DARBY AND COBBS CREEKS WATERSHED ACT 167

STORMWATER MANAGEMENT PLAN

VOLUME I - EXECUTIVE SUMMARY

DELAWARE. CHESTER. MONTGOMERY. AND PHILADELPHIA COUNTIES. PENNSYLVANIA

<u>Januarv 2005 Final Draft</u>

DEP ME# 350208
FILE NO. SWMP 086:23
BLE PROJECT NO. 99613.01

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PREPARED FOR:

DELAWARE COUNTY COUNCIL
Court House and Government Center Bldg.
201 W. Front Street
Media, PA 19063

PREPARED BY:

DELAWARE COUNTY PLANNING DEPT.
Court House and Government Center Bldg.
201 W. Front Street
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ENGINEERING CONSULTANT

BORTON-LAWSON ENGINEERING, INC.
613 Baltimore Drive, Suite 300
Wilkes-Barre, PA 18702-7903

PLAN FORMAT

The format of the Darby-Cobbs Creek Stormwater Management Plan consists of Volume I, the Executive Summary, Volume II, the Plan Report, and Volume III that contains the background technical materials.

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

Volume III provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing municipal ordinance matrix, and obstructions inventory. Due to large volumes of data, one copy of Volume III will be on file at each of the Delaware County Planning Department, the Chester County Planning Commission and Montgomery County Planning Commission, and Philadelphia Water Department offices.

The draft plan's figures were in black and white. The final plan will have color figures. Large-scale copies of the figures are at each county planning office and the Philadelphia Water Department.

I. INTRODUCTION

This plan has been developed for the Darby and Cobbs Creeks Watershed in Delaware, Chester, Montgomery and Philadelphia Counties, Pennsylvania to comply with the requirements of the Pennsylvania Stormwater Management Act, Act 167, of 1978. The Darby and Cobbs Creek watersheds are two separate DEP Act 167-designated watersheds. However, the Cobbs Creek is actually a tributary of Darby Creek. In order to properly address stormwater management in the Darby Creek Watershed below the confluence of Cobbs and Darby Creeks, it was determined that both watersheds needed to be hydrologically evaluated. One Act 167 plan was, therefore, developed encompassing the two watersheds, thus satisfying the Act 167 planning requirements for both watersheds. For the purposes of this report, when the combined watersheds are being formally referenced such as in section headings, the text used to refer to them will read the Darby and Cobbs Creeks watershed. When the combined watersheds are being informally referenced such as in the text of the report, for ease of reading the acronym used to refer to them will be the Darby-Cobbs watershed. Otherwise, they will be referenced individually when appropriate to do so.

The main objective of a stormwater management plan is to control stormwater runoff from new development on a watershed-wide basis rather than on a site-by-site basis, taking into account how development in any part of the watershed will affect stormwater runoff in all other parts of the watershed.

II. WATERSHED DESCRIPTION

The Darby and Cobbs Creeks watersheds are two separate DEP Act 167-designated watersheds. The Cobbs Creek is actually a tributary of Darby Creek. The two watersheds are located primarily in eastern Delaware County. The upper portion of the Darby Creek watershed is located in southeastern Chester County. The upper portion of the Cobbs Creek watershed is located in southwestern Montgomery County, and it flows through southwestern Philadelphia County. The Darby-Cobbs watershed lies within twenty-six (26) municipalities in Delaware County, two (2) municipalities in Chester County, two (2) municipalities in Montgomery County, and (1) municipality in Philadelphia County as follows:

Delaware County

- Aldan Borough
- Clifton Heights Borough
- Collingdale Borough
- Colwyn Borough*
- Darby Borough*
- Darby Township*
- East Lansdowne Borough (Cobbs only)
- Folcroft Borough
- Glenolden Borough
- Haverford Township*
- Morton Borough
- Newtown Township
- Norwood Borough
- Prospect Park Borough
- Radnor Township
- Ridley Township
- Ridley Park Borough
- Rutledge Borough
- Sharon Hill Borough
- Springfield Township

Lansdowne Borough*
Marple Township
Millbourne Borough (Cobbs only)
Tinicum Township
Upper Darby Township*
Yeadon Borough*

Chester County

Easttown Township
Tredyffrin Township

Montgomery County

Lower Merion Township
Narberth Borough (Cobbs only)

Philadelphia County

City of Philadelphia

* In both the Darby Creek and Cobbs Creek watersheds

Darby Creek drains a total watershed area of approximately 77.2 square miles and includes the following major tributaries: Little Darby Creek, Julip Run, Ithan Run, Meadowbrook Run, Wigwam Run, Foxes Run, and Muckinipates Creek. Approximately 39.6 square miles of the Darby Creek watershed are upstream of its confluence with Cobbs Creek. Cobbs Creek, a major tributary of Darby Creek, has a drainage area of 22.2 square miles. Approximately 15.4 square miles of the Darby Creek watershed are located below its confluence with Cobbs Creek. Darby Creek flows into the Delaware River just south of Little Tinicum Island.

III. METHODOLOGY

The engineer for the project is Borton-Lawson Engineering, Inc. The plan was developed from data collected on the physical features of the watershed, such as soils, wetlands, topography, floodplains, dams and reservoirs, stream dimensions, and obstructions. Information on existing problem areas was solicited from the Watershed Planning Advisory Committee (WPAC) which consisted of representatives from the 31 municipalities as well as other interested parties including County Conservation Districts, Darby Creek Valley Association (DCVA), and others. Although the plan is not geared toward solving existing problems, knowing where and why they exist aided the engineer in developing the subwatersheds, identifying points of interests, and understanding the hydrologic flow of the watershed as a whole. Information on existing land use and zoning was also collected. This helped the engineer to determine where and to what extent future development would take place. All of this data was compiled into a geographic information system (GIS) database.

The computer model used for the project was the US Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS). This model was chosen for the project because it can be easily adapted to an urban and/or rural area, it has the ability to analyze reservoir or detention basin-routing effects, and it is accepted by the Department of Environmental Protection. To gain a realistic picture of what occurs in the Darby-Cobbs watershed, the model was calibrated against actual stream flow data, regression models, as well as data from the Federal Emergency Management Administration (FEMA) and the U.S. Army Corps of Engineers.

The process of determining how runoff flows throughout the watershed is a complex one. It involves running numerous scenarios through the model taking into account the location of obstructions and tributary confluences. This process produced a few large subbasins, which were then further subdivided. The most downstream point of each of these areas is considered a "point of interest" in which increased runoff must be analyzed for its potential impact.

Another aspect of the analysis involves modeling design storms. This term refers to assigning a frequency to a storm based on the amount of rain that falls over a 24-hour period. As the amount of rain falling over a 24-hour period increases, the frequency or chance of that storm occurring decreases. For example, 2.64 inches of rain falling over a 24-hour period is associated with the 1-year design storm, while the occurrence of 6.24 inches falling over a 24-hour period happens theoretically only every 25 years. For this study, the 1, 2, 5, 10, 15, 20, 25, 50, and 100-year storms were modeled.

To make implementation of the plan viable by the municipalities, a simple, but accurate method was developed for municipal officials, engineers, and developers to abide by the plan. The watershed was divided into four (4) stormwater management districts and assigned the following proposed condition/existing condition runoff rates for each as indicated in following plan table.

TABLE V-3
Stormwater Management Districts In The Darby-Cobbs Creek Watershed

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

** In District C, development sites which can discharge directly to the Darby – Cobbs Creek main channel or major tributaries or indirectly to the main channel through an existing stormwater* *drainage system (i.e., storm sewer or tributary) may do so without control of post-development peak rate of runoff greater than the 5-year storm. Sites in District C will still have to comply with the groundwater recharge criteria, the water quality criteria, and streambank erosion criteria. If the post-development runoff is intended to be conveyed by an existing stormwater drainage system to the main channel, assurance must be provided that such system has adequate capacity to convey the flows greater than the 2-year predevelopment peak flow or will be provided with improvements to furnish the required capacity. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the post-development peak rate of runoff must be controlled to the pre-development peak rate as required in District A provisions (i.e., 10-year post-development flows to 10 pre-development flows) for the specified design storms.*

All regulated activities not otherwise exempt from the ordinance are required to implement water quality controls as defined by the ordinance. Generally, they are as follows:

1. Provide infiltration capacity for the net increase in the 2 year-volume of runoff from the development site in Exceptional Value (EV) and High Quality (HQ) watersheds. In other areas (or if this cannot be physically accomplished in EV and HQ watersheds), a lesser volume of infiltration can be provided based upon capturing and infiltrating one inch of runoff from all new impervious surfaces, but under no conditions should the infiltration capacity provided on the site be less than the minimum of 0.50 inches of runoff from impervious surfaces. The infiltration volume does not have to be provided in one location. However, if site conditions preclude capture of runoff from portions of the impervious area, the infiltration volume for the remaining area should be increased an equivalent amount to offset the loss.

2. If site conditions preclude use of infiltration facilities for such reasons as high groundwater tables or extensive rock conditions, a waiver from Section 405, Groundwater Recharge, would be required by the Municipality.

3. Provide buffer areas on perennial or intermittent streams passing through the site. The buffer areas are recommended to be at least fifty (50) feet wide; municipalities may set a lower figure, but never less than ten (10) feet wide. The buffer shall be maintained with and encouraged to use appropriate native vegetation.

4. If none of the above options are feasible due to site constraints, the applicant must provide stormwater detention that meets the release rate criteria for the site location or else obtain approval from the municipal Engineer to implement other BMPs that will provide water quality benefits of an equivalent level.

5. Exempted activities as defined by the ordinance are still encouraged to implement voluntary stormwater management practices as indicated in Appendix B of the Model Ordinance.

IV. EXEMPTIONS

Exemptions for land use activities include:

1. Use of land for gardening for home consumption.

2. Agriculture when operated in accordance with a conservation plan, nutrient management plan, or erosion and sedimentation control plan approved by the County Conservation District, including activities such as growing crops, rotating crops, tilling of soil, and grazing animals. Installation of new or expansion of existing farmsteads, animal housing, waste storage, and production areas having impervious surfaces that result in a net increase in earth disturbance of greater than five thousand (5,000) square feet shall be subject to the provisions of this Ordinance.

3. Forest management operations which are following the Department of Environmental Protection's (DEP) management practices contained in its publication "Soil Erosion and Sedimentation Control Guidelines for Forestry" and are operating under an approved erosion and sedimentation plan and must comply with the stream buffer requirements in Section 406.G.

4. Road replacement, development, or redevelopment that has less than two thousand (2,000) square feet of new, additional, or replaced impervious surface/cover, or in the case of earth disturbance only, less than five thousand (5,000) square feet of disturbance, is exempt from this Ordinance.

The following land development and earthmoving activities are exempt from the drainage plan submission requirements of this Ordinance.

1. A maximum of two thousand (2,000) square feet of new, additional, or replacement proposed impervious surface.

    Or in the case of earth disturbance resulting in less than two thousand (2,000) square feet of impervious cover (as noted above)

2. Up to a maximum of five thousand (5,000) square feet of disturbed earth.

These criteria shall apply to the total development even if the development is to take place in phases. The date of the municipal Ordinance adoption shall be the starting point from which to consider tracts as "parent tracts" upon which future subdivisions and respective earth disturbance computations shall be cumulatively considered.

V. NPDES REGULATIONS

New Federal regulations approved October 1999 require operators of small municipal separate storm sewer systems (MS4s) to obtain NPDES Phase II (National Pollutant Discharge Elimination System Phase II Stormwater Permitting Regulations) permits from DEP by March 2003. This program affects all municipalities in "urbanized areas" of the State. This definition applies to all Darby-Cobbs Creeks watershed municipalities. Therefore, all municipalities within the Darby-Cobbs Creeks watershed will be subject to the NPDES Phase II requirements mandated by the Federal Clean Water Act as administered by DEP. For more information on NPDES II requirements, contact the DEP Regional Office.

VI. IMPLEMENTATION

All municipalities within the watershed will be required to adopt the provisions of the Darby-Cobbs Creeks Stormwater Management Plan's Model Ordinance. The standards and criteria contained in this ordinance will apply only to those portions of the municipality that are located within the boundaries of the Darby-Cobbs watershed. The areas outside of the watershed will still be regulated by the municipality's subdivision/land development ordinance unless otherwise written so as to apply to other areas of the municipality.

County adoption of the plan is expected to occur in June 2005. Once this occurs, the plan will be sent to DEP to be approved. All of the municipalities will be required to adopt the model ordinance provisions within six (6) months of DEP approval.

DARBY AND COBBS CREEKS WATERSHED ACT 167

STORMWATER MANAGEMENT PLAN

VOLUME II – PLAN CONTENTS

DELAWARE. CHESTER. MONTGOMERY. AND PHILADELPHIA COUNTIES. PENNSYLVANIA

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ENGINEERING CONSULTANT

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

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Volume III provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing municipal ordinance matrix, and obstructions inventory. Due to large volumes of data, one copy of Volume III will be on file at each of the Delaware Co. Planning Department, the Chester County Planning Commission and Montgomery County Planning Commission offices, and the Philadelphia Water Department.

The Draft Plan's figures were in black and white. The Final Plan contains color figures. Large-scale color copies of the figures are at the Delaware County Planning Department office.

Definitions for stormwater related terms or phrases can be found in Article II of the Model Ordinance, Appendix 3.

RESOLUTION

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

WHEREAS, the Delaware County Council entered into contract with the Pennsylvania Department of Environmental Protection to develop the watershed stormwater management plan for the Darby and Cobbs Creeks designated watershed; and

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

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

NOW, THEREFORE, BE IT RESOLVED that the Delaware County Council hereby adopts the Darby and Cobbs Creeks Watershed Stormwater Management Plan, including all volumes, figures, appendices, model ordinance, and forwards the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this day of , 2005 by:

DELAWARE COUNTY COUNCIL

Tim Murtaugh, Chairman

Andrew J. Reilly, Vice Chairman

Linda A. Cartisano

Mary Alice Brennan

Michael V. Puppio, Jr.

RESOLUTION

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

WHEREAS, the Chester County Commissioners entered into a Memorandum of Understanding with Delaware County to support the development of the watershed stormwater management plan for the Darby and Cobbs Creeks designated watershed; and

WHEREAS, policies of the Chester County Comprehensive Plan Landscapes, calls for the reduction of public costs from flood damage and the protection of water quality in streams; and

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

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

NOW, THEREFORE, BE IT RESOLVED that the Chester County Commissioners hereby adopt the Darby and Cobbs Creeks Watershed Stormwater Management Plan, including all volumes, figures, appendices, model ordinance, and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this day of , 2005 by:

CHESTER COUNTY COMMISSIONERS

Carol Aichele

Andrew E. Dinniman

Donald Mancini

RESOLUTION

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

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

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

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

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

This Resolution is hereby adopted this day of , 2005 by:

MONTGOMERY COUNTY COMMISSIONERS

James R. Matthews, Chairman

Ruth S. Damsker

Thomas J. Ellis, Esq.

RESOLUTION

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

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

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

NOW, THEREFORE, BE IT RESOLVED that the Philadelphia City Commissioners hereby adopt the Darby and Cobbs Creeks Watershed Stormwater Management Plan, including all volumes, figures, appendices, model ordinance and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this day of , 2005 by:

PHILADELPHIA CITY COMMISSIONERS

Margaret Tartaglione, Chair

Edgar Howard

Joseph Duda

ENGINEERING CONSULTANT

Borton-Lawson Engineering, Inc.

DARBY CREEK WATERSHED DESIGNATED WPAC MEMBERS
As of March 9, 2004

County	WPAC Designee
Delaware County	
Delaware County Planning Department	Ms. Karen Holm Manager, Environmental Section
Delaware County Conservation District	Mr. Edward Magargee District Manager
Aldan Borough	Mr. Charlie Duffy Designated Representative
Clifton Heights Borough	Mr. Michael Galentino, Esq. Borough Council President
Collingdale Borough	Ms. Eileen Nelson Engineer
Colwyn Borough *	Mr. Daniel McEnhill Manager
Darby Borough *	Ms. Eileen Mulvena Engineer
Darby Township *	Mr. John O'Neill Designated Representative
East Lansdowne Borough (C)	Ms. Eileen Mulvena Engineer
Folcroft Borough	Judith Serratore Secretary
Glenolden Borough	Mr. Earl W. Bell Manager
Haverford Township *	Mr. Michael English Manager
Lansdowne Borough *	Mr. William T. Smith Borough Council
Marple Township	Mr. William Brainerd EAC Member

Millbourne Borough (C)	Mrs. Elizabeth Catania-Smith Engineer
Morton Borough	Ms. Dolores Giardina Borough Council
Newtown Township	Mr. James Sheldrake Manager
Norwood Borough	Ms. Eileen Mulvena Engineer
Prospect Park Borough	Ms. Eileen Nelson Engineer
Radnor Township *	Mr. Dan Malloy Engineer
Ridley Township	Mr. Charles J. Catania Engineer
Ridley Park Borough	Mr. Robert J. Poole Manager
Rutledge Borough	Mr. Edward O. McGaughey Borough Council President
Sharon Hill Borough	Mr. William H. Scott Manager
Springfield Township	Kevin Kane Engineer
Tinicum Township	Mr. Robert Bernauer Engineer
Upper Darby Township *	Mr. Fernando Baldivieso Engineer
Yeadon Borough *	Ms. Eileen Mulvena Engineer

Chester County

Chester County Planning Commission	Mr. Wayne Clapp Assistant Director
Chester County Conservation District	Mr. Dan Greig District Manager

Chester County Water Resources Authority	Ms. Janet Bowers Executive Director
Easttown Township	Mr. Surender S. Kohli Engineer
Tredyffrin Township	Mr. Steve Norcini Munic. Authority Operation Mgr.

Montgomery County

Montgomery County Planning Commission	Mr. Michael M. Stokes, AICP Associate Planning Director
Montgomery County Conservation District	Mr. Richard Kadwill District Manager
Lower Merion Township *	Ms. Andrea Campisi Senior Planner
Narberth Borough (C)	Mr. William Martin Manager

City of Philadelphia *

Philadelphia Water Department	Mr. Howard Neukrug, P.E. Director, PWD Office of Watersheds
Philadelphia Planning Commission	Maxine Griffith, AICP Executive Director

Others

Darby Creek Valley Association	Mr. Fritz Thornton President
Natural Resource Conservation Service (NCRS)	Mr. Sam High District Conservationist

* In both Darby and Cobbs watersheds (C) In Cobbs watershed only

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SECTION I

INTRODUCTION

A. Introduction

This plan has been developed for the Darby-Cobbs Creeks watershed in Delaware, Chester, Montgomery and Philadelphia Counties, Pennsylvania to comply with the requirements of the Pennsylvania Stormwater Management Act, Act 167, of 1978. The Darby and Cobbs Creeks watersheds are two separate DEP Act 167 designated watersheds. However, the Cobbs Creek is actually a tributary of Darby Creek. In order to properly address stormwater management in the Darby Creek Watershed below the confluence of Cobbs and Darby Creeks, it was determined that both watersheds needed to be hydrologically evaluated. One Act 167 plan was, therefore, developed encompassing the two watersheds, thus satisfying the Act 167 planning requirements for both watersheds. For the purposes of this report, when the combined watersheds are being formally referenced such as in section headings, the text used to refer to them will read the Darby-Cobbs watershed. When the combined watersheds are being informally referenced such as in the text of the report, for ease of reading the acronym used to refer to them will be the Darby-Cobbs watershed. Otherwise, they will be referenced individually when appropriate to do so.

The Darby-Cobbs watershed is located predominantly in the eastern portion of Delaware County. Portions of the watershed also extend into eastern Chester, southern Montgomery, and western Philadelphia Counties.

This report is developed with the intent to present all information that may be required in order to implement the plan. The comprehensiveness of the plan covers legal, engineering, and municipal government topics, which combined, form the basis for implementation and enforcement of a final ordinance that will be developed and adopted by each affected municipality. A sample stormwater management ordinance for reference use has been developed as part of the plan and is included in Appendix 3.

B. Stormwater Management

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

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

SECTION II

ACT 167

A. Stormwater Management Act 167

Recognizing the adverse effects of excessive stormwater runoff resulting from development, the Pennsylvania General Assembly approved the Stormwater Management Act, P.L. 864, No. 167 on October 4, 1978. Act 167 provides for the regulation of land and water use for flood control and stormwater management purposes. It imposes duties, confers powers to the Department of Environmental Protection (DEP), municipalities and counties, and provides for enforcement and appropriations. The Act requires the DEP to designate watersheds, develop guidelines for stormwater management, and model stormwater ordinances. The designated watersheds were approved by the Environmental Quality Board July 15, 1980, and the guidelines and model ordinances were approved by the Legislature May 14, 1985. The Act provides for grants to be appropriated by the General Assembly and administered by DEP for 75% of the allowable costs for the preparation of a stormwater management plan. It also provides for 75% of administrative, enforcement and implementation costs incurred by any municipality or county in accordance with Chapter III - Stormwater Management Grants and Reimbursement Regulations (adopted by the Environmental Quality Board August 27, 1985).

All counties must, in consultation with its municipalities, prepare and adopt a stormwater management plan for each of its designated watersheds. The county must review and revise such plans at least every five years when funding is available. Within six months following adoption and approval of a watershed stormwater plan, each municipality is required to adopt or amend stormwater ordinances as laid out in the plan. These ordinances must regulate development within the municipality in a manner consistent with the watershed stormwater plan and the provisions of the Act.

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

B. Purpose of the Study

Development in the Darby-Cobbs watershed causes an increase in stormwater runoff and a reduction in groundwater recharge. A number of negative effects result from uncontrolled stormwater runoff in addition to the risk of flooding downstream. It also causes erosion and sedimentation problems, reduces stream quality, raises the temperature of the streams, and impairs the aquatic food chain. It can also reduce the baseflow of streams, which is imperative for aquatic life during the drier summer months. Erosion of the streambanks caused by accelerated stream velocities due to increased runoff is already evident in the following municipalities: Chester County - Easttown Township; Delaware County - Aldan Borough, Haverford Township, Lansdowne Borough, Marple Township, Newtown Township, Radnor Township and Sharon Hill Borough.

There is an increased statewide as well as local recognition that a sound and effective stormwater management plan requires a diversified multiple purpose plan. The plan should address the full range of hydrologic consequences resulting from development by considering tributary timing of flow volume reduction, base flow augmentation, water quality control and ecological protection rather than simply focusing on controlling site specific peak flow.

Managing stormwater runoff on a site-specific basis does not meet the requirements of watershed based planning. The timing of flood peaks for each subbasin within a watershed contributes greatly to the flooding potential of a particular storm. Each stormwater control site within a subbasin should be managed by evaluating the comprehensive picture.

The Darby-Cobbs Watershed Stormwater Management Plan provides reasonable regulations of development activities to control accelerated runoff and protect the health, safety and welfare of the public. The plan includes recognition of the various rules, regulations and laws at the federal, state, county and municipal level. Once implemented, the plan will aid in reducing costly flood damages by reducing the source and cause of local uncontrolled runoff. The plan will make municipalities and developers more aware of comprehensive planning in stormwater control and will help maintain the quality of Darby-Cobbs Creeks and their tributaries.

SECTION III

GENERAL DESCRIPTION OF WATERSHED

The Darby-Cobbs watershed is located predominantly in the eastern portion of Delaware County. Portions of the watershed extend into eastern Chester, southern Montgomery, and western Philadelphia Counties. There are twenty-six (26) municipalities in Delaware County, two (2) municipalities in Chester County, two (2) municipalities in Montgomery, and one (1) municipality in Philadelphia County as listed in Table III-1 and illustrated in Figure III-1A, the Base Map.

TABLE III-1
Darby and Cobbs Creeks Watershed Municipalities

Delaware County

Aldan Borough
Clifton Heights Borough
Collingdale Borough
Colwyn Borough*
Darby Borough*
Darby Township*
East Lansdowne Borough (Cobbs only)
Folcroft Borough
Glenolden Borough
Haverford Township*
Lansdowne Borough*
Marple Township
Millbourne Borough (Cobbs only)
Morton Borough
Newtown Township
Norwood Borough
Prospect Park Borough
Radnor Township
Ridley Township
Ridley Park Borough
Rutledge Borough
Sharon Hill Borough
Springfield Township
Tinicum Township
Upper Darby Township*
Yeadon Borough*

Chester County

Easttown Township
Tredyffrin Township

Montgomery County

Lower Merion Township
Narberth Borough

Philadelphia County

City of Philadelphia

* In both the Darby Creek and Cobbs Creek watersheds

A. Drainage Area

The Darby-Cobbs watershed has a total area of 77.2 square miles; of that, 6.5 square miles lies in Chester County, 4.2 square miles lies in Montgomery County and 6.5 square miles in Philadelphia County and 60 square miles within Delaware County. Darby Creek originates in Easttown Township in Chester County and flows in a south/southeast direction through most of the watershed. It changes direction in the southern portion of the watershed where it flows west/southwest direction until it discharges into the Delaware River between the Townships of Ridley and Tinicum. The major tributaries to Darby Creek include: Cobbs Creek, Little Darby Creek, Julip Run, Ithan Run, Cobbs Creek, Meadowbrook Run, Wigwam Run, Foxes Run, Muckinipates Creek.

Cobbs Creek, a separately-identified watershed for the purposes of Act 167 planning, is a major tributary of Darby Creek, constituting almost 1/3 of the watershed. Therefore, it was included as part of this study. The total drainage area of Cobbs Creek above its confluence with Darby Creek is 22.2 square miles. The drainage area below the confluence is 15.4 square miles. After the confluence with Cobbs Creek, Darby Creek flows for approximately 5 miles until it reaches the Delaware River (see Figure III-1A).

The major routes in the Darby-Cobbs watershed include Interstates 476 and 95, US Routes 30, 13 and 1, and PA Routes 291, 320, and 3. Interstate 476 runs through the watershed for approximately 8 miles following Darby Creek from Radnor Township to Springfield Township. Interstate 95 runs through the southern section of the watershed for approximately 4 miles. Interstate 95 crosses Darby Creek at the Township line between Ridley and Tinicum Townships. US Route 30 runs through the watershed for approximately 12 miles across the northern section of the watershed. US Route 13 enters the watershed in Ridley Township and exits into the City of Philadelphia. US Route 13 crosses Darby Creek in Darby Township and crosses Cobbs Creek in Philadelphia County. US Route 1 runs through the watershed from Media to Philadelphia and crosses Darby Creek in Philadelphia. Route 291 runs parallel with Interstate 95 in the southern portion of the watershed. Route 320 enters the watershed near Villanova then crosses Darby Creek near the Old Foxcroft Quarry, Marple Township, and exits near Cardinal O'Hara High School. Route 3 runs approximately 10 miles through the Darby-Cobbs watershed. Route 3 crosses Darby Creek near Haverford Township and crosses Cobbs Creek near Philadelphia.

Figure III-1A: Base Map

See Maps Appendix

Figure III-1A: Base Map

See Maps Appendix

B. Data Collection

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

1. **Base Map:** The base map for geographic information system (GIS) generated maps was generated from data received from the Pennsylvania Department of Environmental Protection (PADEP) and the Pennsylvania Department of Transportation (PADOT). Streams, lakes, and the watershed boundary were obtained from the PADEP. County and municipal boundaries, roads and railroads were obtained from PADOT.

2. The overall Darby-Cobbs Creek watershed boundary includes the separate PADEP Act 167 boundaries for Darby Creek and Cobbs Creek. These two separate watershed boundaries were merged and overlaid on USGS topographic maps to ascertain accuracy. Minor adjustments to the PADEP boundaries were made based on the USGS topographic maps.

3. **Elevation Data:** A Digital Elevation Model (DEM) for the Darby-Cobbs watershed was developed from DEM data obtained from the USGS. Subwatersheds or subareas used in the watershed modeling process were derived from the DEM. Subareas, drainage courses, land slopes and lengths, and drainage element lengths and slopes could all be determined from the DEM.

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

5. STATSGO maps are statewide soil maps made by generalizing the detailed county soil survey data. The STATSGO data were used to create the generalized soils map. SSURGO is the most detailed level of soil mapping done by the Natural Resources Conservation Service (NRCS). SSURGO are digital duplication the original county soil survey maps. The SSURGO data were used for all other soil maps.

6. **Geology:** The digital geology coverages for Chester, Delaware, Montgomery, and Philadelphia Counties were obtained from the Pennsylvania Geologic Survey.

7. **Land Use:** The existing land use was map was generated by overlaying Delaware Valley Regional Planning Commission (DVRPC) land use data on year 2000 DVRPC aerial photographs and then using parcel data and heads up digitizing to update the DVRPC data and improve the spatial accuracy.

8. **Wetlands:** Wetlands were obtained from the United States Fish and Wildlife Service in the form of digital National Wetlands Inventory Maps.

9. **Streambank Erosion/Stability Assessment:** Achieving natural stream stability plays an important role in minimizing streambank erosion and resultant sediment pollution, and in turn, water quality and aquatic habitat preservation. Natural stream stability is achieved by allowing the stream to develop stable dimensions (stream bankfull width, width/depth ratio and capacity), profile, and pattern so that the stream system neither degrades (erodes) nor aggrades (accumulates sediment). Assessing stream stability requires a fluvial geomorphological assessment and baseline determination. These dimensions for stability can be mathematically determined using the "Rosgen" classification method of fluvial geomorphological (FGM) assessment (D.L. Rosgen, Applied River Morphology 1996). Once the stream is categorized and instability problems identified, effective and sustainable stream restoration measures to bring the stream back into a stable condition can be recommended through proper targeted storm water management and recommended restoration measures.

   A stormwater management plan, in addition to items required under Section 5(b) of the Storm Water Management Act, should include an assessment of stream stability and its relation to flooding events and existing erosion problems. Such an assessment is critical to:

   - Identifying changes in channel configuration in response to changes in stormwater runoff that might contribute to flooding problems in the future as the stream reaches a new equilibrium.
   - Ensuring adequate protection of sewerage infrastructure.
   - Relating stream bank erosion, sedimentation, and downstream water quality problems to changes in stormwater flows (both volume and peak).
   - Living resource protection through aquatic habitat preservation.
   - Recommending effective and sustainable stream restoration measures.

Darby Creek Fluvial Geomorphological Assessment

To properly characterize the Darby Creek watershed measurement of geomorphological parameters and physical and hydraulic relationships was performed at both the Rosgen Level I and Level II. This addressed some of the root causes of streambank erosion and sedimentation, habitat loss, and water quality impairments. It provides critical information for use in identifying and understanding existing and future problems, and in devising an effective framework for stormwater management that will protect any future stream restoration efforts.

Level I: Desktop Survey – A Level I fluvial geomorphological (FGM) assessment of the watershed was performed based on the Rosgen classification methodology. This is desktop delineation of the stream using generalized major stream types A through G based on available topographic information, geological maps, soils maps, and aerial photographs, all of which are part of the overall Act 167 planning effort. The purpose of this inventory was to provide an initial framework for organizing and targeting subsequent field assessments of targeted or important reaches where problems are known to occur or are anticipated to occur.

Available topographical information, geological maps, soils maps, and aerial photographs were reviewed and specific drainage areas for selected stream reaches within the watershed were calculated where needed. Using regional curve data developed for the Northeast, ranges of hydraulic geometry relationships based on the bankfull discharge were estimated. Stream reaches were initially be classified by stream type based on objective comparisons of land forms, soils, slope and channel patterns obtained from aerial photographs, topographical, geological and soil survey maps and the field data collected from the reference reaches and extrapolated reaches. Field verification was required where stream types change or where distinct variations in conditions are observed.

