**

Table 1-1 Population Estimates for the Wissahickon Creek Watershed. Sources: Census and 2014 Wissahickon Creek Act 167 Stormwater Management Plan. Philadelphia County and City of Philadelphia are congruous.

Throughout its history, the Wissahickon Creek watershed has undergone tremendous growth and urbanization. Its location within the Philadelphia metropolitan area made it attractive for development, especially between the 1950s through the 1980s. The pattern of growth has resulted in dense development in the center third of the watershed, with riparian areas along much of the lower and central main stem and portions of the northwestern headwaters protected as parks and preserves.

Pre-1970s development within the Wissahickon Creek watershed typically did not take into account stormwater management controls. As these communities continued to develop and expand, some areas experienced high levels of flooding resulting in loss of property and in some cases, loss of life. Although stormwater management controls were put in place in later years, the controls initially focused on management of peak flows and storms. Water quality considerations were not among the priority considerations in designing and implementing stormwater controls until the late 1980s.

As of 2005, more than 50% of the Wissahickon Creek watershed was used for single- or ~~mulit-family~~ multi-family residences. Population in both the suburban communities and the City of Philadelphia is expected to increase by approximately seven percent by 2040, requiring 5,800 new housing units.

Commercial and industrial use comprise just under five percent of the watershed. Parking to support commercial, residential and community activities comprised an additional three percent of the land use. Woodland covers 17 percent of the watershed, agriculture seven percent, and recreational space occupies an additional eight percent. The remaining land use, ten percent, includes transportation, community services, water, utility operations, and vacant properties.

Even though the Wissahickon Creek faces ecological and water quality stresses that are directly linked to extensive urbanization, it is well-recognized that the watershed has many extraordinarily positive attributes that enhance the quality of life in the region. For example, the Wissahickon Creek watershed serves as a source of great aesthetic beauty, with a vast network of readily accessible trails surrounding the mainstem. These trails provide extraordinary recreational opportunities in and along the stream, including hiking, fishing, biking, jogging, and walking. The Pennsylvania Department of Conservation and Natural Resources has recognized the value of the watershed's trail system by naming Forbidden Drive, a five mile stretch along the Wissahickon Creek situated within the Wissahickon Valley Park, as the 2018 Pennsylvania Trail of the Year. These are among the features that led the WCWP and its collaborators to develop this forward-looking comprehensive WQIP as a TMDL alternative.

1.2 Water Quality Impairments and Total Maximum Daily Loads

The entire mainstem of the Wissahickon Creek and most of its tributaries have been identified by the Pennsylvania Department of Environmental Protection (PADEP or Department) as not supporting their designated aquatic life uses based on the results of PADEP's long-term benthic macroinvertebrate watershed sampling effort. PADEP identified segments of the Wissahickon Creek as impaired on Pennsylvania's Clean Water Act § 303(d) List in 1996, 1998, 2002, and 2016. Many of these segments have also been identified as impaired for nutrients and siltation.

In 2003, EPA established TMDLs to address nutrients, siltation, and low dissolved oxygen levels in the impaired segments of the Wissahickon Creek watershed (the 2003 Nutrient and Siltation TMDLs)[2]. Because Pennsylvania does not have specific numeric water quality criteria for nutrients or siltation, EPA selected an endpoint for the 2003 Nutrient and Siltation TMDLs based on a linkage between nutrient concentrations, dissolved oxygen concentrations, and biological activity in the streams. The 2003 Nutrient and Siltation TMDLs resulted in wasteload allocations (WLAs) for wastewater treatment plants (WWTPs) and the municipal separate storm sewer systems (MS4s) for several pollutants[3].

For the WWTPs, PADEP issued National Pollutant Discharge Elimination System (NPDES) permits that are consistent with the 2003 Nutrient and Siltation TMDLs that required significant treatment plant upgrades. Although WLAs for phosphorus were not assigned, the treatment plant upgrades indirectly resulted in improved phosphorus removal capabilities.

MS4 WLAs under the 2003 Nutrient and Siltation TMDLs are being addressed by the Pennsylvania Stormwater Management Act of 1978 (Act 167) and municipal MS4 permits. Act 167 requires preparation and adoption of stormwater management plans for each watershed to manage stormwater on a watershed basis. Peak rates for flood control are established to reduce erosion, preserve natural stormwater runoff regimes, and protect groundwater resources. PADEP-issued MS4 NPDES permits for

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[2] EPA (2003). Nutrient and Siltation TMDL Development for Wissahickon Creek, Pennsylvania. Final Report. October 2003.

[3] The 2003 Nutrient and Siltation TMDLs resulted in WWTP WLAs for ammonia nitrogen, nitrate-nitrite nitrogen, 5-day carbonaceous biological oxygen demand, and requirements to increase effluent dissolved oxygen concentrations to 7.0 milligrams per liter.

Philadelphia (2006) and the Small MS4s in the watershed (2013) to address the sediment WLAs in the Siltation TMDL. The MS4 permit renewal applications that were due to PADEP in 2018 for Small MS4s required TMDL Plans and Pollutant Reduction Plans (PRPs) to further reduce MS4 sediment loads.

In 2005, PADEP requested that EPA develop a TMDL with a total phosphorus endpoint of 0.24 milligrams per liter (mg/L). EPA conducted a study to establish total phosphorus endpoints for six watersheds in southeastern Pennsylvania, including the Wissahickon Creek watershed. EPA selected an endpoint of 0.04 mg/L for all six watersheds[4]. In 2015, EPA issued the Draft TMDL based on the premise that phosphorus is the primary cause of the low macroinvertebrate scores in the watershed.[5]

PADEP and the communities reviewed the Draft TMDL and other supporting information and provided comments to EPA. Of specific concern was the uncertainty associated with the Draft TMDL's stressor-response approach.[6] Analysis of macroinvertebrate index scores across a wide range of phosphorus concentrations showed that phosphorus levels could not be correlated with the measured aquatic life impairment in the watershed. This conclusion is illustrated by the fact that the significant phosphorus reductions achieved by the WWTPs pursuant to the 2003 Nutrient and Siltation TMDLs have not produced an observable improvement in macroinvertebrate bioassessment scores (Figure 1-1). Simply stated, reductions in point source phosphorus loads are not projected to improve IBI scores or reduce benthic algal growth.

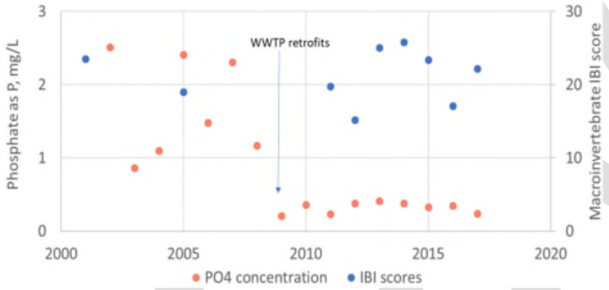

Figure 1-1 Measured phosphate (PO_4) and macroinvertebrate index of biological integrity (IBI) scores at the U.S. Geological Survey Fort Washington gage before and after WWTP retrofits.

Further, studies of the relationship between phosphorus and algae have shown that once phosphorus levels exceed a "threshold" level, algal growth is not constrained by phosphorus[7,8,9]. In addition to the absence of a phosphorus driver, phosphorus levels in the watershed cannot be reduced to the target level needed to restrain algal growth. Examples of why this numeric target cannot be achieved include:

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[4] EPA (2007). Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application. Prepared by Tetra Tech

[5] *See* infra Footnote 1.

[6] Jones, Benjamin W. Letter to Lenka Berlin, USEPA Region III. July 30, 2015. Wissahickon Creek TMDL. Manuscript.

[7] Thomann, R.V. and Mueller, J.A., 1987, Principles of Surface Water Quality Modeling and Control, Harper-Collins, New York

[8] Hill, et al. (2009) W.R. Hill, S.E. Fanta, and B.J. Roberts. Quantifying phosphorus and light effects in stream algae. (Limnol. Oceanogr., 54(1), 2009, 368–380)

[9] Goyette, J.O., Bennet, E.M. and Maranger R. (2018) Low buffering capacity and slow recovery of anthropogenic phosphorus pollution in watersheds. Nature Geoscience 11, 921-925.

- Total phosphorus levels in baseflow from the least impacted streams in the watershed are approximately 0.08 mg/L, essentially two times the proposed endpoint.

- Stormwater from urbanized areas generally contains total phosphorus levels of 0.2 to 0.4 mg/L; runoff in forested areas contains approximately 0.1-0.2 mg/L[10,11].

- WWTP effluent limits that would be required to achieve the WLAs for total phosphorus in the Draft TMDL ranged from 0.033 to 0.072 mg/L, which are levels beyond that typically required in municipal WWTPs and ~~are difficult to~~ which cannot consistently ~~achieve~~ be met in any WWTP ~~without~~ even after the expenditure of significant ~~cost~~capital and operating costs.

The combined WLAs (for WWTPs and MS4s) that would be imposed by the Draft TMDL are technologically unachievable.

Given ~~these conclusions -~~ the conclusion that the WLAs in the Draft TMDL will not improve water quality conditions in the Wissahickon Creek, the WCWP and its collaborators set out to define other feasible strategies that can be implemented to move toward achieving applicable water quality standards. Available studies have established that the degree of historical urbanization in the watershed is the single most important factor that influences benthic macroinvertebrate community structure.[12,13,14] Comprehensive and feasible strategies for minimizing the impacts of urbanization in the watershed were developed and are presented in the WQIP including stormwater BMPs and other projects that address (1) hydrologic (stream flow) changes; (2) riparian (streambank) degradation; (3) stream channel disturbances; (4) sedimentation; and (5) stormwater discharges.[15]

After the publication of the Draft TMDL in 2015, PADEP identified the Wissahickon Creek as a candidate for a TMDL alternative and included the stream under Category 5a (a designation supporting a TMDL alternative) in PADEP's 2016 Clean Water Act Section 303(d) List. PADEP's designation of the Wissahickon Creek as a candidate for a TMDL alternative was prompted by EPA's reassessment of the TMDL program, as reflected in the Long-Term Vision for Assessment, Restoration, and Protection Under the Clean Water Act Section 303(d) Program (December 2013).[16] EPA's Long-Term Vision framework recognizes the potential advantages of employing strategies that are tailored to meet the needs of a given watershed, with the possibility that site-specific measures provide immediate water quality benefits and added practicality for achieving the water quality goals of the Clean Water Act. Consistent

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[10] PADEP (2006). Pennsylvania Stormwater Best Management Practice Manual. Bureau of Watershed Management, Document 363-0300-002. December 30, 2006.

[11] Elliot, W.J., E. Brooks, D.E. Trauemer and M. Dobre. 2015. Extending WEPP Technology to Predict Fine Sediment and Phosphorus Delivery from Forested Hillslopes. Presented at the SEDHYD 2015 Interagency Conference. 19-23 April 2015. Reno, NV. 12 p.

[12] Walsh et al. (2005) C.J. Walsh, A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, R.P. Morgan (J. North Am. Benthol. Soc. 24(3):706-723) The Urban Stream Syndrome: Current Knowledge and the Search For A Cure. 2005.

[13] Steuer, J.J. (Urban Ecosyst DOI 10.1007/s11252-010-0131-x) A generalized watershed disturbance-invertebrate relation applicable in a range of environmental settings across the continental United States. 2010

[14] Moore, A.A. and M.A. Palmer (Ecological Applications, 15(4):1169–1177) Invertebrate Biodiversity in Agricultural and Urban Headwater Streams: Implications for Conservation and Management. 2005

[15] Barbour, et al. (2007), M.T. Barbour, M.J. Paul, D.W. Bressler, A.P. O'Dowd, V.H. Resh, E. Rankin. Bioassessment: A Tool for Managing Aquatic Life Uses for Urban Streams, Prepared for the Water Environment Research Foundation, Research Digest 01-WSM-3.

[16] EPA (2013). A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program. December 5, 2013. www.epa.gov/sites/production/files/2015-07/documents/vision_303d_program_dec_2013.pdf , accessed February 6, 2019.

with the Long-Term Vision framework, the WQIP has been developed to improve water quality in the Wissahickon Creek watershed by leveraging local interests and building upon a fresh, comprehensive understanding of the site-specific factors contributing to the ecological impairments of the Wissahickon Creek. The regulatory framework of a TMDL alternative provides an appropriate mechanism for the implementation of measures identified by the WCWP and its collaborators for improving water quality in the Wissahickon Creek.

1.3 Wissahickon Clean Water Partnership

Recognizing the challenges of improving ecological conditions in the face of high levels of urbanization, 13 municipalities and the four WWTPs formed the WCWP (*see* Figure 1-2) to develop a TMDL alternative through adoption of an Intergovernmental Agreement (IGA) (Appendix 1) that committed the municipalities and WWTPs to work collaboratively to improve overall ecological conditions.[17] The members of the Partnership unanimously extended the term of the IGA through the end of 2019 to ensure completion of this WQIP.

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[17] The three municipalities that make up the remaining one percent of the land area in watershed have voiced their support of the WCWP without having formally entered into the IGA.

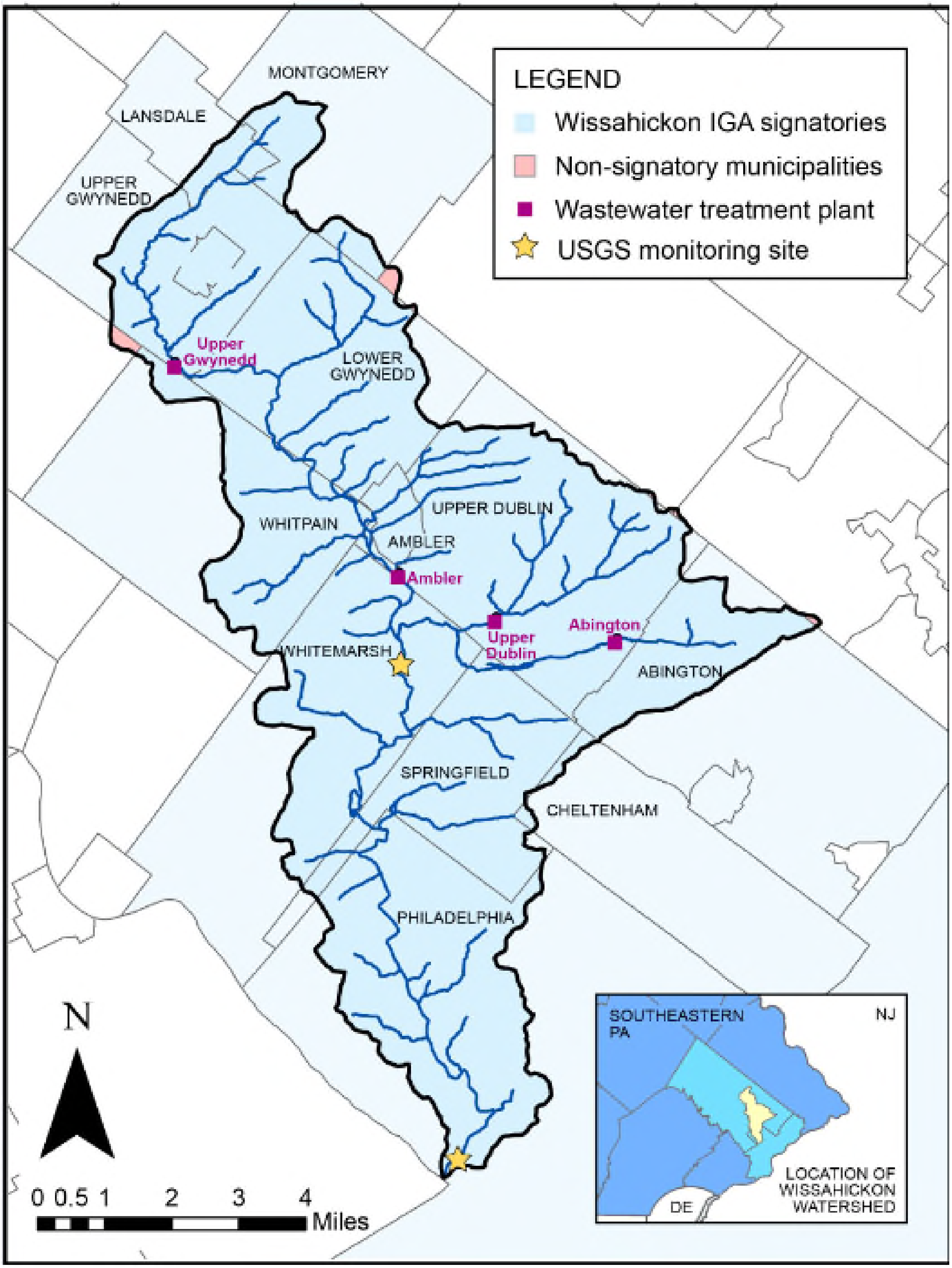

Figure 1-2 - Wissahickon Clean Water Partnership Municipalities and Wastewater Treatment Plants

Collaborative implementation of the IGA has enabled the WCWP to reduce the financial burden on the individual municipalities as they share resources and collective expertise from specialists in the field. For example, development of this WQIP enabled the leveraging of municipal funding with grant funding, most evident in the $1.3 million-dollar grant from the William Penn Foundation to the Pennsylvania Environmental Council (PEC) for instream monitoring, data collection, analysis and evaluation of options for developing strategies for a TMDL alternative. The municipalities collectively contributed $457,500 in matching funds for this effort. After the municipalities and the WWTPs signed the IGA and funding was secured through PEC from the William Penn Foundation, representatives from the WCWP met with PADEP and EPA to discuss an alternative to the Draft TMDL, consistent with PADEP's designation of the Wissahickon Creek under Category 5a in PADEP's 2016 Clean Water Act § 303(d) List.

This collaborative effort is unprecedented and earned the WCWP the 2019 Municipal Achievement Award from the Water Resources Association of the Delaware Basin. Additional information about the participating municipalities and their governance structures can be found in the Municipal Fact Sheet in Appendix 2.

1.4 Watershed Plan Purpose and Goals

The WQIP is intended to improve water quality conditions in the Wissahickon Creek watershed through implementation of an adaptive management approach to controlling stormwater flow rates and volumes that is supported by local stakeholders, inclusive of municipalities, WWTPs, and key environmental partners. This adaptive management plan will continually incorporate new data and information and identify new opportunities and actions to positively impact the watershed over time. As discussed in greater detail in Section 3, the measures established in this WQIP will be implemented over a time horizon of at least twenty years, a schedule that is reflective of the significant challenges to improving water quality in this highly urbanized watershed and the recognized need for iterative changes to the implementation measures over time. As a frame of reference, the WQIP was designed to generally conform with EPA's guidance on the preparation of watershed plans for improving water quality and EPA's handbook providing instruction for identification of critical source areas for implementation of BMPs and other measures to ultimately achieve water quality and quantity goals and objectives.[18]

The initial five-year phase of the WQIP includes significant commitments from the municipalities. ~~More than 80~~ A total of 91 BMP projects throughout the watershed, that are in addition to the projects identified in the municipalities' existing MS4 permits (*see* Table 3-1), have been identified for prioritization and consideration as part of the WQIP. Although not intended to be an exhaustive list~~ or to represent a minimum commitment~~, this ~~tentative~~ list of projects ~~fairly~~ represents potential opportunities that have been identified by the Management Committee and its collaborators to address the leading causes of water quality impairment. Consistent with the WQIP's adaptive management framework, the hydrologic model developed by Temple University, described in detail in Appendix 3, will be used as a tool for iterative decision-making and prioritization of targeted storm water management projects as the WQIP is implemented over time.

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[18] EPA (2018). Critical Source Area Identification and BMP Selection: Supplement to Watershed Planning Handbook. Office of Water: Nonpoint Source Control Branch. EPA 841-K-18-001, July 2018.

Section 3 also includes a discussion of the collaborative programs that will be initiated by the municipalities and WWTPs to leverage efficiencies by working together to identify and prioritize projects, programs, and policies that will lead to improvements in stream quality.

The WQIP also includes a series of tracking metrics and a comprehensive stream monitoring program for measuring progress implementing the identified stormwater BMPs and water quality improvements to the stream over time. As discussed in greater detail in Section 3.3, The tracking metrics include: (1) acres managed ~~for~~ to control storm water impacts; (2) linear feet of stream restored and stream bank stabilized; (3) number of projects implemented; and (4) area of open space protected. Comprehensive water quality monitoring will be conducted periodically to confirm that the measures being implemented in accordance with the WQIP are having a positive impact, and to develop priorities for future actions. The WQIP also includes detailed reporting requirements to inform EPA, PADEP, and the public at large about the status of the projects and the progress that is being made through the implementation of the TMDL alternative.

SECTION 2 Watershed Characterization and Impairment Findings

2.1 The Watershed and its Supporters

The Wissahickon Creek watershed has many positive attributes notwithstanding the ecological impacts resulting from urbanization. Much of the mainstem benefits from wide, wooded stream corridors with dense tree canopy that provides shade and cooling, and wetlands. These features provide habitat, decrease flooding, reduce bank erosion, and maintain stream flows to sustain aquatic life during dry seasons. Healthy riparian vegetation intercepts and filters sediments in sheet and shallow subsurface flows. ~~Much of the mainstem benefits from a relatively dense tree canopy, providing shade and cooling.~~

Open space preservation in the Wissahickon Creek watershed dates back to the 1860s when Philadelphia developed the 1,800-acre Wissahickon Valley Park and established a large riparian buffer along the creek's east and west banks. The park begins at the border of Montgomery County and continues along the last 7 miles (11 km) of the Wissahickon Creek until its confluence with the Schuylkill River.

Based on a 2010 study conducted by Heritage Conservancy and funded by PADEP and the Montgomery County Planning Commission, 56% of the Wissahickon Creek watershed has tree cover on both sides, 25% has tree cover on one side, 14% has no tree cover on either side, and 6% has culverts or underground channels (Figure 2-1).[19] For Philadelphia, the statistics are more favorable, with 76% of the stream reach having tree cover on both sides. Tributaries in the city have less favorable canopy than the mainstem; Lorraine Run has only 50% canopy, as it runs through a golf course. Sandy Run headwaters also have low canopy with only 60% cover. The tributaries with the best cover are Prophecy Creek (93%) and Haines Run (92%). The survey found that riparian corridors provide shading to help reduce algae blooms, stabilize banks reducing erosion and siltation, and filter nutrients and sediment from overland flow. The large reaches of wooded buffer contribute to the health of the stream. The canopy cover maps identify potential locations for additional improvements including the headwaters and several golf courses.

The aesthetic beauty of the watershed, amid its urban and suburban setting, is recognized by the WCWP and others as providing important social benefits. A vast network of trails surrounds the creek, providing a high degree of public access (Figure 2-1). Recreational uses along the stream are common, including hiking, fishing, biking, walking, and jogging. This public access connects the residents to the watershed, reinforcing a culture of watershed stewardship.

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[19] Pennsylvania Spatial Data Access: The Pennsylvania Geospatial Data Clearinghouse. www.pasda.psu.edu/uci/DataSummary.aspx?dataset=36, accessed Feb. 13, 2019

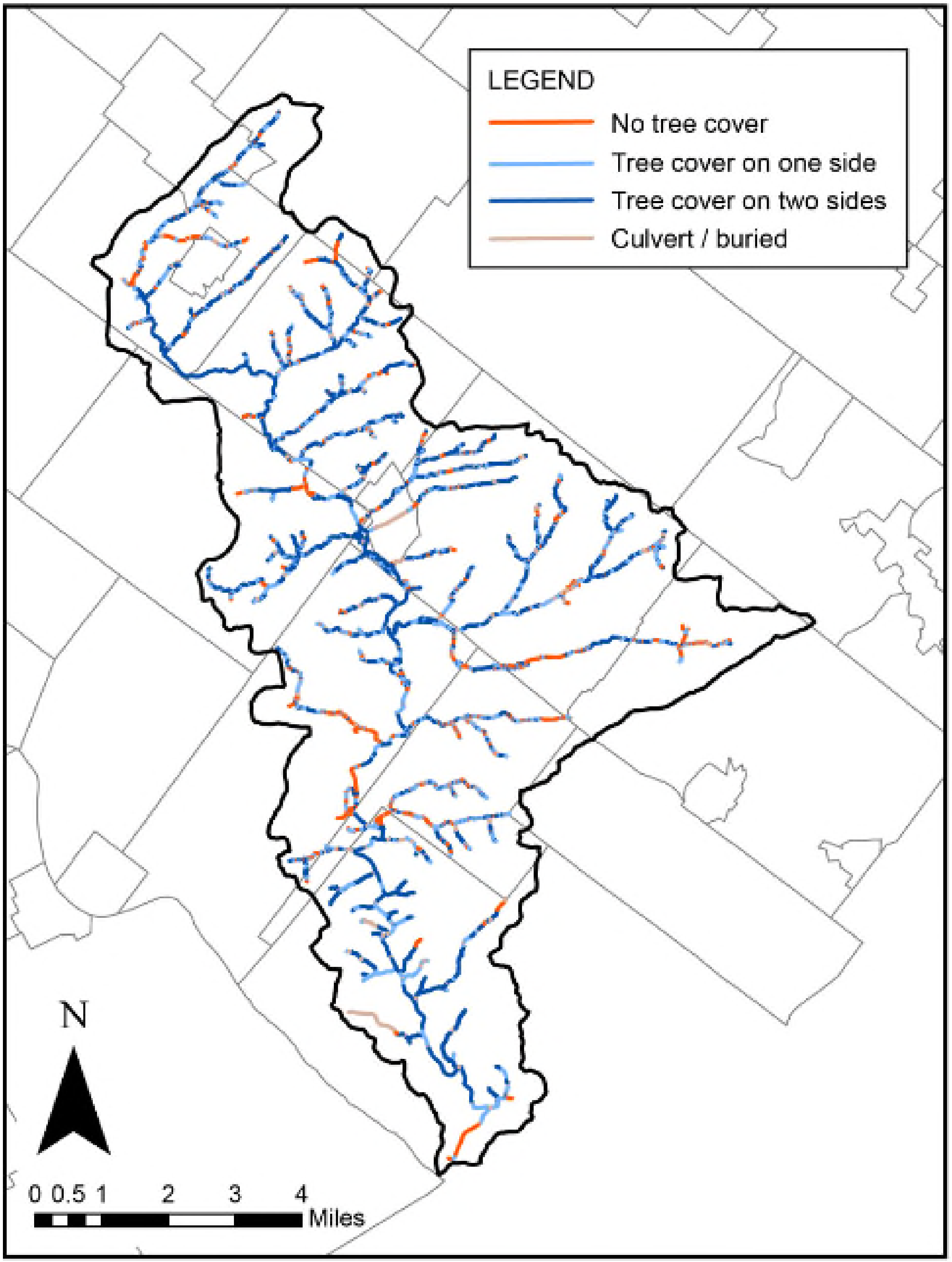

Figure 2-1 - Heritage Conservancy 2012 Riparian Buffer Assessment for Wissahickon Creek Watershed

Supporting the watershed's aesthetic beauty is an active network of watershed organizations and local environmental groups who raise awareness about the importance of improved water quality and will help to ensure that the goals of this WQIP are realized.[20] WVWA, Friends of the Wissahickon, Wissahickon Environmental Center, and Chestnut Hill Conservancy are a few of the organizations that provide resources and information to residents and municipalities in the watershed to help protect and steward the Wissahickon Creek. This robust cohort of organizations has contributed to a high level of environmental awareness and fluency among varied stakeholders in the watershed, which is crucial to the successful improvement of water quality in the Wissahickon Creek. Through continued and expanded engagement from watershed advocates as part of the WQIP, these groups will help to ensure that ecological conditions in the Wissahickon Creek continue to improve.

WVWA, a community leader in providing environmental education for the citizens who reside in the watershed since 1957, plays a particularly important role for the watershed community, including:

- Support to municipalities on public education and programs, planning projects for water quality improvement, and preserving open space for water quality improvement;
- Public lectures about environmental issues;
- Training for residents regarding implementation of green stormwater infrastructure on their private properties;
- Workshops and support for large landowners to implement best management practices on their private properties;
- Extensive student education programs on water quality science and monitoring;
- Ongoing training for a group of citizen scientists monitoring the Wissahickon Creek and its tributaries; and
- Annual creek clean ups, removing hundreds of pounds of trash, debris, and tires from the Wissahickon and surrounding trails.

There are nine Environmental Advisory Councils (EACs) in the Wissahickon Watershed who contribute to watershed education through the following activities:

- Green stormwater infrastructure workshops;
- Informational articles shared with residents through municipal newsletters, websites, or social media accounts;

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[20] Grant, L. and Langpap, C. (2018) Private provision of public goods by environmental groups, *Proceedings of the National Academy of Sciences* (stating that that "the presence of water groups in a watershed resulted in improved water quality and higher proportions of swimmable and fishable water bodies") DOI: 10.1073/pnas.1805336115

- Public education offerings at municipal events (tabling at community fairs, schools, recycling events);
- Educational resources and tools for residents and businesses to assist them in pollution reduction activities; and
- Grants to support implementation of residential and public property stormwater enhancement/management projects such as rain gardens, rain barrels, and flow through planters.

This history of educational services has created a knowledgeable constituency of residents, businesses, municipal staff, and elected officials to make informed decisions about planning for improving water quality and ecological conditions in the watershed.

Despite the many positive features of the watershed, there are unalterable hydrologic, geographic, and land-use realities that make the task of improving ecological conditions in the Wissahickon Creek challenging and that require a coordinated, collaborative response. For example, seventy-four percent (74%) of the watershed is urbanized; twenty-seven percent (27%) is impervious; and twenty-four percent (24%)[21] is semi-pervious. The negative impacts of urbanization on stream biological health ("urban stream syndrome") are well documented[22]. These impacts include altered hydrology, degraded riparian habitat, stream degradation from channelization and culverts, and increased erosion and sedimentation. The hydrology of the Wissahickon Creek is also influenced by limestone quarries such as Plymouth Meeting Quarry (formerly known as Corson Quarry). While the quarry is an important source of water for Lorraine Run, the dewatering effect associated with it can lower groundwater levels and reduce baseflow in the stream.

Numerous road crossings (Figure 2-2) with culverts and bridges also increase velocities by forcing stream flow through narrow channels. Each crossing represents a potentially significant stressor to the stream due to channelization, hydraulic impacts, and stormwater impacts. As part of an infrastructure survey stream walk conducted for the Wissahickon Creek Watershed Comprehensive Characterization Report, PWD identified 315 bridges and 163 culverts in the watershed, the vast majority (~80%) of which cross streams. The 2014 Wissahickon Creek Watershed Act 167 Plan (Act 167 Plan)[23] estimated that 34 of the 370 bridges and culverts assessed for the Act 167 Plan have inadequate capacity and would be overtopped by a 1-year design storm (2.75 inches of rain). A copy of the Act 167 Plan is included with this WQIP at Appendix 4.

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[21] University of Vermont Spatial Analysis Laboratory. (2013). High-Resolution Land Cover, Commonwealth of Pennsylvania, Chesapeake Bay Watershed and Delaware River Basin, 2013. Burlington.

[22] Walsh et al. (2005) C.J. Walsh, A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, R.P. Morgan (J. North Am. Benthol. Soc. 24(3):706-723) The Urban Stream Syndrome: Current Knowledge and the Search For A Cure. 2005.

[23] Center for Sustainable Communities, Temple University and Newell Tereska & Mackay Engineering (2014). Wissahickon Creek Act 167 Plan, Fromuth, R. (Ed.). April 2014 (revised November 2014) www.montcopa.org/2264/Wissahickon-Creek-Watershed-Act-167-Plan , accessed Feb. 9, 2019.

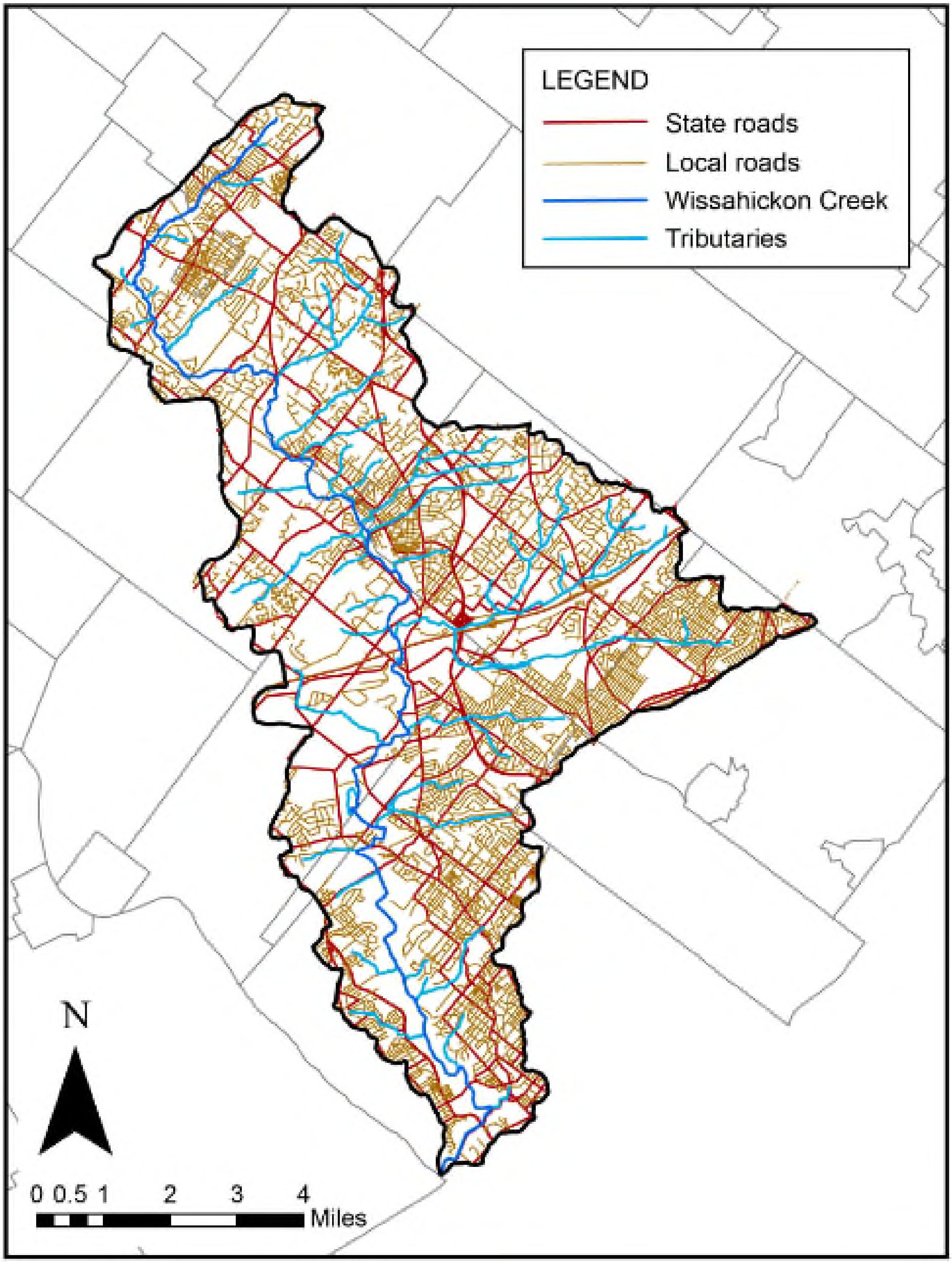

Figure 2-2 - Road Crossings

2.2 General Findings from the Watershed Evaluation

In Pennsylvania's 2016 Integrated Water Quality Monitoring and Assessment Report setting forth the Commonwealth's Clean Water Act § ~~303(d)~~ 303(d) list, the Pennsylvania Department of Environmental Protection (PADEP) determined that approximately 87 miles (140 kilometers) of the Wissahickon Creek and its tributaries do not meet their designated aquatic life uses.[24] This includes Pine Run and tributaries; Sandy Run and tributaries; and Trewellyn Creek and tributaries. Only Prophecy Creek is attaining its aquatic life use.

As part of the development of the WQIP, an assessment of the Wissahickon Creek watershed was performed to holistically assess the cause of impairment in the stream. This effort included a comprehensive sampling plan administered by Temple University that resulted in the collection of more than two years of new data that significantly expands upon the historical dataset for the Wissahickon Creek. Additionally, Kleinfelder, the technical consultant for the Management Committee, performed an independent watershed assessment based on the robust historic dataset for the Wissahickon Creek and the data collected by Temple through its study for the WQIP.

Both the Temple study for the WQIP and the Kleinfelder assessment[25] revealed that total phosphorus is not the primary cause of aquatic life impairment at this time. Instead, the available data show that storm water flows (both rate and volume) in the highly urbanized Wissahickon Creek watershed are the primary drivers of macroinvertebrate disruption, and efforts to reduce total phosphorus will produce no measurable impact on water quality, if ever and certainly not until stormwater improvements throughout the watershed are implemented. This fundamental conclusion based on the unalterable urban realities of the watershed is the central underpinning of the WQIP and the strategies for improving water quality conditions in the stream. Details of the Temple study for the WQIP can be found in Appendix 6. The Kleinfelder assessment can be found in Appendix 7.

Primary production (conversion of light energy to biomass) in aquatic systems is performed by one or more of these broad categories of producers: phytoplankton (suspended algae); rooted aquatic plants; and periphyton (algae attached to rocks and other substrates). There is no evidence that phytoplankton accumulate to any significant degree in the Wissahickon Creek or its tributaries, and plants appear to be mostly insignificant. Periphyton therefore account for most of the primary production. However, the periphyton densities in the Wissahickon Creek are consistent with other urban streams and do not rise to nuisance levels.

Flow and dissolved oxygen are monitored continuously by the United States Geological Survey (USGS) at two locations on the mainstem. These locations are (1) near the Wissahickon Creek confluence with the Schuylkill River at Ridge Avenue (USGS 01474000), and (2) just downstream of Sandy Run at Skippack Pike, commonly referred to as the Fort Washington gauge (USGS 01473900). Flow and dissolved oxygen were also measured during the Temple Study for the WQIP at two locations. *See* Appendix 6. Diurnal

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[24] Pennsylvania Department of Environmental Programs (PADEP) (2018). 2016 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report: Clean Water Act Section 305(b) Report and 303(d) List. Jan. 10, 2018 http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4168, accessed February 5, 2019.

[25] Counsel for the Partnership originally shared a copy of the Kleinfelder assessment with the WQIP update letter that was sent to EPA Region III on July 18, 2019. *See* Gold, Marc E. (2019). Letter to Jenifer Fields, Wissahickon Creek TMDL Alternative. July 18, 2019. A copy of the July 18, 2019 letter along with letters of support from the Wissahickon Valley Watershed Association, the Pennsylvania Environmental Council, and the Montgomery County Planning Commission can be found in Appendix 5.

variations in dissolved oxygen ("swings") provide a relative indication of productivity. These swings are caused by primary producers pumping dissolved oxygen into the water column during the day (from photosynthesis) and depleting oxygen at night (from respiration and decomposition).

We have found that the potential link between phosphorus and aquatic life impairments is through the direct stimulation of excessive plant growth, which impacts diurnal dissolved oxygen and can lead to indirect impacts on benthic aquatic life. Phosphorus is elevated in most streams in the Wissahickon Creek watershed. In addition, algal (periphyton) density and growth rate (productivity) are high at many locations throughout the watershed. However, reducing phosphorus loads to the Wissahickon Creek watershed would not decrease algal productivity.

Phosphorus levels in the Wissahickon Creek watershed cannot be reduced to levels that will restrain algal growth. The algal growth rate exhibits a threshold-type response, and that threshold occurs at a very low concentration of available phosphorus.[26] As a result, only small amounts of phosphorus are needed to support maximum periphyton growth rates. The study performed for EPA Region 3 and used to establish a recommended instream endpoint of 0.040 milligrams per liter (mg/L) total phosphorus cited the range of "algal growth saturation" at 0.025 to 0.050 mg/L available phosphorus.[27] Additional phosphorus above the saturation level will not result in higher algal growth rates. Conversely, algal growth rates will not decrease unless the available phosphorus is below the "algal growth saturation" levels.

Conditions in Prophecy Creek were used to help inform the selection of the three strategies to improve water quality in the Wissahickon recommended in the WQIP. There are no point sources discharging to Prophecy Creek and it is considered the least impacted by urbanization. A substantial portion of the sub-watershed drains Prophecy Creek Park and Briar Hill Preserve. The entire length of Prophecy Creek also benefits from an intact riparian corridor with mostly dense canopy, and the creek is crossed by only a few roads. PWD's 2005 evaluation of the Wissahickon Creek watershed[28] noted that Prophecy Creek exhibits the best resident fishery community in the entire watershed. Prophecy Creek therefore provides the best reference condition in the watershed. Phosphorus levels in Prophecy Creek were measured quarterly over a one-year period by Temple University; two of those quarterly samples captured baseflow conditions, which average 0.071 mg/L dissolved phosphorus. These levels are nearly identical to phosphorus levels observed in other areas of the Wissahickon Creek watershed upstream of the influence of point sources. Thus, the available phosphorus concentrations in baseflow, even in the most unimpacted areas of the watershed, exceeds the range of algal growth saturation and the EPA-proposed target of 0.04 mg/L total phosphorus in the Draft TMDL.

Based on these observations and a comprehensive assessment of the potential factors contributing to the aquatic life impairment in the Wissahickon Creek watershed, an evaluation of ongoing efforts to address urbanization-related stormwater impacts in the watershed, and informed by the hydrologic model projections discussed in Appendix 3, this WQIP recommends the following three types of measures for improving water quality in the Wissahickon Creek:

- **Additional Stormwater Management Measures** represent the principal means available to restore a more natural hydrologic regime to the Wissahickon Creek by decreasing runoff rates

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[26] *See* infra Footnote 8.

[27] Paul and Zheng, 2007, Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application. Report prepared by Tetra Tech for the U.S. Environmental Protection Agency, Region III, November 2007.

[28] PWD (2007). Wissahickon Creek Watershed Comprehensive Characterization Report. January 2007.

and volumes and enhancing baseflow. Stormwater management measures can directly improve stream corridors and mitigate riparian degradation. Improvements to stream crossings can directly alleviate stream channel disturbances. Stormwater management directly affects sediment loads and therefore mitigates siltation. In addition, it can reduce peak stream flows and decrease instream erosion. Addressing hydrologic impacts may also mitigate other stressors affecting aquatic life.

- **Riparian Improvements** lessen riparian degradation and hydrologic impacts while reducing the load of sediment impacting the stream. Riparian improvements also extend canopy, which limits light availability and directly reduces the potential for algal growth.

- **Instream Restoration** mitigates channel disturbances and reduces sedimentation by decreasing instream erosion.

Section 3 of the WQIP presents the ambitious commitments of the WCWP to collectively implement projects keyed to these recommended strategies throughout the Wissahickon Creek watershed.

The WQIP does not recommend WWTP upgrades to further reduce phosphorus loads at this time because such measures will not help restore aquatic life until a more natural hydrology is established in the Wissahickon Creek watershed, something that may take decades to achieve. Additionally, reducing phosphorus loads from treatment plants would impose secondary environmental costs, principally increased use of chemicals and increased sludge production and disposal costs. Consideration of additional improvements at the WWTPs as part of the TMDL alternative should be deferred until the measures recommended in this WQIP are implemented and the water quality benefits from these measures are evaluated.

2.3 ~~Section 3, presents the ambitious commitments of the WCWP to collectively implement projects keyed to these recommended strategies throughout the Wissahickon Creek watershed.~~ Evaluation of Ongoing Efforts to Manage Stormwater

In light of the conclusions derived from the comprehensive stream assessment described in Appendices 6 and 7 that rates of stormwater volume and flow linked to urbanization are the primary cause of water quality impairments in the stream, the existing efforts of the MS4s and WWTPs that discharge to the Wissahickon Creek and its tributaries were assessed to provide an understanding of baseline conditions in the watershed and to define additional efforts to improve ecological conditions in the stream. While the existing efforts by the MS4s and WWTPs generally described in this section are significant, the assessment revealed that additional efforts to manage stormwater are needed to improve ecological conditions in the stream, particularly the establishment of additional stormwater BMPs throughout the watershed. *See* Section 3 for additional detail.

2.3.1 Municipal Efforts to Address Stormwater

Act 167 requires municipalities to develop comprehensive stormwater management programs and to manage stormwater programs for local development. Municipalities may also be required to manage stormwater pursuant to their MS4 permits, which generally require the employment of stormwater

BMPs and the development of Pollutant Reduction Plans (PRPs)[29] and/or plans to meet any TMDL-based WLAs. The municipalities in the Wissahickon Creek watershed are already addressing sediment and nutrient pollution in stormwater to meet the requirements of the Nutrient and Siltation TMDL[30]. Some of the municipalities have decided to address their full WLAs for nutrients and sediments, while others have chosen to reduce their existing loads by 10%, as permitted under PADEP's MS4 permitting framework.

For the development of this WQIP, the 13 municipalities' MS4-related plans were reviewed, including a representative sample of community plans and annual reports that were prepared under the MS4 program. A general summary of the municipal plans and annual reports that were reviewed can be found in Appendix 8. The review indicated that the municipalities already have undertaken significant work to reduce stormwater impacts in the watershed since the establishment of the 2003 Nutrient and Siltation TMDLs, as further described below.

To achieve their required goals under the MS4 permitting program and the 2003 Nutrient and Siltation TMDLs, the municipalities are implementing stormwater BMPs, including retrofits of existing BMPs and installing new BMPs. BMP installation requires resources for planning, siting, design, and construction. Pursuant to their MS4 permits, each municipality is reporting on the status of its BMP inventory, an activity that becomes more involved as new BMPs are implemented.

Stormwater BMPs also require regular maintenance to ensure that they continue to function as designed. This requires resources to train municipal staff in proper operations and maintenance, develop systems to monitor continued effectiveness of BMPs, correct deficiencies, and report on BMP inspection and status.

Table 2-1 outlines the number, locations, and types of BMP each municipality has proposed to implement in order to meet its obligations under the 2003 Nutrient and Siltation TMDLs. Many of the proposed BMPs fall into two categories: stormwater basin retrofits and streambank restoration. These are important commitments that will continue to require considerable attention and resources.

In addition to BMPs, the MS4 program requires the municipalities to provide community education and outreach with respect to stormwater management. The 13 municipalities have established a robust set of public education and outreach programs that provide various means of providing relevant information to their residents. The current public education and outreach programs for a representative sample of the Wissahickon Creek watershed municipalities are summarized in Table 2-2. The existing framework serves as a useful starting point for the municipalities to coordinate efforts and share resources as they administer the stormwater BMPs on a watershed basis, in accordance with this WQIP.

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[29] Pollutant Reduction Plans (PRPs) are required if a TMDL has not been developed or the permittee has not been assigned a specific wasteload allocation (WLA) in a TMDL.

[30] *See* infra Footnote 2.

Table 2-1 – Proposed BMPs in PRP and TMDL Plans

Municipality	Proposed BMPs under permit	Characterization of Proposed Best Management Practices
Abington Township	10	Sandy Run Stream Bank Stabilization Project; Madison Avenue Meadow Construction; Roychester Park Rain Garden; Roychester Riparian Buffer Restoration; Roychester Park Bioretention/Infiltration Trench; Roychester Park Infiltration Berms/Retentive Grading; Evergreen Manor Park Infiltration Basin; Grove Park Stream Restoration; Ardsley Wildlife Sanctuary Streambank Stabilization and Basin.
Ambler Borough	2	Potential BMPs include street sweeping, inlet filter inserts, and streambank restoration.
Cheltenham Township	2	Street sweeping, private redevelopment, Caroll Brooke Park Swale, Glasgow, Inc./ Caroll Brooke Park Raingarden, Caroll Avenue stormwater conveyance channels improvements, Carroll Avenue BMP, Church Road and Willow Grove Avenue stormwater conveyance facility improvement, Route 309 Offset Road improvements, Cresheim trail BMP
Lansdale Borough	NA	Existing BMPs meet load reduction requirements.
Lower Gwynedd Township	4	3 basin retrofits; Streambank Restoration
Montgomery Township	8	Riparian buffer restoration; floodplain restoration; 5 basin naturalizations
North Wales Borough	2	Diversion of parking lot runoff of 1.22 acres to rain garden and 0.36 acres of residential site draining to infiltration bed.
Philadelphia	NA	Existing BMPs meet load reduction requirements
Springfield Township	NA	Existing BMPs meet load reduction requirements
Upper Dublin Township	~~NA~~2	~~Existing BMPs meeting load reduction requirements.~~Township-wide temporal basin discharge coordination to reduce flow variability in the stream; reduction of road salt to reduce levels of chloride and conductivity in the stream.
Upper Gwynedd Township	~~5~~1	~~Elm Avenue large-scale wetland; Swedesford Road roadside bioretention facility; Haines Drive bioretention berm; Haines Run in-stream restoration.~~ Wissahickon Creek streambank restoration with WVWA.
Whitemarsh Township	6	Rain barrel distribution, street sweeping, tree-planting
Whitpain Township	10	7 basin retrofit BMPs and 3 streambank restoration and stabilization projects

Table 2-2 – Representative Sample of Existing MS4 Public Education and Outreach Programs

Activity	Abington Township	Ambler Borough	Lansdale Borough	Lower Gwynedd Township	Montgomery Township	North Wales Borough	Philadelphia	Upper Gwynedd Township
Distribute information via municipal newsletter	●	●	●	●	●	●	●	●
Distribute information via community calendar	●							
Distribute information via municipal website	●	●	●	●	●	●	●	●
Distribute information via local newspaper								●
Distribute information via social media		●	●			●	●	
Distribute information to local businesses					●		●	
Provide information at municipal facilities	●	●				●	●	●
Provide stormwater education materials to contractors				●		●	●	
Swimming pool water discharge guidelines						●	●	●
Educational signage water quality project site					●			●
Homeowners Guide to Stormwater BMP Maintenance - article						●		
When it Rains it Drains - pamphlet						●		
Please Don't Feed the Geese - article						●		
Help make Community a Shade Better		●						
Community workshops (rain barrels, rain gardens, etc.)	●	●		●	●	●	●	
Seedling shade tree distribution					●			
New resident welcome packets					●			
Displays/Presentations at community events	●	●	●	●			●	
Storm drain stenciling	●			●			●	
Recruit community members to assist	●						●	
Sought public input on ordinances, SOPs, PRPs, and TMDL plans	●	●	●	●	●	●	●	●
Sought public input on capital improvements	●						●	
Partner with local schools	●					●	●	
Tree planting							●	●
Information meetings regarding stream restoration projects							●	●
Stream clean-up days				●		●	●	

2.3.2 Wastewater Treatment Plants

The WWTPs in the watershed have been upgraded since the 2003 Nutrient and Siltation TMDLs to improve their phosphorus removal capabilities. Methods for removal include addition of magnetite, aluminum, ferric chloride, and polymers. The WWTPs engaged in further phosphorus removal optimization during the development of the WQIP and provided progress reports on those efforts to EPA in December 2017, May 2018, December 2018, and May 2019. The efforts undertaken by the WWTPs during the WQIP development process demonstrate that three of the WWTPs are able to meet a seasonal average of 0.5 mg/L of orthophosphate.

