POQUESSING WATERSHED
ACT 167
STORMWATER MANAGEMENT PLAN

VOLUME II – PLAN CONTENTS

FINAL REPORT
December 7, 2012

BUCKS, MONTGOMERY, AND PHILADELPHIA COUNTIES, PENNSYLVANIA

NTM PROJECT NO. 09052.00

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STORMWATER MANAGEMENT PLAN

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PREPARED BY:
NTM ENGINEERING, INC.
130 W Church Street, Suite 200
Dillsburg, PA 17019

IN CONJUNCTION WITH:
PHILADELPHIA WATER DEPARTMENT
Office of Watersheds
1101 Market Street, 4th Floor
Philadelphia, PA 19107

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ENGINEERING CONSULTANT

NTM Engineering, Inc.
Temple University

IN CONJUNCTION WITH:

Philadelphia Water Department

POQUESSING WATERSHED
DESIGNATED WPAC MEMBERS

Poquessing Watershed Partnership Contact List

Last Name	First Name	Affiliation
Abrams	Glen	Philadelphia Water Department
Barletta	Marissa	CDM for Philadelphia Water Department
Barsamian	Sherry	Kraft
Belfield	Tony	Bensalem Township Supervisor
Bickel	Barry	Friends of Pennypack
Blaustein	Joan	Philadelphia Parks and Recreation
Binder	Joseph	Franklin Mills Mall
Brown	Drew	Philadelphia Water Department
Butler	Lance	Philadelphia Water Department
Bryson	Deane	Lower Southampton EAC
Connor	Bruce	Friends of Poquessing Watershed
Cruz	Jason	Philadelphia Water Department
Cuorato	James	Brandywine Realty Trust
Dahme	Joanne	Philadelphia Water Department
Davenger	Calvin	Philadelphia International Airport
DeBarry	Paul	NTM Engineering
Donegan	Christopher	Franklin Mills Mall
Featherstone	Jeff	Temple University Center for Sustainable Communities
Ferguson	Jeanise and Tom	Stream Buffer Program Participant
Gabor	Elizabeth	Philadelphia Industrial Development Corporation
Graham	Glenn	Philadelphia NorthEast Trail: Advocate for trail project proposed in watershed along a PECO Right of Way
Grumbrecht	Patrick	
Hassinger	David	KSEngineers
Hatala	Mike	Parkwood Civic Association
Hazel	Mary Jane	Somerton Civic Association
Hoffman	Christopher	Lower Moreland Township
Ihlein	Eric	Benjamin Rush State Park
Kates	Jim	Lower Southampton EAC
Kenney, Jr.	George T.	State Rep.George Kenney (R-170th dist)
Kiefer	Wayne	Engineer, Lower Southampton Township
Kolbas	Georgia	Park Ranger/Volunteer
Lambert	Alice	Bucks County Planning Commission
Ledesma Groll	Tiffany	CDM for Philadelphia Water Department
LePage	Ben	PECO Energy Company
Maurer	Fred	Friends of Poquessing Watershed
May	Thom	Urban Engineers, Inc.
McCartney	Mike	Planning & Environmental Stewardship, Philadelphia International Airport

Ledesma Groll	Tiffany	PWD (CDM)
LePage	Ben	PECO Energy Company
Leff	Michael	PHS
Marge	Jaclyn	Philadelphia Water Department
Maurer	Fred	Friends of Poquessing Watershed
May	Thom	Urban Engineers, Inc.
McCartney	Mike	Planning & Environmental Stewardship, Philadelphia International Airport
Mellor	Richard	Lower Moreland Township
Monaghan	Rea	Bucks County Planning Commission
Mora	Denis	PWD
Mowday	Rhonda	Kraft
Offner	Bruce	Lower Southampton EAC
Olson	Jackie	FPC
O'Neill	Councilman Brian J.	City Councilman O'Neill (R-10th dist.)
Pilling	Beth	Montgomery County Planning Commission
Pomerantz	Cindy	Friends of Poquessing
Rapone	Bill	Councilman Brian O'Neill's Office
Racette	Paul	Pennsylvania Environmental Council
Rapone	Bill	Councilman Brian O'Neill's Office
Remick	Donna	Friends of Poquessing Watershed
Rogalus	Meghan	Bucks County Conservation District
Ryan	Jim	Friends of Pennypack Park
Taylor	Ted	Lower Southampton
Thompson	Michael	Philadelphia City Planning Commission
Trainer (RSM, Ph.D)	Mary	Cranaleith Spiritual Center
Ulinski	Ski and Kathie	Cranaleith Spiritual Center
Wallis	Carolyn	PA Department of Conservation and Natural Resources, Bureau of Recreation and Conservation
Waldowski	Jeanne	PWD
Walters	Alice	Bucks County Planning Commission
Wilson	Steve and Beverly	Stream Buffer Program Participant
Witmer	Tom	Fairmount Park Commission
Young	Karen	Fairmount Water Works Interpretive Center
Zlotnick	Suzanne	Friends of Poquessing Watershed

Philadelphia
PWD
Water Department

RESOLUTION

WHEREAS, the Stormwater Management Act 167 of 1978 provides for the regulation of land and water use for flood control and stormwater management, requires the Pennsylvania Department of Environmental Protection to designate watersheds, and provides for grants to be appropriated and administered by the Department for plan preparation and implementation costs, and provides that each county will prepare and adopt a watershed stormwater management plan for each designated watershed; and

WHEREAS, the purpose of the Pennypack and Poquessing Creeks Watershed Stormwater Management Plans are to protect public health and safety and to prevent or mitigate the adverse impacts related to the conveyance of excessive rates and volumes of stormwater runoff by providing for the management of stormwater runoff and control of erosion and sedimentation; and

WHEREAS, design criteria and standards of stormwater management systems and facilities within the Pennypack and Poquessing Creeks Watersheds shall utilize the criteria and standards as found in the watershed stormwater management plan;

WHEREAS; the City of Philadelphia Water Department has been authorized under the ordinances of the City of Philadelphia to develop regulations for the management of stormwater and to review stormwater management plans for development within the City of Philadelphia;

NOW, THEREFORE, BE IT RESOLVED that the City of Philadelphia, acting through its Water Department, hereby adopts the Pennypack and Poquessing Creeks Watershed Stormwater Management Plans, including all volumes, figures, appendices, and model ordinance and forwards the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this 1 day of 11, 2012 by:

CITY OF PHILADELPHIA
WATER COMMISSIONER

HOWARD M. NEUKRUG, P.E., BCEE

RESOLUTION

WHEREAS, the Stormwater Management Act 167 of 1978 provides for the regulation of land and water use for flood control and stormwater management, requires the Pennsylvania Department of Environmental Protection to designate watersheds, and provides for grants to be appropriated and administered by the Department for plan preparation and implementation costs, and provides that each county will prepare and adopt a watershed stormwater management plan for each designated watershed; and

WHEREAS, the purpose of the Poquessing Watershed Stormwater Management Plan is to protect public health and safety and to prevent or mitigate the adverse impacts related to the conveyance of excessive rates and volumes of stormwater runoff by providing for the management of stormwater runoff and control of erosion and sedimentation; and

WHEREAS, design criteria and standards of stormwater management systems and facilities within the Poquessing Watershed shall utilize the criteria and standards as found in the watershed stormwater management plan.

NOW, THEREFORE, BE IT RESOLVED that the Philadelphia County Commissioners hereby adopt the Poquessing Watershed Stormwater Management Plan, including all volumes, figures, appendices, Model Ordinance and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this _____day of _____, 2012 by:

PHILADELPHIA COUNTY COMMISSIONERS

_____

<Name>, **<Title>**

_____

<Name>

_____

<Name>

RESOLUTION

WHEREAS, the Stormwater Management Act 167 of 1978 provides for the regulation of land and water use for flood control and stormwater management, requires the Pennsylvania Department of Environmental Protection to designate watersheds, and provides for grants to be appropriated and administered by the Department for plan preparation and implementation costs, and provides that each county will prepare and adopt a watershed stormwater management plan for each designated watershed; and

WHEREAS, the Philadelphia County Commissioners entered into a Memorandum of Understanding with Bucks County to support the development of the watershed stormwater management plan for the Poquessing designated watershed; and

WHEREAS, the purpose of the Poquessing Watershed Stormwater Management Plan is to protect public health and safety and to prevent or mitigate the adverse impacts related to the conveyance of excessive rates and volumes of stormwater runoff by providing for the management of stormwater runoff and control of erosion and sedimentation; and

WHEREAS, design criteria and standards of stormwater management systems and facilities within the Poquessing Watershed shall utilize the criteria and standards as found in the watershed stormwater management plan;

NOW, THEREFORE, BE IT RESOLVED that the Bucks County Commissioners hereby adopt the Poquessing Watershed Stormwater Management Plan, including all volumes, figures, appendices, Model Ordinance and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this _____day of _____, 2012 by:

BUCKS COUNTY COMMISSIONERS

_____

<Name>, **<Title>**

_____

<Name>

_____

<Name>

RESOLUTION

WHEREAS, the Stormwater Management Act 167 of 1978 provides for the regulation of land and water use for flood control and stormwater management, requires the Pennsylvania Department of Environmental Protection to designate watersheds, and provides for grants to be appropriated and administered by the Department for plan preparation and implementation costs, and provides that each county will prepare and adopt a watershed stormwater management plan for each designated watershed; and

WHEREAS, the Philadelphia County Commissioners entered into a Memorandum of Understanding with Montgomery County to support the development of the watershed stormwater management plan for the Poquessing designated watershed; and

WHEREAS, the purpose of the Poquessing Watershed Stormwater Management Plan is to protect public health and safety and to prevent or mitigate the adverse impacts related to the conveyance of excessive rates and volumes of stormwater runoff by providing for the management of stormwater runoff and control of erosion and sedimentation; and

WHEREAS, design criteria and standards of stormwater management systems and facilities within the Poquessing Watershed shall utilize the criteria and standards as found in the watershed stormwater management plan;

NOW, THEREFORE, BE IT RESOLVED that the Montgomery County Commissioners hereby adopt the Poquessing Watershed Stormwater Management Plan, including all volumes, figures, appendices, Model Ordinance and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this _____day of _____, 2012 by:

MONTGOMERY COUNTY COMMISSIONERS

_____

<Name>, **<Title>**

_____

<Name>

_____

<Name>

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PLAN FORMAT

The format of the Poquessing Stormwater Management Plan consists of Volume I, the Executive Summary, Volume II, the Plan Report that includes GIS maps and the Model Ordinance, and Volume III that contains the background technical materials.

Volume I provides an overview of Act 167 and a summary of the standards and criteria developed for the Plan. Volume II, the Plan Report, provides an overview of stormwater management, purpose of the study, data collection, present conditions, stormwater management problem areas, projected land development patterns, calculation methodology, and Ordinance provisions and implementation discussion.

Volume III provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing Municipal Ordinance matrix, problem area forms, and obstructions inventory. Due to large volumes of data, one copy of Volume III will be on file at the Philadelphia Water Department office.

SECTION I
INTRODUCTION

Introduction

This Stormwater Management Plan (SMP) has been developed for the Poquessing Creek Watershed in Bucks, Montgomery, and Philadelphia Counties, Pennsylvania to comply with the requirements of the Pennsylvania Stormwater Management Act, (Act 167), of 1978. The Act requires Pennsylvania counties to prepare and adopt SMPs for each watershed located in the county, as designated by the Pennsylvania Department of Environmental Protection (PaDEP). It also requires municipalities to implement a stormwater management ordinance, limiting stormwater runoff from new development and redevelopment. This SMP details the analyses that were performed in order to fulfill the requirements of Act 167.

The main objective of this SMP is to control stormwater runoff on a watershed-wide basis rather than on a site-by-site basis, taking into account how development and land cover in one (1) part of the watershed will affect stormwater runoff in all other parts of the watershed. Consistent with Act 167, the SMP seeks to:

- preserve and restore the flood-carrying capacity of watershed streams;
- reduce erosion and sedimentation;
- preserve natural stormwater runoff regimes and the natural course, current and cross sections of streams; and
- protect and conserve ground water and ground water recharge areas.

The SMP seeks to address serious water quality problems that are noted in Section 3. The vast majority of the watershed's streams are considered impaired, according to water quality reports prepared by PaDEP. Through implementation of the stormwater improvements recommended, the SMP will simultaneously reduce flooding, erosion and sedimentation, and improve water quality.

The final SMP offers a unique approach to the Act 167 planning process that incorporates watershed scale hydrologic modeling. While all study elements required for an Act 167 study were completed, the study team included alternative stormwater improvements to reduce runoff and improve water quality. As this watershed is essentially "built-out," the concentration of much of the research was on identifying opportunities for retrofitting existing stormwater facilities and finding locations for new Best Management Practices, or BMPs, in areas that are not currently served by stormwater facilities. Restoration of riparian stream buffers is recommended as an opportunity to address the goal of preserving and restoring flood-carrying capacity of streams. The use of stormwater BMPs as the preferred means to achieve improved water quality, groundwater recharge and retention, streambank protection, and volume control is strongly endorsed. The implementation of these retrofits and new BMPs in conjunction with regulation of new development and redevelopment through new stormwater ordinances will reduce stormwater problems in the Poquessing Creek Watershed. The SMP lays the framework for municipalities to construct the stormwater improvements over a ten-year period. The various improvements are assigned a priority according to their cost-effectiveness and capture potential, and municipalities can use this ranking as a basis for funding projects.

The SMP presents criteria and standards for new development and redevelopment in **Section V** and a model stormwater management ordinance in **Appendix A**. Within six (6) months of the adoption of the SMP, each municipality shall adopt or amend ordinances and regulations, including zoning, subdivision and development, building codes, and erosion and sedimentation ordinances, as are necessary to regulate development within the municipality in a manner consistent with the SMP. The project team recommends that the municipalities adopt the model ordinance in its entirety as part of its zoning regulations. If the municipality lies in more than one (1) watershed, the applicable criteria and standards should be identified for the different watersheds.

The county must review and, when necessary, revise such plans at least every five (5) years. These Ordinances must regulate development within the municipality in a manner consistent with the SMP and the provisions of the Act.

Developers are required to manage the quantity, velocity, and direction of resulting stormwater runoff in a manner that adequately protects health and property from possible injury. They must implement control measures that are consistent with the provisions of the SMP and the Act. The Act also authorizes for civil remedies for those aggrieved by inadequate management of accelerated stormwater runoff.

The Poquessing Creek Watershed SMP was prepared by NTM Engineering, Inc. with assistance from Temple University's Center for Sustainable Communities (CSC). The SMP was funded by the Philadelphia Water Department and prepared in consultation with municipalities located in the watershed, working through a Watershed Planning Advisory Committee (WPAC) comprised of municipal officials and other interested parties. The SMP provides technical standards and criteria applicable throughout the watershed for the management of stormwater runoff from road construction, new land development and redevelopment sites.

SECTION II
DATA COLLECTION

Data Collection

In order to evaluate the hydrologic response of the watershed, data was collected on the physical features of the watershed as follows:

1. Base Map: The base map for Geographic Information System (GIS) generated maps was built from data received from the Pennsylvania Department of Environmental Protection (PaDEP), the Pennsylvania Department of Transportation (PennDOT), and the Philadelphia Water Department (PWD). Streams, lakes, and the watershed boundary were obtained from PaDEP and PWD. County and municipal boundaries, roads, and railroads were obtained from PennDOT and PWD. The data provided by PWD was primarily for areas within Philadelphia and did not include areas in Bucks or Montgomery Counties.

2. Elevation Data: A Digital Elevation Model (DEM) for the Poquessing Watershed was developed from DEM data obtained from the USGS and from topographic data developed by Sanborne for the City of Philadelphia. Subwatersheds or subareas used in the watershed modeling process were derived from the DEM. Subareas, drainage courses, land slopes and lengths, and drainage element lengths and slopes were all determined from the DEM.

3. Soils: Soil mapping data was obtained from the United States Department of Agriculture, Natural Resources Conservation Service (NRCS). Two (2) sets of data were used, the State Soil Geographic Database (STATSGO) and the Soil Survey Geographic Database (SSURGO).

   The STATSGO data is a statewide data layer made by generalizing the detailed county soil survey data and merging it into a single layer covering the entire state. The STATSGO data was used to create the Generalized Soils Map that gives a general overview of the watershed soil characteristics.

   SSURGO is the most detailed level of soil mapping done by the NRCS. SSURGO is a digital duplication of the original county soil survey maps. Each county was digitized separately to create a stand-alone, county specific GIS layer. The soil mapping units at the county boundaries were examined and edited by the NRCS to create as much continuity as possible between counties. The SSURGO soils GIS data layer shows only the boundaries of the soil mapping units. The detailed information about the individual mapping units is contained within an access database referred to as the National Soil Information System (NASIS) database.

4. Geology: The digital geology data for the watershed was obtained from the Pennsylvania Department of Conservation and Natural Resources (DCNR). This is a statewide GIS data layer showing geologic formation boundaries and identifying the formations. The geology information is provided for illustrative and general information only. The descriptions of the geologic formations were also obtained from the DCNR in the document Explanations.pdf. This PDF files contains the descriptions of geologic formation as were modified from Berg, T. M., Geyer, A. R., Edmunds, W.

E., and others, compilers, 1980, *Geologic map of Pennsylvania*, Pennsylvania Geological Survey, 4th ser., Map 1.

5. Land Cover: The existing land use map was generated by overlaying the Delaware Valley Regional Planning Commission (DVRPC) land use data on year 2000 DVRPC aerial photographs.

6. Wetlands: Wetlands were obtained from the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) in digital format and incorporated into the overall GIS. NWI maps are compiled from photointerpreted aerial photography from the National Aerial Photography Program (NAPP) 1:40,000 Scale, and the National High Altitude Photography Program (NHAP) 1:58,000 or 1:80,000 Scale. Sources dates range from the 1970s to the present. The minimum mapping unit for treeless areas is 1/4 acres, one to three acres in general. The wetlands data is provided for illustrative purposes. Other wetland areas likely exist in the watershed that are not depicted on NWI maps.

7. Floodplains: Flood hazard areas for Philadelphia, Bucks, and Montgomery counties were derived from the Federal Emergency Management Agency (FEMA) National Flood Insurance Program Q3 Flood Data CD, September 1996. The floodplain boundaries are considered to be a "best representation", are not intended for engineering or insurance purposes, and do not supplant on-site surveys to determine flood hazard areas.

8. Obstructions: Bridges, culverts, and pipes that convey streams and tributaries under roads, railroads, and other similar infrastructure are referred to as obstructions. The obstruction locations and approximate sizes for the Poquessing Watershed were provided by PWD in shape file format. PWD conducted field work to determine the shape and skew of the obstructions and to measure the openings.

9. Problem Areas: Stormwater problems include flooding, erosion, sedimentation, landslides, groundwater impacts, pollution, and other potential issues. Data on the location of these problems in the watershed were collected by the municipalities within the watershed with assistance from NTM for plotting and incorporation into the watershed GIS. The municipalities were provided a base map of their township or borough and a set of data collection forms. With some assistance from NTM, the locations of the known problem areas were identified and plotted on paper maps or in digital format and completed the forms that describe the problems at each location. NTM compiled the data from the municipalities and created a data layer to illustrate problem areas throughout the watershed. The data collection forms are located in **Volume III, Technical Appendix 1**.