Level II: Reach Stream Survey – A field team was sent out to traverse up to 18 miles of the highest order streams and tributaries within the Darby Creek watershed. Field teams of two-stream surveyors walked along the designated lengths of each stream and tributary and estimated the following parameters by observation:

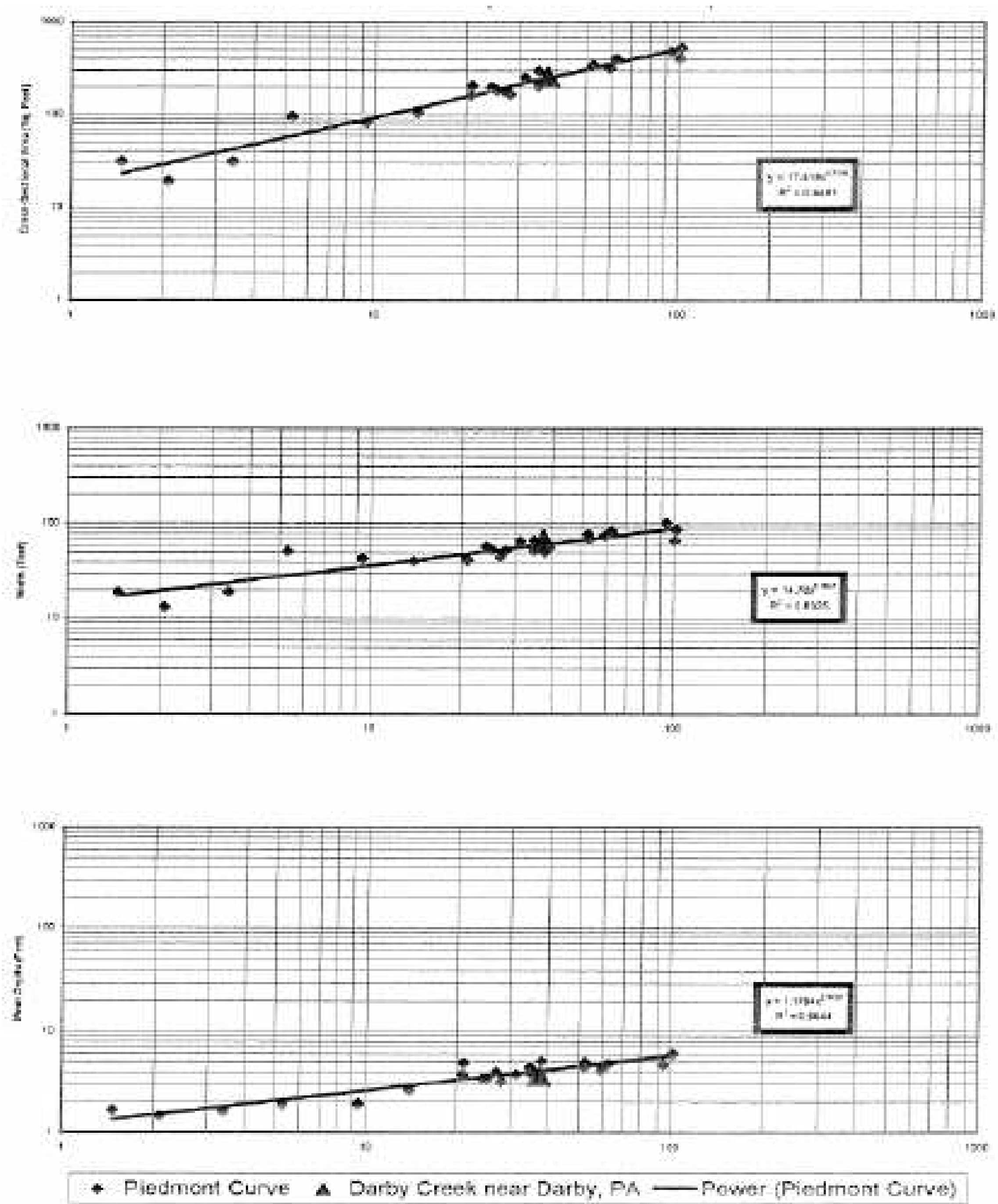
Channel Morphology

- Bankfull Elevation
- Bankfull Width
- Entrenchment Ratio Range
- Width/Depth Ratio Range
- Sinuosity Range
- Channel Slope Range
- Channel Materials (pebble count)
- Meander Pattern

Photographs were taken at strategic points throughout the inventoried portions of the streams, and coded for future reference. In addition, any obvious erosion or stream blockages were noted for mapping. A Level II Reach Field Form was developed for the Darby Creek, and a Watershed Data Summary Sheet for the parameters observed was completed for each reach. The result is a measured reach-stream classification Level II morphological description of the stream reaches for which Level II data have been collected.

The distribution of reaches measured was determined from the inventoried reach evaluation, the assessment of where problems are occurring, and the importance attached to the stream segment. A single assessment reach typically is not more than about 1,000 feet in length. An average of 5 reaches per stream mile were measured. Part of the classification includes estimation of the bankfull discharge. This was accomplished using the existing USGS discharge gauge information on the Darby Creek. The difference between the water surface elevation and the bankfull elevation was compared with the gauge information. Then, the elevation difference was added to the water surface elevation at the gauge to determine the bankfull stage elevation relative to the gauge staff. The bankfull discharge was then calculated using the gauge station data. Once the stage-discharge relationship was established, the recurrence interval for the bankfull stage was calculated, and the hydraulic geometry data for width, depth, velocity, and cross sectional area vs. stream discharge was calculated as shown in Figure III-1B.

Figure III-1B
Bankfull Channel Dimensions as a Function of Drainage Area
Piedmont Curve (USFWS March 2002)



For each measured reach, the following protocols were adhered to:

Channel Morphology (Rosgen)

One cross-sectional survey (by rod, measuring tape, and level) was performed at a representative crossover location that includes stream invert, maximum depth, bankfull depth, and flood prone level (enough stations to determine if the entrenchment is greater than 2.2 (Rosgen, 1996)). The stations within the cross-section included significant slope changes, and in no case were greater than 2 feet apart. An Excel spreadsheet program was used for entering and plotting the data and cross-section to scale. Each cross-section was marked in the field with labeled flagging, located approximately with global positioning system, and indicted on an area map.

Bankfull depth was determined through field visits and bankfull stage was calibrated to known streamflows from appropriate stream gauging stations. The bankfull stages field-calibrated at streams was plotted in order to build a database to refine the bankfull channel dimensions for ungauged areas within the stream.

In order to assure that the field teams produced consistent results, a modified Wolman Pebble Count for each channel material category (silt/clay, sand, gravel, cobble, boulders) found in the watershed was performed for two reaches. The FGM report is found in Appendix I, of Volume III, the Technical Appendix.

C. Topography and Streambed Profile

The topography of the watershed ranges from hilly terrain in the northwestern portion of the watershed to gently sloping areas throughout most of the central to southern end. The highest point in the watershed is in Tredyffrin Township with an elevation of 557 feet above sea level USGS datum. The lowest elevation, sea level, is found where Darby Creek enters the Delaware River between Ridley and Tinicum Townships and in the large wetland area (John Heinz National Wildlife Refuge at Tinicum) in the southeastern portion of the watershed, near the Philadelphia Airport. The Digital Elevation Model (DEM) for the watershed is displayed in Figure III-2.

D. Soils

There are three generalized soil groups in the Darby-Cobbs watershed as listed below: Generalized soils are groups of soils that exhibit a regularly repeating pattern. The distribution of the three associations in Darby-Cobbs watershed is shown in Figure III-3. The descriptions were derived from the USDA STATSGO state-wide NRCS soils database.

1. **Neshaminy-Lehigh-Glenelg -** The Neshaminy-Lehigh-Glenelg soil association is found in the northwest portion of the watershed. This association consists of moderately deep and deep, well-drained, silty, channery, and gravelly soils on grabbro and granodiorite.

2. **Chester-Glenelg-Manor -** The Chester-Glenelg-Manor soil association is found throughout the watershed except for the southern portion. This association consists of shallow to deep, silty and channery soils on grayish-brown schist and gneiss.

3. **Urban Land-Westbrook-Pits** - The Urban Land-Westbrook-Pits soil association is found in the southern portion of the watershed. This association consists of deep, silty or sandy soils on coastal plain sediments. Urban land and pits are areas that have been highly disturbed.

Soil permeability of the Darby-Cobbs watershed is shown in Figure III-4. The soil permeability is derived from the digital County soils files developed by the NRCS, and represent vertical water movement, when the soil is saturated, and does not consider lateral seepage. Permeability estimates are based upon soil characteristics such as soil structure, porosity, and gradient or texture, which influences the downward movement of water in soil. Soil permeability is measured at rates in inches per hour and classified as follows: *very slow* (less than 0.06 inches/hr); *slow* (0.06 to 0.20 inches/hr); *moderately slow* (0.20 to 0.60 inches/hr); *moderate* (0.60 to 2.0 inches/hr); *moderately rapid* (2.0 to 6.0 inches/hr); *rapid* (6.0 to 20.0 inches/hr); and *very rapid* (more than 20.0 inches/hr). These rates vary based upon soil layer, or depth below the surface. The soil permeability rate mapped in Figure III-4 was derived from the difference between the highest permeability rate (PERMH) and the lowest permeability rate (PERML) for the third soil layer, which can range from 15 to 64 inches below the surface, where most infiltration structures would be constructed. Compaction of soils by construction equipment reduces permeability (Ocean County Soil Conservation District, 2001).

Figure III-5 shows erodible soils in the watershed. The erodibility hazard indicates the level of erosion controls necessary when disturbing soils for development, wood harvesting or agriculture. Slight, moderate and severe indicate the degree of major soil limitations to be considered in management. A slight rating indicates that the risk of soil erosion is low, rating of moderate indicates that erosion control are necessary during earth disturbance activities, and a rating of severe indicates that erosion potential is a severe hazard when disturbing these soils. Approximately 53% of the area within the Darby-Cobbs watershed is classified as slightly erodible soils. Several erodible soils are found in the middle portion the watershed along Darby and Cobbs Creeks and their tributaries. Moderately erodible soils are usually found connected to severe erodible soils. Around 40% of the area in the watershed is classified as Urban Land/ Made Land and their erodibilty cannot be determined.

Figure III-2 Digital Elevation Model

See Maps Appendix

Figure III-2 Digital Elevation Model

See Maps Appendix

Figure III-3 Soil Associations

See Maps Appendix

Figure III-3 Soil Associations

See Maps Appendix

Figure III-4 Permeability

See Maps Appendix

Figure III-4 Permeability

See Maps Appendix

Figure III-5 Erodible Soils

See Maps Appendix

Figure III-5 Erodible Soils

See Maps Appendix

Soil properties influence the runoff generation process. The USDA, Natural Resources Conservation Service (NRCS) has established a criterion determining how soils will affect runoff by placing all soils into four Hydrologic Soil Groups (HSGs) – A through D, based on infiltration rate and depth. Hydrologic soil group A characteristics are found sporadically throughout the Darby-Cobbs watershed. Group B soils are found along Darby Creek in terraces and floodplains. Group B is characterized as having moderate infiltration rates, and it consists primarily of moderately deep to deep, moderately well to well drained soils that exhibit a moderate rate of water transmission. Group C soils have slow infiltration rates when thoroughly wetted and contain fragipans, a layer that impedes downward movement of water and produces a slow rate of water transmission. Found throughout the watershed, D soils that are tight, low permeable soils with high runoff potential and are typically clay soils. This information was incorporated into the GIS and, from this, the watershed HSG map was developed as shown in Figure III-6.

Figure III-6: Hydrologic Soil Groups

See Maps Appendix

Figure III-6: Hydrologic Soil Groups

See Maps Appendix

E. Geology

Geology plays a direct role in surface runoff in Darby-Cobbs watershed because it affects its soil types within the watershed through parent material breakdown. There is no limestone surface geology in the Darby-Cobbs watershed and therefore the presence of limestone sinkholes does not exist. The geologic map of the watershed can be found in Figure III-7. Below is a description of geologic formations in the watershed.

1. **Bryn Mawr Formation -** High level terrace deposits; reddish brown gravelly sand and some silt.

2. **Felsic Gneiss, Hornblende bearing -** Light, medium grained; includes rocks of probable sedimentary origin.

3. **Felsic Gneiss, Pyroxene bearing-** Light, medium grained; includes rocks of probable sedimentary origin.

4. **Granite Gneiss and Granite -** Includes Springfield Granodiorite (granitized Wissahickon).

5. **Mafic Gneiss, Hornblende bearing -** Dark, medium grained; includes rocks of probable sedimentary origin.

6. **Mafic Gneiss, Pyroxene bearing -** Dark, medium grained; includes rocks of probable sedimentary origin.

7. **Pensauken and Bridgeton Formation -** Undifferentiated-Dark-reddish-brown, cross stratified, feldspathic quartz sand and some thin beds of fine gravel and rare layers of clay or silt.

8. **Serpentine -** Includes serpentine, steatite, and other products of alteration of peridotites and pyroxenites.

9. **Trenton Gravel-** Gray or pale reddish brown, very gravelly sand interstratified with crossbedded sand and clay-silt beds.

10. **Wissahickon Formation (Albite-Chlorite Schist) -** Includes "Octoraro Schist"-phyllite, some horneblende gneiss, and granitized members.

11. **Wissahickon Formation (Oligioclase Mica Schist) -** Includes some horneblende gneiss, some augen gneiss, and some quartz-rich and feldspar-rich members due to various degrees of granitization.

Figure III-7 Geology

See Maps Appendix

Figure III-7 Geology

See Maps Appendix

F. Climate

The Darby-Cobbs watershed has a fairly moderate, humid, continental climate. Winters are comparatively short and mild while the warm season is long and frequently humid. In the summer, the relative humidity drops to 35 to 45 percent during the afternoons, but the average relative humidity for the year is generally higher than 65 percent. About two-thirds of the times, skies are clear to partly cloudy, and the average amount of sunshine is about 57 percent of the possible amount. Storms are generally numerous enough that they insure an adequate and dependable supply of moisture throughout the year.

The watershed is near the path of the major weather systems that move across the nation; therefore, the weather is variable. Changes in the temperature, the velocity of the wind, the humidity, and other weather elements tend to occur from day to day and from week to week, and seasonal weather varies from year to year. During winter and spring, changes occur almost daily. During summer and fall, changes are less frequent because the high and low pressure systems that are responsible for the weather move more slowly in these seasons than they do in winter and spring.

From June through October, the weather remains approximately the same for a week or more at a time. Hot humid days and mild nights generally result when a pressure system remains stagnant for several days in the summer. Cool nights are typical when a pressure system remains stagnant for several days in the fall. Several of these spells can be expected in most years, though extreme heat is noticeably absent in some summers. During winter and spring, unseasonably cold spells last for only a few days because the weather systems move more rapidly than in summer and fall.

G. Land Use

The Darby-Cobbs watershed has a long history of settlement and urbanization dating back to the early 17th century. The landscapes of the watershed vary from suburbanized to highly urbanized. While much of the eastern portion of the Cobbs Creek subwatershed lies within the City of Philadelphia, most of the larger Darby-Cobbs watershed falls primarily within the City's inner-ring suburbs of Delaware County, and to a lesser extent Chester and Montgomery Counties. Generally speaking, the central to lower portions of the watershed can be characterized as densely developed with a high degree of urbanization. Most of the central to upper portions of the watershed can be characterized as suburbanized and/or rapidly suburbanizing.

Redevelopment and infill development activities are common throughout the older urbanized areas of the watershed. The limited number of areas that remain open (i.e., large estates and stream valleys at the northern end of the watershed) are experiencing intense development pressure. The natural flow and course of Darby Creek and its tributaries have been significantly altered over the years. Many tributaries in the more urbanized portions of the watershed have been channelized, piped, stabilized, dredged, etc., resulting in little or no natural drainage pattern in many parts of the watershed. There are a significant number of man-made obstructions including old mills/dams and highway and railroad bridges that contribute to the alteration of natural stream flow. Much of the watershed is extensively paved and is served by storm sewer systems that discharge directly into streams with few if any quantity or quality controls. With the exception of Cobbs Creek Park and a few protected areas along tributaries at the top of the watershed, a great deal of development has taken place right up to the edge of the stream bank. This allows for little or no room for conventional riparian buffers to manage stormwater or protect the stream from water quality impacts.

As noted previously, there is intense pressure to develop the few open areas that remain in the northern reaches of the watershed (as evidenced by pressure to develop the Haverford State Hospital site in Haverford Township). Fortunately for the watershed, there are two areas, each at opposite ends of the watershed, which can be considered permanently protected. At the top of the watershed, along the Chester and Delaware County border, approximately 172 acres known as the Waterloo Mills Preserve have been donated to and will be permanently protected and managed by the Brandywine Conservancy. The Conservancy also holds easements on an additional 186.6 acres at the top of the watershed, mostly in Chester County.

At the bottom of the watershed lies the John Heinz National Wildlife Refuge at Tinicum, the largest remaining freshwater tidal marsh in the state. While the Waterloo Mills Preserve is fortunate enough to be located at the headwaters (where it can influence water quality in the watershed), this refuge is at the bottom of the watershed, making it the recipient of all of the water quantity and quality problems that have accumulated along the lengths of Darby and Cobbs Creeks before they enter the refuge as Darby Creek.

The majority of the municipalities within the watershed are urban in nature and largely developed. The predominant land use in the watershed is classified as residential (61%). Approximately 11% of the watershed is undeveloped land (forest or meadow) and 10% is classified as open space (parks, cemeteries, golf courses, etc.). The remaining land is mostly classified as commercial, industrial and institutional. A total of 2.45% of the watershed lands is classified as “paved” and includes the two interstate highways, portions of the Philadelphia Airport and a few large parking areas. This percentage does not include other smaller roads or driveways.

Figure III-8 displays the existing land use of the watershed while Table III-2 details the land uses by category within the Darby-Cobbs watershed.

In summary, the watershed is primarily developed with large areas that have mixed commercial, residential, and industrial uses. Parts of Chester and Delaware Counties still have some forestland and agriculture (cash and forage crops, pasture, and orchards). The watershed is sited within the inner-ring suburbs of Philadelphia. Therefore, any open land in this area is being developed at an incredible rate.

Figure III- 8 Existing Land Use

See Maps Appendix

Figure III- 8 Existing Land Use

TABLE III-2
Land Use Status by Category

LAND USE	SQUARE MILES	ACRES	PERCENT AREA
Commercial	5.43	3475.20	7.03
Farmstead	0.02	12.80	0.03
Forest	5.07	3244.80	6.56
Industrial	1.71	1094.40	2.21
Institutional	3.90	2496.00	5.05
Loose Gravel	0.01	6.40	0.01
Meadow	3.13	2003.20	4.05
Open Space	7.54	4825.60	9.76
Paved	1.89	1209.60	2.45
Residential (1 - 4 acre lots size)	8.60	5504.00	11.13
Residential (1/3 – 1 acre lot size)	10.18	6515.20	13.18
Residential (1/8 – 1/3 acre lot size)	14.83	9491.20	19.20
Residential (1/8 acre or less lot size)	13.65	8736.00	17.67
Water	1.28	819.20	1.66
TOTAL	**77.24**	**49433.60**	**100.00**

Source: Borton-Lawson Engineering, Inc. 2004

H. Land Development Patterns

There is little undeveloped land in the watershed. Zoning maps were used, along with input from the Delaware County Planning Department and Chester and Montgomery County Planning Commissions, to describe the future land development/growth pattern for the watershed over the next 10 years. The majority (approximately 83%) of new development is expected to be residential. Future land use patterns in Philadelphia were estimated by examining the small pockets of undeveloped areas in aerial photographs and then making assumptions about whether these pockets of undeveloped area are likely to be developed in the same manner as the immediately surrounding areas.

The majority of this residential development (approximately 42%) is expected to be single-family dwellings with lot sizes greater than one acre. This type of development is expected to occur in the upper portion of the watershed in Easttown Township in Chester County, Haverford Township, Marple Township, Newtown Township, and Radnor Township in Delaware County, and Lower Merion Township in Montgomery County. The second largest development impact (approximately 23.5%) is from smaller residential lot development, less than 1/8 acre in lot size, and includes townhouses and apartment complexes which is expected to occur in most parts of the watershed. Commercial development accounts for about 11.4 % of the future predicted development within the watershed and is expected to occur primarily near the major road corridors, such as I-476 and Route 3 in Marple Township, Tinicum and Radnor Townships, Upper

Darby Township and Millbourne Borough in Delaware County, and Easttown Township in Chester County. Industrial development accounts for about 4.5 % of the future predicted development primarily in Tinicum Township and spread in the northeastern portion of the watershed in Delaware County.

Table III-3 provides an overview of projected development based on a future land use scenario developed through the use of zoning maps, the comprehensive plan, and by developing land usegrowth trends. The future land use map for the year 2010 projection is shown in Figure III-9. These increased impervious areas were then included in the U.S. Army Corps of Engineers, Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) to develop future condition flows for the 2, 5, 10, 25, 50 and 100-year storms. A comparison of peak flows for the 100-year storm for future and existing conditions can be found in Table III-4.

The future 100-year storm hydrograph peak was found to be an average of ***101.3%*** of the present 100-year storm hydrograph on Darby Creek above the confluence with Cobbs Creek and an average 100.9% on Cobbs Creek above the confluence with Darby Creek. Table III-4 summarizes the flows for each subwatershed for existing conditions and for the 2010 future land use projection, assuming proper stormwater management facilities are not installed.

Other storm frequencies can be found in Volume III, Technical Appendix. Increased development in a watershed increases runoff peaks, volumes and velocities. This decreases the time to peak, worsening the frequency of flooding.

TABLE III-3
Development Potential by Municipality
Based Upon Existing Patterns in the Darby and Cobbs Watershed

Municipality	R-4	R-3	R-2	R-1	I	C	OS	F
Aldan Borough	--	--	--	--	--	--	--	--
City of Philadelphia	O	--	--	--	O	--	r	--
Clifton Heights Borough	O	--	--	O	--	--	--	--
Collingdale Borough	--	O	--	--	X	--	--	r
Colwyn Borough	O	--	--	--	X	--	r	--
Darby Borough	O	O	O	--	X	--	r	r
Darby Township	O	O	--	--	O	--	r	r
East Lansdowne Borough	--	--	--	--	--	--	--	--
Easttown Township	X	O	O	X	--	O	r	r
Folcroft Borough	O	O	--	--	O	O	r	r
Glenolden Borough	--	O	O	--	--	--	--	r
Haverford Township	O	--	O	O	O	--	r	r
Lansdowne Borough	O	--	O	--	--	O	r	r
Lower Merion Township	X	--	O	O	--	--	r	r
Marple Township	--	--	O	O	--	--	--	r
Millbourne Borough	--	--	--	--	--	X	r	--
Morton Borough	--	--	--	--	--	--	--	--
Narberth Borough	O	O	O	X	--	--	r	r
Newtown Township	--	--	O	O	--	--	r	r
Norwood Borough	--	--	--	--	--	--	--	--
Prospect Park Borough	O	O	O	O	--	--	r	r
Radnor Township	--	--	O	O	--	--	--	r
Ridley Township	O	--	--	O	X	--	r	r
Ridley Park Borough	O	O	--	--	--	O	r	--
Rutledge Borough	--	--	--	--	--	--	--	--
Sharon Hill Borough	O	O	--	--	O	--	r	r
Springfield Township	X	--	--	--	--	--	--	r
Tinicum Township	--	--	--	--	O	--	r	--
Tredyffrin Township	O	--	O	--	--	O	r	r
Upper Darby Township	O	--	O	--	--	O	--	r
Yeadon Borough	O	--	O	--	--	O	r	r

R-4	Residential Lots (1/8 acre or less)	---	No Impact
R-3	Residential Lots (1/4 ac. - 1/3 ac)	O	Minor Impact
R-2	Residential Lots (1/2 ac. - 1 ac.)	X	Major Impact
R-1	Residential Lots (greater than 1 acre)	r	Reduction in Land Use

I	Industrial
C	Commercial
OS	Open Space
F	Forest

Source: Borton-Lawson Engineering, Inc. 2004

Figure III- 9: Future Land Use

See Maps Appendix

Figure III- 9: Future Land Use

See Maps Appendix

TABLE III-4
Present (Existing) Versus Future Combined Peak Flows –
100-Year 24-Hour Storm
(Please refer to Appendix A of the Model Ordinance for Subarea Locations)

Subarea No.	Subarea Area (sq. mi.)	Cumulative Area (sq. mi.)	Existing Peak Q (cfs)	Future Peak Q (cfs)
1	0.55	0.55	631	642
2	0.30	0.85	915	927
3	0.29	0.29	354	360
4	0.18	1.32	1,377	1,393
5	0.66	0.66	655	691
6	0.12	2.10	2,274	2,314
7	0.48	0.48	402	432
8	0.05	2.63	2,270	2,312
9	1.50	1.50	1,383	1,534
10	0.55	4.68	3,807	3,857
11	0.50	0.50	516	516
12	1.05	6.22	4,512	4,583
13	0.31	6.53	4,578	4,657
14	0.68	0.68	482	482
15	0.01	7.22	4,930	5,036
16	2.02	2.02	1,353	1,354
17	0.67	0.67	507	512
18	0.12	2.80	1,847	1,851
19	0.32	0.32	246	246
20	0.16	3.28	2,058	2,063
21	0.32	0.32	268	268
22	0.02	3.61	2,197	2,203
23	0.03	10.86	7,285	7,456
24	0.55	0.55	349	349
25	0.02	0.57	335	335
26	0.03	11.46	7,287	7,457
27	0.31	0.31	273	273
28	0.54	12.31	7,546	7,735
29	0.23	0.23	179	179
30	0.54	13.09	7,701	7,896
31	1.50	1.50	762	764
32	1.41	15.99	8,879	9,090
33	0.37	0.37	369	369

TABLE III-4 (Cont.)
Present (Existing)Versus Future Combined Peak Flows –
100-Year 24-Hour Storm
(Please refer to Appendix A of the Model Ordinance for Subarea Locations)

Subarea No.	Subarea Area (sq. mi.)	Cumulative Area (sq. mi.)	Existing Peak Q (cfs)	Future Peak Q (cfs)
34	0.30	0.30	422	422
35	0.48	1.15	1.198	1.199
36	0.21	0.21	224	224
37	1.32	1.32	879	880
38	0.05	2.73	2.123	2.125
39	0.14	0.14	159	159
40	0.69	3.57	2.476	2.478
41	0.49	0.49	350	350
42	0.79	4.85	3.173	3.177
43	0.59	0.59	509	514
44	0.75	0.75	661	664
45	1.05	2.39	1.782	1.797
46	0.12	7.37	4.852	4.866
47	2.95	26.31	13.090	13.358
48	1.42	1.42	1.012	1.012
49	1.42	29.15	13.545	13.794
50	1.11	1.11	928	928
51	0.10	30.36	13.693	13.940
52	1.36	31.73	13.832	14.073
53	1.32	1.32	827	827
54	4.42	37.47	14.921	15.132
55	2.12	39.59	14.931	15.122
56	4.64	4.64	1.906	1.924
57	1.99	6.63	2.817	2.842
58	0.56	0.56	761	774
59	0.42	0.98	1.246	1.264
60	0.68	1.66	1.747	1.815
61	1.93	1.93	1.262	1.290
62	0.33	3.92	2.926	3.024
63	1.43	11.97	5.280	5.364
64	1.13	1.13	984	984
65	2.03	3.16	2.178	2.178
66	1.52	4.67	3.168	3.168

TABLE III-4 (Cont.)
Present (Existing) Versus Future Combined Peak Flows –
100-Year 24-Hour Storm

Subarea No.	Subarea Area (sq. mi.)	Cumulative Area (sq. mi.)	Existing Peak Q (cfs)	Future Peak Q (cfs)
67	3.73	20.38	10,226	10,325
68	1.10	1.10	851	851
69	0.27	21.75	10,733	10,838
70	0.42	22.17	10,798	10,893
71	1.00	1.00	780	799
72	0.74	1.74	1,317	1,348
73	3.33	66.82	18,563	18,714
74	2.12	2.12	1,281	1,289
75	0.76	0.76	663	670
76	0.62	3.51	2,124	2,137
77	0.81	4.32	2,406	2,419
78	2.87	74.01	19,030	19,163
79	0.59	0.59	502	522
80	0.22	0.22	236	240
81	0.22	1.03	859	891
82	0.33	0.33	323	323
83	0.10	0.44	396	396
84	0.78	2.24	1,862	1,891
85	0.71	2.95	2,317	2,338
86	0.16	77.13	19,002	19,134

Note: The computed flow values were derived for watershed planning purposes and should not be considered regulatory values for permitting purposes. While they may be used for comparison or checking purposes, additional hydrologic computations may be needed for the design of bridges, culverts and dams.

Source: Borton-Lawson Engineering, Inc. 2004

I. Present (Existing) and Projected Development in the Flood Hazard Areas

The U.S. Department of Housing and Urban Development, Federal Insurance Administration, Federal Emergency Management Agency (FEMA) prepares Flood Insurance Studies (FISs) and floodplain mapping for the municipalities in the Darby-Cobbs watershed. This activity is now a responsibility of the U.S. Department of Homeland Security. Municipalities and the Pennsylvania Department of Community and Economic Development (PADCED) should be contacted as to the latest FIS studies before use.

There are two types of studies conducted in the FIS program: detailed and approximate. Detailed methods included hydrologic computations and detailed HEC-2 or HEC-RAS backwater computations. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction. Areas studied by the approximate methods were areas having low development potential or minimal flood hazards.

Figure III-10 shows the 100-year floodplains classified as detailed and approximate as taken from the FEMA mapping for the Darby-Cobbs watershed. Encroachments of residential, industrial, and commercial land uses are shown by overlaying these areas on the floodplain in the GIS. Approximately 5,236 acres (10.6%) of the watershed are within floodplains. Of these 5,236 acres, 2,092 are developed. The remainder is forest, meadow, open space or water. Table III-5 provides a summary of the total amount of developed floodplain area.

Table III -5
Summary of the Total Amount of Developed Floodplain Area

Existing Land Use	Acres in Floodplain	Square Miles in Floodplain
Commercial	261.9	0.41
Farmstead	0.30	0.00
Industrial	299.1	0.47
Institutional	66.8	0.10
Paved	587.7	0.92
R1	205.3	0.32
R2	191.7	0.30
R3	234.5	0.37
R4	244.7	0.38
TOTAL	**2092.0**	**3.27**

Source: Borton-Lawson Engineering, Inc. 2004

The overall evaluation of the municipal questionnaires which were received shows several occurrences of stream flooding throughout the watershed during major storm events, resulting in both private and public property damages, as can be seen in Table III-5 and Figures III-10 and III-11.

Figure III-10: Development in Floodplains

See Maps Appendix

Figure III-10: Development in Floodplains

See Maps Appendix

Figure III-11: Overbank Flooding – Darby Creek, Borough of Darby

These problems were very evident on September 16, 1999 when Hurricane Floyd hit the east coast. Many areas across Pennsylvania received up to 12 inches of rain. According to newspaper accounts, Upper Darby Township received 7 inches of rain that flooded the banks of Darby Creek. Forty-three houses along Darby Creek were termed uninhabitable. These homes are in the designated floodplain. The area hit the hardest was that of the 1200, 1300, and 1400 blocks of Chestnut Street in Darby Borough. Two homes were also destroyed on Creek Avenue. All of the 43 homeowners agreed to sell to the Borough. Several other property owners who experienced severe flooding also agreed to sell. Most of the flooding was likely due to encroachments onto floodplain areas and undersized storm drainage systems. A large number of these stormwater related problems have also been traced back to uncontrolled runoff from local and upstream areas, inadequate storm drainage systems, and obstructions in the system that are blocking the natural flow of stormwater.

Stormwater management planning is critical in the areas both affected and currently unaffected by stormwater problems in the Darby-Cobbs watershed. For areas which are currently being affected, the frequency of flooding is mainly during larger storm events. The Act 167 plan can significantly address future more frequent flooding problems in these areas by managing runoff from newly developing areas. This plan shall also provide these communities with information essential in evaluating and upgrading current undersized stormwater systems as indicated in Section III-J. For areas currently unaffected by stormwater problems, the Act 167 plan shall provide controls on future development to aid in preventing future stormwater runoff problems.