The lack of bioassessment response in the watershed based on the results of the data evaluation, combined with the cost of chemical addition and related increases in sludge disposal, suggest that additional phosphorus reduction efforts by the WWTPs would not be productive at this time. Instead, efforts should be directed at activities that will further the implementation of the WQIP, including:

- Participation in the coordinated monitoring plan described in Section 3;
- Targeted stormwater projects on WWTP property;
- Regional collaboration regarding planning and coordination efforts; and
- Periodic re-assessment of the value of additional nutrient removal

For additional information about the assessment of the efforts from the four WWTPs, please refer to Appendix 9.

2.4 Evaluation of Stormwater Alternatives

The recommended improvement measures in the WQIP have been informed by hydrologic modeling that was performed by Temple University as part of the WQIP study. Temple University developed a hydrologic model of the Wissahickon Creek watershed to provide a tool to assess the impact of future changes in land use, stormwater controls, and other alternatives designed to improve the water quality of the creek. The model is a predictive tool that can be used to assess theoretically the effectiveness of proposed alternatives.

Rainfall runoff processes were modeled using PCSWMM Version 7.1.2480[31] This is a proprietary platform that utilizes the EPA supported Storm Water Management Model (SWMM) engine and incorporates an ArcGIS interface to improve data input and provide additional output analysis capabilities. The model combines hydrology, hydraulics, and water quality into a single, well documented, model. The model has a vast user community and has been used in thousands of studies to examine the impact of stormwater controls on runoff quantity and quality. Additional information on model input parameters, data sources used in this project, and modeling scenarios used to evaluate stormwater alternatives is provided in Appendix 3.

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[31] CHI Water, PCSSWMM 7,1,2480, October 31, 2107. https://www.pcswmm.com/Downloads/PCSWMM

SECTION 3 WQIP Implementation, Monitoring, and Reporting

The Water Quality Improvement Plan (WQIP) includes measures that are designed to improve conditions in the Wissahickon Creek and its tributaries in an effort to meet water quality standards in the future. This section of the WQIP presents the measures that the 13 municipalities with municipal separate storm sewer systems (MS4s) and the operators of the four wastewater treatment plants (WWTPs) will implement to address aquatic life impairments in the Wissahickon Creek watershed, in conjunction with regional partners, including the Wissahickon Valley Watershed Association (WVWA). The implementation strategies described in this section are predicated on an adaptive management approach that is intended to improve water quality conditions in the Wissahickon Creek watershed in an iterative and holistic manner.

The framework for these commitments is a collaborative strategy for integrating projects, policies, and programs to improve water quality conditions over time, and provides a process to sustain the prioritization and implementation of measures in an effort to improve water quality in the Wissahickon Creek watershed. Implementation of the WQIP is contemplated to take 20 years or more before water quality standards can be expected to be achieved, with five-year phases allowing for ongoing assessment and refinement of the control measures and strategies.

WQIP implementation will be a collaborative effort among the municipalities and WWTPs, and other regional partners like WVWA. The adaptive management approach embodied in the WQIP recognizes that changes in the science, economy, or support from others (such as private landowners) may create new opportunities. Consequently, as part of the WQIP, the members are committed to working together to adapt to changing circumstances.

3.1 Improvement Strategies

The improvement strategies that will be implemented by the WCWP municipalities as part of the WQIP fall into three main categories discussed in greater detail in this section: (1) projects; (2) programs; and (3) policies. Additionally, the four WWTPs remain committed to assisting with WQIP implementation despite the fact that further reductions in phosphorus discharges from the WWTPs are not the focus of the WQIP based on the updated analysis of the causes of impairment. The specific commitments of the WWTPs are discussed in Section 3.1.1.4.

3.1.1 Projects

Projects to be implemented as part of the WQIP are designed to make progress in achieving the common goal of improving conditions in the watershed. The projects ~~will be largely implemented on an individual (municipality) basis but~~ will be coordinated and collectedly prioritized, when appropriate, to achieve consistency throughout the Wissahickon Creek watershed and to leverage available experience ~~or~~ and optimal project siting. The partners in the WQIP will implement projects that include:

- Comprehensive identification and tracking of BMPs on public and private land (consistent amongst municipalities);
- Installation of BMPs on targeted tax-exempt properties by third parties;

- Additional installation of riparian buffers on appropriate sites;

- Identification and implementation of stream restoration and bank stabilization BMPs at culverts, bridge crossings, and other areas where infrastructure protection is needed.

As part of the WQIP, the WCWP developed a comprehensive inventory of candidate stormwater management projects, available at Appendix 10. Sources reviewed to develop the inventory include: the 2014 Wissahickon Creek Watershed Act 167 Plan (Act 167 Plan), municipal PRPs, 2003 Nutrient and Siltation TMDL plans, sewershed and outfall mapping, desktop analysis of the watershed, and input provided during discussions with individual municipalities between October 2016 and March 2017.

Projects identified through the ~~ACT~~ Act 167 Plan were vetted with the respective municipalities to determine feasibility for implementation. The inventory in Appendix 10 includes the following categories ~~off~~ of candidate projects: stormwater basin retrofits; conversion of existing stormwater detention basins to infiltration basins; stream bank stabilization and channel restoration; riparian buffers; floodplain restoration/storage; native habitat creation; and green stormwater infrastructure such as rain gardens. Projects determined to be potentially feasible were included in the inventory database.

A review of sewershed and outfall maps for each municipality that participated in the focused discussions was completed to determine possible locations where the storm sewer system could be intercepted and directed through a stormwater best management practice (BMP). The result of this detailed research is a database of roughly 190 sites throughout the watershed identified as project opportunities and/or suitable land. Figure 3-1 provides a summary of the projects by type. About 60% of the projects have not been previously identified. Half of these projects are on private land, which requires continued public education efforts, incentives, and partnerships for successful implementation.

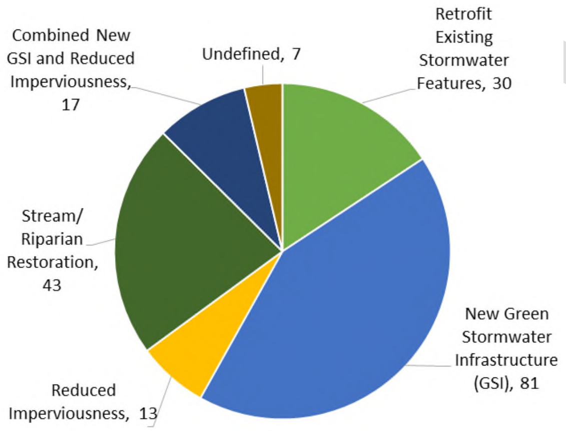

Figure 3-1 – WCWP Stormwater Project Inventory by Project Type. Numbers reflect the number of projects (total = 191).

The stormwater projects included as part of the municipalities' MS4 programs constitute a subset of all projects identified in the inventory. Therefore, the non-MS4 projects in Appendix 10 will provide stream quality benefits beyond those outlined in the municipalities' existing MS4 PRP/TMDL implementation plans. Included among the non-MS4 projects on the inventory list are ~~roughly 80~~ 91 total projects presented ~~on~~ in Table 3-1 that will be evaluated and prioritized for implementation over term of the WQIP. Clearly, this collaborative effort offers greater potential for progress than individual actions.

Table 3-1: Summary of Wissahickon Creek Watershed Non-PRP/TMDL Projects

Municipality	**Projects**	**Ownership: Public**	**Ownership: Private**	**BMP Type: Retrofit**	**BMP Type: New GSI**	**BMP Type: Impervious Reduction**	**BMP Type: Stream, riparian Restoration**	**BMP Type: Unknown**
Abington	5	4	1		5			
Ambler	4	3	1		4			
Cheltenham	3		3		3			
Lansdale	4	2	2		3	1	1	1
Lower Gwynedd	11	4	7	5	4		3	1
Montgomery	4	2	2		1		1	2
North Wales	10	7	3		8	1	1	
Springfield	12	9	3	5	4		3	
Upper Dublin	11	7	4	7	5		2	
Upper Gwynedd	5	3	2	4	1			
Whitemarsh	3	2	1	1	1		1	
Whitpain	3		3	3				
Philadelphia	~~5~~16	~~5~~10	6	11			5	
Total*	~~80~~91	~~48~~53	~~32~~38	~~25~~36	39	2	17	4

*Note: Some projects include multiple practices.

Terms: BMP – Best Management Practice; GSI – Green Stormwater Infrastructure

3.1.2 Programs

The program elements of the WQIP will be performed jointly by the municipal participants and provide for the sharing of resources. The individual roles and responsibilities associated with these programs will be detailed in the IGA, although some programs are expected to commence before the IGA is finalized. The programs include plans to:

- Conduct water quality monitoring and modeling to evaluate alternatives and measure and report on progress (*see* Section 3.2);
- Develop a shared coordination and progress reporting structure;
- Develop a program to help ensure proper operation and maintenance of stormwater BMPs;
- Execute a collaborative funding mechanism for project implementation;
- Encourage installation of BMPs on tax exempt properties;
- Develop a program to identify and implement stream restoration and stabilization BMPs at culverts, bridge crossings, and other areas where infrastructure protection is needed;
- Create a plan to assess riparian buffer opportunities, prioritize identified opportunities, and adopt implementation plans;
- Design a riparian buffer protection strategy using private property easements and stewardship;
- Implement private landowner "small" BMPs through a watershed-wide residential stormwater management program modeled on PWD's Rain Check program; and
- Coordinate public education, outreach, and engagement to further implementation of the WQIP with support from WVWA.

3.1.3 Policies

In addition to the projects and programs discussed above, the municipalities are encouraged to adopt policies in their respective communities that will:

- Ensure any stormwater ordinance enacted in accordance with the Act 167 Plan maximizes water quality benefits, incentivizes compliance, and provides for enforcement if necessary;
- Review subdivision and zoning ordinances and amend as appropriate to limit the creation of new impervious surfaces during development and redevelopment;
- Prioritize protection of high-quality riparian areas;
- Encourage additional tree canopy and cover protection;

- Encourage property owners to reduce impervious areas and/or implement green infrastructure solutions;
- Adopt new open space protection programs to preserve or enhance forested areas and protect existing pervious parcels; and
- Identify and prioritize opportunities to add additional protected open space throughout the watershed.

3.1.4 WWTPs

In December 2017, counsel for the WCWP submitted a letter to EPA on behalf of the WWTPs describing numerous efforts they would undertake while development of this WQIP proceeded (*see* Appendix 11),[32] including:

1) Facility Optimization - The WWTPs attempted to reduce phosphorus-related discharges by fifty percent of the maximum limits set forth in their NPDES permits during WQIP planning. The WWTPs entered into this effort despite knowing that it was unlikely that phosphorus discharges could be lowered enough to improve IBI scores or prevent algae blooms in the creek.

2) Report Progress - The WWTPs have provided semi-annual progress reports to EPA beginning in December 2017~~; May 2018; December 2018; and May 2019~~.

3) Feasibility Analysis - The WWTPs evaluated feasible phosphorus removal targets and strategies that would be subsequently refined taking into account the WQIP findings.

4) Feasibility Analysis Report - After the WQIP is accepted by EPA and PADEP, the WWTPs will prepare and submit a summary of their individual feasibility analyses within 180 days of the agencies' acceptance of the WQIP and confirmation of continued interest in the TMDL alternative.

The WWTPs satisfied the first three items. Despite the clear conclusion that stormwater rate and flows are the primary causes of stream impairment in the watershed, the WWTPs nevertheless will continue with facility optimization and will submit the feasibility analysis reports during the initial phase of WQIP implementation after approval of the TMDL alternative by EPA and PADEP.

In addition, the WWTPs have committed to providing funding for a portion of WQIP administration and to paying for the cost of a new USGS gauge on Sandy Run near the Abington WWTP (above the Upper Dublin WWTP), or at Bethlehem Pike near the confluence with the mainstem, as discussed in detail in Section 3.2, below. They also will evaluate whether stormwater BMPs can be implemented at their facilities.

3.2 Monitoring and Modeling Program

The monitoring and modeling program discussed in this section will provide a mechanism to evaluate stream quality improvements in the watershed resulting from implementation of the WQIP. The

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[32] Gold, Marc E. (2017). Letter to Evelyn MacKnight, Wissahickon Creek Alternative TMDL. September 19, 2017.

program will offer the opportunity for ecological trend analysis of macroinvertebrate assemblages and evaluation of changes in water quality and other ecological metrics over time. Additionally, the modeling program will serve as a tool to assist the WCWP evaluate and prioritize potential future BMP projects.

3.2.1 Water Quality Monitoring

The Philadelphia Water Department (PWD) will administer the WQIP's monitoring plan on behalf of the WCWP, as described below. Additionally, the WWTPs will fund the establishment and annual operation of a new USGS continuous stream flow gauge on Sandy Run near the Abington WWTP (above the Upper Dublin WWTP), or at Bethlehem Pike near the confluence with the mainstem.

PWD presently conducts comprehensive water quality monitoring in the Wissahickon Creek watershed and provided a substantial amount of the data that was used in this analysis. As part of the WQIP, PWD will continue to partner with the USGS and WVWA to operate and maintain continuous streamflow and seasonal water quality monitoring (March through November) at the Fort Washington and Ridge Avenue USGS gauging stations. Parameters monitored at those stations include gauge height, discharge, temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. PWD also will continue to collect dry weather grab samples on a quarterly basis at the Fort Washington and Ridge Avenue USGS gauge stations and will also begin grab sampling at the new USGS station. The grab sampling allows for the assessment of trends over time and contributes to a long-term record of water quality changes as restoration projects are completed. The grab samples are analyzed for ammonia, fecal coliform, specific conductance, *E. coli*, nitrate, orthophosphate (PO_4), DO, pH, total phosphorus (TP), temperature, and turbidity. These data help characterize water quality and are analyzed in a similar fashion as the samples collected at the stream gauges.

As part of the source water protection program, PWD collects monthly water quality grab samples at Ridge Avenue. This program is independent of the quarterly dry weather sampling and will continue pursuant to the WQIP. Parameters include alkalinity, ammonia, chloride, *E. coli*, fecal coliform, flow, hardness, nitrate, PO_4, pH, silica, specific conductance, TSS, and turbidity.

PWD's wadeable streams assessment program also will continue. This program is semi-probabilistic and includes 25 samples collected annually to assess physical habitat and benthic macroinvertebrate communities in area watersheds. Sampling occurs each year at the two USGS gauges. Additionally, a targeted basin is chosen for sampling from among Philadelphia's five major watersheds. Approximately 20% of samples (~5 samples) are collected from randomly selected sites, some of which may be in the Wissahickon Creek watershed. The Wissahickon and Pennypack Creeks are subdivided into mainstem and tributary sampling locations that are sampled intensely by PWD on roughly five-year cycles. The next PWD Wissahickon Creek watershed-wide tributary macroinvertebrate and habitat assessment is scheduled for spring 2022 (11 sites). This will be followed, in 2023, by mainstem assessments (12 sites).

The results of PWD's WQIP monitoring effort will be included within the periodic reports that the WCWP will submit to EPA and PADEP, as further described in Section 3.4, below.

The monitoring plan for the Wissahickon Creek watershed will provide the WCWP with a contemporaneous understanding of how implementation of the projects, programs, and policies implemented as part of the WQIP will contribute to ecological improvements in the stream over time. As implementation of the WQIP progresses, the WCWP will consider additional data needs as understanding of the factors contributing to water quality impairments in the stream may evolve over time.

3.2.2 Use of SWMM Model

The SWMM model described in Appendix 3 can be used on an ongoing basis as a tool to predict the impact of potential stormwater BMP projects and estimate the progress toward improved water quality in the Wissahickon Creek ~~watershed. The infiltration scenarios and the PRP scenario help improve the understanding of the spatial variation in sediment loads and improvements derived by removing runoff and sediment at specific locations within the~~ watershed. The SWMM model can also be used to evaluate placement and design of future projects on an individual as well as cumulative basis. This evaluation can include impacts to surface runoff volume and quality as well as impacts to instream water quality. Funding for these efforts in the Wissahickon Creek watershed is being provided through 2020 by the William Penn Foundation to Temple University as part of their support for the Delaware River Watershed Initiative and is not included as part of the WQIP monitoring programs.

3.3 Implementation Metrics

The following metrics will be used to track implementation progress on an annual basis. These metrics allow for clear tracking of the implementation of the BMPs that have been developed for the WQIP.

1. Overall number of BMPs implemented pursuant to the WQIP.
2. Increases in area treated by BMPs.
3. Increases in ~~miles~~ linear feet of stream restoration and bank stabilization.
4. Increases in protected open space.

Tracking and reporting of these of metrics will facilitate an adaptive management approach to address aquatic life use impairments in the Wissahickon Creek watershed.

3.3.1 Metric Keyed to Land Area Treated

For purposes of the WQIP, “Area Treated” is defined as:

> *an area measured in acres managed via stormwater BMPs to control the volume and peak flow rate of stormwater in accordance with the Pennsylvania Stormwater Management Act of 1978 (Act 167) stormwater ordinances (Montgomery County portion of watershed) or the City of Philadelphia’s stormwater regulations (Philadelphia portion of watershed). This definition applies to new development, re-development, and also areas that are retrofitted with stormwater BMPs to limit the volume and peak flow rate of stormwater runoff. Due to site conditions, it may be possible that certain BMPs are able to for improved stormwater volume and peak flow rate control. In these cases, the area treated metric will be increased based on the ratio of the volume and flow rates actually treated by the BMP relative to the volume and flow rates prescribed in regulations or ordinances. The maximum area treated credit will be*

> *capped at the ~~2~~ 24-hour 1-year design storm as defined in NOAA Atlas 14 Volume 2 (2.73 in.) (Bonnin, et al 2006). Conversely, it may be possible that certain BMPs are unable to fully meet the requirements of stormwater ordinances and regulations. In these cases, the area treated metric will be adjusted (i.e., decreased) based on the ratio of the volume and flow rates actually treated by the BMP relative to the volume and flow rates prescribed in regulations or ordinances.*

The Area Treated metric is well-suited to measure the progress and success of WQIP implementation because it is:

- **Measurable**: Baseline data available to understand progress from current conditions;
- **Inclusive**: Allows for ~~wholistic~~ holistic assessment of the impacts of individual projects;
- **Trackable**: Can be quantified by existing tools; and
- **Relatable to Water Quality Improvements**: The SWMM Model suggests that for each 1% of area treated, there is a similar decline in peak rate flows which is linked to other parameters including runoff volume reduction increased infiltration and removal of pollutants.

The WQIP~~'s~~ presents a total area-treated aspirational goal ~~is~~ of 9,385 acres (using 2003 as the base year) within 20 years after the WQIP is adopted as a TMDL alternative, ~~although that goal is aspirational. This~~ which represents approximately 24% of the ~~total watershed area. This plan also establishes 5-year interim targets to track and evaluate progress towards reaching the 20-year Area Treated goal. Such interim targets~~ watershed area. It is important to understand that there are many factors that may ultimately prevent the attainment of this aspirational goal, including private ownership of land well-suited for priority BMP projects; limited project funding; engineering challenges; and agency permitting to name just a few. The WCWP has an interest in tracking progress within the projected 20-year implementation timetable and formulated for its own purpose tentative interim goals on five-year intervals as a management tool as follows: 15% of total new acreage by year 5; 40% by year 10; 65% by year 15; and 100% by year 20. The interim goals reflect accelerated implementation in later years and will provide opportunities for the WCWP and its collaborators to adjust and adapt implementation priorities ~~. The interim targets also reflect accelerated implementation in future years. Interim target goals include 15% of total new acreage by year 5, 40% by year 10, 65% by year 15 and 100% by year 20~~throughout the various phases of WQIP implementation.

3.3.2 Additional Metrics

In addition to tracking the number of stormwater BMPs that are implemented and the ~~Area Treated~~ area treated metric described above, the WCWP will implement additional measures as part of the WQIP (projects, programs and policies) to enhance watershed restoration and improve water quality conditions within the watershed. These measures also contribute to stream quality improvements but cannot be converted to an area treated metric. In particular, several **stream restoration opportunities** are listed with the potential to improve over 9,600 linear feet (1.8 stream miles) of instream habitat. These projects typically take longer to plan and construct, require more permitting and are more difficult to schedule, as their implementation and ultimate success are ~~based on~~ dependent upon how well the stream responds to other measures.

The **protection and conservation of priority open space** in the watershed will also continue. The existing total protected open space for the watershed is 6,341 acres. Both the Montgomery County Planning Commission and WVWA have documented about 4,000 acres of unprotected open space in the watershed. WVWA has identified approximately 1,600 acres of that total for targeted protection based on several criteria including location along waterways, connectivity to other open space areas and alignment with municipal and county programs.

The ~~recommended~~ proposed WQIP implementation goals, and target metrics for the 20-year plan are summarized in Table 3-2.

Table 3-2: Wissahickon Watershed - ~~Recommended~~ Proposed WQIP Metrics

Name	Measures included in Area Treated Definition	Definition	Aspirational Goal (20 yr plan)	Interim ~~Targets~~Tracking Goals	Water Quality Link	How determined
Area Treated		Area measured in acres managed via a stormwater BMPs to limit the volume and peak flow rate of stormwater runoff *	9,385 acres from existing base year of 2003**	15% of total new acreage yr 5; 40% of total by yr 10, 65% by year 15; 100% by yr 20. ***	Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
	Impervious area removed and/or replaced with pervious feature	Area measured in sf of impervious surface converted to other pervious surface or removal of impervious paving & conversion to meadow	N/A - Rolls up to area treated metric		Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
	Tree canopy/riparian buffers	Increased acres of riparian buffers and increased canopy cover implemented in compliance with PA DEP guidance.	N/A - Rolls up to area treated metric		Reduction in peak flows, removal of pollutants	Projects completed, inspected and reported.
	Green Stormwater Infrastructure: basin retrofits, rain gardens, bioswales, green roofs, & others where area managed can be calculated.	Drainage area managed by GSI measure constructed per PA DEP guidance	N/A - Rolls up to area treated metric		Reduction in peak rate flows; Reduction in runoff volume; removal of pollutants; increased infiltration	Projects completed, inspected and reported.

Stream Restoration		Linear feet of stream restoration via DEP MS4 accredited practice	up to 9,600 LF from projects listed in Table 5.1	as appropriate	Reduction in peak rate flows; reduction in runoff volume; removal of pollutants	Projects completed, inspected and reported.
Increased Protected Open Space^		Protect and increase dedicated open space along riparian areas or part of the MS4 drainage area. Includes areas converted from existing development to open space (e.g. buyout of flood prone structures)	1,600 Acres^^	as appropriate	Reduction in peak flows, removal of pollutants, retain infiltration value	Acres preserved/eased (purchase, gift, easement granted, conservation development)

Note: Of the 9,385 acres, MS4 ~~PRPs~~ PRP credits account for 3,281 acres, 660 acres ~~treated. Total of~~ of which includes new projects and 2,621 acres of which are credited through existing projects constructed since 2003~~, plus new projects estimated at 3,281 acres (not including streambank stabilization)~~.

* Area treated also includes features that are retrofitted to reduce runoff and peak flows according to the area treated metric described in section 3.3.1.

^Total protected open space per WVWA & MCPC data for Wissahickon Creek: 6,341 Acres

^^Total priority open space opportunities as identified by WVWA 2018 study: 1600 Acres

3.4 Proposed Implementation Schedule

The WQIP is intended to be implemented in a phased approach to afford opportunities for periodic re-evaluation, prioritization and modification. Each phase is intended to span a five-year period and provide an opportunity to assess implementation of the WQIP projects, programs, and policies, and make adjustments as necessary for each subsequent phase. The WQIP contemplates a minimum of four phases, with features of each phase as follows:

Phase 1 Years 1-5	• Amend and execute the IGA, plan, adopt policies, implement initial BMP projects, monitor, report
Phase 2 Years 5-10	• Collaborate, implement BMPs, monitor, **adapt**.
Phase 3 Years 11-15	• Same as Phase 2, **adapt.**
Phase 4 Years 16-20	• Same as Phase 3; evaluate new WWTP upgrades and investments, **adapt**.

Phase 1

The initial five-year phase of the WQIP includes the following tasks:

- ~~Developand~~ Develop and enter into a new IGA, as described in Section 3.6 below, to be renewed every five years – Years 1 through 3.
- Implement the monitoring program – Years 1 through 5. ~~The~~ It is contemplated that the monitoring program will commence before the IGA is finalized.
- Commence planning, design, and implementation of the projects ~~on the initial project list at~~ listed Table 3-1 – Years ~~1~~ 4 through 5. ~~The~~ Though the process to implement the projects identified in Table 3-1 will commence ~~before~~ after the IGA is finalized, the municipalities will assess other opportunities to improve the Wissahickon Creek prior to execution of the IGA.
- Develop and adopt policies and programs for mitigating stormwater impacts in the watershed – Years 1 through 5. Certain programs will commence only after the IGA is finalized.
- Update the SWMM model with the data collected as part of the monitoring program – Years 3 through 5.

Additional Phases

The subsequent phases of the WQIP will:

- Continue with the monitoring and reporting framework applicable during the first phase.
- ~~Identify and implement BMP~~ Continue with implementation of the BMP projects identified in Table 3-1, as well as identify other potential projects throughout the watershed using information from the monitoring and modeling programs.
- Evaluate the ongoing effectiveness of WQIP implementation and make adjustments as needed.

3.5 Reporting

Periodic reporting to EPA, PADEP and the public is an integral part of the WQIP after it is approved. Based on the elements of the plan, reports will be submitted in accordance with the following schedule:

- Semi-annual reports as to the status of the new IGA until the IGA is ~~entered~~in place
- Annual reports ~~containing~~ including (1) description of progress implementing BMP projects during each reporting period; (2) policies and programs adopted during each reporting period; (3) results of monitoring undertaken during each reporting period; and (4) accounting of progress towards tracking metrics/goals.

3.6 The Value of Continued Collaboration

Continuing a collaborative watershed-based approach ~~to improve ecological conditions in the Wissahickon Creek~~, as contemplated by this WQIP, will provide substantial water quality benefits. Given the water-quality challenges facing the watershed related to urbanization and stormwater management, sustained collective action over time has a higher likelihood of resulting in improved stream quality conditions in the watershed than any individual actions taken by a municipality or WWTP.

By building on the existing Management Committee structure of the WCWP and entering into a new IGA, the municipalities and WWTPs will be able to maximize water quality improvements related to watershed-wide planning and implementation of the stormwater management activities described in the WQIP. This collaborative structure will allow for the deployment of a holistic asset management strategy to track system operations and schedule regular maintenance of stormwater BMPs that will provide substantial benefit to the watershed when compared to the current approaches for managing stormwater pursuant to individual MS4 permits. Likewise, continuing a strong, coordinated monitoring program will allow ~~for~~ the members of the WCWP to adjust the plan if the data suggests ~~adaptations to~~ modification of the WQIP would be more beneficial for improvement of ~~ecological~~ conditions in the stream.

The IGA that the WCWP members intend to enter into during the first phase of WQIP implementation will outline the governing structure for the collaboration, activities to be jointly funded, and funding mechanisms~~, and withdrawal provisions~~. Sources of funding for contributions from individual municipalities would be up to each municipality but could include general fund revenue, fees-in-lieu, capital fund revenue, bond funds, and stormwater fees. The IGA will likely continue with a Management Committee that has been effective during the WQIP development process. Going forward, the Management Committee has identified a set of preliminary activities for continued collaboration. Leads for these activities have been identified as ~~outlined~~ described below:

- Administration and Reporting – Montgomery County Planning Commission through a community planning assistance contract with the municipal partners.

- Public Education and Private Landowner Programming – Wissahickon Valley Watershed Association through a contract with the municipal partners.

- Monitoring and Modeling – The Philadelphia Water Department will implement the monitoring and modeling program described above, work that it values at $200,000.

From a financing perspective, a strong collaborative structure in the Wissahickon Creek watershed will enable the municipalities to maximize the power of leveraging available resources. Combining resources across municipalities provides for greater potential to provide matching funds that may increase the potential of the WCWP to secure higher grant awards. In addition, grant funders often seek out collaborations because they know that investing in collaborations increases the likelihood of achieving economies of scale.

Continuation of the collaboration among the members of the WCWP also will strengthen applications for funding of stormwater and nonpoint source pollution prevention projects to PENNVEST, among others, who is dedicated to helping achieve both environmental improvements and economic development in Pennsylvania communities.

~~With respect to implementation of the initial set of BMPs identified in Table 3-1, the municipalities have committed in principle to commence with planning, designing, and implementing the projects individually during the first five-year implementation phase and in the phases to follow. The municipal partners intend to continue to discuss whether and how to address BMP operations and maintenance within the watershed so as to ensure that investments made continue to provide water quality benefits.~~

APPENDIX 1

Original IGA

(The template IGA and Adoption Resolution are provided here. The actual documents adopted by the municipalities and WWTPs may have been revised in format to conform to municipal procedure)

Intergovernmental Agreement for Development of a Plan for an Alternative TMDL for the Wissahickon Creek Watershed.

Section 1 Intergovernmental Agreement.

THIS AGREEMENT is made by and among each of the Wissahickon Creek Watershed Municipalities and Wastewater Treatment Plants executing this Intergovernmental Agreement (Agreement) for the preparation of the Wissahickon Watershed Alternative TMDL Plan (Plan), each Party shall individually be referred to as a "Party" and shall collectively be referred to as the "Parties". The list of Parties is as follows, and shall be updated by Addendum as necessary. This Agreement is authorized by Chapter 23, Subchapter A (relating to intergovernmental cooperation) of the General Local Government Code, 53 Pa. C.S. §2301 et seq.

Municipalities

- Abington Township
- Ambler Borough
- Cheltenham Township
- Horsham Township
- Lansdale Borough
- Lower Gwynedd Township
- Montgomery Township
- North Wales Borough
- Philadelphia County
- Springfield Township
- Upper Dublin Township
- Upper Gwynedd Township
- Upper Moreland Township
- Whitemarsh Township
- Whitpain Township
- Worcester Township

Wastewater Treatment Plants:

- Abington Township Wastewater Treatment Plant
- Ambler Borough Wastewater Treatment Plant
- Upper Gwynedd Township Wastewater Treatment Plant
- Upper Dublin Township Wastewater Treatment Plant (Bucks County Water & Sewer Authority)

Section 2 Definitions.

Consultant: The team formed by the Pennsylvania Environmental Council (PEC), comprised of members of PEC, the Wissahickon Valley Watershed Association, the Environmental Finance Center, the Center for Sustainable Communities, and the Montgomery County Planning Commission

Legal Services: Legal representation selected by the Management Committee to represent its interests and concerns pertaining to the preparation and adoption of the Alternative TMDL in interaction with the PADEP and/or the US EPA.

Expert Panel Services: A panel of technical experts, whose number and individuals will be selected by the Management Committee, whose purpose is to review the engineering and scientific work portions of the Alternative TMDL Plan, and to independently verify the results of that work.

Section 3 Guiding Principles.

a. The Parties have a mutual interest in restoring the impaired waters of the Wissahickon Creek Watershed and recognize that the issues associated with the TMDL developed by the EPA are too large for any one municipality to effectively address, and therefore commit to work together in a mutually cooperative and respectful manner to develop an Alternative TMDL Plan.
b. To evaluate the data obtained to develop a scientifically defensible strategy that is acceptable to the Parties, PADEP, and USEPA, and which identifies specific areas within the watershed that have characteristics that may be contributing to the reduced water quality.
c. Said strategy will include developing a list of potential projects and or policies to reduce the existing deleterious characteristics and practices, including remediating degraded physical conditions in the watershed, replacing existing structures, implementing new practices and constructing facilities to enhance the impaired surface waters in the Wissahickon Creek Watershed as effectively and efficiently as possible.
d. The Parties agree that projects will be assessed and prioritized based on the anticipated ability to provide results that can be measured to monitor the progress of water quality improvements. The effectiveness of a project, or projects, would be evaluated and a determination made on the type(s) of subsequent work projects to pursue during the implementation phase, which is a separate phase from this plan development phase.

Section 4 Goals and Objectives: The scope of study

The goal of the Alternative TMDL is to achieve water quality standards in water bodies throughout the Wissahickon Creek watershed.

Objectives: The objectives of the Alternative TMDL are delineated in Attachment “A”, “Milestones”.

Section 5 Administration and Organization.

Effective Date.

a. The Effective Date of this Agreement shall be (____), by which time all Parties will have adopted the attached Ordinance authorizing the Agreement and executed the Agreement.
b. This Agreement shall become effective as to each Party upon execution and adoption of the Ordinance.

Term

a. The term of this Agreement (Term) shall be two (2) years, beginning on the Effective Date. All Parties approving this Agreement must participate for the entire time period.
b. This Agreement may be extended by those Parties desiring to participate for an additional year, by resolution.

Party Representation

a. Participation in preparation of the Plan shall be through either the Stakeholder Group or the Management Committee. Members of the Management Committee are entitled to be part of the Stakeholder Group.
b. A Stakeholder Group shall be convened, consisting of one or more representatives of each Party, the Wissahickon Valley Watershed Association, Friends of the Wissahickon, PADEP, EPA, and

Montgomery County. Other stakeholders may be invited to attend the Stakeholder Group meeting as appropriate.

c. The Stakeholder group shall review and comment on various materials, sections of the Plan, and the complete Plan in draft and final. The Stakeholder group shall have no voting privileges, but is intended to provide input on the Plan.

d. Management Committee: Each Party shall designate a primary voting representative and an alternate to serve as the representative on the Management Committee regarding all matters related to the Plan preparation. The name of and contact information for the representative and alternate shall be provided to the Consultant in writing, as well as any subsequent changes.

   1) The Management Committee shall consist of one (1) representative from each Party. The twenty (20) voting representatives (primary voting representatives) will form the Management Committee. The alternate shall be entitled to fully participate in all Stakeholder and Committee meetings, but may vote only when the designated representative is unavailable.

   2) The members of the Management Committee shall be appointed by their governing board, shall serve at the discretion of their board for an indefinite term, and shall regularly report to their governing body and provide drafts of materials prepared for review and comment by their governing body.

   3) Where a Management Committee member vacates his or her position, the Party shall appoint a new representative, in a timely manner, such that the Management Committee does not have a vacancy for any forthcoming meeting.

e. Officers - Members of the Management Committee shall elect officers, to include 2 Co-Chairs, a Secretary and a Treasurer. Those Officers shall perform the duties necessary to implement this Agreement and as generally envisioned by Robert's Rules of Order, latest edition. An Officer shall serve for the duration of the Term, unless he or she resigns as an officer, as agreed to by the Management Committee. The Management Committee shall appoint a replacement for any officer who is unable to complete the term.

   1) Treasurer - shall collect, maintain and disburse funds in a timely fashion for legitimate expenses related to Legal Services and Expert Panel Services, as approved by the Management Committee.

f. Administration: Officers of the Management Committee will administer the activities of the Management Committee. The following are tasks that shall be undertaken and the responsibility of administration. The Management Committee may choose to delegate some or all of these activities to the Consultant:

   1) Preparation and circulation of minutes to all Parties from all Management Committee meetings.
   2) Hold all Management Committee meetings.
   3) Review and comment on all draft Alternative Plan documents and revisions prepared by the Consultant, and submit the Plan as approved by the Management Committee to PADEP and EPA.
   4) Review and Submit progress reports prepared by the Consultant to PADEP and EPA in a timely manner.
   5) Calculate and invoice fees for each Party.
   6) Retain all records, as that term is defined by the Pennsylvania Right-to-Know Law, for the time period required by applicable law but not less than six (6) years.

Meetings.

a) The Management Committee shall organize and schedule routine meetings of the Management Committee as needed, but at least quarterly.
b) The purpose of the meetings shall be to conduct the following activities as necessary:
   1) Review and comment on, and when necessary vote on draft and final sections of the Plan.
   2) Presentation and approval of Progress Reports.
   3) Presentation and approval of the Financial Report.
   4) Presentation of report(s) to PADEP, EPA and other agencies.
   5) Presentation and vote on other Party business pertaining to the Plan process.
   6) Oversight and coordination of all aspects of the Legal Services and Expert Panel Services.
c) Except as otherwise provided herein, all voting shall be completed by voice vote and decisions shall be based on a simple majority vote of Management Committee Parties in attendance.
d) Each Party in attendance shall be entitled to one (1) vote on all matters addressed at a meeting and for which a vote is taken.
e) Quorum. A quorum (more than 50% of Management Committee members as represented by a voting representative) is necessary for the Management Committee to take official action.
f) The Management Committee shall comply with all laws applicable to the Parties, including, but not limited to, the Public Official and Employees Ethics Act, the Sunshine Act, and any and all other applicable laws. All actions of the Management Committee shall be approved by a majority of its voting members. Management Committee members shall be entitled to attend meetings of the Management Committee, which shall occur no less than four (4) times per year or more frequently as needed, following advance written notice to all members of the Management Committee by regular mail, facsimile or email.

Financing

a) A monetary contribution shall be provided by each Party, to cover the costs of Legal Services and Expert Panel Services. The total cost for these services is not to exceed $250,000 in total.

   1) Contribution Formula. The contribution from each Party shall be $6,250 per Party per year for the Term. Depending on the costs incurred for Legal Representation and the Expert Panel Service, these costs may be less, but in any event they shall not exceed a total of $12,500 per Party for the duration of the Term.

   2) Invoicing and Payment. Parties shall be invoiced no later than June 30 of each calendar year, and the Parties' respective payments shall be due on or before July 31 of each year.

   3) Organization Account. A separate Management bank account shall be established by the Management Committee for the deposit of each Party's Annual Contributions and the funds therein shall be used solely for reimbursement for eligible costs and expenses pertaining to Legal Services and Expert Panel Services. Administration of these funds to pay for proper expenses under this Agreement shall be the responsibility of the Management Committee.

   4) Remaining Funds. Any funds remaining at the conclusion of the Term, shall be returned to the Parties, divided equally among the Parties that have paid their Annual Contribution. Such funds shall be disbursed to the Parties remaining at the completion of the Term no more than thirty (30) days after the date of Term completion.

Section 6 Applicable Law

The Parties agree and affirm that Pennsylvania law applies to this Agreement and all matters covered by and addressed by this Agreement. It is acknowledged and agreed that the sole and exclusive jurisdiction and venue for any dispute relating to any matter covered by this Agreement, and/or regarding any dispute over the enforcement or Interpretation of this Agreement, shall rest with the Montgomery County Court of Common Pleas. The Parties hereby submit to the exclusive jurisdiction of that Court.

Section 7 Integration

This Agreement contains the entire agreement between the Parties. There are no understandings or agreements, verbal or otherwise, in relation hereto, except those expressly and specifically set forth herein. The Parties have not relied upon any statement, projection, disclosure, report, information or any other representation or warranty except for those as may be specifically and expressly set forth in this Agreement.

Section 8 No Oral Modification

This Agreement may not be modified except in writing executed by all Parties. This Agreement shall be amended only in writing, by duly authorized representatives of all Parties, and such revision(s) must be approved by official action of each Party jurisdiction, and as required by any applicable law of the Commonwealth.

Section 9 Severability

No determination by any court, governmental body, arbitration, or other judicial body, that any provision of this Agreement or any amendment that may be created hereto, is invalid or unenforceable in any instance shall affect the validity or enforceability of any other provision of the Agreement or applicable amendment. Each provision shall be valid and enforceable to the fullest extent permitted by applicable law, and shall be construed where and whenever possible as being consistent with applicable law.

Section 10 Representation by Counsel

This Agreement has been negotiated by the Parties through their respective legal counsel and embodies terms that were arrived at through mutual negotiation and joint effort, and the Parties shall be considered to have contributed equally to the preparation of this Agreement. The Parties warrant and represent that the terms and conditions of this Agreement have been discussed and negotiated between them, and their respective counsel, and are voluntarily and knowingly accepted for the purpose of making a full and final compromise between the Parties, as referenced herein. The Parties further acknowledge that they understand the facts and their respective legal rights and obligations pursuant to this Agreement.

Section 11 Counterparts

This Agreement may be executed in counterparts, each of which will be an original, and all of which taken together shall constitute one and the same instrument.

Section 12 Execution by Facsimile or Electronic Scanning

Delivery of an executed counterpart of this Agreement by facsimile, or by electronically scanning and e-mailing an executed counterpart signature page, while not specifically required, will be acknowledged by the Parties as being equally as effective as delivery of a manually executed counterpart of this Agreement. The use of a signature page received by facsimile, or through an electronic scan and e-mail, shall not affect the validity, enforceability, or binding effect of this Agreement.

Attachment “A”
Alternative TMDL Milestones and Activities

Project Result:

An Alternative Nutrient TMDL Plan (Plan) supported by the Permittees and approved by PADEP and USEPA, with associated MS4/TMDL permit issuance to follow. The Plan will demonstrate benefits of a successful multi-municipal approach to coordinating required stormwater and phosphorous discharges to achieve regulatory reductions into the Wissahickon Creek.

Milestone 1

Montgomery County Planning Commission (MCPC) designated to convene the 'Wissahickon Alternative TMDL Stakeholder Collaborative' (aka ‘Collaborative’) consisting of a core group of the (16) watershed municipalities and (4) WWTPs (the 20 Permittees) that is recognized by the US EPA and includes external stakeholders such as WVWA and FOW.

Activities:

- Led by MCPC, organizational structure finalized and implemented for the Collaborative.
- Coordination procedures with regulatory agencies approved and implemented.
- MCPC conducts regular monthly Collaborative meetings for the duration of the project.

MILESTONE 2

EFC works with each Collaborative member to develop a long term comprehensive financial strategy for implementing approved Alternative Nutrient TMDL plan projects/programs.

Activities:

- Initial individual Collaborative member engagement and baseline economic assessments completed
- Agreement with EPA executed for implementation expenditures.

MILESTONE 3

PEC coordinates the Technical Team to develop an Alternative Nutrient TMDL, using strategic guidance from WVWA, with plan approval by PA DEP and US EPA.

Activities:

- PEC forms a Technical Team consisting of CSC, EFC, MCPC, and legal counsel to be selected by the Permittees, with input from the Technical Team.

MILESTONE 4

Within 3 years of the signing of the IGA or sooner, Technical Team recommends an Alternative Nutrient TMDL science-based strategy for the Wissahickon watershed, submitted to PA DEP and US EPA for review and approval.

Activities:

- Key results of recent and ongoing studies and modeling efforts for the Wissahickon Creek watershed are compiled to fully describe the problems causing the water quality impairments
- Strategies and projects for Permittees to address water quality impairments and improve water quality are identified, evaluated, and prioritized for the watershed

- Temple CSC implements a preliminary adaptive watershed monitoring program during the planning process (month 6) with a long-term plan developed and adopted by the Collaborative to assess water quality improvements going forward

MILESTONE 5
Within 3 years of the signing of the IGA or sooner, EFC and Collaborative develop a long term comprehensive financial strategy for implementing approved Alternative Nutrient TMDL plan projects/programs.

Activities:
- In coordination with Temple CSC work, costs of plan projects/programs and associated timelines identified
- Equitable funding strategy approved by Collaborative members reflective of the capacities of individual municipalities, multi-municipal authorities and potential for other public and private funding sources.

MILESTONE 6
By the beginning of the third year from the signing of the IGA or sooner, strategies developed and deployed to ensure education and outreach is completed to build support for the Alternative TMDL plan.

Activities:
- Lead by WVWA, residents of the Wissahickon are kept informed of project progress, educated and encouraged to understand why Wissahickon water quality needs to be improved and how a TMDL Alternative may be a beneficial solution.
- Expand on existing DRWI programs including workshops, restoration site visits, and municipal technical assistance as necessary to accomplish the above activities.

MILESTONE 7
By the first quarter of the third year from the signing of the IGA or sooner, approved Alternative Nutrient TMDL Plan process documented with benefits/lesson learned compiled and, led by PEC, information dissemination actively underway in the DRWI, Delaware Watershed and Pennsylvania.

Activities:
- TMDL Alternative Plan Draft Report compiled and presented to public and regulators for review with multi-municipal TMDL Alternative Plan Report finalized thereafter.
- PEC devises and initiates a process for documentation and dissemination of a successful Alternative TMDL process; recruits and contracts with a professional to document alternative TMDL process.
- PEC defines multi-municipal benefits and develops strategies to promote multi-municipal Alternative TMDL process elsewhere in the DRWI clusters, across the Delaware basin and throughout Pennsylvania. Robust dissemination implemented as evidenced by a minimum of five (5) professional presentations, and three (3) articles published via print or electronic platforms.

The following is suggested language for use by the Permittees in adopting the IGA. It is based on Intergovernmental Cooperation Law, Pennsylvania Consolidated Statutes, Title 53 - Municipalities Generally, SUBPART D - AREA GOVERNMENT AND INTERGOVERNMENTAL COOPERATION. Please feel free to use this in the preparation of your ordinance to adopt the IGA.

ORDINANCE NO. _____
(Municipality)
Montgomery County, PA

An Ordinance of (*Municipality*), Montgomery County, Pennsylvania adopting the Intergovernmental Agreement for the completion of the Alternative TMDL Plan for the Wissahickon

Section 1. Conditions of Agreement.

The Intergovernmental Agreement (Agreement) is made by and among each of the Wissahickon Creek Watershed Municipalities and Wastewater Treatment Plants executing the Agreement for the preparation of the Wissahickon Watershed Alternative TMDL Plan (Plan), collectively, the "Parties", each Party shall individually be referred to as a "Party" and shall collectively be referred to as the "Parties". The list of the Parties is as follows, and shall be updated by Addendum as necessary.

Municipalities
- Abington Township
- Ambler Borough
- Cheltenham Township
- Horsham Township
- Lansdale Borough
- Lower Gwynedd Township
- Montgomery Township
- North Wales Borough
- Philadelphia County
- Springfield Township
- Upper Dublin Township
- Upper Gwynedd Township
- Upper Moreland Township
- Whitemarsh Township
- Whitpain Township
- Worcester Township

Wastewater Treatment Plants:
- Abington Township Wastewater Treatment Plant
- Ambler Borough Wastewater Treatment Plant
- Upper Gwynedd Township Wastewater Treatment Plant
- Upper Dublin Township Wastewater Treatment Plant (Bucks County Water & Sewer Authority)

Section 2. Duration of the Term of the Agreement

The duration of the term of the Agreement (Term) shall be two years. The Agreement may be extended by those Parties desiring to participate for an additional term or terms, by resolution.

Section 3. Purpose and Objectives of the Agreement

The Agreement is the document by which the Parties signify their commitment to participate in the preparation of the Plan. The goal of the Plan is to achieve water quality standards in water bodies throughout the Wissahickon Creek watershed. Further, the Agreement establishes the role and duties of the Parties, the Consultant, the Legal Services Representation, and the Expert Panel Services, and the scope of the Plan, as defined in the Agreement and further outlined in Attachment A of the Agreement.

Section 4. Manner and Extent of Financing the Agreement

A fee not to exceed $6,250 per year shall be provided by each Party. This fee is to cover the costs of Legal Services and Expert Panel Services.

Section 5. Organizational Structure
The Plan shall be prepared by the Consultant, with guidance and input provided through a Stakeholder Group and a Management Committee, whose roles are defined in the Agreement.

Section 6. Real or Personal Property
The Agreement does not empower any of the Parties, the Consultant, Legal Services Representation, or Expert Panel Services to acquire, manage, license or dispose of any real or personal property related to or in conjunction with the preparation of the Plan.

Section 7. Contracts
The Parties entering into the agreement shall be empowered to contract with the Consultant, Legal Services Representation, and Expert Panel Services for services pertaining to the preparation of the Plan and securing approval of the Plan from the US Environmental Protection Agency and the Pennsylvania Department of Environmental Protection.

Section 8. Effective Date

The Effective Date of this Ordinance shall be (*DATE*).

ORDAINED AND ENACTED by the (*Board or Council*) of (*Municipal Name*), Montgomery County, Pennsylvania, this _______ day of ________________, 2016.