10. Stormwater Management Facilities: Stormwater management facilities may include detention/infiltration basins, swales, underground storage, and constructed wetlands. These types of facilities were also identified, plotted, and described on forms by the municipalities. As with the problem area data, the municipal stormwater management facilities information was compiled by NTM and converted into GIS format. Some municipalities submitted storm sewer maps, which enabled NTM to illustrate the areas of these townships and boroughs that are served by storm drains.

11. Stormwater Sewer System Outfalls: Municipalities in urban areas (as defined by the US Census Bureau) are required to map the location of storm sewer outfalls as part of the PaDEP Municipal Separate Storm Sewer System (MS4) program. This information was collected by PWD and provided to NTM for inclusion in the GIS.

12. Flood control: Data on the location of flood control projects in the watershed were collected by the municipalities within the watershed with assistance from NTM for plotting and incorporation into the watershed GIS. The municipalities were provided a base map of their township or borough and a set of data collection forms. With some assistance from NTM, the locations of the known problem areas were identified and plotted on paper maps or in digital format and completed the forms that describe the problems at each location. NTM compiled the data from the municipalities and created a data layer to illustrate problem areas throughout the watershed. The data collection forms are located in **Volume III, Technical Appendix 1**.

13. Precipitation: PWD maintains a network of 24 rain gages throughout Philadelphia. The network receives routine monthly maintenance to clear the rain gages of obstructions. Following typical maintenance, standard calibration procedures are followed to ensure proper function. Rainfall recorded at three rain gages (4, 20 and 24) was used as input to the Poquessing Creek hydrologic model.

    In addition to the PWD rain gage network, additional rainfall data was examined for use in the model. Data from two WeatherBug rain gage stations were examined for use; however, it was determined that this additional information was not reliable for use in the model. Design storm data was obtained from NOAA Atlas 14 The USGS StreamStats program indicates that the mean annual precipitation is 47.0 inches for the watershed.

SECTION III
GENERAL DESCRIPTION OF WATERSHED

The Poquessing Watershed is located within Bucks, Montgomery, and Philadelphia Counties, approximately 11 to 12 miles Northeast of Center City Philadelphia. The watershed boundary extends into five municipalities: the City/County of Philadelphia, Bensalem Township, Lower Southampton Township, Upper Southampton Township, and Lower Moreland Township. The respective areas for all municipalities in the Poquessing Watershed are listed in **Table III-1**. **Map III-1** is a base map of the watershed that depicts political subdivisions, roads, and streams.

TABLE III-1

Poquessing Watershed Municipalities

Bucks County	**Area (Sq. Miles/Acres)**
Bensalem Township	4.71 / 3,01.6
Lower Southampton Township	3.02 / 1,934.9
Upper Southampton Borough	0.01 / 8.5
Montgomery County	
Lower Moreland Township	0.85 / 542.7
Philadelphia County	
City of Philadelphia	12.96 / 8,295.3

A. Drainage Area

The Poquessing drainage area covers a total of 21.55 square miles, or approximately 13,800 acres, as determined from the drainage area boundary obtained from the Pennsylvania Department of Environmental Protection (PaDEP). The main stem of the Poquessing Creek flows approximately 9.8 linear miles from the headwaters in Lower Southampton Township to the Delaware River. The creek itself has one major tributary, Byberry Creek, which flows along the western side of the watershed and enters Poquessing Creek north of Route 13. Byberry Creek originates southeast of Somerton in Philadelphia and flows approximately 6.6 miles southward under Route 1 towards Route 13, where it flows east before entering the Poquessing Creek. A second, smaller tributary, Walton Run, feeds into Byberry Creek west of Route 63. The Poquessing Creek Watershed, as shown in **Map III-1**, is bordered to the north and east by the Neshaminy Creek Watershed and to the west by the Pennypack Creek Watershed, both of which also have Act 167 SMPs. All three of these watersheds are part of the much larger Delaware River Watershed, which flows directly into the Delaware Bay before flowing into the Atlantic Ocean.

The watershed is almost entirely urbanized. Most undeveloped land consists of patches of forested areas that are located in park and recreational areas. Based on 2010 census data, the population within the watershed is approximately 169,500 people, which yields an average population density of 12.3 persons/acre. This data was determined by multiplying the densities from each township by the respective area of each township in the watershed. This data was then summed to determine the approximate population.

Being highly urban, the watershed is traversed by several roads. Interstate 276, which is a portion of the Pennsylvania Turnpike, runs northwest to southeast through the northern portion (Lower

Southampton and Bensalem Townships) of the watershed. Interstate 95 runs northeast to southwest through the southern portion (Bensalem Township and Northeast Philadelphia) of the watershed.

Other major routes include U.S. Route 1/Roosevelt Boulevard and state routes 532/Bustleton Avenue, 132/Street Road, 63/Woodhaven Road, and 13/Bristol Pike. These highway systems connect with a network of local primary, secondary, and tertiary roadways to form the watershed's roadway grid.

B. Stream Environmental Characteristics

According to the Water Quality regulations (Chapter 93 of Title 25 of the Pennsylvania Code)[1], streams within the Poquessing Creek Watershed are designated as a Warm Water Fisheries with Migratory Fishes (WWF, MF). The Pennsylvania Fish and Boat Commission[2] does not list any stream within the Poquessing Watershed as approved trout waters, capable of supporting natural trout reproduction, or Class A wild trout waters. The PaDEP eMap website[3] indicates that all streams within the watershed are on the Clean Water Act Section 303(d) list of impaired waters. From the mouth of the watershed to just north of I-95, the stream has a fish consumption designated use. It fails to meet this designated use due to high levels of PCB contamination. The stream has an aquatic life designated use from the Bristol Pike north to the watershed source. This portion of the watershed fails to meet its designated use due to urban runoff that is causing flow variability, siltation, excessive algal growth, and flow alterations. Urban runoff is the primary cause of impairment in 95 percent of the designated streams[4]. Given the state of the watershed and widespread impacts of stormwater, a major part of this study is focused on measures to improve control of existing runoff and improve water quality, in addition to criteria for future development.

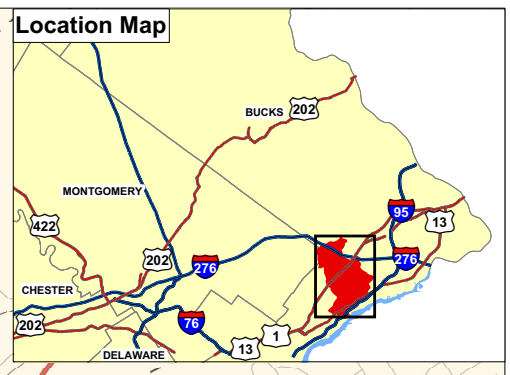
C. Topography and Streambed Profile

The lower part of the watershed, near the Delaware River, lies in the Middle Coastal Plains ecoregion characterized primarily by flat plains and elevations ranging from 0 to 80 feet above mean sea level. The remainder of the watershed is in the Northern Appalachian Piedmont ecoregion characterized by hilly to rolling terrain with occasional high ridges reaching up to 300 feet above mean sea level. The Piedmont area between the coastal plain and the Appalachian Mountains is described as "…the roots of an ancient coastal mountain chain that is now worn down to low relief"[5]. The highest elevation in the watershed is located in Lower Moreland Township at 311 feet above mean sea level, whereas the lowest elevation is located at sea level at the confluence with the Delaware River. The topography of the watershed is shown on **Map III-2** that depicts the digital elevation model (DEM) for the watershed.

[1] www.pacode.com/secure/data/025/Chapter93/chap93toc.html
[2] http://www.fish.state.pa.us/waters_trout.htm
[3] http://www.emappa.dep.state.pa.us/
[4] http://www.epa.gov/reg3wapd/tmdl/303d.htm
[5] "Ecological Subregions of the United States" US Forest Service WO-WSA-5, McNabb and Avers

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Location Map



Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY
Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run
Byberry Creek
Poquessing Creek
Poquessing Creek
132
532
213
276
1
532
63
1
63
513
132
13
95
13

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-1: BASE MAP

Newell Tereska & MacKay Engineering

GeographIT

Prepared for:
PHILADELPHIA WATER DEPARTMENT

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-2: DIGITAL ELEVATION MODEL

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Walton Run
Black Lake Run

Location Map
BUCKS
MONTGOMERY
CHESTER
DELAWARE

Elevation
High : 311 Feet
Low : 0 Feet

Legend
- Watershed Boundary
- Contours 25'
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads
- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

DATA SOURCES:
Watershed Boundary - PA DEP
Digital Elevation Model - PWD
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

Newell Tereska & MacKay Engineering
GeographIT

D. Soils

The NRCS State Soil Geographic (STATSGO) database is compiled by generalizing more detailed soils survey maps, such as a County Soils Survey. Map unit composition for a STATSGO map is determined by transecting or sampling areas on the more detailed maps and expanding the data statistically to characterize the whole map unit. A generalized soils group can consist of up to 21 different soil components; however the naming convention is typically based upon the three largest components which make up the group. In the Poquessing Watershed, two generalized soil groups were identified. These were the *Chester-Glenelg-Manor Association* and *Urban Land-Westbrook-Pits*. A listing of the two generalized soils groups within the watershed, and a description of the three largest components are included in **Table III-2** and **Table III-3**. The distribution of the generalized soil groups in the Poquessing Watershed is shown in **Map III-3**.

TABLE III-2

Chester-Glenelg-Manor (PA061) Generalized Soil Characteristics

CHESTER	The Chester series consists of very deep, well drained, moderately permeable soils on uplands. They formed in materials weathered from micaceous schist. Slopes range from 0 to 65 percent.
GLENELG	The Glenelg series consists of very deep, well drained, moderately permeable soils on uplands formed in residuum weathered from micaceous schist. Slopes range from 0 to 55 percent.
MANOR	The Manor series consists of very deep, well drained to somewhat excessively drained, moderately permeable soils on uplands. They formed in materials weathered from micaceous schist. Slopes range from 0 to 65 percent.

TABLE III-3

Urban Land-Westbrook-Pits (PA072) Generalized Soil Characteristics

URBAN LAND	Urban land is a nearly level to moderately steep mixture of soils, rock, and miscellaneous manmade material. It is in industrial, commercial, and some residential areas where urban structures and works so obscure the land surface that identification of the soils is not practical. Most areas are on uplands or terraces, but some are on flood plains.
WESTBROOK	The Westbrook series consists of very deep, very poorly drained soils formed in organic deposits over loamy mineral material. They are in tidal marshes subject to inundation by salt water twice daily. Saturated hydraulic conductivity is moderately high to very high in the organic layers and low to high in the underlying mineral sediments.
PITS	The Pit series consists of very deep, poorly drained soils that formed in fine-textured alluvium weathered from extrusive and basic igneous rocks. Pit soils are on flood plains and in basins. Slopes range from 0 to 5 percent.

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Upper Southampton

Lower Southampton

Lower Moreland

MONTGOMERY COUNTY

BUCKS COUNTY

PHILADELPHIA COUNTY

Bensalem

Philadelphia

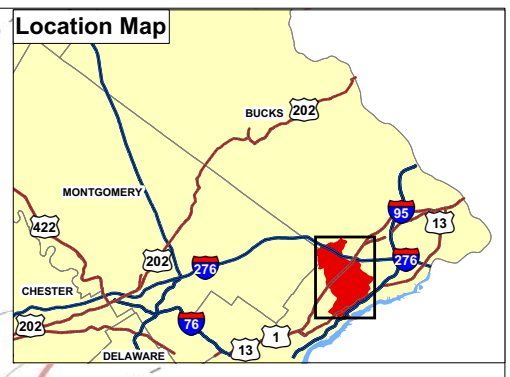
Poquessing Creek

Byberry Creek

Black Lake Run

Walton Run

Location Map



Generalized Soils

- PA061 - CHESTER-GLENELG-MANOR
- PA072 - URBAN LAND-WESTBROOK-PITS

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:
Watershed Boundary - PA DEP
Generalized Soils - USDA NRCS
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-3: GENERALIZED SOILS

Newell Tereska & MacKay Engineering

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Soil properties influence the runoff generation process. The USDA Natural Resources Conservation Service (NRCS) has established a criterion determining how soils will affect runoff by placing all surface horizon soils into four Hydrologic Soil Groups (HSGs), A through D, based on infiltration rate and depth. The HSGs can be classified as follows:

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Among the soil characteristics recorded by the USDA-NRCS is the soil's runoff potential. Almost all of the soil within the watershed has a high runoff potential because the majority of the soil in the Philadelphia area is densely developed. Individual lawns, recreational areas, and other areas of disturbed open space are generally highly compacted and have an increased runoff potential. Soils with high runoff potentials have the ability to significantly impact streams. Increased runoff and limited infiltration make urban areas susceptible to flash flooding and decreased groundwater supplies. Additionally, uncontrolled flows from urban areas contribute to increased erosion within stream channels. **Map III-4** depicts hydrologic soil groups within the watershed.

E. Geology

Geology plays a direct role in surface runoff in the Poquessing Creek Watershed because it affects soil types within the watershed through parent material breakdown as well as has a bearing on the topography of the watershed. The southern two-thirds of the watershed is underlain by the Wissahickon Formation and the undifferentiated Pennsauken and Bridgeton Formation. The Wissahickon Formation is characterized by schist and gneiss. The Pennsauken and Bridgeton Formation contains unconsolidated sand and gravel. The geology of the northern portion of the watershed is composed of the Chickies Formation, Felsic Gneiss, Mafic Gneiss, and Ledger Formation with a band of Metadiabase in the northwestern corner. There is a very minimal amount of limestone (carbonate) geologic formations within the Poquessing Watershed and there are no sinkholes listed in the DCNR Sinkhole Inventory for this area.

The geologic map of the watershed can be found in **Map III-5**. The following descriptions of non-carbonate geologic formations in the watershed are modified from Berg, T. M., Geyer, A. R., Edmunds, W. E., and others, compilers, 1980, *Geologic map of Pennsylvania*, Pennsylvania Geological Survey, 4th ser., Map 1.

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Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run

Location Map
BUCKS
MONTGOMERY
CHESTER
DELAWARE

Hydrologic Soil Groups
- A - High Infiltration Rate
- B - Moderate Infiltration Rate
- C - Low Infiltration Rate
- D - Very Low Infiltration Rate (High Runoff Potential)

Legend
- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads
- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:
Watershed Boundary - PA DEP
Hydrologic Soil Groups - USDA NRCS
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:
Portions of this map were generated from the existing data sources as listed above. Hydrologic soil group descriptions were joined to their respective layers so that the data could be displayed as shown. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-4: HYDROLOGIC SOILS

Newell Tereska & MacKay Engineering

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Non-Carbonate Geologic Formations:

Chickies Formation (Cch): Light-gray, hard, massive, Skolithos-bearing quartzite and quartz schist; thin, interbedded dark slate at top; conglomerate (Hellam Member) at base.

Felsic gneiss, Pyroxene bearing (fgp): Light, medium grained; includes rocks of probable sedimentary origin.

Ledger Formation (Cl): Light-gray, locally mottled, massive, pure, coarsely crystalline dolomite; siliceous in middle part.

Mafic gneiss, Hornblende bearing (Xmgh): Dark, medium grained; includes rocks of probable sedimentary origin; may be equivalent to "mgh" in places.

Metadiabase (md): Dark-gray, fine-grained intrusives; locally, mineralogy is altered and unit has greenish color.

Pensauken and Bridgeton Formations, undifferentiated (Tpb): Dark-reddish-brown, cross stratified, feldspathic quartz sand and some thin beds of fine gravel and rare layers of clay or silt.

Trenton Gravel (Qt): Gray or pale-reddish-brown, very gravelly sand interstratified with crossbedded sand and clay-silt beds; includes areas of Holocene alluvium and swamp deposits.

Wissahickon Formation (Xw): Includes oligoclase-mica schist, some hornblende gneiss, some augen gneiss, and some quartz-rich and feldspar-rich members due to various degrees of granitization.

Weather/Climate

The Poquessing Watershed experiences a vast range of weather conditions through seasonal variations and day to day changes in weather patterns. Bucks, Montgomery, and Philadelphia Counties are all classified as somewhat humid continental climates in which the Atlantic Ocean plays a significant role in modifying the weather patterns. Changes in topography throughout the region affect local weather systems and the change in weather between higher elevated regions and the low lying metropolitan area is rather noticeable.

The average annual temperature in the watershed is approximately 55 degrees F. It can be expected that the average summer temperature is approximately 75 degrees F. Extremely cold conditions are not common during the winter months due to a combination of factors, including coastal low pressure systems that originate in the Carolinas and move through the area. The average winter monthly temperature is approximately 33 degrees F.[5]

Because of the moderate conditions that exist during the winter, it is not uncommon for the watershed to experience thunderstorms throughout the entire year. On average, thunderstorms will occur on 15 days throughout the summer. Average annual precipitation is approximately 47 inches (from both rainfall and the water equivalent of melted snow). The amount of precipitation that occurs in each month does not significantly fluctuate.

Hurricanes, although not common, have been recorded to pass through the area, and have brought uncharacteristic amounts of rainfall and resultant flooding.

---

[5] *The Pennsylvania State Climatologist. http://climate.met.psu.edu/*

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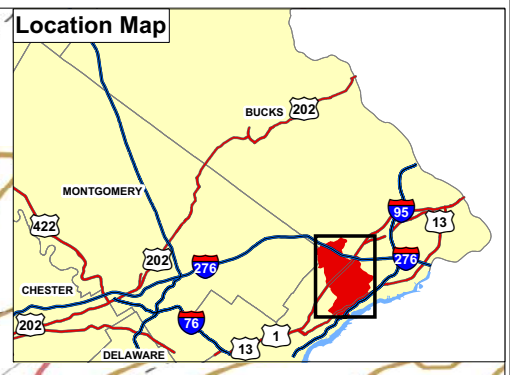
PHILADELPHIA WATER DEPARTMENT

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run

Location Map



Geology Legend

- Regional Geology

Watershed Geology

- Chickies Fm
- Felsic Gneiss, Pyroxene bearing
- Ledger Fm
- Mafic Gneiss, Hornblende bearing
- Metadiabase
- Pensauken and Bridgeton Fms Undiv
- Trenton Gravel
- Wissahickon Fm (Oligioclase Mica Schist)

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Watershed Boundary - PA DEP
Geology - PWD
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-5: GEOLOGY

Newell Tereska & MacKay Engineering

GeographIT

F. Existing Land Cover

The Poquessing Watershed has a long history of settlement and urbanization dating back to the early 17th century. The landscape of the watershed varies from suburbanized to highly urbanized. As illustrated in **Map III-6**, the Poquessing Creek Watershed is a complex mosaic of differing land cover classifications. It is almost entirely urbanized with some forested areas that are associated with parklands. A summary of land use characteristics is included in **Table III-4**.

The lower portion of the watershed can be characterized as densely developed with a high degree of urbanization. The central portion has a significant amount of manufacturing and commercial areas. The upper portions are mainly suburbanized.

Even with the grouping of multiple land use categories, it is evident that the watershed is fairly fragmented. There is evidence of a semi-contiguous greenway area in the form of a riparian buffer immediately adjacent to the main stem of the Poquessing Creek. This area leads from the mouth of the creek northward towards the upper reaches of the watershed. This greenway is very narrow in some places and non-existent in other locations due because of development adjacent streams in the watershed.