One of the biggest problems in floodplain management is the increase in peak flow caused by development in the watershed. Recognizing this, the Natural Flood Insurance Program (NFIP) has developed a Community Rating System (CRS) to give communities credit for floodplain management activities that exceed the minimum requirements. As part of this rating system, credit points can be awarded to communities if they implement the following:

- regulatory language (ordinance) requiring peak rate of runoff from development to be no greater than the pre-development runoff.
- a stormwater master plan (such as this Act 167 Plan)
- state review of the stormwater management plan
- requirement for a building's lowest floor to be elevated above flood levels
- erosion and sediment control regulations (such as Chapter 102)
- water quality regulations

The more credits a community can accumulate, the less its residents will have to pay for flood insurance. For further information on the community rating system, the publication *"CRS Credit for Stormwater Management,"* July 1996, published by FEMA, is available at the County Planning office.

J. Obstructions

Locations of significant waterway obstructions (i.e., culverts, bridges, etc.) were obtained by inspection of the United States Geologic Survey (USGS) topographic base map. Data on these obstructions was then obtained from the Pennsylvania Department of Transportation (PADOT), FEMA Flood Insurance Studies, and field surveys.

The obstruction flow capacities were then compared to the peak flow at that point derived through the modeling process for each design storm frequency. The obstructions were then classified into seven categories as follows:

- Those obstructions which are able to pass the 100-year, 24-hour storm without obstructing the flow.

- Those obstructions which are able to pass the 50-year, 24-hour storm and greater without obstructing the flow.

- Those obstructions which are able to pass the 25-year, 24-hour storm and greater without obstructing the flow.

- Those obstructions which are able to pass the 10-year, 24-hour storm and greater without obstructing the flow.

- Those obstructions which are able to pass the 5-year, 24-hour storm and greater without obstructing the flow.

- Those obstructions which are able to pass the 2-year, 24-hour storm and greater without obstructing the flow.

- Those obstructions which are NOT able to pass the 2-year, 24-hour storm and greater without obstructing the flow.

The locations of all obstructions, including those that fall into the seven categories above, can be found in Figure III-12. The obtained data and the obstruction flow capacities can be found in the Technical Appendix.

During the field work phase of this project, project team members noted that there were large numbers of pipes and culverts either in disrepair or clogged to a point that the flow capacity of the pipe was reduced or completely blocked. It is recommended that municipalities take advantage of the data collected and shown in Figure III-12 to rank which culverts may need repair. A program should be established by the municipalities to maintain unobstructed flow on all culverts and bridges.

K. Existing Drainage Problems and Proposed Solutions

Information on drainage problems and proposed solutions was solicited from each municipality within the Darby-Cobbs watershed by providing forms to each Watershed Plan Advisory Committee (WPAC) member early in the Watershed Plan study.

Problems were discussed at the WPAC meetings and were varied, ranging from regional flooding to minor, local in nature, consisting of mostly clogged or undersized inlets and cross pipes.

The recorded stormwater related problems were analyzed to determine if they were caused by localized (i.e., inadequately sized storm sewers) or regional (i.e., stream overbank flooding) sources. As can be seen in Figure III-11, the problems identified can be classified generally into one of these two classes. One is those directly related to or adjacent to the stream, an indication of a regional or watershed-wide problem. The other problem areas are most likely caused by a localized situation, inadequately sized storm water conveyance systems, sedimentation, or uncontrolled local runoff.

Table III-6 summarizes the problems discussed. These are shown graphically in Figure III-13 (Problem Areas). Solutions have been proposed both formally and informally because of WPAC discussions.

Three hundred and forty nine (349) problem areas were identified in this study, including several types of problems. The type, cause, and occurrence of these problems are indicated on Table III-6. The categories selected in Table III-6 typically have similar causes and solutions that are discussed below.

Figure III-12: Obstructions

See Maps Appendix

Figure III-12: Obstructions

See Maps Appendix

Figure III-13: Problem Areas

See Maps Appendix

Figure III-13: Problem Areas

See Maps Appendix

TABLE III-6
Darby and Cobbs Creeks Watershed Problems

MUNICIPALTIY	TYPE OF PROBLEMS (A)	CAUSE OF PROBLEMS (B)	OCCURANCES OF PROBLEMS (C)	TYPES OF DAMAGES (D)
Aldan Borough	1	1,2,3,4	1	
City of Philadelphia	*			
Clifton Heights Borough	N/A			
Collingdale Borough	1,6	1,2,3	1,2	
Colwyn Borough	1,2,6	1,2,3,4	1,2	3
Darby Borough	1,2,3,4,6,7	1,2,4,5	1,2	2,3
Darby Township	1,2,6	1,2,3,4	1	3
East Lansdowne Borough	N/A			
Easttown Township	1,2,3,6	1,2,3,4	1,3	3
Folcroft Borough	1,7	1,2,3,4	2	3
Glenolden Borough	*			
Haverford Township	N/A			
Lansdowne Borough	1,2,3,6	1,2,3,4	1,2	3
Lower Merion Township	1,2,3,5	1,2,3,4,5	1,2	3
Marple Township	*			
Millbourne Borough	2,3	1,2,4	3	3
Morton Borough	1,2,3	1,2,3,4	1,2	3
Narberth Borough	1	1	2	3
Newtown Township	7	1,2,3	1	3
Norwood Borough	1,2,3	5	1,3	3
Prospect Park Borough	1,3	1,2,3,4	1,2	
Radnor Township	1,2,3,6	1,2	1,2	3
Ridley Township	1,2,3,6	1,2,3,4	1,2	3
Ridley Park Borough	N/A			
Rutledge Borough	1	1,2,3	1	3
Sharon Hill Borough	1,2	1,2	1	3
Springfield Township	1,2,3,6	1,2,3,4,5	1,2	3
Tinicum Township	1,2,3	1,2,4	1	3
Tredyffrin Township	N/A			
Upper Darby Township	1,6	1,5	1,2	3
Yeadon Borough	1,2,3,6,7	5	2,3	3

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

Types of Problems
(A)
1. Flooding
2. Accelerated Erosion
3. Sedimentation
4. Landslide
5. Groundwater
6. Water Pollution
7. Other

Causes of Problems
(B)
1. Stormwater Volume
2. Stormwater Velocity
3. Stormwater Direction
4. Water Obstruction
5. Other

Occurrences of Problems
(C)
1. > 1 time per year
2. < 1 time per year
3. Only major flood events

Types of Damages
(D)
1. Loss of life
2. Loss of vital services
3. Property damage

Source: Borton-Lawson Engineering, Inc. 2004

Erosion and Sedimentation (E & S)

The Chester, Montgomery, and Delaware County Conservation Districts and the City of Philadelphia are responsible for administering PA Title 25, Chapter 102 (Erosion Control Regulations). These regulations address accelerated erosion and the resulting sedimentation from earthmoving activities. Permanent stabilization of exposed areas and proper stabilization of channels of conveyance will reduce erosion problems.

Storm Sewers, Culverts, and Outlets

Some of the problems identified in Table III-6 are the result of inadequately sized storm culverts, and/or unstable outlets that traverse state, township, or private roads. The typical solution involves performing a hydrologic study to determine pipe size and replacing the pipe with a properly sized unit. Costs are typically borne by the owner of the road.

Bridges

Because of the high bedloads of streams within the watershed, gravel deposits reduce the waterway opening which in turn threatens bridge conveyance capacity. The proposed solution typically involves performing a hydrologic study and increasing the hydraulic capacity underneath the roadway. Costs are typically borne by the owner of the bridge.

Flooding

As discussed in Section III-I, Darby Creek and its tributaries have caused flooding conditions in the Darby-Cobbs watershed. The areas within the watershed immediately adjacent to Darby Creek and various low lying wetland areas are generally subject to minor flooding after rain or thaw conditions. Flooding in the watershed can be classified into two categories: 1) local flooding caused by inadequately sized storm culverts; and 2) flooding caused by the location of structures within the floodplain of the major tributaries. Of the sites identified in Table III-6, most are caused by inadequate conveyance systems in developed areas; however, for instance the flooding in Darby Borough is caused by overbank flooding.

L. Existing and Proposed Stormwater Collection Systems

Based on the information in the data collection forms, supplied by the municipalities through the survey, stormwater collection systems in the Darby-Cobbs watershed are located in the southwestern part of the watershed near Morton Borough and Ridley Township. In Colwyn Borough also has stormwater collection system. There are no proposed storm water collection systems for the next ten years known at this time.

M. Existing and Proposed State, Federal and Local Flood Control Projects

Several agents including U. S. Army Corps of Engineers, Delaware River Basin Commission (DRBC), and the Pennsylvania Department of Environmental Protection (DEP) have studied the problems and proposed solutions for flood control, and streambank erosion control at Springfield and Upper Darby Townships, and Lansdowne and Darby Boroughs within the Darby-Cobbs watershed in the 70's and early 80's. An environmental report related to flood control and a recreation project in Darby Creek and Cobbs Creek Watershed was prepared by U. S. Army Corps of Engineers in early 1970. According to the information collected using data collection forms that were submitted by the municipalities in the Darby-Cobbs watershed, there are various existing flood control projects in the lower middle portion of the watershed. Dam and bioengineering stream bank stabilization has been found in Darby Borough along Darby Creek. Upper Darby Township, in the vicinity of Naylor's Run, has several gabion dams and trash rack dams for the 25-year designed flood frequency. In Ridley Township, impoundment and channel widening/rip rap control projects are found. Morton Borough has a concrete lining flood control project, and Marple Township has 100 lineal feet of rip-rap for control of the 100-year flood frequency control. Several flood control projects were proposed in Darby Creek by Darby Borough and Morton Borough. Morton Borough has proposed a channel excavation/widening flood control project in the watershed while Darby Borough has finished a preliminary phase study of stream bank stabilization projects along Darby Creek.

N. Existing and Proposed Stormwater Control Facilities

There are many known private stormwater control facilities as shown in Figure III-14. The cost, design, capacity, construction and operation of these private facilities cannot be projected at this time since they occur on a case by case basis as a developer buys land, submits plans, and develops the tract. Typically, the cost of such facilities is paid through the developer's financing with costs transferred to the buyer.

As part of the modeling effort, an investigation was made into the hydrologic impacts which existing stormwater control facilities have on current watershed flows. A field visit was performed to collect information on several stormwater management facilities within the Darby-Cobbs watershed, such as size, drainage area and outlet control configurations. Since information on all stormwater control facilities within the watershed could not be collected due to site access constraints or lack of structure information, it was decided to use a representative site, and then extrapolate the impacts of the site stormwater control facilities to the watershed. The representative site for this investigation was the Harrison Estate's residential subdivision in Newtown Township (Subareas 12 and 17). This site contains four large stormwater control basins which control approximately 68 acres of drainage area, or approximately 0.14%, of the total Darby-Cobbs watershed. Table III-7 shows that the basins have minimal impact on the 25- year and 100- year flows on Darby Creek at a point immediately above the confluence with Cobbs Creek. Since no major impacts on watershed flows were noted due to these large basins, it is unlikely that the smaller basins would have any significant impact on watershed flows.

Figure III-14: Flood and Stormwater Facilities

See Maps Appendix

Figure III-14: Flood and Stormwater Facilities

See Maps Appendix

TABLE III-7
Harrison Estate Detention Basins
Impacts of Watershed Flows

Flow Frequency (yrs)	Flow Without Basins (cfs)	Flow With Basins (cfs)	% Change
2	2.674	2.675	0.00 %
25	9.503	9.501	0.00 %
100	14.931	14.932	0.00 %

Source: Borton-Lawson Engineering, Inc. 2004

There are 15 known dams in the Darby-Cobbs watershed, according to PADEP records. The majority (11) of these dams are classified as small impoundments, which have little impact on watershed hydrology. The four (4) larger dams within the watershed were included in the hydrologic model and are listed in Table III-8 below, along with their attenuation impacts and maximum storage volume for the 100- year storm event.

TABLE III-8
Darby and Cobbs Dams
100-Year Flow Attenuation

			100- Year Flow (cfs)		Maximum Storage Volume
Lake	**DEP ID**	**Subarea**	**Into Dam**	**Out of Dam**	**(acre-ft)**
Devon Detention Basin	D15-327	5	655	645	15.5
Earles Lake	D23-036	24	349	330	51.3
Knox Road Detention Basin	D46-303	58	761	745	8.2
Remington Road Detention Basin	D46-265	59	1,246	1,244	23.7

*Storage above normal pool volume

Source: Borton-Lawson Engineering, Inc. 2004

O. Wetlands

Wetlands were obtained from the National Wetlands Inventory Maps in digital format and incorporated into the overall GIS. Figure III-15 shows the wetlands for the watershed.

Wetlands play an important part in flood flow attenuation and pollutant filtering. Wetlands within the watershed are primarily found along Darby Creek's overbanks and in the lower portion of the watershed within the John Heinz National Wildlife Refuge. Wetland flood flow attenuation was accounted for in the computer modeling by adjusting the stream routing time, or stream velocities, for overbank events. Wetlands should be preserved through the joint permit application process.

Figure III-15: Wetlands

See Maps Appendix

Figure III-15: Wetlands

See Maps Appendix

P. Outfalls

Mapping and documenting storm water outfalls is one of the six municipal control measures (MCMs) categories itemized in the PADEP MS4 Stormwater Management Program Protocol to meet the requirements of the NPDES Phase II program. The objective is to detect and eliminate illicit discharges from municipal storm sewers.

The municipalities within the watershed were tasked with locating the storm sewer outfall locations and completing an outfall information form (Form O). Information to be entered on the form included a unique identifier for the outfall, the receiving water, the municipality, basic structural information and observations that may indicate illicit discharges (colors, odors, etc.).

Maps showing the outfall locations and the forms with the outfall information were provided to Borton-Lawson in both hard copy and digital formats. Not all municipalities submitted data. Borton-Lawson created a point shape file for each municipality showing the location of the outfalls within the watershed and compiled all the outfall information into Excel spreadsheets. The individual municipal shape files were merged into a single watershed-wide shape file and the individual spreadsheets were compiled into a single master spreadsheet.

The master spreadsheet and watershed-wide outfall shape file were then linked to create a single GIS layer representing storm sewer outfall information in the watershed. Over 600 outfalls were identified and mapped and labeled. Figures III-16A through III-16E show the outfall locations and IDs at a readable scale. Springfield Township supplied a Microstation file (stormswr.dgn) and an Access database (stormsewer.mdb) of storm sewers. The database did not distinguish outfalls but they are included in the overall stormwater appurtenances. (See Appendix D of the Technical Appendices).

Figure III-16A: Outfalls

See Maps Appendix

Figure III-16A: Outfalls

See Maps Appendix

Figure III-16B: Outfalls

See Maps Appendix

Figure III-16B: Outfalls

See Maps Appendix

Figure III-16C: Outfalls

See Maps Appendix

Figure III-16C: Outfalls

See Maps Appendix

Figure III-16D: Outfalls

See Maps Appendix

Figure III-16D: Outfalls

See Maps Appendix

Figure III-16E: Outfalls

See Maps Appendix

Figure III-16E: Outfalls

See Maps Appendix

SECTION IV

WATERSHED TECHNICAL ANALYSIS

A. Watershed Modeling

An initial step in the preparation of this stormwater management plan was the selection of a stormwater simulation model to be utilized. It was necessary to select a model which:

- Modeled design storms of various durations and frequencies to produce routed hydrographs which could be combined.
- Was adaptable to the size of subwatersheds in this study.
- Could evaluate specific physical characteristics of the rainfall-runoff process.
- Did not require an excessive amount of input data yet yielded reliable results.

The model decided upon was the U. S. Army Corps of Engineers, Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) for the following reasons:

- It had been developed at the Hydrologic Engineering Center specifically for the analysis of the timing of surface flow contributions to peak rates at various locations in a watershed.
- Although originally developed as an urban runoff simulation model, data requirements make it easily adaptable to a rural situation.
- Input parameters provide a flexible calibration process.
- It has the ability to analyze reservoir or detention basin routing effects and location in the watershed.
- It is accepted by the Pennsylvania Department of Environmental Protection.

Although other models, such as TR-20, may provide essentially the same results as the HEC-HMS, HMS's ability to compare subwatershed contributions in a peak flow presentation table make it specifically attractive for this study. The HEC-HMS Model generates runoff flows for selected subareas along the drainage course and compares subarea contributions to the total runoff. The model generates runoff quantities for a specified design storm based upon the physical characteristics of the subarea, and routes the runoff flow through the drainage system in relation to the hydraulic characteristics of the stream. The amount of runoff generated from each subarea is a function of its slope, soil type or permeability, percent of the subwatershed that is developed, and its vegetative cover. Composite runoff curve numbers were generated by overlaying the land use map with the subarea and hydrologic soil group maps. The generated curve numbers were then used for input into the computer model. Figure IV-1 displays the subarea delineation for Darby-Cobbs Creek watershed on digital USGS Quadrangles or digital raster graphics (DRG's).

B. Modeling Process

After delineating the Darby-Cobbs Creek watershed on the USGS topographic map, the watersheds were divided into subwatersheds for modeling purposes. The main considerations in the subdivision process were the location of obstructions problem areas, and tributary confluences. The most downstream point of each of these areas is considered a "point of interest" where increased runoff must be analyzed for its potential impact.

The reason points of interest are selected is to provide watershed runoff control through effective control of individual subarea runoff. Thus, control of stormwater runoff in the entire watershed can be achieved through stormwater management in each subbasin.

The watersheds were then modeled to determine the hydrologic response for the 1, 2, 5, 10, 25, 50, and 100-year for the 24-hour storm events. The results are shown in Volume III, Technical Appendix available at the County Office.

The modeling process addressed:

- peak discharge values at various locations along the stream and its tributaries;
- time to peak for the above discharges;
- runoff contributions of individual subareas at selected downstream locations; and
- overall watershed timing.

C. Calibration

In order to simulate storm flows for a watershed with confidence and reliability, the computer model must first be calibrated. This involves "fine tuning" the model to provide the most accurate representation of the real runoff and timing conditions of a watershed. Calibration of a model involves the adjustment of input parameters (within acceptable value ranges) to reproduce the recorded response of storm events.

When actual storm event data is available (i.e. stream flow and rain gauge data), this information can be input into the model and simulated "hydrographs" developed by the model. Hydrographs are simply a plot of time versus flow in cubic feet per second. To simulate a specific event, antecedent moisture conditions and rainfall distribution must be duplicated in the model input. Adjustments to other parameters are then made to attempt to duplicate hydrograph shapes and peak flow rates at points in the watershed where flow recordings were made. In order to utilize actual stream flow and rain gauge data for

Figure IV-1 – Subareas

See Maps Appendix

Figure IV-1 – Subareas

See Maps Appendix

calibration, sufficient data must be available. Rain gauges must be in close proximity to the watershed so that actual rainfall conditions from these gauges are representative of the actual rainfall that occurs over the watershed. Localized events, snowmelt, and unique conditions are typically not used for calibration due to their unique circumstances.

In order to maximize the accuracy of the HEC-HMS model, the model was calibrated effort was undertaken. At several essential points in the watershed, HEC-HMS generated flows were compared to historic event discharges from USGS gauge data and developed from available regression models typically used in the estimation of design storm peak flow on large watershed.

FEMA Flood Insurance Studies were also referenced in areas where detailed floodplain information was available. FIS cross-sections were referenced for Manning's values, channel capacities, and channel and overbank velocities. Certain areas were field verified.

There are several potential calibration parameters within HEC-HMS. These include initial abstraction, surface roughness, subbasin time of concentration, runoff curve number, and hydrograph routing velocity and travel time. Several runs were performed for sensitivity analyses of each of these parameters. From these runs, it was determined that the initial rainfall abstraction and subarea travel time, were the most sensitive parameters. These numbers could be revised with confidence, while remaining within an acceptable range of values, for similar soil and sloped subareas, to arrive at flow values from the gauge data.

Historic Storm Calibration Results

In order to calibrate the watershed model against historic storm events, streamflow data was collected from USGS at six available stream gauges (Table IV-1) within the Darby-Cobbs watershed. This data was analyzed to select events which could be modeled using the HEC-HMS model. Typically, events which are results of isolated thunderstorm, snowmelt or a combination of rainfall/snowmelt are not ideal for modeling since many factors, other than rainfall can affect results.

TABLE IV-1
USGS Stream Gauges within the
Darby – Cobbs Creek Watershed

USGS Gauge No.:	Location	Period of Record
01475300	Darby Creek At Waterloo Mills Near Devon, Pa.	1972-97
01475510	Darby Creek Near Darby, Pa	1964-90
01475530	Cobbs Cr At U.S. Highway No. 1 At Philadelphia, Pa	1965-80
01475550	Cobbs Creek At Darby, Pa	1964-90
01475560	Muckinipattis Creek At Glenolden, Pa	1975-86
01475660	Stony Creek At Prospect Park, Pa	1975-86

Accurate rainfall data is also critical to historic event modeling. Since rainfall patterns can vary greatly throughout a watershed area, it is desirable to have many rainfall gauges located within the watershed boundary to accurately model a given storm event. However for the Darby-Cobbs Creek watershed, no rainfall gauges were located within the watershed boundary. Several gauges were located outside of the Darby-Cobbs Creek watershed boundary, within a 30-mile radius of the watershed. Rainfall data from these gauges were collected and reviewed along with the streamflow data in order to select historical events for modeling. The final list of selected events is listed in Table IV-2 along with the recorded peak flow. This table also compares the results of the hydrologic model simulation of these events.

TABLE IV-2
Comparison of Recorded Peak Flows
To Calibrated Model Flows for Selected Events

	Flow Location			
Storm Event	Darby Creek near Darby		Cobbs Creek at Darby	
Date	Recorded Flow	Model Flow	Recorded Flow	Model Flow
July 1984	4,084	4,166	3,940	3,383
April 1984	2,570	2,374	2,040	1,592
September 1985	2,080	2,073	2,540	2,844
December 1986	2,510	2,617	2,270	2,754

Figures IV-2 and IV-3 show a comparison of the recorded hydrographs for the December 1986 storm event to the hydrographs developed by the HEC-HMS model of the Darby-Cobbs Creek watershed. Results of this model showed very good overall results of peak flow, time of peak and runoff volume when compared to the actual recorded events. Additional plots comparing results of the model for the other historical events can be found in Volume III, Technical Appendix.

FIGURE IV-2
Hydrographics Comparison – December, 1986 Event and HEC-HMS model output at Cobbs Creek at Darby, PA

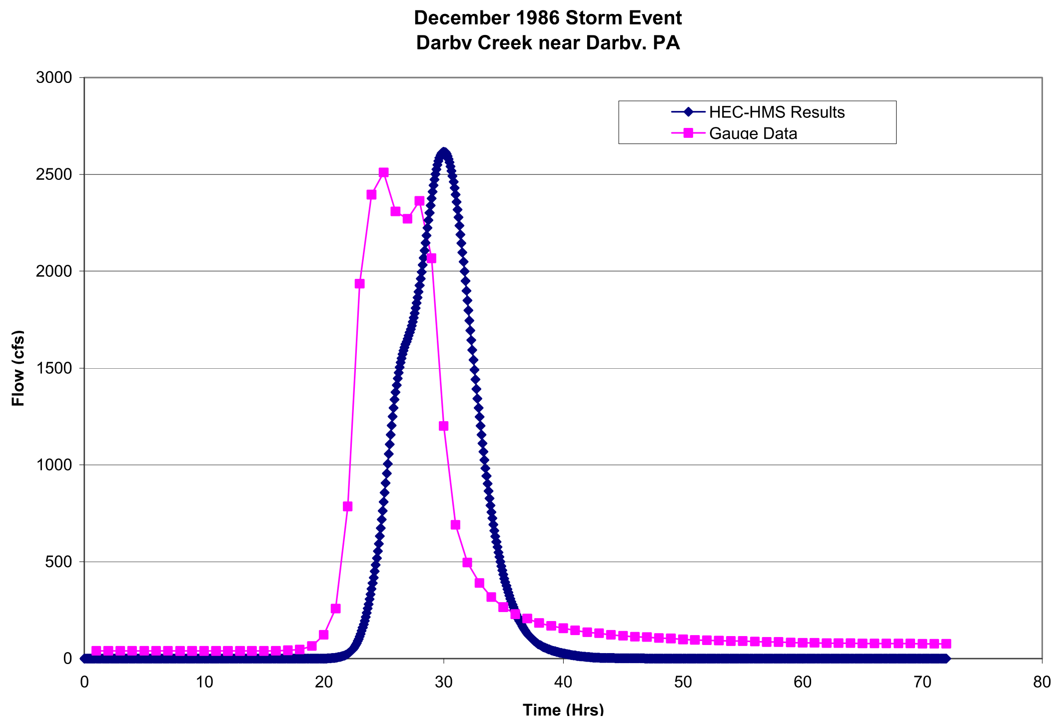
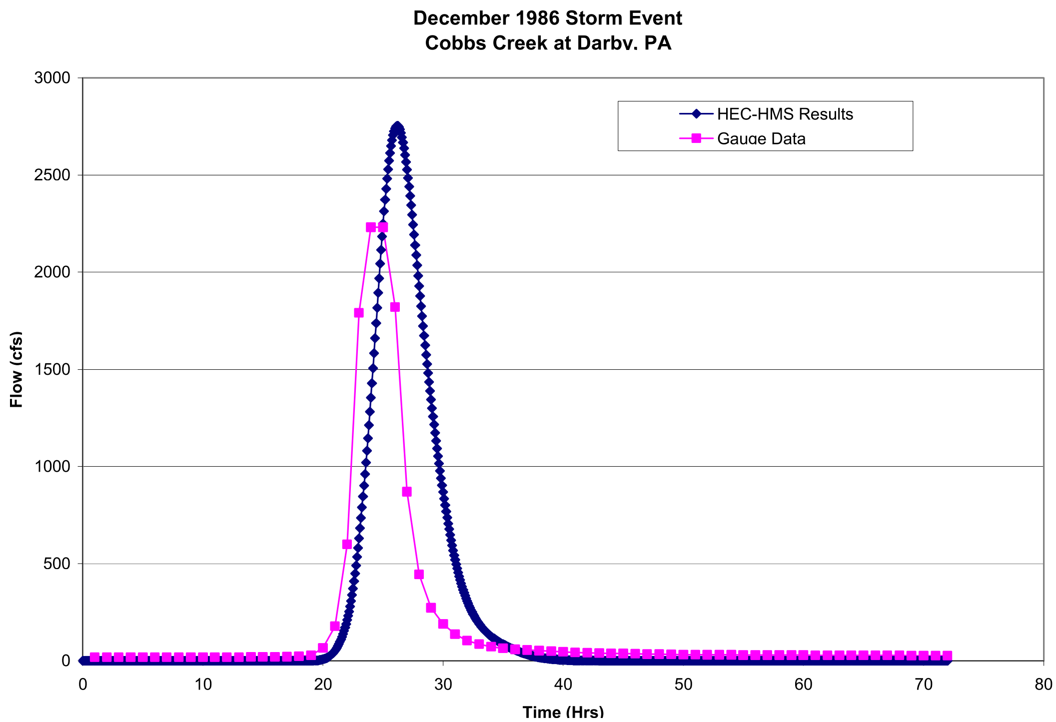


FIGURE IV-3
Hydrographics Comparison – December, 1986 Event and HEC-HMS model output at Darby Creek near Darby, PA



Design Storm Calibration Results

In order to calibrate to develop design event flood flows, the 2-, 10- and 100- year design storms were analyzed to compare HEC-HMS generated flow to flows developed by the regression models as well as in the available FEMA Flood Insurance Studies.

Figures IV-4 through IV-6 show results of the peak flow values developed by the calibrated HEC-HMS model compared to predicted flow values determined from several regression methods at various locations throughout the Darby-Cobbs Creek watershed. Table IV-4 compares the calibrated HEC-HMS model to flood flow values determined by FEMA at several locations throughout the watershed. It should be noted that regression methods oftentimes do not account for localized variables such as soils and topography. Therefore, on a subwatershed basis, the results may vary.