Appendix 2

Municipal Fact Sheet

Municipal Fact Sheet

The Wissahickon Creek Watershed encompasses two counties[1] and all or part of 16 municipalities. In Pennsylvania, residents pay taxes to both the county and the municipality. Counties are required to provide certain services to their residents, including community development, environmental planning, and real estate tax assessments. The primary source of revenue for local governments is through real estate taxes. Income tax is the second largest source of revenue. Philadelphia is the only municipality authorized to impose sales tax. Tax law in Pennsylvania is complicated and state law limits the millages that can be imposed by municipalities. Court approval is required if a municipality needs to levy an additional millage to meet an approved budget. Boroughs and first class townships can issue additional millages for certain services including debt service, recreation, and shade trees.

The municipalities in the Wissahickon Creek watershed include Montgomery County, the City of Philadelphia (first class city), three boroughs, six first class townships, and six second class townships. Each type of municipality is governed by a different governance structure which require extensive coordination to fund the WQIP:

- Counties are governed by three commissioners.
- First class cities have a population of 1,000,000 or more. Philadelphia is Pennsylvania's only first class city and is governed by a mayor, 10 district council members, and seven council members at-large. The managing director is responsible for overseeing day-to-day operations.
- Boroughs tend to be smaller than cities, elect mayors, and have between 3-9 council members. They may also have an appointed manager to institute policies.
- First class townships have a population density of 300 or more per square mile and voters have approved the change of classification from a second class township. They are governed by 5-15 commissioners.
- Second class townships typically have between 3-5 elected supervisors.

As a result of these various governance structures, there are 122 elected officials within the watershed. In addition, four of the Wissahickon Creek municipalities (Philadelphia, Cheltenham, Horsham and Whitemarsh) have adopted home rule charters, which allow greater autonomy in decision making.

Each of the 16 municipalities adopts and implements its own individual suite of land use regulations. Municipalities are required under the 2014 Wissahickon Creek Watershed Act 167 Plan (Act 167 Plan) to implement the plan through adoption of stand-alone ordinances or incorporation of the ordinance criteria into their existing code. All municipalities regulate stormwater discharges, development in floodplains and include provisions to protect water courses, lakes and ponds.

As part of the Act 167 Plan, a model ordinance was created based on a review of existing regulations that could impact the volume and velocity of stormwater runoff. The Act 167 ordinance requires a minimum 50-foot riparian buffer[2] if a perennial or intermittent stream passes through a site proposed for development in the Montgomery county portion of the watershed.

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[1] The City of Philadelphia governs Philadelphia County.

[2] Section 407 of the Act 167 model ordinance also specifies that municipalities may select a smaller buffer width if desired, but the selected buffer may not be less than 10 feet.

Appendix 3

Report on SWMM Model Development and Calibration for the Wissahickon Creek

Report on SWMM Model Development and Calibration for the Wissahickon Creek

October 22, 2018

Robert Ryan

Manahel Soro

Temple University

I. Purpose of modeling

Temple University is developing a model of the Wissahickon Creek watershed in order to assess the impact of future changes in land use, storm water control and other alternatives designed to improve the water quality of the creek.

Rainfall runoff processes were modeled using the EPA supported Storm Water Management Model (SWMM v 5.1.12, EPA, 2017). This model is a lumped parameter model (i.e., parameter values apply across the entire subcatchment) which can function as a quasi-distributed parameter model with careful definition of subcatchment boundaries. The model combines hydrology, hydraulics and water quality in a single, well documented, open source model. The model has a vast user community (https://www.openswmm.org/) and has been used in thousands of studies to examine the impact of storm water controls on runoff quantity and quality.

II. Data Needs

1. Precipitation

Precipitation data drives SWMM and is available from weather stations located at Temple Ambler and from the Philadelphia Water Department (RG_19, located at the Emlen Middle School on Chew Ave; RG_21 located at the Shawmont Middle School on Shawmont Ave, just east of Ridge Ave; RG_29 located at the Springfield Township High School on Paper Mill Rd). Each station collects depth of rainfall at 15-minute intervals. Figure 1 shows the location of the gages and indicates how the rainfall from each gage is distributed across the watershed.

2. Land Use

Land use is needed to define infiltration characteristics and quality of surface runoff. Land use data for 2015 was obtained from the Delaware Valley Regional Planning Commission (DVRPC, 2017). The distribution of land use within the Wissahickon Creek watershed is shown in Figure 2. Land use data was used to define infiltration characteristics (see Section II.A.10) and surface runoff water quality (see Section II.A.13)

3. Impervious Cover

SWMM requires the percent impervious cover as an input for each subcatchment. This parameter is used in the calculation of infiltration and overland runoff. Impervious surface coverage for 2015 was obtained from DVRPC (2018) and is shown in Figure 3.

4. Soils

Information on soil type is also needed to estimate infiltration characteristics. The hydrologic soil group (HSG) is a qualitative estimate of infiltration capacity as described in Table 1. The HSG is needed to estimate the value of the Curve Number as discussed below. HSG values were obtained from the USDA's Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Due to the highly urbanized nature of the Wissahickon Creek watershed, much of the soil is classified as 'Made Land' or "Urban Soil". These soils are generally fill with unknown qualities. Therefore, no HSG is applied by USDA. In cases of Made Land or Urban Soil, we assumed a 'C' soil which has poor to fair infiltration characteristics. Figure 4 shows the distribution of HSG throughout the Wissahickon Creek watershed.

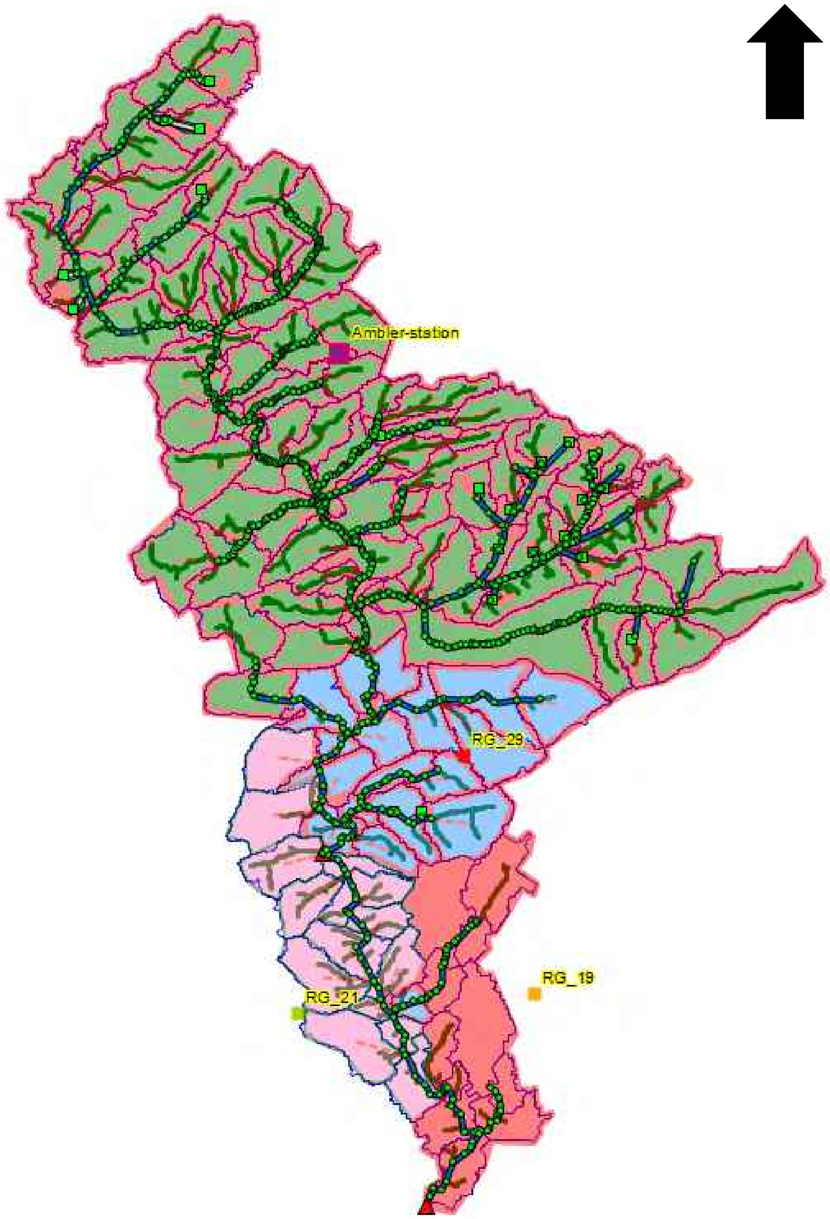


Figure 1 Representation of SWMM model of Wissahickon Creek watershed. Four rain gages are used. Temple Ambler (green), PWD RG_29 (blue), PWD RG_21 (pink) and PWD RG_19 (red).

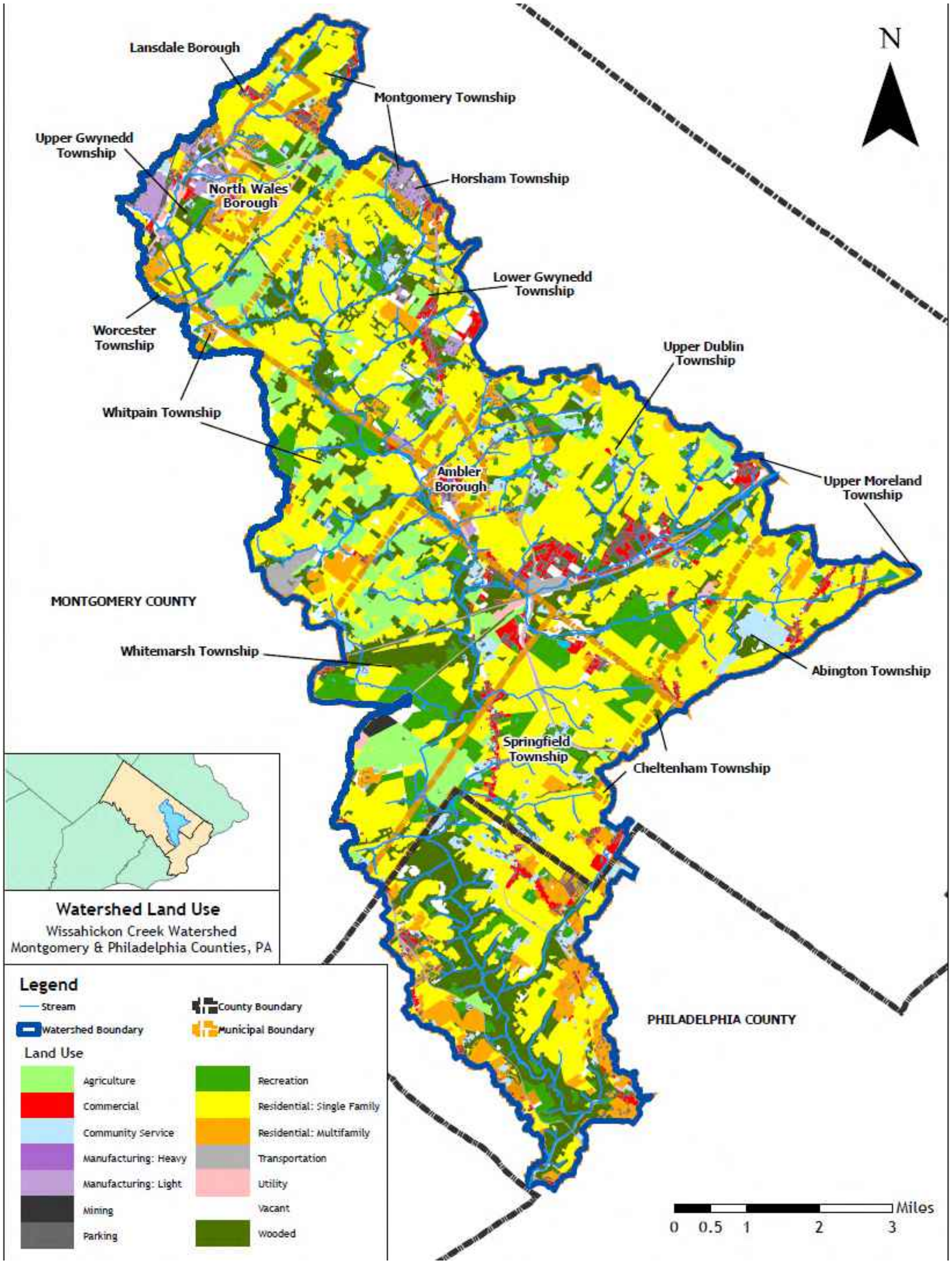


Figure 2. Wissahickon Creek watershed land use based on 2015 data published by DVRPC (2017)

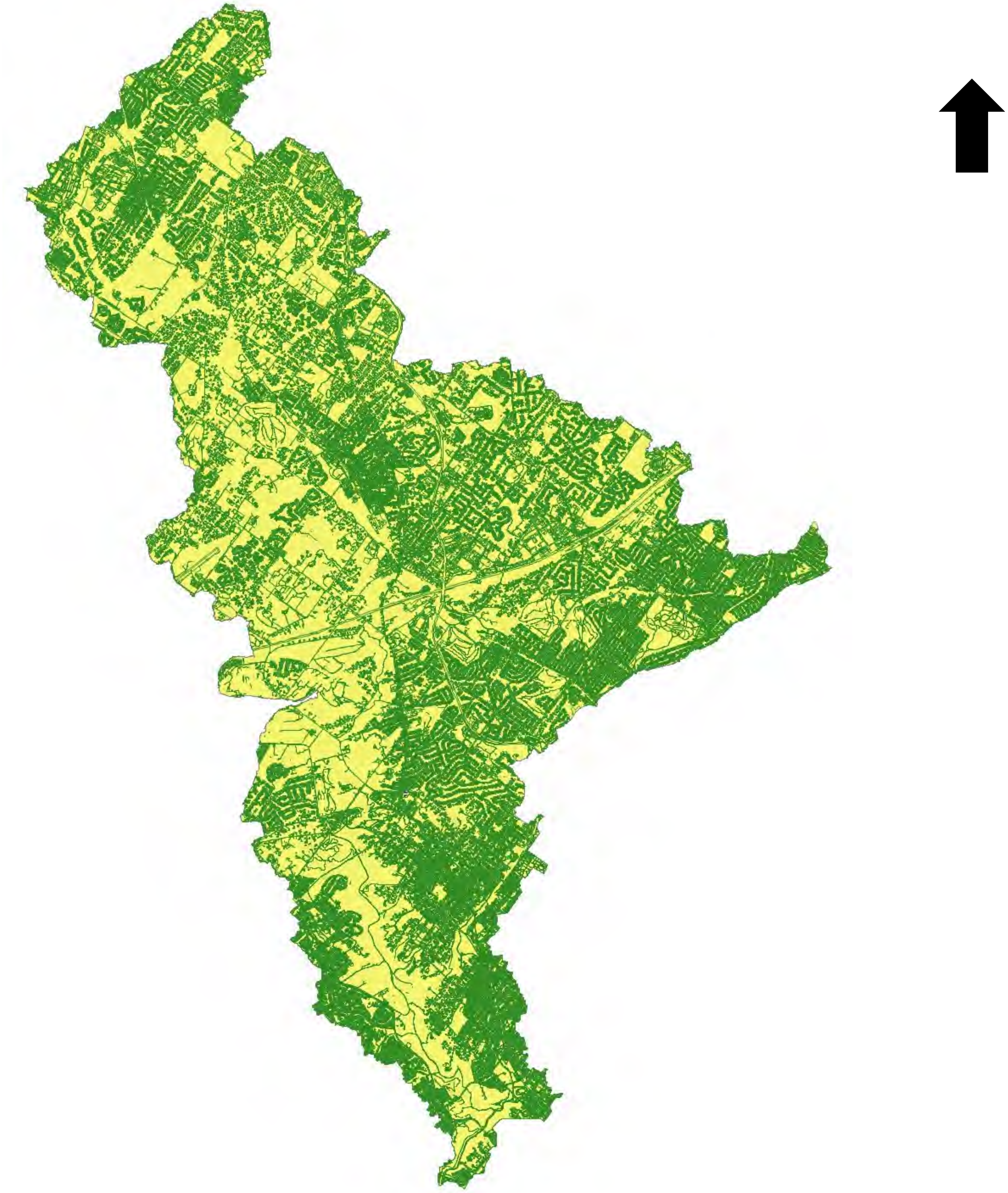


Figure 3. Wissahickon watershed impervious surface (green) and pervious surface (yellow)

Table 1. Hydrologic Soil Groups as described by NRCS (1986)

ISG	Description	Infiltration Rates (in/hr)
A	Sand, Loamy Sand, Sandy Loam	> 0.30
B	Silt Loam or Loam	0.15 – 0.3
C	Sandy Clay Loam	0.05 – 0.15
D	Loam, Silty Clay Loam, Sandy Clay, Silty Clay, Clay	< 0.05

5. Topography

Topography is used to define subcatchment boundaries and other characteristics such as slope and overland flow path length. In 2015, Temple University contracted with BAE Systems to develop Digital Elevation Model (DEM) and topographic contour intervals with a 2 ft resolution through enhancement of breaklines and LiDAR data based on 2008 PAMAP aerial imagery files. This up-to-date data was then used in conjunction with Geospatial Hydrologic Modeling Extension (HEC-GeoHMS tool) to delineate subbasins and document watershed characteristics such as slope and flow path. Figure 5 shows the DEM data for the Wissahickon Creek watershed.

6. Slope

The value of the subcatchment slope was determined as a typical value for the overland flow path slope. We first identified multiple overland flowpaths within ArcGIS10.4, using the DEM data as corrected by BAE Systems. The elevation at the beginning and end of each flow path was extracted and the slope was calculated as the difference in elevation divided by the length of the flowpath. The typical flowpath slope was then assigned as the subcatchment slope.

7. Roughness

SWMM uses Manning's Equation (Equation 1) to estimate watershed runoff flow rates.

$$Q = \frac{1.49}{n} S^{1/2} R^{2/3} A \qquad (1)$$

where Q is runoff flow rate (cfs), n is Manning's roughness coefficient, S is the subcatchment slope, R is the hydraulic radius (ft) and A is the cross-sectional area of surface flow (ft^2).

Manning's n is an empirical constant that increases with roughness. Typical estimates of Manning's n are shown in Table 2 (Rossman, 2015). The initial values of Manning's n for overland flow were set to 0.01 for impervious surfaces and 0.10 for pervious surfaces. These values were then adjusted during the calibration process.

S was estimated from the BAE Systems corrected DEM using ArcGIS.

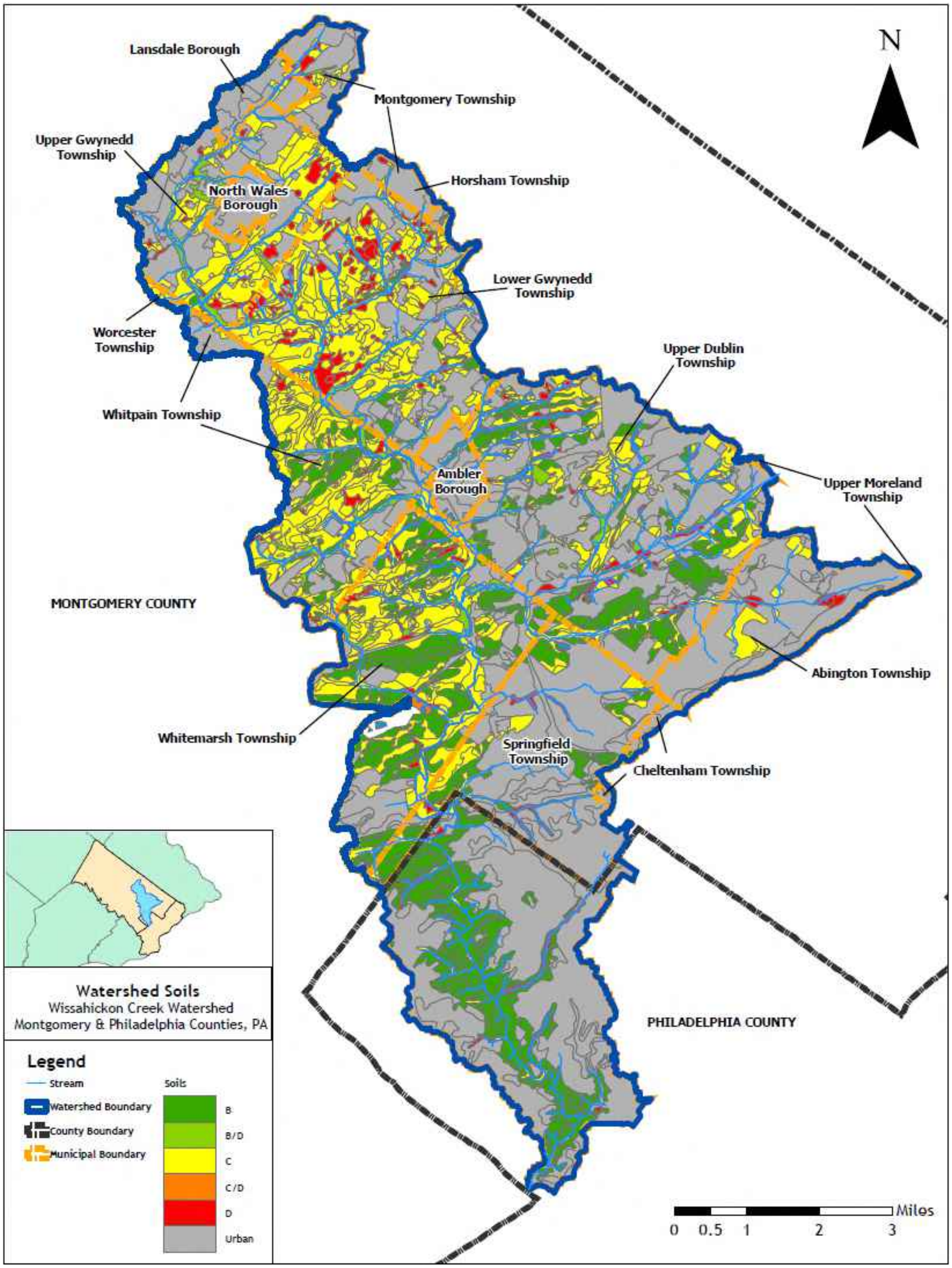


Figure 4. Wissahickon Creek watershed HSG categories. Note that Urban soils were assumed to be HSG C for modeling and infiltration purposes.

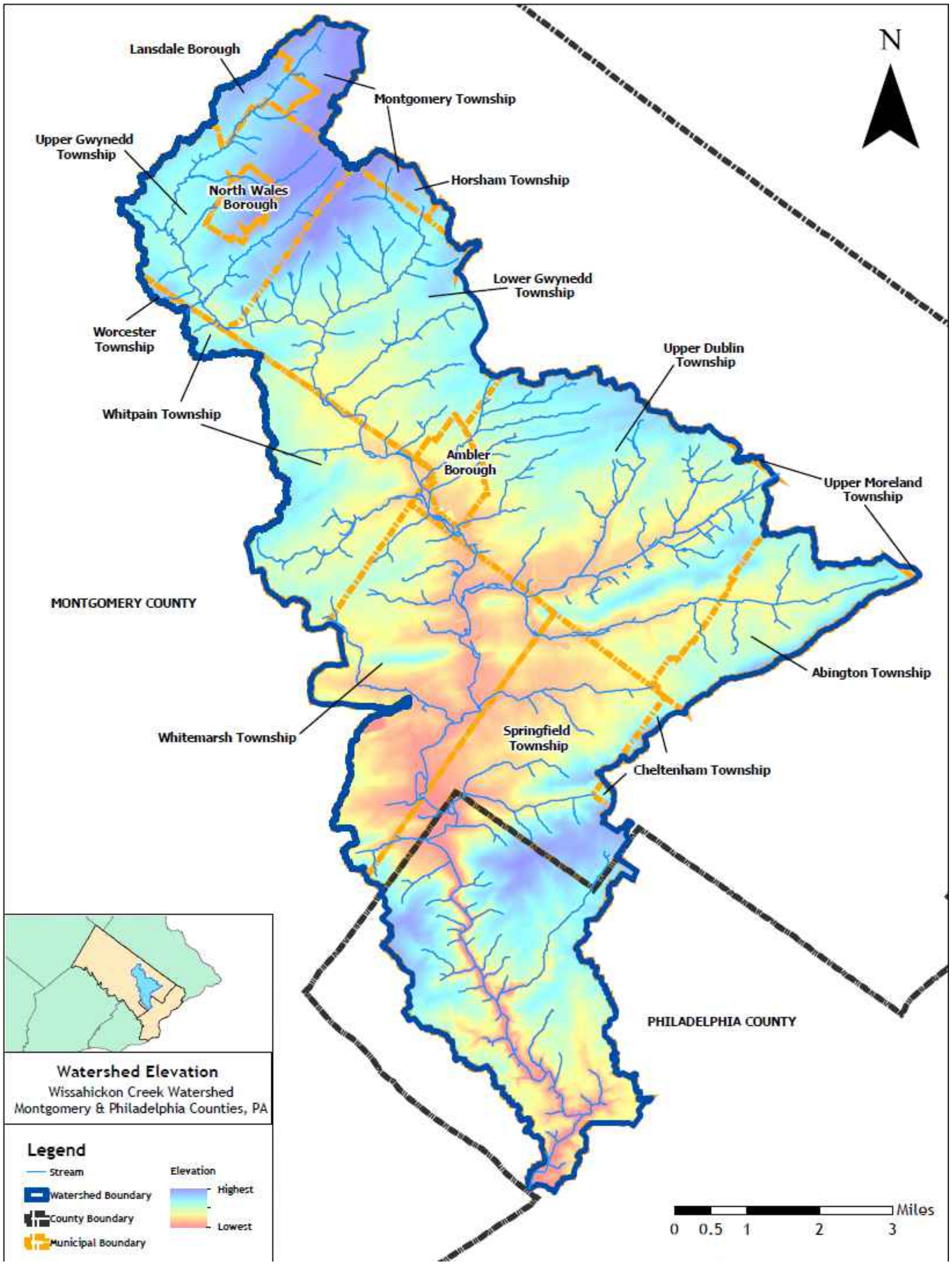


Figure 5 Wissahickon Creek watershed Digital Elevation Model.

Table 2. Representative values of Manning's n for overland flow as cited by Rossman (2015)

Source	Ground Cover	Typical Value of Manning's n
Cuen, et al. (1996)	Smooth Asphalt	0.011
	Smooth Concrete	0.012
	Fallow Soils (no residue)	0.050
	Cultivated Soils (<20% residue cover)	0.060
	Cultivated Soils (>20% residue cover)	0.017
	Range (natural)	0.130
	Short Prairie Grass	0.150
	Dense Grass	0.240
	Bermuda Grass	0.410
	Woods, Light Underbrush	0.400
	Woods, Dense Underbrush	0.800

The value of R is calculated as A/P where P is the wetted perimeter of flow (width (w) of the flow path plus two times the depth (d) of flow as shown in Equation 2

$$R = \frac{A}{P} = \frac{w*d}{2d+w} \tag{2}$$

Assuming wide, shallow flow, d is much less than w and so the value of P approaches w and Equation 2 reduced to Equation 3

$$R = \frac{A}{P} \cong \frac{w*d}{w} = d \tag{3}$$

8. Depression Storage

Depression storage (d_s) is the maximum volume of water stored in the subcatchment prior to the inception of runoff. For impervious surfaces, d_s was set to a default value of 0.05 inches. For pervious surfaces, the initial value of d_s was set equal to S_{max} in the Curve Number equation (see Section 10 and Equation 6 below). Depression storage was adjusted on both pervious and impervious surfaces during the calibration process.

9. Evapotranspiration

SWMM calculates evapotranspiration based on temperature and solar radiation (Hargreaves and Samani, 1985) as shown in Equation 4

$$ET = 0.0023\left({}^{R_a}/_{\lambda}\right)T_r^{1/2}(T_a + 17.8) \tag{4}$$

where ET is the evaporation rate (mm/d), R_a is the incoming solar radiation (MJ/(m^{2}d) which is determined based on latitude and day of the year, T_r is the average daily temperature range for the preceding 7 days, T_a is the average daily temperature for the preceding 7 days, and λ is the latent heat of vaporization (MJ/kg) calculated using T_a. Units of ET are then converted to inches for consistency. Temperature data was obtained from the Temple Ambler weather station.

10. Infiltration

SWMM has the capability of modeling infiltration using one of three methods:

1) Horton (1939)
2) Green-Ampt (1912)
3) Curve Number (NRCS, 1986)

Horton (1939) developed an empirical equation to describe the change in infiltration capacity for long rain events as an exponential function of time. This method requires an estimate of the initial (maximum) infiltration rate, equilibrium (minimum) infiltration rate and a decay term which describes how fast infiltration decreases from the initial rate to the equilibrium rate. Each of these terms are difficult to estimate and so uncertainty is added to the model results.

Green-Ampt (1912) developed a method which assumes there is a sharp divide between saturated and unsaturated soils in the subsurface. As infiltration continues, this line moves down through the soil column. Green-Ampt (1912) is most representative of the physical processes driving infiltration. However, required input parameters (e.g. hydraulic conductivity, suction head and moisture deficit recovery rate) are difficult to accurately estimate and thus add additional uncertainty to model results.

The Curve Number method used in SWMM is adapted from NRCS (1986). In SWMM's implementation, the maximum runoff is calculated as shown in Equation 5

$$Q = \frac{P^2}{P+S_{max}} \qquad (5)$$

Where Q is runoff (in), P is precipitation (in) and S_{max} is the maximum storage in the watershed after runoff begins (in). S_{max} is defined as a function of the Curve Number (CN) as shown in Equation 6.

$$S_{max} = \frac{1000}{CN} - 10 \qquad (6)$$

Values of CN based on land use and HSG have been published by multiple sources (NRCS, 1986; Bedient et al, 2001; Haestad Methods, 2007)

SWMM then reduces this maximum runoff depth by the depth of depression storage, evapotranspiration and infiltration such that all P is accounted for as shown in Equation 7

$$P = Q - d_s - ET - I \qquad (7)$$

Where d_s is depression storage (in), ET is evaporation (in) and I is infiltration (in). Depression storage and ET are determined as described above in Sections II.A.8 and II.A.9. Combining Equations 5 and 7, I is calculated as

$$I = P - \frac{P^2}{P+S} - d_s - E \qquad (8)$$

This method allows for infiltration to be calculated using well accepted literature values for the curve number in combination with readily available measured quantities (precipitation and temperature) and a small calibration parameter (d_s). The curve numbers used in the model are based on NRCS (1986) land use categories and are shown in Table 3.

TABLE 3. Curve numbers used in SWMM model based on Land Use and HSG

Land Use Category	Hydrologic Soil Group			
	A	**B**	**C**	**D**
Agriculture	49	69	79	84
Commercial	89	92	94	95
Community Services	81	88	91	93
Manufacturing: Light Industrial	81	88	91	93
Military	63	77	85	88
Parking:	98	98	98	98
Recreation	49	69	79	84
Residential: Mobile Home	77	85	90	92
Residential: Multi-Family	77	85	90	92
Residential: Row Home	77	85	90	92
Residential: Single-Family Detached	57	72	81	86
Transportation	83	89	92	93
Utility	89	92	94	95
Vacant	77	85	90	92
Water	100	100	100	100
Wooded	36	60	73	79

11. Existing SW Basins

All accessible storm water management basins with a storage volume of 2 ac-ft or larger, plus smaller, easily accessible basins, were visited and field measurements were obtained to confirm the outlet location (latitude and longitude) and outfall configuration (invert elevation and dimension of each orifice or weir in the outfall structure; invert and dimensions of emergency overflow). Table 4 lists the basins explicitly modeled. For each basin modeled, a stage-surface area relationship and drainage area were developed using the contour intervals and DEM data as corrected by BAE Systems. The land use within the basin drainage area was determined based on the DVRPC 2015 Land Use data.

12. Channel Characteristics

Channel characteristics include cross section, slope, and roughness (Manning’s n). These characteristics are used to define volume, depth and velocity of water as well as the volumetric flow rate.

a. Cross Section

Cross sections were primarily cut using ArcGIS 3D Analyst in conjunction with the BAE Systems corrected TIN and break line data referenced to LIDAR flown as part of the PAMAP program. The most recent orthophotography was used as a base map for reference. Additional cross sections were provided by the City of Philadelphia Water Department in 2011 for the Act 167 Study conducted by Temple University's Center for Sustainable Communities (CSC, 2014).

b. Bank/Bed roughness

As with surface runoff flow rates, SWMM uses Manning’s equation (Equation 2) to estimate flow in channels and pipes. The Manning’s n values for channel flow are shown in Table 5 (adapted from Chow, 1959).

Table 4. Storm Water Control Basins Included in SWMM Model. Outlet location and configuration for each basin were confirmed with field measurements.

Basin ID	Latitude	Longitude
AB_001	40.12330	-75.15040
LG_23 (riser 1 of 2)	40.18030	-75.24110
LG_23 (riser 2 of 2)	40.18030	-75.24110
MO_004	40.22610	-75.25727
MO_101	40.23625	-75.24922
PH_104	40.04350	-75.18920
SF_14A	40.09634	-75.21876
UD_008	40.16208	-75.16490
UD_014	40.15954	-75.15897
UD_015	40.15610	-75.15937
UD_018	40.15382	-75.18869
UD_021	40.14948	-75.18079
UD_026	40.15112	-75.16237
UD_027	40.15313	-75.15675
UD_032	40.14127	-75.17574
UD_036	40.14392	-75.16705
UD_037	40.13988	-75.16281
UD_039	40.13178	-75.18629
UD_044	40.15639	-75.17464
UD_045	40.15860	-75.17254
UD_051	40.14423	-75.16382
UD_065	40.15270	-75.14404
UD_067	40.15385	-75.14916
UD_123A	40.17060	-75.21200
UD_126	40.14920	-75.20290
UD_128A	40.15270	-75.20550
UD_131	40.14750	-75.20720
UD_135	40.15440	-75.20810
UD_136	40.15580	-75.20460
UD_137	40.14190	-75.18410
UD_138	40.14300	-75.16470
UG_001	40.22809	-75.26762
UG_012R	40.21271	-75.25755
UG_018	40.19809	-75.29367
WM_008	40.11770	-75.21960
WM_101A	40.13223	-75.20048
WP_023	40.14200	-75.25730
WP_030	40.13770	-75.26680
WP_030A	40.14010	-75.25870
WP_104	40.19124	-75.29117

The initial values of Manning's n used in the SWMM model were the same as those specified in CSC (2014) and the calibrated HEC-RAS model discussed therein. Generally, Manning's n was approximately 0.045 for the stream bed, 0.035 for bare stream banks and 0.16 for highly vegetated stream banks. These values were then adjusted during the calibration process.

13. Runoff Quality

Surface runoff quality values in SWMM were input as Event Mean Concentrations (EMCs) for each pollutant (Total Suspended Sediment, TSS; Total Phosphorus, TP; and Total Nitrogen, TN) and for each land use type (e.g. Single Family Residential, Commercial, etc.). The values used in the SWMM model are shown in Table 6.

We began with EMCs published by The Pennsylvania Department of Environmental Protection (PADEP, 2005) for TSS, TP and TN for various pervious and impervious land covers as shown in Table 7. The PADEP data was then used to develop EMCs for each land use category shown in Table 6 based on the area-weighted averages of land cover within each land use as shown in Table 8.

14. WWTP

The Wissahickon Creek watershed includes four municipal wastewater treatment plants as shown in Figure 6:

Abington Township
Ambler Borough
Bucks County Water and Sewer Authority (Upper Dublin Township)
Upper Gwynedd Township

Discharge flow rate, and TSS, TP and Nitrate-Nitrite concentrations were obtained from Monthly Discharge Monitoring Reports (DMRs) submitted by each facility to the PA DEP. Abington Township, Bucks County Water and Sewer Authority and Upper Gwynedd Township DMRs were obtained from the PA DEP EDMR online database. DMRs for Ambler Borough were reviewed in the PA DEP office in Norristown.

Table 5. Manning's n values for streams and floodplains (adapted from Chow, 1959)

1. Main Channels	**Min**	**Normal**	**Max**
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in summer	0.040	0.060	0.080
3. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. same as above, but with heavy growth of sprouts	0.050	0.060	0.080
3. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
4. same as 4. with flood stage reaching branches	0.100	0.120	0.160

Table 6. Land Use-based EMCs as used in SWMM model.

		Event Mean Concentration [mg/L]		
Land Use		**TSS**	**TP**	**Nitrate-Nitrite**
Residential	Single family detached	127	0.35	0.42
	Row home	86	0.90	0.74
	Mobile home	86	0.26	0.38
	Multi-family	86	0.26	0.38
ndustrial/Commercial	Manufacturing	77	0.21	0.38
	Transportation	103	0.31	0.54
	Agricultural	54	0.99	0.61
	Commercial	71	0.18	0.39
	Recreational	153	0.51	0.56
Uniform cover	Wooded	39	0.15	0.17
	Vacant	48	0.19	0.31
	Water	0	0.00	0.00
	Parking	120	0.39	0.60
Other	Utility	55	0.16	0.37
	Community Services	71	0.18	0.39
	Military	71	0.18	0.39

Table 7. Surface runoff quality (mg/l) from various pervious and impervious land covers as published by PADEP (2005)

Land Cover		**ID**	**Total Suspended Solids, TSS**	**Total Phosphorus, TP**	**Nitrate-Nitrite**
Pervious Surfaces	Forest	P1	39	0.15	0.17
	Meadow	P2	47	0.19	0.3
	Fertilized planting area	P3	55	1.34	0.73
	Lawn, low-input	P4	180	0.4	0.44
	Lawn, high-input	P5	180	2.22	1.46
	Grassed athletic field	P7	200	1.07	1.01
Impervious surfaces	Rooftop	I1	21	0.13	0.32
	Medium traffic street	I2	113	0.33	0.58
	Low traffic, residential street	I3	86	0.36	0.47
	es. driveway, play courts, etc.	I4	60	0.46	0.47
	High traffic parking lot	I5	120	0.39	0.6
	Low traffic parking lot	I6	58	0.15	0.39

Table 8 Land use by cover type based on NRCS (1986)

LAND USE BY GROUND COVER TYPE

		Residential				Industrial/Commercial					Uniform Cover					
ID	Cover Type	Single Fam Det	Row home	Mobile Home	Multi-family	Manuf.	Transp.	Ag.	Comm.	Rec.	Wooded	Vac.	Prkg	Utility	Comm. Serv.	Mil.
P1	Forest										100%					
P2	Meadow						15%	20%		15%		90%		25%		
P3	lized planting area							70%								
P4	Lawn, low-input	60%		35%	35%	28%			15%	50%					15%	15%
P5	Lawn, high-input		35%													
P6	Grassed athletic field									25%						
I1	Rooftop	20%	50%	50%	50%	40%			15%						15%	15%
I2	Medium traffic street						85%									
I3	Low traffic, residential street	10%	15%	15%	15%											
I4	Res. driveway, play courts, etc.	10%														
I5	High traffic parking lot					32%							100%			
I6	Low traffic parking lot							10%	70%	10%		10%		75%	70%	70%

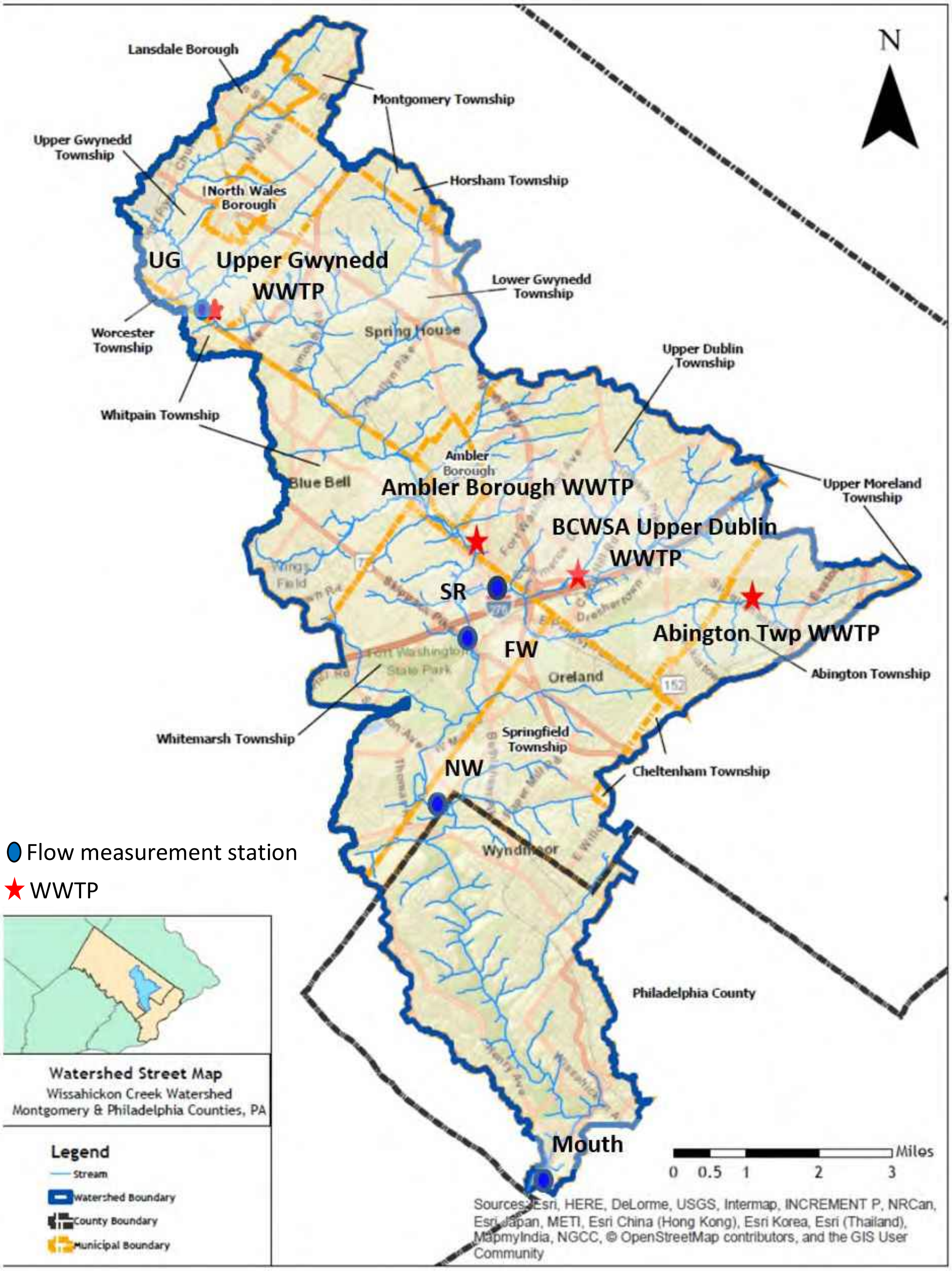


Figure 6. Location of municipal waste water treatment plants (red stars) and hydrologic calibration points (blue circles) in the Wissahickon Creek watershed.

III. Flow data for calibration

Model calibration is a process in which model parameters are adjusted until model output matches measured or observed flow rates. Once properly calibrated, the model can then be used for predictive purposes to estimate the impact of future land use, waste treatment and storm water management scenarios.

SWMM was hydrologically calibrated for the period of March 2017 through November 2017. This period was chosen because it is the most recent warm weather (non-snow) period available.

Five locations, as shown in Figure 6, were identified as calibration points. Two calibration points are co-located with USGS flow gages (FW, USGS#01473900 and Mouth, USGS#01474000). At each of the other three locations, stage-discharge relationships were developed based on continuous (15 min interval) depth measurements using Onset HOBO pressure transducers and periodic flow measurements taken using SONTEC River Surveyor or SONTEC ADV instruments. We also examined the regression relationship between each of these three stations and the USGS reported flow at FW.

Figure 7 shows the regression of flow at FW as measured by the USGS versus the measured flow at UG and the stage-discharge relationship at UG. The USGS regression analysis proved to be slightly stronger than the stage-discharge relationship here. Similarly, Figure 8 shows the regression of flow at FW as measured by the USGS versus the measured flow at NW and the stage discharge relationship at Northwestern Avenue (NW). In this case, the USGS regression is much stronger that the stage-discharge analysis.

At the Sandy Run tributary (SR), the stage – discharge relationship (shown in Figure 9) was stronger than the USGS regression at all flows except for shallow baseflow (depth < 0.2m, flow less than 1 m^3/s). Under low baseflow conditions, we found the stage discharge relationship overestimated flow from Sandy Run such that it was as large as or larger than the flow reported at FW by USGS. We then used USGS StreamStats (https://streamstats.usgs.gov/ss/) to estimate baseflow at FW and at SR. This web app uses equations developed by Stuckey (2006) which estimate baseflow as a function of drainage area, land use, geology, and precipitation. Since land use, geology and precipitation are similar for both SR and FW, baseflow differences are driven by differences in drainage area. The drainage area at SR is approximately 1/3 the drainage area at FW and so baseflow at SR (flows at depths measured less than 0.2 m) was estimated to be 1/3 the USGS reported flow at FW.

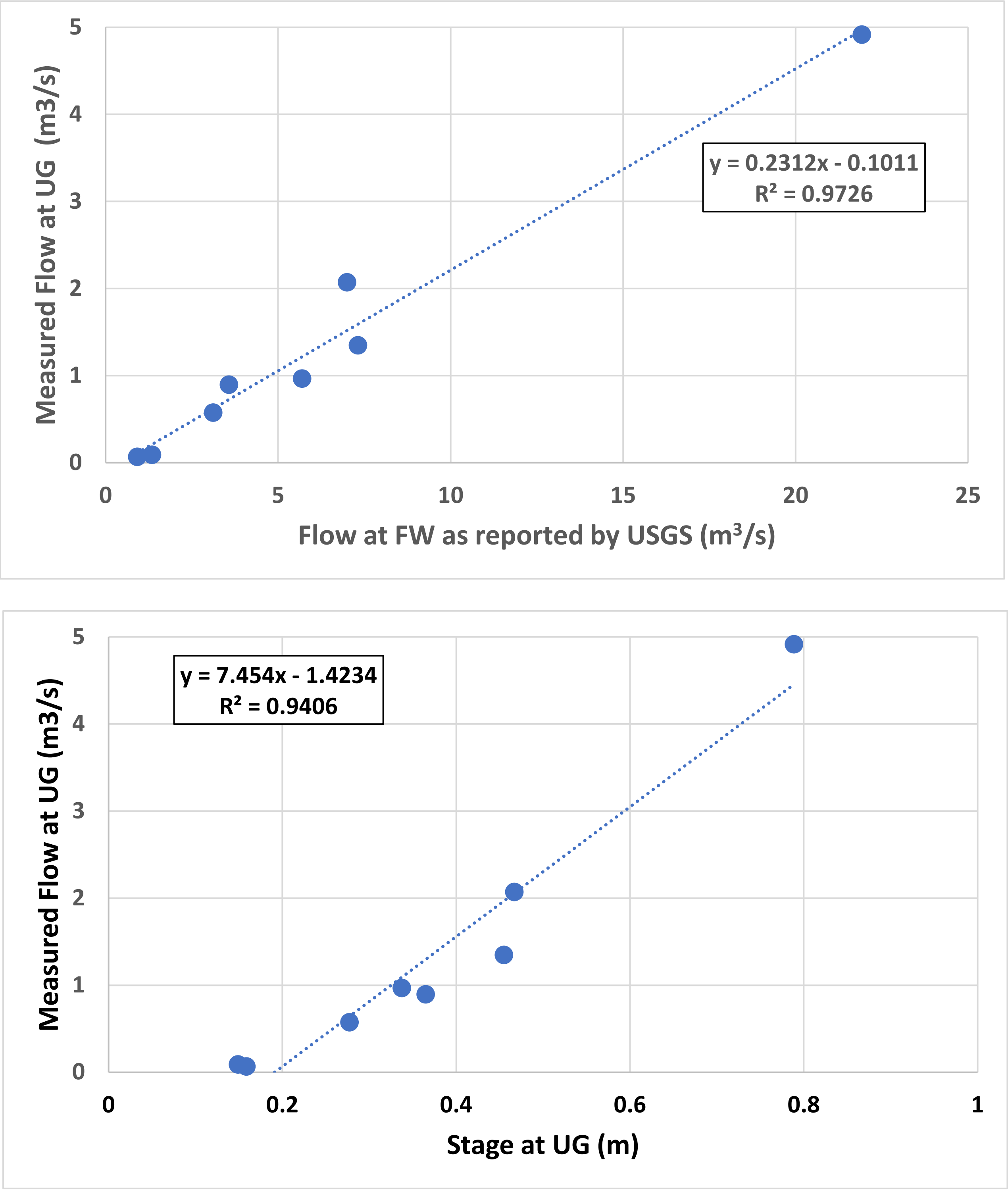
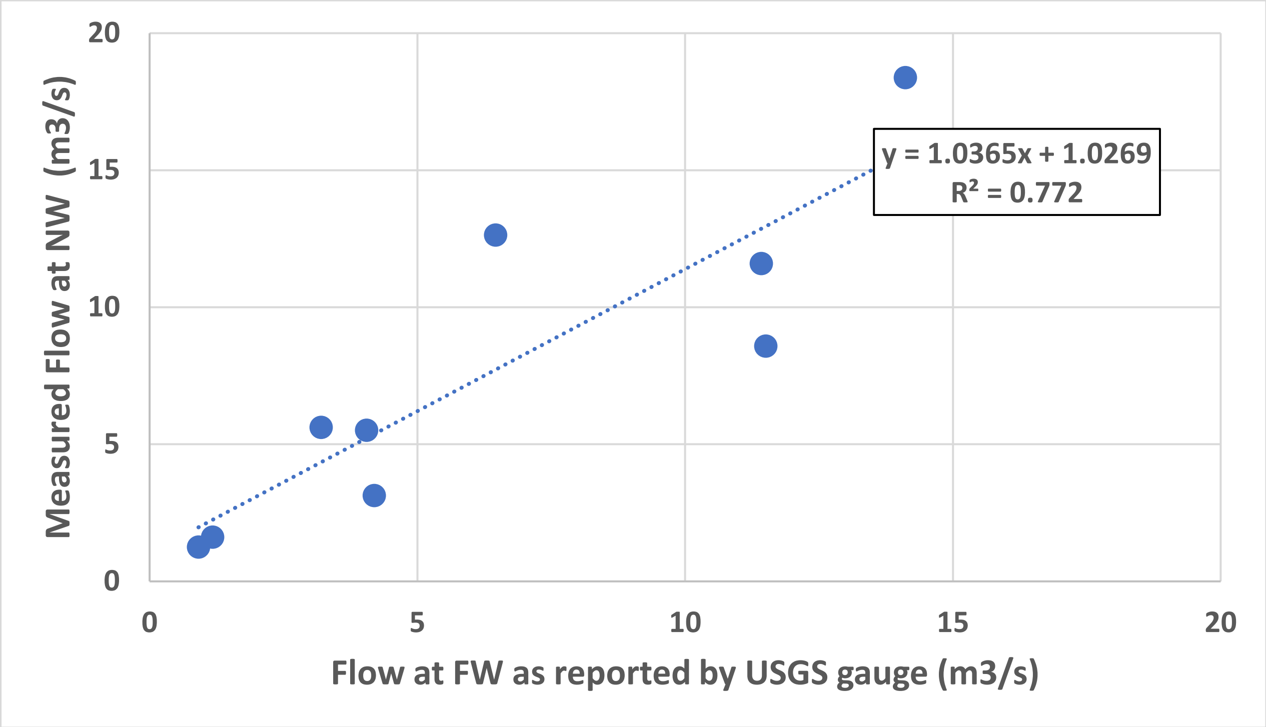


Figure 7. The regression of flow at FW as reported by USGS versus measured flow at UG (upper panel) was slightly stronger than the stage discharger relationship at UG (lower panel).



