SWAMP CREEK WATERSHED

Act 167

Stormwater Management Plan

SECTION I – ACT 167 STORMWATER MANAGEMENT PLANNING AND IMPLEMENTATION

A. INTRODUCTION

The Swamp Creek Watershed Stormwater Management Plan has been prepared under an agreement with the Pennsylvania Department of Environmental Protection (DEP), and with assistance from ARRO Consulting, Inc. The intent of this plan is to coordinate stormwater management efforts among all the municipalities within the Swamp Creek watershed. Specifically, this is accomplished by identifying existing stormwater problem areas and projecting where future stormwater problems may occur within the 10-year timeframe of the plan. The model ordinance contains stormwater regulations that will prevent existing problems from becoming worse, and avoid the projected problems. Additional regulations pertaining to stormwater infiltration, water quality, and streambank protection are included. Public input was received from participating municipalities and agencies through the Watershed Plan Advisory Committee (WPAC) and the public hearing held on September 28, 2006.

B. ACT 167 STORMWATER MANAGEMENT PLANNING AND IMPLEMENTATION

The water that runs off the land into surface waters during and immediately following rainfall is referred to as stormwater. In a watershed where development is occurring, the volume of stormwater resulting from rainfall is greater than in an undeveloped watershed. The increase is due to the increased impervious areas (i.e., land covered by pavement, concrete, or buildings). The conversion of undeveloped land to residential, commercial, industrial uses disrupts the natural hydrology of the site. The hydrology of the site is even disrupted when land is converted from forest or meadow to cropland uses. This disruption involves decreased infiltration of rainfall and an increased rate and volume of runoff.

As development occurs, the increased quantity of stormwater runoff must be managed. Failure to do so can result in greater flooding, stream channel erosion, sedimentation, and reduced groundwater recharge. Stormwater management must be addressed in every land development proposal or any proposal that causes changes in land surface conditions. Past efforts to manage stormwater have usually focused on controlling the rate of discharge from individual sites after development. Ordinances typically have addressed stormwater control at the municipal level, but give no consideration to downstream impacts outside the municipality. This focus is changing to consider the overall hydrology of the development site, and the stormwater impacts of development on a watershed-wide basis.

Land development projects are often viewed as isolated occurrences and not necessarily related to a bigger picture. Even if a municipality takes a comprehensive look at the impacts of development in its portion of the watershed, its focus usually does not extend beyond municipal borders. However, the cumulative impact of stormwater runoff from individual developments dramatically affects flooding conditions. This cumulative effect includes flooding, streambank erosion, property damage (sometimes running into the millions of dollars), and at times, loss of life. Because development is usually distributed across the watershed, and because runoff from various areas in the watershed may combine to cause large-scale problems downstream, the best approach towards creating an effective stormwater management strategy is the watershed based approach. At the same time, any stormwater management strategy must be practical and easily implemented by the municipalities, since under DEP's program, they are charged with implementing the plan.

1. The Pennsylvania Stormwater Management Act (Act 167)

The Pennsylvania General Assembly recognized the need to address serious flooding problems and in 1978 enacted Act 167, the Pennsylvania Stormwater Management Act. The statement of legislative findings at the beginning of Act 167 sums up the relationship between land development, accelerated runoff, and floodplain management. Specifically, this statement of legislative findings points out the following:

a. Inadequate management of stormwater runoff from development increases flood flows and velocity, contributes to erosion and sedimentation, overloads the carrying capacity of streams and storm sewers, greatly increases the cost of public stormwater facilities, undermines flood management and flood control efforts in downstream communities, reduces groundwater recharge, and threatens public health and safety.

b. A comprehensive stormwater management program, including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety and welfare and the protection of the people of the Commonwealth, their resources and their environment.

Until the enactment of Act 167, stormwater management addressed the *rate* of runoff, that is, how fast the runoff was leaving a site at various times during a storm. The peak rate of runoff, that period when the largest volume was leaving the site in the shortest time period, was of particular concern. The increase in the peak rate of runoff discharging from a development site was controlled to protect property immediately downstream. Minimal attention was given to the effects on locations further downstream (frequently because they were located in other municipalities), or to designing stormwater controls within the context of the entire watershed or the hydrologic cycle. Comprehensive stormwater management planning or intentional consistency among adjoining municipalities in the same watershed was rare, if not nonexistent.

Act 167 changed this approach by instituting a *watershed-based, comprehensive program* of stormwater management. The Act requires Pennsylvania counties to prepare and adopt stormwater management plans for each watershed located in the county, as designated by the DEP. This plan for the Swamp Creek watershed was prepared to satisfy the requirements of Act 167, in consultation with municipalities located in the watershed, working through the WPAC. The plan contains stormwater controls to manage stormwater runoff from new development sites.

The controls prescribed in the plan are based on the expected development patterns and hydrologic characteristics of each individual watershed. The standards and criteria were developed from the technical evaluations performed in the planning process. The local watershed conditions and their effect on the timing and flow of stormwater from new development were considered through the modeling process. As required by Act 167, the plan is a comprehensive and practical implementation plan, developed with sensitivity to the overall needs (e.g., financial, legal, political, technical, etc.) of the municipalities in the watershed.

2. The Stormwater Management Planning Process

The watershed planning process for this study area considered the watershed characteristics as well as the resources (technical, political, and economic) of this area. This section presents the approach that has been developed to meet the specific requirements of Act 167.

3. Benefits of the Plan

The purpose of the plan is to provide all of the municipalities in the watershed with a consistent implementation strategy for comprehensive stormwater management. Currently, not all of the watershed municipalities enforce stormwater management regulations using the same criteria. A consistent management requirement throughout the watershed is imperative for sound stormwater control. The plan and ordinance developed will provide consistent regulations for the watershed.

The watershed planning approach recommended by DEP also provides the municipalities with a considerable amount of technical information, such as a detailed watershed runoff simulation model, that can be used for numerous other associated purposes. Municipalities and the county will have products that are usable for other planning and engineering purposes, such as land use updates. The technical component of the plan will provide a unique environmental database for county and municipal use. Technical support information provided as a part of the watershed modeling effort can be used by public works officials for bridge replacement and floodplain management analysis, design and regulatory permitting efforts. The stream encroachment permit process, which requires detailed stream flow data as a part of the application process, can be more efficiently and cost-effectively developed using the calibrated watershed model.

The benefits of the watershed planning process are wide-ranging, even beyond the important function of developing comprehensive stormwater management strategies and ordinance provisions.

4. The Swamp Creek Watershed Plan Development Process

In order to implement watershed-wide planning for stormwater runoff, it was necessary to consider all portions of the watershed. The process relies on municipalities to provide local data needed for stormwater management. The involvement of each municipality was critical to the process.

The WPAC was formed to initiate municipal level involvement in the overall development of the plan. The WPAC was formed of representatives from the following municipalities, the County Conservation District and interested groups:

WPAC Member	Affiliation
William Dingman	Bechtelsville Borough Engineer
John Ravert	Berks County Conservation District
Shannon Rossman	Berks County Planning Commission
Sandra Moser	Bechtelsville Borough Secretary
Charles Clark	Boyertown Borough Manager
Allen Stauffer	Colebrookdale Township
Eileen Pinder	District Township Secretary
Eileen Pinder	Douglass Township (Berks Co.) Secretary
Georgeann Rohrbach	Douglass Township (Mont. Co.) Secretary
William Bradford	Limerick Township Roadmaster
Lorraine Cuddy	Lower Frederick Township Manager
Rodney Hawthorne	Lower Pottsgrove Township Asst. Manager
Richard Kadwill	Montgomery County Conservation District
Drew Shaw	Montgomery County Planning Commission
Anne Klepfer	New Hanover Township Manager
George Rodenbough	Pike Township
Thomas Snyder	Schwenksville Borough Manager
Jennifer Bolognese	Upper Frederick Township Secretary
Sandra Fritz	Upper Pottsgrove Township Manager
Sandra Moser	Washington Township Secretary

5. Data Collection

The watershed model simulates the behavior of runoff and analyzes hydrologic data in the watershed for a range of storms. The data needed for the model includes elevations, soils, geology, land use, floodplain/wetlands, and stream obstructions (bridges and culverts). The watershed covers a large area. The modeling effort requires that the watershed be divided into subwatersheds. The subwatersheds are created based on stream junctures, municipal boundaries, and identified problem areas where flooding or streambank erosion is occurring.

A municipal questionnaire was distributed to each WPAC member. The questionnaire solicited input from each municipality on specific problems in the watershed, as well as for the needs they may see for stormwater management in their particular area. The questionnaire was distributed at the first WPAC meeting, along with a summary of the purpose and goals of Act 167. The questionnaire was designed to develop interest by the responding municipalities in the need to implement stormwater management measures within their community. The results of the questionnaire are summarized in Table 1.

Table 1
Summary of Response Items from Phase I Municipal Questionnaire
(numbers refer to the various lists at the end of the questionnaire)

Municipality	Problems Concerns Identified (A)	Causes of Stormwater Problems (B)	Frequency of Occurrence (C)	Type of Damages Incurred
Bechtelsville Borough	1	3, 5	4	Private property damage, Road closure, Loss of vital services
Boyertown Borough	Survey not received			
Colebrookdale Township	1	3, 4, 5	4	Private property damage, Road closure
District Township	Survey not received			
Douglass Township (Berks)	Information not provided			
Douglass Township (Mont.)	1, 2	2, topography	3	Private property damage, Road closure
Limerick Township	1	2, 3, 4, 5	4	Public property damage
Lower Frederick Township	1, 2	4, backwater	4	Public property damage, Road closure
Lower Pottsgrove Township	Survey not received (very small portion of Township in watershed)			
New Hanover Township	1	1, 3	4	Private property damage (cars), Road closure
Pike Township	Survey indicated no problems within the watershed			
Schwenksville Borough	Survey not received (very small portion of Borough in watershed)			
Upper Frederick Township	1, 2	1, 4	3	Private property damage, Public property damage, Road closure
Upper Pottsgrove Township	Survey indicated no problems within the watershed			
Washington Township	2	3, 4	4	Private property damage, Road closure

(A) Problems/Concerns Identified
1. Stream flooding
2. Street flooding
3. Soil erosion
4. Stormwater pollution
5. Other

(B) Causes of Stormwater Problems
1. Too large an increase in uncontrolled runoff
2. Uncontrolled runoff from upstream
3. Inadequate drainage system
4. Obstructions that need to be removed
5. Lack of maintenance of drainage ways
6. Other

(C) Frequency of Occurrences
1. Every rain
2. More than 10 times per year
3. More than 1 time per year
4. Only on major flood events

6. Development of Standards and Criteria

The data gathered via the survey and through field investigations were then loaded into a model of the watershed. The modeling effort is described in more detail in

Section VI, Stormwater Control Standards. The output from the model, along with conclusions from the municipal questionnaire, were used to propose stormwater management release rate(s) that would serve to avoid future flooding problems and keep existing problems from becoming worse. Based on the model results, a 50% release rate was recommended for the entire watershed. This release rate was then incorporated in the model ordinance.

Other stormwater management criteria are required by DEP. Ordinance language to meet these requirements was developed, including detention standards to protect streambanks from excessive erosion and to improve water quality, and infiltration standards to encourage groundwater recharge. The ordinance was also reviewed and language added to bring it into compliance with DEP's MS4 stormwater program. A draft of the ordinance was distributed to the WPAC and DEP for review, and the final ordinance is included in the Plan.

SECTION II – WATERSHED CHARACTERISTICS AND THE IMPACT ON RUNOFF

A. Watershed Characteristics

The Swamp Creek watershed, as illustrated in Figure 1, is located in western Montgomery County and eastern Berks County. The municipalities found in the watershed are:

- Bechtelsville Borough
- Boyertown Borough
- Colebrookdale Township
- District Township
- Douglass Township (Berks County)
- Douglass Township (Montgomery County)
- Limerick Township
- Lower Frederick Township
- Lower Pottsgrove Township
- New Hanover Township
- Pike Township
- Schwenksville Borough
- Upper Frederick Township
- Upper Pottsgrove Township
- Washington Township

The Swamp Creek drains an area of approximately 55.52 square miles and includes the following major tributaries: Goshenhoppen Creek, Middle Creek, Minister Creek, Scioto Creek, Schlegel Creek, and the West Branch to Swamp Creek. Swamp Creek flows into the Perkiomen Creek above Schwenksville.

1. Watershed Description

The Swamp Creek watershed extends from the headwaters in District and Pike Townships, Berks County, to the confluence of Swamp Creek with the Perkiomen Creek north of Schwenksville, Montgomery County. The 55.8 square mile watershed is divided between the two counties; 26% or 14.6 square miles in Berks County, and 73.8 % or 41.2 square miles in Montgomery County. The Berks county portion of the watershed includes all or part of 7 municipalities. Eight municipalities are included in the Montgomery County portion.

Figure 1 General Watershed Map

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SWAMP CREEK WATERSHED AREA DATA

Total Area: 55.52 square miles

Municipality	**Watershed Area (sq.mi.)**
Berks County	
District Township	0.8
Pike Township	2.0
Washington Township	6.0
Bechtelsville Borough	0.5
Colebrookdale Township	4.5
Boyertown Borough	0.5
Douglass Township (Berks Co.)	0.2
Total Watershed – Berks County	**14.5**
Montgomery County	
Douglass Twp. (Montgomery Co.)	12.5
New Hanover Township:	15.3
Upper Frederick Township	5.8
Lower Frederick Township	4.8
Schwenksville Borough	0.02
Limerick Township	2.0
Upper Pottsgrove Township	0.4
Lower Pottsgrove Township	0.2
Total Watershed – Montgomery County	**41.02**

According to the Pennsylvania Code, Chapter 93, Swamp Creek has the following protected water uses:

- Swamp Creek basin, source to Bechtelsville Dam: High Quality; Cold Water Fishes and Migratory Fishes.
- Swamp Creek basin, Bechtelsville Dam to bridge at Route 100: Cold Water Fishes and Migratory Fishes.
- Swamp Creek basin, bridge at Route 100 to mouth: Trout Stocking Fishes and Migratory Fishes.

2. Land Characteristics

The main stem of the Swamp Creek rises in the hills of Pike, District, and Washington Townships. The watershed boundary in this area is above the 1,000 foot contour, reaching 1,080 feet above sea level at its highest point. The area is hilly, and the stream corridor is narrow.

Below Bechtelsville, the Swamp Creek enters a wide, shallow bowl. Slopes along the main stem and its tributaries in this area are typically less than 5%, although towards the watershed boundary the slopes increase to about 15%. The stream meanders in this area, and three tributaries (Schlegel Run, Middle Creek, and Minister Creek) join the main stem.

In the lower third of the watershed, the width narrows and the two ridges that form the watershed converge on Schwenksville. The steeply sloped ridges are paralleled by the main stem, Goshenhoppen Creek, and Scioto Creek. The steeply sloped sides of the two ridges result in long straight channels for these three creeks. The Scioto and Goshenhoppen Creeks run in a relatively straight path for over 3 miles, and the main branch, including an unnamed tributary, flows without any significant meanders for about 6 miles. Please refer to Figure 2 for watershed slope information.

Figure 2 Slopes Map

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There are several important hydrologic features in the last few miles of the Swamp Creek before it empties into the Perkiomen Creek. The main stem is dammed at Sunrise Mill, a county historic site located about three miles upstream from the confluence of the Swamp and Perkiomen Creeks. A little over a mile downstream, a second dam crosses the main stem. The Scioto joins the main stem just 3,000 feet below the dam, and the Goshenhoppen Creek joins the main stem 5,000 feet below that. A third dam impounds the creek 500 feet downstream from the confluence of the main stem and the Goshenhoppen Creek. The confluence of the Swamp and Perkiomen Creeks is just 2,000 feet below this third dam.

Existing land use information was obtained from Berks and Montgomery Counties. Figure 3 shows the existing land cover information for the watershed. Woodland is the dominant land cover for portions of the watershed located in Pike Township, District Township, Limerick Township and Lower Frederick Township. There are also large woodland areas in Washington Township, Douglass Township, and New Hanover Township. These areas tend to be undeveloped. Additionally, there tends to be less development in the Berks County/upland portion of the watershed. Development in this portion of the watershed is concentrated near Route 100 and in Boyertown Borough and is a mix of commercial, industrial, and residential development. According to the existing land use information, most of the development within the watershed has generally occurred within Douglass and New Hanover Townships, in the central portion of the watershed. Most of the development in these municipalities is residential. There has also been some low density residential development in Upper Frederick Township, also in the central portion of the watershed. Despite development in these areas, Douglass, New Hanover, and Upper Frederick Townships still have significant areas that are agricultural, open space, or woodland.

3. Soils

The soils in the watershed include the following series.

- *Abbottstown Series (AbA, AbB2):* These are deep and moderately deep, somewhat poorly drained soils formed from weathered red and brown shale and sandstone. These soils have a slowly permeable subsoil that impedes the downward movement of water. These soils are wet late in fall, in winter, and early in spring.
- *Bouldery Alluvial Land (Bo):* This series consists of nearly level to gently sloping areas covered by boulders and stones. This soil is subject to flooding, usually several times each year. Permeability is moderate, and the water table is near or at the surface late in fall and during winter and spring.
- *Bowmansville Series (Bp, BrA, BrB):* Deep, poorly drained silt loams and silty clays make up the Bowmansville series. These soils formed from material washed from upland areas underlain by shale, sandstone, and

diabase. They are nearly level or gently sloping and occur in floodplains along streams. These soils have a moderate permeability, and experience a high water table late in fall, in winter, and in spring. Bedrock can be within 2 to 3 feet of the surface.