FIGURE IV-4 2-Year Calibrated Model Comparison

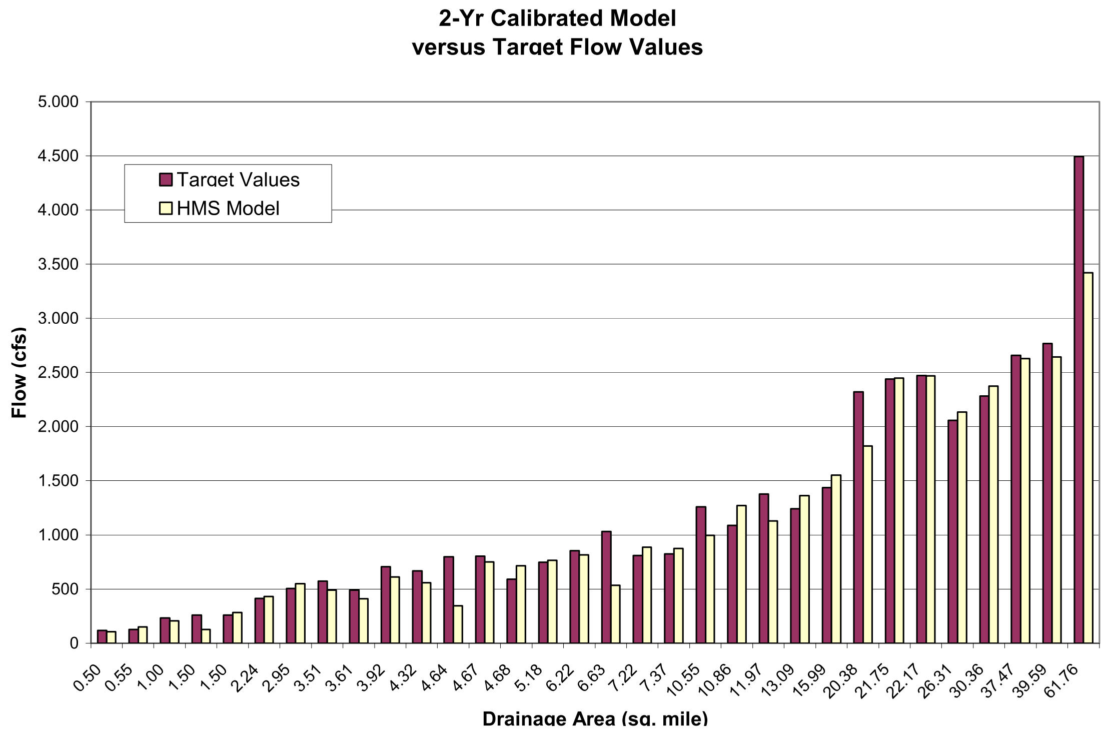


FIGURE IV-5 10-Year Calibrated Model Comparison

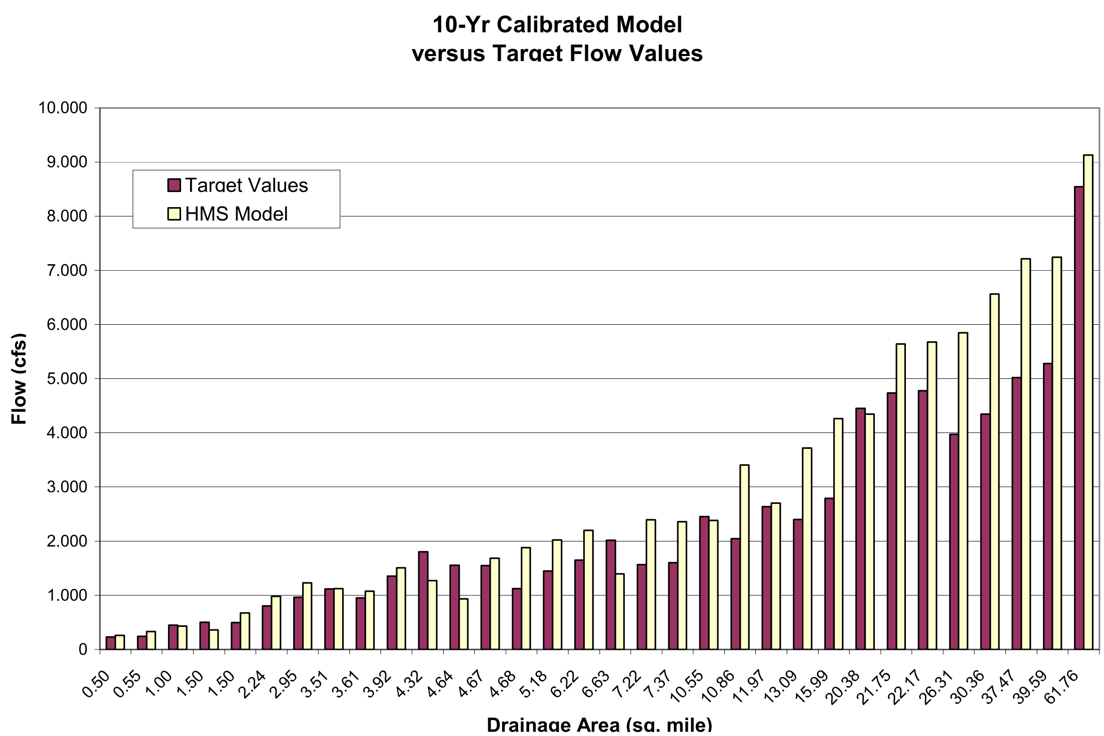


FIGURE IV-6 100-Year Calibrated Model Comparison

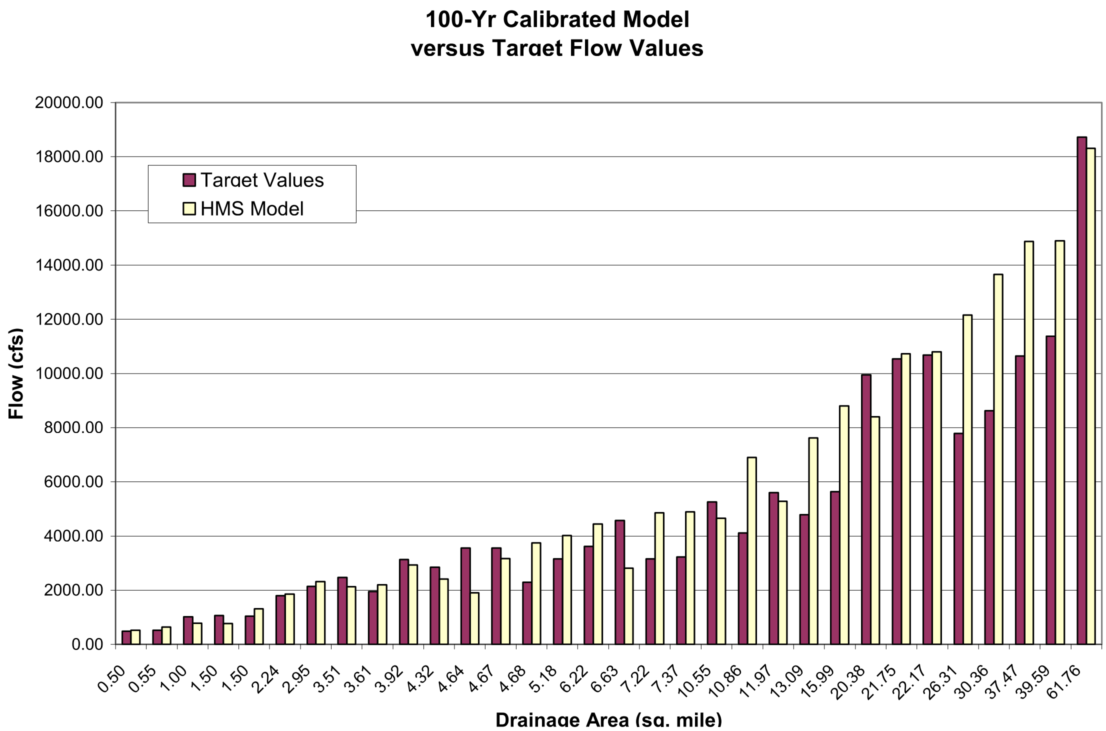


TABLE IV-3
Comparison of Calibrated Model To
100- Year FEMA Flow Values

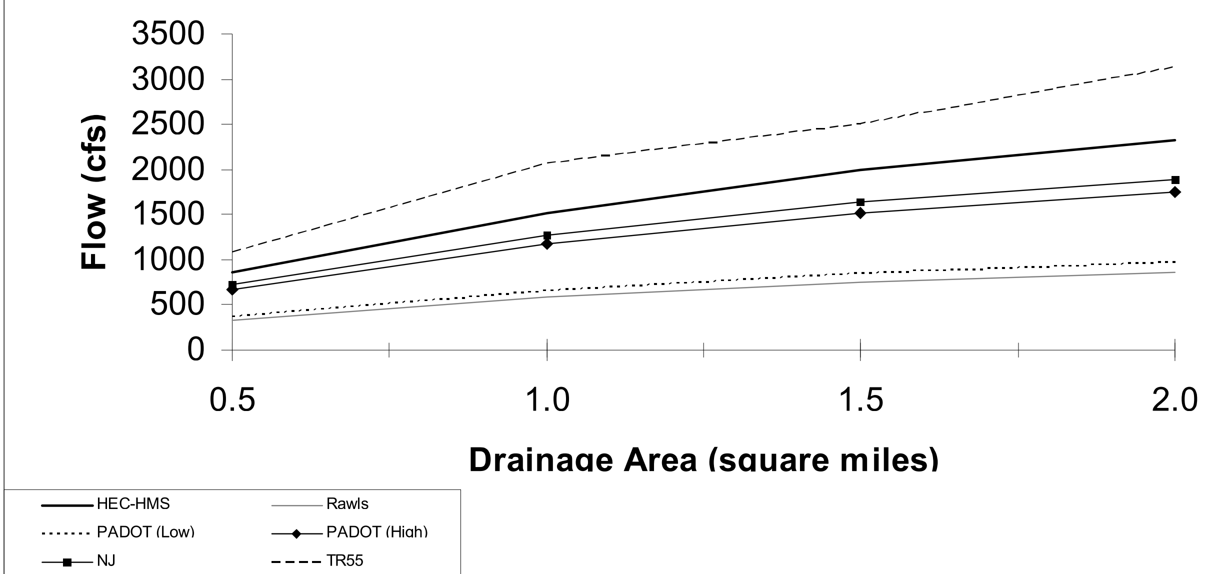
Subarea No.	Drainage Area (sq. miles)	FEMA Flows (cfs)	Calibrated Model Flows (cfs)
13	6.50	4.100	4.578
23	3.60	2.450	2.197
31	1.30	1000	762
32	15.00	8.100	8.879
55	39.70	17.000	14.931
66	4.50	3.000	3.168
67	16.90	8.400	8.403
70	22.00	11.200	10.798
71	1.00	640	780
78	2.90	1.650	2.317

D. Hydrologic Method Comparison

The calibrated model was run under different scenarios to compare the results obtained by the model with the results from various other calculation methodologies. This evaluation was conducted to determine the applicability of other engineering methods in generating stormwater flows within the watershed. These other methods, which included the S.C.S. Tabular Method and the Rational Method, were analyzed for watershed areas from 0.5 to 2.0 square miles. For the Rational Method, various sources of Rational "C" coefficients were referenced. Results for these methods were then compared with results generated from runs on the calibrated HEC-HMS model. Figure IV-7 summarized these comparisons.

Results from this comparison show that either the curve number method or Rational Method could be used in determining pre- and post-development runoff peak rates. These results are valid when using the SCS curve numbers and Rational "C" values specified the New Jersey Department of Transportation (1984), (given in Ordinance Appendix B).

Figure IV-7
Hydrologic Method Comparison



SECTION V

STANDARDS AND CRITERIA FOR STORMWATER CONTROL

A. Watershed Level Control Philosophy

An increase in development, and in turn, an increase in impervious surfaces, results not only in an increase in runoff peaks but also in runoff volume. The primary difference between on-site runoff control philosophy and the watershed level philosophy is the manner in which runoff volume is managed. Conventional on-site control philosophy has as its goal the control of runoff peaks from the site. There are numerous volume controls that can be implemented on-site such as infiltration basins, porous pavement, etc. The proposed watershed level runoff control philosophy seeks to manage the increase in runoff volumes such that the peak rates of runoff throughout the watershed are not increased. The basic goal is therefore the same for both on-site and watershed level philosophies.

B. National Pollutant Discharge Elimination System (NPDES) Phase II Requirement

Federal regulations approved in October 1999 required operators of small municipal separate storm sewer systems (MS4s) to obtain NPDES Phase II permits from DEP by March 2003. This program affects all municipalities in "urbanized areas" of the state. This definition applies to all Darby-Cobbs watershed municipalities as listed in Section III, Table III-1. Therefore, all municipalities within the Darby-Cobbs watershed are subject to the NPDES Phase II requirements mandated by the Federal Clean Water Act.

Municipalities required to implement the MS4 program must address the following six minimum control measures (MCM's):

- Public Education and Outreach
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Storm Water Runoff Control
- Post-Construction Storm Water Management in New Development & Redevelopment
- Pollution Prevention/Good Housekeeping for Municipal Operations

At a minimum, municipal entities regulated under MS4 *must:*

- Specify BMPs and implement them to the "maximum extent practicable"
- Identify measurable goals for control measures
- Develop an implementation schedule of activities or frequency of activities, and
- Define the entity responsible for implementation

The affected municipalities must, if they already do not have one in place, develop a stormwater management program. If a municipality has an established stormwater management program, and is subject to the provisions of the Phase II Rule, then provisions of the rule must be implemented to satisfy the federal requirements. Applicable information concerning some of the specifics of this permitting program can be found in Appendix 2 of this plan.

Adoption of the Darby-Cobbs Watershed Stormwater Management Plan and model ordinance provisions will satisfy the four basic requirements noted above and, at a minimum, one of the six required elements of the NPDES II program, specifically, post-construction stormwater management in new development and redevelopment.

The NPDES program has no exemption criteria; thus, all projects within regulated municipalities will be required to comply with the additional water quality and quantity measures of the regulations. The exemption criterion of the model ordinance (see Section V.L of this plan for further details and Section 105 of the model ordinance for specific exemption language) requires water quality control regardless of project size.

For example, if an activity meets the water quantity exemption criterion of the model ordinance, the applicant would still be required to implement specified minimum BMPs to satisfy the water quality objectives of the stormwater management plan. This applicant would not need to submit the formal drainage plan, but would need to indicate to the municipal Engineer the type of BMP being used. In this way, municipalities adopting the model ordinance provisions will be able to show compliance with one or more of the required elements of the NPDES II regulations.

C. Standards and Criteria – Five Phased Approach

The goal of Act 167 and this stormwater management plan is to encourage planning and management of stormwater runoff that is consistent with sound water and land use practices. In addition, the Act authorized a comprehensive stormwater management program designated to preserve and restore flood carrying capacities of streams, preserve to the maximum extent practical natural stormwater runoff regimes and the natural course, current and cross sections of streams, and to protect and conserve ground waters and groundwater recharge areas. Maintaining the existing hydrologic regime for newly developing areas in the watershed and restoring the previously functioning hydrologic regime in redeveloping areas of the watershed is the best means to accomplish this goal. The technical standards and criteria developed as a part of this task will be watershed-wide in their interpretation and/or application. To strive towards achieving this goal, and to address streambank erosion, flooding, water quality, groundwater recharge, and stormwater management measures on development sites should consider the following five (5) objectives noted in Figure V-1:

- Maintain groundwater recharge

- Maintain or improve water quality
- Reduce channel erosion
- Manage overbank flood events
- Manage extreme flood events

Recommended standards and criteria accommodate various types of land development activities. The standards and criteria provide management practices for the implementation of stormwater control measures.

The standards and criteria also addresses the following:

a. Identification of all areas within the watershed where different criteria apply;

b. Recommended Stormwater Management Districts to manage accelerated runoff from the subareas identified in item a;

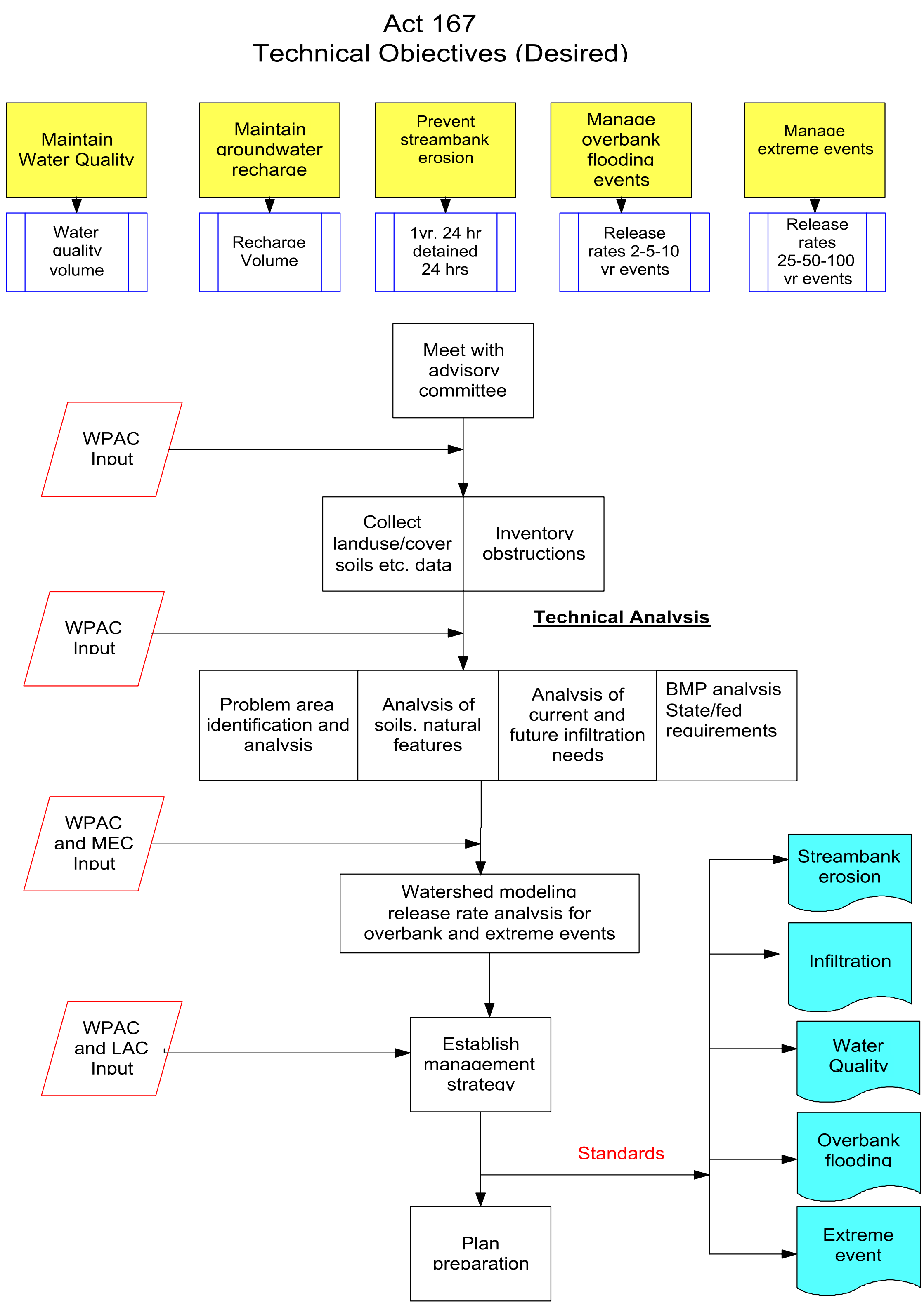
c. Recommended design flood frequencies and computational methodologies for stormwater management measures;

d. A list of recommended alternate stormwater collection and control measures;

e. Specifications for construction and maintenance of stormwater systems;

f. Safety requirements for stormwater systems during and after construction;

FIGURE V-1
Process Utilized Analyzing Five Comprehensive Management Objectives



1. Groundwater Recharge

Recharging rainfall into the ground replenishes the groundwater that provides baseflow to streams, (a process that keeps streams flowing during the drier summer months), and maintains groundwater for drinking water purposes. As development occurs and the impervious area increases, less rainfall reaches the groundwater systems resulting in lower base flows and smaller groundwater supplies. It has also been found that streambank capacities are equivalent to approximately the 1½ year storm, and streambanks begin to erode when flows approximate this depth, a term called critical velocity.

Although detention basins can reduce the proposed conditions peak rate of flow to the existing conditions rate, the increased volume of runoff still gets passed downstream unless special provisions are designed into the basin to recharge this increase in runoff volume.

Thus in highly developed watersheds, it is not uncommon to see dry streams along with severely depleted groundwater drinking supplies during periods of drought. Stormwater management measures such as porous pavement with underground infiltration beds and infiltration/recharge structures or Best Management Practices (BMPs) can be designed to promote groundwater recharge. These measures are encouraged, particularly in hydrologic soil groups A and B and should be utilized wherever feasible.

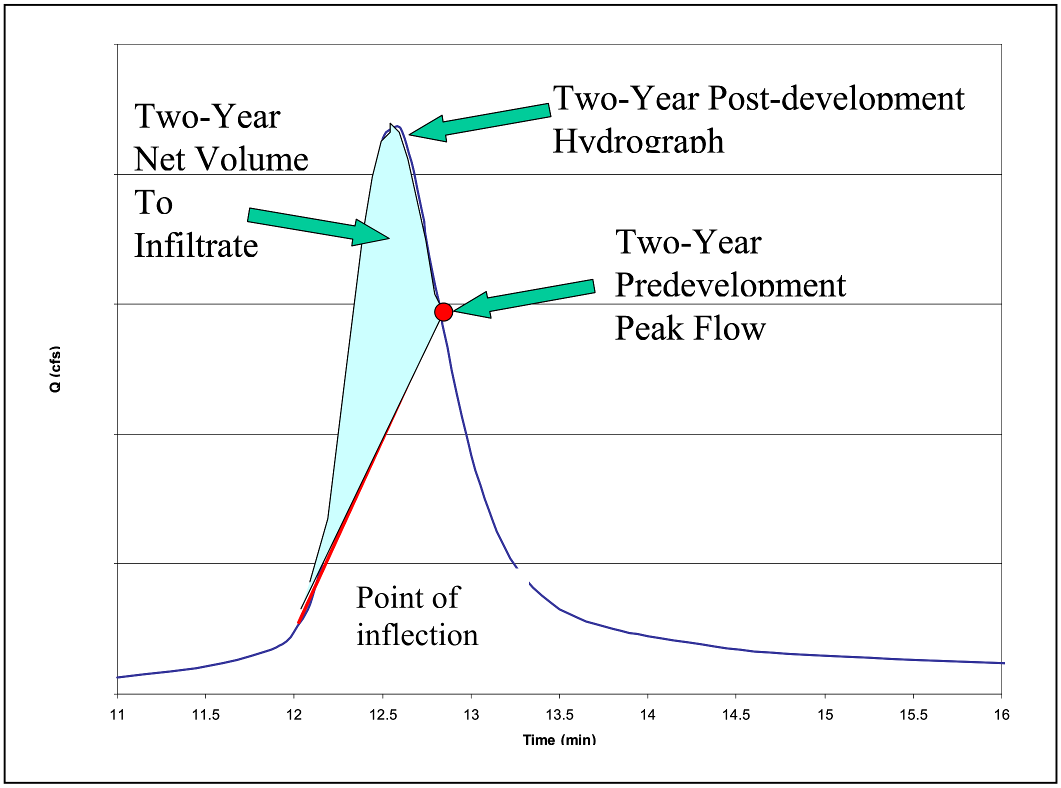
It is realized, however, that due to certain soils and topographic conditions, recharge may not be feasible on every site. It will be up to the design professional, therefore, to show that this cannot be *physically* accomplished. If it can be physically accomplished, then the volume of runoff to be infiltrated shall be determined from the following criteria.

Size of the Infiltration Facility

The size of the infiltration facility shall be based upon the following volume criteria:

a. Net Two Year Volume Approach - In High Quality or Exceptional Value (HQ/EV) Watersheds, the retention (infiltration) volume (Re_v) volume to be captured and infiltrated shall be the net 2 year-volume approach. The net 2-year volume shall determined by plotting the 2-year project site post-development hydrograph, drawing a straight line from the point-of-inflection of the rising limb of the hydrograph to the predevelopment 2-year storm and measuring the volume under the curve as shown in Figure V-2.

FIGURE V-2
Infiltration Hydrograph



b. One Inch from Impervious Surface - In other portions of the watershed that are not classified as High Quality or Exceptional Value (HQ/EV), the retention (infiltration) volume (Re_v) will be equal to capturing one (1) inch of rainfall over all proposed impervious surface.

$$Re_v = I * \text{impervious area (square feet)} \div 12 \text{ (inches)} = \text{cubic feet (cf)}$$

An asterisk (*) in equations denotes multiplication.

c. Obtaining the Re_v volume as described. above may not be feasible on every site due to site-specific limitations such as soil type. If it cannot be physically accomplished, then the design professional shall be responsible to show that this cannot be physically accomplished. If it can not be physically accomplished, then the retention (infiltration) volume Rev required shall be as much as can be physically accomplished with a minimum of 0.50 inches depending on demonstrated site conditions. It has been determined that capturing and infiltrating 0.50 inches of runoff from the impervious areas will aid in maintaining the hydrologic regime (baseflow) of the watershed. If the goals of the Net Two Year Volume Approach nor the One Inch From Impervious Surface Approach can be met, then 0.50 inches of rainfall shall be retained and infiltrated from all impervious areas.

The minimum recharge volume (Re_v) required would therefore be computed as:

Re_v = I * impervious area (square feet) ÷ 12 (inches) = cubic feet (cf)

An asterisk (*) in equations denotes multiplication.

Where:

I = The maximum equivalent infiltration amount (inches) that the site can physically accept or 0.50 inches, whichever is greater.

The retention volume values derived from the above is the minimum volume the Applicant must control through an infiltration BMP facility. However, if a site has areas of soils where additional volume of retention volume can be achieved, the applicant is encouraged to infiltrate as much of the stormwater runoff from the site as possible.

If the minimum of 0.50 inches of infiltration requirement cannot be achieved, a waiver from Ordinance Section 405, Groundwater Recharge would be required from the Municipality.

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:

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 is not permitted to 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 retention (Re_v) volume based on field determined capacity at the level of the proposed infiltration surface.

d. If on-lot infiltration structures are proposed by the Applicant's design professional, it must be demonstrated to the municipality that the soils are conducive to infiltration on the lots identified.

Minimum Requirements for all Infiltration BMPs:

Infiltration BMPs shall meet the following minimum requirements:

a. Infiltration BMPs intended to receive runoff from developed areas shall be selected based on suitability of soils and site conditions. A detailed soils evaluation of the project site shall be required where practicable to determine the suitability of recharge facilities. The evaluation shall be performed by a qualified design professional, and at a minimum, address soil permeability, depth to bedrock and subgrade stability.

b. Infiltration BMPs shall be constructed on soils that have a minimum depth of 24 inches between the bottom of the facility and the seasonal high water table and/or bedrock (limiting zones)

c. Infiltration BMPs shall be constructed on soils that have an infiltration rate sufficient to accept the additional stormwater load and drain completely as determined by field tests conducted by the Owner's professional designer.

d. The Infiltration BMP shall be capable of completely infiltrating the recharge volume within 4 days (96 hours).

e. Pretreatment shall be provided prior to infiltration.

Designing the Infiltration BMP

Extreme caution shall be exercised where infiltration is proposed in geologically susceptible areas such as limestone. Extreme caution shall also be exercised along roadways and road salt storage areas where salt or chloride would be a pollutant since soils do little to filter these pollutants and they may contaminate the groundwater. The qualified design professional shall evaluate the possibility of groundwater contamination from the proposed infiltration/recharge facility and perform a hydrogeologic justification study if necessary. A detailed hydrogeologic investigation may be required by the municipality. The infiltration requirement in High Quality/Exceptional Value waters shall be subject to the Department's Chapter 93 Antidegradation Regulations. The municipality may require the installation of an impermeable liner in detention basins where the possibility of groundwater contamination exists.

Safeguards shall be provided against groundwater contamination for uses that may cause groundwater contamination from a mishap or spill. Extreme caution shall be exercised where infiltration is proposed in Source Water Protection Areas. Recharge/infiltration facilities should be used in conjunction with other innovative or traditional BMPs, stormwater control facilities, and nonstructural stormwater management alternatives. It is extremely important that strict erosion and sedimentation control measures be applied surrounding infiltration structures during installation to prevent the infiltrative surfaces from becoming clogged.

Stormwater Hotspots

If a proposed site is designated as a hotspot, as defined in Table V-1, 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. Therefore, the Re_v requirement shall NOT applied to development sites that fit into the hotspot category (the entire WQv must still be treated). Second, a greater level of stormwater treatment shall be considered at hotspot sites to prevent pollutant washoff after construction. EPA's NPDES stormwater program requires some industrial sites to prepare and implement a stormwater pollution prevention plan.

Table V-1 – Classification of Stormwater Hotspots	
• Vehicle salvage yards and recycling facilities	• Outdoor liquid container storage
• Vehicle fueling stations	• Outdoor loading/unloading facilities
• Vehicle service and maintenance facilities	• Public works storage areas
• Vehicle and equipment cleaning facilities	• Facilities that generate or store hazardous materials
• Fleet storage areas (bus, truck, etc.)	• Commercial container nursery
• Industrial sites (based on SIC codes outlined in the SPDES)	• Other land uses and activities as designated by an appropriate review authority
• Marinas (service and maintenance)	

Source: Borton-Lawson Engineering, Inc. 2004

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

- Residential streets and rural highways
- Residential development
- Institutional development
- Office developments
- Non-industrial rooftops
- Pervious areas, except golf courses and nurseries (which may need an Integrated Pest Management (IPM) Plan).

While large highways (average daily traffic volume (ADT) greater than 30,000) are not designated as a stormwater hotspot, 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 the 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. The qualified design professional shall evaluate the possibility of groundwater contamination from the proposed infiltration facility and perform a hydrogeologic justification study if necessary.

- The infiltration requirement in High Quality/Exceptional Value waters shall be subject to the Department's Chapter 93 Antidegradation Regulations.

- An impermeable liner will be required in detention basins where the possibility of groundwater contamination exists. A detailed hydrogeologic investigation may be required by the municipality.

The municipality shall require the Applicant to provide safeguards against groundwater contamination for uses which may cause groundwater contamination, should there be a mishap or spill.

2. Water Quality

Pollutants accumulate on impervious surfaces between rainfall events or during dry weather. Pollutant concentrations in runoff from developed land, therefore, tend to be greatest at the beginning of the storm event, or during the first one half (1/2) inch to one (1.0) inch of runoff, a phenomenon commonly known as the first flush. It has also been found that approximately eighty percent of the rainfall events are one half inch of rainfall or less, storms that essentially simulate this "first flush." The majority of the nonpoint source pollutants, therefore, are being washed into streams during this first flush. Capturing this first flush and smaller storms will, depending on the BMP design, allow the stormwater to be detained and will allow pollutants to settle out, allowing biological breakdown or uptake of these pollutants.

a. Water Quality Standards

The applicant shall comply with the following water quality requirements.

No regulated earth disturbance activities within the Municipality shall commence until approval by the Municipality of a plan which demonstrates compliance with State Water Quality Requirements post-construction is complete.

The BMPs shall be designed, implemented and maintained to meet State Water Quality Requirements, and any other more stringent requirements as determined by the Municipality.

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).

To achieve the water quality goal, the following criterion is established:

Developed areas will provide adequate storage and treatment facilities necessary to capture and treat stormwater runoff specifically for water quality purposes. The Recharge Volume computed when calculating the groundwater recharge/infiltration volume may be incorporated as a component of the Water Quality Volume (WQv). If the required Recharge Volume is less than the required Water Quality Volume, only that portion of the Water Quality Volume exceeding the recharge volume may be treated by methods other than recharge/infiltration BMPs.

The required Water Quality Volume (WQv) is the storage capacity needed to capture and to treat a portion of stormwater runoff from the developed areas of the site produced from 1 inch of rainfall. The following calculation formula is to be used to determine the water quality storage volume, (WQv), in acre-feet of storage for the Darby-Cobbs watershed:

$WQv=[(P)(Rv)(A)]/12$

Where:

WQv = Water Quality Volume (acre-feet)
P = 1 inch
A = Area of the project contributing to the water quality BMP (acres)
Rv = 0.05 + 0.009(I) where I is the percent of the area that is impervious surface (impervious surface/A)*100)

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 and shall follow the guidelines of the BMP manuals referenced in Ordinance Appendix G.

Release of water 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 which include Exceptional Value (EV) and High Quality (HQ) waters, the temperature and quality of water and streams shall be maintained through the use of temperature sensitive BMPs and stormwater conveyance systems.

To accomplish the above, the Applicant shall submit original and innovative designs to the municipal Engineer for review and approval. Such designs may achieve the water quality objectives through a combination of different BMPs.

Evidence of any necessary permit(s) for regulated earth disturbance activities from the appropriate DEP regional office must be provided to the Municipality. The issuance of an NPDES Construction Permit (or permit coverage under the statewide General Permit (PAG-2) satisfies the requirements of Ordinance Section 406.A. [*This requirement is optional*]

The WQv shall be utilized to size water quality BMPs. Design of these BMPs shall be in accordance with design specifications outlined in the *Pennsylvania Handbook of Best Management Practices for Developing Areas* or other applicable manuals. The following factors shall be considered when evaluating the suitability of BMPs used to control water quality at a given development site:

1. Total contributing drainage area.
2. Permeability and infiltration rate of the site soils.
3. Slope and depth to bedrock.
4. Seasonal high water table.
5. Proximity to building foundations and wellheads.
6. Erodibility of soils.
7. Land availability and configuration of the topography.
8. Peak discharge and required volume control.
9. Streambank erosion.
10. Efficiency of the BMPs to mitigate potential water quality problems.
11. The volume of runoff that will be effectively treated.
12. The nature of the pollutant being removed.
13. Maintenance requirements.
14. Creation/protection of aquatic and wildlife habitat.
15. Recreational value.
16. Enhancement of aesthetic and property value.

b. Buffers

Maintaining or restoring natural buffers has many storm water related benefits (see Table V-2) including aiding in groundwater recharge, improving water quality of runoff and protecting streambanks from erosion. Therefore, if a perennial or intermittent stream passes through the site, the applicant shall create a stream buffer extending 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 (Reference to Appendix H of Pennsylvania Handbook of Best Management Practices for Developing Area for plant lists). If the applicable rear or side yard setback is less than fifty (50) feet or a stream traverses a site, the buffer width may be reduced to twenty-five (25) percent of the setback and/or to a minimum of ten (10) feet. If an existing buffer is legally prescribed (i.e. deed, covenant, easement, etc.) and it exceeds the requirements of this Ordinance, the existing buffer shall be maintained. Note: The Municipality may select a smaller buffer width (above) if desired, but the selected buffer may not be less than ten (10) feet. This does not include lakes or wetlands.