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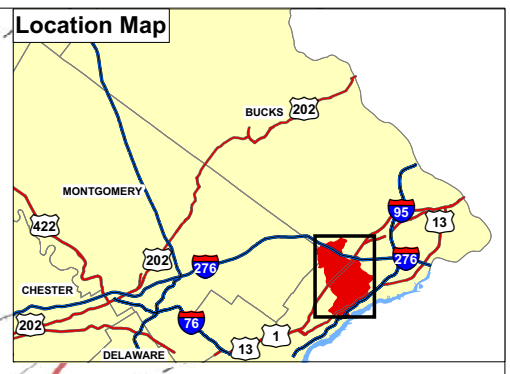
PHILADELPHIA WATER DEPARTMENT

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run

132 532 213 276 1 63 513 95 13

Location Map



Land Use

Description

- Agriculture
- Commercial
- Community Services
- Manufacturing:Light Industrial
- Military
- Recreation
- Residential:Mobile Home
- Residential:Multi-Family
- Residential:Row Home
- Residential:Single-Family Detached
- Parking
- Transportation
- Utility
- Mining
- Vacant
- Water
- Wooded

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:
Watershed Boundary - PA DEP
Existing Land Use - PWD
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP III-6: EXISTING LAND USE

Newell Tereska & MacKay Engineering

GeographIT

Table III-4

Detailed Existing Land Cover Status by Category

Land Use	Square Miles	Acres	Percent Area
Agriculture	0.26	166.1	1.20
Commercial	1.41	900.0	6.52
Community Services	1.21	776.5	5.63
Manufacturing: Light Industrial	1.56	999.8	7.25
Military	0.01	4.7	0.03
Mining	0.02	10.9	0.08
Parking	1.62	1034.9	7.50
Recreation	1.50	959.7	6.96
Residential: Mobile Home	< 0.01	1.9	0.01
Residential: Multi-Family	1.51	968.4	7.02
Residential: Row Home	1.59	1019.4	7.39
Residential: Single-Family Detached	5.85	3744.0	27.11
Transportation	1.04	663.1	4.81
Utility	0.09	57.4	0.42
Vacant	0.97	622.5	4.51
Water	0.10	62.6	0.45
Wooded	2.83	1809.1	13.11
TOTAL:	**21.55**	**13,801**	**100**

G. Land Development Patterns

The majority of the watershed is currently developed. Undeveloped areas consist mainly of forested and open spaces that are a part of the Fairmount Park System and cannot be developed. It is anticipated that the majority of future development will be in the form of redevelopment. As such, the amount of new impervious area is not expected to significantly increase. Based on current land cover patterns, the majority of redevelopment is expected to be residential (both single and multi family). This type of redevelopment is expected to occur throughout the watershed. Since the watershed is essentially built out, and most development in the watershed will be redevelopment, the future land cover of the watershed will look similar to existing conditions.

SECTION IV
STORMWATER PROBLEMS AND ANALYSIS

A. Introduction

In the Poquessing Watershed, the conversion of existing land cover to less permeable surfaces has increased the volume and frequency of runoff and led to a number of stormwater problems, including increased incidence of flooding, streambank erosion, impaired water quality, low base flow, and ecological degradation. Of paramount concern is the increase in the amount of impervious cover (i.e., roads, rooftops, turf grass), which has contributed to the escalation of runoff and flood levels. Approximately three-fourth of the Poquessing Watershed is covered by impervious land uses. Increased volumes of runoff are not only the result of increases in impervious surfaces, but also from substantial areas of natural landscape and stream buffers that have been converted to lawns or playing fields. Development of this nature, results in compacted soils and a flat uniform surface void of natural depressions that help to detain and infiltrate runoff. In addition to increased runoff, development has also altered natural drainage patterns. Stormwater runoff from developed areas is subject to contamination by many pollutants, such as sediment, nutrients (in fertilizers), pesticides, and bacteria as it flows to the next downstream waterbody.

Development in many of the watershed's municipalities took place long before stormwater management plans and ordinances were adopted. As with many of the largely developed suburbs surrounding Philadelphia, ordinances that were in place during the suburban growth period did not adequately manage the increased volume of stormwater runoff resulting from the increase in impervious cover. It was not until the 1970s that municipalities began to recognize the need to get involved with this type of regulatory oversight. Impacts of uncontrolled urban runoff include: faster runoff; increasing pollutant loads in stormwater runoff; decreased groundwater recharge and; (4) increased stream temperatures; all of which result in increased flooding, increased streambank erosion, impaired water quality, and decreased aquatic diversity.[6]

With the majority of the watersheds already developed, minimal potential exists for new development. Unlike rural watersheds, where stormwater management planning focuses on future development of undeveloped tracts, redevelopment is the major concern within the Poquessing Creek Watershed. Therefore, the best approach for appropriately managing stormwater within the watershed will be to apply corrective measures to existing problem areas and implement regulations geared towards redevelopment. With this in mind, it is even more important to determine what the problems are, what is causing them, how they are affecting the watershed, and what can be done to fix them.

B. Determination of Problem Areas

Problem areas were determined by collecting data from a number of sources, as shown in **Table IV-1**. Information on drainage problems and proposed solutions was solicited from each municipality within the Poquessing Watershed by providing forms for each Watershed Plan Advisory Committee (WPAC) member early in the Watershed Plan study. Seventy-one (71) problem areas were identified by the municipalities. The problem types are indicated in **Table IV-2**.

[6] *DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.*

TABLE IV-1

Poquessing Watershed Problem Identification

Types of Problems	Source	# of Problems
Sedimentation Sites	PWD	8
	Bensalem Twp.	6
Erosion Sites	PWD	50
	Bensalem Twp.	6
	Backyard Buffer Program (BYB)	11
Flooding	Bing, PASDA (Floodplains), Flood Insurance Claims	60 Areas 255 Buildings
	Bensalem Twp.	1
FIS Bridge Backwater Data	FEMA FIS Profiles	43
Non-Attaining Streams	PaDEP 303d List -PASDA	Entire Watershed 2 Non-Attaining Uses
Obstructions	PWD	148

TABLE IV-2

Problems Reported by Municipalities

Municipality	**Type of Problems** (A)
Bensalem Township	1, 2, 3, 4, 5 & 6
City of Philadelphia (PWD)	1, 2 & 3
Lower Moreland Township	N/A
Lower Southampton Township	*
Upper Southampton Borough	*

N/A No problem areas reported
* No Data Collection Forms Received

Types of Problems

1. Flooding
2. Accelerated Erosion
3. Sedimentation
4. Landslide
5. Groundwater
6. Water Pollution

In addition to the municipal problem area forms, PWD's Backyard Buffer Program survey (BYB Program) was also referenced to determine streambank erosion sites within the watershed, which were based on a "Bank Erosion Hazard Index" (BEHI). This program is discussed in more detail in Section IV-D.1.

Only one flooding problem area was reported by municipalities on the problem area data collection forms. Flash flooding is a common occurrence within the greater Philadelphia area. Therefore, NTM analyzed information from the U.S. Department of Housing and Urban Development, Federal Insurance Administration, Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FISs) and floodplain mapping to determine if and where additional flooding areas exists throughout the watershed.

Water surface profiles contained in the FEMA studies were analyzed to determine bridges with significant backwater that could contribute to upstream flooding. Floodplain data was also imported into Google Earth and cross-referenced with Bing "fly-by" aerial maps to show the location of buildings within the 100-year floodplain. This data was then cross-referenced with the FEMA FIS profiles to categorize the flooding as backwater from bridges or general flooding. General flooding refers to flooding along a stream that does not have a specific cause. Flooding could be the result of increased runoff, natural topography, development within the floodplain, etc. FEMA's flood insurance claim data was also obtained to determine the worst flooding areas. This data is further discussed under Section IV-D.3.

It should be noted that FEMA detailed and approximate study areas were used to determine flooding problem areas. There are two types of studies conducted in the FIS program: detailed and approximate. Detailed methods included hydrologic computations and detailed HEC-2 or HEC-RAS backwater computations. FEMA detailed study areas are selected with priority based on all known flood hazards areas and areas of projected development and proposed construction. FEMA approximate study areas are selected based on areas that have low development potential or minimal flood hazards. Problem areas within approximate areas were identified if they were in residential areas where flooding is likely to occur. Flood claims were taken into account to see if approximate areas have flooded in the past[7].

C. Analysis of Problems

Each problem area reported by municipalities was catalogued based on the type of problem, e.g., erosion, sedimentation, flooding, water quality. The problems were then investigated to determine potential causes and severity as well as general solutions. Problem area forms were generated to document these problems. The forms include a description of the problem location, photos of the area, and list of general solutions. These forms are available in **Appendix B**. The original problem area data collection forms are included in **Volume III, Technical Appendix 1**. Flood insurance profiles with labeled backwater bridges are included in **Appendix C.** Aerial images with overlaid flooding data are available for these areas in **Appendix D.**

Due to the large quantity of problem areas, they were classified as stormwater *quantity* problems and stormwater *quality* problems to be more discernible on the maps. The problem area locations can be seen on **Map IV-1** and **Map IV-2** for quantity (flooding) and water quality related problems, respectively. Water quality problems shown on **Map IV-2** include streambank erosion, sedimentation, and stream impairment. From the problem area analysis, categories of general watershed problems were developed. This included streambank erosion, sedimentation, flooding, obstructions, stream impairment, existing basins, and existing management procedures. Each general watershed problem type is discussed in further detail in Section IV.D and generalized solutions for these problems are provided in Section VII.A.

[7] http://www.fema.gov/index.shtm

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

LSF12 LSF13 LSF11 LSF10 LSB1 LSF9 LSB2 LSF7 LSF8 LSB3 LSF6 LSB4 LSF19 LSF5 LSB5 LSF18 LSB6 LSF17 LSB7 LSF4 LSB8 LSF16 LSF3 LSF14 LSF2 LSF15 LSB9 LSB10 LSF1 PHB5 PHF27 PHB4 PHF28 PHB3 PHF29 PHF31 PHF30 PHF32 PHB1 PHB2 BEB1 BEB2 PHF26 BEB3 PHF25 BEB4 PHF24 PHF23 PHF41 PHF22 BEB5 PHB6 PHF21 PHB7 PHB8 PHB9 PHF20 BEB6 PHF19 PHB13 PHB10 PHF18 BEB7 PHF40 PHB11 PHF17 PHB12 PHB14 PHB15 PHF16 PHF15 PHF39 PHB16 PHF14 PHF38 PHF13 PHF37 PHF12 BEB8 PHF36 PHB17 PHF11 PHF35 PHF10 BEA3 PHB18 PHB19 PHF34 PHF9 PHF8 PHF7 PHF6 PHF33 BEB9 PHB22 PHB20 PHB23 PHF5 PHB21 PHF4 PHF3 BEB10 PHF2 PHF1

Byberry Creek
Walton Run
Poquessing Creek
Black Lake Run

Location Map

Problem Areas

From NTM Analysis

- FIS Backwater Bridges
- Flood Problem Areas

Reported by Bensalem

- Flooding

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Floodplain
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

DATA SOURCES:

Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)
Problem Areas - Data Submitted by
Municipalities - Bensalem, NTM and PWD

NOTES:

Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-1: WATER QUANTITY PROBLEMS

Newell Tereska & MacKay Engineering

GeographIT

Prepared for:
PHILADELPHIA WATER DEPARTMENT

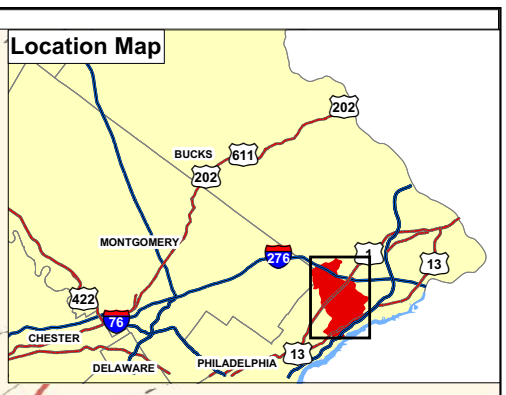
Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Detailed Problem Area 1
Detailed Problem Area 10
Detailed Problem Area 4
Detailed Problem Area 7
Detailed Problem Area 8
Detailed Problem Area 9
Detailed Problem Area 6
Detailed Problem Area 3
Detailed Problem Area 2

PHA50 PHA51 PHA8 PHA27 PHA28 PHA58 PHA57 PHA56 PHA26 PHA25 PHA23 PHA24 PHA22 PHA21 PHA20 PHA49 PHA19 PHA7 PHA47 PHA48 PHA39 PHA38 PHA18 PHA17 PHA16 PHA45 PHA52 PHA54 PHA53 PHA15 PHA55 PHA5 PHA4 PHA14 PHA46 PHA13 PHA12 PHA3 PHA2 PHA1 PHA36 PHA37 PHA42 PHA41 PHA43 PHA44 PHA35 PHA40 PHA34 PHA33 PHA32 PHA31 PHA30 PHA29 PHA9 PHA10

BEA13 BEA12 BEA11 BEA10 BEA9 BEA8 BEA7 BEA6 BEA5 BEA4 BEA2 BEA1

Location Map



Problem Areas

Reported by Philadelphia
- Problem Area - Sedimentation
- Problem Area - Accelerated Erosion
- Problem Area - Accelerated Erosion and Sedimentation

Reported by Bensalem
- Sedimentation
- Accelerated Erosion and Sedimentation

Detailed Problem Areas
- Location of Detailed Problem Area

Impaired Streams

Cause of Impairment
- Urban Runoff/Storm Sewers
- Unknown Cause - PCB

Backyard Buffer Program Erosion Sites

Parcel Rank
- Extreme
- Very High
- High to Very High
- High
- Moderate
- N/A

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Parcel
- Water Body
- Stream
- Railroad
- Local Road

Major Roads
- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Streams (Non-attaining 303d) - DEP
Water Bodies - U.S. Fish and Wildlife Service (Derived from NWI Wetlands)
Problem Areas - Data Submitted by Municipalities - Bensalem, Philadelphia and PWD
Detailed Problem Areas - NTM
Backyard Buffer Program - URS/PWD

NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-2: WATER QUALITY PROBLEMS

Newell Tereska & MacKay Engineering

geographIT

D. Generalized Stormwater Problems

1. Streambank Erosion

Erosion of the streambanks was the most noted problem throughout the watershed. Of the 142 problem areas reported in **Table IV-1**, 67 involved erosion of the streambanks. During field investigations, erosion cuts ranged from 1 foot to 10 feet high along the banks. Streambank erosion occurs due to the force of water. As flow depths and velocities are increased, the force of the water flowing against the streambank removes soil particles from the banks, and in many cases erosion causes banks to slump and fall into the flowing water. These conditions are often caused by increases in stormwater runoff due to increased development in the watershed and can be difficult to remedy.

Erosion problems are typically one of the most common problems in a watershed, but they are also one of the most frequently overlooked. Erosion problems are deceptive because they typically develop over a long period of time, in areas hidden from the public eye, and are often visually unspectacular. Therefore, they often go unnoticed from one year to the next until they create a serious problem, and by this point, the damaged caused is often widespread and permanent[8]. Negative impacts of streambank erosion include loss of property due to an expanding top of bank, sedimentation of downstream reaches or structures, structural instability of adjacent roads and buildings, diminished riparian buffers, and unsightly conditions. The main stem of the Poquessing Creek and several of the tributaries in the watersheds contain substantial lengths which are severely eroded.

The Philadelphia Water Department (PWD) developed the Backyard Buffer Program (BYB Program) which assesses the condition of individual properties along the stream and addresses problems related to each individual property. The goal of the program is to provide property owners with the knowledge to restore an optimal area of their yard adjacent to the stream to a healthy riparian buffer that will protect the property from erosion, significantly improve the stability of the streambank, and enhance the ecological habitat of the buffer and stream. For each participant property, backyard landscape and layout conditions were documented, stream geomorphology data was collected, photographs taken, and a site sketch was produced. All participating properties were given a Bank Erosion Hazard Index (BEHI) which ranged from very low to extreme. Most properties in the Poquessing Watershed had a BEHI rating of high to very high. Solutions were developed for the properties to implement in order reduce the effects of erosion and runoff on their properties. A total of 11 properties were identified in the BYB Program, all of which were incorporated in the GIS for this project and are included as problem areas within this report. The locations of these properties are shown on **Map IV-2**.

2. Sedimentation

Sedimentation was the second highest reported problem in the watershed. There were 14 reported problems related to sedimentation, all of which were reported along Poquessing Creek. Since sedimentation is a byproduct of erosion, the causes are often similar. High flows and diminished riparian buffers cause increased erosion, which in turn, causes increased sedimentation. Generally, sedimentation problems arise when eroded soil is deposited downstream at locations where stream slopes lessen, channels widen, and velocities decrease.

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[8] *Cordone, Almo J. and Kelley, Don W.The Influences of Inorganic Sediment on the Aquatic Life of Streams. California Department of Fish and Game, Inland Fisheries Branch.*

Often this occurs due to flow being interrupted by a structure or other obstruction. Sedimentation also results from land disturbance activities associated with construction.

Sediment is a pollutant and typically has phosphorus bound to it, a leading contributor to eutrophication. Sediment accumulations upstream of bridges and culverts can create flooding conditions by reducing available cross sectional area. High sediment levels in streams can create a sediment blanket over the natural stream bottom. This blanket chokes the streambed, killing the majority of the natural organisms, which in turn disrupts the natural ecosystem of the stream and surrounding areas.

3. Flooding

A total of 61 flooding problem areas were identified in the watershed. One (1) problem area was documented through the municipal reporting process and 60 problem areas were identified through the floodplain analysis described in **Section IV.B**. This analysis included overlaying FEMA 100-year floodplain boundaries on aerial photography and identifying areas with impacted structures, a sample of which is shown in **Figure IV-1**. The analysis yielded a total of 218 residential and 37 commercial buildings that were impacted by the 100-year floodplain boundary.

These flooding areas were further classified as general flooding or backwater flooding to distinguish between areas where flooding is resulting from backwater from downstream bridges or more general causes. General flooding areas are areas where the flow frequently results in overbank conditions, causing hazards and/or damage to adjacent properties and structures. This type of problem is regional in nature and not typically caused by undersized bridges or culverts, which are addressed as a different problem area type. Very often, regional flooding is attributable to new impervious surfaces created by development within the watershed, which increases runoff and/or encroachment in the natural floodplain. **Table IV-3** summarizes identified flooding problems and their associated impacts to structures in the floodplain.