- *Brecknock Series (BsB2, BsC2, BtC, BtD, BvD):* The Brecknock series consists of deep to moderately deep, well-drained channery silt loams (*channery* refers to a soil that contains more than 15% fragments of thin, flat sandstone, limestone, or schist). The soil is formed from metamorphosed shale, called hornfels. These are gently sloping to steep, located on top of hills or low ridges. Depth to bedrock ranges from 2 to 5 feet, and permeability is moderate.
- *Croton Series (CrA, CrB2):* The Croton series is made up of soils that are deep, poorly drained, nearly level or gently sloping, formed from shale and sandstone. The thick subsoil impedes the downward movement of water. The water table is near the surface in late fall, in winter, and early in the spring.
- *Klinesville Series (KsE3):* The soils in the Klinesville series are well-drained, gently sloping to steep. These soils have a moderately rapid permeability. The bedrock is within 2 feet of the surface.
- *Lansdale Series (LdA2):* The Lansdale silt loam is a deep soil, with the bedrock at a depth of 5 to 10 feet. Slopes are gentle, usually 0 to 3 percent. It is moderately permeable, and surface runoff is slow to medium.
- *Legore Series (LgC3, LgD3):* The soils in this series are well-drained, moderately deep to deep soils that were formed from weathered diabase. They are found on moderately sloping to steep hills and ridges in the watershed. The Legore soils are moderately permeable. Surface runoff is rapid, and the hazard of erosion is severe.
- *Lehigh Series (LhB2, LhB3, LhC2, LhC3, LsD):* The Lehigh series consists of moderately deep to deep soils that are moderately well drained to somewhat poorly drained. These soils are formed from weathered hornfels, a metamorphosed shale. They have a slowly permeable layer in the subsoil that restricts the downward movement of water. The water table is within a foot of the surface in late fall, in winter and early in spring.
- *Made Land (MeB):* This category of soils, which refers to areas where earthmoving has altered the characteristics of soils, varies greatly from soil to soil. The characteristics of the soil also vary within each type. The MeB soil results from altering and mixing soils formed from shale and sandstone. It is mainly level to gently sloping, and may be comprised almost entirely of pieces of shale. The permeability is moderate to slow, and the water table is at the surface during winter and spring.

Figure 3 Existing Land Cover Map

Back of land cover map

- *Mount Lucas Series (MoA, MoB2, MoC2, MuB, MuD):* These are deep, moderately well-drained to somewhat poorly drained soils, formed from diabase. They are nearly level, and have moderately slow permeability in the subsoil. The MuB and MuD soil types are very stony silt loams that can contain stones up to 12 feet in diameter. The stones can be so numerous in places that there is little soil between them.
- *Neshaminy Series (NhB2, NhC2, NhD2, NsD):* The Neshaminy series is typified by deep, well-drained soils formed from weathered diabase. Permeability is moderate. The steeper soil types (NhC2, NhD2) are prone to rapid runoff. The NsD soil type is stonier than the other soil types in this series.
- *Penn Series (PeB2, PeB3, PeC3):* The Penn series soils are moderately deep to shallow soils, formed from weathered shale, sandstone and siltstone. They occur on undulating and hilly uplands, and are important agricultural soils. They have a rapid permeability. The Penn-Klinesville soil type (PkD3) consists of Penn and Klinesville soils that occur together too closely to separate. This soil type has moderate to rapid permeability, though surface runoff is rapid.
- *Raritan Series (RaA, RaB2):* This series consists of moderately well-drained to somewhat poorly drained soils formed from old stream sediments. The subsoil is firm, and restricts the downward movement of water. There is also a seasonal high water table.
- *Readington Series (ReA, ReB2):* Deep, moderately well-drained silt loam soils are in the Readington series. Surface drainage is slow, and the water table is within 18 inches of the surface in late fall, in winter, and early spring.
- *Reaville Series (RsA2, RsB2, RsB3, RsC3):* Moderately deep, moderately well-drained or somewhat poorly drained silt loams make up this series. These soils have a thin, slowly permeable subsoil that restricts the downward movement of water. There is a seasonal high water table, and bedrock is often near the surface.
- *Rowland Series (Rt, RwA, RwB):* The Rowland series consists of deep, moderately well-drained to somewhat poorly drained nearly level silt loam on floodplains. The soils have a high water table and are subject to flooding in late fall, in winter, and in early spring, as well as during high intensity storms.
- *Stony Land, Steep (Ste):* Slopes on this soil type are usually above 25%. The soil layer is thin, and runoff rapid.
- *Watchung Series (WaA, WaB, Wc):* These are deep, poorly drained soils. They have a slow permeability, and the subsoil inhibits percolation (the

downward movement of water). The water table is at the surface late in fall, in winter, and early in spring. Surface runoff is slow, and water frequently ponds.

The USDA Natural Resources Conservation Service (NRCS) has divided soils into four groups, referred to as hydrologic soil groups, based on the potential for having similar runoff potential under similar storm and cover conditions. Factors that would influence this potential include the following: depth to seasonally high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. The four groups are called A, B, C, and D, and they describe soils with increasing runoff potential from A to D. Group A soils have a high infiltration rate even when thoroughly wetted. Group B soils have a moderate infiltration rate when thoroughly wetted. They are typically deep, moderately well drained soils. Group C soils have a relatively low infiltration rate when thoroughly wetted. They typically consist of soils of fine texture or have a layer that impedes percolation. Group D soils have a very slow infiltration rate when thoroughly wetted. They typically consist of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay layer near the surface, or shallow soils over nearly impervious material.

Group A soils are not found in the Swamp Creek watershed. Much of the upstream, Berks County portion of the watershed consists of B soils. Some other scattered pockets of B soils can be found in the watershed, most notably on the south side of the downstream end of Swamp Creek. The majority of the watershed consists of C soils, especially within the Montgomery County portion of the watershed. Much of the watershed's floodplain areas consist of D soils.

The implication of this information, which is confirmed by observations during storm events, is that the majority of the watershed is not conducive to infiltration and does not drain very well, resulting in flooding, particularly in areas of development and roadways that are adjacent to Swamp Creek and any of its tributaries. Stormwater infiltration facilities therefore, will need to be carefully designed and sited in order to function well.

These soil series have been mapped and grouped according to hydrologic grouping during Phase II data preparation activities. Please refer to Figure 4 for the soils map.

4. Rainfall Information

The annual average total amount of precipitation (including rainfall and the water equivalent of snowmelt) is 43 inches (measured at Pottstown, PA). Within Montgomery County, a low of 32 inches and a high of 51 inches per year have been recorded. Early spring (March and April) and late summer (July, August, September) tend to be the wettest months. Most of the rainfall in the warm months comes in the form of showers and thunderstorms. At times these storms produce considerable local flooding when the soils are unable to absorb the large volume of water coming off impervious surfaces and the natural or artificial drainage systems become overloaded.

B. Floodplains / Flood Hazard Areas

The Federal Emergency Management Agency (FEMA) manages the National Flood Insurance Program (NFIP). Thousands of communities across the United States and its territories participate in the NFIP by enforcing floodplain management ordinances in exchange for the opportunity for their property owners to purchase Federally-backed flood insurance. FEMA also identifies and maps the Nation's floodplains through the NFIP.

FEMA has identified 100-year floodplains for Swamp Creek and its tributaries through both detailed and approximate methods. When a floodplain has been studied by detailed methods, it means that hydrologic and hydraulic models, such as HEC-HMS and HEC-RAS, were used to develop the floodplain elevations at specific cross sections, and these floodplain elevations are used with topographic information to delineate the 100-year floodplains. Detailed studies result in 100-year base flood elevations, floodplain delineations, and floodway delineations. Floodways are defined as the stream channel and adjacent floodplain areas that are to be kept free of encroachments so the 100-year flood can be conveyed without increases in floodplain elevations greater than 1 foot. Streams that have been studied using detailed methods should have floodplains that have been delineated more accurately than those with floodplains determined using approximate methods. Floodplains for streams with higher flood and/or development potential are generally studied using detailed methods, and floodplains for streams considered to have lesser flood and/or development potential are determined using approximate methods. Floodplains determined using approximate methods are delineated considering criteria such as area topography and past flood observations.

The effective date for the floodplain delineation and mapping of the Montgomery County portions of the watershed is December 19, 1996, and the effective date of the Berks County portions of the watershed is December 5, 1997. Detailed floodplain analyses have been completed for the following stream reaches within the watershed, listed from the downstream limit of detailed study to the upstream limit of detailed study (all lengths are approximate):

<u>Swamp Creek</u>

- Confluence with Perkiomen Creek to a distance 16,500 feet upstream of the confluence or 6,000 feet upstream of the dam at Camp ArthurReeta.
- New Hanover Township boundary to a distance 8,700 feet upstream of the Township boundary, or 1,500 feet upstream of Colonial Road.
- Route 73 upstream to the Montgomery County – Berks County boundary.

- Montgomery County – Berks County boundary to a distance 4,300 feet upstream of the County boundary or 2,100 feet upstream of Mill Crest Road.
- Washington Township boundary to a distance 7,050 feet upstream of the Township boundary or 50 feet upstream of Race Street.

Goshenhoppen Creek

- Confluence with Swamp Creek to a distance 14,750 feet upstream of the confluence or 400 feet upstream of Faust Road.

Scioto Creek

- Confluence with Swamp Creek to a distance 19,700 feet upstream of the confluence or at Township Line Road.

West Branch Swamp Creek

- Confluence with Swamp Creek to a distance 14,500 feet upstream of the confluence or just upstream of Rhoads Road.

Minister Creek

- Reifsnyder Road (approximately 5000 feet upstream of confluence with Swamp Creek) to a distance 31,550 feet upstream of the confluence with Swamp Creek or the Montgomery County – Berks County boundary .

Minister Creek Tributary

- Confluence with Minister Creek to a distance 4,100 feet upstream of the confluence with Minister Creek.

Oley Creek

- Confluence with Minister Creek to a distance 4,100 feet upstream of the confluence with Minister Creek or the Montgomery County-Berks County boundary.

Schlegel Run

- Confluence with Swamp Creek to a distance 17,500 feet upstream of the confluence or at Hoffman Road.

Middle Creek

- Confluence with Swamp Creek to a distance 13,500 feet upstream of the confluence or 2,700 feet upstream of Congo Road.

Please refer to Figure 1 for the Swamp Creek floodplain delineation. The floodplains shown on this map include those determined by FEMA using both detailed and approximate methods.

Figure 4 Hydrologic Soil Group Map

Back of map

C. Survey of Existing Runoff Characteristics

The runoff characteristics of the Swamp Creek watershed are changing as increased development and new stormwater management regulations impact the hydrologic cycle. As existing forested areas, farmland and open spaces are developed, these natural areas are often converted to impervious areas or areas of grass or landscaping over relatively compacted soils. These changes result in the decreased ability of the ground to slow and/or infiltrate stormwater runoff, which then results in increased stormwater flow volumes and decreased groundwater recharge. This stormwater flow can often contain sediment or other pollutants from the land-altered areas, resulting in the decreased water quality of the receiving stream.

Portions of the watershed located near areas of land development are seeing streams reach their bankfull volumes more frequently and during smaller storm events due to the stormwater runoff volume increases. This results in streambank erosion and also undercut streambanks.

Several municipalities in the Swamp Creek watershed have indicated that they are concerned about decreasing groundwater recharge due to development. As impervious area increases, there is less available ground area where stormwater runoff can infiltrate before flowing toward a drainage structure or stream. As a result of this, the groundwater table is not being replenished as it was in the past.

Another factor influencing existing runoff characteristics is the lack of porous soils (hydrologic soil groups A and B) found within the Swamp Creek watershed. This watershed characteristic implies that there are limited areas where significant groundwater recharge is feasible, resulting in areas of significant runoff or pooling, depending on area slopes and the presence of stormwater management facilities.

D. Runoff Control Techniques and Their Efficiencies

As development occurs, the increased quantity of stormwater runoff must be addressed. Failure to do so can result in greater flooding, stream channel erosion, sedimentation, and reduced groundwater recharge. Stormwater management must be addressed in every land development proposal or any proposal that causes changes in land surface conditions. Past efforts to manage stormwater have usually focused on controlling the rate of discharge on a municipality-by-municipality basis. One goal of an Act 167 plan is to change this focus from runoff control by individual development or municipality to consider the stormwater impacts of development on a watershed-wide basis. The model Swamp Creek Stormwater Management Ordinance, discussed in Section VI, provides stormwater management requirements, design guidelines, and enforcement provisions to achieve this goal.

There exist several types of runoff control techniques that can be employed on development sites to meet the performance criteria outlined in the Swamp Creek Stormwater Management Ordinance. Various techniques to reduce and/or delay runoff corresponding to development type are listed in Table 2. A more exhaustive list of techniques, along with specific design criteria, can be found in the *Pennsylvania Stormwater Best Management Practices Manual*, latest edition.

The design of an effective stormwater management plan involves careful planning. It may be necessary for the development site engineer / design professional to consider multiple runoff control techniques to meet the stormwater management requirements. Some items to consider when selecting the most appropriate runoff control measures for a particular development site include the following:

- Design constraints specific to watershed.
- Physical constraints such as soil characteristics, geology, depth to high groundwater table, development area slope and topography, existing drainage patterns, and stormwater facility siting.
- Ability of stormwater facility(ies) to meet design requirements / recommendations for development site.
- Advantages and disadvantages to each runoff control technique.
- Community acceptance of runoff control technique.
- Cost of runoff control technique.
- Maintenance required for runoff control technique to operate effectively.
- Permitting requirements for proposed improvements.

Table 2
Measures for Reducing and Delaying Urban Storm Runoff
Various On-Site Storm Water Control Methods

Area	Reducing Runoff	Delaying Runoff
A. Large Flat Roof	1. Cistern storage 2. Rooftop gardens 3. Pool storage or fountain storage	1. Ponding on roof by constructed downspouts 2. Increasing roof roughness: a. Rippled roof b. Graveled roof
B. Parking Lots	1. Porous pavement: a. Gravel parking lots b. Porous or punctured asphalt 2. Concrete vaults and cisterns beneath parking lots in high value areas 3. Vegetated ponding areas around parking lots 4. Gravel trenches	1. Grassy strips on parking lots 2. Grassed waterways draining parking lot 3. Ponding and detention measures for impervious areas: a. Rippled pavement b. Depressions c. Basins
C. Residential	1. Cisterns for individual homes or groups of homes 2. Gravel driveways (porous) 3. Contoured landscape 4. Ground-water recharge: a. Perforated pipe b. Gravel (sand) c. Trench d. Porous pipe e. Dry wells 5. Vegetated depressions	1. Reservoir of detention basin 2. Planting a high delaying grass (i.e. high roughness) 3. Gravel driveways 4. Grassy gutters or channels 5. Increased length of travel of runoff by means of gutters, diversions, etc.
D. General	1. Gravel alleys 2. Porous sidewalks 3. Mulched planters	1. Gravel alleys

Source: Urban Hydrology for Small Watersheds. Technical Release No. 55

1. Best Management Practices

The impacts of the clearing, grading, addition of impervious area, and construction that are associated with land development include declining water quality, diminishing groundwater recharge and quality, degradation of stream channels, increased overbank flooding, and floodplain expansion. Best management practices (BMPs) have been developed to lessen these impacts of development on the environment. BMPs may be structural or non-structural and are designed to detain or treat stormwater to improve water quality and recharge, protect stream channels from erosion, and decrease flooding. Some BMPs specifically control runoff, while others specifically control pollution. Several BMPs perform both of these functions.

The following is a summary of various BMPs. This is not an exhaustive list of BMPs. Additional information may be found in the *Pennsylvania Stormwater Best Management Practices Manual,* latest edition.

a. Nonstructural practices:

1) *Natural Area Conservation*: Natural areas are conserved at development sites, retaining pre-development hydrologic and water quality characteristics. Examples include forest retention areas, non-tidal wetlands and associated buffers, other areas in protective easements, and stream systems.

2) *Disconnection of Rooftop Runoff:* Rooftop runoff is disconnected and directed to a pervious area where it can infiltrate into the soil or filter over it.

3) *Disconnection of Non Rooftop Runoff:* Impervious surface runoff is disconnected by directing it to pervious areas where it can infiltrate into the soil or filter over it. This may be achieved by site grading that promotes overland vegetative filtering or by providing bioretention areas.

4) *Grass Channels:* Grass channels may be used to reduce the volume of runoff and pollutants during smaller storms. Grass channels may be designed to provide opportunities for groundwater recharge and water treatment.

5) *Sheetflow to Buffers:* Effective treatment in using this method is achieved when runoff from pervious and impervious areas is discharged to a grass or forested buffer through overland flow. A Riparian Buffer Zone (RBZ) is an example of this type of nonstructural BMP.

6) *Environmentally Sensitive Development:* Environmental site design techniques can be applied to low density or residential development. Design techniques include reducing impervious cover; increasing lot sizes or using clustering techniques; and using grass channels, rooftop runoff disconnections, and natural conservation areas.

7) *Riparian Buffer Zone (RBZ):* A RBZ is an area adjacent to a wetlands or watercourse that extends a minimum of fifty (50) feet to either side of the top-of-bank of the channel. The buffer area

shall be maintained with and encouraged to use appropriate native vegetation.

8) *Street Sweeping:* This BMP involves the removal of trash and other pollutants from roadways and parking areas before they may enter a stream.

9) *Application and Storage of Fertilizers, Pesticides, and Highway Deicing Compounds*: Proper application and storage of these compounds can reduce the amounts entering a stream system.

b. *Structural Practices:*

1) *Bioretention Facility:* In a bioretention facility, sand and soil mixtures are mixed with native plants to remove pollutants such as suspended solids and nutrients in a low area or basin. These areas may also be designed to act to reduce peak runoff rates and recharge groundwater by infiltrating runoff.

2) *Constructed Treatment Wetland*: A constructed treatment wetlands is an artificial shallow water-filled basin that has been planted with emergent plant vegetation. These wetlands may be used to remove pollutants such as suspended solids, nutrients (nitrogen and phosphorus), heavy metals, toxic organic pollutants, and petroleum compounds. They may also be an effective means of reducing peak runoff rates and stabilizing flow adjacent to natural wetlands and streams.

3) *Filter Strip:* Filter strips are vegetated areas with mild, uniform slopes. These areas may be forested or vegetated with grasses. Filter strips located adjacent to waterbodies are called buffers. Filter strips are provided downgradient of development to trap sediment and sediment-born pollutants. They are used to "disconnect" impervious surfaces from storm sewers and lined channels and may be used to help to reduce peak discharge rates.

4) *Infiltration Trench:* An infiltration trench is an excavated, stone-filled trench in which stormwater runoff is collected and percolated to the surrounding soil. These trenches allow runoff from small drainage areas to percolate into the ground.

5) *Infiltration Basin:* An infiltration basin is an excavated, stone-filled area with a relatively-permeable soil bottom. The basin temporarily stores runoff and allows it to infiltrate into the ground.

6) *Permeable Paving:* Permeable paving is an alternative to conventional paving practices, which includes the use of porous bituminous concrete mixtures, permeable interlocking concrete paving blocks, concrete grid pavers, perforated brick pavers, or compacted gravel. Permeable paving reduces impervious area at a

development site, reducing surface runoff and increasing infiltration.