TABLE V-2
Twenty Benefits Of Buffers

1. Reduce watershed impervious area.
2. Maintain distance from impervious cover.
3. Help prevents small drainage problems and complaints.
4. Stream "right-of-way" allows for lateral movement.
5. Land area may provide effective flood water storage.
6. Protection from streambank erosion.
7. Increase property values.
8. Increased pollutant removal.
9. Foundation for present or future greenways.
10. Provide food and habitat for wildlife.
11. Mitigate stream warming.
12. Protection of associated wetlands.
13. Prevent disturbance to steep slopes.
14. Preserve important terrestrial habitat.
15. Corridors for conservation.
16. Essential habitat for amphibians.
17. Fewer barriers to fish migration.
18. Discourage excessive storm drain enclosures/channel hardening.
19. Provide space for stormwater ponds.
20. Allowance for future restoration.

3. Streambank Erosion

Preservation of stream geomorphology is an important aspect of sustainable flood protection and water quality. A fluvial geomorphologic (FGM) survey had previously been conducted on the Cobbs Creek for the City of Philadelphia as part of their NPDES requirements. Therefore, an FGM assessment was also performed on the Darby Creek as part of this Act 167 Plan. The purpose of the FGM assessment was to integrate the fluvial geomorphologic assessment and associated stormwater quantity and quality control management strategy for the Darby-Cobbs Creeks which includes:

- Identifying the extent to which streambank erosion, sedimentation, and downstream water quality problems contribute to changes in stormwater flows (both volume and peak).
- Considering living resource protection through aquatic habitat preservation.
- Identifying changes in channel configuration in response to changes in stormwater runoff that might contribute to flooding problems in the future as the stream reaches a new equilibrium.
- Recommending effective and sustainable stream restoration measures.

The results of the FGM assessment, besides providing the framework for future stream restoration work, indicate that there are several streambank erosion problem areas along the entire length of the Darby Creek, from its headwaters in Easttown Township in Chester County to it's confluence with Cobbs Creek near the fall line in Sharon Hill Borough, Delaware County as shown in Figure III-13.

As storm flows increase, velocities in the stream also increase thus exacerbating streambank erosion problems. The greatest stream velocities and therefore, the greatest amount of streambank erosion typically occurs during near- bank full and bank full flow events. From the separate Darby Creek and Cobbs Creek FGM assessments, bank full flow has been found to equate to approximately the 1.5-year storm. Therefore, stream flows kept to below the 1.5- year storm flow, or near the one-year storm flow, would aide in minimizing streambank erosion. Furthermore, allowing this volume to discharge from the control facility over a minimum 24- hours would reduce discharge velocities during near bank full and bank full flows. Streambank erosion criteria based upon the above discussion were therefore incorporated into the standards and criteria and Model Ordinance (Section 407). Summarizing this criterion, Section 407 would require detaining the 2-year post-development storm to the one-year predevelopment storm and detaining the 1-year storm a minimum of 24 hours, thereby minimizing the number of storms causing streambank erosion. This same management criterion also improves the water quality from stormwater runoff. Therefore applying the groundwater recharge in Section V.1 above and the water quality criteria in Section V.2 will also help the streambank erosion problems.

In addition to the control of water quality volume (in order to minimize the impact of stormwater runoff on downstream streambank erosion), the primary requirement is to design a 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 made (such as adding a small orifice at the bottom of the outlet structure) so that the proposed conditions 1-year storm takes a minimum of 24 hours to drain from the facility from a point where the maximum volume of water from the 1-year storm is captured (i.e., the maximum water surface elevation is achieved in the facility). Release of water 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 minimum orifice size in the outlet structure to the BMP shall be three (3) inches in diameter where possible, and a trash rack shall be installed to prevent clogging. On sites with small contributing drainage areas to this BMP that do not provide enough runoff volume to allow a 24 hour attenuation with the 3 inch orifice, the calculations shall be submitted showing this condition. Orifice sizes less than 3 inches can be utilized provided that the design will prevent clogging of the intake.

In "Conditional Direct Discharge Districts" (District C) only - (See Section 408), the objective is not to attenuate the storms greater than the 2-year recurrence interval. This can be accomplished by configuring the outlet structure not to control the larger storms, or by a bypass channel that diverts only the 2-year stormwater runoff into the basin or conversely, diverts flows in excess of the 2-year storm away from the basin.

4. Overbank Events

Flooding and stormwater problems are caused by excess stormwater quantity. Storm events which result in water exceeding the natural bank of a stream are termed as “overbank” events and are typically defined as an expected frequency of occurrence. Based upon the realization that most bankfull events occur at approximately the 1.5- to 2-year event, events greater than the 2-year storm result in overbank flooding. These “overbank” events typically range from the 2- year to 10-year events. Management of these “overbank” events requires a detailed knowledge of the interrelationship between all contributing areas of a watershed. Analysis of peak runoff, timing of runoff, and duration of runoff from the various areas of a watershed is critical for establishing these criteria. The result of this analysis is the Management District Concept, discussed in Section V.D.

5. Extreme Events

“Extreme” flooding events are separated from “overbank” flooding events by the severity of damage which is incurred. Typically, events such as the 25-, 50- and 100-year events are labeled as “extreme” events.

While some overbank and extreme flooding events are inevitable, the goal is to control the frequency of occurrence for such events such that the level of overbank flooding is the same over time so that damages to existing conditions infrastructure are not exacerbated by upstream development. Therefore, different management criteria are given for these “overbank” and “extreme” event floods.

It must be recognized that there is a difference between the meanings of storm and flood when considering 5-year storms and 5-year floods. Although a certain quantity of rain may classify a rainfall event as a 5-year storm, this does not mean that same amount of rain will result in a 5-year flood. For example, if the event would occur during a drought, a 5-years storm may result in only a 2-year flood because of the capacity of the soil and ground to absorb water. However, if the same event occurred on top of a snow melt, then a 10-year flood may occur because of the extra water volume present in the melting snow.

Similarly, the term “5-year flood” does not mean that this event will occur once every five years. Nor does it mean that once a 5-year event occurs, it will be another five years until that event may occur again. A 5-year event refers to the probability that the event will occur in any given year, which is the inverse of the frequency event. Therefore, a 5-year event has a 20% probability of occurring in any given year.

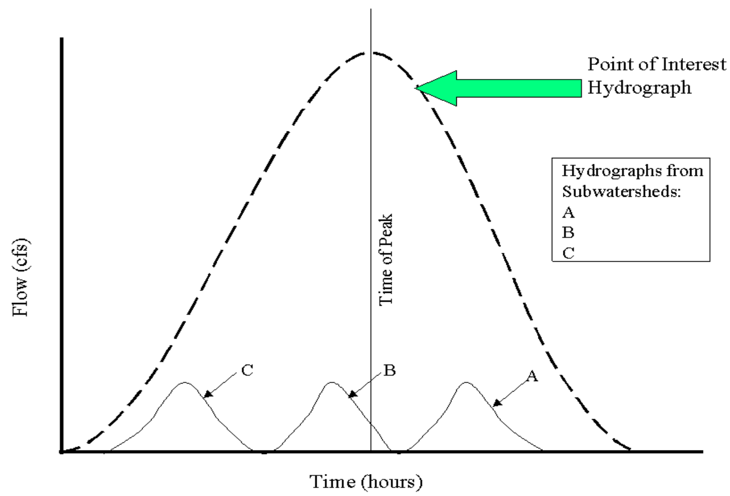
D. Management District Concept (For Overbank and Extreme Events)

Many Act 167 plans were based upon the release rate concept where each subarea of the watershed was assigned a release rate (as a percent value). For any development scenario, the post development runoff rate must meet a percent (release rate) of the pre development runoff rate. These release rates were developed by analyzing the individual subarea contribution to the overall watershed runoff. This plan equates release rates to equivalent design storms and places the subareas in separate management districts. The management district concept uses the same idea as the release rate concept; however, it displays the final criteria by grouping subareas into "management districts" rather than assigning a release rate to each individual subarea. Each management district contains specific criteria that are to be met in order to address "overbank" and "extreme" design events.

Figure V-3 shows a simplified version of how various subarea hydrographs would contribute to the peak flow at a particular point of interest (POI). As can be seen from Figure V-3, hydrograph "A" peaks after the point of interest hydrograph. In this case, standard detention or reducing post development flows to existing conditions rates would attenuate the flows past A's peak, which would not influence the peak of the POI. A development site in subarea B would contribute flow at a time between the start and end of that subarea's hydrograph. Standard detention would attenuate flow to a point where it is increasing flow at the POI; therefore, stormwater management controls would need to reduce the outflow to a higher frequency (smaller) storm. Flows in subarea C enter and exit the stream system before the peak flow occurred at the POI; therefore, if possible, it would be advantageous not to detain these flows. Subareas A, B, and C on the sample would fall into districts A, B, and C as shown on Appendix A of the Model Ordinance. Development of the design storm criteria was based upon downstream obstruction capacities and problem areas identified in the study, as well as the overall goal of maintaining the existing conditions condition's flow at all points in the watershed in the future.

A major goal was to determine where in the watershed stormwater detention was appropriate for new development and, just as importantly, where detention was not appropriate. It was also important to determine to what extent stormwater detention would be required in individual subareas as described above. Table V-3 shows how the peak rate of post-development runoff would have to be reduced to the peak rate of pre-development runoff for the design storms specified.

FIGURE V-3
Relative Timing of Subwatershed Hydrographs



A major goal of the Darby-Cobbs Act 167 Plan was to determine where in the watershed stormwater detention was appropriate for new development and, just as importantly, where detention was not appropriate. It was also important to determine to what extent stormwater detention would be required in individual subareas as described above. On the table below, the peak rate of proposed conditions runoff would have to be reduced to the peak rate of existing conditions runoff for the design storms specified below. Individual subareas would fall into one of four districts:

TABLE V-3
Stormwater Management Districts In The Darby-Cobbs Creek Watershed

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

** In District C, development sites which can discharge directly to the Darby-Cobbs Creek main channel or major tributaries or indirectly to the main channel through an existing stormwater drainage system (i.e., storm sewer or tributary) may do so without control of post-development peak rate of runoff greater than the 5-year storm. Sites in District C will still have to comply with the groundwater recharge criteria, the water quality criteria, and streambank erosion criteria. If the post-development runoff is intended to be conveyed by an existing stormwater drainage system to the main channel, assurance must be provided that such system has adequate capacity to convey the flows greater than the 2-year predevelopment peak flow or will be provided with improvements to furnish the required capacity. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the post-development peak rate of runoff must be controlled to the pre-development peak rate as required in District A provisions (i.e., 10-year post-development flows to 10 pre-development flows) for the specified design storms.*

Source: Borton-Lawson Engineering, Inc. 2004

As in District C, development in those subareas designated on Appendix A- Stormwater Management District Map of the Model Ordinance must convey the generated stormwater runoff to a stream or watercourse in a safe manner. **The conveyance must manage the quantity, velocity and direction of resulting stormwater runoff in a**

manner that adequately protects health and property from possible injury pursuant to Act 167, does not overtax existing conditions drainage facilities and does not cause erosion or sedimentation. Anyone who proposes no detention must comply with Section 408G. and H of the Model Ordinance. Acceptable velocities shall be based upon criteria contained in the DEP "Erosion and Sediment Pollution Control Program Manual." **The proposed conditions flow that is greater than existing conditions flow can only be released if it would not aggravate a significant obstruction or existing conditions problem area or overload existing conditions storm sewer networks.** If it would, proper stormwater management, obstruction replacement or standard detention would be required. Additionally, any flow from the 50-year storm not carried by downstream drainage facilities must be addressed and where necessary, additional controls must be installed to assure collection of this water by control facilities where required by the stormwater design.

When discharging greater than existing conditions peak flow rates, proper analysis of channel capacity downstream of a development site is essential to insure that the goal of not creating any new problem areas or aggravating existing conditions drainage problem areas is achieved. The analysis must include the assumption of complete build-out of the tributary areas to the channel being evaluated based upon the latest zoning revision after plan adoption. The analysis must also analyze the future conditions assuming that stormwater detention on development sites is not implemented. This is required to evaluate the impacts if all proposed conditions development to increase flows. In addition, stormwater control measures consistent with the Plan must be assumed in analyzing projected development upstream of the point of evaluation.

E. Redevelopment

This Plan did not want to create a disincentive to redevelop existing urbanized areas. The stormwater management criteria is based upon meeting the existing conditions flow for a specified design storm. Since existing conditions includes any impervious area existing at the site at the time of the proposed development, the criteria, by default, relaxes the storm water quantity peak rate of flow by allowing them to match existing conditions for the design storm specified in the management district. However, to promote redevelopment to consider adding additional open space and properly managing stormwater runoff in the redevelopment design, in lieu of meeting the stormwater quantity control criteria established in Section V.D. the applicant may chose to reduce the total impervious surface on the site by at least twenty percent (20%); based upon a comparison of existing impervious surface to proposed impervious surface.

F. Process to Accomplish Standards and Criteria

Table V-4 provides a process to accomplish the required standards and criteria, on a priority basis, looking at means other than detention to promote recharge, improve water quality and prevent streambank erosion and to reduce proposed conditions peak flows to the required existing conditions rate.

TABLE V-4 Process to Achieve the Standards and Criteria in Order of Required Consideration
(Ultimate Goal - Match Existing Conditions Hydrograph)

1. Maximize use of Nonstructural Stormwater Management Alternatives
   - Minimize disturbance of natural features
   - Minimize grading
   - Minimize impervious surfaces, consider pervious surfaces
   - Break up large impervious surfaces
2. Satisfy groundwater recharge (infiltration) objective
3. Satisfy water quality
4. Satisfy streambank erosion requirements
5. Apply BMPs near the source of the runoff
6. Satisfy the runoff peak attenuation objective considering all measures other than detention basins.
7. After satisfying the above requirements, incorporate dual purpose detention measures, if necessary, to attenuate peaks. Dual purpose detention is recommended, e.g., recycling water, wetlands basins, water storage for fire flow, etc.

The sources in the Reference Section of this Plan should be consulted to aid the design engineer in BMP selection and design.

The required standards and criteria developed are summarized in Table V-5 while recommended standards and criteria can be found in Table V-6. The ultimate goal would be to match the predevelopment hydrograph, not just the predevelopment peak. Nonstructural stormwater management measures (also referred to as conservation design or low impact development, LID) should be evaluated to help achieve this goal. Conservation design focuses on preserving the areas most beneficial to environmental conservation, and developing on the areas most suitable to development. This typically includes development of an opportunity and constraints map. Conservation design measures are discussed in more detail in Section V-E. Section V of Pennsylvania's BMP Manual should also be consulted to achieve these goals.

TABLE V-5
Required Criteria & Standards in the Darby-Cobbs Creek Watershed

<u>REQUIRED STANDARD</u>	<u>BENEFIT</u>
<u>Stormwater Management</u> A, B, and C Management Districts	No increase in runoff on a watershed wide basis, stormwater attenuation.
<u>Recharge/Infiltration/Retention</u> All development proposed should investigate the implementation of infiltration or retention structures for the stormwater control measures as opposed to surface detention (in all Hydrologic Soils Groups) and adhere to the recharge requirements of the Model Ordinance. This also pertains to the portions of the watershed that have storm sewers. Recharge structures installed prior to tapping into the storm sewers are recommended where soils and physical conditions permit. Impacts on subsurface mine pools and Karst areas should be evaluated before recommending this type of practice.	Groundwater/stream baseflow recharge, flow attenuation.
<u>Water Quality</u> Provide adequate storage and treatment facilities necessary to capture and treat the Water Quality Volume (WQv).	Allows pollutants to settle thus providing improved water quality.
<u>Calculations Methodology</u> Parameters must be obtained from the Model Ordinance.	Calculations for consistent stormwater management.
<u>Existing Storm Sewers or Culverts</u> 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.
<u>Discharge of Accelerated Runoff</u> Only excess accelerated stormwater runoff (after all criteria has been met) shall be safely discharged into existing drainage patterns and storm sewers without adversely affecting properties or causing channel scouring and erosion.	Safe conveyance, continued surface and groundwater quality, flow attenuation.
<u>Inappropriate Outlets</u> If outlet from stormwater conveyance systems from a development site to a stream, tributary, stabilized channel, or storm sewer is not possible, 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.	Safe conveyance, continued surface and groundwater quality, flow attenuation.
<u>District C</u> Those subareas shown on the Appendix A map in the Model Ordinance as being in District C shall safely discharge runoff directly into an existing conveyance system with no detention or attenuation of greater than the 5-year storm.	Allows excess runoff to exit watershed system prior to peak while still meeting water quality and groundwater recharge goals.
<u>Wetlands</u> Refer wetland impacts to state agency for review.	Infiltration, surface and groundwater recharge, stream baseflow, water quality, flow attenuation, detention.

Note: *See the Model Ordinance for more detailed standards and criteria.*

TABLE V-6
Recommended Criteria & Standards in the Darby-Cobbs Creek Watershed

RECOMMENDED STANDARD	**BENEFIT**
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 recharge or leave areas of native vegetation intact.	Infiltration, structure integrity, surface water quality, safe conveyance, stream, culvert, and channel capacity.
Floodplains Those floodplains in which the floodplain stores floodwaters shall not be filled or covered with impervious surface so as to not reduce the storage capacity.	Natural stormwater detention/flood control downstream.
Roof Drains, Residential/Commercial Prevent all roof drains from discharging into storm sewers, roadside ditches, or channels. Discharge to lawn; recharge basin or storage facilities for re-use.	Promotes infiltration, flow attenuation, and increases runoff time of concentration, flow attenuation.
Pervious Surfaces The use of pervious materials will be encouraged for parking surfaces and sidewalks. Compaction of soils is discouraged and natural or undisturbed areas onsite are encouraged in order to keep open space pervious. Aquifer or groundwater recharge beds are encouraged.	Infiltration, groundwater recharge.
Structures Concentrate on locating facilities within areas conducive to recharge and accommodate recharge to meet management district requirements. No stormwater structures are allowed in floodplains that would reduce the storage volume.	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 base flow, flow attenuation, conveyance integrity, surface water quality.
Streambank Protection Reduce 2-year post-development flow to 1-year predevelopment flow.	Reduces the number of erosive storms thereby reducing streambank erosion.
Green Roof Construct rooftop gardens	Flow attenuation and small storm retention
Riparian Buffer Width that is recommended is 50 feet measured from the top of bank on both sides of the stream.	Water quality, flood drainage reduction, habitat enhancement erosion reduction.

Note: *See the Model Ordinance for more detailed standards and criteria.*

G. Alternative Runoff Control Techniques

Each developer must not allow the runoff from his site to exceed the applicable release rate applied to the subwatershed where the site is located. This runoff control can be obtained in a number of different ways. The following tables indicate an overview of general measures that can be applied to reduce or delay stormwater runoff as well as the advantages and disadvantages for several types of runoff control measures. It will be up to the developer or the developer's engineer to select the technique that is the most appropriate to the type of project and physical characteristics of the site.

In determining what measures or combination of measures to install, the following parameters should be considered:

- Soil characteristics (hydrologic soil group, etc.)
- Subsurface conditions (high water table, bedrock, etc.)
- Topography (steepness of slope, etc.)
- Existing drainage patterns
- Economics
- Advantages and disadvantages of each technique

Some runoff control techniques are “structural” stormwater management controls meaning that they are physical facilities for runoff abatement. Others are “non-structural” controls, referring to land use management techniques geared toward minimizing storm runoff impacts through control of the type and extent of new development throughout the study area. The Darby-Cobbs Creek Watershed Stormwater Management Plan is based on the assumption that new development of various types will occur throughout the study area (except as regulated by floodplain regulations) and that structural controls may be required to minimize the runoff implications of the new development.

1. Nonstructural Runoff Controls - Non-structural methods of controlling stormwater runoff quantity and quality, such as innovative site planning, impervious area and grading reduction, protection of natural depression areas, temporary ponding on site and other techniques are recommended. Non-structural BMPs are increasingly recognized as a critical feature of stormwater BMP plans, particularly with respect to site design. In most cases, non-structural BMPs shall be combined with structural BMPs to meet all stormwater requirements. The key benefit of non-structural BMPs is that they can reduce the generation of stormwater from the site thereby reducing the size and cost of structural BMPs. In addition, they can provide partial removal of many pollutants. The non-structural BMPs have been classified into broad categories including, but not limited to:

- Natural area conservation
- Limiting disturbed areas
- Conservation design

A more detailed discussion on nonstructural Stormwater BMPs can be found in Ordinance Appendix E.

Table V-7
Nonstructural Stormwater Best Management Practices

Nonstructural Stormwater Measure	**Description**
Natural Area Conservation	Conservation of natural areas such as forest, wetlands, or other sensitive areas in a protected easement thereby retaining their existing conditions hydrologic and water quality characteristics.
Disconnection of Rooftop Runoff	Rooftop runoff is disconnected and then directed over a undisturbed area where it may either infiltrate into the soil or filter over it. This is typically obtained by grading the site to promote overland flow or by providing bioretention on single-family residential lots.
Disconnection of Non-Rooftop Runoff	Disconnect surface impervious cover by directing it to undisturbed areas where it is either infiltrated or filtered though the soil
Stream Buffer	Stream buffer effectively treats stormwater runoff. Effective treatment constitutes capturing runoff from pervious and impervious areas adjacent to the buffer and treating the runoff through overland flow across a undisturbed grass or forested area.
Grass Channel (Open Section Roads)	Open grass channels are used to reduce the volume of runoff and pollutants during smaller storms.
Environmentally Sensitive Rural Development	Environmental site design techniques are applied to low density or rural residential development.

2. **Structural Runoff Controls** - Structural controls for managing storm runoff can be categorized as either volume controls or rate controls. Volume controls are designed to prevent a certain amount of the total rainfall from becoming runoff by providing an opportunity for the rainfall to infiltrate into the ground. Greater opportunity for infiltration can be provided by minimizing the amount of impervious cover associated with development, by draining impervious areas over undisturbed areas or into specific infiltration devices, and by using grassed swales or channels to convey runoff in lieu of storm sewer systems. Rate controls are designed to regulate the peak discharge of runoff by providing temporary storage of runoff which otherwise would leave the site at an unacceptable peak value. Rate controls, much more so than volume controls, are adaptable to regional considerations for controlling much larger watershed areas than one development site.

d. **Innovative BMPs** - The use of traditional and innovative best management practices (BMPs) is encouraged to meet the recharge, water quality and quantity criteria established in this Plan. *The Pennsylvania Handbook of Best Management*

Practices for Developing Areas prepared by the Pennsylvania Association of Conservation Districts, Inc., (Spring, 1998). BMP Manuals referenced in Section VIII or the PA Stormwater BMP Manual developed subsequent to this plan, should be used to design and maintenance of these practices/facilities.

e. **Temperature Sensitive BMPs** - Runoff from blacktop during hot summer months can provide a "slug" of warm water into the streams, which could affect trout. Therefore, for areas within defined Special Protection subwatersheds which includes Exceptional Value (EV) and High Quality (HQ) waters, the temperature and quality of stormwater entering streams shall be maintained through the use of temperature sensitive BMPs and stormwater conveyance systems. Temperature sensitive BMPs are simply those BMPs which help reduce the temperature of the discharge of the BMP, typically by shading or by providing temporary underground storage. A list of some temperature sensitive BMPs and the source for further information on them can be found in Table V-8.

TABLE V-8
Temperature Sensitive BMPs

To minimize temperature increases caused by new development in watersheds Stormwater BMP designs should:

- Provide shading for pools and channels (particularly south side)
- Maintain existing forested buffers
- Bypass available baseflow and/or springflow
- Utilize underground storage where possible
- Utilize recharge

f. **Quantity Control** - Proposed conditions development runoff from a site must not exceed the applicable existing conditions rate applied to the subwatershed where the site is located. This runoff control can be obtained in a number of different ways. The following tables indicate an overview of general measures that can be applied to reduce or delay stormwater runoff as well as the advantages and disadvantages for several types of runoff control measures. The applicant must select the technique that is the most appropriate to the type of project and physical characteristics of the site. Best Management Practices can be utilized to manage water quality, ground water, recharge, streambank erosion and quantity (peak and volume).The runoff control(s) most applicable to a development site may vary widely depending upon site characteristics such as:

- Type of development proposed
- Soil characteristics (hydrologic soil group, etc.)
- Subsurface conditions (high water table, bedrock, etc.)
- Topography (steepness of slope, etc.)
- Existing drainage patterns
- Economics

- Advantages and disadvantages of each technique

1. Applicable performance standard

The use of traditional and innovative Best Management Practices (BMPs) is encouraged to meet the recharge, water quality and quantity criteria established in this Plan. The Pennsylvania Handbook of Best Management Practices for Developing Areas prepared by the Pennsylvania Association of Conservation Districts, Inc., Spring, 1998 should be referenced for design and maintenance of these practices/facilities.

Table V-9 provides possible on-site stormwater control methods while Table V-10 explains the advantages and limitations of various on-site stormwater control methods. Table V-11 explains the suitability of control measures in the Darby-Cobbs watershed.

TABLE V-9
Possible On-Site Stormwater Control Methods

AREA	REDUCING RUNOFF	DELAYING RUNOFF
Large Flat Roof	1. Cistern storage. 2. Rooftop gardens. 3. Pool storage or fountain storage.	1. Ponding on roof by constricted downspouts.
Parking Lots	1. Porous pavement. a. Gravel parking lots. b. Porous or punctured 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 a. Rippled pavement b. Depressions c. Basins
Residential	1. Cisterns for individual homes or groups of homes. 2. Gravel driveways (porous). 3. Contoured landscape. 4. Groundwater recharge: a. Perforated pipe b. Gravel (sand) c. Trench d. Porous pipe e. Dry wells 5. Vegetated depressions.	1. Reservoir or detention basin. 2. Planting a high delaying grass (high roughness). 3. Gravel driveways. 4. Grassy gutters or channels. 5. Increased length of travel of runoff by means of gutters, diversions, etc.
General	1. Gravel alleys. 2. Porous sidewalks. 3. Mulched planters.	1. Gravel alleys.

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

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods

Bioretention Facility

ADVANTAGES:

1. If designed properly, has shown ability to remove significant amounts of dissolved heavy metals, phosphorous, TSS, and fine sediments.
2. Requires relatively little engineering design in comparison to other stormwater management facilities (e.g. sand filters).
3. Provides groundwater recharge when the runoff is allowed to infiltrate into the subsurface.
4. Enhances the appearance of parking lots and provides shade and wind breaks, absorbs noise, and improves an area’s landscape.
5. Maintenance on a bioretention facility is limited to the removal of leaves from the bioretention area each fall.
6. 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.

LIMITATIONS:

1. Low removal of nitrates.
2. Not applicable on steep, unstable slopes or landslide areas (slopes greater than 20 percent).
3. Requires relatively large areas.
4. Not appropriate at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable.
5. Clogging may be a problem, particularly if the BMP receives runoff with high sediment loads.

Catch Basin Inserts

ADVANTAGES:

1. Provides moderate removal of larger particles and debris as pretreatment.
2. Low installation costs.
3. Units can be installed in existing traditional stormwater infrastructure.
4. Ease of installation
5. Requires no additional land area.

LIMITATIONS:

1. Vulnerable to accumulated sediments being resuspended at low flow rates.
2. Severe clogging potential if exposed soil surfaces exist upstream.
3. Maintenance and inspection of catch basin inserts may be required before and after each rainfall event, excessive cleaning, and maintenance.
4. Available head to meet design criteria.
5. Dissolved pollutants are not captured by filter media.
6. Limited pollutant removal capabilities.

Cisterns

ADVANTAGES:

1. Low installation cost.
2. Requires little space for installation.
3. Reduces amount of stormwater runoff
4. Conserves water usage.

LIMITATIONS:

1. Limited amount of stormwater runoff can be captured.
2. Restricted to structure runoff.
3. Aesthetically unpleasing.

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods (continued)

Constructed Wetlands

ADVANTAGES:

1. Artificial wetlands offer natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal.
2. Artificial wetlands can offer good treatment following treatment by other BMPs, such as wet ponds, that rely upon settling of larger sediment particles (Urbonas, 1992). They are useful for large basins when used in conjunction with other BMPs.
3. Wetlands that are permanently flooded are less sensitive to polluted water inflows because the ecosystem does not depend upon the polluted water inflow.
4. Can provide uptake of soluble pollutants such as phosphorous, through plant uptake.
5. Can be used as a regional facility.

LIMITATIONS:

1. 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.
2. Wetlands require a continuous base flow.
3. If not properly maintained, wetlands can accumulate salts and scum which can be flushed out by large storm flows.
4. Regular maintenance, including plant harvesting, is required to provide nutrient removal.
5. Frequent sediment removal is required to maintain the proper functioning of the wetland.
6. A greater amount of space is required for a wetland system than is required for an extended/dry detention basin treating the same amount of area.
7. Although artificial wetlands are designed to act as nutrient sinks, on occasion, the wetland may periodically become a nutrient source.
8. Wetlands that are not permanently flooded are more likely to be affected by drastic changes in inflow of polluted water.
9. Cannot be used on steep unstable slopes or densely populated areas.
10. Threat of mosquitoes.
11. Hydraulic capacity may be reduced with plant overgrowth.

Dry Wells

ADVANTAGES:

1. Recommended in Residential Areas
2. Requires minimal space to install.
3. Low installation costs.
4. Reduces amount of runoff.
5. Provides groundwater recharge.
6. Can serve small impervious areas like rooftops.
7. Helps to disconnect impervious surfaces.

LIMITATIONS:

1. Offers little pretreatment which may cause clogging.
2. 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.
3. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
4. Not suitable on fill sites or steep slopes.
5. Must have a minimum of 3 to 4 feet between the bottom of the dry well and the seasonal high water table.

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods (continued)

6. Dry wells service a limited drainage area, typically only rooftop runoff.
7. Dry wells must be located at least 10 feet away, on the down slope side of the structure, from building foundations to prevent seepage.

Dry Wells

LIMITATIONS(cont):

8. Stormwater runoff carrying bacteria, sediment, fertilizer, pesticides, and other chemicals may flow directly into the groundwater.
9. Loss of infiltrative capacity and high maintenance cost in fine soils.
10. Low removal of dissolved pollutants in very coarse soils.
11. Soils must be permeable.
12. Not recommended for use with commercial rooftops unless adequacy of pretreatment is assured.

Extended / Dry Detention Basins or Underground Tanks

ADVANTAGES:

1. Modest removal efficiencies for the larger particulate fraction of pollutants.
2. 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.
3. Can be designed for combined flood control and stormwater quality control.
4. Requires less capital cost and land area when compared to wet pond BMP.
5. Downstream channel protection when properly designed and maintained.

LIMITATIONS:

1. Require sufficient area and hydraulic head to function properly.
2. Generally not effective in removing dissolved and finer particulate size pollutants from stormwater.
3. 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.
4. Extended/dry detention basins have moderate to high maintenance requirements.
5. Sediments can be resuspended if allowed to accumulate over time and escape through the hydraulic control to downstream channels and streams.
6. Some environmental concerns with using extended/dry detention basins include potential impact on wetlands, wildlife habitat, aquatic biota, and downstream water quality.
7. May create mosquito breeding conditions and other nuisances.

Infiltration Basins

ADVANTAGES:

1. High removal capability for particulate pollutants and moderate removal for soluble pollutants.
2. Groundwater recharge helps to maintain dry-weather flows in streams.
3. Can minimize increases in runoff volume.
4. When properly designed and maintained, it can replicate pre-development hydrology more closely than other BMP options.
5. Basins provide more habitat value than other infiltration systems.

LIMITATIONS:

1. High failure rate due to clogging and high maintenance burden.
2. Low removal of dissolved pollutants in very coarse soils.
3. Not suitable on fill slopes or steep slopes.

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods (continued)
LIMITATIONS(cont):

4. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
5. Should not be used if significant upstream sediment load exists.
6. Slope of contributing watershed needs to be less than 20 percent.
7. Not recommended for discharge to a sole source aquifer.
8. Cannot be located within 100 feet of drinking water wells.
9. Metal and petroleum hydrocarbons could accumulate in soils to potentially toxic levels.
10. Relatively large land requirement.
11. Only feasible where soil is permeable and there is sufficient depth to bedrock and water table.