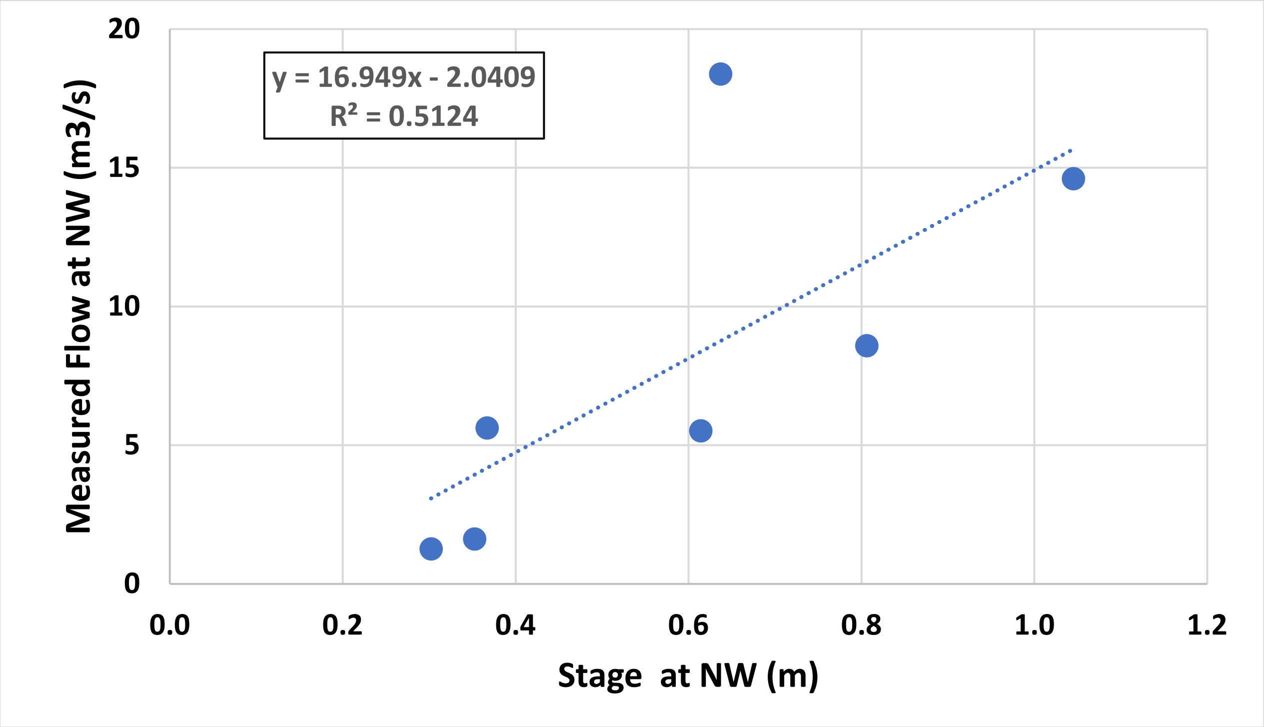


Figure 8. The regression of flow at FW as reported by USGS versus measured flow at NW (upper panel) was slightly stronger than the stage discharger relationship at NW (lower panel).

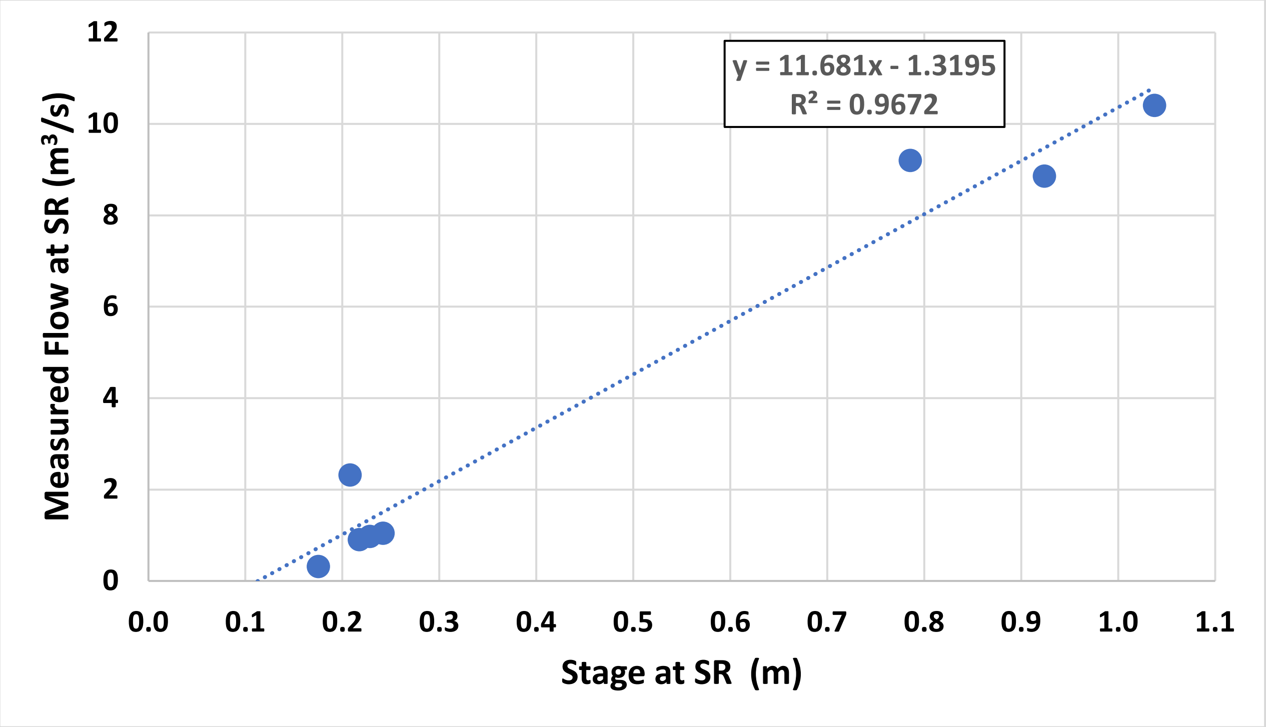


Figure 9. Stage-Discharge relationship at SR

IV. SWMM Calibration

The model reflects land use (Figure 2) and impervious cover (Figure 3) as of 2015 (DVRPC, 2017). Surface runoff quality was modeled using Event Mean Concentrations developed from values published by PA DEP (2005). Soils information (Figure 4) was obtained from USDA Soil Survey. Topographic data developed from LiDAR collected in 2008 and updated in 2015 was used to determine drainage areas for each basin and DVRPC (2017) data was used to determine land use with the basin drainage areas. Additional information regarding stormwater basins and wastewater treatment plants are discussed in the following sections.

1. Stormwater Basins

As of 2014, there were 227 stormwater detention basins in the Wissahickon Creek watershed with a total storage capacity of 387 ac-ft (CSC and NTM Engineers, 2014). Of these, 69 basins were explicitly modeled as part of this project (Figure 10). This includes all basins with a storage capacity of 2 ac-ft or more, plus 17 smaller basins with readily available location, storage and outlet information. Outlet structure dimensions were measured during field visits for 53 basins. An additional 16 basins were modeled based on design information contained in plan sheets and engineer's reports obtained from the municipality or basin owner. The remainder of the basins were implicitly modeled through the calibration process by adjusting the subcatchment curve number, surface roughness, routing and impervious cover. The modeled basins have a combined storage capacity of 240 ac-ft or 62% of the total basin storage capacity reported in the Wissahickon Creek Watershed Act 167 Plan (CSC and NTM Engineers, 2014) and these basins capture runoff from approximately 4.3% of the watershed.

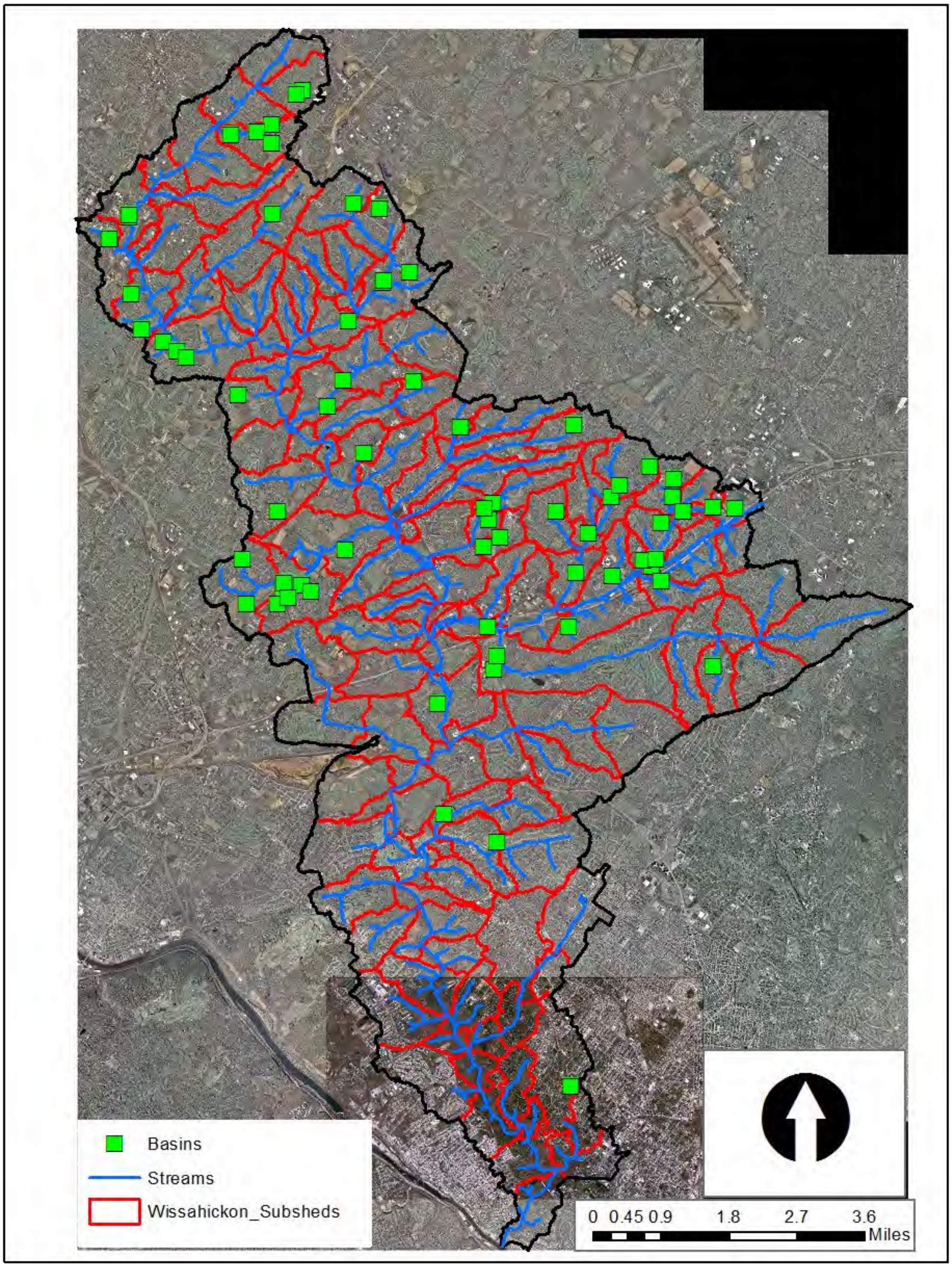


Figure 10. Stormwater detention basins (green squares) explicitly modeled in SWMM. These include all basins greater than 2 ac-ft plus 17 smaller basins with readily available outlet structure dimensions.

2. WWTPs

There are four municipal wastewater treatment plants (WWTP) in the Wissahickon watershed (Figure 6). These were modeled using average monthly flows and average monthly effluent pollutant concentrations as reported in Discharge Monitoring Reports (DMRs) submitted to PA DEP. Average values for these parameters are provided in Table 9. Note that two WWTPs (Abington and Upper Dublin) report effluent Total Phosphorus (TP) and two (Ambler and Upper Gwynedd) report effluent Ortho-Phosphorus (OP). An analysis of in-stream phosphorus measurements shows that the majority of TP is in the form of OP. In addition, Abington Township reports both TP and OP which shows that TP is approximately 85% OP. Based on this, the OP values were input to the model as TP.

Table 9. Average values of flow and pollutant concentration for the wastewater treatment plants. Note that actual values used in the model were the monthly values reported in DMRs

Facility	Average Flow, MGD	Average Effluent TSS, mg/L	Average Effluent TP, mg/L
Abington Township	2.74	2.73	1.39
Ambler Borough	3.67	8.20	0.48
Bucks County Water and Sewer Authority	0.67	8.08	1.36
Upper Gwynedd Township	2.38	2.72	0.39

3. Calibration Results

As discussed above, the SWMM model was calibrated at five locations (Figure 6). Two calibration points were co-located with USGS flow gages (at Ft. Washington, USGS#01473900, and at the Mouth, USGS#01474000). At each of the other three locations, stage-discharge relationships were developed based on continuous (15 min interval) depth measurements using Onset HOBO pressure transducers and periodic flow measurements taken using SONTEC River Surveyor or SONTEC ADV instruments. We also examined the regression relationship between each of these three stations and the USGS reported flow at Ft Washington. The hydrologic calibration period of the PCSWMM model was March 2017 through November 2017. This period was chosen based on availability of flow data at the three stations with HOBO pressure transducers.

Calibration was considered successful when multiple criteria were met. The primary criterion was the Nash Sutcliffe Efficiency (NSE) which is shown in Equation 9. The NSE can range from -∞ to +1. A value of 0 or less indicates the model is no better at predicting measured values than a straight line through the mean of the data would be. A NSE value of 0.5 or greater is generally considered acceptable (Rosa, et al., 2015; Dongquan et al., 2009; Moriasi et al., 2007).

$$NSE = 1 - \frac{\sum_{t=1}^{T}\left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T}\left(Q_o^t - \overline{Q_o}\right)^2} \qquad (9)$$

where Q_o^t is observed flow, Q_m^t is modeled flow and $\overline{Q_o}$ is the mean observed flow value.

Additional calibration criteria included the Integral Square Error (ISE) and Coefficient of Determination (R^2). The ISE is a function of the sum of the model error (the difference between the observed data and the modeled data) and the observed data, as shown in Equation 10. A model that perfectly matches the observed data would have an ISE of 0. As reported by Shamsi and Koran (2017) and the sources cited therein, an ISE less than 10 is considered good and an ISE less than 3 is considered excellent.

$$ISE = \frac{\left(\sum_{t=1}^{T}\left(Q_o^t - Q_m^t\right)^2\right)^{1/2}}{\sum_{t=1}^{T} Q_o^t} \qquad (10)$$

The Coefficient of Determination (R^2) is calculated as shown in Equation 11. While this is typically not considered a strong calibration parameter, it is nonetheless often reported for hydrologic models and is included here for completeness. R^2 represents the degree to which the variability of the observed data can be explained by the model. A model that perfectly fits the observed data would have an R^2 of 1. That is, 100% of the observed variability would be explained by the model and a plot of the model versus the observed data would be a straight line. R^2 less than 1 indicate the model explains only part of the variability of the observed data.

$$R^2 = \frac{\sum_{t=1}^{T} Q_o^t Q_m^t - \frac{\sum_{t=1}^{T} Q_o^t * \sum_{t=1}^{T} Q_m^t}{T}}{\sqrt{\left(\sum_{t=1}^{T}\left(Q_o^t\right)^2 - \frac{\left(\sum_{t=1}^{T} Q_o^t\right)^2}{T}\right)\left(\sum_{t=1}^{T}\left(Q_m^t\right)^2 - \frac{\left(\sum_{t=1}^{T} Q_m^t\right)^2}{T}\right)}} \qquad (11)$$

PCSWMM calibration results for each calibration location are reported in Table 10 and indicate a well calibrated model. Visual representations of the calibration at each calibration point are shown in Figures 11-15.

Table 10. Summary of flow calibration statistics

Calibration Location	Nash Sutcliffe Efficiency	Integral Square Error	R^2
Upper Gwynedd	0.63	1.19	0.67
Sandy Run	0.72	0.69	0.75
Fort Washington (USGS)	0.62	0.88	0.64
Northwest Avenue	0.56	0.95	0.59
Mouth (USGS)	0.68	0.71	0.69

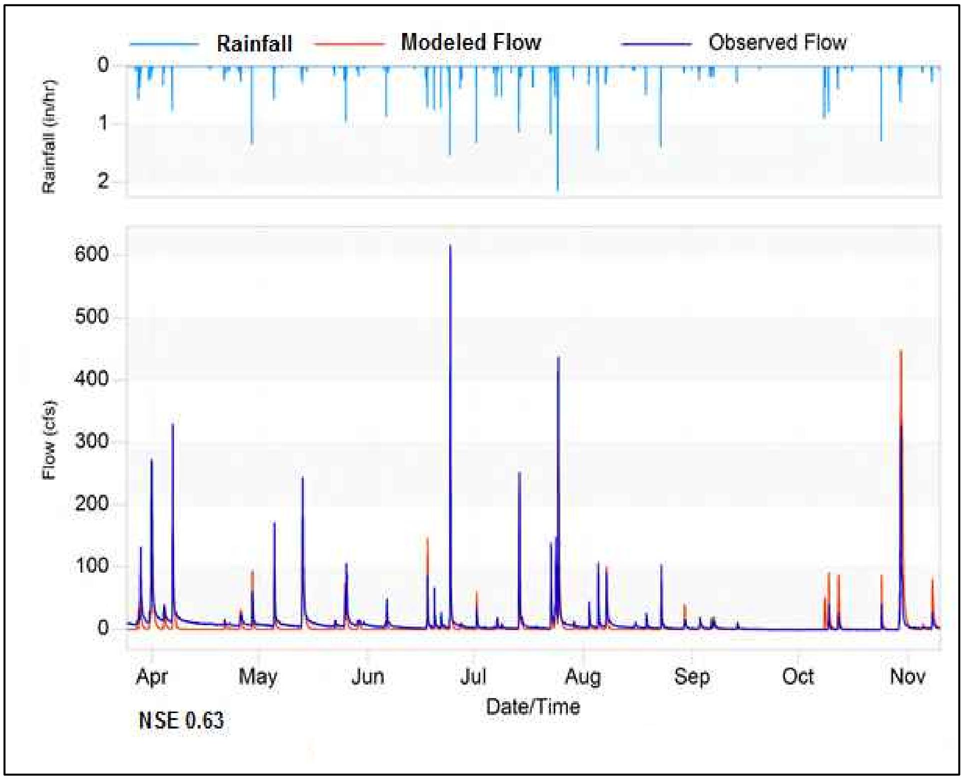


Figure 11. PCSWMM calibration plots at Upper Gwynedd

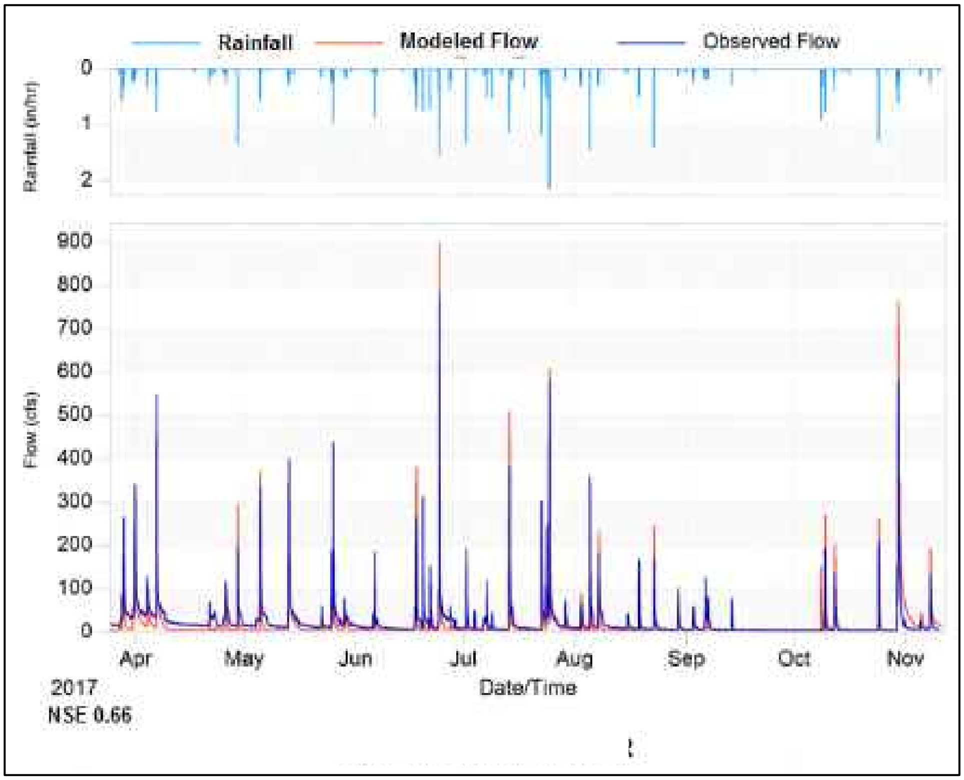


Figure 12. PCSWMM calibration plots at Sandy Run

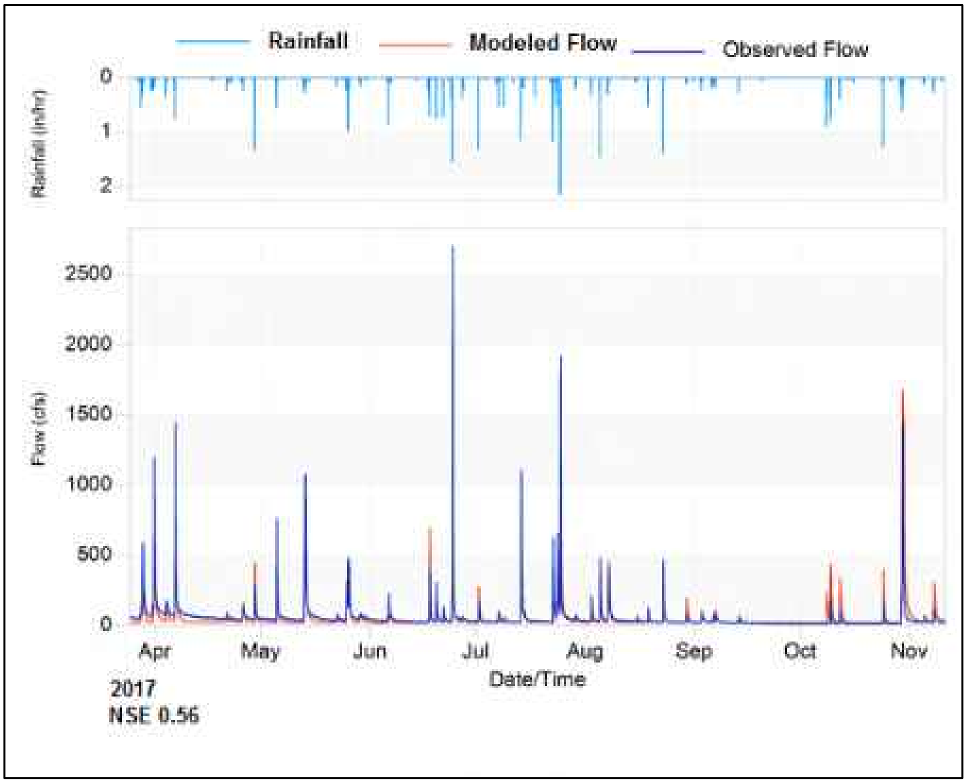


Figure 13. PCSWMM calibration plots at Fort Washington

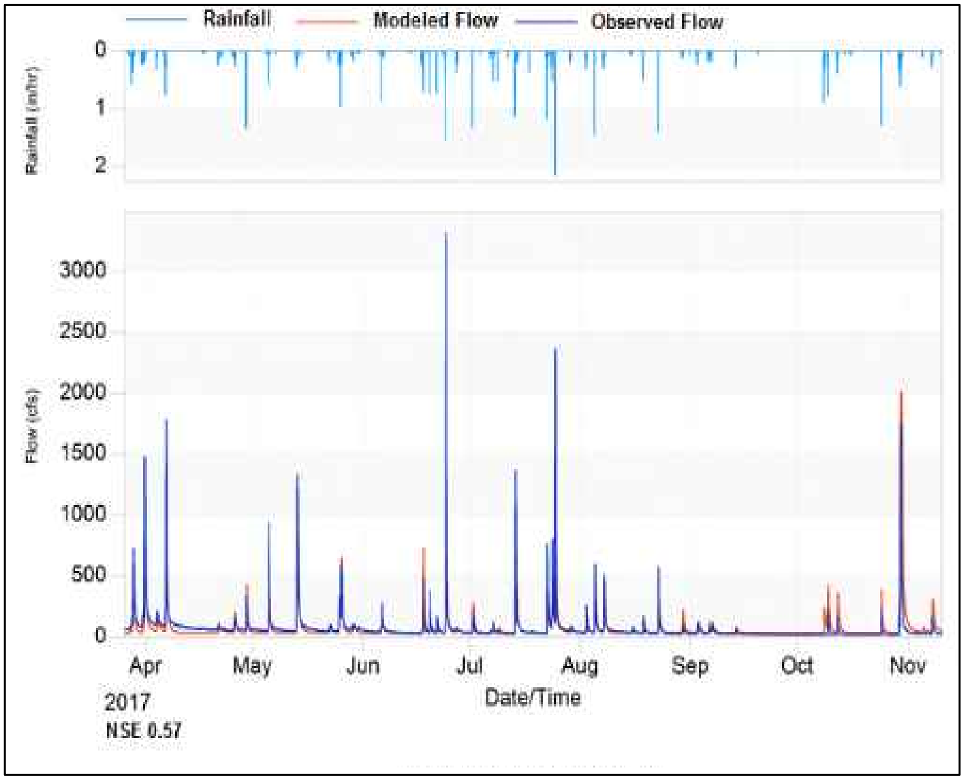


Figure 14. PCSWMM calibration plots at Northwest Avenue

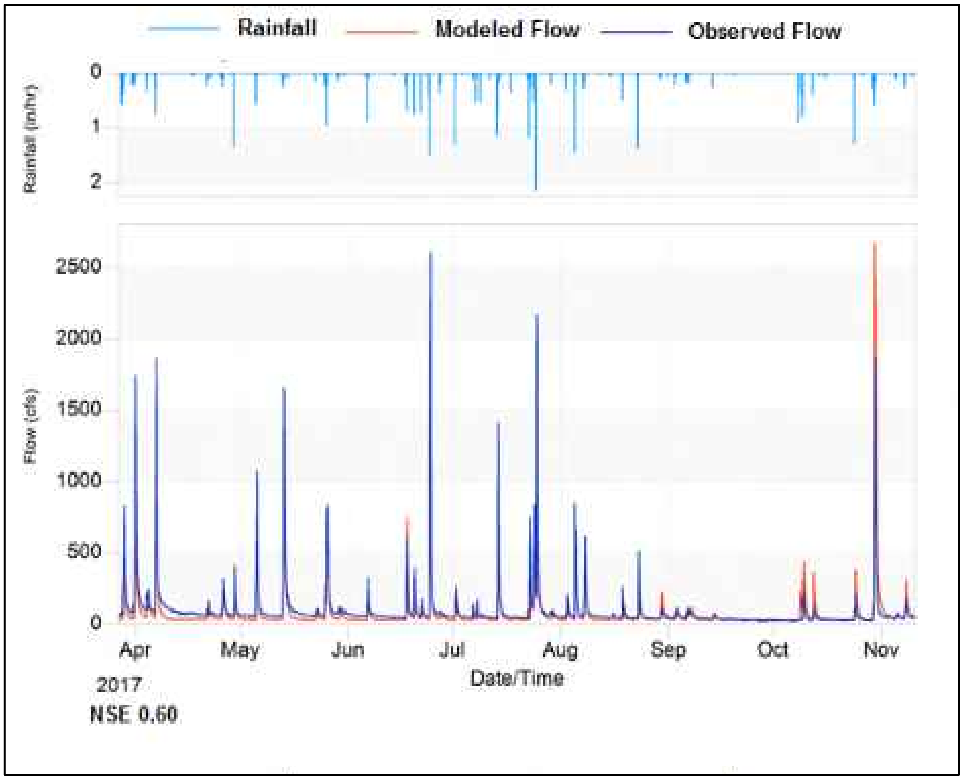


Figure 15. PCSWMM calibration plots at the USGS station located at the mouth of Wissahickon Creek

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Appendix 4

Link to Wissahickon Creek Act 167 Stormwater Management Plan

Wissahickon Creek Watershed Act 167 Stormwater Management Plan
https://www.montcopa.org/2264/Wissahickon-Creek-Watershed-Act-167-Plan

Appendix 5

July 2019 WQIP Update Letter from Marc Gold to EPA on behalf of the Management Committee and Letters of Support from WVWA, PEC, and Montgomery County Planning Commission

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A LIMITED LIABILITY PARTNERSHIP
FORMED IN PENNSYLVANIA

Partner responsible:
John F. Gullace (NJ)
Brenda H. Gotanda (HI)

July 18, 2019

Jenifer Fields
Chief of Staff
USEPA Region 3
1650 Arch Street
Mail Code: 3RA00
Philadelphia, PA 19103-2029

Re: Wissahickon Creek TMDL Alternative

Dear Ms. Fields:

On behalf of the Management Committee for the Wissahickon Clean Water Partnership[1] (the “Partnership”), we wanted to thank you, Cosmo, Cathy, and Chris for meeting with us last month to discuss the multi-stakeholder effort to develop a TMDL alternative for the Wissahickon Creek. We appreciated the opportunity to tell you about the exciting work that has been done to date to prepare the Water Quality Improvement Plan (“WQIP” or “Plan”), which will serve as the foundational document for implementing the TMDL alternative for the Wissahickon Creek.

Background

As you know, the Partnership was formed in 2016 to collaborate with the Pennsylvania Environmental Council (“PEC”), the Wissahickon Valley Watershed Association (“WVWA”), the Montgomery County Planning Commission (“MCPC”), the University of Maryland Environmental Finance Center, and Temple University to evaluate stream conditions in the Wissahickon Creek and to develop strategies for improving water quality in the watershed as an alternative to the May 2015 Draft Total Phosphorus TMDL for the Wissahickon Creek Watershed (“Draft TMDL”) prepared by United States Environmental Protection Agency (“EPA” or the “Agency”).

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[1] The Partnership consists of 13 municipalities representing roughly 99% of the land area within the Wissahickon Creek Watershed, and four wastewater treatment plant operators including the Abington Wastewater Treatment Plant, the Ambler Borough Wastewater Treatment Plant, the Upper Gwynedd Wastewater Treatment Plant, and the Upper Dublin Wastewater Treatment Plant operated by Bucks County Water and Sewer Authority (collectively, the “WWTPs”).

Through the diligent efforts of this diverse collective – including all the principal municipalities within the Wissahickon Creek watershed, two preeminent local environmental organizations, two leading academic institutions, and Montgomery County – the Partnership is nearly finished with an initial draft of the WQIP that is designed to achieve improved water quality in this heavily urbanized watershed using an adaptive management approach endorsed by EPA. We are very enthusiastic about this process and hope that the Agency will agree that the adaptive management strategies that will be included in the WQIP are the most effective means of restoring water quality in the Wissahickon Creek.

During our meeting, we briefly discussed the elements of the WQIP and the strategies that have been identified for improving water quality in the Wissahickon Creek. We agreed to submit a draft WQIP, determined by the Partnership's Management Committee to be sufficiently complete for EPA review, by the end of September and to meet again sometime in October. Once we receive input from EPA, the Management Committee will finalize the WQIP and will continue the process to obtain approval of the WQIP, which we would hope can be achieved by the end of the year.

We understand your interest in having an opportunity to review elements of the WQIP in advance of the submission of the draft WQIP. Accordingly, I have been authorized by the Management Committee to provide you with (1) a report prepared by Kleinfelder, the Management Committee's technical consultant, setting forth the Partnership's conclusions regarding the causes of water quality impairment in the creek and conceptual recommendations for measures for improvement; (2) a report describing the comprehensive hydrologic stream model developed by Temple University that will be utilized as a tool to prioritize projects through an adaptive management approach over the course of WQIP implementation; and (3) a table from the draft WQIP summarizing the number and type of new projects by municipality that have been identified to improve water quality in the watershed and that would be pursued after the TMDL alternative is approved by EPA.

As you review this information, it is important to recognize that the Plan is rooted in EPA policies, procedures and guidance, as described below. It also reflects the unique features of the watershed: it is home to 222,000 people; it is heavily urbanized (roughly 75% of the watershed area was developed before the advent of storm water management controls); and it is home to both urban and suburban communities (more than 50% of the watershed area is developed with single-family or multi-family homes as of 2005, with an additional 7% expected by 2040). The highly urbanized nature of the watershed spans from the mainstem headwaters at the Montgomery Mall to its endpoint in the City of Philadelphia. These unalterable realities contribute significantly to stream conditions and must be accounted for when selecting effective strategies for improving water quality in the Wissahickon Creek.

Relevant Regulatory Framework

After publication of EPA's Draft TMDL in 2015, many commenters questioned the linkage between total phosphorus concentrations and the aquatic life impairment, and the attainability of the numeric loads assigned to point and nonpoint source dischargers. Among the commenters was the Pennsylvania Department of Environmental Protection ("PADEP" or the "Department"), who urged EPA to take a more holistic approach in the Wissahickon Creek to arrive at a different TMDL endpoint.[2] Shortly thereafter, in early 2016, PADEP updated its Clean Water Act ("CWA") Section 303(d) list to include the Wissahickon Creek in Category 5a, indicating that water quality improvements would best be achieved through a TMDL alternative.[3] At that time, PADEP stated that it was working "in cooperation with EPA" to identify stakeholders interested in developing a TMDL alternative.[4] Since the 2016 Category 5a designation, the Partnership and its collaborators have worked diligently to develop an alternative strategy for improving water quality in the Wissahickon Creek consistent with applicable requirements recognizing the unique features of the watershed. PADEP again listed the Wissahickon Creek as one of four streams in Category 5a when it published its Draft 2018 303(d) List.[5]

Consistent with the classification of the Wissahickon Creek as a stream well-suited for a TMDL alternative, work continued to assess water quality and related conditions of the creek. As a result of that effort, the WQIP is being developed pursuant to EPA's TMDL alternative guidance, as embodied in the Agency's Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program ("Vision Framework").[6] The Vision Framework recognizes the importance of using the "most effective tools(s)" tailored to site-specific conditions of a given watershed that may not comport with traditional TMDL approaches.[7] Indeed, the Vision Framework indicates that through an understanding of the comprehensive challenges facing a given water body, a TMDL alternative should prioritize adaptive management as a means of stream restoration so those implementing the alternative can "iteratively adjust and integrate subsequent implementation actions to meet water quality

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[2] *See* PADEP, Comment Letter to Lenka Berlin Re: Proposed Total Phosphorus TMDL for the Wissahickon Creek Watershed (July 27, 2015).

[3] *See* PADEP, 2016 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report, Clean Water Act Section 305(b) Report and 303(d) List.

[4] *Id.* at 24.

[5] *See* Draft 2018 Pennsylvania Integrated Water Quality Monitoring and Assessment Report, Clean Water Act Section 303(d) List and 305(b) Report.

[6] EPA, A Long-Term Vision for Assessment, Restoration, and Protection Under the Clean Water Act Section 303(d) Program (December 2013).

[7] Vision Framework at 9.

standards."[8] The approach has the added benefit of helping to avoid unnecessary litigation while leading to real progress in addressing water quality.[9]

Wissahickon Creek WQIP Development Approach

With EPA's Vision Framework in mind, a technical team lead by Temple University designed a comprehensive sampling plan intended to holistically assess the cause of impairment in the stream. Temple's effort has resulted in a more complete dataset that significantly expands upon the data EPA had in hand when the Draft TMDL was prepared. This collective body of data reveals that total phosphorus is not the primary cause of aquatic life impairment at this time. Instead, the data shows that storm water flows (both rate and volume) in this highly urbanized watershed are the primary driver of macroinvertebrate disruption, and efforts to reduce total phosphorus will produce no measurable impact on water quality until storm water improvements are realized.[10] Notwithstanding this conclusion, the WWTPs already have committed to optimizing their operations, and recognize that reducing effluent concentrations of total phosphorus may be appropriate in the future as stream quality improves. This is consistent with the adaptive management framework embodied in the WQIP that recognizes a continuum of actions to be taken over time. As the WQIP will describe, during the early stages of implementation, the WWTPs in the watershed have committed to funding the cost of aspects of the proposed water quality monitoring and to fund the installation of an additional USGS monitoring station at Sandy Run, which will be the first such station to measure the Wissahickon Creek's largest tributary. For a detailed discussion of the Partnership's impairment findings, please refer to the Kleinfelder Report in Appendix 1.

Based on these findings and building on EPA's watershed planning framework[11], the WQIP will prioritize storm water management projects throughout the watershed and will include a variety of metrics for measuring progress. As reflected in Appendix 3, the WQIP will include a significant number of proposed projects throughout the watershed that over time would mitigate storm water impacts to the creek. Although not intended to be an exhaustive list, this tentative list of projects fairly represents opportunities that have been identified by the Management Committee and its collaborators to address the leading cause of impairment and it is expected that other such opportunities will be identified over time. Consistent with the WQIP's adaptive management framework, the hydrologic model developed by Temple University, described in detail in Appendix 2, will serve as a tool for iterative decision-making

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[8] *Id.* at 7-9.

[9] *Id.*

[10] Additionally, the data indicates that increasing canopy cover within the watershed will have water quality benefits and the WQIP will recommend implementation of policies and programs to increase canopy cover.

[11] *See* EPA, Handbook for Developing Watershed Plans to Restore and Protect our Waters (2008) (setting forth nine elements of a watershed-based improvement plan).

with respect to the prioritization of additional storm water management projects as the WQIP is implemented over time.

The WQIP also will include a series of tracking metrics and a comprehensive stream monitoring program along the following lines: (1) area treated/acres managed for storm water impacts; (2) linear feet of stream restored; (3) number of projects implemented; and (4) area of open space protected. Comprehensive water quality monitoring will be conducted periodically to confirm that the measures being implemented are leading to water quality improvements, and to develop priorities for future actions. Additionally, the WQIP will include reporting requirements to inform EPA, PADEP, and the public at large about the status of the projects and the progress that is being achieved. To ensure that these reports are useful to the agencies and the public, and as we indicated when we met, we are open to your ideas about the form, frequency, and detail of these status reports.

To round out the groundwork that the Partnership has been pursuing, PEC and WVWA hosted a meeting of environmental stakeholders on June 28 that Mark Grey, Co-Chair of the Management Committee, also attended. The meeting lasted several hours and included a presentation by Temple University on the relevant findings and a discussion of the Partnership's conclusion that the primary causes of impairment are related to storm water flow rates and volume. There was a consensus by those in attendance that the analysis presented is supported by the data and the commitments that will be included in the WQIP are appropriate given the current circumstances.

The Partnership appreciates your continued interest in these issues and we look forward to your feedback on the information we have provided with this letter. Thank you.

Sincerely,

Marc Gold

Marc E. Gold
For MANKO, GOLD, KATCHER & FOX, LLP

MEG/bad/12548-001
Enclosures
cc: Drew Shaw, Montgomery County Planning Commission
Patrick Starr, Pennsylvania Environmental Council
Gail Farmer, Wissahickon Valley Watershed Association

WISSAHICKON valley WATERSHED ASSOCIATION

August 9, 2019

Jenifer Fields
Chief of Staff
U.S Environmental Protection Agency, Region 3
1650 Arch Street
Philadelphia, PA 19103-2029

Re: Wissahickon Creek TMDL Alternative

Dear Ms. Fields:

We received and reviewed the information submitted to you by Marc Gold on behalf of the Wissahickon Clean Water Partnership (Partnership) and would like to provide our perspectives.

The Wissahickon Valley Watershed Association (Watershed Association) serves as part of the leadership team that has been collaborating with the Partnership in developing a plan to improve water quality in the Wissahickon Creek watershed. Our senior staff and Board of Directors have been engaged in this effort since 2015 and we have played an instrumental role in defining the strategy for the Water Quality Improvement Plan (WQIP) with the other members of the Water Quality Advisory Team and the Partnership's Management Committee. Our contribution to the process is informed by the Watershed Association's half-century of work in the watershed and our understanding of the urbanized realities of the area. We recognize that there is no single cure for the impairments to the quality of the stream and that a more integrated approach that addresses multiple aspects including sediment, high water volume, and habitat degradation, offers the best chance to see measurable improvements in stream health.

We have assessed the information recently submitted to EPA and concur with the analysis presented in the Kleinfelder Report and the modeling analysis prepared by Temple University. The Watershed Association fully supports an adaptive management approach that will be included in the WQIP and we have participated in the process to define targeted outcome metrics, including identifying the GSI and basin retrofit projects that are above and beyond each municipality's current MS4 commitments.

The Watershed Association, in partnership with the Pennsylvania Environmental Council, recently held an informational meeting for other environmental stakeholders, including PennFuture, Penn Environment, PA League of Conservation Voters, American Rivers, Coalition for the Delaware River Watershed, and the Center for Watershed Protection. We outlined the strategy for the WQIP and how it has been informed by the work performed by Temple University and others as part of this process. The response to our presentation was very positive. Strengths that environmental stakeholders identified included the watershed-wide and collaborative approach, the multiple layers of accountability (including environmental partners in the collaborative in addition to the regulatory accountability), and the compelling science that provides the underpinnings of the strategy. We also received helpful feedback and suggestions for how we might further strengthen the WQIP.

We look forward to continuing our engagement with EPA and PA DEP on this process and the WQIP. We are optimistic that this effort will result in a plan that will launch the process of building a watershed-wide and community-based approach to improving stream health in a highly developed suburban watershed. Thank you.

Sincerely,

Gail Farmer
Executive Director

John Tierney
Board Chair

cc: MankoGold, Katcher, Fox
Paul Leonard, Management committee co-chair
Mark Grey, Management committee co-chair

pec

pennsylvania environmental council

August 8, 2019

Jenifer Fields
Chief of Staff
USEPA Region 3
1650 Arch Street
Philadelphia, PA 19103-2029

RE: Wissahickon Creek TMDL Alternative

Dear Ms. Fields: Jen

I write to thank you for your interest in the Wissahickon Creek TMDL Alternative, and most particularly for the guidance you've provided since the inception of this complex undertaking.

The Pennsylvania Environmental Council (PEC) has been actively engaged in a multi-faceted effort to determine the cause of the water quality impairment in the Wissahickon and to formulate an implementation strategy that will be effective in improving water quality. Specifically, I've coordinated a team of subject experts (the Water Quality Advisory Team (WQAT)) including the Department of Earth and Environmental Science, Temple University, and the Environmental Finance Center, University of Maryland, as well as, critical stakeholders including the Montgomery County Planning Commission and the Wissahickon Valley Watershed Association.

For the past three years, the WQAT communicated and coordinated with the Management Committee (MC) of the Wissahickon Clean Water Partnership (WCWP) comprised of representatives of 13 municipalities that represent more than 99% of the land area of the watershed and the four wastewater treatment plant operators. We've interacted regularly with the MC's consultants including Kleinfelder and the Manko Gold team. This has been a meaningful and essential dialogue to interpret the data, formulate solutions, and develop an implementation strategy that is both feasible and workable for the Wissahickon Watershed community. Together we've prepared a *draft* Water Quality Improvement Plan (WQIP) that summarizes our findings and recommendations that is still being revised.

I've received and reviewed the information submitted on July 18 by Marc Gold on behalf of the MC. As a team, we had reviewed and contributed to the Kleinfelder assessment, and the WQAT supports the conclusion that *phosphorous reduction is not a useful "control knob."* Additionally, the Kleinfelder assessment identifies interventions that are critically important such as stormwater management, riparian improvements, and instream restoration that the WQAT and PEC fully support. It was gratifying to me and our team that the MC's independent consultant assessed the watershed and arrived at recommendations that validated our own conclusions. *(continued)*

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In closing, the WQAT sees no single cure for the water quality impairments to the Wissahickon. We fully embrace an integrated approach that addresses the multiple challenges facing the Creek including sediment, high storm flow volumes, low base flow, high temperatures, and habitat degradation. Additionally, the WQAT supports an adaptive management approach that is performance-based against agreed upon outcome metrics and goals.

Knowing of your extensive knowledge of environmental stakeholders, I wanted you to know that the WQAT shared our findings and draft recommendations with an array of interest groups including American Rivers, the Center for Watershed Protection, Coalition for the Delaware River Watershed, the Conservation Voters of PA, PennFuture, Penn Environment, and separately the Delaware Riverkeeper Network. While there were good questions and concerns raised, the response was positive, and an eagerness was expressed by all to see this process through to completion to the benefit of the watershed. I'd say all recognized the complexities facing such an urbanized watershed, and they applauded the collaborative and holistic approach we outlined. They valued the extensive monitoring and objective science-based conclusions.

On behalf of the WQAT and the PEC, I applaud the Management Committee for its commitment, and thank EPA and DEP for the opportunity we've been given to find a <u>real</u> solution to the water quality impairments on the Wissahickon Creek.

Sincerely,

Patrick M. Starr
Executive Vice President

MONTGOMERY COUNTY
BOARD OF COMMISSIONERS
VALERIE A. ARKOOSH, MD, MPH, CHAIR
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JODY L. HOLTON, AICP
EXECUTIVE DIRECTOR

August 2, 2019

Cosmo Servidio, Regional Director
USEPA REGION 3
1650 Arch Street
Mail Code: 3RA00
Philadelphia, PA 19103-2029

Re: TMDL Alternative process and the Wissahickon Water Quality Improvement Plan (WQIP)

Dear Mr. Servidio:

Montgomery County once again indicates its support of the TMDL Alternative process, and the Wissahickon Water Quality Improvement Plan (WQIP) that has been prepared over the past 2+ years. A draft of the WQIP has been submitted to the Management Committee for their review and comment. The draft plan outlines an adaptive management water quality improvement strategy that is based on a robust data collection and analysis effort. While the Management Committee reviews the draft, several items have been provided to EPA in preparation for EPA's preliminary review:

- A memo from Kleinfelder, which recommends a strategy of stormwater management, riparian improvements, instream restoration, and WWTP upgrades to reduce othophosphorus.
- A modeling report from Temple University, fully documenting the predictive model developed for the Wissahickon Creek.
- The summary chart of Wissahickon Creek Watershed non-PRP/TMDL Projects, which indicates the type and number of projects being included in the WQIP. These are over and above the municipal projects included in the municipal MS4 programs and pollution reduction plans.

Montgomery County Planning Commission has been actively participating in the development of the WQIP since the municipalities decided to pursue the TMDL Alternative option provided by EPA. In particular, we have organized and run the Management Committee meetings, and have participated as a member of the Water Quality Advisory Committee which acts as consultant to the Management Committee, since its formation. We are confident that the implementation of the soon to be completed WQIP will benefit water quality and overall ecology in the watershed. We are also appreciative of the EPA for providing the option to complete such a plan under its Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program.