7) *Dry Detention Basin:* A dry detention basin is a permanent stormwater management facility that stores stormwater runoff and is generally dry between storm events. The ability of the basin to store water allows a portion of the pollutants contained in the runoff to settle out. Additionally, these basins should be designed to reduce the potential for flooding and streambank scour and erosion in downstream areas. To qualify as a BMP, dry basins should provide extended detention during small storm events.

8) *Wet Detention Basin:* A wet detention basin is a permanent stormwater management facility that retains a permanent pool of water to enhance water quality and additional capacity above the permanent pool to detain stormwater runoff. These may be used in low density residential or commercial developments where there is a source of water to maintain the permanent pool in the pond.

9) *Sand Filter:* Sand filters treat runoff by allowing it to settle through sand. The runoff is then discharged to a storm drain, stream, or channel after it is filtered.

10) *Water Quality Inlet (Oil-Grit Separator):* These inlets are used to remove oil, grease, heavy particulates, absorbed hydrocarbons, and other floating substances from stormwater before the pollutants enter the storm sewer system. These inlets have multiple chambers and are best applied in small drainage areas with heavy vehicular traffic or large amounts of petroleum.

11) *Erosion and Sedimentation Control*: Erosion and sedimentation control measures reduce sediments released to areas downgradient from construction sites. Control measures include temporary construction entrances, silt fence, sedimentation basins, sediment traps, and inlet protection.

12) *Check Dam:* A check dam is a stone dam constructed in a swale or other watercourse to decrease the flow velocity, minimize scour, and promote sediment deposition.

13) *Level Spreader:* A level spreader is a perforated pipe, concrete curb, or other structure that is installed downgradient of a location of concentrated flow for the purpose of converting the flow into sheet flow. Level spreaders prevent erosive flows and promote infiltration.

14) *Trash Rack:* Trash racks are installed on basin risers or roof downspouts to keep trash or other relatively large pollutants from entering a treatment structure.

Please refer to the following design manuals for further information on the BMPs listed above and on additional BMPs:

c. *Pennsylvania Stormwater Best Management Practices Manual, April 2006 (draft)*

To download, go to the following website:
http://www.dep.state.pa.us/dep/subject/advcoun/stormwater/stormwatercomm.html

d. *Pennsylvania Handbook of Best Management Practices for Developing Areas, Spring 1998*

For summary and ordering information, go to the following website:
http://www.pacd.org/products/bmp/bmp_handbook.htm

e. *2000 Maryland Stormwater Design Manual, Volumes I and II*

To download, go to the following website:
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

f. *New Jersey Stormwater Best Management Practices Manual, April 2004*

To download, go to the following website:
http://www.njstormwater.org/tier_A/bmp_manual.htm

g. *Delaware Conservation Design for Stormwater Management Guidance Manual (1997)*

For ordering information, go to the following website:
http://www.dnrec.state.de.us/dnrec2000/divisions/soil/stormwater/apps/designmanualrequest.htm

h. *New York State Stormwater Management Design Manual, August 2003*

To download, go to the following website:
http://www.dec.state.ny.us/website/dow/toolbox/swmanual/

2. Advantages and Disadvantages of Various Runoff Control Facilities

The advantages and disadvantages for various runoff control facilities are tabulated below.

Runoff Control Facility	Advantages	Limitations
Bioretention Facilit y	• If designed properly, has shown ability to remove significant amounts of dissolved heavy metals, phosphorous, TSS, and fine sediments. • Requires relatively little engineering design in comparison to other stormwater management facilities (e.g. sand filters). • Provides groundwater recharge when the runoff is allowed to infiltrate into the subsurface. • Enhances the appearance of parking lots and provides shade and wind breaks, absorbs noise, and improves an area's landscape. • Maintenance on a bioretention facility is limited to the removal of leaves from the bioretention area each fall. • The vegetation recommended for use in bioretention facilities is generally hardier than the species typically used in parking lot landscapes. This is a particular advantage in urban areas where plants often fare poorly due to poor soils and air pollution.	• Low removal of nitrates. • Not applicable on steep, unstable slopes or landslide areas (slopes greater than 20 percent). • Requires relatively large areas. • Not appropriate at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable. • Clogging may be a problem, particularly if the BMP receives runoff with high sediment loads.
Catch Basin Inserts	• Provides moderate removal of larger particles and debris as pretreatment. • Low installation costs. • Units can be installed in existing traditional stormwater infrastructure. • Ease of installation. • Requires no additional land area.	• Vulnerable to accumulated sediments being resuspended at low flow rates. • Severe clogging potential if exposed soil surfaces exist upstream. • Maintenance and inspection of catch basin inserts may be required before and after each rainfall event, excessive cleaning, and maintenance. • Available head to meet design criteria. • Dissolved pollutants are not captured by filter media. • Limited pollutant removal capabilities.
Cisterns	• Requires little space for installation. • Reduces amount of stormwater runoff. • Conserves water usage.	• Limited amount of stormwater runoff can be captured. • Restricted to structure runoff.

Runoff Control Facility	Advantages	Limitations
Constructed Wetlands	• Artificial wetlands offer natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. • Artificial wetlands can offer good treatment following treatment by other BMPs, such as wet ponds, that rely upon settling of larger sediment particles. They are useful for large basins when used in conjunction with other BMPs. • Wetlands that are permanently flooded are less sensitive to polluted water inflows because the ecosystem does not depend upon the polluted water inflow. • Can provide uptake of soluble pollutants such as phosphorous, through plant uptake. • Can be used as a regional facility.	• Although the use of natural wetlands may be more cost effective than the use of an artificial wetland; environmental, permitting and legal issues may make it difficult to use natural wetlands for this purpose. • Wetlands require a continuous base flow. • If not properly maintained, wetlands can accumulate salts and scum which can be flushed out by large storm flows. • Regular maintenance, including plant harvesting, is required to provide nutrient removal. • Frequent sediment removal is required to maintain the proper functioning of the wetland. • A greater amount of space is required for a wetland system than for an extended/dry detention basin treating the same amount of area. • Although artificial wetlands are designed to act as nutrient sinks, on occasion, the wetland may periodically become a nutrient source. • Wetlands that are not permanently flooded are more likely to be affected by drastic changes in inflow of polluted water. • Cannot be used on steep unstable slopes or densely populated areas. • Threat of mosquitoes. • Hydraulic capacity may be reduced with plant overgrowth.

Runoff Control Facility	Advantages	Limitations
Dry Wells	• Recommended in residential areas. • Requires minimal space to install. • Low installation costs. • Reduces amount of runoff. • Provides groundwater recharge. • Can serve small impervious areas like rooftops. • Helps to disconnect impervious surfaces.	• Offers little pretreatment, which may lead to clogging. • Dry wells should not be installed where hazardous or toxic materials are used, handled, stored or where a spill of such materials would drain into the dry well. • Risk of groundwater contamination in very coarse soils may require groundwater monitoring. • Not suitable on fill sites or steep slopes. • Must have a minimum of 2 to 3 feet between the bottom of the dry well and the seasonal high water table. • Dry wells service a limited drainage area, typically only rooftop runoff. • Dry wells must be located at least 10 feet away, on the down slope side of the structure, from building foundations to prevent seepage. • Stormwater runoff carrying bacteria, sediment, fertilizer, pesticides, and other chemicals may flow directly into the groundwater. • Loss of infiltrative capacity and high maintenance cost in fine soils. • Low removal of dissolved pollutants in very coarse soils. • Soils must be permeable. • Not recommended for use with commercial rooftops unless adequacy of pretreatment is assured.

Runoff Control Facility	Advantages	Limitations
Extended / Dry Detention Basins or Underground Tanks	• Modest removal efficiencies for the larger particulate fraction of pollutants. • Removal of sediment and buoyant materials. Nutrients, heavy metals, toxic materials, and oxygen-demanding particles are also removed with sediment substances associated with the particles. • Can be designed for combined flood control and stormwater quality control. • Potentially requires less capital cost and land area when compared to wet pond BMP. • Downstream channel protection when properly designed and maintained.	• Require sufficient area and hydraulic head to function properly. • Generally not effective in removing dissolved and finer particulate size pollutants from stormwater. • Some constraints other than the existing topography include, but are not limited to, the location of existing and proposed utilities, depth to bedrock, location and number of existing trees, and wetlands. • Extended/dry detention basins have moderate to high maintenance requirements. • Sediments can be resuspended if allowed to accumulate over time, and escape through the hydraulic control to downstream channels and streams. • Some environmental concerns with using extended/dry detention basins include potential impact on wetlands, wildlife habitat, aquatic biota, and downstream water quality. • May create mosquito breeding conditions and other nuisances.

Runoff Control Facility	Advantages	Limitations
Infiltration Basins	• High removal capability for particulate pollutants and moderate removal for soluble pollutants. • Groundwater recharge helps to maintain dry-weather flows in streams. • Can minimize increases in runoff volume. • When properly designed and maintained, it can replicate pre-development hydrology more closely than other BMP options. • Basins provide more habitat value than other infiltration systems.	• High failure rate due to clogging and high maintenance burden. • Low removal of dissolved pollutants in very coarse soils. • Not suitable on fill slopes or steep slopes. • Risk of groundwater contamination in very coarse soils may require groundwater monitoring. • Should not be used if significant upstream sediment load exists. • Slope of contributing watershed needs to be less than 20 percent. • Not recommended for discharge to a sole source aquifer. • Cannot be located within 100 feet of drinking water wells. • Metal and petroleum hydrocarbons could accumulate in soils to potentially toxic levels. • Relatively large land requirement. • Only feasible where soil is permeable and there is sufficient depth to bedrock and water table. • Need to be located a minimum of 10 feet down gradient and 100 feet upgradient from building foundations because of seepage problems.

Runoff Control Facility	Advantages	Limitations
Infiltration Trenches	• Provides groundwater recharge. • Trenches fit into small areas. • Good pollutant removal capabilities. • Can minimize increases in runoff volume. • Can fit into medians, perimeters, and other unused areas of a development site. • Helps replicate pre-development hydrology and increases dry weather baseflow.	• Slope of contributing watershed needs to be less than 20 percent. • Soil should have infiltration rate greater than 0.3 inches per hour and clay content less than 30 percent. • The bottom of infiltration trench should be at least 4 feet above the underlying bedrock and the seasonal high water table. • High failure rates of conventional trenches and high maintenance burden. • Low removal of dissolved pollutants in very coarse soils. • Not suitable on fill slopes or steep slopes. • Risk of groundwater contamination in very coarse soils may require groundwater monitoring. • Cannot be located within 100 feet of drinking water wells. • Need to be located a minimum of 10 feet down gradient and 100 feet up gradient from building foundations because of seepage problems. • Should not be used if upstream sediment load cannot be controlled prior to entry into the trench. • Metals and petroleum hydrocarbons could accumulate in soils to potentially toxic levels.
Media Filtration	• May require less space than other treatment control BMPs and can be located underground. • Does not require continuous base flow. • Suitable for individual developments and small tributary areas up to 100 acres. • Does not require vegetation. • Useful in watersheds where concerns over groundwater quality or site conditions prevent use of infiltration. • High pollutant removal capability. • Can be used in highly urbanized settings. • Can be designed for a variety of soils. • Ideal for aquifer regions.	• Given that the amount of available space can be a limitation that warrants the consideration of a sand filter BMP, designing one for a large drainage area where there is room for more conventional structures may not be practical. • Available head to meet design criteria. • Requires frequent maintenance to prevent clogging. • Not effective at removing liquid and dissolved pollutants. • Severe clogging potential if exposed soil surfaces exist upstream. • Sand filters may need to be placed offline to protect them during extreme storm events.

Runoff Control Facility	Advantages	Limitations
Porous Pavement	• Porous pavements operate in a similar fashion to infiltration trenches and thus provide similar water quality benefits, including reductions in fine-grained sediments, nutrients, organic matter, and trace metals. • In addition to water quality benefits, porous pavements also provide significant reductions in surface runoff. • An added benefit provided by the on-site infiltration is the extent to which the stormwater runoff is able to contribute to groundwater recharge. • Reduces pavement ponding.	• Only applicable for low-traffic volume areas. • To maintain effectiveness, porous pavements require frequent maintenance. • Porous pavements are not intended to remove sediments. • Easily clogged by sediments if not situated properly. • Limited to treating small areas (0.25 to 10 acres). • Contributing drainage area slopes should be 5 percent or less to limit amount of sediments that could potentially lead to clogging of porous pavement. • On average, porous pavements clog within 5 years if not maintained. Some studies have shown that porous pavement continues to function at a decreased level with limited clogging. • Underlying soil strata must have adequate infiltration capacity of at least 0.3 inches per hour but preferably 0.50 in/hr or more. Adequate soil permeability should extend for a depth of at least 4 feet. • The bottom of the reservoir layer should be at least 4 feet above the seasonal high water table. Porous pavements should be no closer than 100 feet from drinking wells and 100 feet upgradient and 10 feet down gradient from building foundations. Due to the risk of groundwater contamination, porous pavements should not be used for gas stations or other areas with a relatively high potential for chemical spills. Similarly, special consideration should be given to the use of porous pavements in wellhead protection areas serviced by sole source aquifers. • The porous pavement should not be located where run-on from adjacent areas can introduce sediments to the pavement surface. Similarly, areas subject to wind-blown sediment loads should be avoided. • Extended rain can reduce the pavement's load bearing capacity. • Slightly more expensive than traditional paving surfaces.

Runoff Control Facility	Advantages	Limitations
Storm Drain Inserts	• Low installation costs. • Prefabricated for different standard storm drain designs. • Require minimal space to install.	• Some devices may be vulnerable to accumulated sediments being resuspended during heavy storms. • Can only handle limited amounts of sediment and debris. • Maintenance and inspection of storm drain inserts are required before and after each rainfall event. • High maintenance costs. • Hydraulic losses.
Vegetated Filter Strips	• Lowers runoff velocity. • Slightly reduces runoff volume. • Slightly reduces watershed imperviousness. • Slightly contributes to groundwater recharge. • Aesthetic benefit of vegetated open spaces. • Preserves the character of riparian zones, prevents erosion along streambanks, and provides excellent urban wildlife habitat.	• Filter strips cannot treat high velocity flows, and do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms. This lack of quantity control dictates use in rural or low-density development. • Requires slope less than 5%. • Requires low to fair permeability of natural subsoil. • Large land requirement. • Often concentrates water, which significantly reduces effectiveness. • Pollutant removal is unreliable in urban settings.
Vegetated Swale	• Relatively easy to design, install and maintain. • Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as a vegetated swale. • Relatively inexpensive. • Vegetation is usually pleasing to residents.	• Irrigation may be necessary to maintain vegetative cover. • Potential for mosquito breeding areas. • Possibility of erosion and channelization over time. • Requires dry soils with good drainage and high infiltration rates for better pollutant removal.

Runoff Control Facility	Advantages	Limitations
Wet Ponds	• Wet ponds have recreational and aesthetic benefits due to the incorporation of permanent pools in the design. • Wet ponds offer flood control benefits in addition to water quality benefits. • Wet ponds can be used to handle large drainage areas. • High pollutant removal efficiencies for sediment, total phosphorus, and total nitrogen are achievable when the volume of the permanent pool is at least three times the water quality volume (the volume to be treated). • A wet pond removes pollutants from water by both physical and biological processes, thus they are more effective at removing pollutants than extended/dry detention basins. • Creation of aquatic and terrestrial habitat.	• Wet ponds may be feasible for stormwater runoff in residential or commercial areas with a combined drainage area of at least 5 acres. • An adequate source of water must be available to ensure a permanent pool throughout the entire year. • If the wet pond is not properly maintained or the pond becomes stagnant; floating debris, scum, algal blooms, unpleasant odors, and insects may appear. • Sediment removal is necessary every 5 to 10 years. • Heavy storms may cause mixing and subsequent resuspension of solids. • Evaporation and lowering of the water level can cause concentrated levels of salt and algae to increase. • Cannot be placed on steep unstable slopes. • Ponding volume and depth, pond designs may require approval from DEP Dam Safety.

Note: Advantages / Limitations adapted from Los Angeles County Development Planning for Storm Water Management Manual, September 2002.

3. Applicability of Runoff Control Measures in the Swamp Creek Watershed

a. Cisterns and Covered Ponds:

Cisterns and covered ponds are recommended for large commercial areas or industrial parks where stored runoff could be used for fire protection. These generally have low maintenance costs (for periodic sediment removal only). A disadvantage to these structures is that they generally can not store large runoff volumes. Because these structures do not drain by themselves, storage during various storms is dependent on the runoff volume removed between storm events.

b. Rooftop Gardens:

Rooftop gardens should be for commercial areas, industrial parks, or other areas with large building footprints.

c. Surface Pond Storage:

Surface pond storage is recommended for portions of the Swamp Creek watershed that have relatively porous soils (hydrologic soils group B), where the stored runoff volume will infiltrate at the pond bottom. These structures are relatively inexpensive to install and maintain, and they help entrap sediment to improve the water quality of the receiving stream.

d. *Ponding on Roof, Constricted Downspouts:*

These practices can be used on large buildings, but are impractical for smaller buildings due to the limited storage volume. This may require expensive structural modifications. The community may view this as an undesirable runoff control alternative due to fears concerning using a roof as a storage area. These practices typically have low maintenance costs unless leaks occur.

e. *Increased Roof Roughness:*

Increased roof roughness is possible for industrial and commercial buildings, but is not generally recommended due to the minimal impact on runoff control on a watershed-wide basis. This method has moderate installation cost and little maintenance cost.

f. *Porous Pavement:*

Porous pavement is recommended in areas with large parking facilities and for portions of the Swamp Creek watershed that have relatively porous soils (hydrologic soil group B). This practice promotes groundwater recharge. It has a moderate cost when compared with conventional paving; however, it often eliminates the need for surface pond storage, which requires large land areas.

g. *Grassed Channels and Vegetated Filter Strips:*

These practices are recommended wherever site conditions allow throughout the watershed. Grassed channels and vegetated filter strips slow velocity, reduce erosion, promote infiltration, and promote filtering. These should be constructed in areas with minimal slopes. They have low installation and maintenance costs.

h. *Ponding and Detention on Pavement:*

These practices are recommended for paved areas that would not be adversely impacted by freezing. These are inexpensive, have low maintenance costs, and are capable of entrapping some pollutants. Runoff stored in this way may be warmed, which could impact the temperature of the receiving water.

i. *Reservoir or Detention Basin:*

Reservoirs/Detention Basins are recommended in all areas of the watershed. These are relatively easy to construct and maintain. They have moderate installation and maintenance costs. These can aid in entrapping sediment, which improves water quality.

j. *Groundwater Recharge:*

Groundwater recharge facilities are recommended throughout the watershed, where soil and geologic conditions permit. The installation and maintenance costs for these facilities depend on the type of recharge facility chosen.

k. *High Delay Grass and Routing Flow Over Lawns:*

These practices are recommended throughout the watershed. They delay runoff, entrap sediment, reduce velocities, reduce erosion, and improve water quality of receiving watercourse. They are relatively inexpensive to install and maintain.