Infiltration Basins

12. Need to be located a minimum of 10 feet down gradient and 100 feet up gradient from building foundations because of seepage problems.

Infiltration Trenches

ADVANTAGES:

1. Provides groundwater recharge.
2. Trenches fit into small areas.
3. Good pollutant removal capabilities.
4. Can minimize increases in runoff volume.
5. Can fit into medians, perimeters, and other unused areas of a development site.
6. Helps replicate pre-development hydrology and increases dry weather baseflow.

LIMITATIONS:

1. Slope of contributing watershed needs to be less than 20 percent.
2. Soil should have infiltration rate greater than 0.3 inches per hour and clay content less than 30 percent.
3. Drainage area should be between 1 to 10 acres.
4. The bottom of infiltration trench should be at least 4 feet above the underlying bedrock and the seasonal high water table.
5. High failure rates of conventional trenches and high maintenance burden.
6. Low removal of dissolved pollutants in very coarse soils.
7. Not suitable on fill slopes or steep slopes.
8. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
9. 9 Cannot be located within 100 feet of drinking water wells.
10. Need to be located a minimum of 10 feet down gradient and 100 feet up gradient from building foundations because of seepage problems.
11. Should not be used if upstream sediment load cannot be controlled prior to entry into the trench.
12. Metals and petroleum hydrocarbons could accumulate in soils to potentially toxic levels.

Media Filtration

ADVANTAGES:

1. May require less space than other treatment control BMPs and can be located underground.
2. Does not require continuous base flow.
3. Suitable for individual developments and small tributary areas up to 100 acres.
4. Does not require vegetation.

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods (continued)

5. Useful in watersheds where concerns over groundwater quality or site conditions prevent use of infiltration.
6. High pollutant removal capability.
7. Can be used in highly urbanized settings.
8. Can be designed for a variety of soils.
9. Ideal for aquifer regions.

LIMITATIONS:

1. 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.
2. Available head to meet design criteria.
3. Requires frequent maintenance to prevent clogging.
4. Not effective at removing liquid and dissolved pollutants.
5. Severe clogging potential if exposed soil surfaces exist upstream.

Media Filtration

LIMITATIONS(cont):

6. Sand filters may need to be placed offline to protect it during extreme storm events.

Porous Pavement

ADVANTAGES:

1. 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.
2. In addition to water quality benefits, porous pavements also provide significant reductions in surface runoff with up to 90 percent of rainfall retained within the BMP (Schueler, 1992).
3. An added benefit provided by the on-site infiltration is the extent to which the stormwater runoff is able to contribute to groundwater recharge.
4. Reduces pavement ponding.

LIMITATIONS:

1. Only applicable for low-traffic volume areas.
2. To maintain effectiveness, porous pavements require frequent maintenance.
3. Porous pavements are not intended to remove sediments.
4. Easily clogged by sediments if not situated properly.
5. Porous pavements are limited to treating small areas (0.25 to 10 acres).
6. Contributing drainage area slopes should be 5 percent or less to limit the amount of sediments that could potentially lead to clogging of the porous pavement.
7. On average, porous pavements clog within 5 years.
8. Underlying soil strata must have an 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.
9. The bottom of the reservoir layer should be at least 4 feet above the seasonally 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.

10. 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.
11. Extended rain can reduce the pavement's load bearing capacity.
12. More expensive than traditional paving surfaces.

Storm Drain Inserts

ADVANTAGES:
1. Low installation costs.
2. Prefabricated for different standard storm drain designs.
3. Require minimal space to install.

LIMITATIONS:
1. Some devices may be vulnerable to accumulated sediments being resuspended during heavy storms.
2. Can only handle limited amounts of sediment and debris.
3. Maintenance and inspection of storm drain inserts are required before and after each rainfall event.
4. High maintenance costs.
5. Hydraulic losses.

Vegetated Filter Strips

ADVANTAGES:
1. Lowers runoff velocity (Schueler, 1987).
2. Slightly reduces runoff volume (Schueler, 1987).
3. Slightly reduces watershed imperviousness (Schueler, 1987).
4. Slightly contributes to groundwater recharge (Schueler, 1987).
5. Aesthetic benefit of vegetated "open spaces" (Colorado Department of Transportation, 1992).
6. Preserves the character of riparian zones, prevents erosion along streambanks, and provides excellent urban wildlife habitat (Schueler, 1992).

LIMITATIONS:
1. 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 (Schueler, 1992). This lack of quantity control dictates use in rural or low-density development.
2. Requires slope less than 5%.
3. Requires low to fair permeability of natural subsoil.
4. Large land requirement.
5. Often concentrates water, which significantly reduces effectiveness.
6. Pollutant removal is unreliable in urban settings.

Vegetated Swale

ADVANTAGES:
1. Relatively easy to design, install and maintain.
2. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as a vegetated swale.
3. Relatively inexpensive.
4. Vegetation is usually pleasing to residents.

LIMITATIONS:
1. Irrigation may be necessary to maintain vegetative cover.

TABLE V-10
Advantages and Limitations of Various
On-Site Stormwater Control Methods (continued)

2. Potential for mosquito breeding areas.
3. Possibility of erosion and channelization over time.
4. Requires dry soils with good drainage and high infiltration rates for better pollutant removal.

Wet Ponds

ADVANTAGES:

1. Wet ponds have recreational and aesthetic benefits due to the incorporation of permanent pools in the design.
2. Wet ponds offer flood control benefits in addition to water quality benefits.
3. Wet ponds can be used to handle a maximum drainage area of 10 mi^2.
4. 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).
5. 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.
6. Creation of aquatic and terrestrial habitat.

LIMITATIONS:

1. Wet ponds may be feasible for stormwater runoff in residential or commercial areas with a combined drainage area greater than 20 acres but no less than 10 acres.
2. An adequate source of water must be available to ensure a permanent pool throughout the entire year.
3. If the wet pond is not properly maintained or the pond becomes stagnant; floating debris, scum, algal blooms, unpleasant odors, and insects may appear.
4. Sediment removal is necessary every 5 to 10 years.
5. Heavy storms may cause mixing and subsequent resuspension of solids.
6. Evaporation and lowering of the water level can cause concentrated levels of salt and algae to increase.
7. Cannot be placed on steep unstable slopes.
8. Pending volume and depth, pond designs may require approval from State Division of Dams Safety.

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

TABLE V-11
Suitability of Different Control Measures in the Darby-Cobbs Creek Watershed

1. **Cisterns and Covered Ponds:**
   Recommended in industrial parks where water could be utilized for fire protection; costs vary on size of cistern and material used; low maintenance costs (usually requires periodic sediment removal). Also may be used in existing or newly developed residential areas.

2. **Rooftop Gardens:**
   Recommended in this watershed

3. **Surface Pond Storage:**
   Recommended where pond sites exist or on more porous soils (A and B) for groundwater recharge; relatively inexpensive to install and maintain; helps entrap sediment to improve the water quality of the receiving stream.

4. **Ponding on Roof, Constricted Downspouts:**
   Possible on large buildings; required structure modifications usually expensive; low maintenance costs unless leaks occur.

5. **Increased Roof Roughness:**
   Possible for industrial, commercial, and public buildings; relative effectiveness minimal on a watershed wide basis; moderate installation costs; little maintenance costs.

6. **Porous Pavement:**
   Highly recommended where possible, especially in A and B soils and large parking facilities; promotes groundwater recharge; moderate in expense compared to typical paving; low maintenance costs.

7. **Grassed Channels and Vegetated Strips:**
   Recommended wherever possible throughout the watershed to slow velocity and reduce erosion; minimal slopes recommended; could entrap sediment to improve water quality; low installation and maintenance costs; promotes infiltration.

8. **Ponding and Detention on Pavement:**
   Recommended in entire watershed except in “No Detention” areas; very inexpensive with low maintenance costs; freezing should be considered.

9. **Reservoirs or Detention Basin:**
   Recommended in entire watershed except in “No Detention” areas; moderate installation and maintenance costs.

10. **Groundwater Recharge:**
    Recommended throughout the watershed particularly in Hydrologic Soil Group A and B.

11. **High Delay Grass and Routing Flow Over Lawns:**
    Recommended in entire watershed; delays runoff, entraps sediment, reduces velocities, reduces erosion potential; relatively inexpensive installation and maintenance costs.

H. Sub-Regional (Combined Site) Storage

Traditionally, the approach to stormwater management has been to control the runoff on an individual site basis. However, there is a growing commitment to finding cost-effective comprehensive control techniques that both preserve and protect the natural drainage system. In other words, two developers developing sites adjacent to each other could pool their capital resources to provide for a community stormwater storage facility in the most hydrologic advantageous location.

The goal should be the development and use of the most cost-effective and environmentally sensitive stormwater runoff controls. These controls will significantly improve the capability and flexibility of land developers and communities to control runoff consistent with the Darby and Cobbs Creeks Watershed Stormwater Management Plan.

An advantage to combining efforts is to increase the opportunity to utilize stormwater control facilities to meet other community needs. For example, certain stormwater control facilities could be designed so that recreational facilities such as ballfields, open space, volleyball, etc. could be incorporated. Natural or artificial ponds and lakes could serve both recreational and stormwater management objectives.

To take this concept a step further, there is also the possibility that the stormwater could be managed "off-site;" that is, in a location off the property(s) in question. These stormwater management facilities could be constructed in an offsite location more hydrologically advantageous to the watershed. These facilities could be publicly owned detention, retention, lake, pond, or other physical facilities to serve multiple developments. The design and release rate would need to be consistent with the Plan.

I. Regional Detention Facilities

One option in watershed-wide storm management is to control runoff using regional facilities. Developers could pool their capital to build a regional detention basin at a strategic location in place of installing a basin on each individual site.

The potential for locating regional facilities within the Darby-Cobbs watershed was evaluated. The six parameters used for locating such a facility were:

- Site location's influence on the total watershed hydrology
- Available undeveloped land
- Ownership of the land
- Topography
- Environmental sensitivity of the locations
- Total area and percent of the total contributing area to the basin location.

Due to the existing development and road patterns in the watershed, the only areas with sufficient open space available for construction of regional detention facilities lie within natural / conservation area lands. For discussion purposes, four potential regional detention facilities were located in these areas along Darby Creek and the Abrahams Run and Camp Run tributaries. Modeling results, shown in Table V-12, do not provide significant downstream benefits for flood protection to justify the placement of these facilities.

TABLE V-12
100-Year HMS Flows with
Proposed Regional Detention Facilities

Point of Interest	w/o Basins	Basin #1 Only	Basin #2 Only	Basins #1 & #2	Basin #3 Only	Basin #4 Only	Basins #1, #2, #3 & #4
#1	6.902	6.876	6.819	6.791	6.902	6.891	6.788
#2	18.316	18.048	17.715	17.403	18.216	18.264	17.257
#3	18.977	18.732	18.511	18.251	18.888	18.936	18.121

Notes: POI #1 – Below confluence of Darby Creek and Little Darby Creek
POI #2 – Below confluence of Darby Creek and Cobbs Creek
POI #3 – Mouth of Darby Creek

J. "No Harm Option"

A developer has the option to prove to the municipality that the increase in runoff generated from his site above the allowable release rate will cause "no harm" anywhere in the watershed. The No Harm Option is used when a developer can prove that the post-development hydrographs can match pre-development hydrographs, or if it can be proved that the post-development conditions will not cause increases in peaks at all critical points downstream.

Several developers within the same subwatershed could independently show that they would cause no harm. However, the cumulative effect of these contributions could significantly increase the flow. Therefore, proof of no harm would have to be shown if the entire subarea(s) within which the proposed development is located would be developed and the cumulative effect would not create a problem anywhere in the watershed. The impact of the increase in flow would have to be followed downstream until the increase diminishes due to additional flow from tributaries and/or stream attenuation.

K. "Hardship Option"

The development of the plan and its standards and criteria was designed to maintain existing peak flows throughout the Darby-Cobbs watershed as the watershed becomes developed. There may be certain instances, however, where the standards and criteria established are too restrictive for a particular landowner or developer. The existing drainage network in some areas may be capable of safely transporting slight increases in flows without causing a problem or increasing flows elsewhere. If a developer or homeowner may not be able to possibly meet the stormwater standards due to lot conditions or if conformance would become a hardship to an owner, the hardship option may be applied. The landowner would have to plead his/her case to the Township Supervisors with the final determination made by the Township. Any landowners pleading the "hardship option" will assume all liabilities that may arise due to exercising this option.

L. Stormwater Quantity Control Exemption

Exemptions for Land Use Activities

1. The following land use activities are exempt from the drainage plan submission requirements of this Ordinance.

    a. Use of land for gardening for home consumption.

    b. Agriculture when operated in accordance with a conservation plan, nutrient management plan, or erosion and sedimentation control plan approved by the County Conservation District, including activities such as growing crops, rotating crops, tilling of soil, and grazing animals. Installation of new or expansion of existing farmsteads, animal housing, waste storage, and production areas having impervious surfaces that result in a net increase in earth disturbance of greater than five thousand (5,000) square feet shall be subject to the provisions of this Ordinance.

    c. Forest management operations which are following the Department of Environmental Protection's (DEP) management practices contained in its publication "Soil Erosion and Sedimentation Control Guidelines for Forestry" and are operating under an approved erosion and sedimentation plan and must comply with the stream buffer requirements in Ordinance Section 406.G.

Road replacement, development, or redevelopment that has less than two thousand (2,000) square feet of new, additional, or replaced impervious surface/cover, or in the case of earth disturbance only, less than five thousand (5,000) square feet of disturbance, is exempt from this Ordinance.

2. Exemptions for Land Development Activities

The following land development and earthmoving activities are exempt from the drainage plan submission requirements of this Ordinance.

a. A maximum of two thousand (2,000) square feet of new, additional, or replacement proposed impervious surface.

Or in the case of earth disturbance resulting in less than two thousand (2,000) square feet of impervious cover (as noted above)

b. Up to a maximum of five thousand (5,000) square feet of disturbed earth.

These criteria shall apply to the total development even if the development is to take place in phases. The date of the municipal Ordinance adoption shall be the starting point from which to consider tracts as "parent tracts" upon which future subdivisions and respective earth disturbance computations shall be cumulatively considered.

3. Additional Exemption Criteria:

a. Exemption Responsibilities - An exemption shall not relieve the Applicant from implementing such measures as are necessary to protect public health, safety, and property.

b. HQ and EV Streams - An exemption shall not relieve the Applicant from meeting the special requirements for watersheds draining to identified high quality (HQ) or exceptional value (EV) waters and Source Water Protection Areas (SWPA) and requirements for nonstructural project design sequencing (Ordinance Section 404).

c. Drainage Problems - If a drainage problem is documented or known to exist downstream of or is expected from the proposed activity, then the Municipality may require the Applicant to comply with this Ordinance.

d. Emergency Exemption - Emergency maintenance work performed for the protection of public health, safety, and welfare. A written description of the scope and extent of any emergency work performed shall be submitted to the [*Municipality*] within two (2) calendar days of the commencement of the activity. If the [*Municipality*] finds that the work is not an emergency, then the work shall cease immediately, and the requirements of this Ordinance shall be addressed as applicable.

e. Maintenance Exemption - Any maintenance to an existing stormwater manage-ment system made in accordance with plans and specifications approved by the municipal Engineer or the Municipality.

f. Even though the developer is exempt, he is not relieved from complying with other regulations.

SECTION VI

Municipal Ordinance Introduction

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

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

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

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

Finally, the model stormwater ordinances should be understandable, applied fairly and uniformly throughout the watershed, and should not discourage creative solutions to stormwater management problems. It would be desirable for the municipalities to adopt a uniform regulatory approach for the Darby-Cobbs Watershed.

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

- Not all of the municipalities in the Darby-Cobbs watershed are completely within the watershed. For those portions of the municipality outside Darby-Cobbs watershed, the existing ordinance provisions would still apply.

- Permanent and temporary stormwater control facilities are regulated by the Act 167 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 and Pollution Controls, Title 25 of DEP Regulations.

- The Act 167 Ordinance contains only those minimum stormwater runoff control criterion and standards which 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 following model ordinance has been developed specifically for municipalities within the Darby-Cobbs Creek watershed in order to implement the Darby-Cobbs Creek Stormwater Management Plan. Municipalities may elect to either create a single-purpose stormwater ordinance (recommended) or amend existing subdivision or zoning ordinances to implement the associated stormwater management plan.

All of the provisions within this model ordinance (unless specifically designated as optional) are required to be part of the municipal stormwater ordinance or other ordinances implementing the requirements of the stormwater management plan.

Organization:

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

Article I - General Provisions - This article includes general administrative provisions including applicable land areas and regulated activities.

Article II - Definitions - This article provides a list of common terms and associated definitions used throughout the ordinance.

Article III - Drainage Plan Requirements - This article lists the specific requirements for submittal, content, and review of drainage plans required by the ordinance. This article also includes the stormwater management exemption criterion.

Article IV - Stormwater Management - This article represents the technical provisions for stormwater management within the Darby-Cobbs Creek watershed and includes the stormwater management district implementation provisions, water quality requirements, design criteria, calculation methods, and erosion and sedimentation requirements.

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

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

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

Article VIII - Enforcement and Penalties - This article describes municipal enforcement procedures, remedies, and the appeals process.

Appendices - This section of the ordinance contains five technical support appendices necessary to implement the ordinance provisions.

Please note that the plan and associated ordinance provisions were developed under the authority of and in strict conformance with the requirements of Act 167. These documents were prepared in consultation with a WPAC comprised of designated representatives from each of the watershed municipalities, County Planning and Conservation District staff, the Darby Creek Valley Association and the Chester County Water Resources Authority. Other advisory members invited to serve on the WPAC include PennDOT, Delco Anglers, as well as a number of others. Proposed ordinance provisions were reviewed and accepted by a majority of the voting members (noted above) who attended the meetings.

Within six months following adoption and approval of a watershed stormwater plan, each municipality is required to adopt or amend stormwater ordinances as laid out in the plan. These ordinances must regulate development within the municipality in a manner consistent with the watershed stormwater plan and the provisions of the Act.

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

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

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

ORDINANCE REQUIREMENTS:

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

- Article I - General Provisions
- Article II - Definitions
- Article III - Drainage Plan Requirements – Section 302
- Article IV - Design Criteria for Stormwater Management Facilities Sections 401, 402, 403, 404, 405, 406, 407, 408 (except H), 409, 410
- Article V - Inspections (language may be modified by municipality)
- Article VII - Maintenance (language may be modified by municipality)
- Article VIII - Prohibitions
- Article IX - Enforcement and Penalties (only when enacting a single-purpose Ordinance)

The following ordinance provisions are optional, but recommended to be retained:

- Section 408. G-I
- Section 709. Municipal Stormwater Control and BMP Operation and Maintenance Fund
- Article VI - Fees and Expenses

All other provisions are optional and may be modified to be consistent with other municipal ordinances related to land development.

NOTE: If a municipality chooses to use the model ordinance to implement the stormwater management plan, it is recommended that the ordinance be submitted to the municipal solicitor, engineer, and DEP for review prior to enactment.

NPDES Requirements

Federal regulations approved October 1999 require operators of small municipal separate storm sewer systems (MS4s) to obtain NPDES Phase II permits from DEP by March 2003. (NPDES II is an acronym for the National Pollutant Discharge Elimination System

Phase II Stormwater Permitting Regulations.) This program affects all municipalities in "urbanized areas" of the state. This definition applies to all Darby and Cobbs Creeks watershed municipalities. Therefore, all municipalities within the Darby-Cobbs watershed will be subject to the NPDES Phase II requirements mandated by the Federal Clean Water Act as administered by DEP. For more information on NPDES II requirements, contact the DEP Regional Office.

Implementation

In order to aid the municipalities and developers in the implementation process, flow charts have been developed as shown in Ordinance Appendix.

Administration

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

SECTION VII

PRIORITIES FOR IMPLEMENTATION

The Darby-Cobbs Creeks Stormwater Management Plan preparation process is complete with Chester, Delaware, Montgomery, and Philadelphia County adoption of the draft plan and submission of the final plan to DEP for approval. This sets in motion the mandatory schedule of adoption of ordinances needed to implement stormwater management criteria. As required by the Act, the Darby-Cobbs watershed municipalities have six months from DEP approval to adopt the necessary ordinance provisions. However, the NPDES II deadline of March 10, 2005, for municipal enactment a water quality ordinance accelerated the ordinance adoption process ahead of actual plan adoption. The typical order of events is as follows.

A. DEP Approval of the Plan

Upon adoption of the watershed plan by Chester, Delaware, Montgomery, and Philadelphia Counties, the plan was submitted to DEP for approval. A draft of the stormwater management plan and draft model ordinance was sent to DEP prior to adoption of the plan. The DEP review process involves determination that all of the activities specified in the Scope of Study have been completed. 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.

B. Publishing the Final Plan

Upon DEP approval, the Delaware County Planning Department published and provided, at minimum, one hard copy and one digital copy of the plan to each municipality. The plan includes this report, appendices, figures, and the model ordinance.

C. Municipal Adoption of Ordinance to Implement the Plan

The essential ingredient for implementation of the stormwater management plan is the adoption of the necessary ordinance provisions by the Darby-Cobbs Creek watershed municipalities. Provided as part of the plan is the <u>Act 167 Stormwater Management Plan Model Ordinance</u> which is a single purpose stormwater ordinance that could be adopted by each municipality essentially "as is" to implement the plan. The single purpose ordinance was chosen for ease of incorporation into the existing structure of municipal ordinances. All that is required of any municipality would be to adopt the ordinance itself and adopt the necessary provisions for tying into the existing subdivision and land development ordinance and zoning ordinance as outlined in the Municipal Ordinance Matrix in the Appendix. The tying provisions would simply refer any applicable regulated activities within the Darby-Cobbs watershed from the other ordinances to the single purpose ordinance. It is recommended that the delineation of the watershed subareas and the stormwater management criteria assigned to each subarea be enacted as part of each municipality's zoning or subdivision ordinance. This way the requirements for management of stormwater will be applicable to all changes in land use and not limited to activities that are subject to subdivision and land development regulations.

D. Level of Government Involvement in Stormwater Management

The existing institutional arrangements for the management of stormwater include federal, state, and county governments, as well as every municipality within the watershed.

In the absence of a single entity with responsibility for all aspects of stormwater management within a watershed, it is clear that the "management" that occurs is primarily a function of a multiple permitting process where a developer attempts to satisfy the requirements of all of the permitting agencies. Each public agency has established its own regulations based on its own objectives and legislative mandates as well as its own technical standards according to its particular stormwater concerns.

The minimum objectives of this plan and the minimum mandates of Act 167 can be accomplished without significant modification of existing institutional arrangements. Actions must be taken at the municipal level. Participation by the county in the technical review of stormwater management plans is necessary. In addition, there must be maintenance and operation of the computer model (as necessary), and compilation of data required for periodically updating the plan. In addition, upon adoption of the plan, all future public facilities, facilities for the provision of public utility services, and 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.

The primary municipal level activity will be the adoption or amendment of development regulations to incorporate watershed stormwater management standards. 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 Chester, Delaware, Montgomery, and Philadelphia County Planning agencies will be available upon request to assist municipalities in the adoption of the model ordinance provisions to fit particular municipal ordinance structures.

The primary county level activity will be the establishment of review procedures. The model ordinance calls for review of stormwater management plans for development sites and erosion and sediment pollution control plans by the Delaware, Chester, and, Montgomery County Conservation Districts respectively. Evidence that the appropriate state and federal agencies responsible for administering wetland regulatory programs have been contacted for land development sites containing regulated wetlands is also required. The purpose is to ensure that plan standards have been applied appropriately and that downstream impacts have been adequately addressed. Procedures and capabilities for performing the review function exist within the governmental agencies.

The counties will also be responsible for the maintenance of data for performance of review and of “no-harm” evaluation. The materials prepared by consultants during the plan preparation process that are needed in the development of site specific stormwater management plans, including data needed to perform the “no-harm” evaluation, must be maintained in a place and form that is accessible to users.

E. County-Wide Coordination

There are possible situations of stormwater management functions and concerns which may not be adequately addressed within the structure of the existing institutional arrangements or by the adoption and enforcement of new regulations at the municipal level as outlined above.

For example, the construction of regional storage facilities may offer an economic and technically sound alternative to the construction of individual, on-site detention basins. There is, however, no organization now that is capable of implementing such a concept. To do so would require a multi-municipal entity capable of planning, financing, constructing, operating, and maintaining the shared storage facilities in a manner similar to the management required for the collection, treatment, and disposal of sanitary wastes.

The Darby-Cobbs watershed is a drainage system. All of its parts are interrelated. What happens upstream affects what happens downstream, and what happens downstream places limitations on what happens upstream. If runoff is not controlled in upstream communities, downstream communities will flood. However, if in a downstream community, the capacity of a drainage channel can be safely increased, more upstream runoff may be released, thus reducing somewhat the cost of required upstream control facilities.

The reduced storm frequency standard proposed in this Plan is the primary standard for managing stormwater on a watershed basis and is a very simple concept that can be implemented on a property-by-property basis. It is equitable and can be used to achieve the law's "no-harm" mandate. But the same technical tool that allowed the modeling of rainfall routing throughout the watershed and the development of a usable standard for property-level control, is also capable of testing numerous, technically feasible solutions that would work for combinations of properties and for combinations of subareas. Some of these potential solutions may be preferable to those that would result from the application of release rates to individual properties.

There are, of course, ways to work out agreements on a case-by-case basis to permit the accomplishment of almost any objective, whether a public or a private undertaking. However, as the number of stormwater detention and control facilities increases during future years, continuing maintenance to ensure the integrity of structures and their performance will become very important. A proliferation of “special agreements” to handle special situations may make future accountability very difficult.

An ideal structure for the management of stormwater on a watershed basis would be an entity, a regional stormwater management board, capable of dealing with all interrelated elements of the system to achieve the following:

- the best possible technical solutions in the most effective manner;
- the efficient and competent review of stormwater management components of development plans;
- the continued maintenance and proper functioning of all elements of the system;
- the repair and replacement of system components as necessary;
- continuing monitoring and evaluation of the performance of the drainage system;
- updating and revision of system requirements and standards as necessary;
- responsible financial management including an equitable apportionment of operating and capital costs among the system's users and beneficiaries.

It is clear that not all of these objectives can be achieved on a watershed basis through municipal implementation of the stormwater plan, but that the existence of an inter-municipal entity capable of continuous action at the system or watershed level is required.

An optimum management system would be an entity capable of performing similar functions for multiple watersheds. There are a variety of models for such an entity, ranging from assigning new responsibilities to a coordinated team of existing county departments to the creation of a regional stormwater management board to include stormwater functions. Further, under any management system, some of the elements in the process could be contracted out to a private vendor.

The essential concept is that stormwater can be managed like a public utility and that the costs for planning, construction, operation and maintenance, monitoring and evaluation can be equitably shared by all of the system's users.

A basic assumption underlying the concept of user financing of stormwater management is that damage caused by existing and potential stormwater runoff without controls is intolerable. Therefore, it is in the public interest to undertake stormwater management immediately, and such management should not be delayed until federal and state funding is available.

Based on stormwater management experience elsewhere, users (including beneficiaries) can finance the full cost of stormwater management inexpensively and equitably. The cost to each user is calculated based on user's property characteristics. Because this method is based on a formula, it has the advantage of being objective in its application.

F. Correction of Existing Drainage Problems

The development of the watershed plan has provided a framework for the correction of existing drainage problems, a logical first step in the process of implementation of a stormwater management ordinance. It will prevent the worsening of existing drainage problems and prevent the creation of new drainage problems as well. The step-by-step outline below is by no means a mandatory action to be taken by the municipalities with watershed plan adoption options, it is just one method of solving problems uniformly throughout the watershed in order to solve current runoff situations.

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

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

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

G. Culvert Replacement

The General Procedures for Municipalities to determine size of replacement culverts using Act 167 data is as follows:

1. Determine the location and Municipality of obstruction on the Obstruction Map and obtain the obstruction number.

2. From Section 105.161 of DEP's Chapter 105, determine the design storm frequency.

3. From "Municipal Stream Obstruction Data" tables, locate the Municipality and Obstruction number. Locate the flow value (cfs) for the design storm frequency determined in #2 above.

4. Have the culvert sized for this design flow and obtain any necessary approvals/permits.

Note: Any culverts/stream crossings not identified on the Obstruction Map need to have storm flows computed for sizing purposes (i.e.: Those culverts which were not measured due to lack of maintenance and therefore the inability to determine the actual size of the obstruction).

H. PennVEST Funding

One way in which the completion and implementation of this plan can be of assistance in addressing storm drainage problems is by opening the avenue of funding assistance through the PennVEST program. The PennVEST Act of 1988, as amended, provides low interest loans to governmental entities for the construction, improvement or rehabilitation of stormwater projects including the transports, 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:

1. 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

2. Must have enacted a stormwater control ordinance consistent with the Stormwater Management Act.

I. 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:

1. To assure the maximum rate of stormwater runoff is no greater after development than prior to development activities; or

2. 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.

SECTION VIII

PLAN REVIEW ADOPTION AND UPDATING PROCEDURES

A. County Adoption

Prior to plan completion, Delaware County transmitted a sample of the proposed Darby-Cobbs Stormwater Ordinance for review to affected municipal planning commissions, local governing bodies, the Watershed Plan Advisory Committee and other interested parties. Delaware 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.

Chester, Delaware, Montgomery, and Philadelphia 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 Chester, Delaware, Montgomery, and Philadelphia County Governing Bodies.

Delaware County, then submitted 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 Delaware County has complied with all procedures outlined in Act 167 and requested that DEP approve the adopted plan.

B. 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.

The following recommendations are the minimum requirements to maintain an effective technical position for periodically reviewing and revising the Plan.

1. It is recommended that the Delaware County Council authorize the County Planning Department to undertake the task of organizing stormwater management plans and supporting data submitted for review. The Planning Department should also assume responsibility for periodically reviewing, revising, and updating the stormwater management plan.

2. It is recommended that the Delaware County Planning Department prepare a workable program for the identification, collection and management of the required data. The program should not be limited to the cooperative efforts of the constituent member municipalities within the Darby-Cobbs watershed, but should also include both state and county agencies concerned with stormwater management.

3. It is recommended that the Watershed Plan Advisory Committee convene every five years or as needed to review the Stormwater Management Plan and determine if the plan is adequate for minimizing the runoff impacts of new development. At a minimum, the information (to be reviewed by the Committee) will be as follows:

    a. Development activity data as monitored by the Delaware County Planning Department.

    b. Information regarding additional storm drainage problem areas as provided by the municipal representatives to the Advisory Committee.

    c. Zoning and Subdivision amendments within the watershed.

    d. Impacts associated with any regional or subregional detention alternatives implemented in the watershed.

    e. Adequacy of the administrative aspects of regulated activity review.

    f. Additional hydrologic data available through preparation of the Stormwater Management Plan for the Darby-Cobbs watershed.

The Committee will review the above data and make recommendations to the County for revisions to the Darby and Cobbs Creeks Watershed Stormwater Management Plan.

Delaware 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.

SECTION IX

FORMATION OF THE DARBY AND COBBS CREEKS WATERSHED ADVISORY COMMITTEE

The following is a listing of the meetings held by the Committee during the preparation and adoption of the detailed Watershed Stormwater Management Plan.

Advisory Committee meetings and their purposes were as follows:

Meeting	Date	Purpose
1	11/29/00	Introduction to Stormwater Management; Review Act 167; Distributed data collection forms; coordination with other study initiatives; progress report.
2	6/5/2001	Watershed characteristics, reviewed coordination with other study initiatives; discuss data collection forms - progress report; reviewed GIS mapping efforts; reviewed infill / redevelopment issues and BMPs; reviewed Fluvial Geomorphology study; sample Act 167 Plan.
3	7/10/03	Progress report – reviewed hydrologic modeling efforts; reviewed groundwater recharge standards and criteria; reviewed Philadelphia Water Department study on Cobbs Creek; reviewed NPDES Phase I criteria and requirements; distributed Outfall Data collection forms.
4	3/31/04	Review goals of the Darby-Cobbs draft plan; update on Philadelphia Water Department initiatives/coordination; review plan format, standards and criteria, and implementation; NPDES II initiative update; review timeline.
5	9/17/04	Review goals of the Darby-Cobbs draft plan; Model ordinance standards and criteria review – draft and final draft, and the history of the changes; NPDES II initiative update; implementation.