Table IV-3

Summary of Structures Impacted by 100-Year Floodplain

Flooding Classification	Problem Areas	Residential Buildings	Commercial Buildings
Backwater from Obstruction	30	97	27
General Flooding	30	121	10
TOTAL	**60**	**218**	**37**

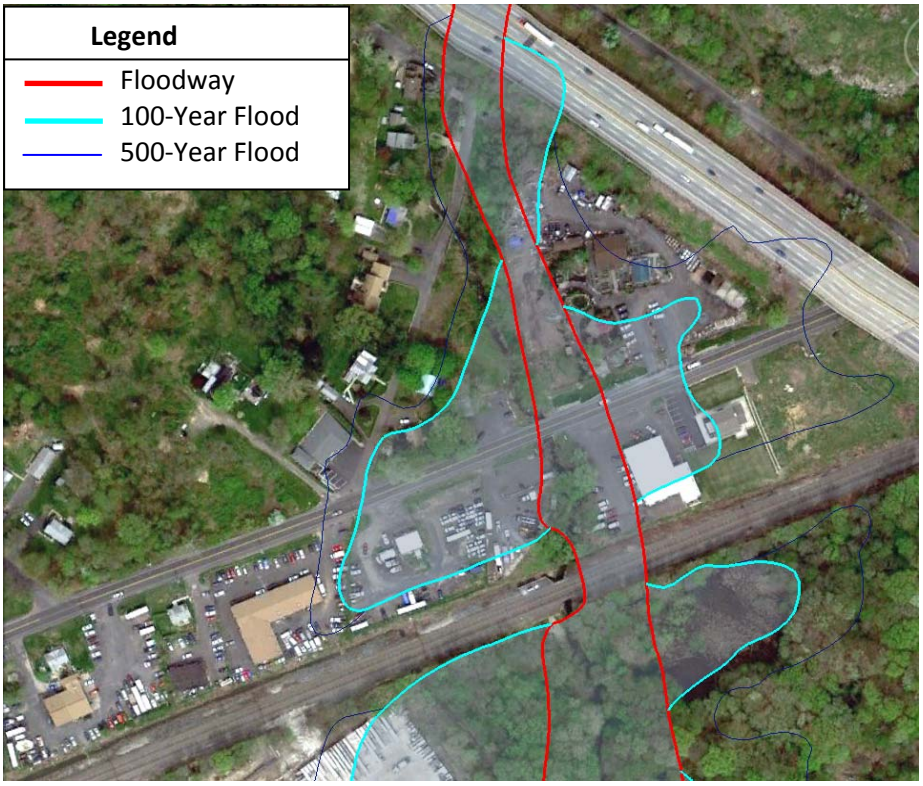

Figure IV-1 – Floodplain Overlaid onto an Aerial Photograph

In addition, flood insurance claims paid under FEMA's federal flood insurance program provide a partial measure of flood damage that has occurred since the late 1970s and is a good source for identifying patterns of flooding. This information can be used to indicate areas where flood damages are clustered and where repetitive flood claims have been filed. **Map IV-3** shows the distribution of all flood insurance claims paid in the Poquessing Watershed for the period from August 1975 through March 2010. As of March 2010, a total of 187 claims had been paid with a total payout of $2 million. The dollar amount is not adjusted for inflation and is only a fraction of the actual damage that has occurred as the result of flooding[9]. Damages to uninsured property, disaster assistance, and damage to public property are not included. Locations of repetitive flood claims are shown in **Map IV-4**, along with the number of claims at the site. Structures have been flooded up to seven times.

Development in the floodplain is a concern in the Poquessing Watershed. Approximately 683 acres (5%) of the watershed are contained within the 100-year floodplain boundary. Approximately 28% of the floodplain area is developed with residential areas, commercial areas, manufacturing areas, developed recreational areas, and pavement. Wooded areas, undeveloped recreational areas, agriculture, community services, and vacant lands make up the remaining 72%. **Map IV-5** depicts developed land coverages that are within the FEMA 100-year floodplain. **Table IV-4** summarizes the land cover and development in the floodplains within the watershed.

[9] http://www.fema.gov/index.shtm

TABLE IV-4

Land Cover and Development in Floodplains

Land Cover		**Acres**	**Square Miles**	**Percentage**
Agriculture		8.2	0.01	1.2
Commercial		24.5	0.04	3.6
Community Services		5.9	0.01	0.9
Manufacturing: Light Industrial		0.6	< 0.01	0.1
Pavement		30.9	0.05	4.5
Recreation	Developed	14.8	0.02	2.2
	Undeveloped	35.5	0.06	5.2
Residential		122.2	0.19	17.9
Vacant		24.0	0.04	3.5
Water		45.7	0.07	6.7
Wooded		370.6	0.58	54.3
TOTAL		**683**	**1.07**	**100**

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run

132 532 213 276 1 63 513 95 13

Location Map

BUCKS 202
MONTGOMERY 422 202 276 95 13
CHESTER 202 76 1
DELAWARE

Total Flood Insurance Claims, 2010

Claim Value (US Dollars)

- $0 - $5,000.00
- $5,000.01 - $10,000.00
- $10,000.01 - $25,000.00
- $25,000.01 - $50,000.00
- $50,000.01 - $100,000.00

NOTE: The information contained on this map is legally privileged and confidential. Its use is protected under the privacy act of 1974, 5 U. S. C. section 552(a). Use of the information provided should be restricted to applicable routine use cited in the systems notice published in 56 FR 26415.

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Flood Insurance Claims - FEMA
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Geology - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. Portions of the Landuse in Floodplains data were adjusted to reflect development in Recreation areas. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-3: FLOOD INSURANCE CLAIMS

Newell Tereska & MacKay Engineering

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Prepared for:
PHILADELPHIA WATER DEPARTMENT

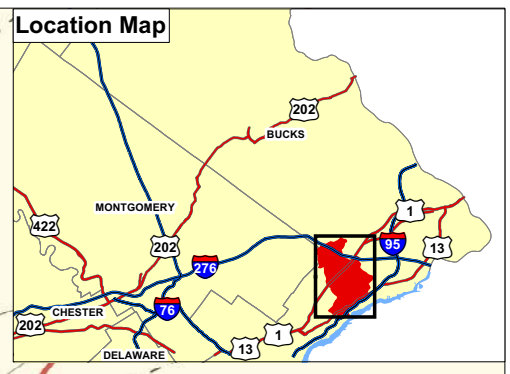
Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia

MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Black Lake Run
Walton Run
Byberry Creek
Poquessing Creek

132 532 213 276 1 63 513 95 13

Location Map



Recurring Claim Incidents

Number of Claims

- 2
- 4
- 6
- 7

NOTE: The information contained on this map is legally privileged and confidential. Its use is protected under the privacy act of 1974, 5 U. S. C. section 552(a). Use of the information provided should be restricted to applicable routine use cited in the systems notice published in 56 FR 26415.

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Recurring Flood Insurance Claims - FEMA
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Geology - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

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POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-4: REPETITIVE FLOOD INSURANCE CLAIMS

Newell Tereska & MacKay Engineering

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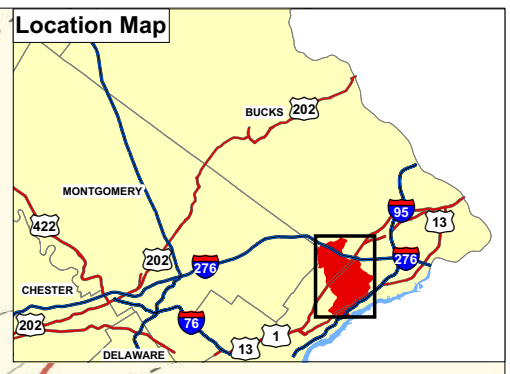
Prepared for:
PHILADELPHIA WATER DEPARTMENT

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-5: FLOODPLAIN DEVELOPMENT

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY

Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run

Location Map



Land Use in the Floodplains

Floodplain

Land Use Descriptions

- Commercial
- Community Services
- Manufacturing:Light Industrial
- Residential:Multi-Family
- Residential:Row Home
- Residential:Single-Family Detached
- Parking
- Transportation
- Utility
- Recreation

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Wetland
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

N W E S

0 0.25 0.5 1 Miles

DATA SOURCES:
Landuse in Floodplains - PWD/DVRPC
Floodplains - FEMA
Wetlands - NWI
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Geology - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. Portions of the Landuse in Floodplains data were adjusted to reflect development in Recreation areas. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

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4. Obstructions

Bridges and culverts can change the flow characteristics of waterways by restricting flow during flood events, thus temporarily raising the upstream water surface elevations. This can cause upstream flooding, bridge deck overtopping, and flooding of low-lying approach areas and roadways. Locations of significant waterway obstructions (e.g., culverts and bridges) were obtained as part of the fluvial geomorphologic (FGM) study conducted by the Philadelphia Water Department. Each obstruction was surveyed to determine the value of all parameters that would determine the hydraulic capacity. These parameters include dimensions and geometry of the opening, construction materials (roughness estimates), bed material (stream bed roughness), deck height, and dimensions of abutments and piers.

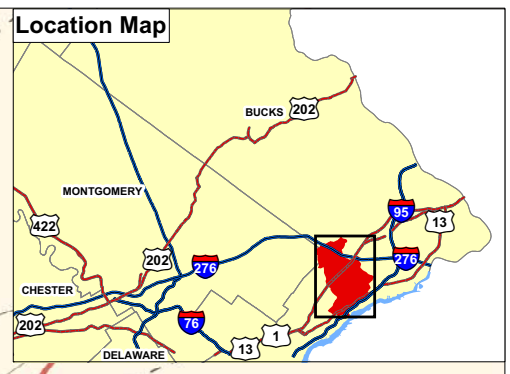
Each obstruction was included in the final hydraulic model for Poquessing Creek using the above field measurements. The Poquessing Creek model was then used to determine the expected frequency of overtopping for each obstruction. The obstructions were classified into seven categories:

1. Able to pass the 100-year, 24-hour storm without obstructing the flow
2. Able to pass the 50-year, 24-hour storm and greater without obstructing the flow
3. Able to pass the 25-year, 24-hour storm and greater without obstructing the flow
4. Able to pass the 10-year, 24-hour storm and greater without obstructing the flow
5. Able to pass the 5-year, 24-hour storm and greater without obstructing the flow
6. Able to pass the 2-year, 24-hour storm and greater without obstructing the flow
7. Not able to pass the 2-year, 24-hour storm and greater without obstructing the flow

The locations of all obstructions that fall into the seven categories above can be found in **Map IV-6**. The obstruction data and the obstruction flow capacities can be found in **Volume III, Technical Appendix 2**.

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Location Map



Obstructions

- Able to Pass 100 Year Flow
- Able to Pass 50 Year Flow
- Able to Pass 25 Year Flow
- Able to Pass 10 Year Flow
- Able to Pass 5 Year Flow
- Able to Pass 2 Year Flow
- Undersized

Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY
Poquessing Creek
Byberry Creek
Black Lake Run
Walton Run
Poquessing Creek
Byberry Creek
Poquessing Creek
132
532
213
276
1
532
63
63
513
132
1
13
95
13

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Flood Obstruction Information - PWD
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-6: FLOODS EXCEEDING OBSTRUCTION CAPACITY

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5. Stream Impairment - Water Quality

A variety of factors can be attributed to stream impairment within a watershed. Surface water quality can become impaired from a lack of stormwater runoff management and non-point source pollution control. Runoff from parking lots or other types of impervious surfaces increases stream temperatures and contributes to non-point source pollution. Pollutants can come from automobile emissions, lawn and garden chemicals, litter, and industrial/commercial discharges.

As shown on **Map IV-2**, the entire Poquessing Watershed is classified as non-attaining or impaired under the designations of Section 303(d) of the Pennsylvania Department of Environmental Protection's Clean Water Act. From the mouth of the watershed to just north of I-95, the stream has a fish consumption designated use. It fails to meet this designated use due to high levels of PCB contamination. North of the Bristol Pike to the watershed source, the stream has an aquatic life designated use. The cause of impairment in these stream sections is listed as urban runoff which is producing flow variability, siltation, excessive algal growth, and flow alterations. Urban runoff is the primary cause of impairment in 95 percent of the designated streams, and further emphasizes the need for appropriate stormwater management controls within the watershed.

6. Existing Stormwater Basins

Generally the inclusion of stormwater basins benefits a watershed, and often any basin is better than no basin at all. Ineffective or deficient stormwater basins can also negatively impact a watershed. Many basins within the Poquessing Watershed were built to detain larger storm events (e.g., 10-, 25-, 50-, 100-year storms) without taking into consideration the effects of smaller storm events (e.g., 1-, 2-year storms). This is a concern because the "first flush," or initial runoff volume, contains the majority of the sediment and pollution from impervious or otherwise developed areas. If untreated, the pollutants are conveyed directly into the stream unfiltered. Additionally, the large majority of erosion in Pennsylvania streams is caused by smaller and more frequent storms, which tend to result in bankfull conditions with the highest velocities and shear stresses.

An inventory of existing detention basins and storage facilities within the watershed was developed based on municipal reporting and locating additional basins on aerial photography. Locations of identified stormwater basins within the watershed can be found on **Map IV-7.** Basins were field viewed to obtain approximate dimensions and evaluate overall basin conditions. Several basin locations within the city of Philadelphia were reported with storage volumes, but without dimensions. For these basins, length and width dimensions were estimated using Google Earth and a depth was calculated. This information was used to determine existing storage volumes and potential basin retrofits. The existing basin inventory is included in **Appendix E**.

During the field view, it was noted that several existing basins contained concrete low flow channels, flat bottoms, and basin inlets that were next to the outfalls. Basins with concrete low-flow channels, which are found in many older basins, heat runoff and quickly transport it along with pollutants through a basin without any filtering. Higher standing native vegetation, which helps to shade, filter, and slow runoff, was not found in many basins throughout the watershed. Many of the basins are planted with lawn grass that is frequently mowed and is limited in treatment capabilities. The mowed flat bottoms of these basins do little to filter sediment and other pollutants. Basins that have outlets located next to points of inflow allow water to pass through the basin quickly without being detained, which is known as short-circuiting the basin.

All of the configurations noted above, are not conducive to the detaining, infiltrating, and filtering of runoff from smaller storm events.

7. Existing Management Problems, Stormwater Collection Systems and Outfalls

Stormwater management planning is critical throughout the Poquessing Watershed. This includes not only the construction of BMPs to treat runoff from developed areas, but also the collection and conveyance of runoff from developed areas to waters of the Commonwealth. Several existing management problems were identified in the Poquessing Watershed. No proposed stormwater collection and control facilities were reported by the municipalities and it is unknown of where future collection and control facilities will be located within the next 10 years. The primary management issues identified were connected impervious areas, limited infiltration type BMPs, and point source discharges. Connected impervious areas are areas that discharge water directly into a waterbody without first being treated by a stormwater control or first flowing over pervious areas. Connected impervious areas negatively affect water quality by increasing pollutant loading and water temperatures in receiving streams. For example, parking lots typically contain pollutants like oil, antifreeze, and salt, which are discharged directly into receiving waterbodies in directly connected areas.

Another common management problem is a lack of infiltration BMPs throughout the watershed. BMPs in the watershed are often designed to manage runoff rates rather than volumes. Infiltration BMPs are a key component to comprehensive stormwater management. They not only help to decrease volumes of runoff, but also increase water quality and help to recharge groundwater supplies. When the natural topography of a landscape is developed and proper stormwater controls are not implemented, the result is often increased flooding and a depleted groundwater supply. Decreased infiltration is a watershed-wide problem and has resulted in depleted groundwater supply throughout the Poquessing watershed. Signs of reduced infiltration in a watershed typically include frequent flash flooding in the spring followed by severally decreased or dry flow conditions in the summer. These conditions are present in the Poquessing Watershed.

Outfalls, when discharging from combined sewers or industrial areas, can contribute significantly to pollution by discharging pollutants directly into receiving waterbodies. Also, outfalls are a common source of erosion problems when unprotected from the effects of high velocity flows. Locations of all reported outfalls within the watershed can be found on **Map IV-8.**

8. Riparian Buffer Degradation

Increasing urbanization in the Poquessing Watershed has led to the destruction of riparian buffers. Riparian buffers help to protect streambanks from erosion and they slow, filter, and treat stormwater runoff. Shading from riparian plantings help to mitigate thermal impacts and remove runoff volume through evapotranspiration. The destruction of riparian buffers can led to the widespread loss of habitat for both aquatic and terrestrial species, as well as propagation of invasive plant species. Unprotected streambanks are often the location of erosion problems that generates sediment in downstream reaches.

An inventory conducted by the Heritage Conservancy in the year 2000 identified over 109 stream reaches, covering approximately 33,400 feet of streambank, where riparian stream buffers could be restored on either one or both sides of streams in the Poquessing Watershed. The distribution of these locations is shown in **Figure IV-2**.

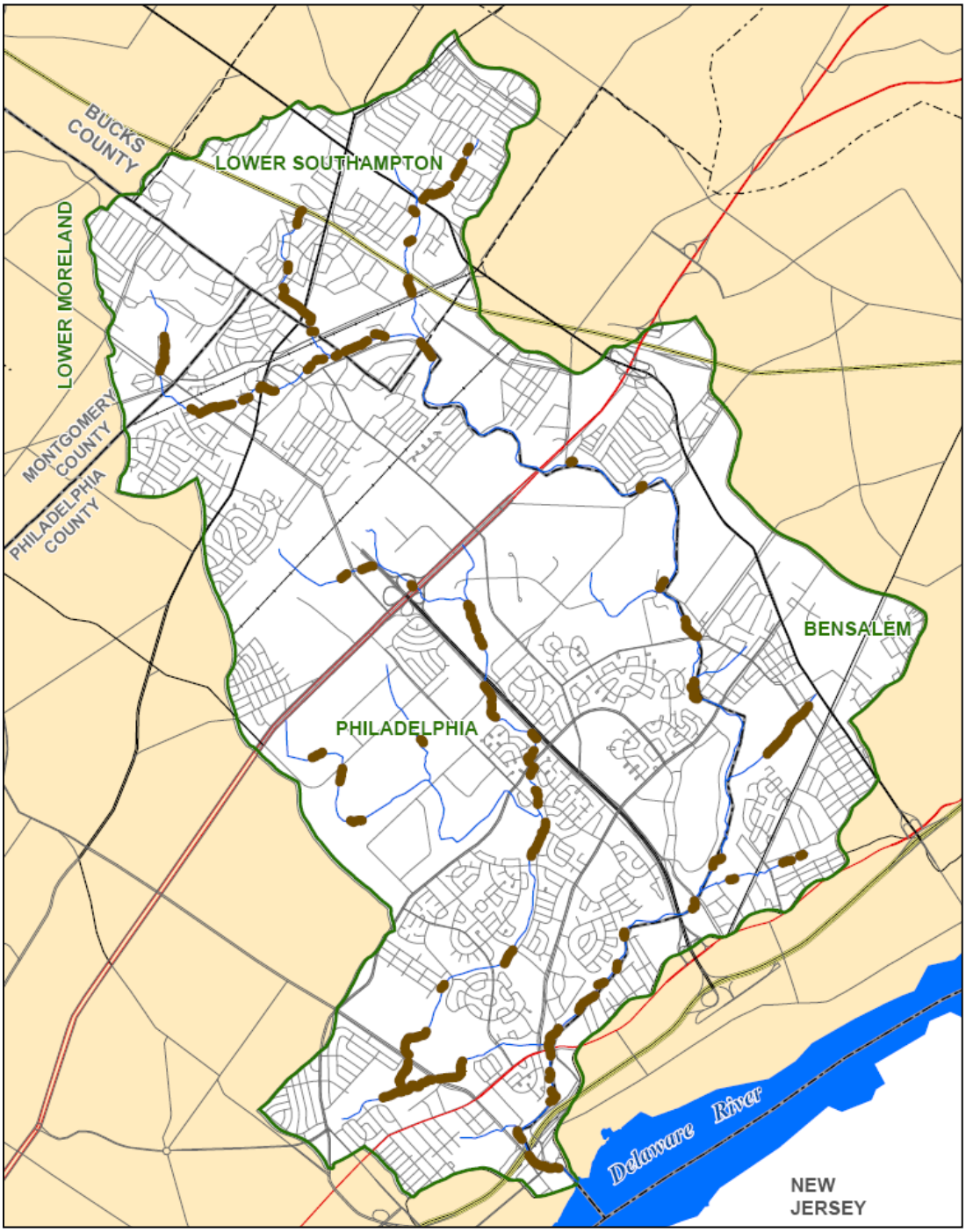


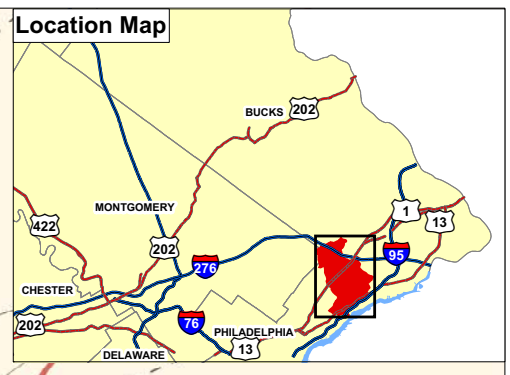
Figure IV-2 – Locations Lacking Sufficient Riparian Buffer

Source: Heritage Conservancy, 2000

Prepared for:
PHILADELPHIA WATER DEPARTMENT

POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-7: FLOOD AND STORMWATER CONTROL FACILITIES

Location Map



Flood and Stormwater Facilities

- Existing Flood Control Project
- Existing Stormwater Control Facility
- Proposed Stormwater Control Facility

Legend

- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:
Watershed Boundary - PA DEP
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service (Derived from NWI Wetlands)
Existing/Proposed Facilities - Data Submitted by Municipalites - Bensalem, Lower Moreland, and Philadelphia

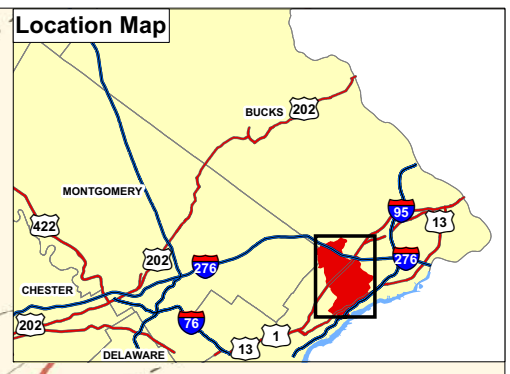
NOTES:
Portions of this map were generated from the existing data sources as listed above. These existing data were utilized for base mapping purposes and are shown for spatial reference only. This map should only be used in conjunction with the complete Poquessing Creek Stormwater Management Plan.