SECTION III – PROBLEM AREAS AND EXISTING CONTROL STRATEGIES

A. Existing Obstructions

For the purpose of developing the Stremtul model, twenty-eight existing obstructions were identified along Swamp Creek and streams that drain into Swamp Creek. Several of these obstructions are located at problem areas identified by participating municipalities in the municipal surveys. The remaining obstructions were identified by research on FEMA Flood Insurance Rate Maps for these streams. The following criteria were also considered when selecting the additional significant flow obstructions: these obstructions are defined as having a drainage area of at least one square mile, having the ability to cause a significant increase in upstream flood elevations, or having sizing to cause significant peak flow reductions.

The following are the locations of the twenty-eight obstructions used in the model:

- Swamp Creek at Spring Mountain Road.
- Goshenhoppen Creek at Silver Brook Road.
- Swamp Creek at Gerloff Road.
- Scioto Creek at Faust Road.
- Scioto Creek at Perkiomenville Road.
- Tributary to Swamp Creek at Bragg Road.
- Swamp Creek at Swamp Creek Road (Camp Joy).
- Swamp Creek at Neiffer Road (above Keyser Road).
- West Branch Swamp Creek at Swamp Pike.
- West Branch Swamp Creek at New Hanover Square Road.
- West Branch Swamp Creek at Romig Road.
- West Branch Swamp Creek at Rhoads Road.
- Swamp Creek at Fagleysville Road.
- Minister Creek at New Hanover Square Road.
- Minister Creek at Reifsnyder Road.
- Minister Creek at Swamp Pike.
- Minister Creek at North Charlotte Street.
- Minister Creek at Kleman Road.
- Minister Creek at Route 100.
- Swamp Creek at New Hanover Square Road.

- Swamp Creek at New Road.
- Schlegel Creek at Kulps Road.
- Schlegel Creek at Hoffmansville Road.
- Middle Creek at Middle Creek Road.
- Swamp Creek at Congo Road.
- Swamp Creek at County Line Road.
- Swamp Creek at Mill Street.
- Swamp Creek at Old Route 100.

A chart of obstructions and their capabilities is included on the following page. Additionally, there are three dams along the Swamp Creek. All of these are low head and/or mill dams, with no storage behind these dams. These dams are full to the crest.

B. Existing Problem Drainage Areas

Municipalities located within the Swamp Creek watershed were asked to complete a municipal questionnaire that encouraged respondents to detail existing stormwater problems and locations within the municipality. The survey also asked for information such as the frequency and cause of stormwater problems, along with activities that have been initiated to address stormwater issues.

According to the survey responses, the sparsely populated, hilly regions of Douglass, Pike and Washington Townships in Berks County and Lower Pottsgrove and Upper Pottsgrove Townships in Montgomery Township, which are located at the headwaters of the Swamp Creek watershed, experience little or no stormwater problems. These areas are dependent on on-site water supply systems and have expressed an interest in management systems that will facilitate local groundwater recharge.

The small towns of Bechtelsville and Eshbach have experienced property damage, road closures and loss of service during major flooding events. In Colebrookdale Township, Berks County, moderate stormwater problems have been reported in the area north of Boyertown. Corrections need to be made in these communities to the existing drainage systems that are too small to handle the increased run-off caused by the significant increase in housing starts in the Route 100 corridor.

The central portion of Douglass Township in Montgomery Township has also seen a dramatic rise in new housing developments in the Gilbertsville area. The Swamp Creek tributaries increase in number and size in Douglass Township where the accumulated run-off from local and upstream sources force road closures and property damage 1 – 3 times per year. The increase in impervious cover has accentuated flooding in areas where the high water table historically forced streams to overflow their banks onto adjacent roads. This increase in stream velocity continues into New Hanover Township where road

Obstructions

closures occur several times a year. The lack of property damage associated with these flooding events may explain why this township only assigned a moderate severity to their stormwater problems. It was noted that streambank stabilization is not a problem in New Hanover Township; however, the road closures are the result of the streams overflowing their banks. Officials in Upper Frederick Township were one of two survey respondents to designate their stormwater problems as critical, yet property damage and road closures were reported at the same frequency as upstream municipalities. Obstructions in exiting systems there have created some of their flooding problems but in general, increased run-off is considered the major cause of flooding.

The conversion of farmland to residential development in these low-lying plains has increased both stormwater run-off during major precipitation events and the potential for property damage. The municipalities with the greatest flooding problems place the blame on an increase in upstream run-off. Upstream communities perceive little or no problem with stormwater. Officials in municipalities representing 95% of the watershed area are willing to participate in a planning process that will support a regional approach to stormwater management beneficial.

1. Proposed Solutions for Existing Drainage Problem Areas

The existing drainage problems within the Swamp Creek watershed can generally be included in the following categories: undersized stormwater conveyance systems, undersized bridges / culverts, roadways located in the floodplain / low areas in close proximity to streams, and poorly maintained drainageways. Commonly proposed solutions to these types of problems are listed below.

a. Undersized Stormwater Conveyance Systems

Conveyance systems should be designed according to the stormwater flows to be conveyed by the system. The stormwater flows could increase over time due to increased impervious areas or new conveyances within the drainage area that contribute stormwater flow to the conveyance system. To correct this type of drainage problem, the pipe sizes of the existing system should be analyzed to see if they carry the stormwater flows to the pipes. If the existing pipes are incapable of conveying the flows to the pipe, the existing pipe should be replaced with a new pipe of appropriate size. The number of inlets in the conveyance system should also be analyzed to determine if the system has an adequate number of inlets to capture the flow to the inlets. Additional inlets should be installed as necessary to capture the flows within the conveyance system drainage area. Typically, the owner of the conveyance system (i.e. municipality or private developer) would bear the cost of the analysis of the existing system, design of proposed system, and construction of proposed system.

b. Undersized Bridges/Culverts

Bridges and culverts should be designed to convey the stream and stormwater flows to these structures without causing a major obstruction to the flow. The flows could be conveyed through the structure or could alternatively be permitted to overtop the structure. To correct an undersized structure, a hydrologic and hydraulic analysis should be performed to determine the appropriate bridge / culvert size considering the stream and stormwater flows to the structure. Then the bridge / culvert could be replaced. Typically, the owner of the structure (i.e. municipality or private developer) would bear the cost of the hydrologic and hydraulic analysis, permitting, and construction of the proposed structure.

c. Roadways Located Within the Floodplain

The most obvious solutions to this type of problem are to move the roadway away from the stream or to increase the capacity of the adjacent stream to decrease the floodplain elevation. These solutions are often impractical due to costs associated with relocating roadways and stream impacts.

d. Poorly Maintained Drainageways

Sediment deposits and excessive vegetation are two common maintenance issues that decrease the conveyance capacity of storm sewers, bridges / culverts, swales, and streams. Maintenance, including the removal of the sediment and vegetation, could be performed to increase the capacity of a drainageway. Typically, the owner of the drainageway bears the maintenance cost.

2. Alternatives to Proposed Solutions

Alternatives to solutions listed above include regional detention facilities and non-structural alternatives such as stormwater, subdivision and land development, and zoning ordinances. Planned regional detention facilities can alleviate flooding impacts on downstream areas. Ordinances could be used to limit development and promote detention and infiltration. These practices can control flood elevation increases.

C. Existing and Proposed Stormwater Collection Systems and Their Impacts

Existing stormwater collection systems in most cases are located in the more urban portions of the watershed, such as Boyertown Borough, Bechtelsville Borough, and at the bottom of the watershed, near Schwenksville. They are also found more frequently in areas with more recent residential housing developments, such as Douglass Township and New Hanover Township, and along the watershed’s more major roadways, including Route 100, Route 663, Route 73, Route 29, and Swamp Pike. Several of these conveyance systems were installed without specific stormwater management ordinance requirements, and are therefore undersized, contributing to roadway flooding during storm events.

Stormwater collection systems are proposed for proposed land development projects. Due to the adoption of updated stormwater ordinances with conveyance system requirements in areas where development is occurring more frequently, proposed stormwater collection systems should have a more positive impact on stormwater conveyance and flooding than older existing systems. One issue that may be aggravated by proposed collection/conveyance systems with larger sizing is streambank erosion, as larger volumes of stormwater could be permitted to enter streams. However, these updated stormwater ordinances also include peak flow reduction requirements, which should act to slow the flow rate to streams.

D. Existing and Proposed Federal, State, and Local Flood Control Projects and Design Capacities

There are no known existing or proposed federal, state, or local flood control projects within the Swamp Creek watershed.

E. Existing Municipal Ordinance Provisions for Stormwater and Floodplain Management

The following municipal ordinances were obtained for the purpose of completing this report: Bechtelsville Borough, Colebrookdale Township, and Washington Township, all in Berks County; and Douglass Township, Lower Frederick Township, Lower Pottsgrove Township, New Hanover Township, and Upper Pottsgrove Township in Montgomery County. Each of these ordinances was adopted in 2004 or 2005. It appears that several of these ordinances are based on the DEP Municipal Separate Storm Sewer System (MS4) model ordinance. The MS4 program and permit falls under the National Pollution Discharge Elimination System program and permit that was established under the Clean Water Act. Municipalities that are considered to be "urbanized areas" according to census data are required to obtain a MS4 permit. The MS4 model ordinance was created for the use of MS4 municipalities to give them guidance in updating their stormwater ordinances, as required by their MS4 permit, to include the applicable MS4 requirements, including prohibited discharges from stormwater outfalls, erosion and sedimentation control requirements, post-construction stormwater management requirements, and sanctions to enforce these requirements.

Nearly all of the ordinances that were evaluated incorporate the MS4 requirements and include low impact development sections and an operations and maintenance agreement. Half of the ordinances have no peak flow reduction requirements, stormwater conveyance requirements, water quality requirements or infiltration requirements. Based on the requirements included in ordinances that were evaluated, and the dates of these ordinances, it appears that the majority of the land development that has occurred in the Swamp Creek watershed prior to the present time has occurred without peak flow reduction requirements, stormwater conveyance requirements, water quality requirements, and infiltration requirements, resulting in various problems such as streambank erosion, undercut streambanks, poor water quality in streams, undersized conveyance systems, and lack of groundwater recharge.

Floodplain ordinances were not collected and evaluated for the purposes of this report.

SECTION IV – THE IMPACT OF FUTURE DEVELOPMENT

A. Projected Land Development Patterns and Potential Impacts on Runoff

1. Roadway Networks Leading To Potential Growth

The Swamp Creek watershed is crossed by several major roads, providing access to major employment/retail areas outside of the watershed. The headwaters area in Pike, Washington and District Townships is hilly, and most of the roads run along the Swamp Creek and its tributaries. Just below Bechtelsville, Route 100 crosses north/south through the watershed. Route 100 connects Pottstown and points south to the Allentown area. Route 663 parallels Route 100 to the east, and connects local employment and retail centers in Pottstown, East Greenville, Pennsburg, and Red Hill.

Three major roads travel East/West across the watershed. Hoffmansville Road, along the northern boundary, joins Route 73 in New Hanover Township. Route 73 connects with Route 29 in Zieglersville, providing access to Route 422 (the Pottstown Expressway) via Route 29. Route 422 connects eastward to King Of Prussia, providing access to the Pennsylvania Turnpike, Route 202, and the Schuylkill Expressway.

In the central portion of the watershed, Route 73 dips southwest, intersects Route 663, and then connects with Swamp Pike. This provides ample access to the central portion of the watershed, where the most rapid development in the watershed is occurring. Swamp Pike is a major East-West road, connecting the Boyertown area to Ridge Pike. Ridge Pike provides access to Routes 29 and 422.

The existing road network makes most of the watershed easily accessible. PADOT's 12-year program has several projects listed in this area. These road improvements should result in better, safer, more convenient access. Route 29 in the vicinity of Schwenksville is scheduled for resurfacing and shoulder work. The intersection of Route 73 and Swamp Pike is to be improved. The intersection of Route 663 and Swamp Pike will see a signal upgrade, new left turn lanes, and an extended culvert for drainage. Bridges over the Swamp Creek and its tributaries at Fagleysville Road, Colonial Road (Upper Frederick Township), and Wilson Avenue (Douglass Township) are scheduled for replacement. All of these projects are due to begin work within the next four years.

2. Types of Developments

Because the Swamp Creek watershed is accessible by major roads and because much of the area is rural, low density development, it has been attracting development for most of the 1990s. The majority of this development is residential, typically single family detached units. Scattered commercial and industrial development has occurred.

The residential development that has been proposed in the last decade is small-scale, most of the proposals are less than a dozen lots. There have been a handful of larger developments, 50 to 100 units each. Along with these, the watershed has seen a fair amount of frontage development, and subdivision of one or two small lots off of a large farm.

Future land use information, based on a 10-year build-out, was obtained from Berks County, Montgomery County, and from individual municipalities in the watershed. Figure 5 shows the future land use information for the watershed. According to this information, it appears that the development anticipated in the watershed over the next 10 years will occur primarily in the Berks County portion

Figure 5 Future Land Cover Map

Back of map

of the watershed, especially along Route 100. Significant residential development is anticipated to occur in Pike, Washington, and Colebrookdale Townships. Additionally, some commercial development is anticipated in Washington Township, and some commercial and industrial development is anticipated in Colebrookdale Township. Within the Montgomery County portion of the watershed, residential development is anticipated in New Hanover, Upper Frederick, and Lower Frederick Townships. Commercial development is anticipated along Route 100 in Douglass Township.

The potential impacts of these developments include increased stormwater runoff volumes due to an increase in impervious area and compacted grass / landscaped areas, and increased runoff velocities. Declining water quality could also result due to sediment from development and pollutants from impervious areas running into drainage systems and then into streams. It should be noted that the majority of the proposed development is located in the upper portions of the watershed; therefore, impacts to the stream will occur through all downstream portions of the watershed. Section VI discusses increases in stormwater runoff rates that are projected to result without the incorporation of peak flow reduction requirements into stormwater management ordinances. The Swamp Creek Model Stormwater Management Ordinance, also discussed in Section VI, includes stormwater requirements that should lessen these potential impacts of development.

B. Areas to Be Served By Stormwater Collection and Control Facilities

It is anticipated that new stormwater collection and control facilities will be installed in the watershed over the next 10 years, especially in areas where development is projected to occur, as discussed above. The design of these facilities will be governed by the applicable municipal stormwater management ordinance that is in place at the time when the proposed development is in its planning stages. The timing related to installation of these facilities will be dependent upon factors such as plan approval by the local municipality and the ability of the developer to fund the development. The costs of these facilities will be borne by private developers in most cases. The operation and maintenance of these facilities will most likely be the responsibility of the private property owner or potentially a homeowner's association. The Swamp Creek Model Stormwater Management Ordinance includes a sample Operations and Maintenance Agreement. The use of this agreement by municipalities is encouraged to ensure that stormwater facilities are properly maintained by the private property owners.

C. Present and Projected Development in Flood Hazard Areas

According to the existing land cover map, most of the flood hazard areas are located in areas designated as woodland, open space, and agricultural. One may conclude from this information that up until this point, there has not been much development in flood hazard areas. The future land cover map indicates that there is some anticipated development within floodplain areas. Most of this development is anticipated residential development within Washington and Colebrookdale Townships. Some commercial development is anticipated within the floodplain in Douglass Township, Montgomery County.

Development in floodplain areas should be addressed by DEP and NFIP regulations.

SECTION V – CONTROL TECHNIQUES – CONSIDERING PRECIPITATION AS A RESOURCE

Stormwater quality has become a municipal issue. The new NPDES permitting program and other water-quality related programs (such as source water area protection program or the TMDL program) look at reducing pollutants in stormwater discharges. Stormwater quality is no longer just an environmental or ecological concern. Sediment in stormwater reduces the ability of the stream to convey stormwater, increasing flooding. Other pollutants in streams that supply drinking water to communities increase the cost of treatment, and the higher cost is passed along to residents and businesses. Basins and other stormwater facilities can be designed for more than just volume and rate control. With a little forethought and an understanding of the available alternatives, stormwater facilities can help meet municipal water quality goals. The discussion that follows is an introduction to the alternatives and considerations pertaining to various stormwater control techniques. The *Pennsylvania Stormwater Best Management Practices Manual*, latest edition, should be consulted for more detailed information.

A. An Assessment of Alternative Runoff Control Techniques and Their Efficiency in the Swamp Creek Watershed

Alternative runoff control techniques, most often referred to as stormwater Best Management Practices (BMPs), provide municipalities and developers with many tools for controlling and cleaning runoff, and restoring site hydrology. Selecting the most appropriate BMP can be difficult, for two main reasons. First, there are factors specific to each site that affect the performance of BMPs, most notably, soil type. Second, different BMPs achieve different goals. As goals or priorities pertaining to a particular site development change, the "right" BMP to achieve the goal may change too. The good news is that most often the use of BMPs are not an "either or" situation, but a "both and" opportunity. Several BMPs can be employed on a site, dispersed across the area or linked together. Combining the BMPs achieves multiple goals. For example, individual infiltration facilities, or rain gardens, can be installed on each lot to infiltrate roof runoff, while runoff from the roads, driveways, and other hard surfaces could be directed to a sediment forebay and naturalized storm basin.

The soils found on a particular site greatly influence the effectiveness of stormwater BMPs, in particular infiltration. Shallow bedrock and high water table may also affect the use of deep-rooted vegetation for naturalization. As mentioned earlier, the soils in the watershed can be grouped into 5 associations. The following generalized comments should be considered when considering BMPs for projects in certain soils groupings.

- *Abbottstown-Readington-Croton Association:* These are soils within the hydrologic soils group C or D. It may be possible to find specific sites within these soils that are suitable for infiltration. However, the seasonal high water table and the slow to moderately slow permeability of the subsoil may hinder efforts to infiltrate stormwater at rates greater than what is occurring on the site naturally.