SECTION X

REFERENCES

1. Conestoga High School, Darby and Cobbs Creek 1998 (1998).

2. Delaware County Planning Department, Stormwater Management Plan Scope of Study for Chester Creek Watershed (June 1997).

3. Delaware County Planning Department & Borton-Lawson Engineering, Act 167 Stormwater Management Plan Phase I Scope of Study Darby and Cobbs Creeks Watershed Watershed, Delaware and Chester Counties.

4. Delaware County Planning Department, Natural Features Inventory of Delaware County (1984).

5. London Grove Township, London Grove Township Stormwater Management Ordinance (1994).

6. Maryland Department of the Environment, Maryland Stormwater Design Manual, Volume I & II.

7. Munro Ecological Services, Inc., Floodplain Study and Conceptual Plan for Colwyn, Sharon Hill, and Darby Boroughs, Delaware County, PA (1997).

8. Pennsylvania Association of Conservation Districts, Pennsylvania Handbook of Best Management Practices for Developing Areas, November 14, 1997.

9. Philadelphia Water Department Office of Watersheds, Technical Memorandum No. 1 - Draft -Historical Water Quality for the Darby and Cobbs Creeks Watershed (February 2000).

10. Philadelphia Water Department Office of Watersheds, Technical Memorandum No. 2 - Draft -Analysis of 1999 Monitoring Data for the Darby and Cobbs Creeks Watershed (February 2000).

11. Philadelphia Water Department Office of Watersheds, Technical Memorandum No. 3 – Table of Contents (February 2000).

12. Southeastern Pennsylvania Transportation Authority, Hydrologic Analysis and Hydraulic Report for SEPTA'S Stone Arch Culvert (1991).

13. The Nature Conservancy, Natural Areas Inventory of Delaware County (1992 & 1998).

14. Opinion by Senior Judge Mirarchi, Commonwealth of Pennsylvania (May 15, 1998).

15. U. S. Army Corps of Engineers. Report on Survey Investigation. Flood Control and Allied Purposes in Darby Creek-Cobbs Creek Watershed (1972).

16. U. S. Army Corps of Engineers. Darby Creek. Darby Borough Flood Control Problem. Reconnaissance Report (October 1980).

17. U.S. Army Corps of Engineers. Flood Control Study (Section 205) Reconnaissance Report. Darby Creek. Darby Borough. Delaware County. Pennsylvania (1993).

18. U. S. Army Corps of Engineers. Special Flood Hazard Report for Darby Creek and Muckinipates Creek. Delaware County (1977).

19. USDA. Soil Conservation Service (sic Natural Resources Conservation Service). Soil Survey of Delaware County. PA (1963) Revised (1972).

20. United States Geological Survey. Groundwater Resources of Delaware County (1996).

PLAN APPENDIX 1

PUBLIC COMMENT

&

RESPONSES

Date	Municipality/Organization/Company	Format
1/29/2004	CDM	e-mail
3/24/2004	Philadelphia Water Department	e-mail
3/24/2004	Chester County Planning Commission	e-mail
4/28/2004	Lansdowne Borough	Letter
4/29/2004	Aldan Borough	e-mail
4/30/2004	Radnor Township	Letter
4/30/2004	Springfield Township	e-mail
4/30/2004	Philadelphia Water Department	e-mail
4/30/2004	Collingdale Borough (Vollmer)	Letter
4/30/2004	Glenolden Borough (Vollmer)	Letter
4/30/2004	Prospect Park Borough (Vollmer)	Letter
6/10/2004	Chester County Water Resources Authority	Letter
8/27/2004	Chester County Planning Commission	e-mail

Comments and responses to appear in final plan.

PLAN APPENDIX 2

MUNICIPAL ORDINANCE MATRIX

Note : Basic Ordinance Matrix to meet ACT 167 Requirements

APPENDIX 2

MUNICIPAL ORDINANCE MATRIX
(WATERSHED STORM MANAGEMENT)

			Within the Subdivision and Land Development Ordinance					
Township/Borough	Zoning	Subdivision Land Dev.	Stormwater	Flood Plain	Road	Grading	Erosion Sedimentation	Other
Aldan Borough	Yes. 1990	Yes. 1990	Sect. 220-34	Ch. 137	Sect. 403	Sect. 407	Ch. 220 Sect. 220.16	- - -
Clifton Heights Borough	Yes. 1993	County Ord.. 1981	Sect. 309	Ord. 545	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Collingdale Borough	Yes. 1993	County Ord.. 1981	Sect. 309	Ord. 594	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Colwyn Borough	Yes. 1994	County Ord.. 1981	Sect. 309	Ord. 374. 479	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Darby Borough	Yes. 1998	County Ord.. 1981	Sect. 309	Ch. 77	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Darby Township	Yes. 1965	County Ord.. 1981	Sect. 309	Ch. 8. Ord. 540	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
East Lansdowne Borough	Yes. 1995	County Ord.. 1981	Sect. 309	Ord. 331	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Folcroft Borough	Yes. 1990	County Ord.. 1981	Sect. 309	Ord. 667	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Glenolden Borough	Yes. 1995	County Ord.. 1981	Sect. 309	Ord. 916	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Haverford Township	Yes. 1996	Yes. 1993	Ch 160-5(1)G	Ord. 1669	Ch 160-5(1)E	Ch 160-5(1)G	Ch 160-5(1)G.9-10	- - -
Lansdowne Borough	Yes. 1985	County Ord.. 1981	Ch 289	Ch. 187. 1982	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Marple Township	Yes. 1999	Yes. 1954	Ch 74 Sect. 74.28	Ord. 77.14 Sect. 74-28	Sect. 74.14	Sect. 74.26	- - -	- - -
Milbourne Borough	Yes. 2001	County Ord.. 1981	Sect. 309	County Ord 77-5	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Morton Borough	Yes. 1995	County Ord.. 1981	Sect. 309	Ord. 579	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Newtown Township	Yes. 1995	Yes. 1986	Ch 148-43	Ch. 91. Ord. 1980-12	Ch 148-27	Ch 148-27-F	Ch 138	- - -
Norwood Borough	Yes. 1990	County Ord.. 1981	Sect. 309	Ord. 3-82	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Prospect Park Borough	Yes. 1996	County Ord.. 1981	Sect. 309	Ord. 1104	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Radnor Township	Yes. 2000	Yes. 1991	Ch 255-53	Ord. 77-24	Ch 255-27	Ch 255-60. 31	Ch 255-32	- - -
Ridley Township	Yes. 1990	Yes. 1982	Ch 260. Ord. 260	Ord. 1714	Ch 268-22	Ch 268-32	Ch 124. Ord. 1689	Hazardous Materials: Ch 151. Ord 1658.
Ridley Park Borough	Yes. 1990	Yes. 1989	Ord 1028 Sect 618	Ch. 109	Sect. 602-611	Sect. 606	Sect 618A	- - -
Rutledge Borough	Yes. 1997	Yes. 1976	Ch 22-1102.2	Ord. 337 Ch 8	- - -	- - -	- - -	- - -
Sharon Hill Borough	Yes. 1995	Yes. 1981	Art. X Ord. 1081.& Sect. 108-15D	Ord. 1236	Sect. 108-10	Sect. 108-10.4. 108-15.B & 108-38	- - -	- - -
Springfield Township	Yes. 1997	Yes. 1995	Sect. 123-36	Art. 13. Sect. 143	Sect. 123-28	Sect. 123-25 A.2. B&C	Sect. 123-37	- - -
Tinicum Township	Yes. 1997	Yes. 1993	Sect. 48A-26	Ord. 890	Sect. 48A-20 to 25	Sect. 48A-24	- - -	- - -
Upper Darby Township	Yes. 1986	County Ord.. 1981	Sect. 309	Ord. 2802	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Yeadon Borough	Yes. 1971	County Ord.. 1981	Sect. 309	Ch. 1448	Sect. 403. 506. 605. 704. 805	Sect. 403.6. 605.4. 805.6	Sect 811	- - -
Easttown Township	Yes. 1997	Yes. 1997	Sect. 625	Art. 15. Sect. 1501-05 (Zoning Ord.)	Sect. 602-612	- - -	Sect. 626	- - -
Tredyffrin Township	Yes. 1998	Yes. 1998	Sect. 181-53	Sect. 208-15. 208-16 (Zoning Ord.)	Sect. 181-46	- - -	Sect. 181-40	- - -
Lower Merion Township	Yes. 1994	Yes. 1978	Ch 121.4	Ch 155.54	Ch 135.27	Ch 135.39	Ch 121.5	- - -
Narberth Borough	Yes. 1986	Yes. 1984	N/A	Ch 50-103	Sect. 4	N/A	N/A	- - -
Philadelphia. City of	Yes. Title 14	Yes. Ch 14-2100	Ch 14-1603.1	Ch 14-1606	Ch 14-2104.3-9	Ch 14-2104.7	Ch 14-1603.1 (6)b.12c.2(6)a	Title 13. Water & Sewer

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PLAN APPENDIX 3

MODEL ORDINANCE

(SEE SEPARATE FOLDER)

PLAN APPENDIX 4

Non Point Discharge Elimination System (NPDES) Phase II Requirements

What is NPDES Phase II?

Polluted stormwater runoff has been determined to be the leading cause of impairment threatening our nation's surface waters. Mandated by Congress under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) Stormwater Program is a comprehensive two-phased approach to addressing sources of stormwater pollution that affects the quality of the nation's waters.

In Pennsylvania, the Department of Environmental Protection (PADEP) has implemented Phase I of this program which affects certain industrial sites, construction sites over 5 acres and municipalities with populations over 100,000, which includes Philadelphia, Pittsburgh, Allentown and Erie. NPDES permits that were issued under this program were the state's first step in addressing the affects of nonpoint source pollution in our lakes and streams.

Building upon the success of this program, Phase II of Pennsylvania's NPDES program will require permitting of over 700 municipal separate storm sewer systems (MS4s) in Pennsylvania. Operators of these regulated MS4s are required to apply for NPDES permit coverage by March 10, 2003. Phase II also requires permitting of all construction sites, regardless of location, with over 1 acre of disturbance.

Am I an MS4 Municipality?

The over 700 MS4s are located in 20 designated Urban Areas (UAs) and 17 potential UAs in Pennsylvania. An Urban Area is defined by the US Census Bureau as "a place and the adjacent densely settled surrounding territory that together have a minimum population of 50,000 people and a density of 1000 persons/square mile." The list of MS4 municipalities can be obtained from DEP's website, DEP ID 385-2000-012.

Even if your municipality is not a designated MS4, it may be beneficial to adopt some or all of the requirements under Phase II of the NPDES program to address existing stormwater pollution problems within your municipality. Although not mandated by federal or state law, non-MS4 municipalities should consider the goals of the program and the overall return it may provide in improving overall water quality in the community.

What Are the Minimum Stormwater Management Requirements Under Phase II?

The Phase II Stormwater regulations specify six program elements that must be addressed by designated Municipal Separate Storm Sewer System (MS4) municipalities. The regulations also imply that additional things will need to be done, but the lack of specific requirements gives permit holders a great deal of flexibility, if not a lot of guidance, about what to do about some aspects of stormwater management, chiefly monitoring.

The six required stormwater program elements include:

1. Public Education and Outreach
2. Public Involvement and Participation
3. Illicit Discharge Detection and Elimination
4. Construction Site Runoff Control
5. Post-Construction Runoff Management
6. Pollution Prevention/Good Housekeeping Practices for All Municipal Operations

1. Public Education and Outreach

Awareness of stormwater related environmental issues and problems is generally low. A variety of surveys suggest that public awareness of the fact that storm drains are usually not connected to the sewers or that individual actions around our homes causes significant environmental impact to urban streams is not high! Many citizens do not know that our urban streams and watersheds are being damaged by the effects of urbanization and by the pollutants found in urban environments. Support for stormwater or urban watershed management will not be strong, particularly if new resources are needed, unless citizens are aware of the condition of urban watersheds and stream segments.

In some Phase II communities the presence of 303d list streams (streams listed by U.S. EPA as impaired streams) and the TMDL (Total Maximum Daily Load) process for reducing pollution and restoring water quality in these streams may help to increase awareness. Nonetheless, a strong, well-designed and ongoing, or at least periodic education program will be needed both to build support for the stormwater program and make citizens aware of changes they can and need to make to reduce unnecessary stormwater impacts. A strong, effective community education program will include general public awareness education as well as more technical education that targets specific groups such as developers, construction contractors, landscapers, lawn care services, and a variety of small businesses. It is important to address specific sectors of the community due to special concerns about pollution or other impacts associated with that activity as well as general things that homeowners and property owners can do to address needless or avoidable pollution.

In many communities there may already be an educator or educators involved in environmental education in the classroom who would be happy to assist the community by developing a stormwater education unit for delivery at appropriate grade levels. Likewise, local scouting organizations or student conservation organizations would probably be willing to conduct educational activities in the neighborhood using activities like the stream walk or storm drain activity. *Hands-on activity and involvement is critical to learning at all ages. Stormwater programs should utilize these existing resources whenever possibl*e.

2. Public Involvement and Participation

It is absolutely vital to involve the public as early as possible in the design and implementation of the stormwater or urban watershed management program. A diverse cross section of the community representing all the different stakeholder groups should be represented. This should include the regulated community (developers, builders, business owners or managers etc.), the taxpayers who will be paying the tab, the property owners who have been impacted by flooding in the past, environmental groups and environmental activists, landowners, educators, volunteer citizen monitors, and others. These are the people who will pay the bills, work with you to reduce pollution from their activities *(or oppose you at every turn if they are not informed and do not buy into the progra*m), work with you to implement school and community education programs, work on cleanups and assist with monitoring through citizen monitoring programs.

The Phase II U.S. EPA requirements include public involvement and there is probably no better way to do this than to form a citizen advisory committee. This should not be a committee appointed from political insiders. It should be composed of stakeholders who come to the table and are interested enough to stay with the process and who are in basic agreement that the community or stormwater management area organization is responsible for and must develop a stormwater management program. Truly open public involvement can avoid expensive and time-consuming controversies that often lead to legal actions. They can also reduce the potential of citizen lawsuits from groups or individuals critical of the progress toward addressing stormwater management. As parties involved from the beginning in designing, implementing, and evaluating the program, it is likely that the concerns of all groups will be addressed sufficiently to avoid serious controversy that can be resolved only through legal remedies. Citizen groups and persons fully involved in a meaningful way in the process will not choose expensive legal action to resolve disputes. Furthermore, most Phase II communities are not going to find it easy to fund stormwater management efforts.

Volunteer involvement will probably be a critical component of many successful programs. Volunteers can contribute a lot, whether it is scout troops interested in helping with neighborhood education through activities like storm drain stenciling, educators willing to help design education materials, citizens interested in working to help via involvement in volunteer water monitoring or businesses willing to contribute to the support of these citizen efforts or other forms of volunteerism.

3. Illicit Discharge Detection and Elimination

In some areas, pollutants from illicit or illegal discharges may be a significant contribution to pollutant loadings. These may be intentional or unintentional. In older areas they may be discharges that were never rerouted to the sewer system as regulations for discharges were put in place. They may also be things like floor drains that were never properly connected to the sewer system. The task facing permit holders is to develop strategies and methods for detecting these illicit/illegal discharges so that they can be eliminated. A strategy for addressing this problem should first employ education of business owners and operators and homeowners and involve the public in detecting and correcting these problems voluntarily. Addressing the problem will also require a monitoring strategy. Monitoring for illicit/illegal discharges should be kept as simple as possible given resource realities and should progress from simpler, cheaper methods to more complex and more expensive methods as needed. Some techniques for detecting these discharges include:

- Visual inspection along water courses for pipes and unusual discharges (at the same time a check can be made for leaking or broken sewer pipes)
- Visual inspections of business and industrial sites
- Smoke or dye testing to detect or confirm suspected illicit/illegal connections
- Dry weather sampling of suspicious discharges for substances indicative of domestic or industrial wastewater (detergent, optical brighteners, caffeine or high conductivity)
- Inspection, visual or remote camera, inside stormwater conveyances
- Reconnaissance sampling upstream of where contamination hot spots are found

4. Construction Site Runoff Control

Perhaps one of the most damaging and preventable forms of pollution in rapidly growing urban areas is the excessive sediment loads that can be contributed to streams due to erosion and transport of sediments from construction sites. Communities must have in place measures to control polluted runoff from construction sites. The Phase II rule requires permitting of construction sites down to 1 acre. Also, a robust and effective program for erosion and sediment control from construction sites will require education and enforcement. Since it is the permit holder that will be the most likely target of any clean water suits filed by local citizens or by environmental groups representing citizens who feel that enforcement is in-adequate, permit holders should have their own program for enforcement. This means that the community or (in cases of a watershed authority with multiple jurisdictions), the authority, will need to have an erosion and sediment control program. Some suggestions for doing this include:

- ✓ adopt and implement a strong erosion and sediment control ordinance
- ✓ provide education and training for municipal personnel who are involved in municipal construction projects from supervisors to equipment operators
- ✓ encourage erosion and sediment control training for construction contractors and
- ✓ homebuilders or if possible work with others to provide training locally
- ✓ require that at least one appropriate individual (an engineer, landscaper, engineering technician etc.) become certified as a Certified Professional in Erosion and Sediment Control Specialist (CPESC) and assist that person with the costs associated with certification
- ✓ create a process for review and approval of construction site erosion and sediment
- ✓ control plans and provide for review of significant projects by the CPESC
- ✓ cross-train building inspectors to do initial inspections of construction sites
- ✓ as necessary have the CPESC conduct more detailed inspections
- ✓ determine whether you wish to develop a local enforcement program

Having an effective erosion and sediment control ordinance and program is a critical part of an effective stormwater management program. An effective erosion and sediment control program coupled with effective public involvement in the stormwater program provides insurance against costly legal actions.

5. Post-Construction Runoff Management

The Phase II minimum requirements also include management of runoff after the active construction period. These requirements assure that a responsible party will take care of maintaining best management practices (BMPs) until the site is stabilized for erosion control practices and that maintenance of detention, retention basins and other structural BMPs will be funded and taken care of in the future. If the permit holder can, through incentives (fee structures etc.), induce developers to utilize non-structural BMPs, the potential and actual future obligations of the permit holder or community will be lessened. Even then, it is desirable to have some sort of bonding mechanism in place or some sort of recurring fee so that funds for maintenance will be available when needed. The permit holder or community should research the positive and negative aspects of different mechanisms for post-construction maintenance before choosing an approach that it believes best suits the needs of the community or area.

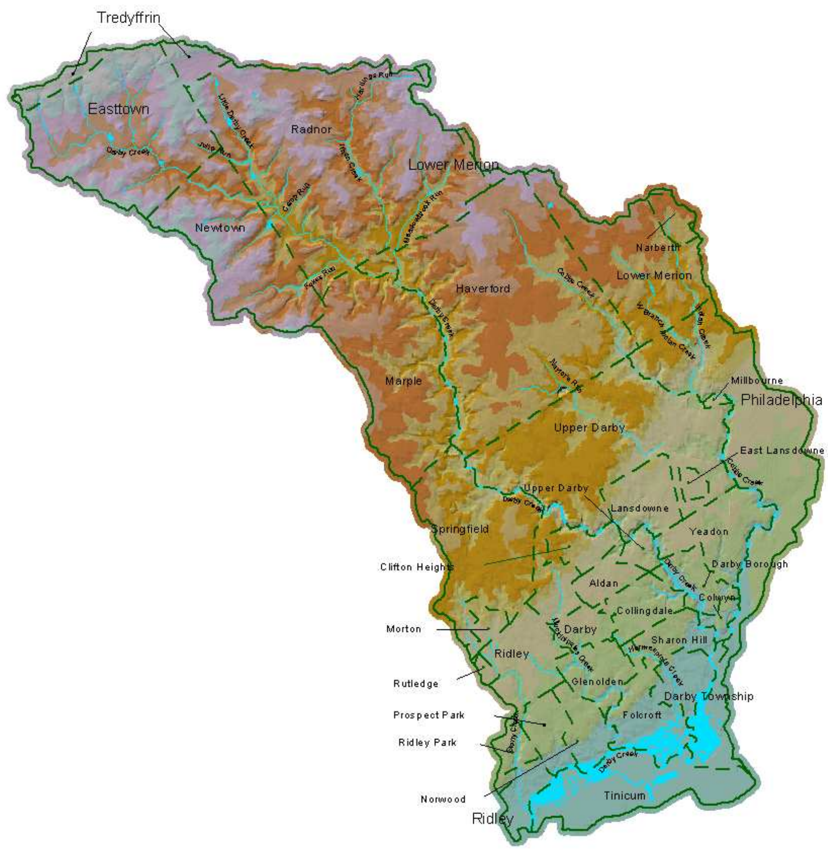
6. Pollution Prevention and Good Housekeeping for Municipal Operations

The final requirement for stormwater Phase II permit holders is for the municipality or municipalities regulated under the permit to develop and implement pollution reduction and good housekeeping procedures for prevention of pollution from stormwater runoff. This means that a program for prevention of stormwater impacts from municipal facilities and municipal operations will have to be developed or perhaps strengthened if such a program already exists. Elements of such a program might include structural components or such things as fuel and materials storage and handling safeguard improvements, erosion and sediment control on municipal projects, protection or restoration of riparian corridors on municipal property, use of design elements to prevent stormwater runoff and pollution on new projects or redevelopment projects, flow and pollution control BMPs for municipal parking areas, and other actions for prevention or reduction of polluted stormwater runoff. Since careless or thoughtless actions of individuals often contribute to stormwater pollution a pollution prevention and housekeeping improvement program should include an education component for appropriate city employees and contractors. This public sector pollution prevention and housekeeping component of the stormwater management program can be important particularly so when a community or permit holder is going to implement voluntary or even regulatory programs for reducing stormwater pollution. The public pollution prevention and housekeeping improvements can be used to demonstrate improvements and thus serve as education activities for private sector businesses and industries in the community.

When Should a Community do More than the Minimum?

Clearly these six activities represent the minimum requirements for Phase II communities or permit holders. Every community is different and every community may have issues, concerns or problems a little different from those in other communities. For example, some communities may have concerns about streams or water bodies that are special, very high quality resources that the community places special value on or which have important economic value. A community may have a TMDL stream for which special additional actions are needed or required to restore water quality in order to avoid growth restrictions or other possible sanctions. A community might have a specific problem like bacteriological contamination from waterfowl that threatens a public beach, flooding problems, or something else that is a special concern in the community that causes it to desire to do more. Communities should pursue everything that makes sense to do for which there is a public consensus and adequate funding to complete. However, permit holders ***should not*** list anything in their plan or permit (if they are applying for an individual permit) that they do not definitely plan and know that they can and will complete. EPA will hold permit holders to those things that they say they will do as part of the permit. *It is safer for permit holders to do more than they indicated than to list something tenuous and not be able to accomplish it*.

DARBY and COBBS CREEKS WATERSHED ACT 167
STORMWATER MANAGEMENT PLAN



VOLUME III – TECHNICAL APPENDIX

DELAWARE, CHESTER, MONTGOMERY, AND PHILADELPHIA COUNTIES, PENNSYLVANIA

DEP ME# 350208
FILE NO. SWMP 086:23
BLE PROJECT NO. 99613.01

DARBY – COBBS CREEK WATERSHED
ACT 167
STORMWATER MANAGEMENT PLAN

DELAWARE, MONTGOMERY, CHESTER & PHILADELPHIA COUNTIES, PENNSYLVANIA

VOLUME III TECHNICAL APPENDIX

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PREPARED FOR:

DELAWARE COUNTY COMMISSIONERS
Government Center
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VOLUME III – TECHNICAL APPENDIX

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Introduction

The following is an investigation into methods employed by various municipalities across the nation to address the issue of stormwater management in areas of redevelopment or infill. Ordinances were reviewed from the states of Maryland and Georgia as well as ordinances from the cities of Seattle, WA and Portland, OR and the Chester Creek Watershed in Delaware County, PA. These ordinances were reviewed to determine if there is a consensus on how stormwater runoff from redeveloping areas should be addressed from a water quantity and quality perspective.

Summary

The five ordinances reviewed varied significantly in the way stormwater issues were addressed. A brief summary of the stormwater quantity and quality criteria from each ordinance is included in the paragraphs below.

Maryland

Runoff Quantity Controls

There are no specific criteria to be met within the ordinance to address recharge, channel protection storage volumes or overbank flood protection volumes unless specified by the approving agency.

Runoff Quality Controls

In areas of redevelopment, there are three options to address stormwater runoff quality:

1) Reduce existing site impervious areas by 20%

2) If site conditions prevent a reduction in impervious areas, provide water quality control for at least 20% of the sites impervious area.

3) A combinations of 1 & 2 can be employed for impervious reductions between 0% and 20%. The combination of impervious area reduction and area control by a stormwater management practice must equal or exceed 20%.

Notes

No explanation is provided as to where the 20% impervious area reduction was determined.

City of Seattle, WA

Runoff Quantity Controls

For redevelopment sites less than 9,000 sq. feet, the peak discharge rate from pervious and impervious surfaces shall not exceed 0.2 cfs per acre under the 25- year design storm. For redevelopment sites greater than 9,000 sq. feet, the peak discharge rate from pervious and impervious surface shall not exceed 0.15 cfs per acres under the 2- year design storm AND shall not exceed 0.2 cfs per acre under the 25- year design storm.

Runoff Quality Controls

No specific criteria is sited for runoff quality control, however is required to “control the sources of sediment and other contaminants and pollutants that could enter drainage water” by use of temporary and permanent best management practices.

Notes

No explanation is provided as to where the 9,000 sq. foot area limit was determined, or where peak allowable flow rates were developed.

City of Portland, OR

Runoff Quantity Controls

Control of on site flows to maintain peak flows at the pre- development (defined as a site’s ground cover prior to development, “i.e. Lewis & Clark days”) for the 2-, 5-, and 10- year storm events.

Runoff Quality Controls

Criteria requires a 70% reduction of TSS from runoff generated by a design storm up to and including 0.83 inches of rainfall over a 24- hour period.

Georgia

Minimum standards for redevelopment sites are same as standards for new development, as follows:

Runoff Quantity Controls

24- hour extended detention of the 1- year, 24- hour storm event; post development to pre development rate control for the 25- year, 24- hour storm event.

Runoff Quality Controls

Stormwater management systems must be designed to remove 80% of the average post-development TSS load. If facility is designed to capture and treat the water quality volume (defined as the first 1.2 inches of rainfall from a site), the facility is considered adequate.

Notes

“Pre- development conditions” is not defined in the case of redevelopment, therefore it could not be determined if existing impervious areas are included in the runoff calculations.

Chester Creek

Runoff Quantity Controls

Runoff quantity control is accomplished by determining the pre-development RCN value or Rational “C” value from a provided chart to reflect existing conditions less restrictive than “meadow on B class soils” (Chester Creek soils are primarily HSG ‘B’) based on the percentage of exiting impervious cover. Post- development runoff must then meet pre- development rates based upon the given release rate criteria for the site.

Runoff Quality Controls

Water quality must be addressed using the following:

1) Infiltration
2) Extended detention
3) Implementation of additional design control

Riparian buffers are required where applicable (404.A.2).

Notes

Chart developed for “Adjusted” RCN or C values is based on the composite value of the impervious and pervious sections as follows:

for RCN Method: %imperv * 98 + %perv * 58 (meadow “B” soils)
for Rational Method: %imperv * 0.95 + %perv * 0.12 (Lawn, sandy soil, avg slope)

Conclusions

An ordinance which addresses development in an area where redevelopment is encouraged should provide the developer with some credit to consider on site exiting impervious conditions when determining the amount of stormwater runoff which should be stored or treated. If no credit is given, and the developer must design to meet pre- existing (i.e. no impervious cover) rates, the standards may discourage the use of redevelopment sites. However, this must be balanced with the desire to improve existing conditions as it relates to improving water quality and reducing potential flood damages to downstream areas.

Of the five ordinances reviewed, the Portland, OR criteria appears to present the most stringent standards to meet by requiring onsite flows for redevelopment sites to be limited to pre-existing (i.e. undeveloped) rates and no credit is given for existing on site impervious cover. The Seattle, WA criteria specifies target flow values which are site independent and again do not consider existing impervious cover. Both of these ordinances are considered to be strict criteria which may discourage redevelopment projects in areas where the developer has an option to use undeveloped sites. In areas where there are little undeveloped available lands and development pressures are high, these ordinances may be considered to reduce downstream flooding and water quality impacts.

Of the remaining ordinances, Georgia, Maryland & Chester Creek, the Georgia and Maryland criteria were not specific enough to determine if existing impervious cover was considered to be part of the pre- development conditions. However, the Chester Creek ordinance clearly considers existing impervious cover in the determination of pre development conditions. The charts developed for the Chester Creek ordinance are based upon assuming that the pre development site is underlain by “B” soils, which is somewhat conservative when determining the storage / treatment volumes for post development runoff, if the site were actually underlain by a “C” or “D” soil. The Chester Creek ordinance also requires that water quality issues be addressed in the form of TSS reductions and groundwater recharge. The approach of this ordinance is more suitable for areas where developer have the option of choosing undeveloped sites for development, rather than redevelopment sites. The water quantity criteria coupled with then currently promoted water quality criteria should both encourage redevelopment projects while improving existing water quality concerns and flooding concerns, to a lesser degree. In areas where downstream flooding is a current problem, additional credits (i.e. exemption from water quantity criteria as in the MD ordinance) may be given to the developer is a reduction in total impervious area can be attained.

Appendix

1 Maryland

1.1 Definition

"Redevelopment" means any construction, alteration, or improvement exceeding 5,000 square feet of land disturbance performed on sites where existing land use is commercial, industrial, institutional, or multifamily residential.

1.2 When Stormwater Management Is Required

Redevelopment

(1) An approving agency shall require that stormwater management be addressed for redevelopment. Proposed redevelopment project designs shall include:

(a) A reduction in impervious area;
(b) The implementation of stormwater management practices; or
(c) A combination of both §D (1) (a) and (b) of this regulation to result in an improvement to water quality.

(2) Unless otherwise specified by watershed management plans developed according to §E of this regulation, all redevelopment projects shall reduce existing site impervious area by at least 20 percent.

(3) Where site conditions prevent the reduction of impervious area, stormwater management practices shall be implemented to provide water quality control for at least 20 percent of the site's impervious area.

(4) When a combination of impervious area reduction and stormwater management practice implementation is used for redevelopment projects, the combination of impervious area reduction and the area controlled by a stormwater management practice shall equal or exceed 20 percent.

(5) An approval authority may allow practical alternatives where conditions prevent impervious area reduction or on-site stormwater management. Practical alternatives include, but are not limited to:

(a) Fees paid in an amount specified by the approving agency;
(b) Off-site BMP implementation for a drainage area comparable in size and percent imperviousness to that of the project;
(c) Watershed or stream restoration;
(d) Retrofitting; or
(e) Other practices approved by the appropriate authority.

(6) The recharge, channel protection storage volume, and overbank flood protection volume requirements specified in the Design Manual do not apply to redevelopment projects unless specified by the approving agency.

(7) On-site or off-site channel protection storage volume requirements as specified in the Design Manual may be imposed if watershed management plans

developed according to §E of this regulation indicate that downstream flooding or erosion need to be addressed.

(8) Variations of this redevelopment policy shall be approved by the Administration.