Newell Tereska & MacKay Engineering

geographIT

Prepared for:
PHILADELPHIA WATER DEPARTMENT

Location Map



Upper Southampton
Lower Southampton
Lower Moreland
Bensalem
Philadelphia
MONTGOMERY COUNTY
BUCKS COUNTY
PHILADELPHIA COUNTY
Poquessing Creek
Byberry Creek
Walton Run
Black Lake Run

Legend

- Outfall
- Watershed Boundary
- County Boundary
- Municipal Boundary
- Water Body
- Stream
- Railroad
- Local Road

Major Roads

- Interstate
- US Federal Highway
- State Highway
- Other Highways

0 0.25 0.5 1 Miles

N W E S

DATA SOURCES:

Watershed Boundary - PA DEP
Outfalls - PWD
Roads - PWD/PennDOT
Counties - PennDOT
Municipalities - PWD
Streams - PWD
Water Bodies - U.S. Fish and Wildlife Service
(Derived from NWI Wetlands)

NOTES:

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POQUESSING CREEK WATERSHED ACT 167 STORMWATER MANAGEMENT PLAN
MAP IV-8: STORMWATER OUTFALLS

Newell Tereska & MacKay Engineering

GeographIT

E. Problem Areas Warranting a Detailed Analysis

Several of the problems areas reported by municipalities were investigated to determine the cause, optimal solution, and associated costs of improvements. These included severe problem areas that pose a significant risk to life, property, or the environment. Ten (10) detailed problem areas are identified in **Table IV-5**. The locations of the problem areas are depicted on **Map IV-2**.

Table IV-5

Problem Areas Warranting a Detailed Analysis

Detailed Problem Area #	Municipality	Problem Description
1	Lower Southampton Twp.	Erosion
2	Philadelphia	Erosion
3	Bensalem Twp.	Erosion
4	Philadelphia	Erosion
5	Philadelphia	Erosion
6	Bensalem Twp.	Erosion
7	Bensalem Twp.	Erosion, Water/Groundwater Pollution, Dumping
8	Philadelphia/ Bensalem Twp.	Erosion, Potential Pond Failure
9	Philadelphia	Existing Management
10	Lower Southampton Twp.	Flooding

Evaluation of the problem areas included field observation, photos, documentation, and a hydrologic summary, including calculations of drainage area and design storm peak flow rates. Evaluation of possible solutions for each detailed problem area and general cost ranges typically associated with the nature of the solutions are discussed in **Section VI.A2**.

SECTION V
Criteria and Standards for New Development and Redevelopment in the Poquessing Creek Watershed

This section provides a summary of the model stormwater management ordinance for the Poquessing Creek Watershed as presented in **Appendix A**. The standards and criteria for the model ordinance were developed based on information from the following sources:

- The Pennsylvania Department of Environmental Protection's (PaDEP's) Best Management Practices (BMP) Manual and Model Stormwater Management Ordinance
- The Philadelphia Stormwater Regulations
- The approved Tookany/Tacony-Frankford Creek Stormwater Management Plan
- The approved Darby-Cobbs Creek Stormwater Management Plan
- The recently completed ordinance for the Pennypack Watershed
- Discussions with representatives from PaDEP, Philadelphia, Bucks, and Montgomery Counties
- Hydrologic modeling results used to establish management districts for peak rate control
- Experience and professional judgment of the study team regarding effectiveness of stormwater requirements.

The objective of the model ordinance is to minimize or prevent the hydrologic and water quality impacts of future development and redevelopment in the watershed. As described in **Section III**, all stream reaches in the watershed are classified as impaired by the PaDEP and the cause of the impairment for 95 percent of the impaired stream reaches is attributed to urban runoff. While adoption and enforcement of the ordinance would address the impacts of future development, the proposed improvements in **Section VI** are also recommended to address the current level of impairment by reducing stormwater flows and runoff volumes.

A. Model Ordinance Summary

The standards and criteria included in the model ordinance apply to regulated activities defined in Article I and vary based on the county of jurisdiction. The standards pertain to the following areas of potential impact as defined in Tables 106.1 of the Ordinance:

- Site Design and Drainage Plan Requirements
- Groundwater Recharge
- Water Volume Control
- Streambank Erosion (Channel Protection)
- Peak Rate Control

Article I, Section 103 requires that all legal water quality requirements under state law, including regulations at 25 Pennsylvania Code Chapter 93.4.a requiring protection and maintenance of "existing and designated uses" and maintenance of the level of water quality to support those uses in all streams, and the protection, maintenance, reclamation, and restoration of water quality in "special protection" streams, be met.

Applicability and Exemptions (Article I, Sections 105 and 106) for Regulated Activities defined in Section 105 of the Ordinance are based on the area of land disturbance and the area of impervious cover included in the project. The exemption thresholds vary by county. Exemptions may be denied by municipalities based on identified downstream problem areas, based on High Quality or Exceptional Value stream designations, or based on known source water protection areas.

Article II, Section 202 of the Ordinance defines terms used in the Ordinance provisions.

Article III specifies stormwater management site plan requirements that must be addressed prior to issuance of land development plans or building, occupancy, or land disturbance permits. Plan contents, including stormwater management and erosion and sedimentation plan contents, and submission requirements are specified.

Article IV contains the stormwater management criteria and provides additional details on the applicability of these standards to regulated activities. Requirements for determining design storms, groundwater recharge, water volume control, streambank erosion control, and peak runoff rate control are provided.

Articles V thru IX cover inspections, fees and expenses, maintenance responsibilities, prohibitions, enforcement, and penalties.

The following two sections highlight the Applicability, Exemptions, and Stormwater Management Criteria provisions of the Ordinance.

B. Applicability and Exemptions

Table V-1 and **Table V-2** summarize ordinance provision applicability throughout the watershed. Table V-1 applies to the Buck and Montgomery County portions of the watershed. Table V-2 applies to the Philadelphia County portions of the watershed.

Table V-1

Eligibility for Exemptions for the Bucks and Montgomery County Portions of the Watershed

Ordinance Article or Section	Type of Project	Proposed New Impervious Cover						
		< 1000 ft²			≥ 1000 ft² to < 5,000 ft²			≥ 5,000 ft²
		Earth Disturb. < 5,000 ft²	Earth Disturb. 5,000 ft² to 1 acre	Earth Disturb. > 1 acre	Earth Disturb. < 5,000 ft²	Earth Disturb. 5,000 ft² to 1 acre	Earth Disturb. > 1 acre	All Earth Disturb. Categories
Article III SWM Site Plan Requirements	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
Section 404 Nonstructural Project Design	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
Section 405 Groundwater Recharge	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
Section 406 Water Volume Control Requirements	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
Section 407 Streambank Erosion Requirements	Development	Yes	No*	No	No*	No*	No	No
	Redevelopment		Yes		Yes	Yes		
Section 408 Stormwater Peak Rate Control and Management Districts	Development and Redevelopment	Yes	No*	No	Yes	No*	No	No
Section 403 Erosion and Sediment Pollution Control Plan	Earth Disturbance	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements
		(Refer to municipal earth disturbance requirements, as applicable)						

Notes:

Yes – Exempt unless a determination is made by the municipality that the project is subject to Section 106.C. SWM Site Plan may still be required by other sections or provisions.

No – Not exempt. All provisions apply.

No* – Modified SWM Site Plan required, Small Project Site Plan possible.

- Sites with less than one thousand (1,000) square feet of new impervious surface, but between five thousand (5,000) square feet and one (1) acre of earth disturbance must submit a SWM Site Plan to the Municipality which need consist only of the items in Sections 301.A.2 and 4; 301.B.7, 8, 11, and 22; and 301.D.1 and 3, and related supportive material needed to determine compliance with Sections 404 through 408. The applicant can use the protocols in the Small Project SWM Site Plan if Municipality has adopted Ordinance Appendix B.

Table V-2

Eligibility for Exemptions for the Philadelphia County Portion of the Watershed

Ordinance Article or Section	Type of Project	Earth Disturbance Associated with Development		
		0-5,000 ft^2	5,000 ft^2-1 acre	> 1 acre
Article III SWM Site Plan Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 405 Groundwater Recharge Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 406 Water Volume Control Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 407 Streambank Erosion (Channel Protection) Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	Yes	Yes (Alternate Criteria)
Section 408 Flood Control / Stormwater Peak Rate Control and Management Districts Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	Yes (Alternate Criteria)	Yes (Alternate Criteria)

Yes – Development project is not subject to requirements of indicated section of this Ordinance.

Yes (Alternate Criteria) - Redevelopment sites with one acre or more of earth disturbance and can demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions are exempt from the Channel Protection/Streambank Erosion (Section 407) Requirements of this Ordinance. All redevelopment sites that can demonstrate a twenty percent (20%) reduction in DCIA from predevelopment conditions are exempt the Flood Control/Peak Rate Control (Section 408) Requirements of this Ordinance.

N/A – Not Applicable, development project is not subject to requirements of the indicated sections of this Ordinance. Voluntary controls are encouraged.

** – If the proposed development results in stormwater discharge that exceeds stormwater system capacity, increases the FEMA regulated water surface elevation, causes a combined sewer overflow, or degrades receiving waters, the design specifications presented in this Ordinance may be applied to proposed development activities as warranted to protect public health, safety, or property.

C. Stormwater Management Criteria

Article IV, Section 401 of the Ordinance sets forth General Requirements.

Sections 402, 403, and 404, pertain respectively to Permit Requirements of Other Governmental Entities, Erosion and Sediment Control during Regulated Earth Disturbance Activities, and Nonstructural Project Design.

Section 405.A.1 contains minimum requirements for Infiltration Best Management Practices (BMPs) and Section 405.A.2 establishes volume criteria for the infiltration facilities, which are computed as follows:

Infiltration Criteria for Bucks County and Montgomery County Portions of the Watershed

Where practicable and appropriate the recharge volume shall be infiltrated on site. The recharge volume shall be equal to one (1.0) inch of runoff over all proposed impervious surfaces (I).

The Re_v required shall be computed as:

$$\mathbf{Re_v = (1/12) * (I)}$$

Where:

Re_v = Recharge Volume (cubic feet)

I = Proposed Impervious Area within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

Infiltration Criteria for Philadelphia County Portion of the Watershed

The recharge volume shall be equal to one (1.0) inch of rainfall over all **Disconnected Impervious Area (DCIA) within the limits of earth disturbance**.

$$\mathbf{Re_v = (1/12) * (I)}$$

Where:

Re_v = Recharge Volume (cubic feet)

I = DCIA within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

Section 405.B sets forth the required soils evaluations on project sites to determine the suitability of proposed infiltration facilities.

Section 406 states the Water Volume Control Requirements, which are excerpted from Section 303 of the Pennsylvania Model Stormwater Ordinance *(Note: Philadelphia County, Bucks County, and Montgomery County will follow different Water Volume Control requirements.)*

Minimum Requirements for all Infiltration BMPs

Infiltration BMPs shall be designed in accordance with the PaDEP Best Management Practices Manual, 2006.

D. Volume Criteria for Water Quality

Bucks County and Montgomery County Portions of the Watershed:

The low impact development practices provided in the BMP Manual shall be utilized for all regulated activities to the maximum extent practicable. Water Volume Controls shall be implemented using the *Design Storm Method* in Subsection 1 or the *Simplified Method* in Subsection 2 below. For regulated activity areas equal to or less than one (1) acre that do not require hydrologic routing to design the stormwater facilities, this Ordinance establishes no preference for either methodology; therefore, the applicant may select either methodology on the basis of economic considerations, the intrinsic limitations on applicability of the analytical procedures associated with each methodology, and other factors. All regulated activities greater than one (1) acre must use the Design Storm Method.

1. The *Design Storm Method* (CG-1 in the BMP Manual) is applicable to any size of regulated activity. This method requires detailed modeling based on site conditions.

    a. The post-development total runoff volume for all storms equal to or less than the 2-year, 24-hour storm event shall not be increased.

    b. For modeling purposes:

        - Existing (predevelopment) non-forested pervious areas must be considered meadow.

        - Twenty (20) percent of existing impervious area, when present, shall be considered meadow in the model for existing conditions.

2. The *Simplified Method* (CG-2 in the BMP Manual) provided below is independent of site conditions and should be used if the *Design Storm Method* is not followed. This method is not applicable to regulated activities greater than one (1) acre, or for projects that require design of stormwater storage facilities. For new impervious surfaces:

    a. Stormwater facilities shall capture at least the first two (2) inches of runoff from all new impervious surfaces. *(Note: An asterisk (*) in equations denotes multiplication.)*

        Volume (cubic feet) = (2/12) * Impervious Surfaces (square feet)

    b. At least the first one (1) inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow-- i.e., it shall not be released into the surface waters of the Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.

        Volume (cubic feet) = (1/12) * Impervious Surfaces (square feet)

    c. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first half (0.5) inch of the permanently removed runoff shall be infiltrated.

    d. This method is exempt from the requirements of Section 408, Peak Rate Controls.

Philadelphia County Portion of the Watershed:

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for regulated activities within the Poquessing Creek Watershed in Philadelphia County:

Water Volume Control (cubic feet) = (1/12) * (I)

Where: I = DCIA within the limits of earth disturbance (square feet)

Section 407 sets forth the requirements for the control of Streambank Erosion. Philadelphia County, Bucks County, and Montgomery County will follow different requirements. If a municipality has adopted a riparian corridor ordinance, the more restrictive requirement as determined by the Municipal Engineer shall apply.

Section 408 sets forth Stormwater Peak Rate Control Standards by Management Districts as in **Table V-3**. The districts are described in **Volume III, Technical Appendix 7** and in the model ordinance as **Ordinance Appendix A**.

Section 409 specifies calculation methodologies that shall be used for the design of stormwater management facilities.

TABLE V-3

Peak Rate Control Standards by Stormwater Management District in the Poquessing Creek Watershed

District	Proposed Condition Design Storm		Existing Condition Design Storm
A	2-year	reduce to	1-year
	5-year		5-year
	10-year		10-year
	25-year		25-year
	50-year		50-year
	100-year		100-year
B	2-year	reduce to	1-year
	5-year		2-year
	10-year		5-year
	25-year		10-year
	50-year		25-year
	100-year		50-year
C*	Conditional Direct Discharge District		

* In District C, development sites that can discharge directly to the Poquessing Creek Main Channel (south of SR-13) and to the Delaware River main channel without use of City infrastructure may do so without control of proposed condition peak rate of runoff.

Projects that are required to obtain a NPDES Permit for stormwater discharges associated with construction activities are required to show no increase in peaks from existing conditions.

When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed condition peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms. In Philadelphia County only, the Predevelopment Condition for new development is the existing condition. For redevelopment purposes in Philadelphia County, the Predevelopment Condition is determined according to the procedures found in the Philadelphia Stormwater Guidance Manual.

SECTION VI
STORMWATER IMPROVEMENTS

A major objective of this study was to identify opportunities for improvements to address the widespread stormwater related problems in the Poquessing Creek Watershed. The following sections summarize proposed improvements to the Poquessing Creek Watershed.

A. Correction of Existing Problems. Each problem area reported by municipalities was investigated to determine potential causes and general solutions.

1. Generalized Problems. To follow is a listing of proposed solutions for the problems categorized as generalized problems, followed by the problems requiring a detailed analysis.

Steambank Erosion: The treatment of erosion and resultant sediment accumulations is generally a two-fold process. First, the cause of the problem (high flows, inadequate energy dissipation at pipe outlet, etc.) needs to be identified and corrective measures implemented and second, the comprised area needs to be stabilized, typically using natural stream channel design techniques. One cause of the problem is increased frequency and intensity of runoff due to urbanization; therefore, one corrective action will be to implement the infiltration, volume reduction, and peak rate controls specified in this Plan and Ordinance. The other cause of the problem is denuding the streambanks, i.e., removing vegetation whose roots hold the soil in place.

The Bucks and Montgomery County Conservation Districts and Philadelphia Water Department are delegated to administer PA Title 25, Chapter 102 (Erosion & Sediment Control regulations) on behalf of the Pennsylvania Department of Environmental Protection (PaDEP). These regulations address accelerated erosion and the resulting sedimentation from earthmoving activities. Permanent stabilization of exposed areas and proper stabilization of channels will reduce erosion problems in the watershed. Improvements in the watershed can be realized by reviewing plans for new or re-development to make certain the methods and techniques are being specified, conducting inspections to ensure the methods specified are being properly installed and maintained. There are numerous streambank stabilization techniques available, including those using bioengineering, such as turf reinforcement mats, natural fiber rolls, reforestation with live plantings, and hooks and vanes to divert flow away from problem erosion areas. These solutions are oftentimes referred to as natural stream channel restoration (NSCR). In certain areas with high shear stress and velocities, streambank armoring with rock riprap, gabion walls, or concrete may be required. A common source of funding for these problems, particularly in areas owned by a municipality, was the State's Growing Greener program.

The addition or enhancement of riparian buffers helps stabilize streambanks and prevent future erosion problems by reducing stormwater peak runoff rates and volumes through infiltration, evapotranspiration, and root stabilization as discussed in **Volume III, Technical Appendix 7**. Outfall protection including riprap aprons and stable swales can be effective in addressing erosion related problems related to stormwater conveyance systems and outlets. The impact of these buffers will be limited without watershed-based stormwater management standards and criteria.

The Back Yard Buffer BYB Program developed ways for single family homes, condos, and twin row homes to reduce runoff and protect the streambanks.