While a more complete picture of the extensive effort that produced the WQIP will become apparent when the plan is submitted this fall, the items recently provided should provide a foundation for understanding the direction that the WQIP has taken. The focus on stormwater management, riparian improvements, instream restoration, and WWTP upgrades when appropriate is based on the data collected, the analysis of the model

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results, and input from the Water Quality Partnership and others. We believe that the adaptive management strategies included in the WQIP are the most effective means of restoring water quality in the Wissahickon Creek.

Sincerely,

Jody Holt

Jody Holton, AICP
Executive Director
Montgomery County Planning Commission

C: Jenifer Fields, USEPA Region 3
Marc E. Gold, Esquire; Manko, Gold, Katcher & Fox, LLP

Appendix 6

Temple University Study for the WQIP

Temple University Study for the WQIP

For development of the Water Quality Improvement Plan (WQIP), an intensive study was conducted by Temple University under two grants from the William Penn Foundation. The Wissahickon Creek has a robust dataset for evaluating stream health. This includes historical monitoring by the USGS and PADEP and routine monitoring by PWD and WVWA. The Temple Study evaluated historic monitoring data in addition to the data generated pursuant to Temple's data collection efforts for the WQIP.

I. Historic Monitoring

USGS flow data go back to the 1960s. PADEP has collected water quality samples 4-6 times a year at the two USGS gauge locations since 1998. PWD has operated two continuous monitoring stations in cooperation with the USGS since 2009: one station at Ft. Washington near the midpoint of the watershed and one at Ridge Avenue in Philadelphia, near the confluence with the Schuylkill (Figure 1). These stations provide a record of discharge, gauge height, temperature, specific conductivity, dissolved oxygen, pH, and turbidity for three seasons of the year. The discharge data are recorded in 15-minute intervals and the water quality parameters are recorded in 30-minute intervals. In the winter, only discharge and stage are measured. PWD also collects monthly or twice-monthly samples at these two locations, with data going back to 2009.

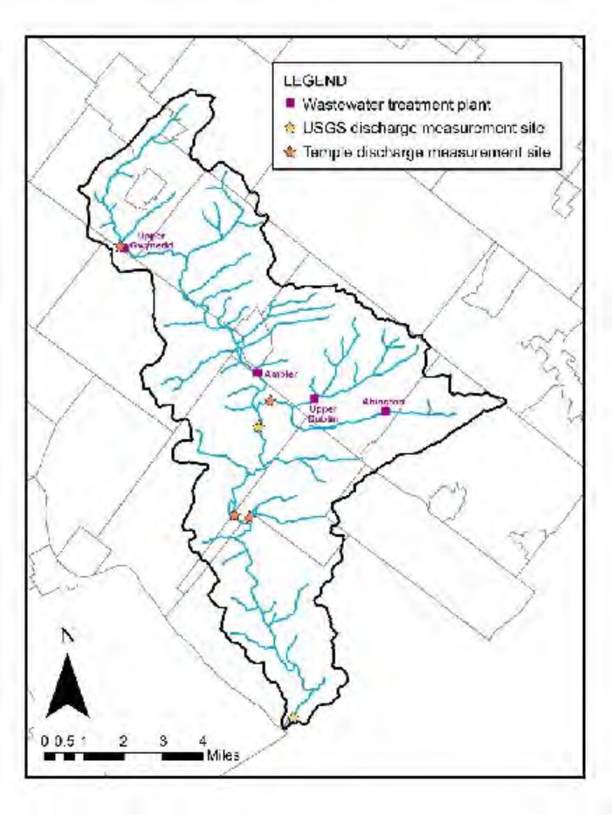

Figure 1 – Monitoring Locations

The WVWA has collected quarterly water quality data at 6-9 mainstem locations since 2003. WVWA has also sampled various sites on 3-4 tributaries, including Sandy Run. In 2005, PWD monitored 8 mainstem and 8 tributary locations for water quality, with one wet weather sample and dry weather sample collected each quarter[1].

The 2005 PWD study included one of the most extensive habitat assessments on the Wissahickon[1]. At 30 sites, parameters such as vegetative cover, riparian width, flow regime (pool, riffle, run), bank stability, and sediment were evaluated. Additionally, WVWA has conducted habitat assessments at their water quality monitoring locations since 2011.

Bioassessments have been conducted by PADEP, PWD, and WVWA. PADEP collected benthic macroinvertebrate data during the fall near the mouth of the Wissahickon since 1991 and at the Fort Washington gauge starting in 2002. In spring 2001, PWD sampled 15 locations in Philadelphia. In spring 2005, PWD conducted a watershed-wide sampling program, including macroinvertebrates at the same 30 sites as their 2005 habitat assessment, of which 13 were on the mainstem. WVWA has conducted annual macroinvertebrate

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[1] PWD (2007). Wissahickon Creek Watershed Comprehensive Characterization Report. January 2007.

surveys at 15 sites, 8 mainstem and 1-3 tributaries (dependent on funding), using Surber samplers since 2011. The number of annual sites has varied from 8 to 13.

One of the first periphyton surveys was conducted in September 1998 by PADEP at 6 mainstem and 3 tributary sites. The same locations were surveyed by PADEP's consultant in June 2005 concurrently with the PWD 2005 study. As a result, PWD reduced their periphyton sampling to four locations in the spring and summer.

The results of these historic data sets will not be reviewed in detail here, as there are reports available from PWD[21], WVWA[3] and PADEP. Some data are included in the following sections for comparison purposes.

II. Temple Study for the WQIP

The Temple University team designed an updated monitoring program to address remaining water quality questions in the Wissahickon Creek. The study period was from November 2016 to May 2018 and some initial monitoring was conducted under a prior grant from the William Penn Foundation. Thus, approximately two years of monitoring are included in the summary presented here (March 2016-May 2018, plus one additional round of sampling in September 2018).

All available historic data were reviewed to select monitoring sites and targets for the Temple study for the WQIP. This monitoring program included:

- quarterly instream water quality samples
- stormwater monitoring using nutrient data loggers (nitrate and PO_4) and ISCO automatic samplers
- turbidity loggers for sediment transport in storms
- dissolved oxygen loggers for stream metabolism assessment
- physical habitat assessment
- macroinvertebrate analysis
- periphyton sampling

The data described in the previous section allowed the current state of the stream and specific factors that impact stream health to be assessed. Methods and site locations are briefly described in this section. Summaries are provided for macroinvertebrates, periphyton, water quality, stormwater, wastewater discharges of phosphorus, and sediment during storm events.

1. Macroinvertebrate Index of Biotic Integrity Metrics

PADEP's Index of Biotic Integrity (IBI) uses 6 different metrics including: structure (total taxa richness, EPT taxa richness); tolerance (modified Beck's index, Hilsenhoff Biotic Index, percent sensitive individuals); and composition (Shannon-Winer Diversity Index)[4]. The IBI combines these scores into a single score ranging from 0-100. Sites with a high score reflect undisturbed ecosystems and scores of 50 or less are considered impaired. To evaluate water quality impacts, IBI scores from sampling and

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[2] PWD (2007). Wissahickon Creek Watershed Comprehensive Characterization Report. January 2007.

[3] Wissahickon Valley Watershed Association (WVWA) (2017). Wissahickon Watershed Stream Monitoring and Assessment Program: A summary of data collected by the Wissahickon Valley Watershed Association from 2004-2016. 92 pp.

[4] PADEP (2012). A Benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania. Division of Water Quality Standards.

identification, conducted by WVWA[5], ANS[6], and PADEP, was aggregated and analyzed. The WVWA dataset was incomplete as samples were collected but not analyzed. The Temple study for the WQIP provided for the analysis of these samples by the ANS. Figure 2 provides the location of the sampling sites from the agencies.

The samples were collected from 2001 through 2017 and all indicated impairments of aquatic life. IBI scores from 2001 and 2005 averaged 21 on the mainstem with a range of 13-30 (Table 1). IBI scores for the tributaries averaged 18 with a range of 10-29. The 2011-2017 data show similar averages - 19 on the mainstem and 22 on the tributaries. Given differences in sites, samples, and counting techniques, the differences between IBI scores are not significant.

The Shannon Diversity Index scores were low (0.07-0.4) for all sites (high integrity sites tend to score closer to 1.0). Chironomidae remained the dominant family throughout all sites with 95% as the highest median percent abundance at a single site. The overall Chironomidae median percent abundance was 73% across all sampling events and sites. These numbers exceeded the historical assessment of midge percent abundance. Over time, there have been some changes in functional feeding groups, with predators and scrapers increasing in relative abundance. This is encouraging and may show a modest increase in stream function; however, the increase may not be statistically relevant.

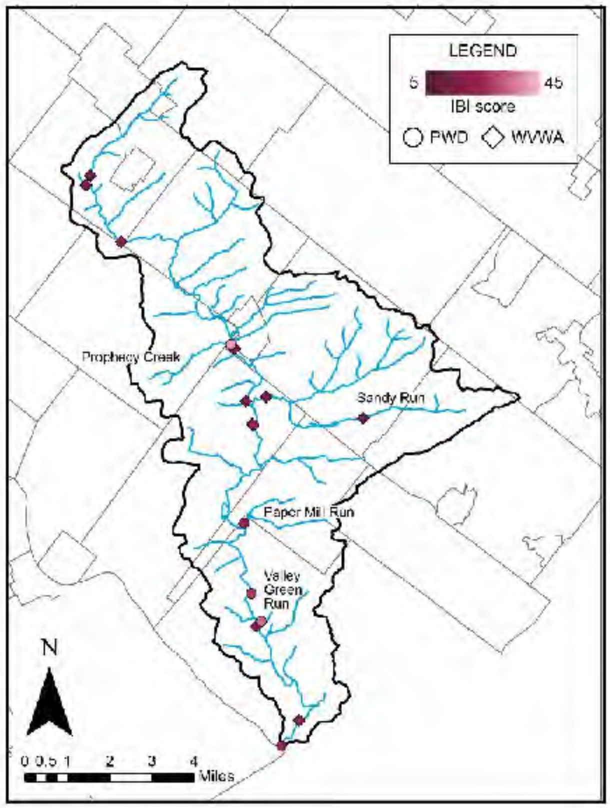

Figure 2 - Map of WVWA and PWD Macroinvertebrate Monitoring and Scores (2017)

	Year	Average	Maximum	Minimum	Count	Number of Sites
Tributaries	2001 + 2005	18	29	10	24	16
Tributaries	2011-2017[1]	22	44[2]	10	57	20
Mainstem	2001 + 2005 + 2006	21	30	13	28	17
Mainstem	2011-2017[1]	19	29	11	84	18

Table 1

[1] *No data collected between 2005, 2006 for mainstem, and 2011. The sites not identical in the two sampling periods, but significantly overlap. All but two of the tributaries in 2005 were in Philadelphia and the additional tributaries in recent years were added in the upstream reaches.*

[2] *The two sites with scores above 40 were Prophecy Creek and Thomas Mill Run. They had scores closer to the average in 2001-2005.*

2. Periphyton Levels

Periphyton (benthic algae) growth patterns were assessed by analyzing chlorophyll-a as an indicator of algal biomass. Although it is best to compare data collected from the same season, there is no standard time of year for data collection. Locations within the stream habitat and types of algae can also influence the chlorophyll-a levels.

Agency	**PADEP**	**PADEP**	**PWD**	**Temple WQIP (Round 1)**	**Temple WQIP (Round 2)**
Year	**1998**	**2005**	**2005**	**2018**	**2018**
Time of year-->	**September**	**June**	**Spring and Summer**	**April**	**September**
RM 19.3	176	314		255-415 (336)	78-128 (103)
RM 16.9	276	205	50-225 (140)	287-882 (657)	38-87 (62)
RM 12.7	119	85		52-1,287 (532)	43-76 (60)
RM 12.0	48	99		69-330 (210)	9-23 (16)
RM 10.7		298	100-230 (150)	568-1,420 (916)	112-113 (112)
RM 6.1	70	74	50-150 (100)*		
RM 0.1	207	252	150-460 (280)		
Sandy Run	274	210		576-655 (628)	13-23 (18)
Trewellyn Creek	73				
Prophecy Creek	216	276			

Table 2

Note: data were transcribed from reports and figures - values may not be exact.

RM = River Mile

* Approximately 0.5 miles upstream of the PADEP studies.

As shown in Table 2, three historic data sets are available for comparison to the Temple study for the WQIP: a PADEP data set from 1998[7], a PADEP data set from 2005[8], and a PWD data set also collected in 2005[1]. For the Temple study for the WQIP, samples were collected at two different times of year providing seasonal contrast. The first round of samples was collected before spring leaf out and levels were (as expected) higher than previous studies. The second round of samples was intended to compare with previous studies, however, higher than normal rainfall likely led to scouring of periphyton.spatial variability. For the April sampling, samples were collected on the right, center, and left bank locations. For the September study, one bank and the center were sampled. Results were reported for each discrete location and as a composite.

The Temple study for the WQIP also included more locations than previous studies. Sites were located (Figure 3), at each of the dissolved oxygen logger monitoring stations the USGS Fort Washington gauge, and two locations in Philadelphia. These sites were sampled in the April round, but three sites were dropped in the September round.

Except for two locations in September 2018, chlorophyll-a levels indicate eutrophic or mesotrophic conditions[9,10]; however, there was no evidence that algal densities are at nuisance levels for recreational uses. There is no trend from 1998 to 2018, particularly considering the high variation between the two sampling rounds in 2018. Seasonal variation far exceeded annual variation. Furthermore, two sets of samples at the same location and similar time in 2005 showed up to 150 milligrams per square meter (mg/m^2) variation. The highest chlorophyll-a values were observed before leaf out in 2018 (up to 1,420 mg/m^2) and the lowest (9 mg/m^2) values were observed after a season of heavy rain (and scouring) in 2018. There was no upstream-downstream trend along the mainstem at the comparison sites.

In the 20 years since the first study, the chlorophyll-a values are quite similar at the four sites on the mainstem. The highest values were observed near the mouth and headwaters and lower values in the middle of the watershed. The Temple study for the WQIP shows greater variability and values much higher and lower than reported in the 1998 study.

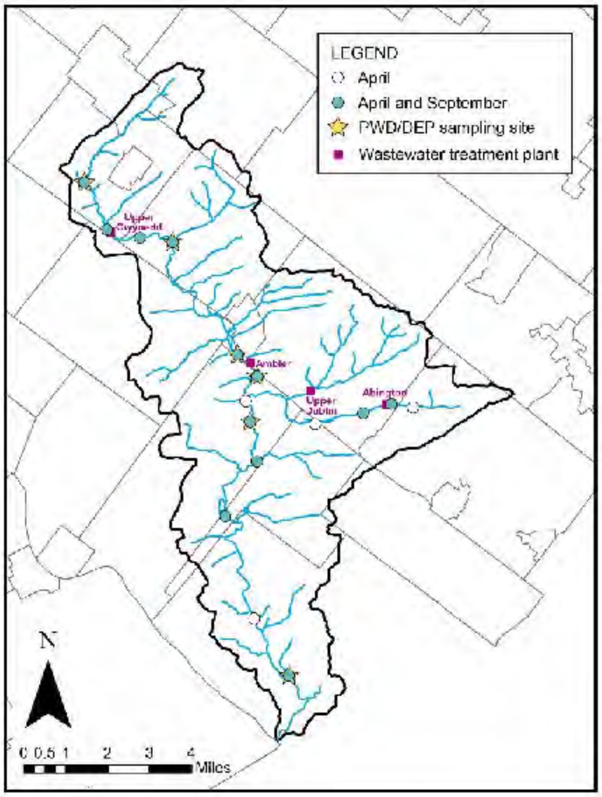

Figure 3 – Periphyton Sampling Locations

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[7] Everett, Alan C. 2002. Periphyton Standing Crop and Diatom Assemblages in the Wissahickon Watershed. PA Department of Environmental Protection Memorandum to Stream File. 40 pp.

[8] Carrick, Hunter J. and Godwin, Casey M. 2006. TMDL endpoint estimates for an urban-suburban stream based upon in-stream periphyton biomass (Wissahickon Creek Watershed, Pennsylvania). Report submitted to PA Department of Environmental Protection, 11 pp.

[9] Dodds WK, Jones JR, Welch EB. 1998. Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Res. 32:1455–1462.

[10] Dodds, W.K. and Smith, V.H., 2016. Nitrogen, phosphorus, and eutrophication in streams. *Inland Waters*, *6*(2), pp.155-164.

This difference might be attributed to the larger number of locations, sampling the center at each site, and the collection time.

Sampling above and below the WWTPs in 2018 did not show any upstream or downstream trends. In each season, some results demonstrated higher chlorophyll-a above the WWTPs, and some results demonstrated higher levels below (Figure 4).

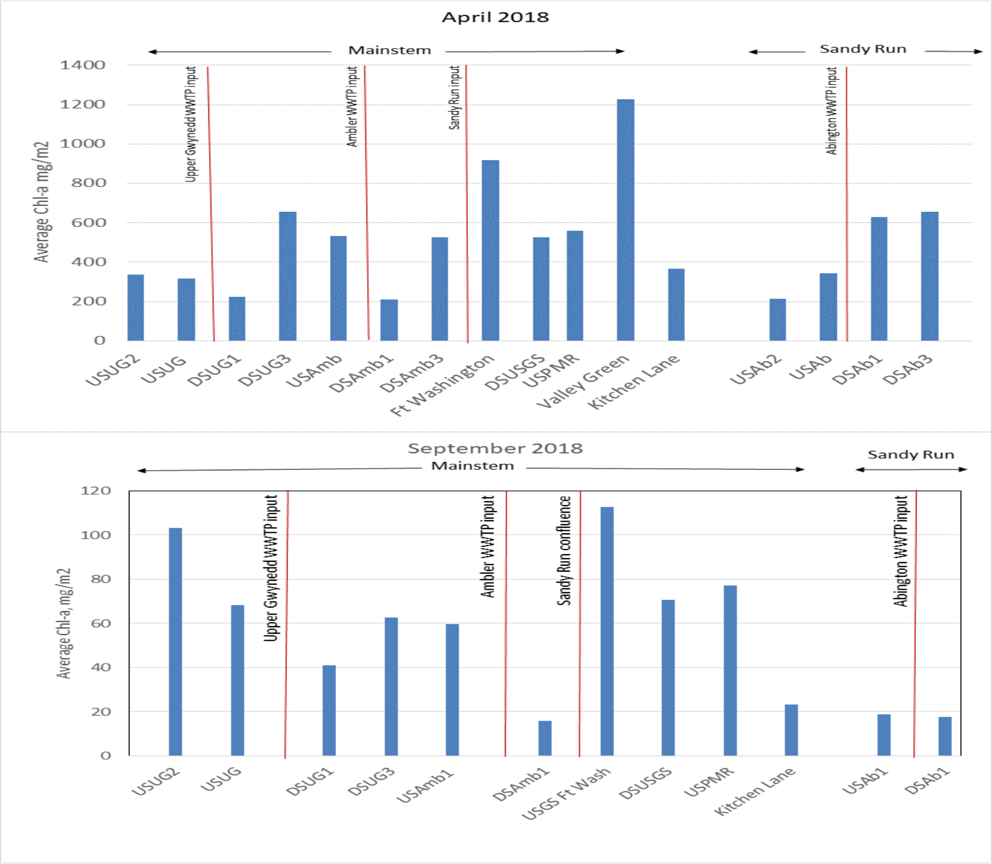

Figure 4- Average Benthic Chlorophyll a-Concentration from Periphyton on Rocks in the Temple Study for the WQIP in Two Different Seasons. Samples collected above and below WWTPs did not show a trend.

Center samples had higher chlorophyll-a levels than the bank samples at 75% of the sites in April, with five sites showing more than twice the bank levels. In contrast, September samples (except for two locations), showed higher chlorophyll-a near the banks. The storms prior to the September sampling may have had more impact in the center of the stream.

Spatial trends in chlorophyll-a were not related to trends in total dissolved phosphorus (TDP). Neither upstream-downstream trends nor seasonal trends related observed chlorophyll-a levels to TDP.

Chlorophyll-a response to phosphorus is complex in stream systems and multiple factors influence algal growth. These factors include light availability, temporal variations in water quality, combined nitrogen and phosphorus availability, temperature, and grazing[11,12,13]. Algae production has been observed in streams with very low nutrient concentrations[14,15] suggesting that stored nutrients in biomass provide growth material even when nutrients are apparently limited. These studies help explain the lack of correlation between seasonal or upstream-downstream variation in TDP concentrations in the Wissahickon Creek. Additionally, the impacts of scour in reducing algal biomass illustrates the impact of stormwater on stream biology. All of these factors impact algal growth in the Wissahickon Creek.

3. Water Quality

This section summarizes bioavailable phosphorus. Phosphorus in the water is either particulate or dissolved, and inorganic or organic. The dominant form of phosphorus in the stream is the inorganic PO_4, essentially equivalent to TDP. Instream concentrations showed that PO_4 comprised, on average, 83% of the total phosphorus concentrations. The fifteen-year record of concentrations at the Fort Washington gauge shows total phosphorus matched PO_4, except at the highest concentrations which occur during storms (Figure 5).

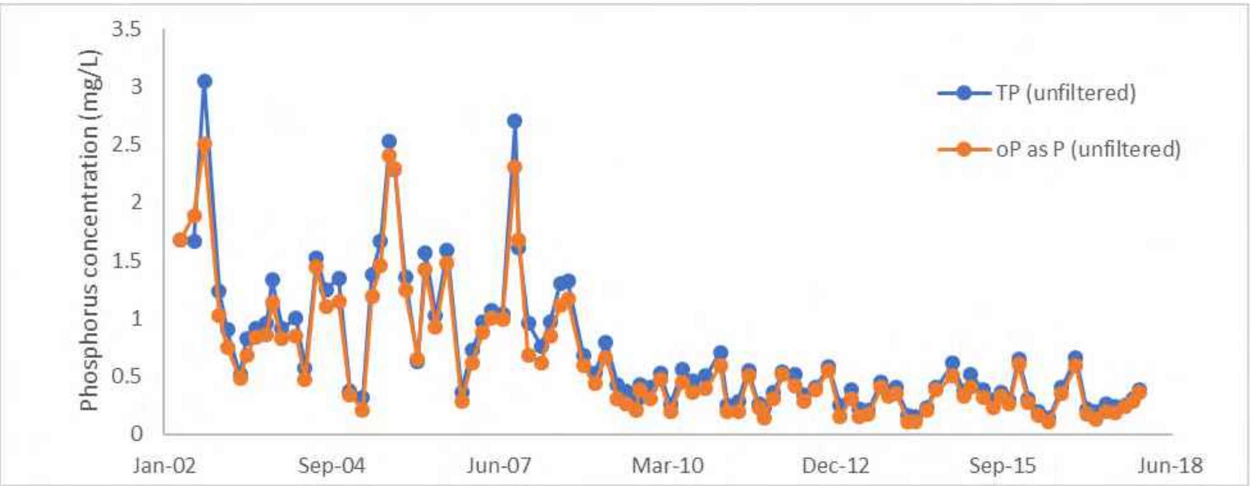

Figure 5 - Historic total phosphorus (TP) and orthophosphorus (oP or PO4) concentrations in the Wissachickon Creek at Fort

The historic trend in TDP from 2003 to 2015 indicates a slight decline in TDP across the period when the WWTPs reduced TDP (circa 2010). Observed reductions ranged from 0.2-1.0 mg/L for data collected in April or May (Table 3, Figure 6). All of the declines were less than actual decreases in WLAs, and the slopes were higher immediately downstream but became more gentle downstream. The variation in trends and gentles slopes are evidence that efforts to reduce TDP from the WWTPs do not produce a

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[11] Dodds, W.K. and Smith, V.H., 2016. Nitrogen, phosphorus, and eutrophication in streams. Inland Waters, 6(2), pp.155-1

[12] Biggs, B.J., 2000. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American Benthological Society, 19(1), pp.17-31.

[13] Riskin, M.L., Deacon, J.R., Liebman, M.L. and Robinson, K.W., 2003. Nutrient and chlorophyll relations in selected streams of the New England coastal basins in Massachusetts and New Hampshire, June-September 2001. Water-Resources Investigations Report, 03-4191.

[14] Droop, M.R., 1983. 25 years of algal growth kinetics a personal view. *Botanica marina*, *26*(3), pp.99-112.

[15] Rier, S.T. and Stevenson, R.J., 2006. Response of periphytic algae to gradients in nitrogen and phosphorus in streamside mesocosms. *Hydrobiologia*, *561*(1), pp.131-147.

predictable decline in the creek. There are multiple sources of TDP to the creek, including overland flow. Thus, further reductions in WLAs might not produce significant decline in stream concentrations.

WVWA Location	Slope of TDP over time*	R^2
Above Upper Gwynedd WWTP (750)	-0.001	0.0004 no trend
WVWA Headquarters, below Upper Gwynedd, above Ambler WWTPs (600)	-0.073	0.73
Below Amber WWTP (550)	-0.146	0.7
USGS Ft. Washington Gage, below Sandy Run (500)	-0.11	0.63
Philadelphia border (400)	-0.073	0.66
Near the mouth (150)	-0.037	0.67

* 2003-2015 or available data range.

Table 3 – Trends in Historic Total Dissolved Phosphorus

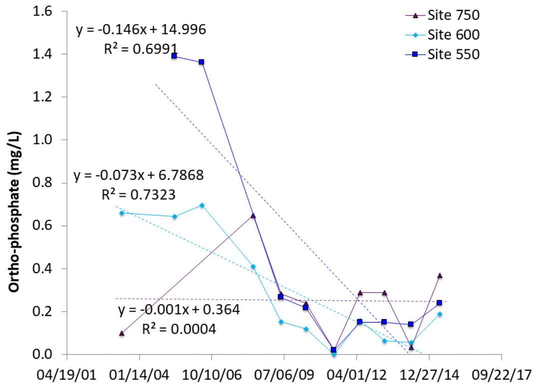

Figure 6 - Historic Total Dissolved Phosphorus from WVWA Sites above the Upper Gwynedd WWTP (750), below Upper Gwynedd and above Ambler WWTP (600) and below the Ambler WWTP (550).

The Temple study for the WQIP focused on the Wissahickon mainstem from the headwaters to the Philadelphia border, as previous studies observed little variation in water quality in the lower Wissahickon. Samples were collected four times (once per season) from July 2016 to May 2017. Samples were collected on the mainstem to reflect conditions above and below the WWTPs and the seven tributaries (Figure 7) during baseflow conditions. For the last three sample rounds, WWTP effluent samples were also collected. Samples were collected within a 4-hour window in the morning to avoid daily swings in concentrations. WWTP effluents were sampled at approximately at the same time, followed by mainstem and tributary sampling.

As shown in Figure 8, TDP concentrations in the headwaters are less than 0.1 mg/L; concentrations of 0.2-0.4 mg/l are observed downstream of the WWTPs. TDP in the WWTP effluents varied from 0.3 to 1.6 mg/L. At the downstream end, the lowest TDP values are seen in May when baseflow was highest (proportionally less flow from WWTPs than other surveys).

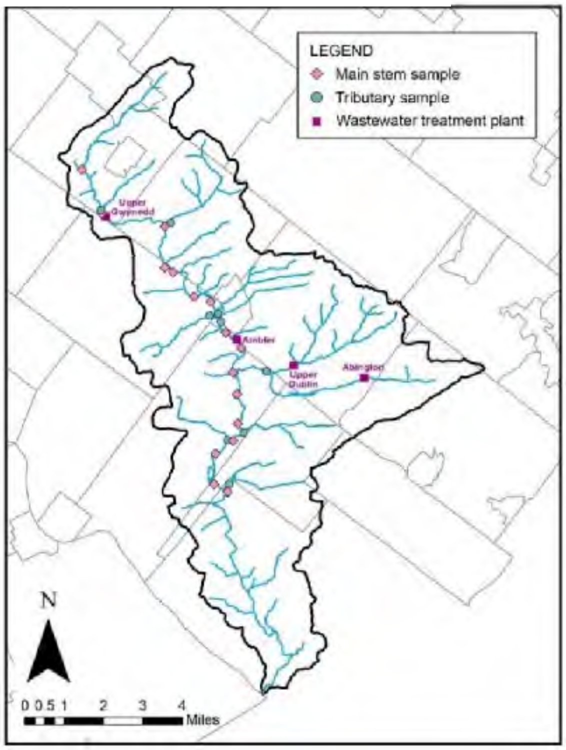

Figure 7 - Locations of Water Quality Grab Samples for Four Seasons of Sampling between July 2016 and May 2017

The highest TDP values are seen in February, which is not the lowest baseflow - the highest mainstem TDP (0.6 mg/L) is downstream of Sunny Brook Run, not the WWTP. The source of TDP in Sunny Brook Run is not known.

Data collected above and below the seven tributaries show that tributaries contribute to dilution in three cases, decreasing TDP by 0.05- 0.1 mg/l. In the other three cases there is little or no change between upstream and downstream locations. As expected, Sandy Run is a source of nutrients due to WWTP discharges.

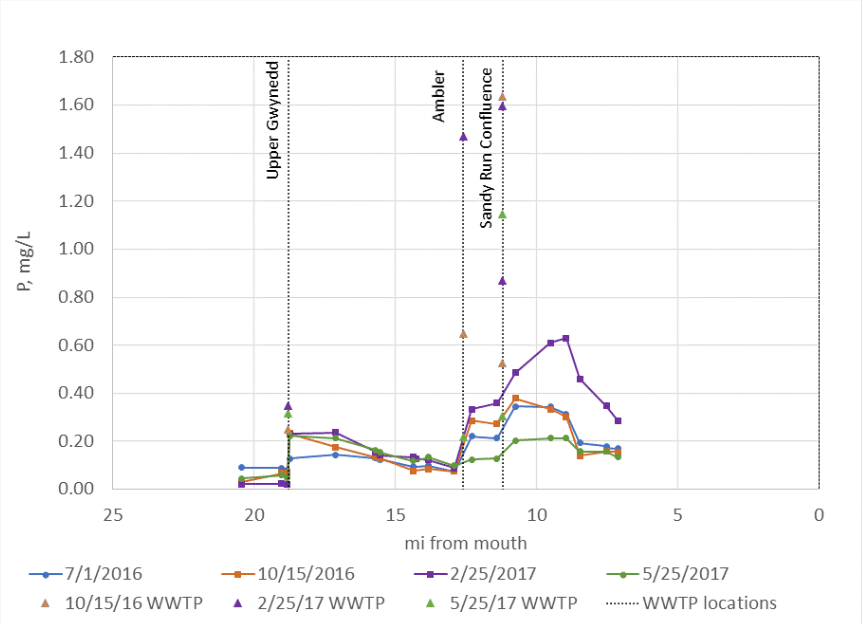

Figure 8 - Total Dissolved Phosphorus Sampled Across Four Seasons, along with Tributary and Wastewater Treatment Plant Outfall Concentrations for the Last Three Sample Dates

4. Stormwater

The Act 167 plan[16] for the watershed provides stormwater management guidance including an evaluation of existing conditions, stormwater model development, ordinance recommendations, evaluation of stormwater control measures, and an implementation plan. The implementation plan involves prioritized construction of stormwater control measures over a 10-year period and updating or strengthening ordinances for new development.

From 1981 through 2010, average annual rainfall was 48 inches (122 cm). In the last decade, rainfall has exceeded 60 inches (152 cm) in 2011 and 2018. A map of flooding potential (Figure 9) closely aligns with impervious cover maps. The floodplain map (Figure 10) includes 137 buildings in the floodway, with 1,157 buildings in the 100-year flood area and 1,768 buildings in the 500-year flood area. The watershed

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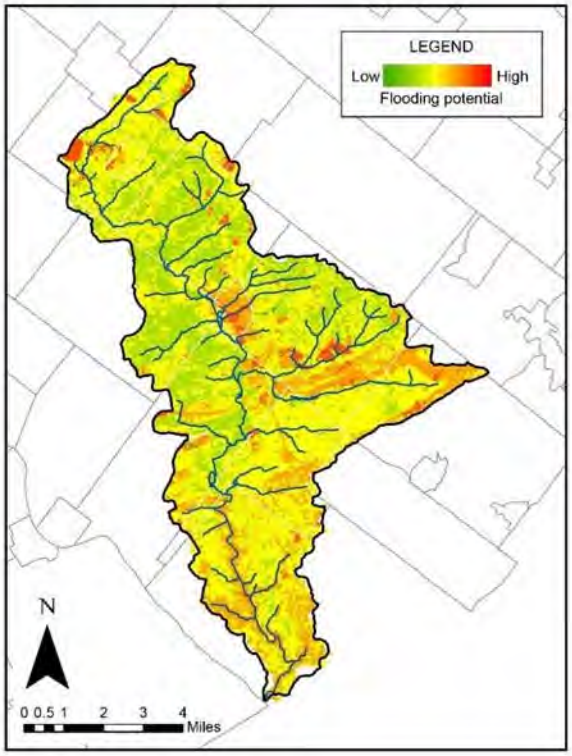
[16] Center for Sustainable Communities, Temple University and Newell Tereska & Mackay Engineering (2014). Wissahickon Creek Act 167 Plan, Fromuth, R. (Ed.). April 2014 (revised November 2014) www.montcopa.org/2264/Wissahickon-Creek-Watershed-Act-167-Plan , accessed Feb. 9, 2019

is highly developed and the DVRPC anticipates approximately 7% growth in population by 2040, with additional development to support this growth.



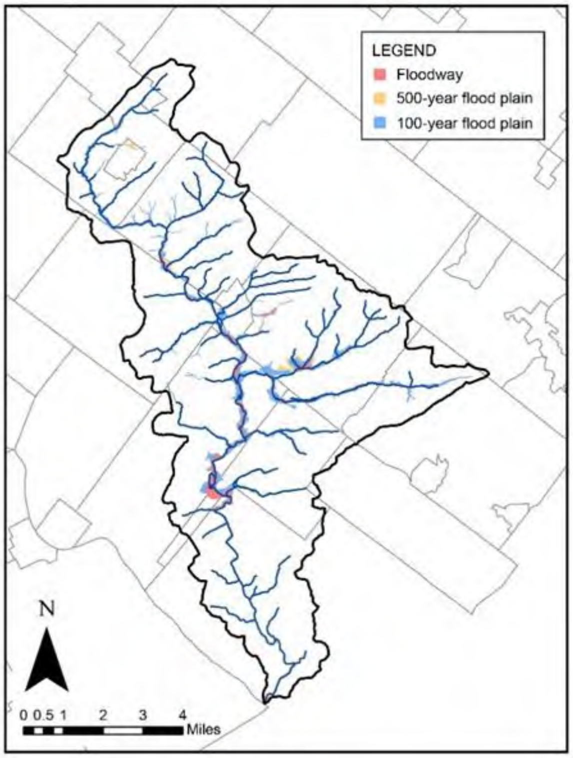


Figure 9 - Map of Flooding Potential

Figure 10 - Floodplain Map

5. Treated Wastewater – Phosphorous

To evaluate the contribution of treated wastewater to phosphorus loads, loads from the WWTPs and upstream sources were calculated at the Fort Washington USGS gauge. Loads at the gauge were calculated using data from January 2002 through May 2018. A regression equation was used to estimate daily total phosphorus loads, which were then aggregated into monthly loads.

Representative WWTP discharge, concentrations, and loads (Table 4) were calculated from monthly averages for April 2016 – August 2017 (a nearly complete data record for all WWTPs). Aggregate monthly WWTP loads were subtracted from the Fort Washington gauge total loads to calculate the contribution of instream load.

	Discharge (MGD)		Total Phosphorus (mg/L)		Total Phosphorus (pounds per day)		Total Phosphorus Load removed (%)	
WWTP	**Avg.**	**Standard Deviation**	**Avg.**	**Standard Deviation**	**Avg.**	**Standard Deviation**	**Avg.**	**Standard Deviation**
Upper Gwynedd[1]	2.3	0.50	0.1	0.12	3.0	1.13	92%	4%
Ambler[2]	3.5	0.60	0.4	0.61	13.0	7.89	NM	NM

Upper Dublin	0.7	0.10	0.5	0.32	3.4	0.99	NM	NM
Abington	2.7	0.20	0.6	0.37	15.4	3.37	77%	5%

Table 4 – Comparison of Wastewater Treatment Plant Effluent Values April 2016 to August 2017

[1] Estimated for five months in 2017 from average of other data points (n=12).

[2] Incomplete data record.

The total flow at the gauge was disaggregated into base flows (49%) and storm flows (51%). Calculations were conducted for two datasets: all flows (Figure 11) and base flows only (Figure 12). The WWTP data record for both datasets is the same. Relative contributions of both discharge and TP load follow similar trends reflecting the larger stream flow in late spring and lower flow in late summer and fall. When storms are included (Figure 11), the instream TP load contribution is positive in the spring season, suggesting that phosphorus is contributed during stormflow (e.g., via surface runoff or resuspension). The seasonal contrast is more moderated in the base flow only calculations (Figure 12). The calculated load shows negative instream components for much of the period. This reduction in load (i.e., negative instream TP load) could be due to various phosphorus removal mechanisms during baseflow including bio-uptake or sediment sorption.

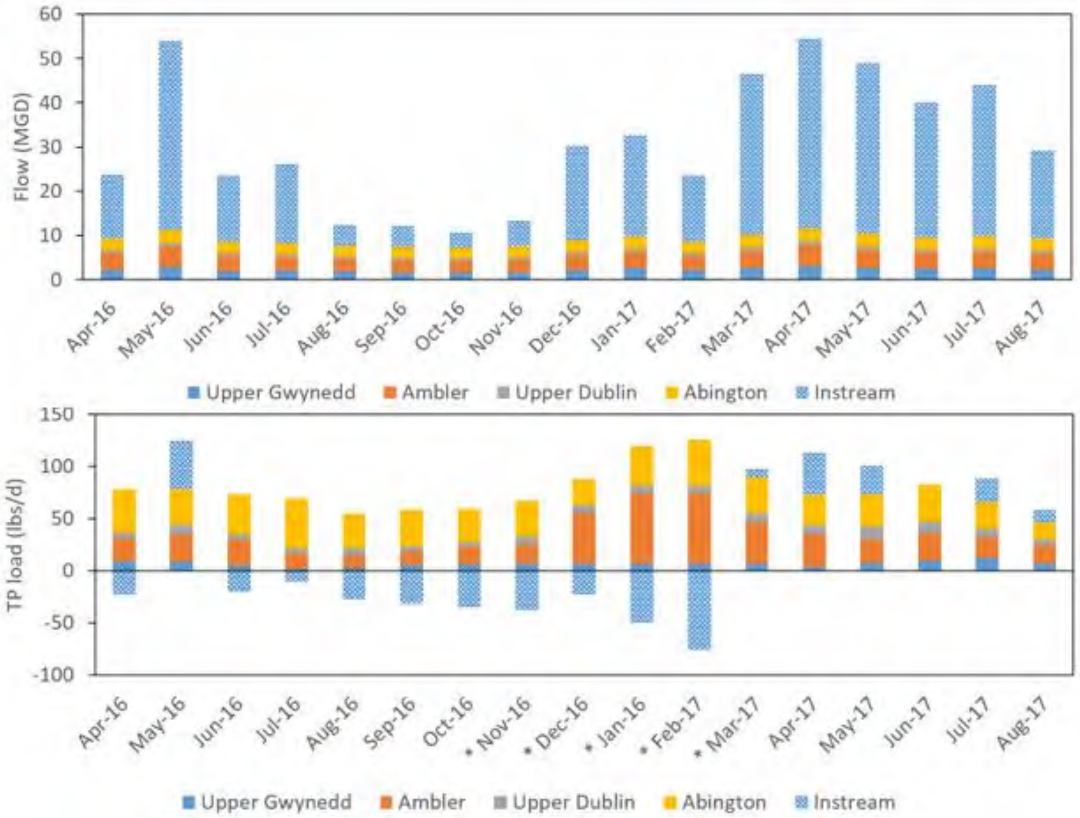


*Figure 11 - Apportionment of Flow (upper) and Total Phosphorus Load (lower) at Fort Washington for Both Storm and Base Flow. Note that Upper Gwynedd loads are estimated for 5-months (indicated with *). Instream discharge and TP load are solved by difference.*

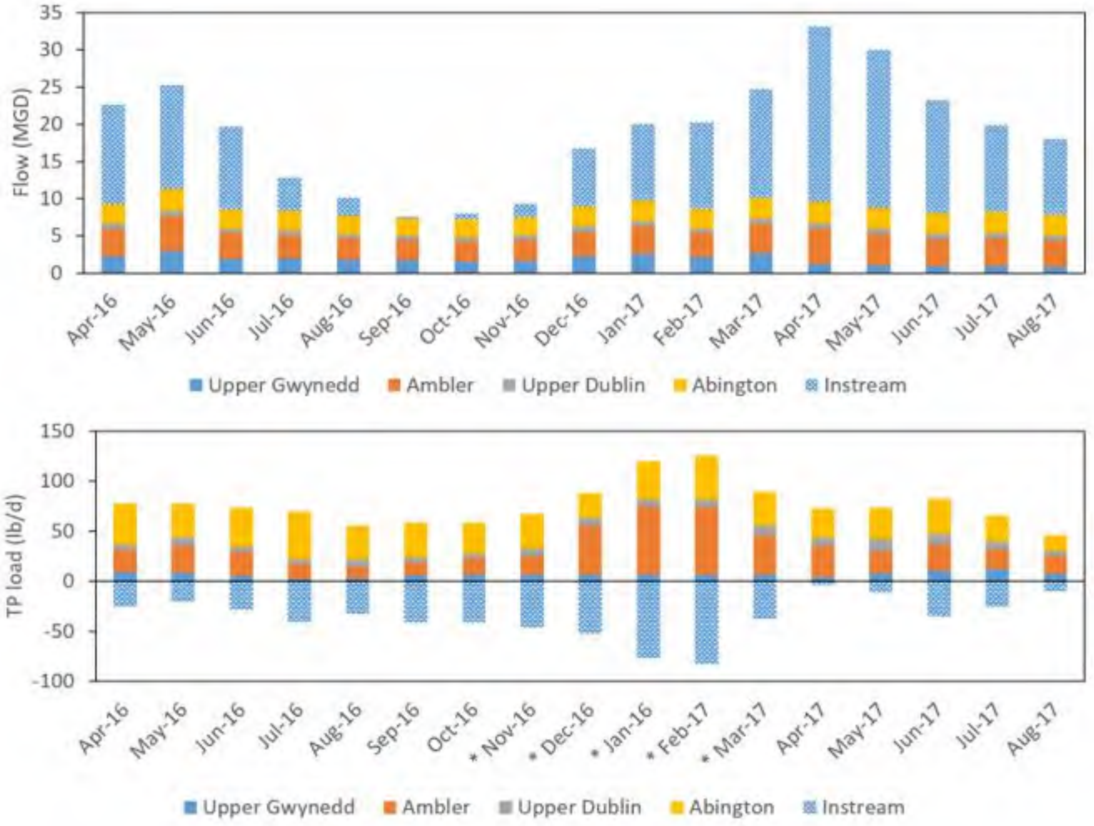


*Figure 12 - Apportionment of Flow (upper) and Total Phosphorus Load (lower) at Fort Washington for Base Flow Only. Note that Upper Gwynedd loads are estimated for 5-months (indicated with *). Instream discharge and TP load are solved by difference.*

WWTPs are the predominant source of total phosphorus load when storms are included and under base flow only calculations. In many months, and in all base flow months, there is uptake in the streams. The impact of stormflow on WWTP phosphorus loads was also evaluated. Loading was similar for storm and non-storm periods at Upper Dublin and Abington. At Upper Gwynedd and Ambler, there was some increase in loading during storms.

6. Sediment Storm Response

In addition to the phosphorus TMDL, a sediment TMDL was calculated in 2003[17]. The Temple Study for the WQIP evaluated sediment transport in Wissahickon Creek. The presence of sediment is an indication of the degree of siltation and can be measured by total suspended solids (TSS). Turbidity can be used as a surrogate for TSS, as turbidity measurements can be recorded using real-time data loggers.

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[17] EPA (2003). Nutrient and Siltation TMDL Development for Wissahickon Creek, Pennsylvania. Final Report. October 2003.

Two monitoring campaigns were conducted using turbidity data loggers (Figure 13). The first campaign (spring through fall 2016) examined turbidity response above and below three tributaries: Haines Run in the headwaters, Sandy Run - the largest tributary, and Papermill Run near the Philadelphia border. An additional logger was placed downstream of the Upper Gwynedd and the Ambler WWTPs, for a total of 10 loggers. The second campaign (May through November 2017) examined turbidity response around three of the WWTPs to determine the relative roles of WWTPs and overland flow as sources of turbidity during storm events, for a total of 12 loggers. During both campaigns, the data loggers were programmed to collect readings of nephelometric turbidity units (NTUs) at 15-minute intervals and to clean the sensors each hour. Water level data were also collected at each site and rainfall was measured at Abington and Ambler rain gauges.

The data for all sites show that turbidity is locally sourced, as turbidity peaks at the same time (± 2 hours) as water level regardless of storm size. During successive storms, there was no evidence of lower turbidity or sediment exhaustion.

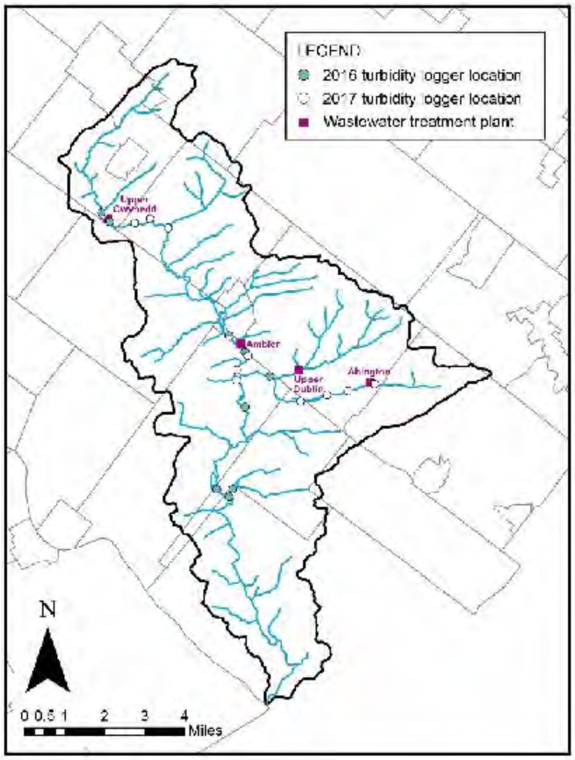

Figure 13 - Turbidity Logger Locations. In 2016, loggers were placed above and below three tributaries

To compare the variation of peak turbidity values between the 12 sites, the maximum turbidity values were divided by the corresponding peak water levels for each storm at each site. The resulting ratios of NTU/meter were plotted on a box and whisker plot (14). A Kruskal-Wallis Z Test (Dunn's Test) was then used to determine which sites were statistically more or less turbid during storm events. Figure 14 shows that the site downstream of the Upper Gwynedd WWTP (DSUG3) has a higher median turbidity to water level ratio. Statistical analysis showed this site to be different than all sites except upstream of the Ambler WWTP (USAmb) and upstream of the Abington WWTP (USAb). The WWTPs do not impact turbidity levels during storm events, as there is no statistical difference in upstream to downstream turbidity.

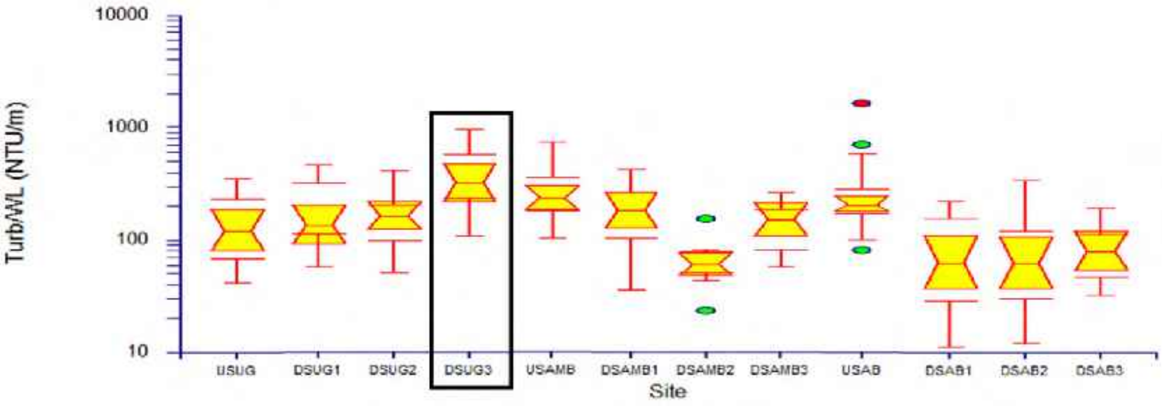

Figure 14 - Plots of Turbidity to Water Level Ratios of Each Storm at Each of the Twelve Sites from Upstream to Downstream on the Mainstem and on Sandy Run (Last Four Sites). DSUG3 (in box) is statistically higher than all sites except USAmb and USAb. The logger sites are named by location relative to the nearby WWTP (US for upstream, DS for downstream).

The maximum relative water level value and maximum turbidity value for each of 35 storms were plotted for each of the 12 sites in 2017 (see example in Figure 15). Small storms with a turbidity rise of less than 10 NTU were omitted from this analysis. The slope of the linear regression for each site describes the relationship between water level rise and turbidity rise. Sites with a high turbidity response (high slope in NTU/meter) indicate sites with more turbidity during storm events. R-squared values were also observed and compared to determine the strength of the relationships and the extent to which water level rise controls turbidity rise at each site.