- *Lehigh-Brecknock-Croton Association:* The Brecknock soils belong to Hydrologic group B, and are among the best soils in the watershed for infiltration. The Lehigh and Croton soils are from groups C and D, respectively. The soils in this association are found along the ridges and hills in the watershed. On the tops of the ridges, the slopes are not as steep. Siting BMPs on the slopes on the sides of the ridges may require additional planning and engineering.
- *Neshaminy-Mount Lucas-Watchung Association*: These are soils from hydrologic soils groupings C and D. Infiltration basins and other similar stormwater BMPs could be appropriate for these soils; site soil testing should be conducted to confirm this. Large stones and boulders, steep slopes, and shallow bedrock may make infiltration and the use of trees for naturalization difficult.
- *Reaville-Penn-Klinesville Association:* These are also soils from the C and D soils group, so soils testing will be necessary to determine the feasibility of BMPs. However, stormwater BMPs will be feasible for these soils in most areas. Again, site soil testing should be conducted to confirm this on individual sites.
- *Rowland-Birdsboro-Raritan Association:* The Rowland and Raritan soils belong to soils group C, while the Birdsboro soils are classified as B soils. Because of the potential for flooding, these soils are less likely to be feasible for infiltration BMPs. However, specific development sites may employ BMPs that preserve and enhance riparian vegetation, and there may be limited areas where BMPs can be used.

1. Applicability in the Swamp Creek Watershed

The upper reach of the Swamp Creek watershed has hills and some steeply sloping areas, while the lower end is shaped like a broad, shallow bowl. As shown on the soils map contained in Section 2, there are significant areas of soils from hydrologic soils grouping D. These conditions generally represent constraints to the use of BMPs. They may not completely preclude the use of BMPs, but rather, may require additional engineering and site work to employ the appropriate BMPs. For example, a development site may have areas of steep slope or shallow bedrock, making it difficult to find a location for a large stormwater basin. If individual infiltration facilities (rain gardens) are installed on each lot, the total amount of stormwater leaving the building lots will be reduced and a smaller basin will be needed. Also, several smaller basins could be used around the site, instead of one large basin. Flexibility and consideration of the broad range of stormwater alternatives will help find the best fit between site constraints and stormwater goals.

The soils in Hydrologic Group D are unlikely to infiltrate stormwater at a greater rate than is occurring naturally before development. However, various techniques, such as minimizing impervious surfaces and using numerous, small scale stormwater facilities, can be used to mimic predevelopment hydrology and reduce the impacts of development. Infiltration facilities should be employed in developments located on the B and C soils.

Once the soils, slopes, bedrock, and other considerations are taken into account, specific stormwater BMPs can be employed to achieve various goals. The following discussion of alternatives should assist in choosing the right BMPs to achieve the goals determined. It is important to remember that more than one BMP can be used on the site, and that several BMPs can be used together for greater effectiveness.

B. Introduction to BMPs Alternatives:

1. Naturalized Basins:

Naturalized basins are stormwater control facilities that are planted with native vegetation rather than maintained as mown lawn. Both dry basins, which drain completely between storms, and wet basins, which contain a permanent pool, can be designed as naturalized basins to address stormwater quality. The stems and leaves of the native plants and the organic layer that develops at the soil surface help filter stormwater. The plants may also take up certain pollutants, such as excess fertilizer, removing them before the stormwater is discharged to a creek. As additional benefits, the native plants encourage infiltration of stormwater, are attractive, and provide food for birds and other desirable animals.

Designing naturalized basins benefits the municipality, residents and the environment. If the basins are owned by the municipality, maintenance costs will be reduced once the vegetation is established and mowing is no longer necessary. Sediments and nutrients are removed by the vegetation before the stormwater reaches a stream, maintaining the stream function of conveying flood flows and supporting fish and wildlife. The vegetation selected can greatly increase the aesthetic appeal of a basin, providing color in all seasons and attracting birds and butterflies to the area.

2. Bioretention:

Bioretention islands are landscaping features adapted to treat stormwater runoff. They are most frequently located within parking lot islands but can also be incorporated into cul-de-sacs and small pocket gardens in residential land uses. Most municipalities require some type of planted island to break up parking lots. The bioretention island can be used instead of raised planters. The bioretention island is designed as a depression that collects and filters the first ½ inch of rainfall off paved surfaces. The paved areas are designed to direct surface runoff into the vegetated areas, which then absorb the stormwater and filter pollutants from the runoff. Often, the filtered runoff is collected in a perforated pipe under the island and discharged to the storm sewer system. In larger storm events, excess runoff is diverted past the island to a storm drain.

Bioretention islands are typically used for stormwater management in small drainage areas, such as a small parking lot, or an individual residential property. Numerous bioretention facilities could be used in larger paved areas if the grading divides the large area into smaller areas, each draining to a bioretention facility. Even existing parking lot landscape islands can be retrofitted to incorporate bioretention. They are quite versatile in that they can be employed in almost any soil condition, although the soil in which the vegetation is planted may need to be amended with sand to improve infiltration. Since the main function of these facilities is to improve stormwater quality, they should be used in conjunction with other stormwater facilities to address volume and rate of runoff.

To enhance pollutant removal, the bioretention island should be sized to be between 5% and 10% of the impervious area draining to it. The underlying planting bed should be designed as a sand/soil mix with a mulch layer above the soil. The surface of a bioretention area is usually planned so that it ponds a small depth of water (6-9 inches) above the filter bed. And some bioretention islands also are designed to help spread flows evenly and settle out large particles.

3. Porous Pavement:

Porous pavement is a permeable pavement surface with a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil. Runoff is thereby infiltrated directly into the soil and receives some water quality treatment. Porous pavement is similar in appearance to traditional asphalt or concrete but is manufactured without "fine" materials, and instead incorporates void spaces that allow for infiltration.

The impervious surfaces in development increase runoff volumes and decrease infiltration that recharges groundwater. Often, the traditional stormwater facilities used to control this increased stormwater volume have no provision for groundwater recharge. As infiltration decreases, base flows in streams are decreased and previously flowing, small streams often dry up between rains. Some homeowners and public water suppliers rely on groundwater sources. With reduced infiltration and recharge, these drinking water supplies are reduced, sometimes significantly.

The ideal location for porous pavement is in low traffic or overflow parking areas. In extremely dense urban areas porous pavement has been used successfully in redevelopment projects, because it treats and stores stormwater without consuming extra land. Porous pavement can also be incorporated into developed sites where a parking lot is being resurfaced. Porous pavement should be avoided where activities generate highly contaminated runoff. Areas of low soil permeability, seasonal high groundwater tables, and areas close to drinking water supply wells should also be avoided. Wherever it is used, maintenance of porous pavement is critical to its performance. The overall maintenance goal for porous pavement is to prevent clogging of the void spaces within the surface material. The surface of porous pavements must not be sealed or repaved with non-porous materials if it is to continue to function. Porous pavement is not suitable for areas where sand and salt are applied often or heavily. Periodic vacuuming of debris will be required to ensure the void spaces do not clog.

4. Wet Pond:

Also called extended detention ponds, these facilities are basins that have a permanent pool of water throughout the year. The wet pond is constructed with additional capacity to store runoff during and after storms. Wet ponds treat and filter stormwater runoff through settling and through nutrient uptake by plants and other aquatic organisms.

Stormwater basins are one of the most common methods chosen by engineers and developers to handle stormwater runoff generated from land development activities. Wet ponds control stormwater volume and rate of discharge, and also provide water quality benefits dry basins can not offer. The ability of a wet pond to store runoff for longer time periods decreases stormwater peak flows. The longer detention times can reduce stream channel erosion, a common result of traditional stormwater practices.

Wet ponds may be inappropriate in dense urban areas due to their space requirements. Most experts agree that in order to maintain a permanent water elevation within the pond, they should only be used for sites with drainage areas greater than 5 acres. Wet ponds have regulatory limitations to where they can be placed. For example, they should not be located within wetlands. Many wet ponds have been designed as an aesthetic site amenity, to create wildlife habitat or as a development focal point or recreational area. The results of one study suggest that "pond front" property can increase the selling price of a new property by 10% (EPA, 1995). Another study found that the perceived value (value estimated by residents of a community) of homes increased by about 15-25% when located near a wet pond (Emmerling-Dinovo, 1995).

5. Retrofitted Basin:

Most of the alternatives listed here are applicable to new development. The retrofitted basin, however, applies to existing stormwater facilities. A stormwater basin retrofit usually involves the modification of an existing basin's outlet structure. Stormwater basins typically contain large outlet pipes. These basins are designed to temporarily store and re-route runoff from large storms. Their primary purpose is to help control floods. Retrofitted basins still provide flood control protection, but through structural modifications that can also provide water quality and erosion control benefits.

Instead of just one outlet hole, retrofitted basins usually have two or more, of varying sizes. The additional holes can be added to an existing outlet structure or through the construction of a low wall inside the basin. The use of weirs with v-notches, and special attachments to outlet structures can also be used to retrofit a stormwater basin. These modifications are meant to manage the smaller more frequent storms. Recent studies in stormwater management have shown that the smaller, more frequent storms typical to this region degrade water quality and increase streambank erosion. By slowing the velocity of the stormwater discharged, the retrofitted basin helps reduce erosion in the receiving stream. Reduced localized flooding can result from a retrofitted basin's ability to detain small storms for longer periods of time.

6. Riparian Buffers:

Also called a forested buffer, this is a buffer area preserved along the stream, including the streambank and all or part of the floodplain area. In nature these areas typically are forested, and as part of a development site they are usually planted as a meadow or woodland.

Riparian buffers provide numerous environmental and recreational benefits to streams, groundwater and downstream land areas. All landowners (individuals, businesses and municipalities) should make every effort to preserve riparian buffers and improve them by planting native vegetation. The existing stream corridor can be protected when development is proposed through ordinance requirements or through easement agreements.

7. Vegetated Swales:

Vegetated swales are constructed open-channel drainageways used to convey stormwater runoff. Vegetated swales are often used as an alternative to, or an enhancement of, traditional storm drains and pipes. They do not pond water for a long period of time or provide significant infiltration. Vegetated swales generally have a trapezoidal or parabolic shape with relatively flat side slopes. Individual vegetated swales generally treat small drainage areas (five acres or less).

Vegetation in swales allows for filtering of pollutants, and infiltration of runoff into groundwater. Densely vegetated swales can be designed to add visual interest to a site or to screen unsightly views. Broad swales on flat slopes with dense vegetation are the most effective at reducing the volume of runoff and pollutant removal. They should not be used in steep slope areas.

8. Sediment Forebay:

A sediment forebay is a small pool located near the inlet of a wet pond other stormwater management facility designed as an initial storage area to trap and settle out sediment and heavy pollutants before they reach the main basin. These facilities provide pretreatment of stormwater and can greatly reduce overall maintenance requirements. An earth berm, gabion wall, or other barrier near the inlet can be used to cause stormwater to pool temporarily. Forebays make basin maintenance easier and less costly by trapping sediment in one small area where it is easily removed, and preventing sediment buildup in the rest of the facility.

These are the alternatives commonly used to control and treat stormwater. Variations of these alternatives and other stormwater BMPs can be used, depending on the conditions on-site and the goals of the stormwater management plan. More information on stormwater BMPs, including design criteria, can be found on the DEP website and in the *Pennsylvania Stormwater Best Management Practices Manual,* latest edition.

SECTION VI – STORMWATER CONTROL STANDARDS

A. Watershed Modeling Approach and Analysis

A decision that was evaluated early in the process of the development of the Stormwater Management Plan for Swamp Creek was which runoff simulation model should be utilized to accurately describe the Swamp Creek watershed. The need for the following model capabilities was considered in making this decision:

- Able to model design storms of various durations and frequencies to produce routed hydrographs that can be combined.
- Adaptable to the size of subwatersheds in this study.
- Capable of evaluating specific physical characteristics of the rainfall-runoff process.

After comparing available models, it was decided that the STREMTUL "front end" for the SCS TR20 hydrology program would be utilized to model the Swamp Creek watershed. Stremtul is a TR-20 based computer model developed by the Lancaster County Engineer's Office, with provisions for modeling infiltration volumes and multiple release rates. The STREMTUL model was chosen for the following reasons:

- The model was developed specifically to satisfy the requirements of the Pennsylvania Act 167 legislation, for which stream flows are the prime consideration.
- The program is designed to study large watersheds that have been broken up into smaller watersheds.
- Subarea parameters may be changed with relative ease using the STREMTUL program.
- STEMTUL provides the results of any combination of release rates.
- The program allows the user to easily move between existing and future parameters and results.

B. Model Development and Data Preparation

The Swamp Creek watershed was delineated using U.S.G.S. topography. The watershed was then further divided into 51 subwatersheds. The subwatershed information is presented on Figure 1. Problem areas identified by municpalities in the watershed, tributary confluences, and structures were factors in delineating the subwatersheds. The most downstream point of each of the subwatersheds was considered a "point of interest", where existing and future flows were determined and compared, and increased runoff was analyzed for its potential impact.

The purpose of choosing these subwatersheds and calculating existing and future flows for each subwatershed was to evaluate various future conditions release rates for the Swamp Creek watershed by controlling the stormwater runoff in each subarea. Recommended release rates were then incorporated into the Swamp Creek Watershed Model Stormwater Management Ordinance.

Other input to the STREMTUL model included time of concentration values and CN values. Time of concentration values were determined using SCS methodology. CN values were determined by using Berks and Montgomery County land use data and soils data, overlaying this information with the subwatershed area map. This information, along with information compiled during field visits to the watershed, was then used for STREMTUL input.

The resulting watershed model addressed the following:

- Peak discharges at the points of interest of each of the 51 subwatersheds.
- Time to peak for the above discharges.
- Runoff contributions of individual subareas at all downstream locations.
- Overall watershed timing.

Stremtul was used to model the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events for the purpose of comparing existing and future flows and then making recommendations regarding appropriate stormwater management practices to prevent future stormwater problems in the watershed.

C. Model Calibration

To assure that the model results are accurate and reliable, the model should be compared with field observations or recorded streamflows. Ideally, there would be records of streamflow and rainfall data for various locations within the watershed that would allow one to run the model using the rainfall and compare the model flows with the recorded streamflows for the same storm event. There are no known United States Geological Survey (USGS) stream gages within the Swamp Creek watershed. The Philadelphia Suburban Water Company and the Philadelphia Water Department were also contacted concerning availability of streamflow or flooding data. Neither agency has this information.

In the absence of recorded streamflow information, the existing conditions model results were compared with flows from FEMA Flood Insurance Studies, and flows calculated using PSU IV and estimated using stream gage data for a USGS gage along the Perkiomen Creek in Graterford and a USGS regional exponent. Flows from these various sources are shown in the table below.

Table 3
Comparison of Stremtul 100-Year Flow
With Other Calculated 100-Year Flows

	100-Year Flow (cfs)			
Location	***Stremtul***	***FEMA***	***PSU IV****	***Stream Gage Estimate*****
Middle Creek *at confluence with Swamp Creek*	3,240	3,840	2,926	1,995
Minister Creek *at confluence with Swamp Creek*	5,374	5,940	4,353	3,057
West Branch Swamp Creek *at confluence with Swamp Creek*	1,964	2,440	2,002	1,396
Scioto Creek *at confluence with Swamp Creek*	3,933	2,200	3,014	1,982
Goshenhoppen Creek *at confluence with Swamp Creek*	3,296	1,700	2,055	1,335
Swamp Creek *at confluence with Perkiomen Creek*	15,451	13,150	11,789	11,635

* *The PSU IV calculations were completed without the urbanized area adjustment. Applying this adjustment results in flows that are closer to the Stremtul flows(for example, the adjusted Swamp Creek flow is 15,679 cfs, which is close to the Stremtul flow of 15,451 cfs)*

** *The following equation was utilized to obtain the stream gage estimate: $Q=Q_{gage}*(DA_{location}/DA_{gage})$^(USGS regional exponent), where Q=flow and DA=drainage area. The gage flow is based on the maximum instantaneous peak flow for the Perkiomen Creek at Graterford, which is 35,800 cfs and occurred on June 22, 1972 according to Water Resource Data, Pennsylvania Water Year 1991. The USGS regional exponent for this area is 0.7.*

The flows generated using the Stremtul model are generally higher than the FEMA, PSU IV, and stream gage estimated flows. However, the flows are relatively close, suggesting that the model results have some level of accuracy. The higher Stremtul flows could reflect increased urbanization. Whereas the main purpose of the analysis is to not increase flows, the actual total flow carries less importance. If the flows are utilized for design, they will be conservatively high.

D. Model Results and Implications

Future flows were evaluated based on projected 10-year land use data, which was provided by Montgomery County, Berks County, and the municipalities. The County chose to evaluate flows based on a 10-year projection instead of an ultimate build-out scenario, anticipating that the required future watershed reevaluations can be utilized to provide stormwater management options for additional development. Future CN values were developed using soils information and the projected 10-year land use information, and input into the future conditions model. The resulting existing and future 100-year flows for the Swamp Creek watershed were determined to be 15, 451 cubic feet per second (cfs) and 15,860 cfs, respectively, a change in flow of less than 3% (although changes in flow in individual subareas were as great as 10%).

To address future increased runoff as a result of development, various release rate scenarios were applied to future conditions. The release rates restricted subarea peak flow rates to rates less than or equal to existing conditions. When a release rate is specified for a particular subarea in the Stremtul program, the entire existing flow of the subarea is reduced according to that release rate, regardless of how much of the actual land use is changing. It is therefore inappropriate to apply a release rate to an entire subarea when there is only a small area of development within a subarea. To accommodate this fact, release rates were only applied to subareas that had a change in CN of 2 or more between existing and future conditions. The subareas without a change of at least 2 were kept at existing conditions so that they did not cause undetained flow increases. Setting the threshold at 2 (change in CN value of at least 2 between existing and future conditions) resulted in 10 subareas that were considered to include future development (mostly along Route 100 or in areas just downstream of Route 100). Release rates were analyzed as follows: 0% reduction (post development flow equals predevelopment flow), 10% reduction (90% of predevelopment peak flow), 20% reduction, 30% reduction, 40% reduction, and 50% reduction. The results showed increases in flow of greater than 5% at multiple subareas, with the exception of the 50% reduction scenario, where only subarea 1-14's future flow was 6% greater than the existing flow. The 50% reduction scenario was the one that had the greatest reduction of flows along the main stem, which is where many of the problem areas and predicted increases in flow due to development are located.

ARRO is recommending a 50% release rate for the entire watershed, based on the modeling results described above. To verify the appropriateness of this recommendation, the future conditions model was run with one fully developed subarea added for each run, with a 50% reduction applied for the subarea. Subareas 1-3, 3-2, and 1-25 were chosen as representative of the various spacial locations throughout the watershed, also representing different runoff travel times. To represent a fully developed subarea, the future condition CN value was increased by 10, which was considered to be representative of a typical increase over existing conditions. Adding an additional "developed" subarea resulted in further flow reductions along the main stem of the stream.