- No mow zone – is a stream buffer where mowing does not occur and native plants, trees and shrubs are grown.
- Rain barrels – disconnects properties from public drains which reduced the overall volume of water runoff that makes it to the streams. The rain barrel can be used to water the lawn, water plants, or wash cars.
- Permeable/Porous Pavers – allow water to infiltrate into the ground instead of runoff into streams.
- Live stakes – are native shrubs that are planted on the streambank. They help reduce the stream erosion and velocity and provided shade that improves the oxygen and temperature conditions for aquatic wildlife.
- Rain gardens – are small depressions with native plants that allow evapotranspiration and infiltration to occur.
- Green lawn basics – such as reducing/eliminating fertilizer, herbicide and pesticide and contouring shallow depressions will improve stream water quality. Eliminate the dumping of clippings and leaves by making a compost pile that will create organic soil amendments.

Sedimentation: Generally, the best way to correct a sedimentation problem is to correct the source erosion problem; therefore, the majority of solutions should be aimed at correcting erosion problems within the watershed, which will in turn correct the sedimentation problems. These solutions are discussed in the erosion section.

Flooding: Correction of regional flooding problems typically requires addressing the problem source. Measures such as reestablishment of riparian stream buffers, reducing existing impervious surfaces, and the creation of regional stormwater management facilities can be effective in mitigating regional flooding problems. The implementation of Low-Impact Development and Low-Impact Redevelopment measures are also effective in promoting infiltration and reducing flooding impacts. Establishment of release rate criteria within the watershed will also help minimize future flooding associated with new development or redeveloped areas. Other structural solutions can also be applied, including: levees, floodwalls, stream restoration or channel improvement, and pumping facilities. Mitigation, i.e., elevating the structures above the regulatory flood elevation (100-year storm event), demolishing or moving the structures, and floodproofing are measures supported by FEMA.

Flooding problem areas may be the result of undersized or clogged conveyance systems, such as culverts and storm sewers. Regular maintenance of existing facilities may help to resolve these problems. Storm sewer system upgrades, including trash racks, sediment basins, or energy dissipaters, may be effective in preventing future clogging and would be helpful for those pipes that are prone to frequent clogging. The cause of the local drainage problems may be undersized facilities. For these situations, the existing facilities need to be removed and replaced with facilities sized to convey the new design storm for the particular location. Detailed design calculations, necessary permits, and construction documents must be prepared as part of any replacement project.

When problems with a deficient storm sewer arise, the following process can be used to develop an effective solution:

a. Identify the type of problem (e.g., clogging with debris or sediment, inadequate inlet spacing, increased stormwater runoff).

b. Determine if the problem can be solved with better or more frequent maintenance.

c. Map the pipe network connected to the system, if necessary.

d. Define the drainage area and flow draining to the inlet and conveyed in the system.

e. Determine if additional inlets, debris or sediment collection device, or pipe capacity is required. If additional capacity cannot be added, consider constructing an upstream detention basin to reduce the amount of conveyance needed.

f. Size the required conveyance features based on the computed design flow and obtain the necessary permits and approval to install the proposed changes to the system.

Obstructions: Obstructions, such as bridges, can significantly alter watershed hydraulics. Often, obstructions restrict flow, causing backwater increases and subsequent upstream flooding. Bridges that cause extensive backwater or flooding should be carefully analyzed to see how a larger opening will affect both the upstream and downstream areas.

Scouring around obstructions increases greatly during flood events, transporting the sediment downstream. If sediment or rock on which an obstruction support rest is scoured by a waterbody, the obstruction could become unstable and collapse. A bridge-site examination for scour helps to monitor the stability of an obstruction. Based on the examination, appropriate countermeasures are designed and implemented to mitigate the effects of stream instability, scour, erosion, and stream aggradation. The solution costs are typically borne by the bridge owner.

Stream Impairment – Water Quality: Implementing the stormwater standards and criteria specified in this plan, including retrofitting existing stormwater detention basins, will improve the quality of water in the Poquessing Creek watershed, a major goal of this Stormwater Management Plan (SMP). Addressing combined sewer overflows and outfall discharges will also improve the quality of water.

There are several possible solutions for areas with reduced infiltration capacities and depleted groundwater supplies. A few of the most effective and cost efficient solutions include infiltration facilities, impervious area reduction, soil amendments, bioretention, and limiting the amount of new impervious areas over rechargeable soils. When implemented on the a watershed-wide basis, these practices will not only help to recharge the groundwater supply, but also provide additional benefits, such as decreasing flooding, reducing pollutants, and increased detention.

Disconnected Impervious Area: Disconnecting downspouts that currently discharge onto impervious surfaces reduces pollutant loads to streams.

Non-point source pollution: Often, non-point source pollution can be effectively addressed through the use of increased or enhanced riparian buffers which filter particulates and allow for biological uptake of organic pollutants by the buffer vegetation. Proper treatment of the

point source effluent to remove/reduce sediment and other pollutants including nitrogen and phosphorous need to be included in the design of new development projects. These measures can include sediment basins/traps for active construction sites and mechanical separation/filtration devices for post construction conditions. If site conditions allow, stormwater Best Management Practices (BMPs) can also be constructed to treat concentrated runoff before discharging into a nearby stream. Ideally, these BMPs would utilize a combination of detention, infiltration, and evapotranspiration to treat runoff and reduce runoff rates and volumes.

2. Problem Areas Requiring a Detailed Analysis

As discussed in Section IV, several problem areas were of such a high magnitude to warrant a detailed analysis and site-specific solution. Effectiveness and cost for each solution were evaluated and compared to choose a preferred solution. Prior to construction of any solution, detailed design calculations, necessary permitting, and construction document preparation for each area will be required. **Table VI-1** provides a summary of detailed problem areas and their preferred solutions. Additionally, a sample of a detailed problem form is shown in **Figure VI-1** and **Figure VI-2**. The full set of detailed problem area forms is available in **Appendix F**.

Where possible, solutions presented in the detailed analysis forms were coordinated with the recognized BMPs outlined in the PADEP *Stormwater BMP Manual*, as shown in **Table VI-2**, and provided a starting point for analysis. Each problem area will require an individual engineering study to obtain topography, characterize the problem, assess alternatives, and identify the most appropriate solution based upon the needs, desires, and constraints of the project stakeholders.

Table VI-1

Detailed Problem Area and Preferred Solutions

Detailed Problem Area #	Problem	Preferred Solution
1	Streambank Erosion	Stabilize stream, build regional basin #1, and retrofit basin, NSCR.
2	Streambank Erosion	Build regional basin #3 and implement rain gardens/cisterns, NSCR.
3	Streambank Erosion	Implement rain gardens/cisterns in the surrounding neighborhoods and enhance the riparian buffer, NSCR.
4	Streambank Erosion	Build regional basin #4, NSCR.
5	Streambank Erosion	Build regional basin #7, NSCR
6	Streambank Erosion	Install pervious parking along Street Rd., NSCR.
7	Erosion, Water/Groundwater Pollution, Dumping	Increase storage of basins on the Parx Racing and Casino property and install pervious parking areas, NSCR.
8	Erosion, Potential Pond Failure	Repair/stabilize the embankment between pond and stream, NSCR.
9	Existing Management	Reduce impervious area of mall or install pervious parking.
10	Flooding	Install culvert to convey partial/full flow of stream under railroad and enhance the riparian buffer to better protect the stream, NSCR.

DETAILED PROBLEM AREA #1

Poquessing Watershed Act 167 Plan

Problem Area(s) - Map ID	Municipality	Stream Name	Preferred Solution
PHA50	Lower Southampton	UNT Poquessing Creek	1, 2, 3

Description: This problem area was reported by the Philadelphia Water Department. The subject channel is located in Lower Southampton Township at the outfall of a large commercial/industrial area. The reach stability was reported as actively degrading and the bank erosion was classified as high. The upstream drainage area is highly impervious with limited stormwater management facilities. This is resulting in high flow rates that are causing significant erosion in the downstream channel where the problem area is located.

Figure VI-1: Detailed Problem Area Form (Page 1)

DETAILED PROBLEM AREA #1

Poquessing Watershed Act 167 Plan			
Problem Area(s) - Map ID:	PHA50	Inspected By/Date:	DJS,BAK / 10-28-2010
Municipality:	Lower Southampton	Checked By/Date:	PAD / 6-28-2011
Type of Problem(s)	Erosion		

The banks of this tributary are experiencing severe erosion. As evident from the pictures above, the channel has been eroded approximately 10-12 feet below the normal channel depth.

Potential Solutions

1) Stream Stabilization: This would help to limit erosion and decrease sediment transport downstream.

2) Regional Basin (RB) #1 (Infiltration, Detention) (BMP 6.8.2): This storage area would be constructed in the wooded area downstream of the commercial area. An embankment would be constructed near the downstream end of the wooded area and would provide storage in the undisturbed upstream area. This would require limited clearing of vegetation as construction would only occur in the area immediately surrounding the proposed embankment. This storage area has the potential to significantly reduce flow rates for both small and large storms, which would help mitigate severe erosion that is occurring in the downstream channel.

3) Basin Retrofit-Increased Storage, Add/Adjust Control Structure: Increased storage capacity and adding/adjusting the outlet structure to better control release rates.

4) Bioretention/Rain Gardens (BMP 6.4.5): Convert small pockets of open space within the commercial area to bioretention/rain garden type BMPs.

Regional Basin Modeling Results			
Drainage Area	RB #1 - 18.38 acres		
Potential Storage	RB #1 - 5.44 acre-ft		
Storm Frequency	Existing Peak Discharge (cfs)	Mitigated Peak Discharge (cfs)	Difference (cfs)
2-Year	63.62	11.35	-52.27
50-Year	135.11	65.11	-70.00

Cost Estimate	
1) N/A*	3) $30,000
2) $481,000	4) $20,000/ Biretention-Rain Garden

*Insufficient information available to determine cost estimate

Figure VI-2: Detailed Problem Area Form (Page 2)

Table VI-2

Runoff Control Techniques per Pennsylvania Stormwater BMP Manual

Chapter 5. Non-Structural BMPs	Chapter 6. Structural BMPs
BMP 5.4.1 Protect Sensitive and Special Value Features	BMP 6.4.1 Pervious Pavement with Infiltration Bed
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas	BMP 6.4.2 Infiltration Basin
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	BMP 6.4.3 Subsurface Infiltration Bed
BMP 5.5.1 Cluster Uses at Each Site; Build on Smallest Area Possible	BMP 6.4.4 Infiltration Trench
BMP 5.5.2 Concentrate Uses Area-wide Through Smart Growth Practices	BMP 6.4.5 Rain Garden and Bioretention
BMP 5.6.1 Minimize Total Disturbed Area	BMP 6.4.6 Dry Well or Seepage Pit
BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas	BMP 6.4.7 Constructed Filter
BMP 5.6.3 Re-vegetate and Re-forest Disturbed Areas Using Native Species	BMP 6.4.8 Vegetated Swale
BMP 5.7.1 Reduce Street Impervious Cover	BMP 6.4.9 Vegetated Filter Strip
BMP 5.7.2 Reduce Parking Impervious Cover	BMP 6.4.10 Infiltration Berm and Retentive Grading
BMP 5.8.1 Rooftop Disconnection	BMP 6.5.1 Vegetated Roof
BMP 5.8.2 Storm Sewer Disconnection	BMP 6.5.2 Runoff Capture and Reuse
BMP 5.9.1 Streetsweeping	BMP 6.6.1 Constructed Wetlands
	BMP 6.6.2 Wet Pond or Retention Basin
	BMP 6.6.3 Dry Extended Detention Basin
	BMP 6.6.4 Water Quality Inlet
	BMP 6.7.1 Riparian Buffer Restoration
	BMP 6.7.2 Landscape Restoration
	BMP 6.7.3 Soil Amendment and Restoration
	BMP 6.7.4 Floodplain Restoration
	BMP 6.8.1 Level Spreader
	BMP 6.8.2 Special Detention Areas

B. Existing Basins Retrofits

Many of the stormwater management/detention basins in the watershed were designed only to reduce the post-development peak flow rate to the existing peak flow rate for a specified storm. These basins can be retrofitted to incorporate volume and peak rate controls.

Properly designed and maintained stormwater basin retrofits provide improved water quality treatment, reduced sediment and nutrient loadings to the stream, and increased detention/infiltration. Retrofitted basins can also help property owners save money by reducing maintenance demands. Retrofitted basins that have been revegetated with native plantings may only need to be maintained once a year, if at all, as opposed to bi-weekly or monthly mowing with typical grass bottomed basins.

1. Basin Retrofit Options and Benefits

Typical basins retrofit measures for basins of any size can include:

- Replace grass with native plantings including trees and shrubs. This promotes evapotranspiration, reduces the volume of stormwater runoff, filters pollutants, enhances habitat for wildlife, and improves basin aesthetics.
- Remove or replace concrete low flow channels with a natural meandering channel. Modify outlet structure to allow detention/infiltration of smaller storm events.
- Install a sediment forebay near the inlet to trap and filter sediment and debris before the water enters the basin. Forebays should be vegetated.
- Construct earthen berms or other flow path controls to extend the flow path and prevent the basin from being short circuited and/or redirect all basin inlets away from the outlet structure to extend the flow path.
- Excavate the basin bottom or raise the surrounding berm to increase storage/detention capacity.
- Modify outlet control structures to detain/infiltrate the "first flush" or provide a low flow first flush diversion to a water quality BMP before being re-routed to the main basin for quantity control.
- Create wetland habitat.
- Construct forebays.

Some of these measures can be seen in the typical retrofit depicted in **Figure VII-3.**

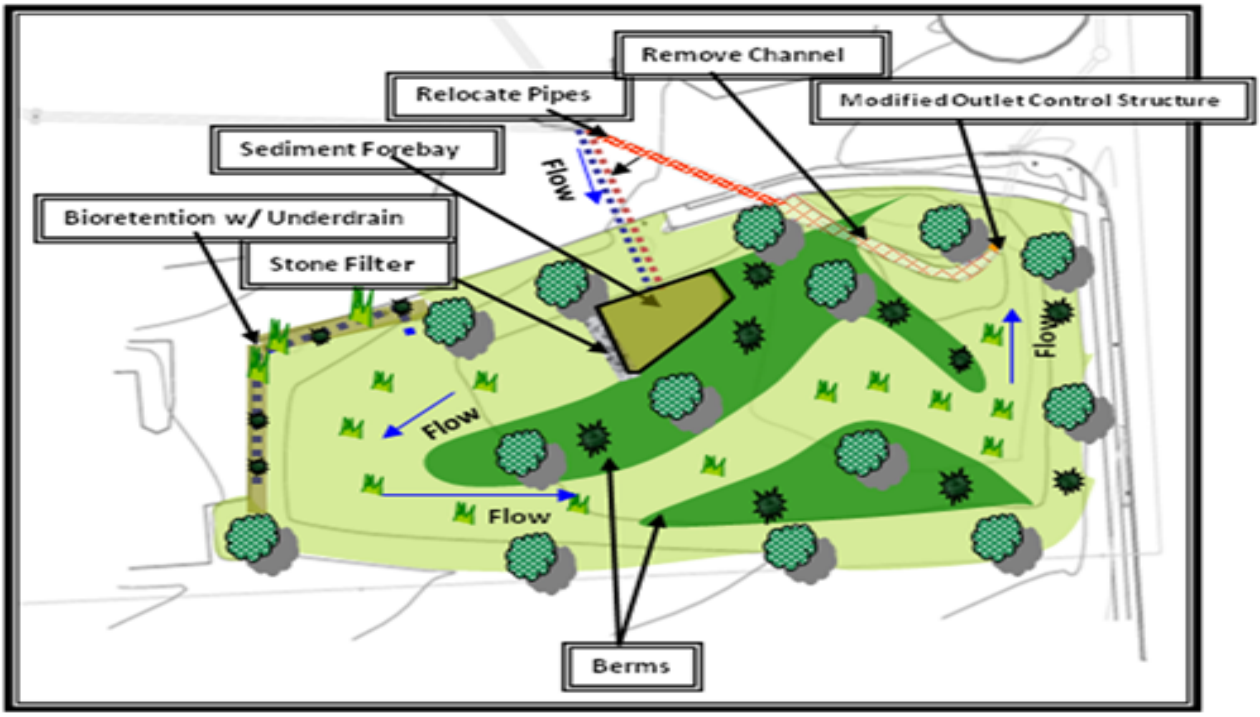

Figure VI-3: Typical Basin Retrofits Source: PEC Basin Retrofit Project, 2006

Some of the benefits of retrofitting stormwater basins are:

- Prevent stream degradation and restore stream water quality.
- Improve control of runoff from small, frequent storms.
- Improve native habitat.
- Reduce pollutant loads by capturing the "first flush."
- Replenish groundwater.
- Reduce maintenance requirements.

Each basin should be analyzed to determine the best options.

2. Basin Retrofit Analysis

In order to determine the relative impact of retrofitting, a retrofit analysis of select basins was performed. Lowering floor elevations, increasing berm heights, and expanding basin footprints were all considered when determining a basin's retrofit potential for increased storage. Increasing storage capacity is only one objective when evaluating detailed basin retrofits. Vegetation enhancement, flow path extension, forebay addition, and outlet reconfiguration are all important retrofitting options and were all considered in addition to increasing the storage capacity. As discussed in the Poquessing SMP, the watershed is suffering from increased volume, increased frequency of runoff, a depleted groundwater supply, and poor water quality. As shown in the Poquessing Creek SMP, the most effective way to mitigate these problems will be to increase storage while increasing biofiltration and infiltration.

The detailed retrofit analysis included an evaluation of the existing basin parameters (storage volume, drainage area, and outlet structure), surrounding area, and downstream problem areas. All of these factors were evaluated to determine the most appropriate basin retrofits and then cost estimates were developed for the recommendations. The detailed analysis was performed for basins with existing storage volumes greater than three acre-feet, and only basins having storage volumes greater than six acre-feet were modeled in SWMM. Of the 175 basins located in the Poquessing Watershed, 15 basins have an existing storage volume greater than 3 acre-feet. Eight basins have an existing storage volume greater than six acre-feet, and of those, four were modeled in SWMM. Data could not be obtained on the other four due to access restrictions that prevented the collection of basin data. These basin locations are shown in **Figure VI-4.** The purpose of this modeling is to show how basin retrofits could benefit the Poquessing Watershed. Existing basin modeling parameters were obtained from municipal reporting, aerial imagery, and site visits.

For an example, the existing basin depicted in **Figure VI-5** was included in the detailed retrofit analysis. As evident from the aerial image the basin is grassed lined with a concrete low flow channel, which would fill during a storm and then empty its entire contents, doing little to manage the volume of stormwater and protect water quality.