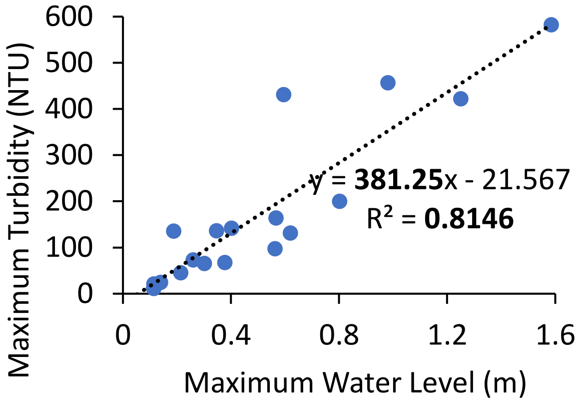

Figure 15 - Maximum Turbidity Versus Maximum Water Level Rise for the Site Upstream of Ambler WWTP. The slope of the linear regression is referred to as the turbidity response (NTU/meter) and provides a comparison of turbidity response for each site.

Relationships between maximum turbidity and relative maximum water level show a strong correlation between water level rise and turbidity, except for one site (Figure 16). The R-squared values calculated for the linear regression are greater than 0.6 at all sites except downstream of Abington WWTP (DSAb2).

The low R-squared at DSAb2 can be explained by the relatively low peak turbidity values for all recorded storms. The high R-squared values at the remaining 11 logger locations suggest stream flow strongly predicts the turbidity response to storm events in the Wissahickon Creek and Sandy Run. All four Abington sites have low slope values compared to the remaining sites, except downstream of the Ambler WWTP (DSAmb2). Although the Abington sites may have low peak turbidities compared to most of the mainstem sites, the falling limb of the turbidity peak is extended at these sites, which suggests these sites have a longer period of sediment disturbance than indicated solely by the peak turbidity. Therefore, at the four Abington sites, the peak turbidity values may not accurately describe the sediment response on Sandy Run.

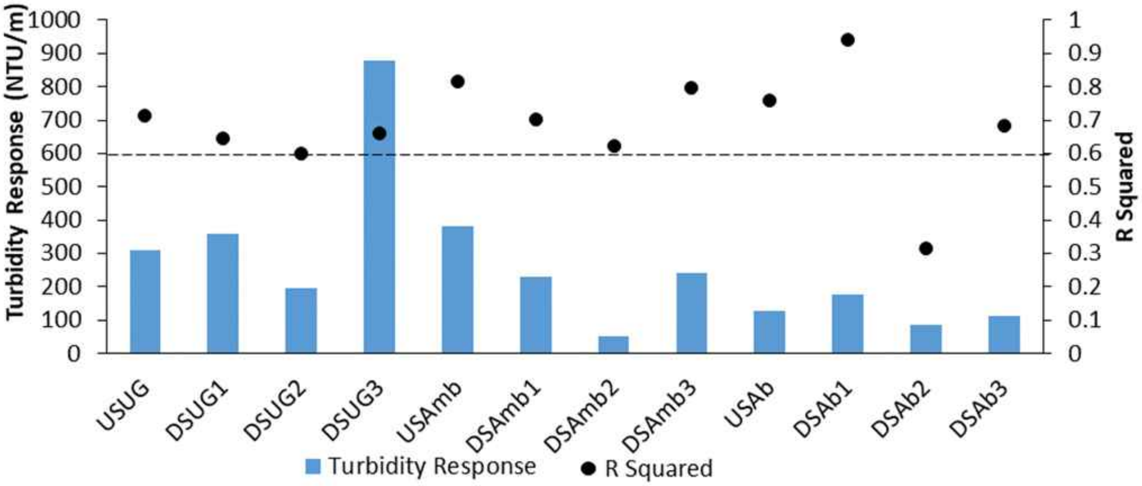

Figure 16 - Slope (Turbidity Response) and R-Squared Values of the Linear Regression of Maximum Turbidity Versus Relative Maximum Water Level at Each Site. R-squared values greater than 0.6 suggest a strong relationship between discharge and turbidity. Slope (NTU/meter) values suggest DSUG3 is significantly more turbid than the remaining sites.

It was anticipated that a turbidity response in Wissahickon Creek would be observed downstream of the tributaries, particularly Sandy Run which is known for high turbidity during storms. However, no increase was observed. Box plots of the turbidity response for the 2016 sites show no statistical differences between sites above and below the three tributaries except for upstream of Papermill Run (Figure 17), which showed a higher turbidity response downstream of the tributary. Additionally, there was no increase in turbidity downstream of the Upper Gwynedd WWTP (DSUG) or Ambler WWTP (DSAmb).

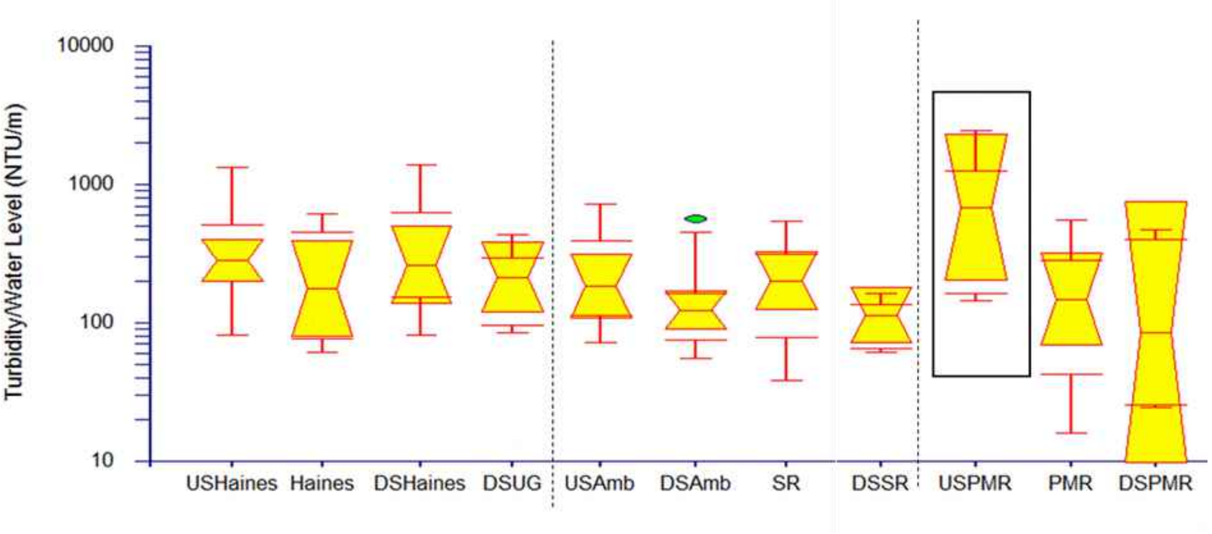

Figure 17 - Box Plots of Turbidity Normalized to Water Level in the Three Study Reaches in 2016. The tributary and WWTP input did not increase turbidity response. The logger sites are named for the position relative to tributaries or the Ambler WWTP (US for upstream, DS for downstream).

Physical characteristics were evaluated at each site (from 2017) to characterize bank height, bank slope, stream width, sediment grain size, sediment embeddedness, bank vegetation, and algae cover. Land use characterization in the vicinity of the sites included impoundments, culverts, and land cover percentages. High resolution land cover data collected by the University of Vermont Spatial Analysis Laboratory**Error! Bookmark not defined.** was used to determine the land cover of each of the subwatersheds. Land covers considered in this analysis included tree canopy, low vegetation, structures, impervious surfaces, and impervious roads.

Number Crunching Statistical Software (NCSS) was used to create a matrix of scatter plots relating the turbidity response (NTU/meter) at each site to other site parameters. For descriptive parameters (such as vegetation type) ranks were assigned and rank regression was used to assess correlations. The site downstream of Upper Gwynedd WWTP (DSUG3) showed a significantly different response and scatter plots were created with and without this site.

The scatter plots showed no correlation between turbidity response (NTU/m) and bank height, bank slope, wetted width, or average water depth at the logger at any of the 12 sites monitored in 2017. Vegetation scatter plots showed no correlation at the logger location. At these sites there were apparently enough mature trees to mitigate erosion (Figure 18). No relationship was observed between turbidity response (NTU/m) and these parameters, or any other upstream parameters measured during the stream assessment[18].

Figure 18 - Vegetation observed along the Wissahickon Creek and Sandy Run. Examples of (a) trees and tree roots, (b) small plants (with trees behind), (c) and Japanese Knotweed.

Sediment was evaluated at each of the 2017 logger sites, but no correlations were found with grain size or embeddedness. There are several sites where the turbidity response is the same, but embeddedness differs. The turbidity response at the sites upstream (USUG) and downstream (DSUG1) of the Upper Gwynedd WWTP are similar. The streambed is 92% embedded at USUG, whereas the streambed consists of 50% loose sediment at DSUG1. A similar pattern is observed at the Ambler and Abington WWTPs, where the turbidity response is the same, but embeddedness differs. Furthermore, similar

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[18] Kanaley, Chelsea. 2018. Turbidity and nutrient response to storm events in the Wissahickon Creek, Suburban Philadelphia, PA. Temple University, MS Thesis. 207 pp.

streambed embeddness measurements exist upstream of the Ambler WWTP (USAmb) and the Abington WWTP (USAb). These two sites, however, have different turbidity responses, as turbidity falls at a much faster rate at USAmb than at USAb. Thus, surprisingly, it is unlikely that embeddedness impacts stream turbidity during storm events at the sites monitored in the Temple study for the WQIP.

Sieve data for streambed sediment samples show variations in streambed grain size between the 12 sites. The sites downstream of Upper Gwynedd WWTP (DSUG2) and Abington WWTP (DSAb3) have considerably higher concentration of fines than the other sites. They do not, however, have relatively higher turbidity responses. It is unknown why there are greater fines at DSUG2. An explanation for excessive fines at DSAb3 may be the construction of a new housing development near the site, although sediment control structures were in place. The regression between fine grain sediment (at sites with less than 1% fines) and the turbidity response (NTU/m) had an R-squared value of 0.04, showing no correlation. Therefore, at these sites streambed grain size did not have a significant impact on the turbidity response.

The frequency of bank flooding (at each of the 12 loggers) depended on streambank height and the extent of water level rise during each of the 35 storm events. The site where the bank was most frequently topped was upstream of the Abington WWTP (USAb), despite the relatively low turbidity response (NTU/meter) at this site. As a result, the relationship between frequency of bank topping and turbidity response (NTU/meter) is weak. However, when USAb is removed, the relationship between the two parameters is stronger, with an R-squared value of 0.7. This correlation suggests that the frequency at which water level exceeds bank height does impact stream turbidity at some sites, likely due to increased erosion that occurs when the bank is flooded.

Outfalls and constrictions, such as dams, culverts, and bridges, were considered as possible sediment sources to the Wissahickon Creek. Outfalls are point sources of sediment, dams collect sediment which is released during storm events, and bridges and culverts constrict the flow, which increases water velocity and the potential for erosion. The number of outfalls and constrictions upstream of each logger within a 0.6-mile (1-km) reach were compared to the turbidity response (NTU/meter) at each site. No relationship was observed between the turbidity response (NTU/meter) and the number of upstream outfalls.

A significant portion of each reach’s subwatershed is non-vegetated and is impacted by impervious cover. At Upper Gwynedd, about 32% of the land cover is non-vegetated, 26% at Ambler, and 40% at Abington. The variations in land use do not correspond to variations in the turbidity response (NTU/meter). Correlation between turbidity response and non-vegetated cover (R^2 of 0.08) and non-vegetated cover and roads (R^2 of 0.22) were insignificant.

There are twice the percentage of roads in the Abington reach than Upper Gwynedd and Ambler (Figure 19), which may also lead to greater sediment input. Roads create a pathway for sediment, which may allow more sediment to be input to the stream from a longer distance and for an extended period[19]. Along two of the reaches (Upper Gwynedd and Abington), a greater area of impervious surfaces corresponds to a greater turbidity response when comparing loggers within the same reach. The site immediately downstream of Abington WWTP (DSAb2) had the lowest non-vegetated cover and lowest turbidity response, as expected due to its location on a golf course. DSAb3 had a higher response than its land cover suggests, but the data from 2013 land cover did not reflect recent construction near this site. The turbidity response at the Ambler sites did not appear to be related to the mapped land cover. Nonetheless, the relationship between land cover and turbidity response along the Upper Gwynedd and Abington reaches suggests that increased impervious cover, structures, and roads increase sediment in overland runoff.

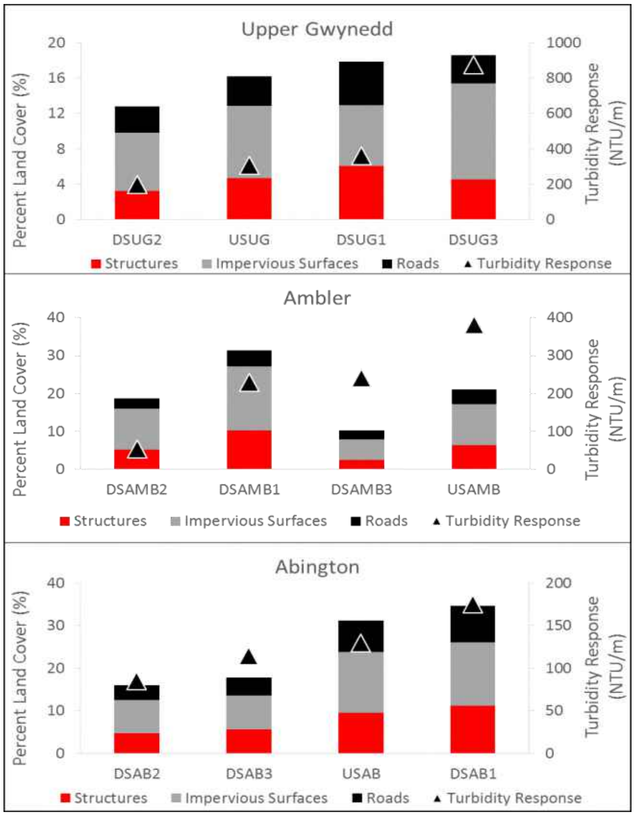

Figure 19 - Land Cover and Turbidity Response at Each Reach. The percent of structures, impervious surfaces, and roads are shown at the (a) Upper Gwynedd sites, (b) Ambler sites, and (c) Abington sites. Although increased non-vegetated surfaces do not always lead to increased turbidity response (DSAmb1, DSAmb3), this pattern is observed between most of the monitored sites.

Sediment is an important metric affecting benthic communities due to the accretion of fine materials. The main factor driving the sediment response in the Wissahickon is discharge, although bank overtopping and higher impervious cover may increase the sediment response in some cases. If the source of the sediment was primarily instream, increased turbidity response would correlate with decreased embeddedness and increased percent of fine sediment in the streambed. Similarities in turbidity responses upstream and downstream of the WWTPs strongly suggest that overland flow is the major source of sediment during storm events and WWTPs do not change the sediment loading significantly. The tributary input was not found to influence turbidity downstream on the mainstem. The knowledge that the source of the sediment is local and mostly due to overland flow is key in considering the most effective means to improve stream habitats.

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[19] Shuster, W.D., Bonta, J., Thurston, H., Warnemuende, E., and Smith, D.R., 2007, Impacts of impervious surfaces on watershed hydrology: A review: Urban Water Journal, v. 2, p. 263-275, doi: 10.1080/15730620500386529.

7. Dissolved Oxygen Monitoring and Stream Metabolism

Dissolved oxygen (DO) data were collected to help interpret metabolic activity in the stream and provide a more quantitative interpretation of impairment. Dissolved oxygen diurnal cycles were used to estimate stream metabolism using the one-station method for calculating gross primary productivity (GPP) and ecosystem respiration (ER).

The Temple study for the WQIP dataset is the only dataset that provides enhanced information on the temporal and spatial variability of DO in Wissahickon Creek. Some data were, however, excluded from the analysis due to sediment fouling the probes, which is not uncommon as urban streams are susceptible to impacts from large storms and high turbidity. The locations of the loggers also included headwater sites with limited streamflow that did not always show diurnal signals. Finally, deployment during the winter included some periods of freezing temperatures.

Data were collected year-round at 12 stations in the Wissahickon Creek and Sandy Run tributary (Figure 20). Data from two USGS/PWD loggers at Fort Washington and Ridge Avenue are included in the analysis. The USGS/PWD loggers are not operated from early December through early March. The Temple study for the WQIP extended the data collection at the USGS/PWD sites by installing a DO logger adjacent to the USGS/PWD loggers. There was a period of overlap in monitoring to compare the data from the two sources.

Monitoring was conducted from April 2017 through early May 2018, providing seasonality and a year of data. Most of the loggers were deployed upstream and downstream of three WWTPs (Figure 20). At the Upper Gwynedd (UG) and Abington (Ab) WWTPs, there were two loggers placed upstream of the plant and two loggers placed 0.6 mile downstream of the plant. Slight adjustments in distance were made to avoid input of tributaries and provide better access. At the Ambler (Amb) WWTP, one upstream DO logger was installed. There were two loggers downstream. The Fort Washington USGS gauge provides data downstream of Sandy Run; another logger was installed downstream to provide additional coverage along this reach. Complementary loggers were also used to collect data needed for stream metabolism modeling. This included water level data for estimating reaeration coefficients (input of oxygen from the atmosphere) and to identify periods of stormwater disruption. Solar radiation data were also collected to establish periods of photosynthesis.

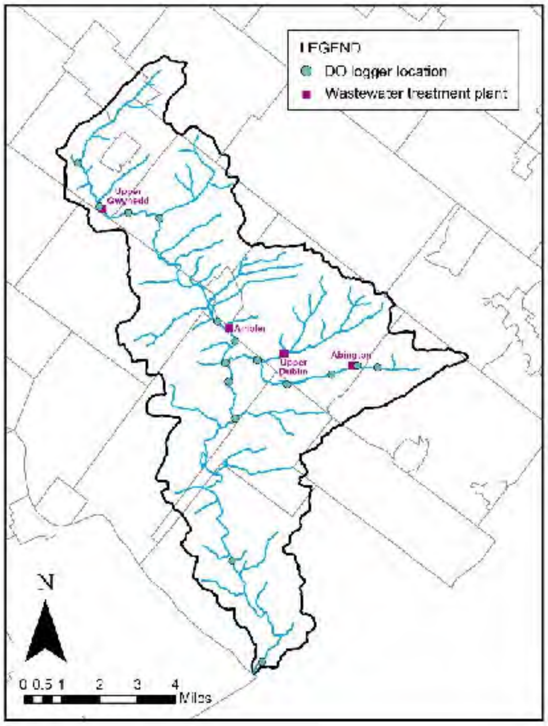

Figure 20 - Locations of 2016-2017 Dissolved Oxygen Loggers, including USGS stations.

Data at the logger upstream of the Ambler WWTP, located at the WVWA headquarters, illustrates seasonal trends in dissolved oxygen (Figure 21). This site is approximately 6.2 miles (10 km) downstream of the Upper Gwynedd WWTP. The DO peaks range from 10-18 mg/L. Minimum DO typically ranges from 5-14 mg/L. Minimum DO shows seasonal variation. The colder temperatures in the winter allow for greater dissolution of oxygen. The only excursions below 4 mg/L were related to a storm which may have resulted in fouling of the sensor (Figure 22).

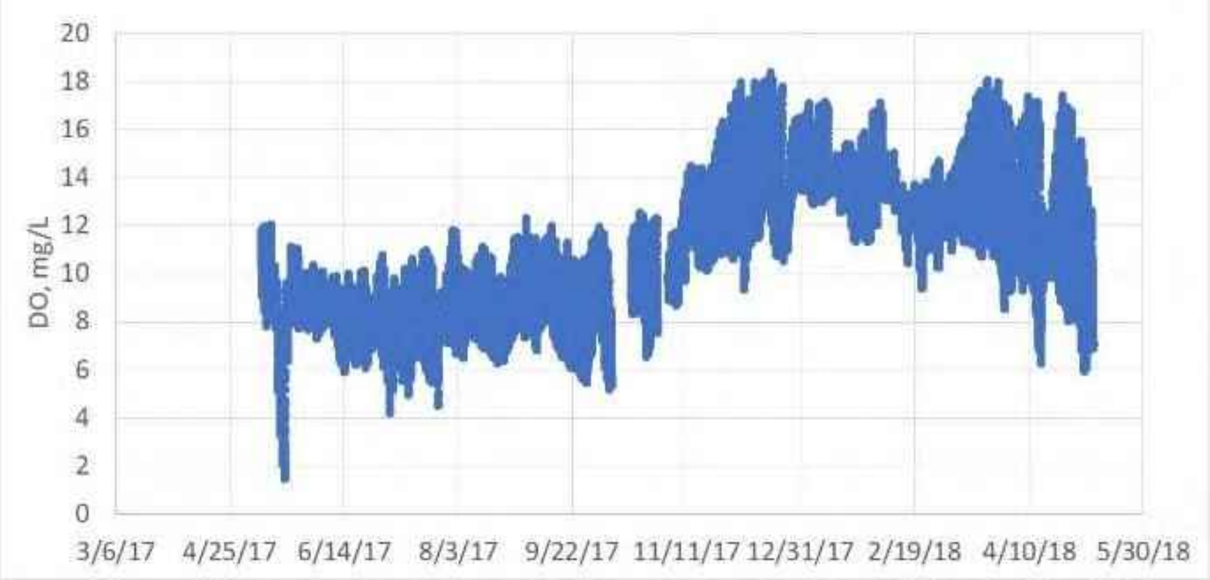

Figure 21 - Diurnal and Seasonal Variation in Dissolved Oxygen at the Logger Upstream of the Ambler Wastewater Treatment Plant.

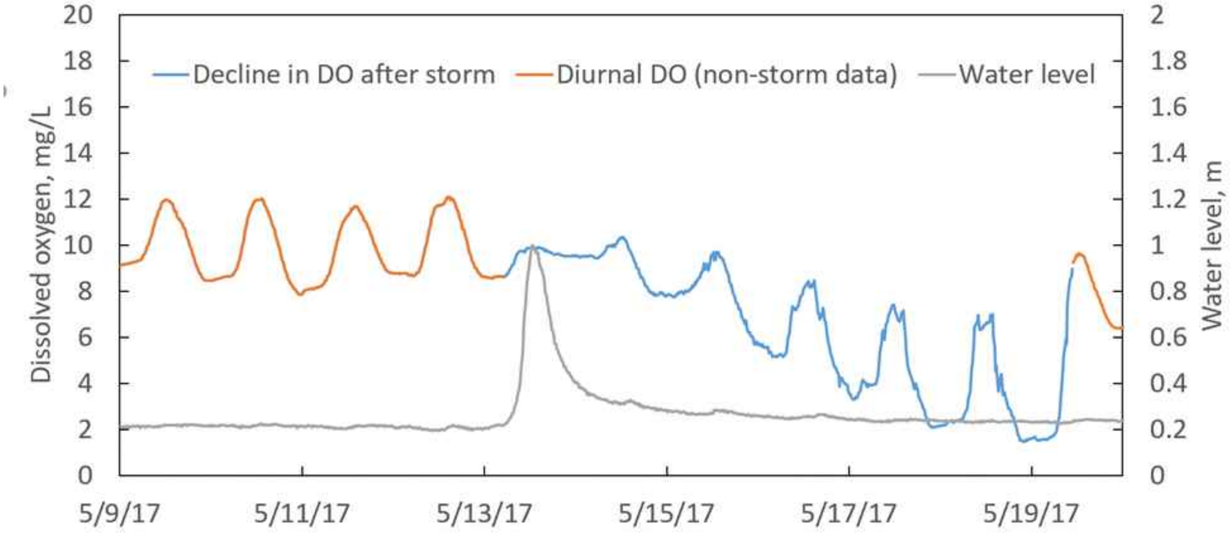

Figure 22 - Declining Dissolved Oxygen at the Site Upstream of the Ambler Wastewater Treatment Plant after a Storm. By May 15, the storm's signal is no longer present and continued declines in dissolved oxygen may be indicative of sensor fouling.

To compare DO across sites, the average diurnal variation in DO (amplitude) and the metabolic activity were calculated. The daily change in DO amplitude reflects two metabolic processes: gross primary productivity and ecosystem respiration. A Matlab script was written to calculate the DO amplitude. The Stream-Metabolizer program[20] was used to estimate GPP and ecosystem respiration based on the DO amplitude. GPP is the production of oxygen by aquatic organisms such as algae. ER is the consumption of oxygen by aquatic organisms. GPP leads to higher oxygen during the day when photosynthesis can occur and lower oxygen at night when photosynthesis stops. The amplitude of the DO variation reflects both processes since ER reduces DO on the falling limb, but the GPP is the process linked to eutrophication.

The data from sites above the WWTPs on Sandy Run is not included in the analysis because they show very little diurnal signal. These sites have shallow water and storms disturb the signal for longer than downstream sites.

Although phosphorus increases downstream of the WWTPs (Figure 8), there is no observed increase in average DO amplitude downstream of the WWTPs (Table 5) based on average DO amplitude over the course of the year. The largest amplitudes were observed in the headwaters above any WWTPs (Figure 23), downstream of the Ambler WWTP, and downstream of the Sandy Run confluence. The high average amplitudes at the latter two sites were followed by lower amplitudes just 0.6 miles (1 km) further downstream. The open canopy and slow-moving water at the headwaters site (Figure 24) may contribute to high DO amplitudes in the headwaters. The stream is wider with open canopy at the Fort Washington USGS gauge, downstream of this gauge (DSUSGS), and the Ridge USGS gauge. However, the last two sites have sandy beds, which may reduce algal productivity and DO amplitude.

	Dissolved Oxygen Amplitude, mg/L			Data available
Site	**Average**	**Maximum**	**Minimum**	**(days)**
Wissahickon Creek				
USUG2	7.0	16.8	1.3	127
USUG1	5.5	12.1	5.5	115
DSUG1	4.8	13.0	0.8	92
DSUG3	3.4	9.5	0.4	189
USAmb	4.0	8.9	0.9	134
DSAmb1	6.0	12.7	0.9	86
DSAmb3	4.9	11.3	1.6	76
USGSFtWash	6.0	16.9	0.9	249
DSUSGS	2.8	6.7	0.7	24
USGSRidge	3.6	9.3	3.6	199
Sandy Run				
DSAb1	2.4	7.7	0.3	227
DSAb3	3.4	9.6	0.2	143

Table 5

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[20] Appling, A.P., Hall, R.O., Yackulic, C.B. and Arroita, M., 2018. Overcoming equifinality: Leveraging long time series for stream metabolism estimation. Journal of Geophysical Research: Biogeosciences, 123(2), pp.624-645.

A closer look at a week of data with amplitudes downstream of the Upper Gwynedd WWTP shows that they are within the range of the amplitudes upstream of the WWTP (Figure 23). The amplitudes downstream of the Abington WWTP were not as high as any of the mainstem sites.

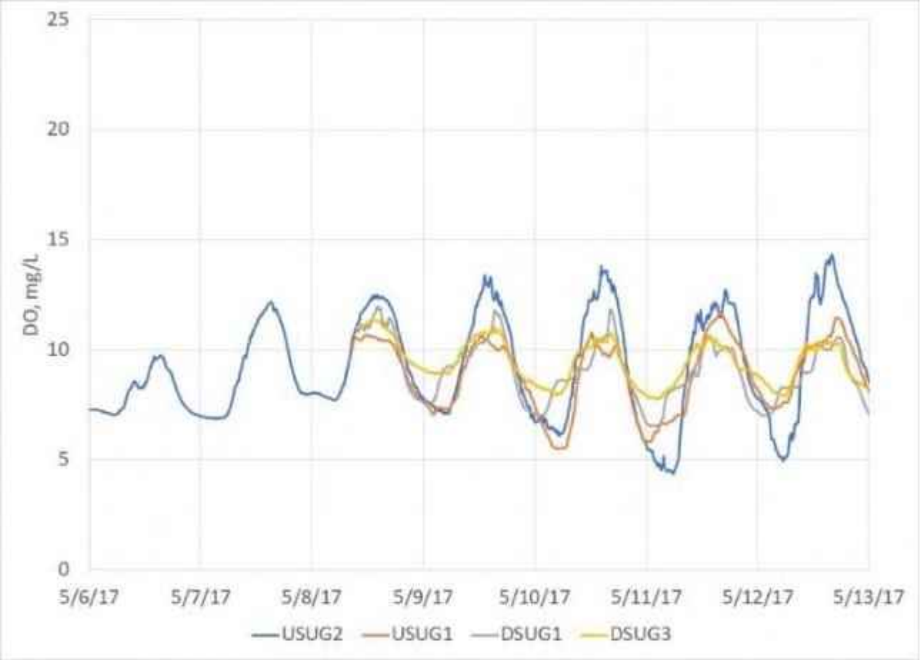

Figure 23 - Variation in Dissolved Oxygen Amplitude Upstream and Downstream of Wastewater Treatment Plants along the Mainstem Wissahickon Creek and Sandy Run for a week in May 2017.

The Wissahickon has both gross primary productivity and ecosystem respiration (Figure 25) within the range of streams from a world-wide study which included 72 streams[21] (Figure 26). There is a similar balance between GPP and ER (values above and below the 1:1 line on each figure). The range in values is smaller for the Wissahickon than for the large stream set (GPP scale is reduced by a factor of 6). Thus, the rates of productivity and respiration observed in the Wissahickon are not atypical values occurring at the low end of the spectrum. Furthermore, the range in GPP does not vary at the sites upstream and downstream of the WWTPs except for a few high points at DSAmb1 (Figure 25).

Figure 24 - Headwaters Site with High Gross Primary Production and Dissolved Oxygen Amplitude. This site is upstream of the wastewater treatment plants, but in an open reach with slow moving water.

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[21] Hall, Robert O, and Erin R Hotchkiss. 2017. Stream Metabolism. In Methods in Stream Ecology G. A. Lamberti and F. R. Hauer, eds. Third ed. London, United Kingdom: Academic, an Imprint of Elsevier. pp 219-233

In summary, the spatial trends show no clear influence from WWTP-impacted water despite the influx of nutrients. This finding disrupts the notion that the DO signals that show wide amplitude or low DO are indicative of nutrient impairment. Other factors such as light availability, stream flow rate, and sediment clogging are also important to consider. This study points out some additional monitoring considerations are needed to evaluate stream health using DO loggers.

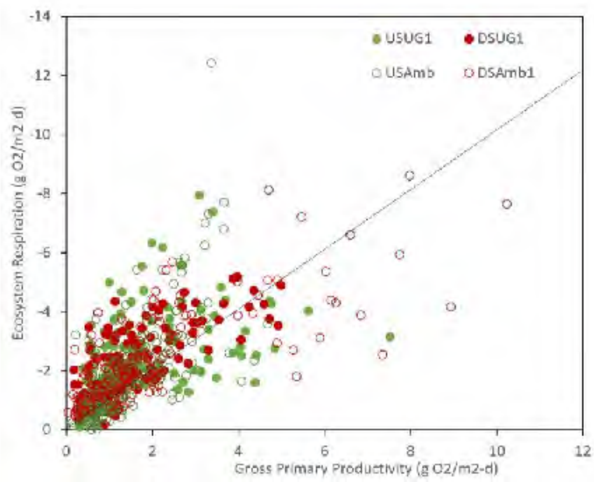

Figure 25 - Ecosystem Respiration and Gross Primary Productivity for Sites Upstream and Downstream of the Upper Gwynedd and Ambler Wastewater Treatment Plants. Range is similar except for a few points in DS Amb1. These values fall within the range of stream metabolism calculations from other sites globally.

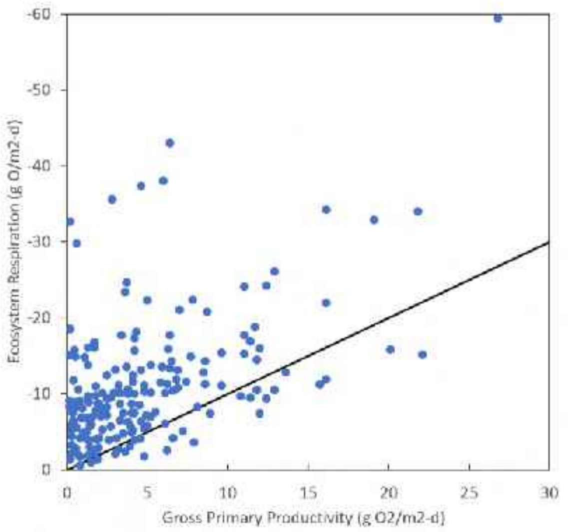

Figure 26 - Comparison of Ecosystem Respiration and Gross Primary Productivity for Streams from around the World. Source: Hall & Hotchkiss (2017). Note difference in scale with Figure 25

Appendix 7

Kleinfelder – Wissahickon Creek Water Quality Improvement Strategy

KLEINFELDER
Bright People. Right Solutions.

TECHNICAL MEMORANDUM

TO: Wissahickon Creek Clean Water Partnership Management Committee (“the Committee”)

FROM: Thomas W. Amidon, Kleinfelder

DATE: January 9, 2019 FINAL

SUBJECT: Wissahickon Creek Water Quality Improvement Strategy

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This Technical Memorandum documents the watershed assessment, regulatory review, and causal analysis that together constitute the technical basis for a TMDL alternative. These elements have been provided to the Committee in presentation form, and are summarized here to suggest a strategy upon which the Committee can prepare a Water Quality Improvement Plan (WQIP) for the Wissahickon Creek watershed.

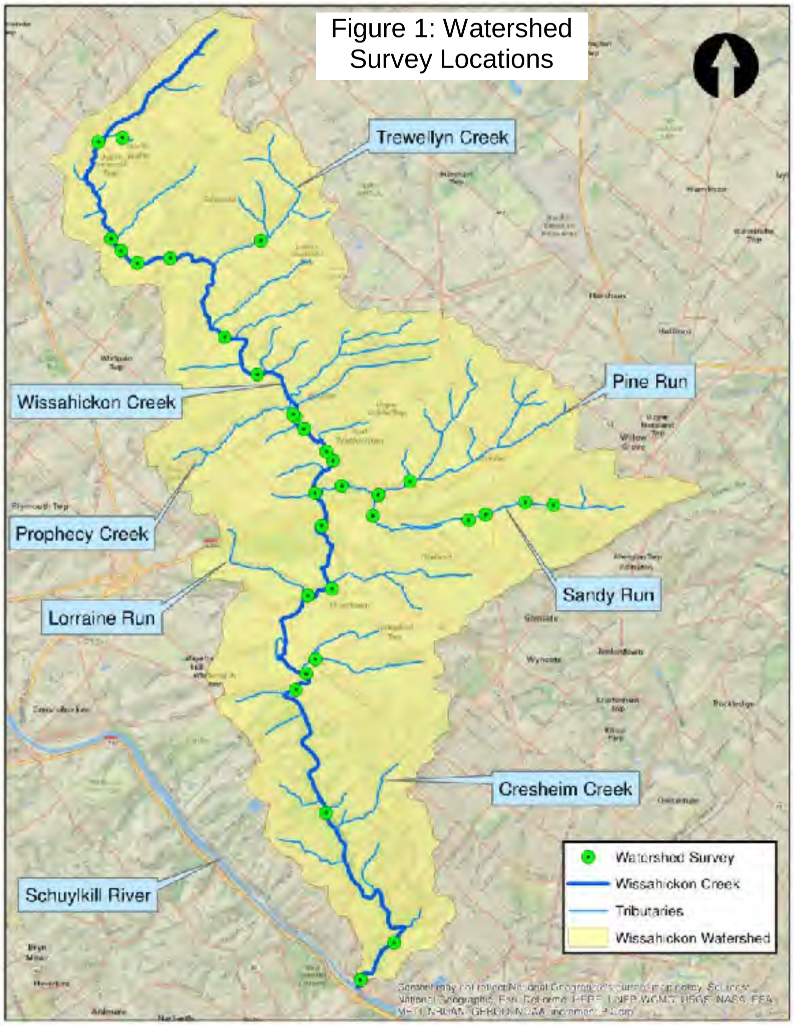


Figure 1: Watershed Survey Locations

Watershed Assessment

A watershed survey was performed in May of 2018 to photo-document conditions throughout the Wissahickon Creek watershed. As shown in Figure 1 to the right, I visited more than 30 locations throughout the watershed, hiking to most of the locations at which macroinvertebrate sampling has been performed over the years by the Wissahickon Valley Watershed Association (WVWA) and others.

Before discussing the water quality challenges and ecological constraints that exist in the Wissahickon Creek watershed, it is important to document the extraordinary positive attributes of the watershed.

- Much of the mainstem Wissahickon Creek benefits from wide, wooded stream corridors, as shown in Figure 2 to the left. In addition to their obvious habitat benefits, riparian corridors and attendant wetlands reduce flooding, reduce bank erosion (itself a major source of sedimentation), and help maintain stream flows that sustain aquatic life during dry seasons. Healthy riparian vegetation also provides a filter function by intercepting sediments in sheet and shallow subsurface flow before they can reach streams or rivers.
- The aesthetic beauty of the Wissahickon Creek, in the midst of its urban and suburban setting, is truly striking. A vast network of trails surrounds the mainstem Wissahickon Creek, providing an unusually high degree of access to the public (Photo 1). As a result, recreational uses along the stream are common, including hiking, fishing, biking, walking, and jogging (Photo 2). The streamside access and public use in the Wissahickon Creek watershed represents an important asset in terms of watershed protection and restoration because the residents are more connected to the Creek and its watershed.

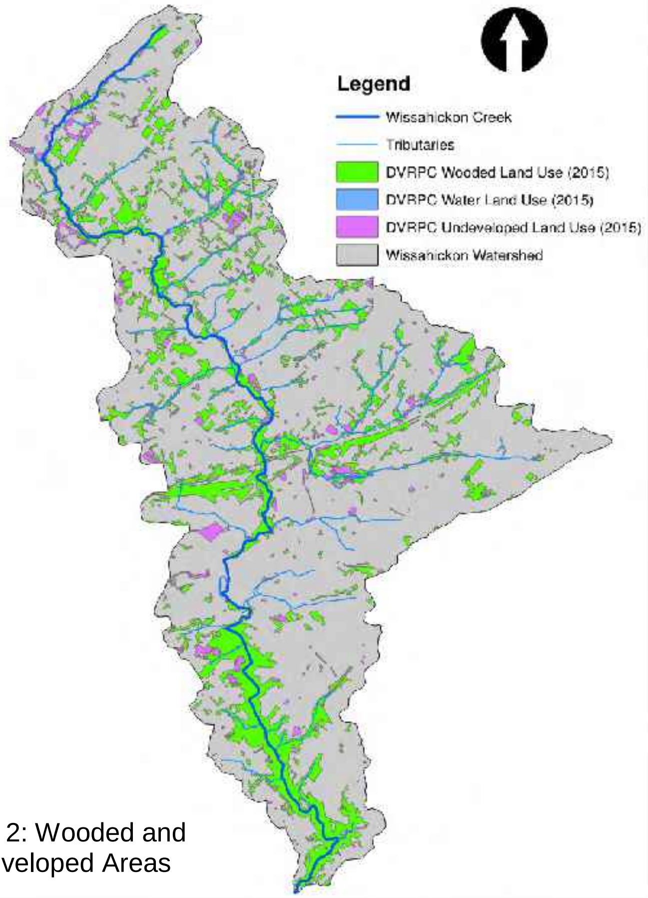


Figure 2: Wooded and Undeveloped Areas

Photo 1: Pedestrian Stream Crossing

Photo 2: Wissahickon Trailhead

The local passion and pride of place is evident in many small ways, such as the planters mounted on the Butler Avenue bridge (Photo 3) over the Wissahickon Creek in Upper Dublin Township.

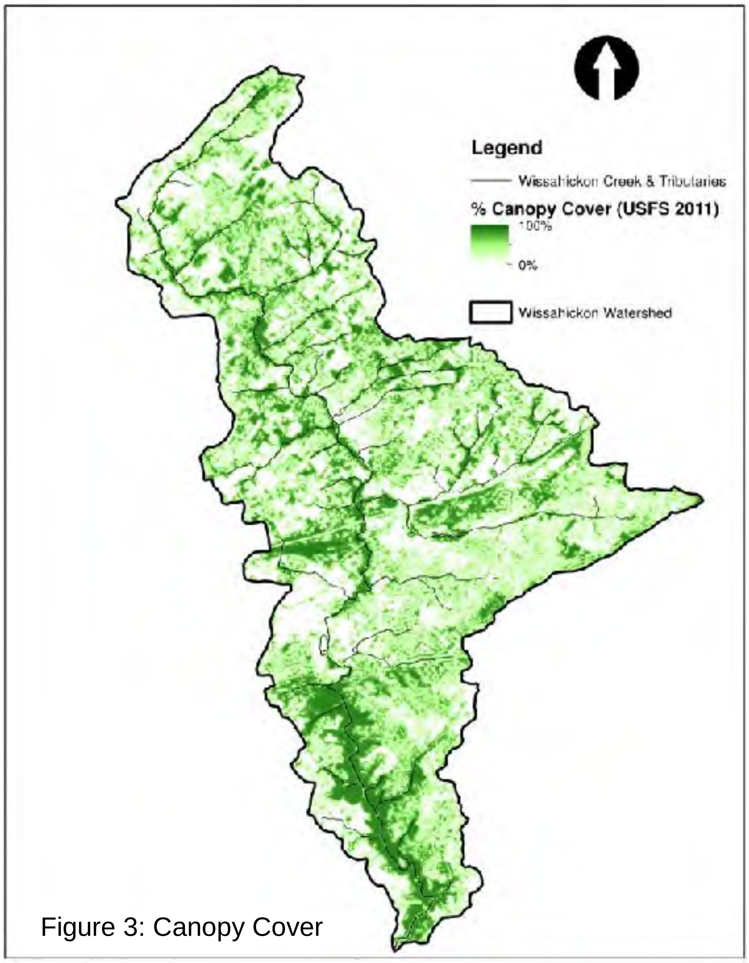


Figure 3: Canopy Cover

Photo 3: Planters on Butler Avenue bridge

The fact that half a dozen planters on a public structure connected to the Creek (adjacent to the Wissahickon Trail) were freshly planted by volunteers reflects the sense of local pride and connection to the water that permeates the watershed. It is therefore not surprising that stakeholders with diverse interests in this watershed have come together to form the Wissahickon Creek Clean Water Partnership and to develop a WQIP.

- Much of the mainstem Wisshickon Creek also benefits from a relatively dense canopy, as shown in Figure 3 to the left. Shade provided by tree canopy benefits streams by keeping temperatures low and by limiting algal growth. Of course, the wooded stream corridors described previously provide much of the canopy, especially evident in the lower portion of the watershed that is dominated by vast park area. However, as the stream widens, the benefits of canopy cover are reduced. Canopy cover in the upper portions of the watershed where streams are narrow is actually more valuable. The fact that many of the urban areas in the upper portion of the mainstem Wissahickon Creek exhibit mostly intact canopy represents a significant ecological asset.

Despite the considerable ecological assets noted above, the Wissahickon Creek watershed also exhibits important ecological constraints related to urbanization that present significant water quality challenges.

- As shown below in Figure 4, 74% of the Wissahickon Creek watershed is urbanized. The negative impacts of historical urbanization on stream biological health (i.e., “urban stream syndrome”) are well documented and attributed primarily to the alteration of natural hydrology as well as degradation of riparian habitat, instream degradation from channelization and culverts, and increased erosion and sedimentation. The hydrology of the Wissahickon Creek watershed is also influenced by dewatering activities associated with limestone quarries such as Corsons Quarry, which pumps its water into Lorraine Run; dewatering can lower groundwater levels and thereby reduce baseflow.

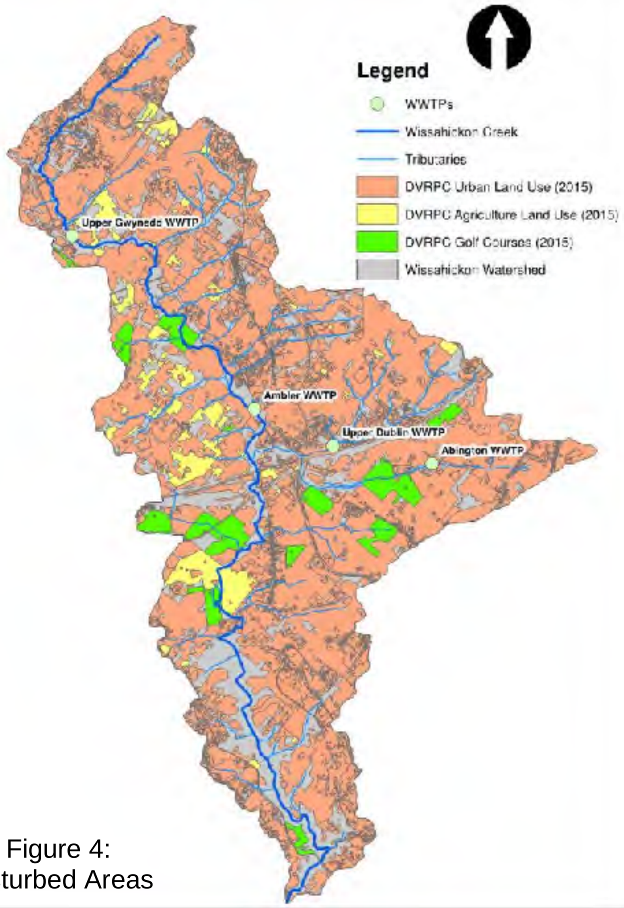


Figure 4:
Disturbed Areas

- While significant wooded areas exist in the park areas surrounding the lower portion of the mainstem Wissahickon Creek, there is little forested area in the remainder of the watershed. In fact, the watershed is developed all the way to its headwaters, as clearly shown in Figure 4. The proportion of watershed area covered by forest is among the most important correlates with good biological water quality. Forests produce little runoff, filter pollutants, and recharge groundwater that provides baseflow for the streams. Forests are important to the riparian areas, but equally important in the headwaters. The Wissahickon Creek watershed contains almost no forested headwater areas; the headwater of the mainstem is actually the Montgomery Mall and parking area.

- Golf courses can exert deleterious impacts on biological water quality due primarily to turf management and riparian degradation. As shown in Figure 4, there are more than a half dozen golf courses within the Wissahickon Creek watershed. These golf courses can significantly impact canopy and stream corridors, as shown in Photo 4 below.

- While canopy cover and riparian corridor in the mainstem Wissahickon Creek are relatively intact, many of the tributaries have little or no canopy or stream corridor, as shown in Figure 3 on page 3. The thermal and sedimentation impacts of the poor riparian cover in the tributaries may be affecting the mainstem as well.

Photo 4: Sandy Run at Manufacturers' Golf Club

Photo 5: Sandy Run crossing at Susquehanna Rd.

- Finally, it is important to recognize that the extent of urbanization has resulted in a large number of road crossings of streams throughout the watershed, as shown in Figure 5. Every single road crossing represents a potentially significant stressor to the stream due to channelization, hydraulic impacts, and stormwater impacts, all of which can be seen in Photo 5 on page 4 showing one road crossing one stream. The impervious cover data developed by the City of Philadelphia identified over 400 bridges in the Wissahickon Creek watershed, the vast majority (~80%) of which cross streams. The number of unidentified stream culverts under roads is certainly several fold higher than the number of identified bridges.

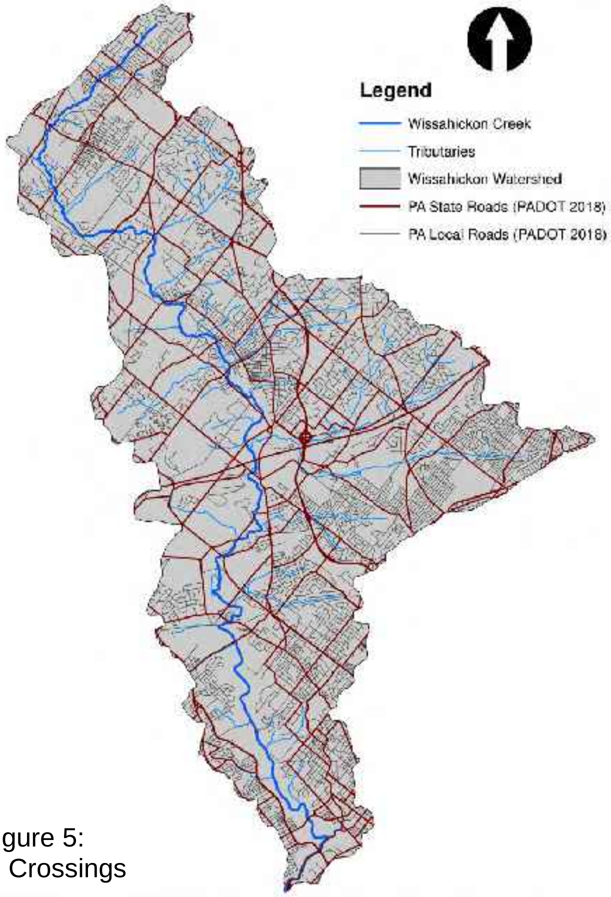


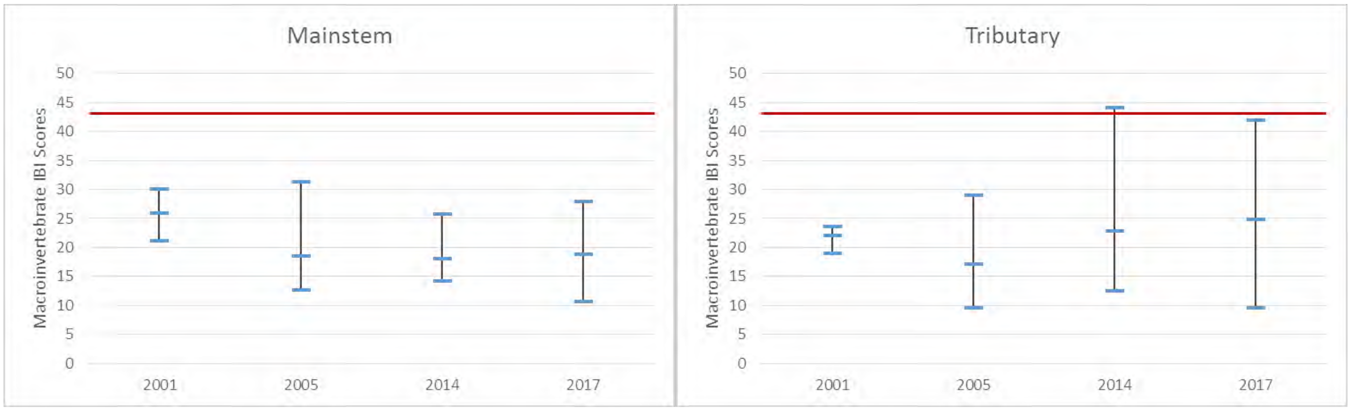
Figure 5:
Road Crossings

The Wissahickon Creek has been the subject of extensive characterization study, including: Wissahickon Creek Watershed Comprehensive Characterization Report, published by the Philadelphia Water Department (PWD) in 2007; Wissahickon Creek Stream Assessment Study of the Lower Wissahickon Creek Watershed, published by the PWD in 2010; and ongoing monitoring and assessment performed by the Wissahickon Valley Watershed Association. Over the last two years, more intensive monitoring and analysis was performed by Temple University on behalf of the Pennsylvania Environmental Council in order to provide a technical basis for the Committee to prepare a WQIP for the watershed.