The future conditions model was also run for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events assuming that the first 2.4" of rain would be infiltrated. This infiltrated value was determined based on a typical development scenario using current infiltration requirements for NPDES Phase II permits for construction activities, where the difference in the 2-year pre-development and 2-year post-development flows must be infiltrated. The infiltration was applied by the Stremtul model at any subarea that was determined to be "developed" based on the CN value and display threshold (in this case, a subarea was "developed" when the change in CN value was greater than or equal to 2). Using a release rate of 50% and 2.4" of infiltration resulted in watershed flows that were less than existing conditions flows.

The tables below list the existing peak flow, future peak flow, future peak flow with 50% reduction, and future peak flow with 50% reduction and infiltration for each subarea for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events.

Table 4
Swamp Creek Watershed Model Results: 2-Year Storm Event

subarea	*existing peak (cfs)*	*future peak (cfs)*	*future peak with 50% reduction (cfs)*	*future peak with 50% reduction and 2.4" infiltration (cfs)*
1-1	202.0	202.0	202.0	202.0
1-2	83.0	83.0	83.0	83.0
1-3	175.0	175.0	175.0	175.0
1-4	300.0	300.0	300.0	300.0
1-5	561.0	561.0	561.0	561.0
1-6	366.0	500.0	183.0	122.0
1-7	657.0	687.0	639.0	554.0
1-8	669.0	969.0	335.0	234.0
1-9	1,160.0	1,365.0	1,139.0	558.0
2-1	384.0	446.0	192.0	150.0
2-2	360.0	360.0	360.0	360.0
2-3	917.0	936.0	912.0	856.0
2-4	933.0	949.0	922.0	874.0
3-1	942.0	942.0	942.0	942.0
3-2	484.0	484.0	484.0	484.0
3-3	2,360.0	2,560.0	2,212.0	1,941.0
4-1	607.0	718.0	374.0	139.0
4-2	759.0	759.0	759.0	759.0
4-3	725.0	814.0	511.0	363.0
4-4	1,315.0	1,376.0	1,205.0	1,100.0
4-5	570.0	570.0	570.0	570.0
4-6	409.0	409.0	409.0	409.0
4-7	1,169.0	1,225.0	1,105.0	909.0
4-8	1,471.0	1,510.0	1,420.0	1,305.0
5-1	669.0	669.0	669.0	669.0
5-2	1,117.0	1,117.0	1,117.0	1,117.0
5-3	1,231.0	1,231.0	1,231.0	1,231.0
6-1	502.0	502.0	502.0	502.0
6-2	786.0	786.0	786.0	786.0
1-10	1,440.0	1,726.0	1,341.0	649.0
1-11	361.0	466.0	181.0	89.0
1-12	1,346.0	1,589.0	1,338.0	623.0
1-13	494.0	597.0	247.0	123.0
1-14	1,381.0	1,620.0	1,497.0	726.0
1-15	2,397.0	2,595.0	2,250.0	1,992.0
1-16	2,213.0	2,399.0	2,175.0	1,728.0
1-17	418.0	418.0	418.0	418.0
1-18	2,218.0	2,395.0	2,202.0	1,758.0
1-19	307.0	307.0	307.0	307.0

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
1-20	2,247.0	2,423.0	2,228.0	1,792.0
1-21	3,202.0	3,377.0	3,191.0	2,885.0
1-22	353.0	353.0	353.0	353.0
1-23	445.0	445.0	445.0	445.0
1-24	3,501.0	3,550.0	3,463.0	3,353.0
1-25	3,225.0	3,398.0	3,213.0	2,960.0
1-26	433.0	433.0	433.0	433.0
1-27	3,652.0	3,694.0	3,622.0	3,535.0
1-28	287.0	287.0	287.0	287.0
1-29	3,730.0	3,773.0	3,699.0	3,603.0
1-30	4,321.0	4,338.0	4,320.0	4,282.0
1-31	4,601.0	4,619.0	4,652.0	4,571.0

(shaded) greater than 5% increase in flow from existing condition

Table 5
Swamp Creek Watershed Model Results: 5-Year Storm Event

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
1-1	535.0	535.0	535.0	535.0
1-2	219.0	219.0	219.0	219.0
1-3	421.0	421.0	421.0	421.0
1-4	643.0	643.0	643.0	643.0
1-5	1,313.0	1,313.0	1,313.0	1,313.0
1-6	742.0	931.0	371.0	371.0
1-7	1,534.0	1,599.0	1,472.0	1,456.0
1-8	1,246.0	1,613.0	623.0	623.0
1-9	1,978.0	2,218.0	2,048.0	1,710.0
2-1	717.0	799.0	359.0	359.0
2-2	614.0	614.0	614.0	614.0
2-3	1,461.0	1,495.0	1,415.0	1,287.0
2-4	1,390.0	1,422.0	1,337.0	1,239.0
3-1	1,578.0	1,578.0	1,578.0	1,578.0
3-2	958.0	958.0	958.0	958.0
3-3	4,161.0	4,264.0	3,754.0	3,335.0
4-1	924.0	1,056.0	608.0	580.0
4-2	1,277.0	1,277.0	1,277.0	1,277.0
4-3	1,081.0	1,172.0	838.0	629.0
4-4	2,039.0	2,097.0	1,908.0	1,726.0
4-5	963.0	963.0	963.0	963.0
4-6	671.0	671.0	671.0	671.0
4-7	2,062.0	2,154.0	1,926.0	1,594.0
4-8	2,397.0	2,462.0	2,298.0	2,090.0
5-1	1,109.0	1,109.0	1,109.0	1,109.0
5-2	1,719.0	1,719.0	1,719.0	1,719.0
5-3	1,876.0	1,876.0	1,876.0	1,876.0
6-1	841.0	841.0	841.0	841.0
6-2	1,398.0	1,398.0	1,398.0	1,398.0
1-10	2,382.0	2,622.0	2,344.0	2,085.0
1-11	625.0	746.0	313.0	313.0
1-12	2,297.0	2,539.0	2,406.0	1,964.0
1-13	795.0	919.0	398.0	398.0
1-14	2,426.0	2,575.0	2,556.0	1,979.0
1-15	4,222.0	4,324.0	3,807.0	3,412.0
1-16	3,936.0	4,056.0	3,726.0	3,215.0
1-17	673.0	673.0	673.0	673.0
1-18	3,895.0	3,996.0	3,765.0	3,264.0
1-19	512.0	512.0	512.0	512.0

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
1-20	3,937.0	4,035.0	3,802.0	3,305.0
1-21	5,440.0	5,585.0	5,218.0	4,684.0
1-22	748.0	748.0	748.0	748.0
1-23	824.0	824.0	824.0	824.0
1-24	5,769.0	5,895.0	5,654.0	5,429.0
1-25	5,465.0	5,610.0	5,246.0	4,728.0
1-26	787.0	787.0	787.0	787.0
1-27	5,935.0	6,012.0	5,853.0	5,668.0
1-28	567.0	567.0	567.0	567.0
1-29	6,063.0	6,151.0	5,951.0	5,753.0
1-30	6,897.0	6,807.0	6,881.0	6,807.0
1-31	7,282.0	7,132.0	7,294.0	7,211.0

greater than 5% increase in flow from existing condition

Table 6
Swamp Creek Watershed Model Results: 10-Year Storm Event

subarea	*existing peak (cfs)*	*future peak (cfs)*	*future peak with 50% reduction (cfs)*	*future peak with 50% reduction and 2.4" infiltration (cfs)*
1-1	880.0	880.0	880.0	880.0
1-2	357.0	357.0	357.0	357.0
1-3	668.0	668.0	668.0	668.0
1-4	1,018.0	1,018.0	1,018.0	1,018.0
1-5	2,123.0	2,123.0	2,123.0	2,123.0
1-6	1,094.0	1,319.0	547.0	547.0
1-7	2,417.0	2,486.0	2,350.0	2,351.0
1-8	1,764.0	2,162.0	882.0	882.0
1-9	2,853.0	3,150.0	2,946.0	2,531.0
2-1	1,015.0	1,110.0	508.0	508.0
2-2	835.0	835.0	835.0	835.0
2-3	1,854.0	1,887.0	1,935.0	1,677.0
2-4	1,776.0	1,816.0	1,752.0	1,556.0
3-1	2,144.0	2,144.0	2,144.0	2,144.0
3-2	1,343.0	1,343.0	1,343.0	1,343.0
3-3	5,512.0	5,799.0	5,093.0	4,796.0
4-1	1,194.0	1,354.0	804.0	784.0
4-2	1,722.0	1,722.0	1,722.0	1,722.0
4-3	1,360.0	1,478.0	1,087.0	842.0
4-4	2,670.0	2,745.0	2,487.0	2,245.0
4-5	1,297.0	1,297.0	1,297.0	1,297.0
4-6	893.0	893.0	893.0	893.0
4-7	2,831.0	2,934.0	2,652.0	2,333.0
4-8	3,165.0	3,244.0	3,028.0	2,788.0
5-1	1,492.0	1,492.0	1,492.0	1,492.0
5-2	2,257.0	2,257.0	2,257.0	2,257.0
5-3	2,459.0	2,459.0	2,459.0	2,459.0
6-1	1,127.0	1,127.0	1,127.0	1,127.0
6-2	1,921.0	1,921.0	1,921.0	1,921.0
1-10	3,263.0	3,647.0	3,280.0	3,062.0
1-11	851.0	992.0	426.0	426.0
1-12	3,124.0	3,505.0	3,342.0	2,978.0
1-13	1,055.0	1,179.0	528.0	528.0
1-14	3,094.0	3,469.0	3,339.0	2,897.0
1-15	5,606.0	5,890.0	5,199.0	4,901.0
1-16	5,205.0	5,556.0	4,857.0	4,615.0
1-17	894.0	894.0	894.0	894.0
1-18	5,039.0	5,356.0	4,848.0	4,574.0
1-19	677.0	677.0	677.0	677.0

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
1-20	5,088.0	5,405.0	4,893.0	4,622.0
1-21	7,157.0	7,366.0	7,071.0	6,680.0
1-22	1,077.0	1,077.0	1,077.0	1,077.0
1-23	1,123.0	1,123.0	1,123.0	1,123.0
1-24	7,802.0	7,999.0	7,791.0	7,425.0
1-25	7,188.0	7,409.0	7,103.0	6,703.0
1-26	1,114.0	1,114.0	1,114.0	1,114.0
1-27	7,952.0	8,129.0	7,943.0	7,618.0
1-28	824.0	824.0	824.0	824.0
1-29	8,086.0	8,258.0	8,066.0	7,746.0
1-30	9,052.0	9,106.0	9,063.0	8,943.0
1-31	9,492.0	9,543.0	9,518.0	9,406.0

greater than 5% increase in flow from existing condition

Table 7
Swamp Creek Watershed Model Results: 25-Year Storm Event

subarea	*existing peak (cfs)*	*future peak (cfs)*	*future peak with 50% reduction (cfs)*	*future peak with 50% reduction and 2.4" infiltration (cfs)*
1-1	1,217.0	1,217.0	1,217.0	1,217.0
1-2	494.0	494.0	494.0	494.0
1-3	907.0	907.0	907.0	907.0
1-4	1,399.0	1,399.0	1,399.0	1,399.0
1-5	2,834.0	2,834.0	2,834.0	2,834.0
1-6	1,434.0	1,655.0	717.0	717.0
1-7	3,095.0	3,137.0	3,123.0	3,123.0
1-8	2,214.0	2,697.0	1,107.0	1,107.0
1-9	3,659.0	3,985.0	3,682.0	3,347.0
2-1	1,292.0	1,397.0	646.0	646.0
2-2	1,032.0	1,032.0	1,032.0	1,032.0
2-3	2,340.0	2,382.0	2,453.0	2,148.0
2-4	2,236.0	2,290.0	2,207.0	1,955.0
3-1	2,640.0	2,640.0	2,640.0	2,640.0
3-2	1,727.0	1,727.0	1,727.0	1,727.0
3-3	7,067.0	7,149.0	6,465.0	6,133.0
4-1	1,451.0	1,603.0	983.0	967.0
4-2	2,130.0	2,130.0	2,130.0	2,130.0
4-3	1,621.0	1,716.0	1,296.0	1,033.0
4-4	3,279.0	3,336.0	3,063.0	2,755.0
4-5	1,595.0	1,595.0	1,595.0	1,595.0
4-6	1,093.0	1,093.0	1,093.0	1,093.0
4-7	3,534.0	3,624.0	3,309.0	2,975.0
4-8	3,881.0	3,954.0	3,713.0	3,449.0
5-1	1,838.0	1,838.0	1,838.0	1,838.0
5-2	2,685.0	2,685.0	2,685.0	2,685.0
5-3	2,907.0	2,907.0	2,907.0	2,907.0
6-1	1,386.0	1,386.0	1,386.0	1,386.0
6-2	2,386.0	2,386.0	2,386.0	2,386.0
1-10	4,233.0	4,548.0	4,181.0	4,046.0
1-11	1,057.0	1,205.0	529.0	529.0
1-12	4,077.0	4,369.0	4,278.0	3,922.0
1-13	1,276.0	1,422.0	638.0	638.0
1-14	4,028.0	4,250.0	4,212.0	3,681.0
1-15	7,188.0	7,270.0	6,592.0	6,261.0
1-16	6,687.0	6,795.0	5,961.0	5,640.0
1-17	1,081.0	1,081.0	1,081.0	1,081.0
1-18	6,419.0	6,551.0	5,960.0	5,579.0
1-19	840.0	840.0	840.0	840.0

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
1-20	6,479.0	6,610.0	6,013.0	5,634.0
1-21	8,873.0	9,036.0	8,489.0	8,032.0
1-22	1,340.0	1,340.0	1,340.0	1,340.0
1-23	1,408.0	1,408.0	1,408.0	1,408.0
1-24	9,666.0	9,786.0	9,411.0	9,077.0
1-25	8,916.0	9,078.0	8,537.0	8,084.0
1-26	1,374.0	1,374.0	1,374.0	1,374.0
1-27	9,874.0	9,986.0	9,633.0	9,308.0
1-28	1,070.0	1,070.0	1,070.0	1,070.0
1-29	10,019.0	10,133.0	9,776.0	9,451.0
1-30	11,203.0	11,269.0	11,108.0	10,914.0
1-31	11,672.0	11,734.0	11,613.0	11,449.0

greater than 5% increase in flow from existing condition

Table 8
Swamp Creek Watershed Model Results: 50-Year Storm Event

subarea	*existing peak (cfs)*	*future peak (cfs)*	*future peak with 50% reduction (cfs)*	*future peak with 50% reduction and 2.4" infiltration (cfs)*
1-1	1,589.0	1,589.0	1,589.0	1,589.0
1-2	647.0	647.0	647.0	647.0
1-3	1,157.0	1,157.0	1,157.0	1,157.0
1-4	1,807.0	1,807.0	1,807.0	1,807.0
1-5	3,803.0	3,803.0	3,803.0	3,803.0
1-6	1,770.0	2,010.0	885.0	885.0
1-7	4,281.0	4,347.0	4,143.0	4,143.0
1-8	2,689.0	3,219.0	1,345.0	1,345.0
1-9	4,860.0	5,275.0	4,782.0	4,441.0
2-1	1,580.0	1,696.0	790.0	790.0
2-2	1,238.0	1,238.0	1,238.0	1,238.0
2-3	2,860.0	2,895.0	2,969.0	2,634.0
2-4	2,731.0	2,787.0	2,698.0	2,436.0
3-1	3,134.0	3,134.0	3,134.0	3,134.0
3-2	2,133.0	2,133.0	2,133.0	2,133.0
3-3	8,599.0	8,853.0	8,108.0	7,651.0
4-1	1,703.0	1,855.0	1,172.0	1,166.0
4-2	2,550.0	2,550.0	2,550.0	2,550.0
4-3	1,870.0	1,960.0	1,518.0	1,234.0
4-4	3,908.0	3,973.0	3,670.0	3,314.0
4-5	1,898.0	1,898.0	1,898.0	1,898.0
4-6	1,296.0	1,296.0	1,296.0	1,296.0
4-7	4,250.0	4,349.0	3,998.0	3,650.0
4-8	4,621.0	4,702.0	4,430.0	4,150.0
5-1	2,194.0	2,194.0	2,194.0	2,194.0
5-2	3,156.0	3,156.0	3,156.0	3,156.0
5-3	3,413.0	3,413.0	3,413.0	3,413.0
6-1	1,659.0	1,659.0	1,659.0	1,659.0
6-2	2,840.0	2,840.0	2,840.0	2,840.0
1-10	5,607.0	6,164.0	5,311.0	5,111.0
1-11	1,273.0	1,414.0	637.0	637.0
1-12	5,243.0	5,730.0	5,358.0	5,006.0
1-13	1,505.0	1,663.0	753.0	753.0
1-14	5,063.0	5,480.0	5,262.0	4,759.0
1-15	8,739.0	8,986.0	8,264.0	7,807.0
1-16	8,199.0	8,544.0	7,531.0	7,055.0
1-17	1,275.0	1,275.0	1,275.0	1,275.0
1-18	7,852.0	8,180.0	7,475.0	6,994.0
1-19	993.0	993.0	993.0	993.0

subarea	existing peak (cfs)	future peak (cfs)	future peak with 50% reduction (cfs)	future peak with 50% reduction and 2.4" infiltration (cfs)
1-20	7,923.0	8,249.0	7,539.0	7,058.0
1-21	10,772.0	11,048.0	10,440.0	9,848.0
1-22	1,584.0	1,584.0	1,584.0	1,584.0
1-23	1,675.0	1,675.0	1,675.0	1,675.0
1-24	11,721.0	11,896.0	11,463.0	10,980.0
1-25	10,818.0	11,094.0	10,490.0	9,900.0
1-26	1,636.0	1,636.0	1,636.0	1,636.0
1-27	11,862.0	12,036.0	11,619.0	11,177.0
1-28	1,336.0	1,336.0	1,336.0	1,336.0
1-29	12,036.0	12,219.0	11,778.0	11,322.0
1-30	13,267.0	13,366.0	12,936.0	12,670.0
1-31	13,812.0	13,898.0	13,454.0	13,232.0