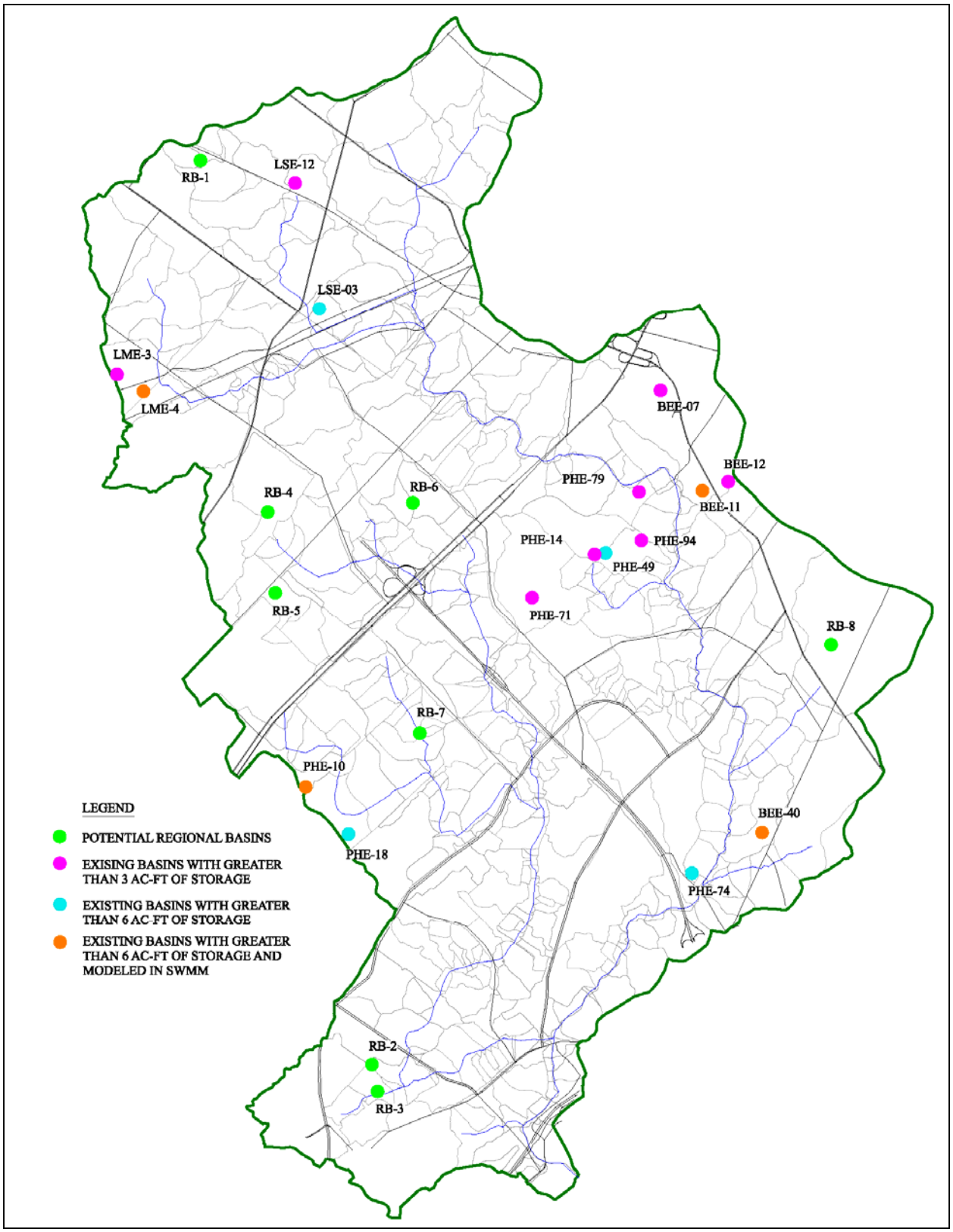

Figure VI-4 – Locations of Potential New Regional Basins and Basins Greater Than 3 AC-FT of Storage with Retrofit Potential

Figure VI-5 – Typical Stormwater Basin Retrofit

Basin Retrofit ID: BEE40 – Bensalem Township, Chancellor Circle Road

Recommendation: Increase depth 2 feet, remove concrete low flow channel, modify outlet structure, plant native vegetation, incorporate infiltration component if possible.

Additional Volume = 2.6 ac-ft Estimated Cost: $150,000

Cost estimates for retrofits were obtained by averaging cost/acre-ft of storage for similar basin retrofits found in the Pennypack Act 167 Plan. Given the detailed nature of the Pennypack cost estimates, similar construction activities, and close proximity to the subject watershed, these cost estimates were considered valid. Cost estimates for this plan were also developed using Means construction cost estimating software, union labor rates for Philadelphia and the suburbs, 15 percent for engineering and permitting, and a 20 percent contingency. The cost for all basin retrofits not evaluated by detailed methods was assumed to be $30,000. This figure includes the cost of reconfiguring outlet structures, enhancing vegetation, and minor earthwork. An inventory of basin retrofits is included in **Appendix G-2**. The inventory contains information such as location, drainage area, available storage, cost estimate, and other pertinent basin parameters. Per PA Code, Title 25, Chapter 105, a dam permit may be required to complete some of the retrofits. Basin retrofits that may require a dam permit are noted in this inventory.

3. Results of Retrofit Analysis

The proposed retrofits were incorporated into the SWMM model to evaluate their hydrologic effects. Primarily, this included increasing basin storage and modifying outlet structures. The same four basins with storage volumes greater than 6 ac-ft which had sufficient basin information were included in the model.

The proposed retrofits were modeled for the 2- and 50-year storms. **Figure VI-6** depicts the results of this analysis for one of the modeled basins. For this basin, the peak flow rate from 50-year storm was reduced by 59% by incorporating the proposed retrofits. Output summary tables for the 2- and 50-year storms for all of the modeled basins are included in **Table VI-3.**

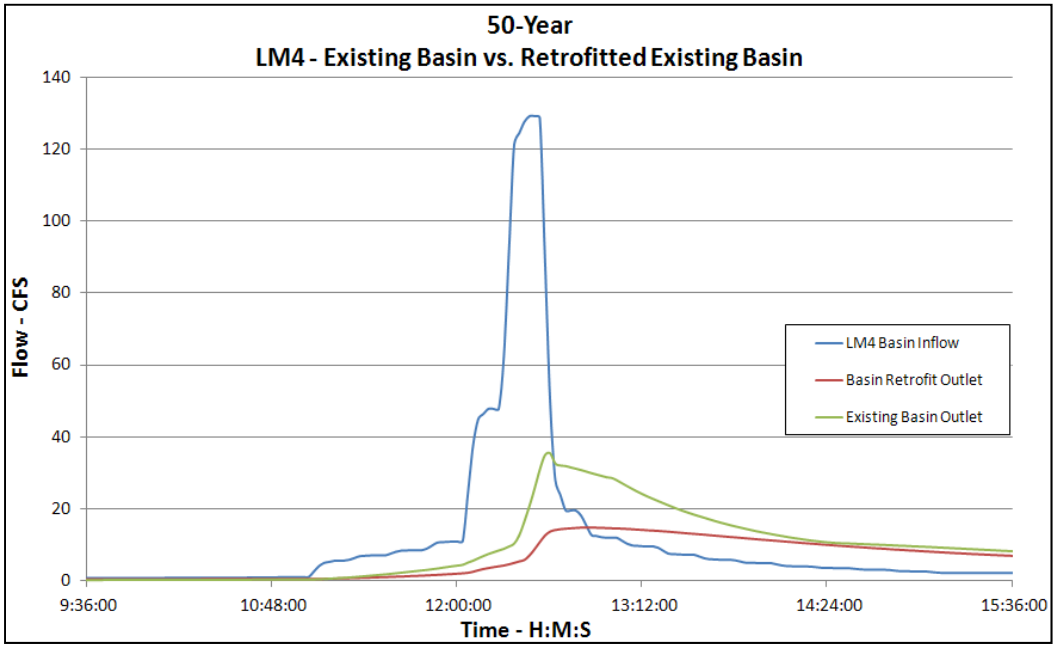

Figure VI-6: Comparison Hydrograph Outflow from Existing Basin to Retrofitted Basin

TABLE VI-3

2-Year and 50-Year Summary of Retrofitted Basins

2-Year					
Basin	Peak Flow In (CFS)	Existing Peak Flow Out (CFS)	Retrofit Peak Flow Out (CFS)	Difference (CFS)	Reduced By %
LME4	62	10	4	-5	54%
BEE11	83	39	3	-37	93%
BEE40	174	8	1	-8	93%
PHE10	136	46	32	-14	31%

50-Year					
Basin	Peak Flow In (CFS)	Existing Peak Flow Out (CFS)	Retrofit Peak Flow Out (CFS)	Difference (CFS)	Reduced By %
LME4	129	35	15	-21	59%
BEE11	178	69	14	-55	80%
BEE40	378	41	22	-19	46%
PHE10	282	130	125	-5	4%

This detailed retrofit analysis was performed on selected large basins. Retrofitting of smaller basins may be included in future plan updates.

C. Proposed Regional Basins

One option in watershed-wide stormwater management is to control runoff using regional facilities. In addition to retrofitting existing basins, locations for new regional basins were developed in conjunction with the detailed problem area analysis. Eight potential regional basin locations were identified within the watershed. The locations of regional basins are also shown in **Figure VI-4**. An inventory of regional basins is included in **Appendix G-1**. The inventory contains information such as location, drainage area, available storage, cost estimate, and other pertinent basin parameters. Per PA Code, Title 25, Chapter 105, a dam permit may be required to complete some of the regional basins. Regional basins that may require a dam permit are noted in this inventory. An example of a proposed regional basin location is shown in **Figure VI-7**.

Figure VI-7 – Typical Proposed Regional Basin

Basin ID: RB #4, City of Philadelphia, Kelvin Avenue
Recommendation: Construct new regional basin at downstream limits of residential area.
Estimated New Storage: 21.2 ac-ft Estimated Cost: $1,000,000
Drainage Area: 88.0 acres

1. Results of Regional Basin Analysis

All eight regional basins were modeled in SWMM to evaluate the hydrologic effects that the basins had on peak flow rates from their respective drainage areas. The 2- and 50-year storms were used for this analysis. **Table VI-4** and **Table VI-5** present the results at the basin outlet.

TABLE VI-4

2-Year Summary of Regional Basins

2-Year				
Regional Area	Peak Flow In (CFS)	Peak Flow Out (CFS)	Difference (CFS)	Reduced By %
RB#1	64	11	-52	82
RB#2	98	8	-91	92
RB#3	1026	690	-336	33
RB#4	310	101	-209	68
RB#5	485	203	-282	58
RB#6	135	5	-131	97
RB#7	1528	1029	-499	33
RB#8	472	124	-348	74

TABLE VI-5

50-Year Summary of Regional Basins

50-Year				
Regional Area	Peak Flow In (CFS)	Peak Flow Out (CFS)	Difference (CFS)	Reduced By %
RB#1	135	65	-70	52
RB#2	206	96	-111	54
RB#3	2115	1714	-401	19
RB#4	635	591	-44	7
RB#5	997	740	-256	26
RB#6	227	43	-183	81
RB#7	2536	1697	-839	33
RB#8	1016	612	-403	40

The results of the regional basin analysis indicate that the basins will reduce peak flows from their respective drainage areas by an average of 67% for the 2-year storm and 39% for the 50-year storm. This significant reduction in the 2-year storm event is important because of its known correlation with streambank erosion, which is a widespread problem in the watershed. RB #1, RB #2, RB #6, and RB #7 reduce the peak 50-year storm event down to near the existing 2-year storm event peak rate. Reductions in peak rates of this magnitude have the potential to significantly improve downstream channel stability and reduce flooding impacts in downstream areas.

Additionally, the proposed regional basins were analyzed concurrently with the basin retrofits to evaluate the cumulative effects the improvements would have on the overall watershed. **Table VI-6** and **Table VI-7** present these results for the 2-year and 50-year storm events, respectively.

TABLE VI-6

Results of Regional Basin and Basin Retrofits for the 2-Year Storm

2-Year		
Peak Flow on Poquessing Above Confluence With Byberry With Basins (CFS)	Peak Flow on Poquessing Above Confluence With Byberry With Regional Basins and Basin Retrofits (CFS)	Difference (CFS)
2780	2655	-125

2-Year		
Peak Flow on Byberry Above Confluence With Poquessing With Basin (CFS)	Peak Flow on Byberry Above Confluence With Poquessing With Regional Basins and Basin Retrofits (CFS)	Difference (CFS)
2122	2050	-72

2-Year		
Peak Flow at Mouth of Poquessing With Basins (CFS)	Peak Flow at Mouth of Poquessing With Regional Basins and Basins Retrofits (CFS)	Difference (CFS)
4066	3938	-128

TABLE VI-7

Results of Regional Basin and Basin Retrofits for the 50-Year Storm

50-Year		
Peak Flow on Poquessing Above Confluence With Byberry With Basins (CFS)	Peak Flow on Poquessing Above Confluence With Byberry With Regional Basins and Basin Retrofits (CFS)	Difference (CFS)
7030	6869	-161

50-Year		
Peak Flow on Byberry Above Confluence With Poquessing With Basin (CFS)	Peak Flow on Byberry Above Confluence With Poquessing With Regional Basins and Basin Retrofits (CFS)	Difference (CFS)
4913	4743	-170

50-Year		
Peak Flow at Mouth of Poquessing With Basins (CFS)	Peak Flow at Mouth of Poquessing With Regional Basins and Basins Retrofits (CFS)	Difference (CFS)
9995	9696	-299

With the modeled improvements, the peak flow rate was reduced by approximately 300 cfs (3%) for the 50-year storm and 128 CFS (3%) for the 2-year storm. The minimal impact of the basin improvements on the overall watershed is not surprising given the small number of basins modeled. The analysis does show that the improvements do have an impact on peak rate reduction. If the majority of the existing basins were retrofitted and modeled, it is anticipated that the impact would be substantially greater. In addition, other measures, such as greening parking lots, rooftops, etc. will contribute to reduced peak flows and improved water quality. Exact quantification of the benefits will depend on physical characteristics of the site, drainage area, concentration of pollutants and design.

Actual implementation of regional basins or retrofits will depend on access, property ownership and cooperation, topography, wetlands, long term maintenance agreements, etc. It is recommended that these issues be accomplished for each basins identified.

2. Sub-Regional (Combined Site) Storage

Stormwater management preserves and protects the natural drainage system.

The goal is the development and use of the most cost-effective and environmentally sensitive stormwater runoff controls available.

Regional stormwater management increases the opportunity to utilize stormwater control facilities to meet multiple community needs. For example, certain stormwater control facilities could be designed so that recreational facilities such as ball fields, open space, volleyball, etc. could be incorporated. Natural or artificial ponds and lakes could serve both recreational and stormwater management objectives.

Stormwater management facilities could be constructed at a location most advantageous to the watershed. These facilities could be publicly owned detention, retention, lake, pond, or other physical facilities to serve multiple developments and multiple purposes. The design will need to be consistent with the SMP.

The implementation of smaller widespread stormwater facilities, such as rain gardens/bioretention, cisterns/rain barrels, infiltration trenches, porous pavement with underground storage, etc., should be investigated before constructing larger individual BMPs that treat runoff further downstream in a watershed. These smaller BMPs treat runoff at the source and often include components for mitigating volume, rate, and water quality that more closely mimic an area's hydrology before development. The cumulative impact of several smaller BMPs can have a substantial impact when evaluated at a regional or watershed scale, and can sometimes be used in lieu of large BMPs downstream.

D. Riparian Buffer Restoration

As discussed in Section IV, there are many areas which lack riparian buffers. Restoring these areas with an average buffer width of 75 feet for each side of the stream will provide an additional 115 acres of riparian buffer in the watershed. To estimate the potential additional infiltration storage capacity available, an average annual runoff volume reduction of one inch was utilized based upon the hydrologic budget developed as part of the Darby-Cobbs Creeks Act 167 Plan. The estimated acreage and cost of re-establishing the buffers by affected stream is presented in **Table VI-8**. The total additional annual infiltration storage volume provided to the watershed would be 7.2 acre-feet. Actual buffer width would vary significantly from site to site due to existing development, fences, property ownership, etc., and buffers may no longer be feasible at some locations. The lack of

acceptance by property owners can limit the area of the re-established buffers. The riparian buffer inventory and the GIS file with the locations of the identified buffer restoration locations and storage calculations is provided in **Appendix G-3**, and a sample site map is shown in **Figure VI-8**.

Table VI-8

Riparian Buffer Restoration Improvements

Primary Affected Streams	*Acreage Requiring Riparian Buffers	**Cost Assuming $4,500 per acre	Rounded-Up Cost	***Average Volume Reduction per event (acre-feet)
Walton Run	4.24	$19,102	$20,000	0.35
Byberry Creek	32.23	$145,037	$146,000	2.69
Poquessing Creek	49.53	$222,893	$223,000	4.13

*Base data on riparian buffer needs were obtained from the Heritage Conservancy. These data indicate stream lengths requiring a riparian buffer, either on one side or both sides of the stream. It is assumed that an average buffer width is 75 feet, recognizing that 50 feet may be appropriate for some locations and 100 feet for others. Acreage was derived using GIS analysis.

**Cost assumes 430 three- to four- foot high trees per acre, protective tubes, stakes, and labor, including some replacement in the second year.

*** Average volume reduction is an average value per event and assumed to be an inch of water per acre. The reduction would be the greater in the summer during dry periods, and substantially less in the winter during wet periods.

Figure VI-8 - Sample Riparian Buffer Restoration Location

Riparian Buffer Restoration Based on Survey by Heritage Conservancy
Location: Poquessing Creek in Lower Southampton Township
Restoration for one side of stream. Width = 75 ft.

SECTION VII
MUNICIPAL ORDINANCE INTRODUCTION

Municipalities within the Commonwealth of Pennsylvania are empowered to regulate land use activities that affect runoff by the authority of the Act of October 4, 1978, 32 P.S., P.L. 864 (Act 167) Section 680.1 et seq., as amended, The "Stormwater Management Act." Act 167 requires that:

- Counties prepare a watershed stormwater management plan in conformance with the requirements of Act 167 for each watershed within their boundaries.
- The plans evaluate present and future runoff within the watershed and make technical recommendations for the control and management of runoff from new development (both quantity and quality).
- Municipalities implement the plan via a Stormwater Ordinance developed as part of the plan.
- Developers control the quantity and quality of runoff from new development (including redevelopment) in accordance with each Municipality's implementing Ordinance.

The Stormwater Management Act emphasizes locally administered stormwater programs with the watershed municipalities taking the lead role. Implementation and enforcement of the watershed plan standards and criteria will require the municipalities to adopt the appropriate Ordinance provisions that address subdivision and land development. As part of the preparation of the Poquessing Watershed Stormwater Management Plan, a Model Municipal Ordinance has been prepared that will implement the Plan provisions. The Ordinance is a single purpose Ordinance that could be adopted by each Municipality with minor changes to fulfill the needs of a particular Municipality. This could be adopted essentially "as is" (with some modification) by the municipalities. Provisions would also be required in the Subdivision and Land Development Ordinance to ensure that activities regulated by the Ordinance were appropriately referenced.

In addition to adopting the Ordinance itself, the municipalities would also have to revise their existing subdivision, land development, and zoning Ordinances to incorporate the necessary linking provisions. These linking provisions would refer to any applicable regulated activities within the watershed to the single purpose Ordinance. Key provisions of the Model Stormwater Ordinance include the drainage standards and criteria, performance standards for stormwater management, and maintenance provisions for stormwater facilities.

The implementation of the runoff control strategy for development will be through municipal adoption of the appropriate Ordinance provisions. The "Poquessing Watershed Act 167 Stormwater Management Ordinance" will not completely replace the existing storm drainage Ordinance provisions currently in effect in the municipalities. The reasons for this are as follows:

- Not all of the municipalities in the Poquessing Watershed are completely within the watershed. For those portions of the Municipality outside Poquessing Watershed, the municipality is not required to implement the Poquessing Ordinance provisions.
- Permanent and temporary stormwater control facilities are regulated by the Act 167 Ordinance. Stormwater management and erosion and sedimentation control associated with activities also are regulated under the Chapter 102 Erosion and Sediment and Pollution Controls, Title 25 of PaDEP Regulations.
- Stormwater management design criteria (i.e., inlet spacing, inlet type, collection system details, etc.) maybe regulated under the current Ordinance provisions.