Our watershed assessment focused on biological health and potential nutrient impacts. We relied primarily on these data sources: Temple University data collected expressly for this purpose; macroinvertebrate data collected by PWD, Pennsylvania Department of Environmental Protection (PADEP), and WVWA (assembled by Jason Cruz of PWD); and stream chemistry data collected at two locations by PADEP. We also reviewed the recent biological assessments documented for this project: 1) periphyton data collected by Temple University and analyzed by the Academy of Natural Sciences, and 2) historical macroinvertebrate data assessed by the Academy of Natural Sciences. Temple University performed extensive data collection and assessment specifically for this project, including long term data logging of depth, dissolved oxygen, turbidity, and nutrients at strategic locations. For the purpose of this focused assessment, we directly used the following data obtained by Temple University: 1) longitudinal grab samples collected during four events at locations upstream and downstream of point and nonpoint sources throughout the watershed and analyzed for stream chemistry; and 2) diurnal measurements of dissolved oxygen performed at locations upstream and downstream of point and nonpoint sources throughout the watershed. The resulting assessment can be summarized as follows.

- Stream biological condition, as measured by macroinvertebrate Index of Biological Integrity (IBI) scores (using PADEP methodology), is considered by PADEP to be poor. Picking four years during which many macroinvertebrate samples were taken throughout the Wissahickon Creek watershed, the graphs in Figure 6 below show the maximum, minimum, and average IBI scores in the mainstem and tributaries. The red line at an IBI score of 43 shows the threshold below which PADEP considers the waterbody biologically impaired. The vast majority of benthic assessments over many years and at multiple locations result in IBI scores substantially less than PADEP's impairment threshold. This finding is typical for urbanized watersheds such as the Wissahickon.

Figure 6: Historical Benthic IBI Scores in Wissahickon Creek Watershed



- Nutrients are abundant in streams throughout the watershed. Regarding nutrient impacts, two observations are significant.
  - Streams in the Wissahickon Creek watershed are periphyton dominated. Primary production (conversion of light to energy) in aquatic systems can be performed by one or more of these broad categories of producers: 1) phytoplankton (floating algae); 2) aquatic plants; and/or 3) periphyton (algae attached to rocks and other substrate in stream bed). There is no evidence that phytoplankton accumulate to any significant degree in the Wissahickon Creek watershed, and plants appear to be mostly insignificant. This indicates that primary production is being performed primarily by periphyton. The limited number of periphyton density measurements in the Wissahickon Creek watershed indicate that periphyton densities are elevated. However, there is no evidence that algal densities are considered to be at nuisance levels with regard to recreational uses at any locations in the Wissahickon Creek watershed. It is common for inland streams to be periphyton dominated, whether perturbed or natural.
  - Dissolved oxygen is monitored continuously by the United States Geological Survey (USGS) at two locations on the mainstem Wissahickon Creek: near the outlet at Ridge Avenue, and just downstream of Sandy Run at Skippack Pike. Diurnal dissolved oxygen swings provide a relative indication of productivity, since they are caused by primary producers pumping dissolved oxygen into the water column during the day as a result of photosynthesis and depleting oxygen at night due to respiration and decomposition. Diurnal dissolved oxygen swings at the two monitored locations in the Wissahickon Creek are often very large during critical low-flow periods, typically up to 5 mg/L/d at the outlet and up to 7.5 mg/L/d at Skippack Pike. Spring diurnal swings are even higher, up to 7.5 mg/L/d at the outlet and up to 15 mg/L/d at Skippack Pike. The higher productivity in spring is not uncommon, especially in periphyton-

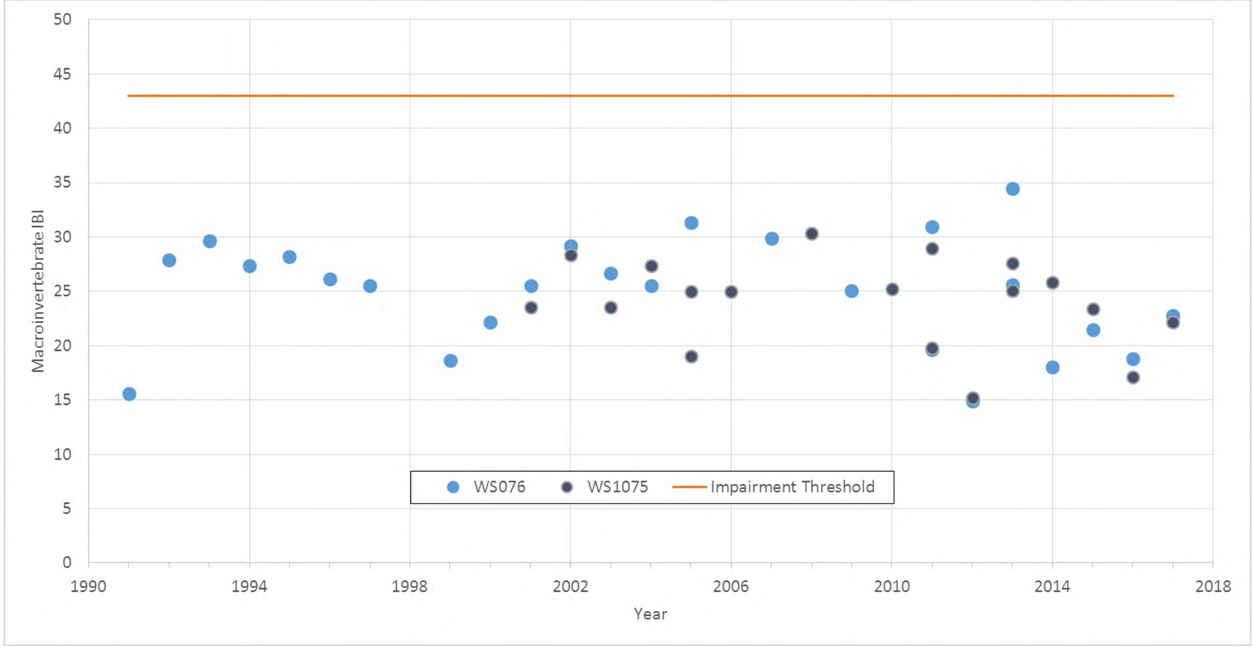
dominated systems. The spring bloom likely occurs before leaf out when more light can penetrate. Diurnal monitoring by Temple University indicates that the dissolved oxygen conditions at the USGS continuous monitoring locations are representative of many locations throughout the watershed. Furthermore, the observed level of diurnal dissolved oxygen swings is not atypical, especially for urbanized streams.

Regulatory Review

In its latest (2016) water quality assessment, PADEP designated streams in the Wissahickon Creek watershed (Pine Run and tributaries; Sandy Run and tributaries; Trewellyn Creek and tributaries; and Wissahickon Creek and tributaries) as impaired with respect to aquatic life. The basis for this assessment is primarily long-term macroinvertebrate sampling at two locations in the Wissahickon Creek mainstem: Wissahickon Creek downstream of Henry Avenue (WS076) and Wissahickon Creek at Skippack Pike (WS1075). IBI scores integrate six different ecological metrics that measure various aspects of macroinvertebrate communities and provide a useful assessment of aquatic life condition. Historical macroinvertebrate IBI results from PADEP and PWD at these locations are shown in Figure 7 below. As noted previously, the results in terms of IBI scores at the two PADEP assessment locations are not atypical compared to results at other locations in the mainstem as well as tributaries throughout the watershed. While these IBI scores are typical for streams in heavily urbanized watersheds, they are nonetheless lower than the threshold of 43 used by PADEP to designate aquatic life impairment.

PADEP attributed the causes of aquatic life impairments in various stream segments within the Wissahickon Creek watershed to “siltation, nutrients, and organic enrichment.” In 2003, USEPA Region 3 promulgated a TMDL for sediments and nutrients in the Wissahickon Creek watershed, which included wasteload allocations for $CBOD_5$, ammonia, nitrate, and orthophosphate from wastewater treatment plants (WWTPs), primarily to address low dissolved oxygen conditions. These wasteload allocations were implemented by PADEP in NPDES permits, resulting in significant treatment plant upgrades in 2008-2009. Nonpoint source load allocations for sediments and nutrients are being implemented within MS4 permits, triggering the requirement for Pollutant Reduction Plans (PRPs). Municipalities are currently in various stages of PRP development and implementation, with most having submitted draft PRPs and anticipating regulatory approval.

Figure 7: Historical Benthic IBI Scores in Wissahickon Creek Mainstem



While the 2003 TMDL did address nutrients, the focus of the nutrient targets was organic enrichment. In this context, "organic enrichment" means pollutants such as $CBOD_5$ and ammonia that decompose and thereby exert an oxygen demand on the system. USEPA Region 3 proposed another TMDL in 2015 designed to address biological impairment (low macroinvertebrate IBI scores) by reducing total phosphorus (TP) to a level of 0.04 mg/L in all streams in the watershed. Subsequent to the publication of EPA's 2015 Draft TP TMDL, 13 municipalities and four WWTPs within the Wissahickon Watershed established the Wissahickon Clean Water Partnership to pursue the development of a TMDL Alternative for improving water quality. A cursory evaluation of the wastewater and stormwater allocations that would have been imposed by the proposed TMDL demonstrates that the ambient water quality target of 0.04 mg/L TP is unachievable.

- Proposed wastewater allocations ranged from 0.033 to 0.072 mg/L TP, levels that may not even be technologically achievable.
- Stormwater from urbanized areas generally contains phosphorus at levels of around 0.2-0.4 mg/L TP, and even runoff in forested areas tends to contain approximately 0.1 mg/L TP.[1]

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[1] *Author collected extensive land use specific stormwater quality data for the Passaic River Basin and Raritan River Basin TMDL studies in New Jersey. Additionally, the International Stormwater BMP Database 2016 Summary Statistics and Appendix A of PADEP's 2006 Pennsylvania Stormwater BMP Manual provide additional stormwater quality data.*
(http://bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf)
(http://www.stormwaterpa.org/assets/media/BMP_manual/11_Appendix_A.pdf)

- Baseflow measured in the least impacted streams within the Wissahickon Creek watershed contains approximately 0.07 mg/L dissolved phosphorus and 0.08 mg/L TP.

Clearly, even if wastewater discharges were removed and the entire watershed were to be restored to a reference baseflow condition, the water quality target of 0.04 mg/L TP would not be achieved.

Equally important is to ask whether drastically reducing phosphorus in the Wissahickon Creek watershed would in fact improve benthic biological health as measured by IBI scores. This question will be explored more thoroughly in the subsequent section on Macroinvertebrate Impairment Causal Analysis. Broadly, phosphorus is regulated because it can stimulate excessive growth of plants and algae in freshwater systems, leading to eutrophication and consequent impairment of uses under certain conditions. PADEP does not have numerical nutrient criteria in its water quality standards, but relies on the following two criteria to impose phosphorus regulation under specific circumstances.

> *93.6.(a) "Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life."*
>
> *96.5.(c) "When it is determined that phosphorus impairs uses in a free flowing surface water, phosphorus discharges from point source discharges shall be limited to an average monthly concentration of 2 mg/l. More stringent controls on point source discharges may be imposed as a result of a TMDL."*

The simplest and most direct means of assessing whether plants and algae are growing quickly is to measure the secondary chemical changes in the water column caused by high rates of photosynthesis and respiration, namely high supersaturated concentrations of dissolved oxygen (and elevated pH) during the day followed by low dissolved oxygen at night when respiration continues in the absence of photosynthesis. Pennsylvania does have numerical criteria for both dissolved oxygen and pH, and PADEP has not designated waters in the Wissahickon Creek watershed as impaired for either parameter. However, as described previously, the Wissahickon Creek and its tributaries exhibit significant diurnal swings of dissolved oxygen. PADEP recently published a new Draft Eutrophic Cause Determination Protocol,[2] which broadly bases its assessment approach on the proposition that if: 1) benthic biology indicates impairment; and 2) phosphorus concentrations are elevated; and 3) productivity appears to be significant; then phosphorus must be the cause of the observed biological impairment. A cursory evaluation of PADEP's draft protocol indicates that Wissahickon Creek would likely be assessed as eutrophic, providing additional basis for regulators to link phosphorus levels to biological stream quality and regulate accordingly. As described below, this assessment approach is not without merit, but is not appropriate in every case due to the myriad factors affecting biological stream quality and the threshold nature of phosphorus impacts.

The proposed 2015 TMDL was based on the fundamental premise that phosphorus is a primary driver causing the poor macroinvertebrate IBI scores in the Wissahickon Creek, and that reducing phosphorus levels in the stream would improve benthic stream biology such that the scores would no longer indicate

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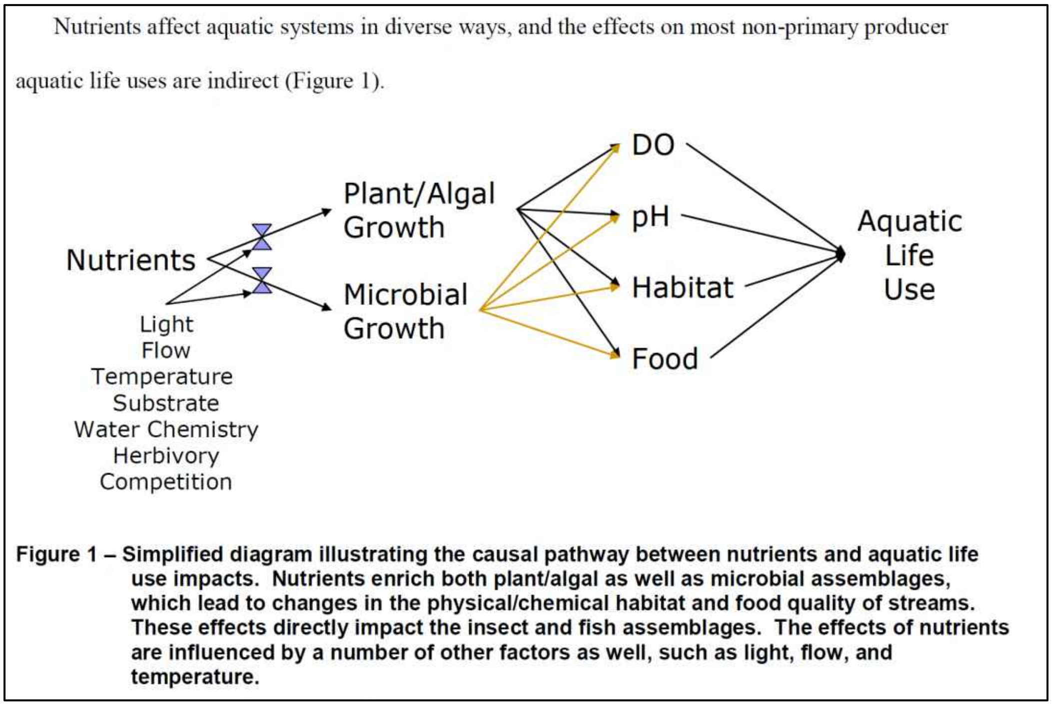
[2] *http://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Technical%20Documentation/EUTROPHICATION_CAUSE_DETERMINATION_PROTOCOL_Tech.pdf*

impairment. A stringent instream water quality target of 0.040 mg/L TP was developed to restore stream macroinvertebrates based on technical studies published in 2007 and 2012 (two reports). The studies were regional in nature, designed to apply to Northern Piedmont stream macroinvertebrates generally.

The conceptual model relied upon in both studies to relate phosphorus to biological health is reproduced in Figure 8 below. Note that the conceptual model acknowledges the many factors in addition to nutrients that are known to affect benthic stream biology: light, flow, temperature, substrate, water chemistry, herbivory, competition. Others could be added, such as top-down trophic impacts. The conceptual model also acknowledges that, to the degree nutrients impact aquatic life, that impact is indirect: nutrients impact algal growth directly, which leads to secondary chemical changes (e.g., dissolved oxygen swings), which lead to tertiary impacts on aquatic life. The study used multiple lines of evidence – a reference approach, a stressor-response approach, and a literature approach – to establish a recommended endpoint of 0.04 mg/L TP. Since many of the factors affecting stream biology co-vary with each another, the 2012 follow-up study performed stepwise regression and principal component analysis to further isolate the impact of nutrients.

It is worth noting that the conceptual relationship between phosphorus and aquatic life impacts begins with the stimulation of algal growth; therefore, except in systems like lakes where one might expect significant nutrient recycling, only available phosphorus sources have any potential to influence aquatic life. Any reduction of phosphorus sources to the Wissahickon Creek watershed should therefore focus on orthophosphorus or soluble reactive phosphorus rather than total phosphorus.

Figure 8: Conceptual Model from 2007 Study Establishing Water Quality Endpoint of 0.04 mg/L TP



Nutrients affect aquatic systems in diverse ways, and the effects on most non-primary producer aquatic life uses are indirect (Figure 1).

Figure 1 – Simplified diagram illustrating the causal pathway between nutrients and aquatic life use impacts. Nutrients enrich both plant/algal as well as microbial assemblages, which lead to changes in the physical/chemical habitat and food quality of streams. These effects directly impact the insect and fish assemblages. The effects of nutrients are influenced by a number of other factors as well, such as light, flow, and temperature.

NOTE: This figure is reproduced directly from:

Paul and Zheng, 2007, Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania: TMDL Application, USEPA Region 3.

The studies found that: 1) the majority of the variance in benthic biological metrics are associated with urbanization (e.g., imperviousness and flashiness), and 2) many urban sites exhibited poor benthic biological metrics despite having low phosphorus concentrations, "confounding" the nutrient relationship. Despite these findings, the studies were used to support the recommended endpoint of 0.04 mg/L TP. The studies are regional and somewhat generic in nature, but they provide a useful conceptual model that we can apply in a broad sense using extensive and local data from the Wissahickon Creek watershed. As will be shown below, the extensive study performed in the Wissahickon Creek watershed, especially over the last two years, provides ample real data to determine whether an instream phosphorus water quality target would improve stream biology as measured by macroinvertebrate IBI index scores.

Macroinvertebrate Impairment Causal Analysis

Many studies, including those referenced above that were used to develop a recommended instream endpoint of 0.04 mg/L TP for Northern Piedmont streams, have established that the degree of historical urbanization is the single most important factor that influences benthic ecological quality. A small sample is provided below.

- Walsh, *et al* (J. North Am. Benthol. Soc. 24(3):706-723) published a paper in 2005 entitled *The Urban Stream Syndrome: Current Knowledge and the Search For A Cure*. In it they conclude:

  > *"The term 'urban stream syndrome' describes the consistently observed ecological degradation of streams draining urban land. […] The mechanisms driving the syndrome are complex and interactive, but most impacts can be ascribed to a few major large-scale sources, primarily urban stormwater runoff delivered to streams by hydraulically efficient drainage systems. Other stressors, such as […] wastewater treatment plant effluents […] can obscure the effects of stormwater runoff. Remediation of stormwater impacts is most likely to be achieved through widespread application of innovative approaches to drainage design."*

- J.J. Steuer (Urban Ecosyst DOI 10.1007/s11252-010-0131-x) published a paper in 2010 entitled *A generalized watershed disturbance-invertebrate relation applicable in a range of environmental settings across the continental United States*. This study found that percent imperviousness was the most important (inverse) predictor of benthic biological metrics.
- Moore, A.A. and M.A. Palmer (Ecological Applications, 15(4):1169–1177) published a study in 2005 entitled *Invertebrate Biodiversity in Agricultural and Urban Headwater Streams: Implications for Conservation and Management*. This study drew two noteworthy conclusions: 1) "taxa richness was related negatively and linearly (no statistical threshold) to the amount of impervious surface cover;" and 2) "for the urban streams, there was a strong positive relationship between invertebrate diversity and riparian forest cover. Urban streams with high amounts of intact riparian forest exhibited biodiversity levels more comparable to less urban areas despite high amounts of impervious cover in their catchments."

The Water Environment Research Foundation published a monograph in 2007 (Barbour, *et al*, *Bioassessment: A Tool for Managing Aquatic Life Uses for Urban Streams*, Research Digest 01-WSM-3) that provides a methodology to establish aquatic life goals for urbanized streams. It summarizes the factors of urbanization known to impact aquatic life, as follows.

> *"The activities with the greatest impacts on aquatic in urban catchments include the wholesale alteration of catchment hydrology, loss and degradation of riparian habitat, direct instream habitat degradation via channelization and culverting, excessive*

> *sedimentation resulting from historical and recent land disturbance activities and stream bank erosion (strongly linked to riparian encroachment), and contributions of excessive nutrients, oxygen-demanding wastes, and toxic pollutants via urban runoff, point source discharges (both permitted and unpermitted), spills, and other releases."*

Broadly, these factors can be aggregated into: hydrologic changes, riparian degradation, channel disturbances, sedimentation, stormwater discharge, and point source impacts. Each of these factors is discussed below with regard to the Wissahickon Creek watershed.

- There is wide agreement that hydrologic changes as a result of historical urbanization (i.e., prior to modern stormwater controls) exert the most important impact on aquatic life, as evidenced most directly by the clear and strong inverse relationship between degree of imperviousness and aquatic life metrics. In fact, the technical literature[3] refers to hydrology as the "master variable" affecting aquatic life. One study of 67 upland streams in the northeastern United States[4] found that one hydrologic attribute alone accounted for up to 65% of benthic variability.

  As described previously, the Wissahickon Creek watershed is 74% urbanized, resulting in 23% impervious land cover. Altered hydrology is the most important driver impacting aquatic life in the Wissahickon Creek watershed.

- As discussed previously, many of the stream segments in the Wissahickon Creek watershed are designated as impaired due to "siltation" and therefore subject to the 2003 TMDL to address sedimentation. The reduction of sediment loads is a primary objective of the PRPs developed by municipalities in the watershed as part of their MS4 programs. Research performed by Temple University identified turbidity as an important metric affecting benthic communities due to the accretion of fine materials affecting bed habitat. Whether quantified as suspended solids or turbidity, sedimentation directly affects benthic habitat and therefore aquatic life. Sedimentation is an important driver affecting aquatic life, as would be expected given the proportion of urbanized areas and the extensive road network throughout the Wissahickon Creek watershed.

- While the lower portion of the mainstem Wissahickon Creek exhibits impressive riparian forested areas due to the park systems, portions of the upper mainstem and most of the major tributaries exhibit little if any riparian corridor even in the headwater areas. The small amount of intact forested areas within the watershed and especially the headwater and riparian areas in the upper portion likely accounts for a substantial degree of aquatic life degradation in the Wissahickon Creek watershed.

- The extensive road network and sheer number of stream crossings and consequent culverting throughout the watershed ensure that channel disturbance is an important factor affecting aquatic life.

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[3] *For example: Mazor, R.D. et al. 2018. <u>Tools for managing hydrologic alteration on a regional scale:Setting targets to protect stream health</u>. Freshwater Biology. 2018;63:786–803.*

[4] *Kennen, Jonathan & Riva-Murray, Karen & Beaulieu, Karen. 2009. <u>Determining hydrologic factors that influence stream macroinvertebrate assemblages in the northeastern US</u>. Ecohydrology 3:88-106.*

- Stormwater discharge can introduce loads of suspended sediment, nutrients, biological oxygen demand, and toxics. Of these, there is no indication that toxics are prevalent in the Wissahickon Creek watershed. However, stormwater discharge contains substantial quantities of sediments and, along with bank and bed erosion, will affect sedimentation. Stormwater discharge in the Wissahickon Creek watershed therefore represents a significant source of sediment, associated organic material, and nutrients.
- In the Wissahickon Creek watershed, remaining point source[5] impacts can be further narrowed down to phosphorus discharges. The contribution of oxygen-demanding wastes (ammonia and BOD_5) was reduced due to upgrades performed in 2008-2009 as a result of the TMDL established in 2003; levels in the streams are insignificant during dry weather (<0.1 mg/L ammonia and non-detect BOD_5). Regarding phosphorus, point sources account for a significant portion of the phosphorus in the Wissahickon Creek, Sandy Run, and Pine Run. Phosphorus is required for algal growth, and algal growth is significant in the Wissahickon Creek and may well be indirectly affecting aquatic life. However, as explained in more detail below, the impact of phosphorus on algal growth and aquatic life in the Wissahickon Creek watershed would be the same regardless of the degree of point source contributions.

Having reviewed the factors that can potentially affect aquatic life in the Wissahickon Creek watershed, we now turn to the available “Control Knobs” – what types of management measures can improve aquatic life? Broadly speaking, there are four types of control knobs that might be expected to mitigate the factors listed above and thereby improve aquatic life. These are listed below and described as they relate to the factors affecting aquatic life in the Wissahickon Creek watershed.

- Stormwater Management represents the principal means available to restore a more natural hydrologic regime by decreasing runoff rates and volumes and enhancing baseflow. Moreover, stormwater management measures can directly improve stream corridors, mitigating riparian degradation. Stormwater improvements to stream crossings can directly mitigate stream channel disturbances, and of course stormwater management directly affects sediment loads and therefore mitigates sedimentation. In addition, stormwater management can reduce rates of stream flows, which also mitigates sedimentation by decreasing instream erosion. Because it can address hydrologic impacts and also mitigate the other factors affecting aquatic life, stormwater management is certainly the most important control knob available to improve aquatic life in the Wissahickon Creek watershed.
- Riparian Improvements, in addition to the obvious direct mitigation of riparian degradation, can also improve hydrologic impacts and reduce the loads of sediments reaching the stream. The extent of forest cover, especially along riparian areas and headwater areas, is an important control knob that can be expected to improve aquatic life in the Wissahickon Creek watershed. Riparian improvements also extend canopy, which directly reduces algal growth rates by limiting light availability. Canopy improvement would be most effective along the southern banks of the many east-west oriented tributaries that currently have little or no canopy cover.

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[5] *In this context, point source is reserved to mean wastewater discharges. Stormwater discharge from urban areas is regulated as a point source, but discussed separately.*

- Instream Restoration can directly mitigate channel disturbances, and also reduce sedimentation by decreasing instream erosion.
- WWTP Upgrades principally affect wastewater loads of phosphorus, and would provide little other benefit that could reasonably be linked to aquatic life. For reasons that will be described more completely below (see section entitled *Why phosphorus reduction is not a useful "Control Knob"*), it is apparent that reducing phosphorus loads would not restore aquatic life in the Wissahickon Creek watershed. Also, reducing phosphorus loads from treatment plants brings secondary environmental costs, principally increased use of chemicals and greatly increased sludge production. Having no effect on the objective (aquatic life restoration), and nonzero secondary environmental impacts, this would make it a particularly ineffective control knob. As stated previously, to the extent that reductions of phosphorus loads from point sources are implemented, these reductions should focus on orthophosphorus, which is available to support algal growth, rather than total phosphorus.

Table 1 below summarizes which factors affecting aquatic life can be addressed by each of the broad control knobs described above.

Table 1: Control Knobs to Mitigate Factors Affecting Aquatic Life

	"Control Knobs"			
Factors Potentially Affecting Aquatic Life	Stormwater Management	Riparian Improvements	Instream Restoration	WWTP Upgrades
Hydrologic Changes	X	X		
Sedimentation	X	X	X	
Riparian Degradation	X	X		
Channel Disturbances	X		X	
Stormwater Loads	X			
Wastewater Loads				X

Why phosphorus reduction is not a useful "Control Knob"

Recall from the conceptual model reproduced on page 10 that the potential link between phosphorus and aquatic life quality is through the direct stimulation of excessive algal (or plant) growth, which affects diurnal dissolved oxygen and can lead to indirect impacts on benthic aquatic life. Phosphorus is elevated in most streams in the Wissahickon Creek watershed, particularly those impacted by wastewater discharges (Pine Run, Sandy Run, and the mainstem Wissahickon Creek). In addition, algal (periphyton) density and growth rate ("productivity") are high at many locations throughout the Wissahickon Creek watershed. However, as explained below, reducing phosphorus loads to the Wissahickon Creek watershed would not decrease algal productivity. Recall that algal growth is conceptually the most direct impact of phosphorus; if the most direct impact of reducing phosphorus loads would be negligible, clearly any potential indirect impacts, such as improvement to aquatic life, would be equally negligible.

- Phosphorus levels in the Wissahickon Creek watershed cannot be reduced to levels that will restrain algal growth. It is well established that algal growth rate exhibits a threshold-type response, and that the threshold occurs at a very low concentration of available phosphorus. As a result, only a small concentration of phosphorus is needed to support maximum periphyton growth rates. The study performed for USEPA Region 3 and used to establish a recommended instream endpoint of 0.040 mg/L TP (Paul and Zheng, 2007, Development of Nutrient Endpoints for the Northern Piedmont Ecoregion of Pennsylvania) cited the range of "algal growth saturation" at 0.025 to 0.050 mg/L available phosphorus. Nutrient limitation is typically simulated using half-saturation values (the phosphorus concentration at which algal growth rate is 50% of maximum) that generally range from 0.001 up to 0.007 mg/L.[6] The algal saturation range can be estimated as approximately ten times the range of half-saturation values (i.e., 0.01 to 0.07 mg/L). As shown in Figure 9 below, this is consistent with the range of effective saturation cited in the USEPA Region 3 report of between 0.025 and 0.050 mg/L available phosphorus. Additional phosphorus above the saturation level will not result in higher algal growth rates.

Prophecy Creek in the Wissahickon Creek watershed receives no point source discharge and is considered the least impacted by urbanization. A substantial portion of the sub-watershed drains Prophecy Creek Park and Briar Hill Preserve, the entire length of Prophecy Creek benefits from an intact riparian corridor with mostly dense canopy, and the creek is crossed by only a few roads. PWD's Comprehensive Characterization Report for the Wissahickon Creek Watershed (2007) noted that Prophecy Creek exhibits the best resident fishery community in the entire watershed. Prophecy Creek therefore provides the best reference condition in the watershed. Phosphorus in Prophecy Creek was measured quarterly over a one year period by Temple University; two of those quarterly samples captured baseflow conditions, which average 0.071 mg/L dissolved phosphorus. This baseflow phosphorus concentration is nearly identical to that observed in other areas of the Wissahickon Creek watershed upstream of the influence of point sources, according to the same dataset. In other words, available phosphorus concentrations in baseflow, even in the most unimpacted areas, exceeds the range of algal growth saturation and the USEPA-proposed level of 0.04 mg/L. This reality is illustrated in Figure 9 below showing nutrient threshold kinetics. The reference baseflow concentration coincides with the high end of the algal saturation range, meaning that algal growth rates will be essentially the same at any available phosphorus concentration equal to or higher than the reference baseflow concentration.

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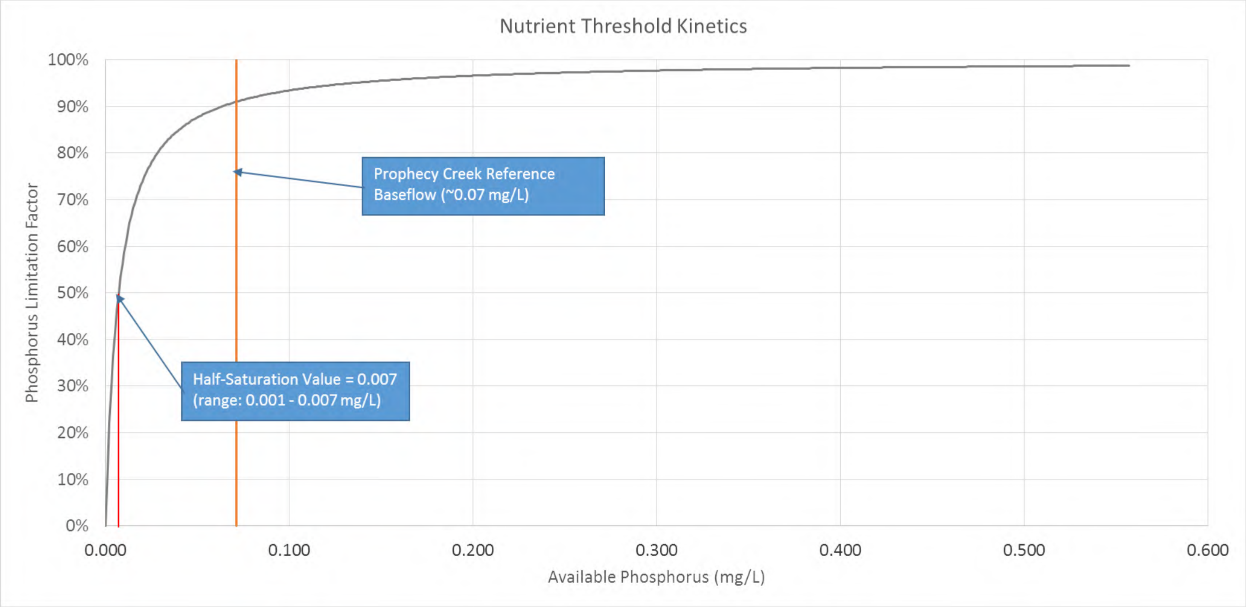
[6] *For instance:*

Thomann, R.V. and Mueller, J.A., 1987, Principles of Surface Water Quality Modeling and Control, Harper-Collins, New York, 644 p – recommends P-hsat range of 0.001 to 0.005 mg/L.

Hill, WR et al *(Limnol. Oceanogr., 54(1), 2009, 368–380) experimentally established a phosphorus saturation level of 0.025 mg/L specifically for periphyton. This is equivalent to a half-saturation value of approximately 0.0025.*

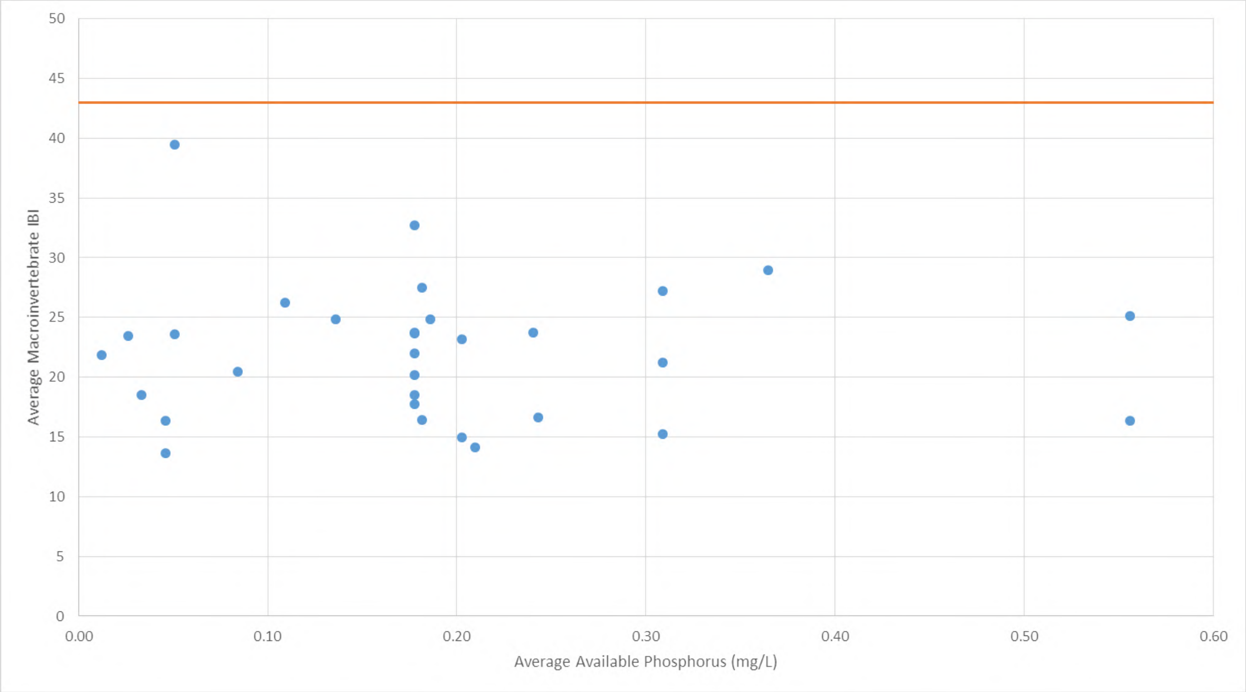
Figure 9: Why Phosphorus Levels Cannot Be Reduced to Levels That Will Restrain Algal Growth



- While the concepts of algal growth kinetics are well established, there is no need to rely on theory to demonstrate that macroinvertebrate index scores do not correlate with phosphorus in the Wissahickon Creek watershed.

  A significant nutrient gradient exists in the Wissahickon Creek and its tributaries, meaning that different locations exhibit different levels of phosphorus. Using the macroinvertebrate IBI dataset assembled by the PWD, we selected recent measurements (since 2010) for all locations in the watershed for which an average available phosphorus concentration could be assigned based on Temple University's longitudinal data or PADEP's water quality data in STORET database. Figure 10 below shows average IBI scores at each location versus average available phosphorus (total dissolved phosphorus or orthophosphorus). The lack of any correlation between IBI scores and phosphorus across a wide range of available phosphorus concentrations demonstrates that phosphorus is not driving aquatic life impairment as measured by macroinvertebrate IBI scores in the Wissahickon Creek watershed. This includes data from three tributaries (Lorraine Run, Paper Mill Run, and Trewellyn Creek) that happen to exhibit phosphorus concentrations below the baseline reference concentration. All exhibit very near the average IBI score for the entire watershed and show no indication of better quality aquatic life than other locations in the watershed with much higher phosphorus concentrations.

Figure 1: Impact of Phosphorus Concentration on IBI Scores in Wissahickon Creek



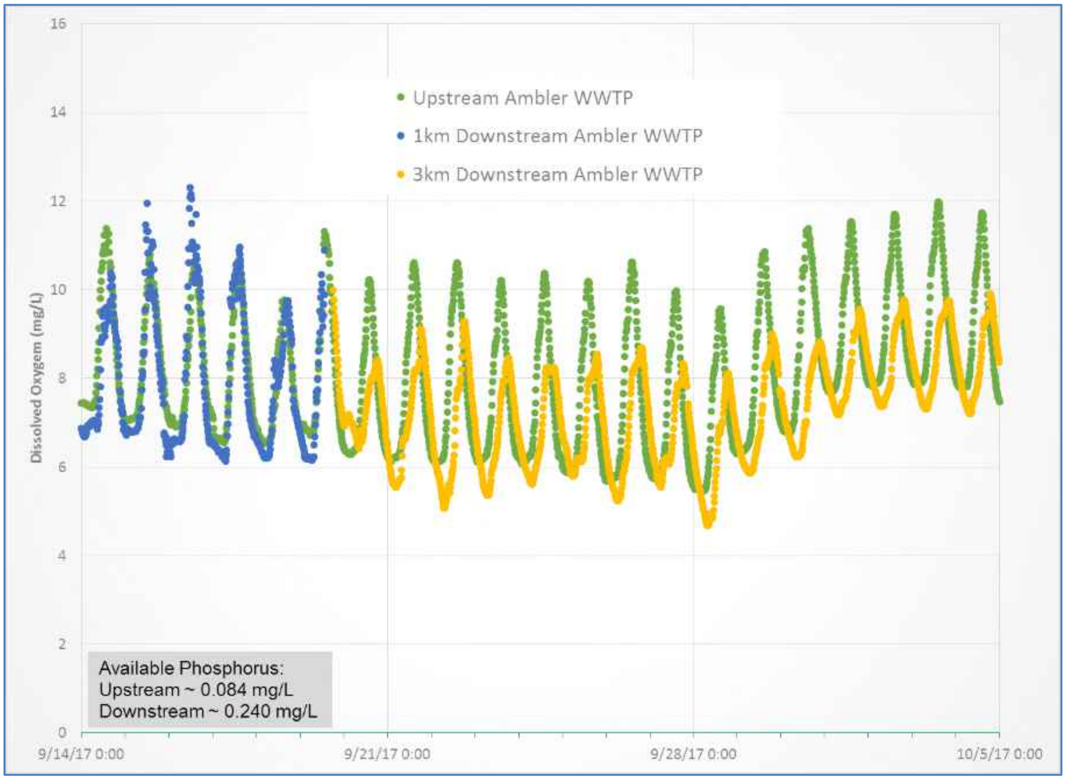
The same demonstration can be made by looking at IBI scores before and after the wastewater treatment plant upgrades in 2008-2009. We compared IBI scores from 2001-2007 to those from 2010-2017 at locations downstream of treatment plants, as shown in Figure 11 below. IBI scores did not improve substantially when treatment plants upgraded in 2008-2009, despite the fact that instream available phosphorus concentrations decreased by a factor of three-to-four times depending on location. Any marginal improvement can be attributed to the fact that the plant upgrades also decreased organic loads (ammonia and $CBOD_5$).

Figure 11: Average IBI Scores Downstream of WWTPs Before and After 2008-2009 Upgrades

- Diurnal dissolved oxygen variation (an indicator of algal productivity) also does not correlate with phosphorus levels in the Wissahickon Creek watershed. Since diurnal dissolved oxygen variation is caused by primary productivity (i.e., algal growth), the fact that lower phosphorus concentration does not decrease diurnal dissolved oxygen variation demonstrates that algal growth is not sensitive to phosphorus levels. In other words, lower phosphorus levels do not change the algal growth rates; obviously, if lower phosphorus levels do not even change algal growth rates, they would certainly not produce any secondary (i.e., less direct) benefits such as improved aquatic life metrics.

  Using the continuous data obtained by Temple University for this project, we compared diurnal dissolved oxygen results upstream and downstream of the Ambler WWTP during periods of time when flows were steady and the meters and dataloggers appeared to be capturing meaningful data simultaneously. As expected, available phosphorus conditions were higher downstream of the WWTP; however, the amplitude of dissolved oxygen swings did not increase. This comparison is provided below in Figure 12.

Figure 12: Diurnal Dissolved Oxygen Upstream and Downstream of Point Source



Available Phosphorus:
Upstream ~ 0.084 mg/L
Downstream ~ 0.240 mg/L

In summary, phosphorus reductions will not restore aquatic life in the Wissahickon Creek watershed because the controllable levels of phosphorus are still higher than algal saturation levels. The response of algal growth rate to nutrient concentration can be described as a threshold-type response, meaning that sensitivity to nutrient concentrations occurs over a narrow range of nutrient concentration. Whether nutrient concentrations are a little higher or much higher than the saturation level will not have any impact on algal growth rates. In the Wissahickon Creek watershed, that saturation level is below even reference baseflow conditions, and much lower than can be achieved through phosphorus reduction measures. By contrast, stormwater management, riparian improvements, and instream restoration can be expected to produce incremental improvements to aquatic life, since biological responses to these types of controls, while not necessarily linear, do not exhibit threshold-type responses. In other words, mitigation of drivers (e.g., hydrologic improvements and reduction of sedimentation) can be expected to improve aquatic life regardless of the existing level of driver perturbation.

WQIP Strategy

In its 2016 Integrated Water Quality Monitoring and Assessment Report, PADEP placed the aquatic life use impairments in the Wissahickon Creek watershed on Category 5alt, which means: "waters impaired for one or more designated uses by any pollutant that have been selected for water quality standards restoration through alternatives to TMDLs." The Water Quality Improvement Plan being developed by the Management Committee will provide an alternative to a TMDL to address aquatic life use impairments in the Wissahickon Creek watershed.

Based on the watershed assessment, regulatory review, and causal analysis presented above, we recommend that the Management Committee focus its WQIP on "control knobs" that impact the factors known to affect aquatic life. The state of the science does not allow us to quantify the degree of aquatic life improvement that various management controls can be expected to achieve. Nonetheless, enough is known to at least identify the right control knobs that can be expected to incrementally improve aquatic life over time in the Wissahickon Creek watershed.

- Stormwater Management controls should be focused on restoring a more natural hydrologic regime, reducing sedimentation, reducing channel disturbances, and restoring riparian areas. Practically, this means measures to: decrease runoff rates and volumes, enhance baseflow, reduce sediment loads, and minimize the hydraulic impacts of stream crossings.
- Riparian Improvements should be focused on increasing the extent of riparian forest cover, especially along the southern banks of the many east-west oriented tributaries that currently have little or no canopy cover.
- Instream Restoration should be focused on decreasing instream erosion and mitigating hydraulic channel disturbances.

It is important to understand that significant mitigation of drivers such as hydrologic alterations is difficult to achieve over an entire watershed. An adaptive management approach will therefore be best suited to achieve incremental improvements over time. Furthermore, historical urbanization will limit the improvement of macroinvertebrate scores. The low IBI scores prevalent in the Wissahickon Creek watershed are not atypical for watersheds with this degree of urbanization. While PADEP considers any IBI score under 43 an indication of impairment, we recommend that the Management Committee develop its own interim aquatic life use goals that are customized for this region and that directly acknowledge the factors of urbanized watersheds that affect aquatic life. The Research Digest referenced previously (Barbour, *et al*, 2007, *Bioassessment: A Tool for Managing Aquatic Life Uses for Urban Streams*, Water Environment Research Foundation) provides an excellent methodology that could be adapted for this purpose. Such an effort would greatly facilitate the adaptive management approach that the Management Committee will need to use to address aquatic life use impairments in the Wissahickon Creek watershed.

In preparing and implementing a WQIP, we recommend that the Management Committee integrate its efforts with other regulatory programs, namely the MS4 Pollutant Reduction Plans and the Act 167 Plan.

- The Pollution Reduction Plans required under MS4 stormwater permits for municipalities subject to siltation TMDLs are intended specifically to address sedimentation, which was identified previously as an important factor affecting aquatic life in the Wissahickon Creek watershed. These provide a natural starting point, given that stormwater management was identified as the most important control knob to improve aquatic life.

- The Wissahickon Creek Watershed Act 167 Plan (2014) addresses flooding. Measures to prevent flooding directly mitigate hydrologic alterations due to urbanization, which was identified as the most important factor affecting aquatic life. Flooding involves the arrival of too much water at the same time and place in the watershed; better distribution of flows mitigates flooding but also results in a more natural hydrologic regime, which benefits aquatic life.

Finally, we recommend that the Management Committee measure progress not only by tracking macroinvertebrate IBI scores, but also by developing program implementation measurements such as area treated by BMPs, percent of “water quality volume” (stormwater quality design storm) infiltrated over the watershed, and addition of riparian wooded areas. These types of metrics will also facilitate an adaptive management approach to address aquatic life use impairments in the Wissahickon Creek watershed.

Appendix 8

MS4 Community Plans

MS4 Community Plans

For the Water Quality Improvement Plan (WQIP), seven of the 13 municipalities' MS4-related documents were reviewed. An eighth was reviewed but lacked the necessary information for the WQIP. Many of these documents are under review by the Pennsylvania Department of Environmental Protection (PADEP). They were also developed prior to the WQIP. As such, project specifics are subject to change.

Three municipalities – Lansdale Borough, Springfield Township, and Upper Dublin Township – have stated in the plans that accompany their current MS4 permits that their TMDL-required sediment load reductions have been met through existing BMPs. The City of Philadelphia also has met its sediment removal requirements for the 2003 Nutrient and Siltation TMDL. Abington Township and Upper Gwynedd Township both have large load reduction requirements to meet the 2003 Nutrient and Siltation TMDL. Lower Gwynedd Township and Whitpain Township have load reductions in the mid-range for the watershed.

Abington Township

In their draft TMDL Plan and PRP[1], Abington Township identified specific pollutant control measures to achieve the 73% reduction in sediment from the 2003 Nutrient and Siltation TMDL. The township estimates that it can achieve a siltation reduction of 537,629 pounds per year (lbs/yr) by using existing and new (to be constructed) BMPs. These measures are also estimated to reduce 2,428 lbs/yr of nitrogen and 533 lbs/yr of phosphorus. The existing and proposed measures will meet the WLAs for nutrients in the 2003 Nutrient and Siltation TMDL. Abington Township has or will implement a total of 18 BMPs to comply with the 2003 Nutrient and Siltation TMDL TMDL.