greater than 5% increase in flow from existing condition

Table 9
Swamp Creek Watershed Model Results: 100-Year Storm Event

subarea	existing peak (cfs)	future peak (cfs)	future peak with 50% reduction (cfs)	future peak with 50% reduction and 2.4" infiltration (cfs)
1-1	1,967.0	1,967.0	1,967.0	1,967.0
1-2	804.0	804.0	804.0	804.0
1-3	1,424.0	1,424.0	1,424.0	1,424.0
1-4	2,256.0	2,256.0	2,256.0	2,256.0
1-5	4,751.0	4,751.0	4,751.0	4,751.0
1-6	2,110.0	2,395.0	1,055.0	1,055.0
1-7	5,285.0	5,373.0	5,104.0	5,104.0
1-8	3,204.0	3,696.0	1,602.0	1,602.0
1-9	6,094.0	6,444.0	6,084.0	5,861.0
2-1	1,880.0	2,002.0	940.0	940.0
2-2	1,442.0	1,442.0	1,442.0	1,442.0
2-3	3,375.0	3,422.0	3,490.0	3,146.0
2-4	3,240.0	3,303.0	3,200.0	2,926.0
3-1	3,658.0	3,658.0	3,658.0	3,658.0
3-2	2,548.0	2,548.0	2,548.0	2,548.0
3-3	10,122.0	10,460.0	9,493.0	9,193.0
4-1	1,949.0	2,117.0	1,345.0	1,343.0
4-2	2,978.0	2,978.0	2,978.0	2,978.0
4-3	2,108.0	2,225.0	1,649.0	1,412.0
4-4	4,564.0	4,650.0	4,207.0	3,892.0

subarea	***existing peak (cfs)***	***future peak (cfs)***	***future peak with 50% reduction (cfs)***	***future peak with 50% reduction and 2.4" infiltration (cfs)***
4-5	2,217.0	2,217.0	2,217.0	2,217.0
4-6	1,488.0	1,488.0	1,488.0	1,488.0
4-7	4,977.0	5,090.0	4,625.0	4,280.0
4-8	5,374.0	5,466.0	5,110.0	4,834.0
5-1	2,559.0	2,559.0	2,559.0	2,559.0
5-2	3,642.0	3,642.0	3,642.0	3,642.0
5-3	3,933.0	3,933.0	3,933.0	3,933.0
6-1	1,926.0	1,926.0	1,926.0	1,926.0
6-2	3,296.0	3,296.0	3,296.0	3,296.0
1-10	6,771.0	7,459.0	6,644.0	6,440.0
1-11	1,480.0	1,640.0	740.0	740.0
1-12	6,266.0	6,891.0	6,570.0	6,243.0
1-13	1,747.0	1,894.0	874.0	874.0
1-14	6,006.0	6,504.0	6,322.0	5,964.0
1-15	10,287.0	10,613.0	9,678.0	9,374.0
1-16	9,669.0	10,138.0	8,792.0	8,624.0
1-17	1,480.0	1,480.0	1,480.0	1,480.0
1-18	9,241.0	9,675.0	8,744.0	8,539.0
1-19	1,161.0	1,161.0	1,161.0	1,161.0
1-20	9,323.0	9,755.0	8,815.0	8,612.0
1-21	12,547.0	12,884.0	12,084.0	11,605.0
1-22	1,840.0	1,840.0	1,840.0	1,840.0
1-23	1,964.0	1,964.0	1,964.0	1,964.0
1-24	13,642.0	13,867.0	13,276.0	12,766.0
1-25	12,597.0	12,934.0	12,139.0	11,663.0
1-26	1,903.0	1,903.0	1,903.0	1,903.0
1-27	13,807.0	14,015.0	13,467.0	12,988.0
1-28	1,602.0	1,602.0	1,602.0	1,602.0
1-29	13,965.0	14,199.0	13,633.0	13,168.0
1-30	14,955.0	15,314.0	15,008.0	14,738.0
1-31	15,451.0	15,860.0	15,676.0	15,444.0

(shaded) greater than 5% increase in flow from existing condition

E. Criteria and Standards for Stormwater Management

1. Comprehensive Stormwater Management

Land development within the Swamp Creek watershed impacts the hydrologic cycle of the watershed. As previously undeveloped areas are converted to impervious areas or compacted grass or landscaped areas, groundwater recharge decreases and stormwater runoff increases, leading to increased erosion in receiving streams. Typically, stormwater management has been addressed on a site-by-site basis or a municipality-by-municipality basis, where it is mainly the stormwater impacts to the development site or to the municipality that are considered when designing facilities to mitigate stormwater impacts. One of the purposes of the Act 167 program is to encourage a comprehensive watershed approach to stormwater management, where it is acknowledged that land development affects not only the individual site or municipality, but the entire watershed.

2. National Pollutant Discharge Elimination System (NPDES), Phase II Requirements

In addition to the Pennsylvania Act 167 program, the Federal NPDES program also serves to encourage a comprehensive widespread approach to stormwater management. The NPDES Program Phase II regulations were published in the Federal Register in December 1999. The Phase II program impacted operators of small municipal separate storm sewer systems (MS4s) by requiring them to obtain NPDES permits for their storm sewer discharges. These permit holders are municipalities located in “urbanized areas” of the state, as identified using census data. All municipalities within the Swamp Creek watershed are MS4 municipalities, with the exception of District and Pike Townships in Berks County.

As a part of the NPDES permit, the impacted municipalities are required to implement six minimum control measures, including the following: public education and outreach, public involvement and participation, illicit discharge detection and elimination, construction site stormwater runoff control, post-construction stormwater management, and pollution prevention/good housekeeping for municipal operations. In Pennsylvania, the NPDES program is regulated by the DEP, which also regulates the Act 167 program. The Act 167 program serves to fulfill several NPDES permit requirements, including the following:

- A municipality’s participation in the Act 167 program fulfills the public involvements and participation minimum control measure.
- The Swamp Creek Model Stormwater Management Ordinance incorporates stormwater ordinance updates that are required for MS4 municipalities, including ordinance requirements related to prohibited stormwater discharges, construction site stormwater runoff control, and post-construction stormwater management.
- The Act 167 program strongly encourages the use of stormwater management BMPs, including BMPs for groundwater recharge and water quality volume. The NPDES program requires groundwater recharge and

water quality volume for newly developed areas and also requires that municipalities have some method for ensuring that stormwater management BMPs are properly maintained.

3. Goals of the Act 167 Plan

Recognizing the need to deal with the serious problem of flooding, the Pennsylvania General Assembly enacted Act 167, the Pennsylvania Stormwater Management Act. The statement of legislative findings at the beginning of Act 167 sums up the critical relationship between land development, accelerated runoff, and floodplain management. Specifically, this statement of legislative findings points out the following:

a. Inadequate management of stormwater runoff from development increases flood flows and velocity, contributes to erosion and sedimentation, overloads the carrying capacity of streams and storm sewers, greatly increases the cost of public stormwater facilities, undermines floodplain management and floodplain control efforts in downstream communities, reduces groundwater recharge, and threatens public health and safety.

b. A comprehensive stormwater management program including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety and welfare and the protection of the people of the Commonwealth, their resources and their environment.

To prevent the inadequate management or stormwater runoff from development and promote sound water and land use practices, a comprehensive stormwater management plan should address the following objectives:

- Maintain groundwater recharge.
- Implement non-point source pollution removal technologies.
- Reduce channel erosion.
- Manage overbank flood events.
- Manage extreme flood events.

The performance standards listed below were incorporated in the model ordinance for Swamp Creek, and should serve to help to meet these objectives.

4. Performance Standards

a. Groundwater Recharge Standard – to maintain groundwater recharge

Groundwater recharge involves infiltrating stormwater into the ground, replenishing the groundwater supply, which then provides baseflow to streams. Design of the infiltration facilities shall consider groundwater recharge to compensate for the reduction in the recharge that occurs when the ground surface is disturbed or impervious surface is created. Infiltration may not be feasible on every site due to site-specific limitations such as soil type.

Infiltration BMPs shall meet the following minimum requirements:

1) Infiltration BMPs intended to receive runoff from developed areas shall be selected based on suitability of soils and site conditions and shall be constructed on soils that have the following characteristics:

   a) A minimum depth of twenty-four (24) inches, and preferably 36 inches, between the bottom of the BMP and the top of the limiting zone (e.g., seasonally high water table, groundwater, bedrock, etc.).

   b) An infiltration rate sufficient to accept the additional stormwater load and dewater completely as determined by field tests.

   c) The infiltration facility shall be capable of completely infiltrating the recharge (infiltration) volume within three (3) days (72 hours) or less.

   d) Pretreatment shall be provided prior to infiltration.

2) The size of the infiltration facility shall be based upon the Net Two Year Volume Approach, where the recharge volume to be captured and infiltrated shall be the volume difference between the pre-development 2-year, 24-hour storm event and post-development 2-year, 24-hour storm event.

3) Soils - A detailed soils evaluation of the project site shall be required to determine the suitability of infiltration facilities. The evaluation shall be performed by a qualified design professional and at a minimum address soil permeability, depth to bedrock, and subgrade stability. The general process for designing the infiltration BMP shall be the following:

   a) Analyze hydrologic soil groups as well as natural and man-made features within the site to determine general areas of suitability for infiltration practices. In areas where development on fill material is under consideration, conduct geotechnical investigations of sub-grade stability; infiltration may not be ruled out without conducting these tests.

   b) Provide field tests such as double ring infiltrometer or hydraulic conductivity tests (at the level of the proposed infiltration surface) to determine the appropriate hydraulic conductivity rate. Percolation tests are not recommended for design purposes.

c) Design the infiltration structure for the required recharge volume based on field determined capacity at the level of the proposed infiltration surface.

d) If on-lot infiltration structures are proposed, it must be demonstrated that the soils are conducive to infiltrate on the lots identified.

4) Stormwater Hotspots – Below is a list of examples of designated hotspots. If a site is designated as a hotspot, it has important implications for how stormwater is managed. First and foremost, untreated stormwater runoff from hotspots shall not be allowed to recharge into groundwater where it may contaminate water supplies. Second, a greater level of stormwater treatment shall be considered at hotspot sites to prevent pollutant washoff after construction. The Environmental Protection Agency's (EPA) NPDES stormwater program requires some industrial sites to prepare and implement a stormwater pollution prevention plan.

Examples of hotspots include the following:

- Vehicle salvage yards and recycling facilities.
- Vehicle fueling stations.
- Vehicle service and maintenance facilities.
- Vehicle and equipment cleaning facilities.
- Fleet storage areas (bus, truck, etc.).
- Industrial sites based on Standard Industrial Codes.
- Marinas (service and maintenance).
- Outdoor liquid container storage.
- Outdoor loading/unloading facilities.
- Public works storage areas.
- Facilities that generate or store hazardous materials.
- Commercial container nursery.
- Other land uses and activities as designated by an appropriate review authority.

The following land uses and activities are not normally considered hotspots:

- Residential streets and rural highways.
- Residential development.
- Institutional development.
- Office developments.
- Nonindustrial rooftops.
- Pervious areas, except golf courses and nurseries (which may need an integrated pest management (IPM) plan).

While large highways (average daily traffic volume greater than thirty thousand) are not designated as stormwater hotspots, it is important to ensure that highway stormwater management plans adequately protect groundwater.

Extreme caution shall be exercised where infiltration is proposed in Source Water Protection Areas as defined by a local Municipality or water authority. Infiltration facilities shall be used in conjunction with other innovative or traditional BMPs, stormwater control facilities, and nonstructural stormwater management alternatives.

Extreme caution shall be exercised where salt or chloride (municipal salt storage) would be a pollutant since soils do little to filter this pollutant, and it may contaminate the groundwater. Specific consideration should be given to the particular type of salt or deicing material to be used within this watershed in regards to its potential long-term effects on the soils, especially in areas that contain clay soil.

The infiltration requirement in High Quality or Exceptional Value waters shall be subject to DEP's Chapter 93 Anti-degradation Regulations.

An impermeable liner will be required in detention basins where the possibility of groundwater contamination exists. Safeguards should be provided against groundwater contamination for land uses that may cause groundwater contamination should there be a mishap or spill.

b. Water Quality Standard – to implement non-point source pollution removal technologies

Pollutants such as sediments and oils tend to accumulate on the impervious surfaces that result from land development. During storm events, these pollutants are washed off of the impervious surfaces and into stormwater management facilities or directly into streams, resulting in declining water quality in the receiving streams. A goal of the Act 167 program is to reduce non-point source pollution to receiving streams. The water quality standard has been established to achieve this goal.

To control post-construction stormwater impacts from regulated earth disturbance activities, state water quality requirements can be met by BMPs, including site design, which provide for replication of pre-construction stormwater infiltration and runoff conditions so that post-construction stormwater discharges do not degrade the physical, chemical, or biological characteristics of the receiving waters. As described in the DEP Comprehensive Stormwater Management Policy (#392-0300-002, September 28, 2002), this may be achieved by the following:

1) Infiltration: replication of pre-construction stormwater infiltration conditions,
2) Treatment: use of water quality treatment BMPs to ensure filtering out of the chemical and physical pollutants from the stormwater runoff, and
3) Streambank and Streambed Protection: management of volume and rate of post-construction stormwater discharges to prevent physical degradation of receiving waters (e.g., from scouring).

Developed areas shall provide adequate storage and treatment facilities necessary to capture and treat stormwater runoff. If site conditions allow for infiltration, the water quality volume and the recharge volume are the same volume and may be managed in a single facility. If infiltration can not be physically accomplished, the water quality volume should be calculated using the Net Two Year Volume Approach, where the recharge volume to be captured and infiltrated shall be the volume difference between the pre-development 2-year, 24-hour storm event and post-development 2-year, 24-hour storm event. In this case, the water quality volume may be captured and treated by methods other than infiltration BMPs.

This volume requirement can be accomplished by the permanent volume of a wet basin or the detained volume from other BMPs. Where appropriate, wet basins shall be utilized for water quality control.

The water quality volume shall take a minimum of 24 hours to be discharged from a BMP facility. Release of the water quality volume can begin at the start of the storm (i.e., the invert of the water quality orifice is at the invert of the facility). The design of the facility shall provide for protection from clogging and unwanted sedimentation.

For areas within defined special protection subwatersheds that include High Quality and Exceptional Value waters, the temperature and quality of water and streams shall be maintained through the use of temperature sensitive BMPs and stormwater conveyance systems.

A combination of different BMPs may be utilized to achieve the design objectives described above.

If a perennial or intermittent stream passes through the development site, a stream buffer should be created that extends a minimum of fifty (50) feet to either side of the top-of-bank of the channel. The buffer area shall be maintained with and encouraged to use appropriate native vegetation.

c. *Streambank Erosion Standard - to reduce channel erosion*

Another land development impact to receiving streams is streambank erosion. The addition of new impervious areas results in increased stormwater flow rates and volumes. Streambank erosion occurs due to the increased stream velocities resulting from increased stormwater flow rates. It also occurs due to increased stormwater flow volumes. Streams are generally expected to flow full to the tops of their banks during a 2-year storm event. The streambank erosion standard involves detaining stream flows to the 1-year storm event to minimize streambank erosion.

BMP design to minimize streambank erosion involves designing the BMP to detain the proposed conditions 2-year, 24-hour design storm to the existing conditions 1-year flow using the SCS Type II distribution. Additionally, provisions shall be so that the proposed conditions 1-year storm takes a minimum of twenty-four (24) hours to drain from the facility from a point where the maximum volume of water from the 1-year storm is captured. Release of water can begin at the start of the storm.

d. *Stormwater Peak Rate Control Standard – to manage overbank and extreme flood events*

Stream flooding is impacted by land development within the stream's watershed. Flooding may be aggravated by the placement of buildings or other obstructions in floodplain areas, and it may also be aggravated by increased in stormwater runoff from new land development. Streams are generally expected to flow full to the tops of their banks during a 2-year storm event. Therefore, overbank flood events are considered to be flood events resulting from 2-year, 5-year, and 10-year storms. Extreme flood events are considered to be flood events resulting from more severe storms, such as the 25-year, 50-year, and 100-year storm events. The peak rate control standard is proposed as a method to protect against increased flooding as land development increases. The watershed model completed for the Swamp Creek Act 167 Plan included an analysis related to the level of peak rate control necessary to protect against the impacts of proposed development within the watershed. This analysis is described in the model results and implications section above and resulted in the components of the peak rate control standard described below:

Within the Swamp Creek watershed, the criteria for peak runoff control are designed to reduce the post-development peak flow to 50% of the pre-development peak flow. Development sites must control proposed conditions runoff rates to 50% of the existing conditions runoff rates for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events.

For any proposed development site, a less restrictive runoff control may be used (including no detention) if the developer can prove that "no harm" would be caused by discharging at a higher runoff rate. The "no harm" option may be used when an developer can prove that the proposed conditions hydrograph is less than the existing conditions hydrograph at all points in time for a 24-hour hydrograph, or if it can be proven that the proposed conditions will not cause increases in 2-, 5-, 10-, 25-, 50-, and 100-year peak flows at all points downstream within the Act 167 study area.

e. *Recommended Procedure to Achieve Performance Standards*

The following sequence should be used by a developer to minimize the increases in stormwater runoff and impacts to water quality resulting from the proposed regulated activity:

1) Prepare an Existing Resource and Site Analysis Map (ERSAM) showing environmentally sensitive areas including, but not limited to, steep slopes, ponds, lakes, streams, wetlands, hydric soils, vernal pools, stream buffers, hydrologic soil groups, wooded areas, and potential infiltration areas. Land development, any existing recharge areas, and other requirements outlined in the municipal SALDO shall also be included.
2) Establish a stream buffer.
3) Prepare a draft project layout avoiding environmentally sensitive areas.
4) Identify site-specific existing conditions drainage areas, discharge points, recharge areas, and hydrologic soil group B (areas conducive to infiltration). Infiltration should still be considered in well draining soils listed as hydrologic soil group C, but additional

soils testing should be performed to verify onsite conditions and placement of these BMPs.

5) Evaluate nonstructural stormwater management alternatives:
   a) Minimize earth disturbance.
   b) Minimize impervious surfaces.
   c) Break up large impervious surfaces.
6) Satisfy the groundwater recharge (infiltration) objective and provide for stormwater pretreatment prior to infiltration.
7) Provide for water quality protection.
8) Provide streambank erosion protection.
9) Conduct an existing conditions runoff analysis.
10) Prepare final project design to maintain existing conditions drainage areas and discharge points, to minimize earth disturbance and impervious surfaces, and, to the maximum extent possible, to ensure that the remaining site development has no surface or point discharge.
11) Conduct a proposed conditions runoff analysis based on the final design that meets the release rate requirements.
12) Manage any remaining runoff prior to discharge through detention, bioretention, direct discharge, or other structural control.