The following Model Ordinance has been developed specifically for municipalities within the Poquessing Watershed in order to implement the Poquessing Watershed Stormwater Management Plan. Municipalities may create a single-purpose Stormwater Ordinance.

All of the provisions within this Model Ordinance are required to be part of the Municipal Stormwater Ordinance or other Ordinances implementing the requirements of the stormwater management plan.

Organization:

The standards and criteria included in the model ordinance apply to regulated activities defined in Article I and vary based on the county of jurisdiction. The standards pertain to the following areas of potential impact as defined in Table 106.1 of the Ordinance:

- Site Design and Stormwater Management Site Plan Requirements
- Groundwater Recharge
- Water Volume Control
- Streambank Erosion (Channel Protection)
- Peak Rate Control

This Ordinance contains the following eight articles, each with specific provisions.

Article I – General Provisions: This article includes general administrative provisions including applicable land areas and regulated activities. This article also includes the stormwater management exemption criteria. Article I, Section 103 requires that all legal water quality requirements under state law, including regulations at 25 Pennsylvania Code Chapter 93.4.a requiring protection and maintenance of "existing uses" and maintenance of the level of water quality to support those uses in all streams, and the protection and maintenance of water quality in "special protection" streams, be met.

Applicability and Exemptions (Article I, Sections 105 and 106) for Regulated Activities defined in Section 105 of the Ordinance are based on the area of land disturbance and the area of impervious cover included in the project. The exemption thresholds vary by county. Exemptions may be denied by municipalities based on identified downstream problem areas, based on High Quality, or Exceptional Value stream designations, or based on known source water protection areas.

Article II – Definitions: This article provides a list of common terms and associated definitions used throughout the Ordinance.

Article III – Stormwater Management Site Plan Requirements: This article lists the specific requirements for submittal, content, presentation, and review of drainage plans required by the Ordinance.

Article IV – Stormwater Management: This article represents the technical provisions for stormwater management within the Poquessing Watershed and includes the stormwater management district implementation provisions, water quality requirements, design criteria, calculation methods, and erosion and sedimentation requirements.

Article V – Inspections: This article describes inspection procedures for permanent stormwater management and water quality facilities.

Article VI – Fees and Expenses: This article contains the provisions for a municipal review fee.

Article VII – Maintenance Responsibilities: This article outlines the applicants' responsibilities for operation and maintenance of stormwater management facilities.

Article VIII – Prohibitions: This article, required by NPDES Phase II, prohibits the discharge of non stormwater flows to any municipal separate storm sewer system with the exception of certain activities found not to contribute pollution to surface waters.

Article IX – Enforcement and Penalties: This article describes municipal enforcement procedures, remedies, and the appeals process.

Appendices: This section of the Ordinance contains five (5) technical support appendices necessary to implement the Ordinance provisions.

These documents were prepared in consultation with a WPAC comprised of designated representatives from each of the watershed's municipalities, County Planning, and Conservation District staff.

Within six months following adoption and approval of a watershed stormwater plan, each Municipality is required to adopt or amend stormwater Ordinances to regulate development within the Municipality in a manner consistent with the watershed stormwater plan and the provisions of the Act.

The following amendment is required for municipalities that issue an occupancy permit:

- An Occupancy Permit shall not be secured or issued unless the provisions of the Poquessing Watershed Stormwater Management Ordinance have been followed. The Occupancy Permit shall be required for each lot owner and/or developer of all major and minor subdivisions and land development in the Municipality

Municipalities without an Occupancy Permit may want to adopt the above draft language and include other regulatory items in the occupancy permit requirement for their own use.

Administration

Due to differences in administration of the building permit process in Philadelphia County, the applicability requirements for the Philadelphia portion of the watershed will be based upon earth disturbance as opposed to the amount of proposed impervious area. Table 105.1a summarizes the applicability requirements for the municipalities in Montgomery and Bucks Counties. Ordinance Table 105.1b summarizes the applicability requirements for the City of Philadelphia.

SECTION VIII
PLAN IMPLEMENTATION

The Poquessing Watershed Stormwater Management Plan preparation process is complete with Bucks, Montgomery and Philadelphia Counties' adoption of the draft Plan and submission of the final Plan to PaDEP for approval. DEP's approval sets in motion the mandatory schedule of adoption of Ordinances needed to implement stormwater management criteria. Watershed municipalities have six months from PaDEP's approval to adopt the necessary Ordinance provisions.

A. PaDEP Approval of the Plan

Upon adoption of the Watershed Plan by Bucks, Montgomery and Philadelphia Counties, the Plan was submitted to PaDEP for approval. A draft of the Stormwater Management Plan and draft Model Ordinance was sent to PaDEP prior to adoption of the Plan. The PaDEP review process involves determination that all of the activities required by Act 167 have been completed. The PaDEP also reviewed the Plan for consistency with municipal floodplain management plans, State programs that regulate dams, encroachments and other water obstructions, and State and Federal flood control programs. The review process also ensures that the Plan is compatible with other watershed stormwater plans in the basin.

B. Publishing the Final Plan

Upon PaDEP approval, the Philadelphia Water Department published and provided, at minimum, two copies of the Plan to each Municipality. The Plan includes this report, appendices, figures, and the Model Ordinance.

C. Municipal Adoption of Ordinance to Implement the Plan

The essential ingredient for implementation of the Stormwater Management Plan is the adoption of the necessary Ordinance provisions by the Poquessing Watershed municipalities. Provided as part of the Plan is the Act 167 Stormwater Management Plan Model Ordinance which is a single purpose stormwater Ordinance that could be adopted by each Municipality essentially "as is" to implement the Plan. The single purpose Ordinance was chosen for ease of incorporation into the existing structure of Municipal Ordinances. All that is required of any Municipality would be to adopt the Ordinance itself and adopt the necessary provisions for tying into the existing subdivision and land development Ordinance and zoning Ordinance as outlined in the Municipal Ordinance Matrix in the **Appendix H**. The tying provisions would simply refer any applicable regulated activities within the Poquessing Watershed from the other Ordinances to the single purpose Ordinance. It is recommended that the delineation of the watershed subareas and the stormwater management criteria assigned to each subarea be enacted as part of each Municipality's zoning or subdivision Ordinance. This way the requirements for management of stormwater will be applicable to all changes in land use and activities that may alter the characteristics of stormwater runoff.

D. Correction of Existing Drainage Problems

The development of the watershed plan has provided a framework for the correction of existing drainage problems, a logical first step in the process of implementation of a stormwater management Ordinance. The step-by-step outline below is just one method of solving some of the current runoff problems.

1. Prioritize a list of storm drainage problems within the municipalities based on frequency of occurrence, potential for injury, as well as damage history.

2. Develop a detailed engineering evaluation to determine the exact nature of the top priority drainage problems within the municipalities in order to determine cost estimates and a recommended course of municipal action.

3. Incorporate implementation of recommended solutions regarding stormwater runoff in the annual municipal capital or maintenance budget.

E. PennVEST Funding

The PennVEST Act of 1988, as amended, provides low interest loans to governmental entities for the construction, improvement or rehabilitation of stormwater projects, including the transport, storage, and infiltration of stormwater and BMPs to address Nonpoint Source Pollution associated with stormwater.

F. Operation & Maintenance

Maintenance of individual BMPs shall follow the guidelines as outlined in the PA DEP BMP Manual. A description of how each stormwater facility and BMP will be operated and maintained, and the identity and contact information associated with the person(s) responsible for operations and maintenance shall be provided in an Operation & Maintenance Plan.

SECTION IX
PLAN REVIEW ADOPTION AND UPDATING PROCEDURES

A. County Adoption

Prior to plan completion, Philadelphia, Montgomery and Bucks Counties transmitted a sample of the proposed Stormwater Ordinance for review to affected municipal planning commissions, local governing bodies, the Watershed Plan Advisory Committee, and other interested parties. Philadelphia, Montgomery, and Bucks Counties transmitted a draft Stormwater Management Plan (SMP), which included the draft Model Ordinance for review to the following organizations: municipal planning commission; governing body of each involved Municipality; County Planning Department or Commission; and the Watershed Plan Advisory Committee. This review included an evaluation of the plan's consistency with other plans and programs affecting the watershed. The reviews and comments were submitted to the county by official correspondence. The county will receive, tabulate, and respond to the comments and will revise the SMP as necessary.

Philadelphia, Montgomery, and Bucks Counties held public meetings. A notice for the hearing was published two weeks prior to the hearing date. The meeting notice contained a summary of the principal provisions of the Plan and stated where copies of the Plan could be examined or obtained within each Municipality. The comments received at the public hearing were reviewed by the county and appropriate modifications to the Plan were made.

The Plan was passed as a resolution by the County Commissioners for the purpose of adoption. The resolution included references to the volumes, figures, appendices, and Model Ordinance. The County resolution was recorded in the minutes of a regular meeting of the Bucks, Montgomery, and Philadelphia County Commissioners.

Philadelphia, Montgomery, and Bucks Counties submitted to PADEP the following documentation: letter of transmittal; the adopted plan; municipal and County SMP comments; public hearing notice and minutes; and the resolution of adoption of the Plan by each County. The letter of transmittal stated that Philadelphia, Montgomery, and Bucks Counties have complied with all procedures outlined in Act 167 and requested PaDEP approve the Commissioner-adopted SMP.

B. Provisions for Plan Revision

Section 5 of the Stormwater Management Act requires that a SMP be reviewed for an update at least every five years. This requirement considers the changes in land use, obstructions, flood control projects, floodplain identification, and management objectives or policy that may take place within the watershed.

Should the County determine that no revisions to the Plan are required for a period of five consecutive years, the County will adopt a resolution stating that the Plan has been reviewed and been found satisfactory to meet the requirements of Act 167. The resolution will be forwarded to PaDEP.

SECTION X
FORMATION OF THE POQUESSING WATERSHEDADVISORY COMMITTEE

The meeting was held by the Committee during the preparation and adoption of the detailed Watershed Stormwater Management Plan.

Advisory Committee meetings and their purposes were as follows:

Meeting	Date	Purpose
1	2/5/2010	Introduction to Stormwater Management; Reviewed Act 167; Distributed data collection forms; NPDES coordination, coordination with other study initiatives; Watershed characteristics.
2	9/28/2010	Watershed characteristics, reviewed coordination with other study initiatives; discussed data collection forms - progress report; reviewed GIS mapping efforts; reviewed infill / redevelopment issues and BMPs; reviewed Fluvial Geomorphology study; sample Act 167 Plan.
3	3/3/2011	Reviewed Goals and Act 167 NPDES Ordinance; discussed status of project and mapping; reviewed municipal data collection efforts and status; discussed modeling variables; discussed timeline and milestones.
4	12/8/2011	Update on status of problem area analysis; discussed current modeling efforts; reviewed SW ordinance; reviewed other related efforts within the watershed; reviewed timeline for work completion.
5	5/21/2012	Present FINAL DRAFT Plan to municipalities, discuss exemption criteria, establish timeline for review and adoption

PLAN APPENDIX A

MODEL ORDINANCE

ORDINANCE APPENDIX A

STORMWATER MANAGEMENT DISTRICT WATERSHED MAP

POQUESSING WATERSHED
ACT 167
STORMWATER MANAGEMENT PLAN

VOLUME I - EXECUTIVE SUMMARY

FINAL REPORT
December 7, 2012

BUCKS, MONTGOMERY, AND PHILADELPHIA COUNTIES, PENNSYLVANIA

NTM PROJECT NO. 09052.00

POQUESSING WATERSHED
ACT 167
STORMWATER MANAGEMENT PLAN

BUCKS, MONTGOMERY, AND PHILADELPHIA COUNTIES, PENNSYLVANIA

VOLUME I - EXECUTIVE SUMMARY

FINAL REPORT

NTM PROJECT NO. 09052.00

December 7, 2012

PREPARED FOR:
PHILADELPHIA WATER DEPARTMENT
Office of Watersheds
1101 Market Street, 4th Floor
Philadelphia, PA 19107

PREPARED BY:
NTM ENGINEERING, INC.
130 W Church Street, Suite 200
Dillsburg, PA 17019

TABLE OF CONTENTS

PLAN FORMAT

The format of the Poquessing Watershed Stormwater Management Plan consists of Volume I, the Executive Summary, Volume II, the Plan Report, and Volume III that contains the background technical materials.

Volume I, the Executive Summary, provides an overview of Act 167 and a summary of the standards and criteria developed for the plan. Volume II, the Plan Report, provides an overview of stormwater management, purpose of the study, data collection, all GIS maps, present conditions, projected land development patterns, calculation methodology, the Model Ordinance and implementation discussion.

Volume III, the Technical Appendix, provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing municipal ordinance matrix, and obstructions inventory. Due to large volumes of data, one copy of Volume III will be on file at the Philadelphia Water Department office.

I. INTRODUCTION

This plan has been developed for the Poquessing Creek Watershed in Bucks, Montgomery, and Philadelphia Counties, Pennsylvania to comply with the requirements of the Pennsylvania Stormwater Management Act, (Act 167), of 1978. The Poquessing system is actually a tributary of the Delaware River. In order to properly address stormwater management in the Poquessing Watershed above the confluence with the Delaware River in Philadelphia City, it was determined that the watershed needed to be hydrologically evaluated. This Stormwater Management Plan (SMP) details the analyses that were performed in order to fulfill the requirements of Act 167.

The main objective of the SMP is to control stormwater runoff utilizing a comprehensive watershed-wide approach to manage stormwater volume, promote infiltration, minimize streambank erosion, and minimize flooding and stormwater problems. This can be accomplished by implementing the standards and criteria set forth in the SMP for new and redevelopment in addition to retrofitting existing basins and correcting the problem areas identified in the SMP.

II. STORMWATER MANAGEMENT

Stormwater management entails bringing surface runoff caused by precipitation events under control. In past years, stormwater control was viewed only on a site-specific basis. Recently, local perspectives and policies have changed. We have realized that proper stormwater management can only be accomplished by evaluating the comprehensive picture (i.e., by analyzing what adverse impacts a development located in a watershed's headwaters may have on flooding downstream). Proper stormwater management reduces flooding, augments baseflow, reduces soil and streambank erosion and sedimentation, and improves the overall quality of the receiving streams.

Stormwater management requires cooperation between the state, county, and local officials. It involves proper planning, engineering, construction, operation, and maintenance. This entails educating the public and local officials and also requires program development, financing, policy revision, the development of workable criteria, and the adoption of ordinances. The Poquessing SMP, under the Pennsylvania Stormwater Management Act (Act 167), will enable continued development to occur within the Poquessing Watershed, utilizing both structural and non-structural measures to properly manage stormwater runoff in the watershed.

III. WATERSHED DESCRIPTION

The Poquessing Creek is a tributary to the Delaware River in southeastern Pennsylvania. The watershed boundary extends into three counties: Bucks, Montgomery and Philadelphia. The main stem of the Poquessing Creek flows in a southerly direction from Lower Southampton Township in Bucks County, forming the boundary between Bensalem Township in Bucks County and the City of Philadelphia (Philadelphia County).

Although Upper Southampton Township is intersected by the watershed boundary, the majority of the area of this municipality lies outside of the watershed, and contributes only a small amount of runoff to the creek system. The Poquessing Watershed encompasses a total area of approximately 21.5 square miles and has one major tributary, Byberry Creek. A summary of the percentage of each municipality in the watershed follows.

Bucks County	Area (mi^2)	Percent of Watershed
Bensalem Twp.	4.70	21.85%
Lower Southampton Twp.	3.02	14.03%
Upper Southampton Twp.	0.01	0.06%
Montgomery County		
Lower Moreland Twp.	0.83	3.93%
Philadelphia County		
Philadelphia City	12.93	60.13%
Total	**21.5**	**100%**

IV. METHODOLOGY

The engineer for the project is NTM Engineering, Inc. with assistance from Temple University's Center for Sustainable Communities (CSC). The SMP was developed by analyzing data collected on the physical features of the watershed, such as soils, wetlands, topography, floodplains, dams and reservoirs, stream dimensions, and obstructions. Information on existing problem areas was solicited from the Watershed Planning Advisory Committee (WPAC), which consisted of representatives from the five municipalities as well as other interested parties, including County Conservation Districts and Planning Commissions, Philadelphia Water Department (PWD), Pennsylvania Environmental Council (PEC), and others. Although the SMP in and by itself cannot fix all existing problems, knowing where and why they exist aided the engineer in developing the subwatersheds, identifying points of interests, and understanding the hydrologic flow of the watershed as a whole. Information on existing land cover and zoning was also collected. All of this data was compiled into a Geographic Information System (GIS) database.

The computer model used for the project was the Environmental Protection Agency's Stormwater Management Model (EPA SWMM 5.0). This model was chosen for the project because it can be easily adapted to an urban area, it has the ability to analyze reservoir or detention basin-routing effects, and it is accepted by the Pennsylvania Department of Environmental Protection (PaDEP). To gain a realistic picture of what occurs in the Poquessing Watershed, the model was calibrated by PWD against actual stream flow data, regression models as well as data from the Federal Emergency Management Administration (FEMA).

The process of determining how runoff flows throughout the watershed is a complex one. It involves running numerous scenarios through the model, taking into account the location of obstructions and tributary confluences. This process sub-divided the watershed into subwatersheds for analysis. The most downstream point of each of these subwatersheds is considered a "point of interest" in which increased runoff must be analyzed for its potential impact.

Another aspect of the analysis involves modeling design storms. This term refers to assigning a frequency to a storm based on the amount of rain that falls over a 24-hour period. As the amount of rain falling over a 24-hour period increases, the frequency or chance of that storm occurring decreases. For example, 2.83 inches of rain falling over a 24-hour period is associated with the 1-year design storm, while the occurrence of 6.10 inches falling over a 24-hour period happens theoretically only every 25 years. For this study, the 1, 2, 5, 10, 25, 50, and 100-year, 24-hour storm events were modeled.

To make implementation of the SMP viable by the municipalities, a simple, but accurate method was developed for municipal officials, engineers, and developers to abide by the SMP. Standards and criteria were incorporated into the model stormwater ordinance to promote infiltrate, manage stormwater volume, minimize streambank erosion and reduce peak flows to reduce flooding. The watershed was divided into three stormwater management districts and assigned proposed condition/existing condition runoff rates for each. Problems identified were analyzed and proposed solutions to correct the problem, and to improve the overall health of the watershed, were developed.

V. EXEMPTIONS

Any activity that affects stormwater runoff within the Poquessing Watershed is required to be conducted in a manner consistent with the Plan. Certain land uses are exempt from the plan submission requirements of the Ordinance; however, these activities must still implement and construct stormwater management controls that are consistent with the management strategies contained in the SMP.

VI. IMPLEMENTATION:

All municipalities within the watershed will be required to adopt an ordinance that is consistent with the Poquessing Watershed SMP.

County adoption of the plan is expected to occur in June of 2012. Once this occurs, the SMP will be sent to PaDEP to be approved. All of the municipalities will be required to adopt an Ordinance to regulated development in a manner consistent with this SMP within six months of PaDEP's approval. The municipalities are encouraged to begin implementation of correction of the problem areas identified in the Plan, beginning with the sites ranked highest in Appendix G.