Cheltenham Township

Cheltenham Township has developed a PRP that includes implementation strategies to reduce sediment pollutant loads by 10% and phosphorus load by 5%[2]. In preparing its plan, Cheltenham Township analyzed available public land opportunities using geospatial considerations, drainage area delineations, site evaluations and other tools, to determine the projects with the highest suitability for implementation. The township also evaluated opportunities for private land with potential for public/private collaboration for green stormwater infrastructure and stream restoration. The township plans to evaluate these opportunities further to identify specific projects. A proposed project at Carroll Brooke Park to convert the existing eroded drainage feature to a stabilized bioswale is found in Section 4.2.3. of this report.

Borough of Lansdale

In July of 2017, an updated TMDL Plan report was prepared for Lansdale Borough to reflect new guidance from PADEP[3]. The updated report was developed concurrently with the Borough's PRP and addresses sediment and total phosphorus pollutant loading in the 5-year permit term beginning in 2018. Upon permit coverage, the Borough will also implement Pollutant Control Measures (PCMs). Lansdale Borough has already achieved sediment reductions that exceed the Borough's TMDL obligations in the Wissahickon

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[1] BCM Engineers (2017). Total Maximum Daily Load Plan Pollutant Reduction Plans Pollutant Control Measures – Draft Report. Prepared for the Township of Abington, Montgomery County, PA. May 3, 2017.

[2] Cheltenham Township (2017). Cheltenham Township Pollutant Reduction Plan: Tookany Creek Requirements – Appendix E – Organic Enrichment/Low D.O., Wissahickon Creek Requirements- TMDL Plan Siltation & Suspended Solids – Appendix E – Nutrients. August 2, 2017, Revised September 8, 2017.

[3] AKRF (2017). Borough of Lansdale MS4 TMDL Plan Report. Prepared for Pennsylvania Department of Environmental Protection. Revision to June 2016 TMDL Strategy Report. July 2017.

Creek Watershed through previously implemented (post-TMDL) control measures. These control measures include the Borough street sweeping program and the Wissahickon Creek Park Stream Corridor Project, which included infiltration basins, bioretention, riparian forest buffer, and stream bank restoration. These projects collectively reduce sediment load by 157,330 lbs/yr, exceeding the required load reductions by 65,338 lbs/yr.

The Borough over many years has adopted ordinances to establish needed authorities to comprehensively manage stormwater. The ordinances that regulate and guide stormwater management in Lansdale Borough are contained in the Borough Sub-Division and Land Development Ordinance (SALDO), which embodies the Borough's regulations and authorities for comprehensive stormwater management. The Borough routinely seeks to identify any inconsistencies and update stormwater regulations/code in its SALDO or zoning ordinances to improve stormwater pollution controls or eliminate restrictions for green stormwater management implementation.

The Borough is also implementing a participation plan to inform the public about its stormwater management program, specifically the Borough's TMDL program, its goals, proposed control measures, and to solicit public input on the updated Lansdale Borough MS4 TMDL Plan. The Borough maintains a public education and outreach program as part of its overall stormwater program that aims to enlist public participation in stormwater management activities.

Lower Gwynedd Township

In August of 2017, Lower Gwynedd Township prepared a draft TMDL Plan and PRP [4]. The 2003 Nutrient and Siltation TMDL requires a 5% reduction in nutrient loads from the township and for the township to establish compliance with the sediment WLA. According to guidance received from PADEP, achieving a 10% reduction in sediment will also result in nutrients reductions of five percent (5%). The goal of the current PRP is to demonstrate that a 20% reduction in sediment (245,117 lbs/yr) can be achieved in the next five years, keeping the Township on track for full compliance in 25 years. The Township plans to achieve the sediment reduction by designing, constructing, operating and maintaining BMPs including basin retrofits and streambank restoration.

Lower Gwynedd intends to apply for related grants, such as Growing Greener, Watershed Restoration Protection, and others to fund these projects. The municipality intends to utilize general funds to cover the design and construction costs for the proposed BMPs should grant money not be awarded. Once the PRP has been approved by PADEP, Lower Gwynedd intends to authorize design of the BMPs, at which time a feasibility and cost analysis will be prepared to determine the order of BMP implementation.

City of Philadelphia

The 2003 Siltation TMDL set the base sediment load from the Philadelphia portion of the watershed at 1,547,690 lbs/yr. The Waste Load Allocation (WLA) was set at 380,861 lbs/yr, therefore requiring a reduction of 1,166,829 lbs/yr of sediment. Philadelphia's strategy for TMDL compliance was to focus on meeting the sediment load reduction target of 1,166,829 lbs/year through a variety of approaches, including stream restoration, stormwater treatment wetlands, inlet catchbasin cleaning, and implementation of the City of Philadelphia's Stormwater Management Regulations. Through the implementation of the 2012 Wissahickon Siltation TMDL Plan the City of Philadelphia has exceeded the

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[4] Gilmore & Associates, Inc. (2017). Total Maximum Daily Load (TMDL) & Pollutant Reduction Plan for Lower Gwynedd Township, Montgomery County, PA – Draft Report. August 1, 2017.

sediment load reduction target, with a total calculated sediment load reduction of 1,458,838 lbs/year**Error! Bookmark not defined.**.

Upper Gwynedd Township

Upper Gwynedd Township drafted a TMDL Plan in 2015[5]. The Township's MS4 permit requires development of implementation plans or design details to meet sediment reductions through watershed restoration and other programmatic measures including the reduction of pollutant loadings to meet WLAs under the 2003 Nutrient and Siltation TMDL, which includes a 550,585 lbs/yr WLA of sediment for Upper Gwynedd Township.

Through years of prudent planning, Upper Gwynedd Township has amassed a considerable holding of open space land (approximately 587 acres) throughout the township, which provide an opportunity to meet goals for pollutant reduction. The Township can design practices that can make a significant impact on its pollution reduction goals without the need to acquire any additional property. Several of the sites have a high degree of sediment and nutrient removal potential. The plan includes programs and projects that show considerable promise in helping the Township meet its share of pollution reduction goals for the Wissahickon and Skippack Watersheds.

Whitemarsh Township

Whitemarsh Township drafted a PRP in 2017[6]. In this plan, the existing load was recalculated by removing land area that does not drain to the Township's MS4 in accordance with PADEP guidelines. This "parsing" effectively reduces the existing load of sediment. Estimates of existing sediment and nutrient loads, as well as expected reduction, were provided but appear to be missing information.

The PRP includes implementation of BMPs such as rain barrels, rain gardens, planting of native trees, and the construction of a water quality filters along with other restoration activities. Future BMPs under consideration include the distribution of residential rain barrels, street sweeping, and additional tree planting.

MS4 Annual Reports

As part of the current MS4 permit requirements, the municipalities documented their development of a manual for improved Operation and Maintenance strategies of existing post construction stormwater management BMPs and pollution prevention related to municipal vehicle operations. Guidance was provided on appropriate timing for maintenance and repairs of stormwater facilities. These ongoing efforts are an example of the significant work that the municipalities in the watershed have already undertaken to reduce the impacts of their MS4 discharges on the Wissahickon Creek and its tributaries.

Abington Township reported storm drain stenciling by the Environmental Advisory Council, watershed partners and municipal staff. New stormwater inlets that were installed have "No dumping – Drains to Creek" directly formed into the casting.

Abington Township reported offering "Go Green Rewards Cards" through Shop Local registered businesses. The cards are provided to residents who Attend Environmental Advisory Committee

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[5] T&M Associates (2015). Upper Gwynedd Township TMDL Implementation Plan – 2015. Prepared for the Pennsylvania Department of Environmental Protection - Draft, In Collaboration with Wissahickon Valley Watershed Association and Perkiomen Watershed Conservancy. December 2015.

[6] T&M Associates (2017). Whitemarsh Township MS4 Pollution Reduction Plan (PRP) – Draft for Public Review. Prepared for Whitemarsh Township, Montgomery County, Pennsylvania. April 2017.

meetings/events, install a rain barrel or rain garden on their property, create Audubon Bird Habitat, or reduce greenhouse gas emissions.

Montgomery Township reported an initiative by the Shade Tree Commission to distribute 450 free trees to residents for Arbor Day.

Montgomery Township has developed a basin naturalization program and to date has naturalized 55 of the 65 municipal owned basins. Educational signage has been installed at 31 basins which describe the intent of the naturalization practice.

The Borough of Ambler was awarded funding through PADEP's Growing Greener program to install 250 rain barrels, 250 downspout planter boxes, 75 rain gardens, and 20 stream buffers on residential properties.

The City of Philadelphia maintains a Waterways Restoration Team, a clean-up team dedicated to removing cars, waste and other debris from receiving waters. The team has expanded into minor stream repairs around outfalls and monitoring and maintenance to prevent clogging.

Philadelphia reported expanded outreach of the dog waste program into community parks, city parks, and at local events.

Residential is the predominant land use in the Wissahickon Creek Watershed. Implementing projects in partnership with residential communities empowers residents to lead by example through demonstration of local green stormwater management practices. Local examples lead to further acceptance of practices which better manage stormwater and provide nonpoint source pollution reductions. Similar residential green stormwater infrastructure programs in the Wissahickon include Philadelphia's RainCheck and the Wissahickon Valley Watershed Association (WVWA) Stream Smart programs. Philadelphia has also produced a Homeowner's Stormwater Handbook – Smart Stormwater Management: A How-to for Homeowners. The document includes tips and information that can guide homeowners on the latest tools and resources

Appendix 9

Wastewater Treatment Plant Data

Appendix 3: Data provided on Waste Water Treatment Plants

Data on discharge and TP concentrations were obtained from the WTPs (Table A3-1) and from electronic discharge monitoring records (eDMRs) from April 2016 to August 2017 (Table A3-2). Note that Upper Gwynedd WWTP values were estimated (average of the other data points; n = 12) for five months in 2017 where data were not available for this period because it is the most complete record at the other three WWTPs.

The data summaries provided in this report are primarily focused on total phosphorus (TP), although the eDRM only reported orthophosphate values (oP or PO_4). The daily data, which included both oP and TP values, was used to determine the percentage of TP that was present as oP. All of the graphs and tables with TP values will have the same pattern as oP because the conversion was linear.

Table A3-1: Description of WWTP reported values

			Average frequency of reported values (#/mo)					
	Submitted daily sample record		Influent			Effluent		
WWTP	**Start**	**End**	**Flow**	**TP**	**oP**	**Flow**	**TP**	**oP**
Upper Gwynedd	January 2016	March 2017	Daily	12.4	0.0	Daily	3.6	29.1
Ambler	April 2016	August 2017	NM	NM	NM	Daily	10.8	10.8
Upper Dublin	January 2016	December 2016	NM	NM	NM	Daily	8.7	4
Abington	January 2016	November 2017	Daily	4.4	3.9	Daily	8.7	11.5
NM = not measured								

Table A3-2: Description of eDMR data

WWTP	eDMR record		Reported effluent parameters						
	Start	**End**	**Flow**	**TP**	**oP**	**TN**	**NH3**	**NO3/NO2**	**TKN**
Upper Gwynedd	April 2017	April 2018	Yes	No	Yes	No	Yes	Yes	No
Ambler	January 2018	April 2018	Yes	No	Yes	No	Yes	Yes	No
Upper Dublin	April 2010	April 2018	Yes	Yes	Yes	No	Yes	Yes	No
Abington	March 2010	April 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes

In addition, discharge and TP concentrations were available over time from the online database of the USGS (https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=01473900). The Ft. Washington site is downstream of all four WWTP inputs, being 1 km downstream of the confluence of Sandy Run where two of the WWTPs are located.

The combined daily and eDMR data records, in combination with Ft. Washington discharge and TP concentration records, were used to estimate flow and TP load apportionment. For this analysis, monthly averages were used to calculate the monthly average in-stream processes, as follows:

$$Discharge_{in\ stream} = Discharge_{Ft.\ Washington} - \sum Discharge_{WWTP\ i}$$

$$Load_{in\ stream} = Load_{Ft.\ Washington} - \sum Load_{WWTP\ i}$$

These calculations were conducted for two datasets: all flows (i.e., base and storm flows, Figure 2-15 main report) and base flows only (Figure 2-16 main report). Storms were removed from the data set to eliminate assumptions about how discharge data would extrapolate during storms. The WWTP data record for both datasets is the same. The height of the vertical bar in the figures represents the amount of discharge or TP load contributed by a particular WWTP.

A. Description of Upper Gwynedd wastewater treatment plant

The Upper Gwynedd WWTP serves the Upper Gwynedd Township and North Wales Borough, as well as portions of several other townships in Montgomery County, PA. Per the National Pollutant Discharge Elimination System Permit (NPDES PA 0023256), the WWTP utilizes an extended aeration and activated sludge treatment approach and the outfall enters the Wissahickon Creek at River Mile 18.4 (40^o 11’ 24” N, 75^o 17’ 01” W). A map of the WWTP is shown in Figure A3-1. Per the permit, the effluent limits for WWTP are calculated based on an annual average flow of 5.7 MGD and the NPDES permit includes pH, TSS, CBOD-5, NH_3, and fecal coliform limits; additionally, the Delaware River Basin Commission (DRBC) has basin-wide limits for TDS and CBOD-5. The more thorough description below of the facilities is from the NPDES docket:

> The WWTP facilities include headworks, dual equalization tanks for use during peak flows, and three (3) parallel primary clarifiers. From the clarifiers, wastewater flows to a split train of aeration tanks and final clarifiers. There are four (4) existing aeration tanks and two (2) clarifiers on the main treatment train, used during normal flows, and two (2) existing aeration tanks and two (2) clarifiers on a supplemental treatment train used during peak flows. Polyaluminium chloride (PAC) and polymer are added to the aeration tanks for phosphorus reduction. The WWTP also features a Biomag process which is added to the aeration tanks for enhanced settling. Wastewater from the clarifiers is sent to two (2) ultraviolet light (UV) disinfection tanks prior to discharge to Wissahickon Creek.

Figure A3-1: Upper Gwynedd Township WWTP (map downloaded from maps.google.com)

During the data record period, the Upper Gwynedd WWTP had a hydraulic design capacity of 6.5 MGD, and the effluent permit limits were calculated based upon an annual average flow of 5.7 MGD. . Observed flow rates are presented based on the daily and eDMR data (Figure A3-2), which demonstrates that flow rates are below the annual average flow of 5.7 MGD. This is due to inherent inaccuracies in flow meters in general versus some actual reduction in the flow. The combined 27 month daily-eDMR data record suggests that winter/spring flow rates are typically the highest.

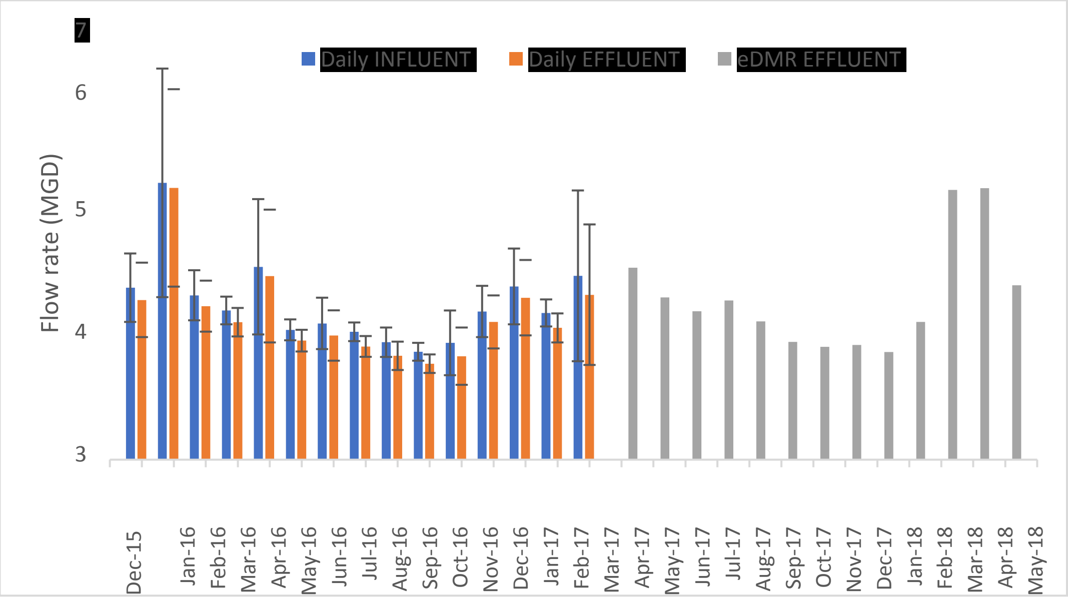

Figure A3-2: Upper Gwynedd WWTP influent and effluent flow from daily and eDMR data sources; daily data is presented as arithmetic mean ± standard deviation. (FILE: UG combined sources)

The daily data for Upper Gwynedd WWTP, which included both oP and TP values, was used to determine the percentage of TP that was present as oP as 81% ± 23% (arithmetic mean ± standard deviation) which was observed to be fairly consistent between non-storm and storm conditions (80% ± 17% and 84% ± 33%, respectively); this was used to estimate eDMR TP concentrations.

The Upper Gwynedd WWTP has included in the Comprehensive Plan Docket (D1970-068 DP-1) since 1970; based on a review of WWTP docket, the WWTP has been rerated/expanded to increase capacity three times (1987, 1992, and 2007), and has been upgraded or modified four times (approved in 2005, 2008, two times in 2010). When the 2003 Wissahickon TMDL was established, a fifth WWTP within the Wissahickon watershed existed, North Wales WWTP; per Docket D-1991-088 CP-7, Upper Gwynedd permit was updated to accommodate the wastewater from the North Wales plant, which was closing (September 2010; 0.43 MGD); associated sewerage infrastructure changes were also approved. Upgrades and improvements have included: redo headworks and equalization tank (2008), replace chlorine disinfection with UV disinfection (approved in 2010, brought online in 2011), and addition of the Biomag^{TM} process via magnetite addition to the aeration tank (approved in 2010, brought online in Feb 2014).

Renewal Docket D-1991-088 CP-8, approved in December 2015, listed no anticipated modifications to the WWTP (expiration date 2022; Docket No. D-1991-088 CP-8), however a Docket D-1991-088 CP-9 was approved in March 2018 which includes an increase in the annual average flow to 6.4 MGD and an increase in the hydraulic design capacity to 7.0 MGD, to expand the service area, and upgrades including improved flow metering, pumping station, a third clarifier, and an additional UV disinfection tank (expiration date 2022; Docket No. D-1991-088 CP-9). The expansion has been approved by PADEP and construction is proceeding.

B. Description of Ambler wastewater treatment plant

The Ambler WWTP discharge is authorized under the NPDES permit number PA0026603 and discharges into the Wissahickon Creek at River Mile 12.7 (40° 08’ 38” N, 75° 13’ 03” W). The Ambler WWTP serves the Borough of Ambler and portions of several other Montgomery Country townships. The WWTP approach includes trickling filters, attached growth nitrification, dissolved air filtration (DAF), with a hydraulic design capacity of 8.0 MGD and effluent limits calculated using anannual average flow of 6.5 MGD. The Ambler WWTP NPDES permit includes pH, TSS, CBOD-5, NH_3, fecal coliforms, and TDS; additionally, the Delaware River Basin Commission (DRBC) has basin-wide limits for TDS and CBOD-5.

The below more thorough description of the facilities is from the 2016 1975-016 C-4 docket and a map of the facilities is shown in Figure A3-3:

> The Ambler WWTP treatment processes consist of fine screening, grit removal, primary clarification, plastic media trickling filters, secondary clarification, attached growth nitrification, enhanced clarification with dissolved air flotation (DAF), UV disinfection and cascade aeration.

Figure 1: Ambler WWTP (map downloaded from maps.google.com)

Ambler WWTP monthly discharge data is shown in Figure A3-4 (21-month period) had an average discharge of 3.9 MGD, with a maximum of 7.3 MGD, which are both within the docket values. Spring appears to have the highest discharge values. Neither data source included influent flow values.

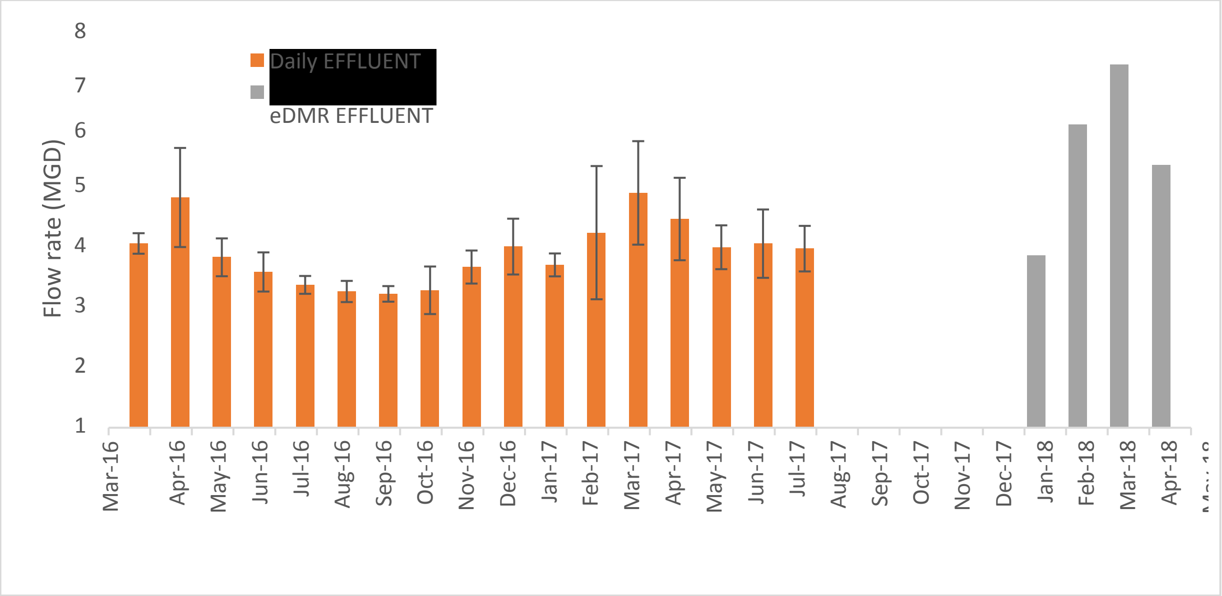

Figure A3-4: Ambler WWTP discharge from daily and eDMR data sources; daily data is presented as arithmetic mean ± standard deviation. (FILE: Ambler combined sources)

Data analysis for Ambler WWTP was conducted in the same manner as described in Section III (Upper Gwynedd WWTP). Similar to Upper Gwynedd WWTP, Ambler WWTP eDRM only reported oP values, so speciation from the daily data report (arithmetic mean ± standard deviation was 48% ± 16%) was used to estimate the TP concentrations. Precipitation reported by Upper Gwynedd WWTP was used to assess storm impacts (overlapping data record was April 1, 2016 to March 23, 2017). A limited data record was used to compare Upper Gwynedd and Ambler precipitation records (4/1/2016 – 7/25/2016) and demonstrated a similar patterns.

The Amber WWTP docket, when it was added to the Comprehensive Plan in 1963, consisted of two facilities known as the North and South Ambler WWTPs. In the 1970s, the Ambler North WWTP was abandoned, and correspondingly, Amber South WWTP was expanded to 6.5 MGD (CP-1), and in 2008 the facility was rerated to 8.0 MGD (CP-2). Per the WWTP website, upgrades to the plant include addition of preliminary treatment (1995), changing disinfection approaches (gas chlorine to UV; 1999), forced air ventilation (2000), and dissolved air flotation (2002), phosphorus removal (2008), (http://boroughofambler.com/departments/public-utilities/wastewater-treatment-plant/). Currently, the WWTP authorized under 1975-016 CP-4 (valid September 14, 2016 through September 14, 2021), and CP-4 does not comment on any planned modifications.

C. Description of Upper Dublin wastewater treatment plant

The Upper Dublin WWTP, authorized by the Docket No D-1993-076 and NPDES permit number PA0029441, has effluent limits calculated based upon an annual average flow of 1.1 MGD to the outfall located at River Mile 0.7 of Pine Run (40^{o} 08’ 3.8” N, 75^{o} 11’ 34.1” W). This WWTP serves the Fort Washington Office Park and portions of Upper Dublin Township, and treatment is achieved through a parallel trickling filter and anaerobic/ox activated sludge plant. A plant schematic and map are presented in Figure A3-5, and the below description is an excerpt from the docket:

> Treatment processes presently consist of prescreening (bar screen and comminutor), the trickling filter (including primary settling, primary and secondary trickling, and chemical addition) in parallel with the A/O unit (includes a flow equalization tank, two anaerobic and four oxic compartments with fine bubble diffusers, a secondary clarifier, chlorination, and post aeration).
>
> - Approximately 0.5 MGD to primary clarifiers, trickling filter, secondary clarifiers and chlorine disinfection.
> - Approximately 0.6 MGD to the A/O treatment plant, secondary clarifiers and chlorine disinfection.
> - The combined effluent flow is dechlorinated prior to discharge.

The NPDES permit includes pH, TSS, CBOD-5, NH_3, and fecal coliforms. Additionally, Docket 1993-076 CP-3 noted that the PADEP has a 2 mg/L TP limit (year-round) and a 1.4 mg/L oP limit (April 1 – July 31), but the DRBC does not have basin-wide TP/oP limits, but this was not noted in the more recent docket (1993-076 CP-4). DRBC does have a basin-wide TDS parameter.

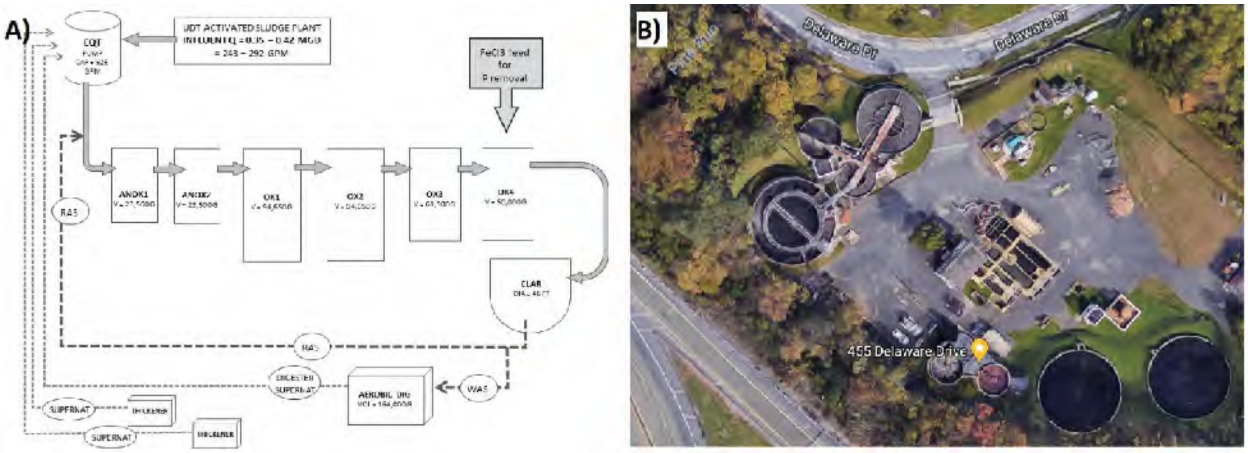

Figure A3-5: Upper Dublin WWTP including detailed schematic of activated sludge process and map showing both trickling filter and activated sludge treatment processes (map downloaded from maps.google.com)

Upper Dublin WWTP monthly discharge data is shown in Figure A3-6 (97-month period) had an average discharge of 0.71 MGD (docket rating is 1.1 MGD), with peak discharge often occurring in the spring.

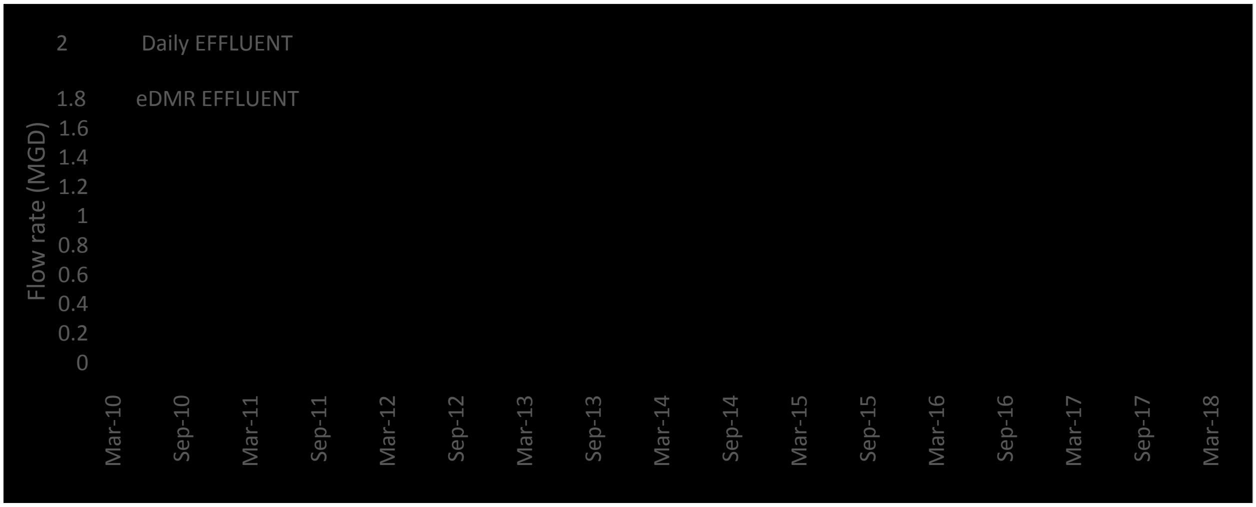

Figure A3-6: Upper Dublin WWTP discharge from daily and eDMR data sources; daily data is presented as arithmetic mean ± standard deviation. (FILE: UDub combined sources)

Data analysis for Upper Dublin WWTP was conducted in the same manner as described in Section III (Upper Gwynedd WWTP), but eDMR values included TP and oP, though neither source included influent flows or P data. In the daily reported data from Upper Dublin WWTP, precipitation was not included; therefore, precipitation reported by Upper Gwynedd WWTP was used to assess storm impacts (overlapping data record was April 1, 2016 to March 23, 2017). As previously mentioned, Ambler and Upper Gwynedd were found to have similar precipitation records, and based on proximity Upper Dublin and Amber are expected to have similar weather patterns; therefore using Upper Gwynedd precipitation record to assess Upper Dublin data is considered an acceptable approach.

The Upper Dublin WWTP docket was added to the Comprehensive Plan in 1994 at a capacity of 0.85 MGD, and was rerated to 1.1 MGD in 2009 which is its current rating (Docket 1993-076 CP-4) and the NPDES permit (PA0029441-A1) is valid until on November 30, 2019. Communication with Mr. Sean Zhang regarding the WWTP modifications reveals the following: ferric chloride tank and pumps (2008), trickling filter primary sludge flight tank rebuild (2010), Hoffman blower rebuild (2012), ferric chloride tank modification (2017), replacement of components (mixers, diffusers; 2017), and replacement of components (chemical feed pump, pumps, blower; 2018). No planned modifications are noted in the dockets.

D. Description of Abington wastewater treatment plant

The Abington WWTP is a 3.91 MGD facility, authorized by the Docket No D-1973-191 and NPDES permit number PA0026867, that discharges into Sandy Run as River Mile 4.4 (40^{o} 07’ 48” N, 75^{o} 09’ 31” W). The WWTP serves portions of Abington as well as several other Montgomery County townships. The NPDES permit includes pH, TSS, CBOD-5, NH_3, fecal coliforms, and TDS. A schematic and map are presented in Figure A3-7, and facility description from the docket is provided below:

The WWTP facilities consist of two (2) filter screens, a grit chamber, flow equalization, two (2) primary clarification tanks, an anaerobic reactor, anaerobic zones for three (3) aeration reactors with post-anoxic zones, chemical addition (alum) for phosphorous removal, three (3) final clarifiers, and ultraviolet light (UV) disinfection. Sludge handling facilities consist of a dissolved air flotation (DAF) thickener, three digesters, and centrifuge dewatering.

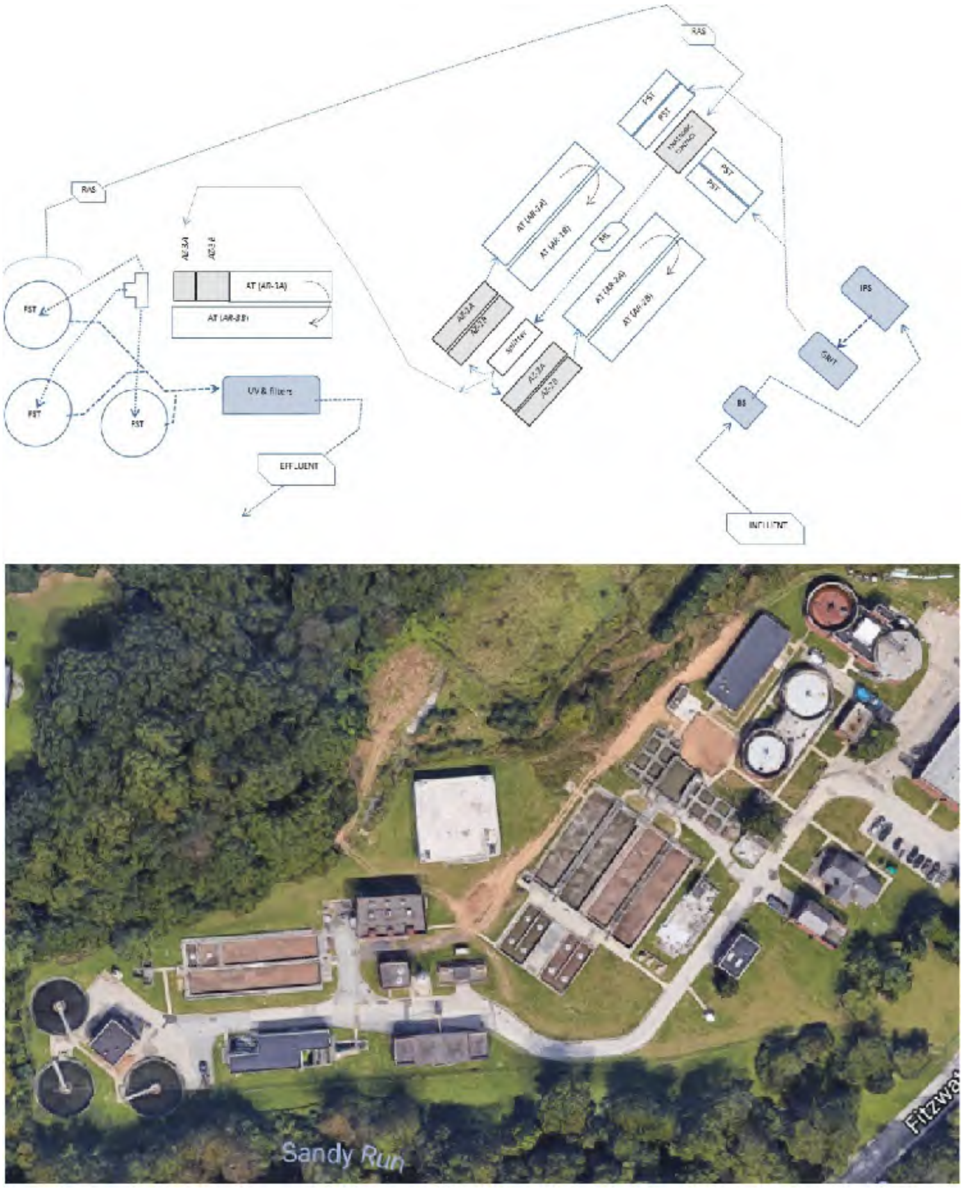

Figure A3-7: Abington WWTP including detailed schematic of the treatment process (top) and map of the site (bottom; map downloaded from maps.google.com)

Abington WWTP monthly discharge data is shown in Figure A3-8 (98-period), where the top provide the full duration of eDMR data and the lower panel allows for a comparison in data sources and influent vs effluent values. The WWTP had an average discharge of 2.76 ± 0.52 MGD (docket rating is 3.91 MGD), and in some years increased discharge was observed in the spring. Influent and effluent values were generally similar, and the difference between monthly averages was less than 0.1 MGD.

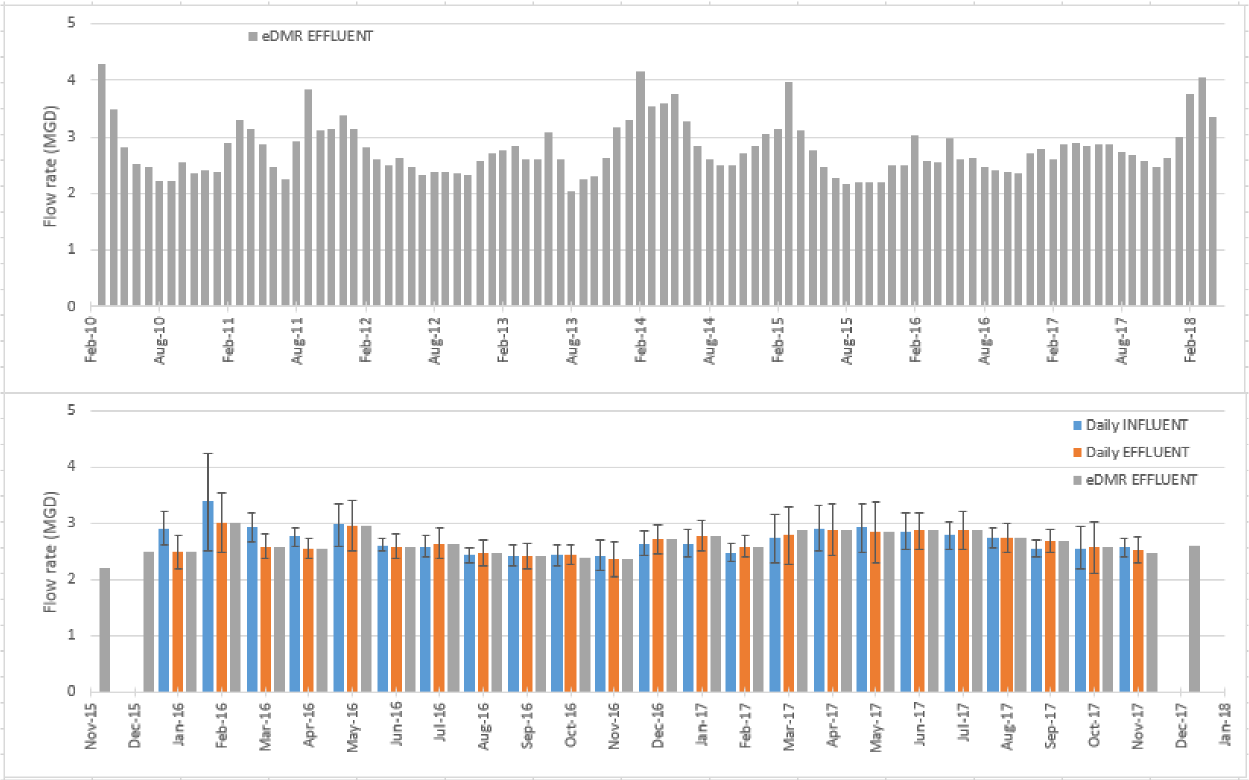

Figure A3-8: Abington WWTP discharge from eDMR (top; full data record) and combined eDMR / daily (limited comparison) data sources; daily data is presented as arithmetic mean ± standard deviation. (FILE: Abington combined sources)

Abington WWTP provided a more complete data record, which included influent and effluent values reflecting TP and oP measurements. Precipitation data was also included in the daily data record.

The Abington WWTP docket was added to the Comprehensive Plan in 1962, with upgrades implemented in 1979 and 2007. At present (Docket 1973-191 CP-5), the WWTP is approved for 3.91 MDG; the current docket contains no modification plans, and the docket is valid until December 31, 2020.

Appendix 11

September 2017 Letter from Marc Gold to EPA on behalf of the WWTPs

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September 19, 2017

Evelyn MacKnight
Associate Director
Office of Standards, Assessment and TMDLs
United States Environmental Protection Agency, Region 3
1650 Arch Street
Philadelphia, PA 19103-2029

Re: Wissahickon Creek Alternative TMDL

Dear Ms. MacKnight:

As counsel to the Wissahickon Clean Water Partnership (the "Partnership"), I have been authorized to submit this letter on behalf of the operators of the Abington Wastewater Treatment Plant, the Ambler Borough Wastewater Treatment Plant, the Upper Gwynedd Wastewater Treatment Plant, and the Upper Dublin Wastewater Treatment Plant operated by the Bucks County Water and Sewer Authority (collectively, the "WWTPs").

As you know, the WWTPs, along with 13 municipalities located in the Wissahickon Creek Watershed, formed the Partnership in 2016 to collaborate with the Pennsylvania Environmental Council ("PEC") and the Wissahickon Valley Watershed Association ("WVWA") to investigate strategies for improving water quality in the watershed as an alternative to the May 2015 Draft Total Phosphorous TMDL for the Wissahickon Creek Watershed ("Draft TMDL") prepared by the United States Environmental Protection Agency ("EPA"). Together, the members of the Partnership account for roughly 98 percent of the land area in the watershed. The Pennsylvania Department of Environmental Protection ("Department") and EPA have been supportive of the Partnership's efforts, which have been greatly appreciated by all of the Partnership's members.

Since the formation of the Partnership, we are aware that the Department and the WWTPs have engaged in discussions about commitments the WWTPs can make to reduce total phosphorous loadings to the Wissahickon Creek, while comprehensive studies and evaluations are conducted to develop a Water Quality Improvement Plan ("WQIP") for the watershed. As currently designed, the WQIP is expected to include a refined analysis of the unique factors contributing to water quality impairments in the Wissahickon Creek that is essential to formulating a long term strategy for improvement. The WWTPs are dedicated to seeing the WQIP development process through to its conclusion. In the meantime, the WWTPs remain committed to implementing interim measures to reduce constituent loadings to the creek until the WQIP is completed, which is anticipated to be mid-2018.

A team of technical experts led by Temple University is currently in the process of collecting comprehensive water quality data throughout the watershed that will be used to develop a water quality model that will be an essential component of the WQIP. The WWTPs are certainly key players in the development of the WQIP, if a comprehensive plan to improve water quality is to be prepared that can serve as the basis for establishing an Alternative TMDL as contemplated by EPA and the Department. The WQIP's holistic approach has the potential to serve as a template for other watersheds in the region and across the country facing the same challenges.

The WWTPs are steadfast in their commitment to seeing the preparation of the WQIP through to completion, as evidenced by the resources that the Partnership, including the individual WWTPs, has invested to ensure that the study is conducted in a scientifically-defensible and thorough manner acceptable to both EPA and the Department. Given the commitment of these resources and the significant investment by the William Penn Foundation, the importance of the WWTPs to the Partnership's larger goal of achieving watershed-wide water quality improvements, and the limited time remaining for the preparation of the WQIP, it is essential that the WQIP be completed before the WWTPs commit to extensive facility upgrades that would result from the immediate imposition of stringent effluent limits, which ultimately may be found to be unnecessary or wrongly focused.

To ensure that progress by the WWTPs is made until the WQIP is prepared and an Alternate TMDL is developed, the WWTPs propose to implement the following interim actions while EPA continues to defer the issuance of the Draft TMDL:

(1) **<u>Facility Optimization</u>** – The WWTPs will continue efforts to optimize their phosphorous removal capabilities using their existing facility infrastructure. Optimization could include chemical or operational modifications, among other measures, short of changes that would require WQM Part II permits. During this time period, the WWTPs will seek to reduce phosphorous related discharges from their facilities by fifty percent of the maximum limits set forth in their NPDES Permits currently in effect as of the date of this letter.

(2) **<u>Report Progress</u>** – Each WWTP will submit a progress report to EPA and the Department on December 15, 2017, May 15, 2018, and December 14, 2018, that will summarize the results of their optimization efforts, including a quantification of the phosphorous-related effluent reductions achieved.

(3) **<u>Feasibility Analysis</u>** – Each WWTP will continue to review potential facility upgrades pending the completion of the WQIP. This preliminary review will generally evaluate feasible phosphorous removal targets and strategies under various conditions that will be subsequently refined taking into account the findings of the WQIP.

(4) **Feasibility Analysis Report** – After the WQIP has been accepted by EPA and the Department, and the agencies confirm their intention to continue to pursue the Alternative TMDL, each WWTP will submit a report to the Department that summarizes the status of their individual feasibility analysis. The report will be submitted to EPA and the Department within 180 days after the agencies' acceptance of the WQIP and receipt of the agencies' confirmation of continued interest in pursuing the Alternative TMDL.

I am authorized to represent that both PEC and the WVWA support the interim actions set forth in this letter, recognizing the importance of finalizing the WQIP over the next twelve to eighteen months and the role the WWTPs invariably will play in achieving water quality improvements in the Wissahickon Creek over time. Like the Partnership, PEC and the WVWA believe that the WQIP will identify the major impediments to water quality improvement in the Wissahickon Creek and offer strategies that Partnership members can implement to successfully improve water quality in the watershed.

The WWTPs understand that EPA and the Department retain the authority to reject the WQIP and to decline to prepare an Alternate TMDL as a substitute for the Draft TMDL. In such a case, EPA could choose to finalize the Draft TMDL in the ordinary course with the attendant opportunities for judicial review. Nevertheless, the Partnership, PEC, and the WVWA are optimistic that the strategies in the WQIP will address the water quality impairments in the Wissahickon Creek in such a manner that the strategies can be incorporated into an Alternative TMDL. The WWTPs have been and continue to be supportive of the Alternative TMDL process, as have the other members of the Partnership.

The Partnership appreciates the agencies' continued engagement on these issues as creative strategies to improve water quality in the Wissahickon Creek are developed. Thank you.

Sincerely,

Marc Gold

Marc E. Gold
FOR MANKO, GOLD, KATCHER & FOX, LLP

cc: Jenifer Fields, Clean Water Program Manager, PADEP
David Burke, Watershed Manager, PADEP
George Wrigley, Director of Wastewater Utilities, Abington Wastewater Treatment Plant
James Napoleon, Manager of Engineering, Asset Management, and
SCADA Operations, Bucks County Water and Sewer Authority
Leonard T. Perrone, Township Manager, Upper Gwynedd Township
Mary Aversa, Borough Manager, Ambler Borough
Drew Shaw, Environmental Planning Section Chief, Montgomery County Planning Commission
Patrick Starr, Executive Vice President, Pennsylvania Environmental Council
Richard Collier, Chair, Board of Directors, Wissahickon Valley Watershed Association
Richard J. Manfredi, Abington Township Manager

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Partner responsible:
John F. Gullace (NJ)
Brenda H. Gotanda (HI)

30th ANNIVERSARY

September 30, 2019

Jenifer Fields
USEPA Region 3
1650 Arch Street
Mail Code: 3RA00
Philadelphia, PA 19103-2029

Re: Wissahickon Creek Water Quality Improvement Plan

Dear Jenifer:

On behalf of the Management Committee of the Wissahickon Clean Water Partnership, I am pleased to enclose three copies of the Draft Water Quality Improvement Plan (WQIP) for the Wissahickon Creek watershed for review by the Environmental Protection Agency (EPA).

The WQIP was developed over the past three years with support and assistance from the Pennsylvania Environmental Council, the Wissahickon Valley Watershed Association, Temple University and the University of Maryland Environmental Finance Center. Additional water quality data were collected throughout the watershed, hydraulic conditions in the stream were modeled and the causes of stream impairment were re-examined. These efforts led to a clearer understanding of local conditions and the unmistakable conclusion that additional measures to control the rate and volume of stormwater would provide the greatest prospect for improving stream conditions in this heavily urbanized watershed.

Through this precedential, collaborative effort among municipalities representing approximately 99% of the watershed area, operators of the four wastewater treatment plants and the leading environmental advocates in the region, agreement was reached on an adaptive management strategy that is focused on stormwater and streambank projects, which have ben determined to offer the most hope of achieving measurable water quality improvements in the shortest period of time. The process that has been followed in developing the WQIP has engendered a broad base of support for the progressive water quality management strategies presented in the WQIP.

As we have discussed, the Management Committee will assess the feedback provided by EPA and will revise the WQIP to address any comments. The revised WQIP will then be presented to the respective municipal Boards and wastewater treatment plant owners for consideration and acceptance. A final version of the WQIP, incorporating responses to EPA's comments and any additional input from the municipal Boards and wastewater treatment plant owners, will be submitted to EPA for approval as part of the TMDL alternative for the Wissahickon Creek. Implementation of the WQIP will commence in accordance with its terms after the TMDL alternative is established by EPA and becomes final.

As you know, all parties involved in this process have worked diligently to prepare the WQIP and all are proud of the final product. Approving the WQIP as the cornerstone of the TMDL alternative will set in motion two decades of coordinated effort and significant investment intended to improve water quality in the Wissahickon Creek through a robust, collaborative and interactive adaptive management program.

Please direct any questions regarding the WQIP to me. We would welcome the opportunity to meet with representatives of EPA to discuss the elements of the WQIP and its anticipated implementation. Thank you for your consideration and continued support.

Very truly yours,

Marc E. Gold
For MANKO, GOLD, KATCHER & FOX, LLP

MEG/dem
Enclosure