Table 10
Required Criteria and Standards in the Swamp Creek Watershed

Required Standard	***Benefit***
<u>Stormwater Management</u> Provide peak rate runoff control.	• No increase in runoff on a watershed wide basis. • Stormwater attenuation.
<u>Recharge/Infiltration</u> Recharge/infiltration BMPs are required where soil and geologic conditions permit. All proposed development shall investigate the implementation of infiltration or retention structures as opposed to surface detention and shall adhere to the infiltration requirements presented in the model ordinance.	• Groundwater recharge. • Stream baseflow recharge. • Flow attenuation.
<u>Water Quality</u> Provide adequate storage and treatment facilities necessary to capture and treat the water quality volume.	• Capture and treats polluted stormwater, providing improved water quality.
<u>Calculation Methodology</u> Required calculation methodology is presented	• Consistent stormwater management calculations.

Required Standard	***Benefit***
in the model ordinance.	
Discharge of Accelerated Runoff Accelerated stormwater runoff shall be safely discharged into existing discharge points and storm sewers without adversely affecting properties or causing channel scouring and erosion.	• Safe conveyance. • Continued surface and groundwater quality. • Flow attenuation.
Inappropriate Outlets If it is not possible to direct stormwater flow from a development site to a stream, tributary, stabilized channel, or storm sewer, then runoff shall be collected in a BMP and discharged at a nonerosive rate. Outlets discharging onto adjacent property owner(s)' properties must have adjacent property owner(s)' written permission, unless the post-development condition is an improvement to the pre-development condition.	• Safe conveyance. • Continued surface and groundwater quality. • Flow attenuation.
Streambank Protection Reduce 2-year post-development flow to 1-year post-development flow.	• Reduces number of erosive storms, thereby reducing streambank erosion.
Wetlands Network with regulatory agencies to determine appropriate management techniques within wetland areas.	• Infiltration. • Surface and groundwater recharge. • Stream baseflow. • Water quality. • Flow attenuation and detention.
Erosion and Sediment Pollution Control Network with administrative and regulatory agencies to sequence and control earth disturbance sites to maintain and protect areas designated for infiltration or leave areas of native vegetation intact.	• Infiltration. • Structure integrity. • Surface water quality. • Safe conveyance. • Stream, culvert, and channel capacity.

Table 11
Recommended Criteria and Standards in the Swamp Creek Watershed

Recommended Standard	***Benefit***
Floodplains Floodplains should be kept free of fill or obstructions to retain stream channel conveyance and storage capacity.	• Natural stormwater detention / flood control downstream. • Protection of existing conveyance capacity.
Roof Drains, Residential/Commercial Prevent all roof drains from discharging into storm sewers, roadside ditches, or channels. Discharge to lawn, infiltration, or storage facilities is recommended so that stormwater is reused.	• Infiltration. • Flow attenuation. • Increases time of concentration.
Pervious Surfaces The use of pervious surfaces is encouraged for parking surfaces and sidewalks.	• Infiltration. • Groundwater recharge.
Structures Concentrate on locating facilities within areas conducive to recharge and accommodate infiltration to meet release rate requirements.	• Infiltration. • Groundwater recharge. • Stream baseflow.
Steep Slopes Regulate activities in critical slope areas where management of stormwater by structure is inappropriate. Slopes should be vegetated with native vegetation.	• Stream baseflow. • Flow attenuation. • Conveyance integrity. • Surface water quality.
Green Roof Construct rooftop gardens.	• Flow attenuation. • Small storm retention.
Stream Buffer Provide stream buffer of 50 feet measured from the top of bank on both sides of a stream.	• Water quality. • Flood drainage reduction. • Habitat enhancement. • Erosion reduction.
Existing Storm Sewers or Culverts Discharge into existing sewer networks or culverts will be based on system capacity or design storm(s), whichever is more restrictive.	• Preserve sewer/culvert capacity, thereby reducing operation and maintenance and replacement costs.

*Note: The Swamp Creek Model Stormwater Management Ordinance should be referenced for more detailed standards and criteria.

F. Model Stormwater Management Ordinance

Pennsylvania municipalities are empowered to regulate land use activities that affect runoff and surface and groundwater quality and quantity by the authority of the Stormwater Management Act, Act of October 4, 1978, 32 P.S., P.L. 864 (Act 167)

Section 680.1 et seq., as amended. Among the requirements of Act 167 is the requirement that municipalities implement the stormwater management plan through a stormwater ordinance that was developed as part of the plan. This ordinance could be adopted essentially "as is" by a municipality, or the municipality could make some modifications to the model ordinance to fulfill the specific needs of the municipality. Additionally, a municipality may need to make some revisions to their Subdivision and Land Development Ordinance and/or their Zoning Ordinance to ensure that these ordinances are consistent with the Stormwater Management Ordinance and include appropriate cross-references.

The Swamp Creek Model Stormwater Management Ordinance will not completely replace the existing storm drainage ordinance provisions currently in effect in the watershed's municipalities for the following reasons:

- Not all of the municipalities in the Swamp Creek watershed are completely within the watershed. For those portions of the municipality outside the Swamp Creek watershed, the existing ordinance provisions would still apply.
- Permanent and temporary stormwater control facilities are regulated by the model ordinance. Stormwater management and erosion and sedimentation control during construction would continue to be regulated under the existing stormwater ordinance and Chapter 102 Erosion and Sediment Pollution Controls, Title 25 of DEP regulations.
- The model ordinance contains only those minimum stormwater runoff control criterion and standards that are necessary or desirable from a total watershed perspective. Additional stormwater management design criteria (i.e. inlet spacing, inlet type, collection system details, etc.), which should be based on sound engineering practice, should be regulated under the current ordinance provisions or as part of the general responsibilities of the municipal engineer.

The model ordinance includes nine articles, each with specific requirements, as well as a set of appendices. Each of these is described below.

Article I – General Provisions: This article includes an introduction to the ordinance as well as a description of the legal authority of the ordinance and applicability of the ordinance to specific development scenarios.

Article II – Definitions: This article includes the definitions for words and terms used in the ordinance.

Article III – Drainage Plan Requirements: This article describes the various components required for a drainage plan submission. The procedure for drainage plan submissions and reviews is also outlined in this article.

Article IV – Stormwater Management: This article includes the technical provisions and requirements specific to stormwater management that resulted from the Swamp Creek model analysis and are recommended to implement the Swamp Creek Stormwater Management Plan. Requirements for groundwater recharge, water quality, and peak rate control, as well as stormwater facility design criteria, and a description of acceptable calculation methodology, are listed in this article.

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

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

Article VII – Maintenance Responsibilities: This article lists the owner's operations and maintenance responsibilities for BMPs and stormwater management facilities.

Article VIII – Prohibitions: This article lists prohibited discharges and connections to a municipality's storm sewer system, and includes requirements related to roof drains and BMP alterations.

Article IX – Enforcement and Penalties: This article describes procedures and penalties to give municipalities the authority to enforce their stormwater management ordinance.

Appendices – The appendices consist of various sets of guidelines that supplement the design requirements and guidelines included in the body of the ordinance.

According to the Stormwater Management Act, Swamp Creek municipalities shall adopt or amend and implement such ordinances and regulations as are necessary to regulate development within the municipality in a manner consistent with the Swamp Creek Stormwater Management Plan and other applicable provisions of the Act. This shall occur within six months of the adoption and approval of the Swamp Creek Stormwater Management Plan.

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 Swamp Creek Stormwater Management Ordinance have been followed. The Occupancy Permit shall be required for each lot owner and/or developer of all subdivisions and land development in the municipality, unless exempted by the exemption criteria.

F. Model Stormwater Management Ordinance

The following ordinance provisions must be retained when a municipality either elects to create a single-purpose stormwater management ordinance or amends existing subdivision and land development or zoning ordinances to implement the stormwater management plan.

Article I – General Provisions

Article II – Definitions

Article IV – Design Criteria for Stormwater Management Facilities: Sections 401, 402, 403, 404, 405, 406, 407, 408 (except section E), 409, and 410 (Sections A through I only)

Article V – Inspections (language may be modified by the municipality)

Article VII – Maintenance (language may be modified by the municipality)

Article VIII – Prohibitions

Article IX – Enforcement and Penalties (only when enacting a single-purpose ordinance)

The following ordinance provisions are recommended to be retained:

Article III – Drainage Plan Requirements

Article IV – Design Criteria: Section 410.J through 410.CC

Article VI – Fees and Expenses

Article VII – Maintenance: Section 709

Appendices

Municipalities may enact a single-purpose stormwater management ordinance different from the model ordinance or may revise language in an existing ordinance as long as the Act 167 Plan requirements for groundwater recharge, water quality, streambank erosion, and peak runoff control are maintained in the ordinance. It is recommended that the revised stormwater management ordinance be reviewed by the municipal engineer, municipal solicitor, and DEP prior to ordinance adoption.

SECTION VII – SWAMP CREEK STORMWATER MANAGEMENT ORDINANCE

SECTION VIII – IMPLEMENTATION

A. Priorities for Implementation

The Swamp Creek Watershed Stormwater Management Plan has been prepared by Montgomery County, with assistance from ARRO Consultants, Inc., Berks County, the municipalities within the watershed, and DEP. The final steps involve adoption of the plan by Berks and Montgomery Counties, and approval of the plan by DEP. Once the plan is approved by DEP, it is implemented by the municipalities, which revise their existing stormwater ordinance or adopt the stand-alone ordinance contained in the plan. As required by Act 167, the Swamp Creek watershed municipalities have six months from DEP approval to adopt the necessary ordinance provisions. This process is described in the following section.

1. DEP Approval

The watershed plan was adopted by Montgomery and Berks Counties, and submitted to DEP for approval. A draft of the stormwater management plan and draft model ordinance had been sent to the Watershed Plan Advisory Committee (WPAC) and DEP prior to adoption of the plan. DEP reviewed the plan to determine that all of the sections specified in the Scope of Study have been included. The DEP 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, and that the plan is consistent with the policies of Act 167.

2. Plan Distribution

Once the Plan was approved by DEP, the Montgomery County Planning Commission distributed one hard copy of the plan to each municipality. The plan includes this report, appendices, figures, and the model ordinance.

3. Plan Implementation

The watershed municipalities are required, under Act 167, to adopt the ordinance provisions contained in the Swamp Creek Watershed Plan. The Plan contains the Act 167 Stormwater Management Plan Model Ordinance. This is a single purpose stormwater ordinance that could be adopted by each municipality with little modification to implement the plan. The municipality could adopt the ordinance itself and reference the existing subdivision and land development ordinance and possibly the zoning ordinance, and comply with the requirements of Act 167.

The municipality may choose to incorporate the standards and criteria of the stormwater ordinance into its existing ordinance rather than adopt the stand alone ordinance. In this case, it is recommended that the subwatershed map delineating 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 not limited to activities that are subject to subdivision and land development regulations.

4. Level of Government Involvement in Stormwater Management

In order to implement this plan, the following actions must occur:

- Municipal adoption of the standards and criteria of the plan through the municipal stormwater ordinance provisions. Act 167 requires that this be accomplished within six months of the plan's adoption and approval. Model ordinance provisions will be distributed to all of the watershed municipalities. The Montgomery and Berks Counties Planning agencies will be available upon request to assist municipalities in the adoption of the model ordinance provisions to fit particular municipal ordinance structures.
- Maintenance and operation of the computer model (as necessary), and compilation of data required for periodically updating the plan.

All future stormwater facilities, including facilities owned or financed by state funds will have to be consistent with the plan, even though they might not otherwise be subject to municipal regulation.

5. PENNVEST Funding

The PENNVEST Act of 1988, as amended, provides low interest loans to governmental entities for constructing, improving or rehabilitating stormwater projects. Eligible projects can include conveyance, storage and infiltration of stormwater and best management practices to address non-point source pollution associated with stormwater.

In order to qualify for a loan under PENNVEST, the municipality or county:

- Must be located in a watershed for which there is an existing county adopted and DEP approved stormwater plan with enacted stormwater ordinances consistent with the plan, or
- Must have enacted a stormwater control ordinance consistent with the Stormwater Management Act.

By adopting the standards and criteria for stormwater control and implementing the plan, the municipality is able to apply for PENNVEST loans for stormwater projects.

6. Landowner's/Developer's Responsibilities

Any landowner and any person engaged in the alteration or development of land that may affect stormwater runoff characteristics shall implement such measures consistent with the provisions of the applicable watershed stormwater plan as are reasonably necessary to prevent injury to health, safety or other property. Such measures shall include such actions as are required:

- To assure the maximum rate of stormwater runoff is no greater after development than prior to development activities; or
- To manage the quantity, velocity and direction of resulting stormwater runoff in a manner that otherwise adequately protects health and property from possible injury.

Many developers throughout the state, after realizing the natural resource, public safety and potential economic advantages of proper stormwater management, are constructing development consistent with natural resources protection. An example of such development procedure is the low impact development ordinance contained in the DEP model ordinance for MS4 municipalities.

B. Plan Review, Adoption, and Updating Procedures

1. County Adoption

Prior to plan completion, Montgomery County transmitted a sample of the proposed Swamp Creek Stormwater Ordinance for review to PADEP and the municipalities represented by the Watershed Plan Advisory Committee. Montgomery County then transmitted a draft plan that included the draft ordinance for review to the municipal planning commission and the governing body of each involved municipality, the County Planning Department or Commission and the Watershed Plan Advisory Committee by official correspondence. 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 received, tabulated, and responded to the comments. The plan was revised as necessary.

Montgomery and Berks Counties held a joint public hearing at a location in the watershed. 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 considered.

The plan was passed as a resolution by the respective County governing bodies for the purpose of adoption. The resolution included references to the volumes, figures, appendices and model ordinance. The County resolutions were recorded in the minutes of regular meetings of the Montgomery and Berks counties commissioners.

Montgomery County then submitted the following to DEP: a letter of transmittal and one hard and one digital copy of the adopted plan, the review by each affected municipal planning agency and local governing body and the County Planning Department, public hearing notice and minutes, and the resolution of adoption of the plan by each County. The letter of transmittal stated that Montgomery County has complied with all procedures outlined in Act 167 and requested that DEP approve the adopted plan.

2. Provisions for Plan Revision

Section 5 of the Stormwater Management Act requires that the stormwater management plan be updated 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.

It will be necessary to collect and manage the required data in a consistent manner and preferably store it in a central location. This is not only to prepare an updated plan, but also, if required, to make interim runs on the runoff simulation model to analyze the impact of a proposed major development or a proposed major stormwater management facility. When the update is initiated, the WPAC will be reconvened to review changes in the watershed and determine the extent if the update required. Montgomery County will review the recommendations of the Watershed Plan Advisory Committee and determine if revisions are to be made. A revised plan would be subject to the same rules of adoption as the original plan. 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 then be forwarded to DEP.

Stormwater Districts Map

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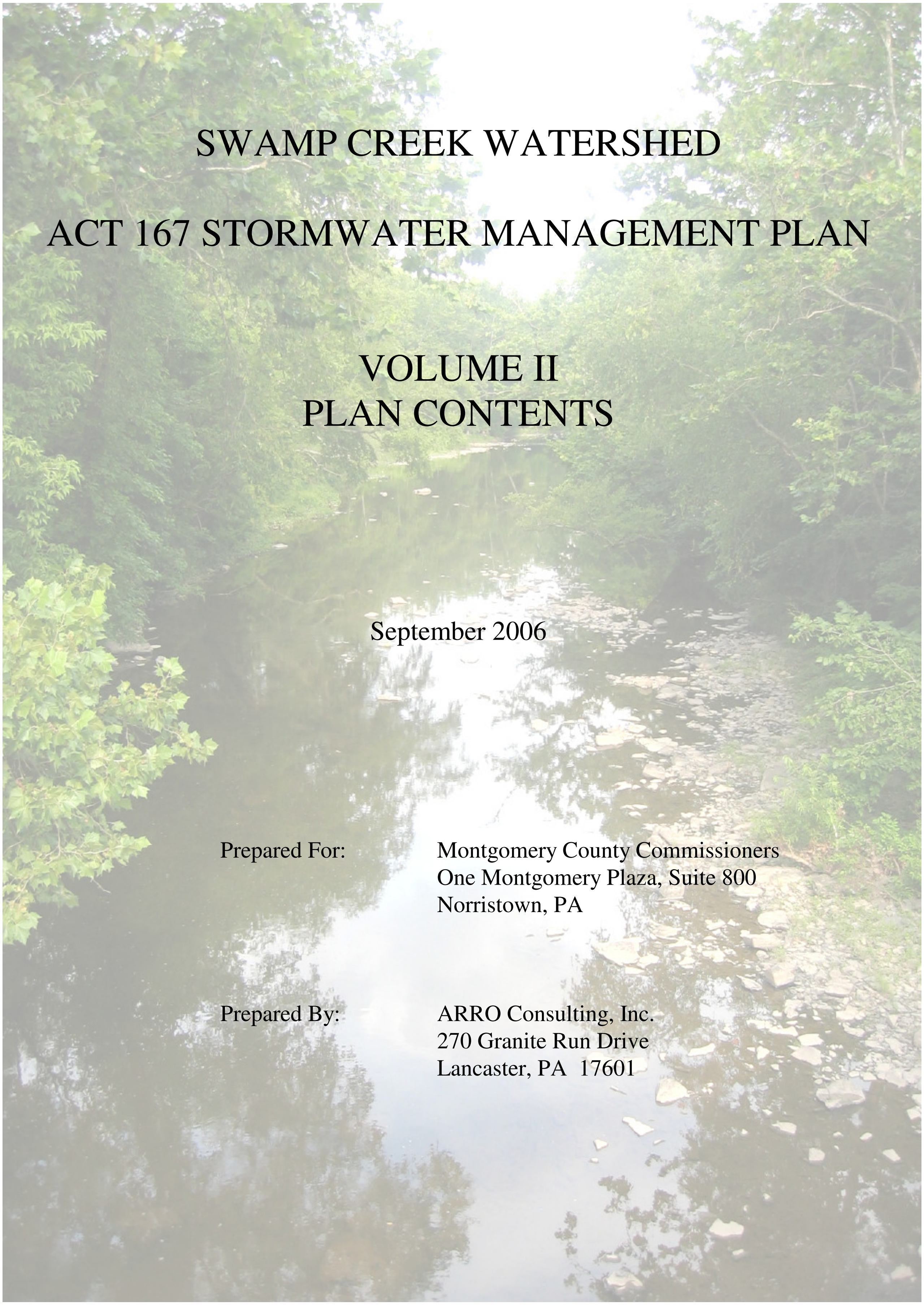

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