1.3 Redevelopment Provisions That Different From Requirement

An approving agency may develop quantitative waiver and redevelopment provisions for stormwater management that differ from the requirements of this chapter. These provisions shall be developed only as part of an overall watershed management plan. Watershed management plans developed for the purposes of implementing different stormwater management policies for waivers and redevelopment shall:

(1) Include detailed hydrologic and hydraulic analyses to determine hydrograph timing;

(2) Evaluate both quantity and quality management;

(3) Include cumulative impact assessment of watershed development;

(4) Identify existing flooding and receiving stream channel conditions;

(5) Be conducted at a scale determined by the approving agency; and

(6) Specify where on-site or off-site quantitative and qualitative stormwater management practices are to be implemented.

1.4 References

Title 26 DEPARTMENT OF THE ENVIRONMENT. Subtitle 17 WATER MANAGEMENT. Chapter 02 Stormwater Management. Authority: Environment Article, §4-203, Annotated Code of Maryland. 26.17.02.00.

1.5 URLs

https://constmail.gov.state.md.us/comar/dsd_web/comar_web/subtitle_chapters/26_Chapters.htm#Subtitle17

2 *City of Seattle*

2.1 Definition

All land disturbing activities or addition or replacement of impervious surface are required to comply with this section, even where drainage control review is not required. Exception: Maintenance, repair, or installation of underground or overhead utility facilities, such as, but not limited to, pipes, conduits and vaults, is not required to comply with the provisions of this section.

"Replaced impervious surface" or "replacement of impervious surface" means impervious surface that is removed down to earth material and a new impervious surface is installed.

"New development" means any of the following activities: Structural development, including construction of a new building or other structure; Expansion or alteration of an existing structure that results in an increase in the footprint of the building or structure; Land disturbing activities; Creation or expansion of impervious surface; Demolition; Subdivision and short subdivision of land as defined in RCW58.17.020.

2.2 When Compliance Is Required

Redevelopment

The portion of the site being redeveloped shall at least comply with the minimum requirements below. Projects exceeding 9,000 square feet of developmental coverage must also comply with the additional requirements. Compliance is required regardless of the type of redevelopment, and regardless of whether or not a permit is required. However, only those projects meeting the review thresholds set forth in Subsection B below must prepare and submit the required plans.

2.3 Minimum Requirements for All Projects

All projects must comply with the requirements of this subsection. Projects with more than 9,000 square feet of developmental coverage shall also comply with the requirements of additional requirement for larger project below. The Director of Construction and Land Use may also require projects with 9,000 square feet or less of developmental coverage to comply with the requirements set forth in additional requirement for larger project when necessary to accomplish the purposes of this Subtitle. In making this determination, the Director of Construction and Land Use may consider, but not be limited to, the following attributes of the site: location within an Environmentally Critical Area; proximity and tributary to an Environmentally Critical Area; proximity and tributary to an area with known erosion or flooding problems.

(1) Discharge Point. The discharge point for drainage water from each site shall be selected as set forth in rules promulgated jointly by the Director of Seattle Public Utilities and the Director of Construction and Land specifying criteria, guidelines and standards for determining drainage discharge points to meet the purposes of this Subtitle. The criteria shall include, but not be limited to, preservation of natural drainage patterns and whether the capacity of the drainage control system is adequate for the additional volume. For those projects meeting the review threshold, the proposed discharge point shall be identified in the drainage control plan required by paragraph C4 below, for review and approval or disapproval by the Director of Construction and Land Use.

(2) Discharge Rate. To the extent practical, the peak drainage water discharge rate from pervious and impervious surfaces on the site shall not exceed 0.2 cubic feet per second per acre under design storm conditions. The Director of Construction and Land Use and the Director of Seattle Public Utilities may jointly promulgate rules modifying the discharge rate requirement for projects which will result in less than 2,000 square feet of new impervious surface. The Director of Construction and Land Use and the Director of Seattle Public Utilities may jointly promulgate rules allowing exceptions to the permissible peak discharge rate for property which discharges water directly to a designated receiving water or directly to a public storm drain which the Director of Seattle Public Utilities determines has sufficient capacity to carry existing and anticipated loads from the point of connection to a receiving water. The design storm used to determine detention volume necessary to obtain the required discharge rate shall be a storm with a statistical probability of occurrence of one in 25 in any given year. If the project is within an environmentally critical area, the design storm requirements of SMC Chapter 25.09, Regulations for Environmentally Critical Areas, shall be applied. The Director of Seattle Public Utilities and the Director of Construction and Land Use shall jointly adopt rules specifying the methods of calculation to determine the discharge rate. Where laws or regulations of the federal government or the State of Washington impose a more stringent requirement, the more stringent requirement shall apply.

(3) Control Measures. During new development, redevelopment and land-disturbing activities, best management practices, as further specific din rules promulgated jointly by the Director of Seattle Public Utilities and the Director of Construction and Land Use, shall be used to accomplish the following:

(a) Control erosion and the transport of sediment from the site through measures such as mulching, matting, covering, silt fences, sediment traps and catch basins, settling ponds and protective berms;
(b) Permanently stabilize exposed soils that are not being actively worked, through such methods as the installation of permanent vegetative cover and installation of slope protective materials; and
(c) Control the introduction of contaminants and pollutants into, and reduce and treat contaminants in drainage water, drainage control

facilities, surface water and groundwater, and the public drainage control system by methods such as covering of material stockpiles; proper disposal of hazardous materials; regular cleaning of catch basins, gravel truck loading and heavy equipment areas; spill control for fueling operations; sweeping; and maintaining erosion control protective features described above.

(4) Drainage Control Plan. For those projects meeting the review thresholds set forth in Subsection B above and which are less than 9,000 square feet, the applicant shall submit a drainage control plan as set forth in rules promulgated jointly by the Director of Seattle Public Utilities and the Director of Construction and Land Use. Standard designs for drainage control facilities as set forth in the rules may be used. Projects exceeding 9,000 square feet must submit a comprehensive drainage control plan as set forth in Subsection D below. The Director of Construction and Land Use may impose additional requirements, including a comprehensive drainage control plan prepared by a licensed civil engineer, when the project has complex or unusual drainage, or when additional requirements are otherwise necessary to accomplish the purposes of this Subtitle.

(5) Memorandum of Drainage Control. The owner(s) of the site shall sign a "memorandum of drainage control" that has been prepared by the Director of Seattle Public Utilities. Completion of the memorandum shall be a condition precedent to issuance of any permit or approval for which a drainage control plan is required. The memorandum shall not be required when the drainage control facility will be owned and operated by the City. A memorandum of drainage control shall include:

(a) The legal description of the site;
(b) A summary of the terms of the drainage control plan, including any known limitations of the drainage control facilities, and an agreement by the owners to implement those terms;
(c)) An agreement that the owner(s) shall inform future purchasers and other successors and assignees of the existence of the drainage control facilities and other elements of the drainage control plan, the limitations of the drainage control facilities, and of the requirements for continued inspection and maintenance of the drainage control facilities;
(d) The side sewer permit number and the date and name of the permit or approval for which the drainage control plan is required;
(e) Permission for the City to enter the property for inspection, monitoring, correction, and abatement purposes;
(f) An acknowledgment by the owner(s) that the City is not responsible for the adequacy or performance of the drainage control plan, and a waiver of any and all claims against the City for any harm, loss, or damage related to the plan, or to drainage or erosion on the property, except for claims arising from the City's sole negligence; and

(g) The owner(s)' signatures acknowledged by a notary public. The applicant shall file the memorandum of drainage control with the King County Department of Records and Elections so as to become part of the King County real property records. The applicant shall give the Director of Seattle Public Utilities proof of filing of the memorandum.

(6) Flood-Prone Areas. Sites within flood prone areas must employ measures to minimize the potential for flooding on the site and for the project to increase the risk of floods on adjacent or nearby properties. Flood control measures shall include those set forth in other titles of the Seattle Municipal Code and rules promulgated there under, including but not limited to, SMC Chapter 25.06 (Floodplain Development) and Chapter 25.09 (Environmentally Critical Areas), and in rules promulgated jointly by the Director of Seattle Public Utilities and the Director of Construction and Land Use to meet the purposes of this subsection.

(7) Natural Drainage Patterns. Natural drainage patterns shall be maintained.

(8) Obstruction of Watercourses. Watercourses shall not be obstructed.

2.4 Additional Requirements for Large Projects

All projects exceeding 9,000 square feet of developmental coverage and those small projects identified by the Director according to subsection C above must comply with the requirements set forth in this subsection. These requirements are in addition to the requirements set forth in Subsection C above. When the Directors develop rules prescribing best management practices for particular purposes, whether or not those rules are adopted by ordinance, BMPs prescribed in the rules shall be the BMPs required for compliance with this Subsection. Best management practices shall include, but not be limited to: maintenance and housekeeping practices such as proper storage of oil barrels and other contaminant sources, covering material stockpiles, proper use and storage of hazardous materials, as well as constructed facilities such as detention tanks, wet ponds, extended detention dry ponds, infiltration, vegetated streambank stabilization, structural stabilization, catch basins, oil/water separators, grassed swales, and constructed wetlands.

(1) In addition to detaining a 25-year storm to a release rate of 0.2 cubic feet per second per acre, the peak drainage water discharge rate from projects of more than 9,000 square feet of developmental coverage shall not exceed 0.15 cubic feet per second per acre in a two-year storm;
(2) Control the sources of sediment and other contaminants and pollutants that could enter drainage water, including the selection, design and maintenance of temporary and permanent best management practices;

(3) Minimize streambank erosion and effects on water quality in streams, including the selection, design and maintenance of temporary and permanent best

management practices, where stormwater is discharged directly to a stream or to a conveyance system that discharges to a stream;

(4) Minimize the introduction of sediment, heat and other pollutants and contaminants into wetlands, including the selection, design and maintenance of temporary and permanent best management practices, where stormwater discharges directly to a wetland or to a conveyance system that discharges into a wetland;

(5) Analyze impacts to off-site water quality resulting from the project. The analysis shall comply with this Subsection and rules promulgated pursuant to this Subsection. The analysis shall provide for mitigation of all surface water quality or sediment quality impacts. The impacts to be evaluated and mitigated shall include at least the following:

(a) Amount of sedimentation;
(b) Streambank erosion;
(c) Discharges to groundwater contributing to recharge zones;
(d) Violations of state or federal surface water, groundwater, or sediment quality standards; and
(e) Spills and other accidental illicit discharges;

(6) A schedule shall be provided for inspection and maintenance of proposed temporary and permanent drainage control facilities and other best management practices. The schedule shall meet the requirements of this Subtitle and rules promulgated under this Subtitle.

(7) In addition to the requirements described above, for land- disturbing activities and demolition of structures, an erosion/sediment control plan designed to comply with the requirements and purposes of this Subtitle and rules promulgated hereunder shall be submitted and implemented. The erosion/sediment control plan shall be designed to accomplish the following:

(a) Stabilization of exposed soils and sediment trapping;
(b) Delineation of limits on clearing and easements;
(c) Protection of adjacent property;
(d) Appropriate timing and stabilization of sediment trapping measures;
(e) Minimization of erosion on cut-and-fill slopes;
(f) Control of off-site erosion;
(g) Stabilization of temporary conveyance channels and outlets;
(h) Protection of storm drain inlets;
(i) Minimization of transport of sediment by construction vehicles;
(j) Appropriate timing for removal of temporary best management practices;
(k) Control of discharges from construction site dewatering devices to minimize contamination of drainage water; and

(l) Inspection and maintenance of best management practices for erosion/sediment control to insure functioning at design capacity.

(8) Comprehensive Drainage Control Plan. A comprehensive drainage control plan to comply with the requirements of this Subtitle and rules promulgated hereunder and to accomplish the purposes of this Subtitle shall be submitted with the permit application. It shall be prepared by a licensed civil engineer in accordance with standards adopted by the Director of Construction and Land Use.

2.5 References

Seattle Municipal Code (SMC) SMC 22.800.010- Stormwater, Grading and Drainage Control Code

An ordinance Relating to the Stormwater, Grading, and Drainage Control Code, as adopted by Ordinance 116425 and amended by Ordinances 117432, 117697, 117789, and 118396; amending Chapter 22.800, entitled "Title, Purpose, Scope, and Authority"; amending Chapter 22.801, entitled "Definitions"; amending Chapter 22.802, entitled "Stormwater, Drainage, and Erosion Control"; amending Chapter 22.804, entitled "Grading"; and amending Chapter 22.808, entitled "Administration and Enforcement."

2.6 URLs

http://clerk.ci.seattle.wa.us/~scripts/nph-brs.exe?s1=22.800&s2=&S3=&Sect4=AND&l=20&Sect1=IMAGE&Sect3=PLURON&Sect5=CODE1&d=CODE&p=1&u=/~public/code1.htm&r=1&Sect6=HITOFF&f=G

http://clerk.ci.seattle.wa.us/~scripts/nph-brs.exe?d=CBOR&s1=119965.ordn.&Sect6=HITOFF&l=20&p=1&u=/~public/cbor2.htm&r=1&f=G

3 *City of Portland*

3.1 Definition

Redevelopment: Any development that requires demolition or complete removal of existing structures or impervious surfaces at a site and replacement with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered to be redevelopment. Interior remodeling projects and tenant improvements are also not considered to be redevelopment. Utility trenches in streets are not considered redevelopment unless more than 50% of the street width is removed and re-paved.

3.2 Requirements

Pollution Reduction Requirements

The City of Portland has a citywide pollution reduction requirement for all new development projects with <u>over 500 square feet</u> of impervious development footprint area, and all redevelopment projects redeveloping over 500 square feet of impervious surface. This requirement is 70 percent removal of total suspended solids (TSS) from runoff generated by a design storm up to and including 0.83 inches of rainfall over a 24-hour period (NRCS Type 1A distribution). Appendix B provides a more detailed definition of "70 percent removal of TSS", which is actually a function of influent TSS concentration.

Flow Control Requirements

Flow control requirements are intended to maintain post-development peak flows at their pre-development levels and to maintain peak flows within the capacity of the conveyance system for most storm events. Specifically, on-site flow control shall be sufficient to maintain peak flows at their pre-development levels for the 2-year, 5-year, and 10-year runoff events. (Note that for redevelopment projects, pre-development conditions are defined as undeveloped land- See definition in Section 1.3). Surface retention facilities are required to the maximum extent practicable to control stormwater volumes (see exceptions in Section 1.6).

3.3 Parking Lots

Surface Parking Lot Requirements

Parking and Loading describes dimensions, landscaping and other requirements for parking lots. Title 33.248: Landscaping and Screening describes planting requirements for parking lots and other site uses. (Also see Chapter 5.0 for a list of approved parking lot trees.) Any new parking lot that creates more than 500 square feet of impervious surface, or any redeveloped parking lot (see definition of redevelopment in Section 1.3) that redevelops more than 500 square feet of impervious surface, must use the landscape area required by the zoning code to manage stormwater from the new or redeveloped area. Existing parking lots required to meet the non-conforming use landscaping requirements under Title 33.258.070, must use simplified approaches where practicable in the newly required landscaped areas. Where it is not practical for runoff to flow into landscaped areas this requirement does not apply. The following exceptions and/or conditions to these requirements may apply. If an exception is claimed, the applicant must still fulfill all other relevant requirements of Chapters 1.0 through 7.0 of this manual.

(1) The parking lot or a portion of it is designated as a high-use (see Chapter 4.0, Section 4.11) and is subject to requirements that may conflict with the use of landscaping for stormwater management.

(2) Contaminated soil conditions on the site preclude the use of landscape infiltration. In this situation, landscape facilities may be used for stormwater management, but must be lined to prevent infiltration.

(3) The parking lot has been approved without landscaping, or has landscaping conditions that conflict with the use of the landscaping for stormwater management. (For example, if landscaping is required in a location that cannot receive stormwater as gravity flow, that portion of the landscaping would not have to be used for stormwater management.) The following simplified approaches from this chapter may be used to meet these requirements:

- (a) Vegetated swales
- (b) Grassy swales
- (c) Vegetated filters
- (d) Planter boxes
- (e) Vegetated infiltration basins
- (f) Sand filters
- (g) Soakage trenches (if site soil conditions support their use, and the surface of the trench is not paved over).The appropriate sizing requirements shown on Form SIM shall be used to calculate the area needed for the applied measures. If the landscaped area(s) within the parking lot are not adequately sized to meet the requirements of this chapter, the applicant has the following options:
  - (i) Increase the landscaped area(s) within the parking lot to accommodate the required stormwater facility size, or
  - (ii) Use additional stormwater management facilities (which can include non-landscaped approaches) to obtain the required level of management.
- (h) Additional disposal measures (e.g., drywells, soakage trenches, off-site storm sewers, drainage ways, or ditches) may be required

through building and plumbing codes, as approved by BES and OPDR.

Tips for Parking Lot Design

(1) Design the grading to direct stormwater runoff into landscape areas. Depress the landscape areas adjacent to the parking surfaces to allow runoff to enter. See the vegetated swale detail in this chapter for a typical cross-section.

(2) Maximize sheet flow opportunities and, if possible, avoid piping that drives the water level down, making it difficult to manage in surface facilities.

(3) Provide numerous curb cuts (one every 10 feet) or use tire stops or other means to protect the landscape areas and allow maximum dispersal of the flows.

(4) Consider design elements such as berms or trench drains.

(5) When possible, situate buildings or fill areas on the high elevations of the site.

(6) Make certain the design includes overflow and appropriate disposal methods. Overflow routes must show a safe escape route for the 100-year storm event.

(7) Note that the parking lot tree standard is 3 caliper inches, unless the tree is chosen from the approved parking lot tree list, when it can be 2 caliper inches.

3.4 References

2002 Stormwater Management Manual, Adopted July 1, 1999, Revised September 1, 2002, Environmental Services, City of Portland Clean River Works.

3.5 URLs

http://www.cleanrivers-pdx.org/tech_resources/2002_swmm.htm

4 *GEORGIA*

4.1 Definitions

Redevelopment is defined as structural development (construction, installation or expansion of a building or other structure), creation or addition of impervious surfaces (creating an additional 5,000 s.f. of impervious area), replacement of impervious surface not part of routine maintenance, and land disturbing activities associated with structural or impervious development. Redevelopment does not include such activities as exterior remodeling.

4.2 Stormwater Management for Area of New Development and Redevelopment

The focus of this Manual is how to effectively deal with the impacts of urban stormwater runoff through effective and comprehensive stormwater management. Stormwater management involves both the prevention and mitigation of stormwater runoff quantity and quality impacts as described in this chapter through a variety of methods and mechanisms. Volume 2 of this Manual deals with ways that developers in Georgia can effectively implement stormwater management to address the impacts of new development and redevelopment, and both prevent and mitigate problems associated with stormwater runoff. This is accomplished by:

(1) Developing land in a way that minimizes its impact on a watershed, and reduces both the amount of runoff and pollutants generated

(2) Using the most current and effective erosion and sedimentation control practices during the construction phase of development

(3) Controlling stormwater runoff peaks, volumes and velocities to prevent both downstream flooding and streambank channel erosion

(4) Treating post-construction stormwater runoff before it is discharged to a waterway Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place

(5) Using various techniques to maintain groundwater recharge

The goal of a set of minimum stormwater management standards for areas of new development and significant redevelopment is to reduce the impact of post-construction stormwater runoff on the watershed. This can be achieved by (1) maximizing the use of site design and nonstructural methods to reduce the generation of runoff and pollutants; (2) managing and treating stormwater runoff though the use of structural stormwater controls; and (3) implementing pollution prevention practices to limit potential stormwater contaminants.

It should be noted that the standards presented here are recommended for all communities in Georgia. They may be adopted by local jurisdictions as stormwater management development requirements and/or may be modified to meet local or watershed-specific stormwater management goals and objectives. Please consult your local review authority for more information.

The minimum standards for development are designed to assist local governments in complying with regulatory and programmatic requirements for various state and Federal programs including the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit program and the National Flood Insurance Program under FEMA.

4.3 Additional Requirements

New development or redevelopment in critical or sensitive areas, or as identified through a watershed study or plan, may be subject to additional performance and/or regulatory criteria. Furthermore, these sites may need to utilize or restrict certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area.

4.4 Georgia Stormwater Management Manual Volume 2 (Technical Handbook)

The following standards are the recommended minimum stormwater management performance requirements for new development or redevelopment sites falling under the applicability criteria in subsection 1.2.2.1. (The word "shall" in brackets is provided for local jurisdictions that wish to adopt these standards as part of their stormwater management ordinances) A more detailed explanation of each minimum standard is provided in the next subsection.

Minimum Standard #1 – Use of Better Site Design Practices for Stormwater Management
Site designs should preserve the natural drainage and treatment systems and reduce the generation of additional stormwater runoff and pollutants to the fullest extent practicable.

Minimum Standard #2 – Stormwater Runoff Quality
All stormwater runoff generated from a site should [shall] be adequately treated before discharge. Stormwater management systems (which can include both structural stormwater controls and better site design practices) should [must] be designed to remove 80% of the average annual post-development total suspended solids (TSS) load and be able to meet any other additional watershed- or site-specific water quality requirements.

It is presumed that a stormwater management system complies with this performance standard if:

It is sized to capture and treat the prescribed water quality treatment volume, which is defined as the runoff volume resulting from the first 1.2 inches of rainfall from a site; and appropriate structural stormwater controls are selected, designed, constructed, and maintained according to the specific criteria in this Manual. Runoff from hotspot land uses and activities is adequately treated and addressed through the use of appropriate structural stormwater controls and pollution prevention practices.

Minimum Standard #3 – Stream Channel Protection
Stream channel protection should [shall] be provided by using all of the following three approaches: 24-hour extended detention storage of the 1-year, 24-hour return frequency storm event; erosion prevention measures such as energy dissipation and velocity control; and preservation of the applicable stream buffer.

Minimum Standard #4 – Overbank Flood Protection
Downstream overbank flood protection should [shall] be provided by controlling the post-development peak discharge rate to the predevelopment rate for the 25-year, 24-hour return frequency storm event. If control of the 1-year, 24-hour storm (Minimum Standard #3) is exempted, then overbank flood protection should [shall] be provided by controlling the post-development peak discharge rate to the predevelopment rate for the 2-year through the 25- year return frequency storm events.

Minimum Standard #5 – Extreme Flood Protection
Extreme flood protection should [shall] be provided by controlling and/or safely conveying the 100-year, 24-hour return frequency storm event such that flooding is not exacerbated. Existing and future floodplain areas should be preserved as possible.

Minimum Standard #6 – Downstream Analysis
A downstream hydrologic analysis should [shall] be performed to determine if there are any additional impacts in terms of peak flow increase or downstream flooding while meeting Minimum Standards #1 through 5. This analysis should [shall] be performed at the outlet(s) of the site, and downstream at each tributary junction to the point(s) in the conveyance system where the area of the portion of the site draining into the system is less than or equal to 10% of the total drainage area above that point.

Minimum Standard #7 – Groundwater Recharge
Annual groundwater recharge rates should be maintained to the extent practicable through the use of nonstructural methods.

Minimum Standard #8 – Construction Erosion and Sedimentation Control
Erosion and sedimentation control practices shall be utilized during the construction phase or during any land disturbing activities.

Minimum Standard #9 – Stormwater Management System Operation and Maintenance
The stormwater management system, including all structural stormwater controls and conveyances, should [shall] have an operation and maintenance plan to ensure that it continues to function as designed.

Minimum Standard #10 – Pollution Prevention
To the maximum extent practicable, the development project should [shall] implement pollutant prevention practices and have a stormwater pollution prevention plan.

Minimum Standard #11 – Stormwater Management Site Plan
The development project should [shall] prepare a stormwater management site plan for local government review that addresses Minimum Standards #1 through 10.

4.5 Better Site Design Practice

Reduce the Parking Footprint- Reduction of Impervious Cover

Description: Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, parking decks, and using porous paver surfaces or porous concrete in overflow parking areas where feasible and possible.

Key Benefits
Reduces the amount of impervious cover and associated runoff and pollutants generated

Using this practice
Reduce the number of parking spaces
Minimize stall dimensions
Consider parking structures and shared parking
Use alternative porous surface for overflow areas

Discussion
Setting maximums for parking spaces, minimizing stall dimensions, using structured parking, encouraging shared parking and using alternative porous surfaces can all reduce the overall parking footprint and site imperviousness.
Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand. Table 1.4.2-2 provides examples of conventional parking requirements and compares them to average parking demand.

Table Conventional Minimum Parking Ratios (Source: ITE, 1987; Smith, 1984; Wells, 1994)

Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit

Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft 2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft 2 GFA
Medical/ dental office	5.7 spaces per 1000 t^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall.

Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier to implementing stall minimization techniques, stall width requirements in most local parking codes are much larger than the widest SUV structured parking decks are one method to significantly reduce the overall parking footprint by minimizing surface parking. Figure 1.4.2-20 shows a parking deck used for a commercial development.

Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings.

Utilizing alternative surfaces such as porous pavers or porous concert is an effective way to reduce the amount of runoff generated by parking lots. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. However, porous pavement surfaces generally require proper installation and more maintenance than conventional asphalt or concrete.

4.6 References

Georgia Stormwater Management Manual Volume 1: Stormwater Policy guidebook First Edition August 2001, Atlanta Regional Commission

4.7 URLs

http://www.georgiastormwater.com

5 Center for Watershed Protection (CWP)

5.1 Definition

"Redevelopment" is the process in which an existing developed area is adaptively reused, rehabilitated, renovated or expanded.

"Infill" is development that occurs on smaller parcels that remain undeveloped but are within or very close to existing urban areas.

5.2 What Are The Best Incentives To Encourage Redevelopment?

(1) Resolving the transportation problems, particularly for suburban commuters.
(2) Waterfront development.
(3) Shortening/ simplifying the approval process.
(4) Unifying codes and ordinances.

5.3 Other Suggestions

(1) Don't forget the temporal scale, e.g. over time redevelopment is very beneficial at the site level.
(2) Don't forget the neighborhood based framework. Don't forget environmentally sensitive techniques inside the building.
(3) Make it applicable to all areas of different climate, politics and technical expertise.
(4) Use a word other than principle.

5.4 Tools and Techniques for Redevelopment and Infill

Practice Oriented

(1) Maintain natural features as part of the landscape at a site and encourage tree planting and other revegetation practices.
(2) Manage rooftop runoff through storage, reuse, and/or redirection to pervious surfaces for stormwater management.
(3) Use alternative paving materials for parking and other pathways whenever possible and feasible.
(4) Provide long term management plans for natural areas, public spaces, stormwater management facilities and lighting.

Program Oriented

(1) Promote the rehabilitation of urban streams and the creation and restoration of aquatic corridors.

(2) Encourage the use of green parking techniques by providing incentives whenever possible.
(3) Monitor and eliminate illicit or unmanaged discharges into streams, lakes and estuaries and foster operation and maintenance practices that prevent or reduce pollutants entering the municipal or natural drainage system.
(4) Promote environmental stewardship through outreach and education for the present and the future.
(5) Encourage pollution prevention practices for businesses and municipalities to reduce pollutant loads and foster an environmental ethic.

Shared Principles

(1) Use appropriate, effective, and economical stormwater management where possible.*
(2) Encourage the incorporation of natural features as part of the streetscape.*
(3) Master plan redevelopment areas to promote planting practices and provide green spaces (trees, urban parks, and community gardens) in the urban environment.*
(4) Encourage the use of open space designs, including reduction of building footprints, preservation of natural areas, and innovative building techniques to reduce the amount of new impervious cover created.*
(5) Encourage development designs that integrate new paths, open spaces, and architecture with the existing community.*

Indicates principles that can be organized under both the Practice and Program.

5.5 URLs

http://www.cwp.org/index.html

6 *Green Roofs*

A. Green Roofs for Healthy Cities

Water Benefit (other benefits are not list here)

In summer, green roofs retain 70-100% of the precipitation that falls on them; in winter they retain between 40-50%. A grass roof with a 4-20 cm layer of substrate can hold between 10-15 cm of water.

6.1 Stormwater Retention

Water is stored by the substrate and then taken up by the plants from where it is returned to the atmosphere through transpiration and evaporation.

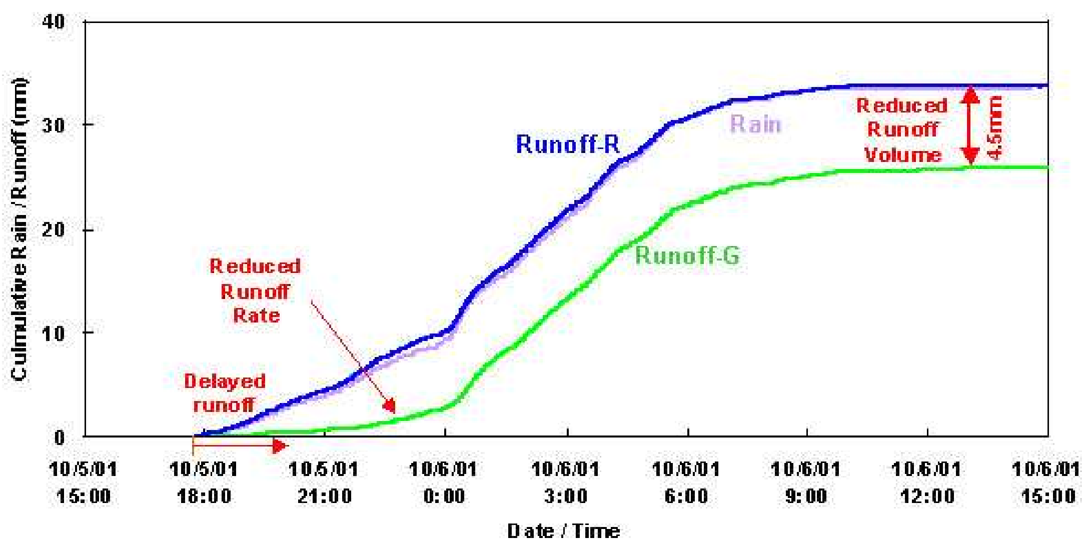
In summer, depending on the plants and growing medium, green roofs retain 70-80% of the precipitation that falls on them; in winter they retain between 25-40%. For example, a grass roof with a 4-20 cm (1.6 - 7.9 inches) layer of growing medium can hold 10-15 cm (3.9 - 5.9 inches) of water.

6.2 Water Filtration

Green roofs not only retain the rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off.

6.3 Temporal Delay of Stormwater Runoff and Reduced Runoff Volume

Green roofs reduce the amount of stormwater runoff and also delay the time at which runoff occurs, resulting in decreased stress on sewer systems at peak flow periods.



Source: National Research Council's Institute for Research in Construction

The graph above records the cumulative rainfall and runoff from the Green Roof and the Reference Roof during a 34mm (1.3 inches) rain event over a 15h period in October 2001. The green roof delayed runoff and reduced the runoff rate and volume. For more details on this research conducted by the National Research Council's Institute for Research in Construction, see the article on page 7 of the Winter 2002 issue of the **Green Roof Infrastructure Monitor**.

6.4 Regulatory/Policy Initiatives

The U.S. Clean Water Act promises to become an important regulatory driver of green roof implementation in the United States. The **Clean Water Act, Section 319 Grant**, addresses non-point source pollution and can provide a source of funding for green roofs.

To inquire about receiving Section 319 grant funding for green roof projects contact your **state nonpoint source coordinator**. Green roofs can be funded as demonstration projects throughout most states and can be used to mitigate the impacts of stormwater and combined sewer overflows in developed areas.

Two projects funded by this grant include:

Maryland: Montgomery Park, Grant Award: $92, 000.00

Arizona: Riverfront Residence, Grant Award: $33, 875.00

The **City of Seattle** requires that all new municipal buildings be LEED™ certified and green roofs provide an opportunity to gain as many as 5 points under this system. A number of LEED™ certified buildings have green roofs.

The City of Toronto’s “Environmental Plan” and draft “Official Plan” both contain policies that encourage the implementation of green roof infrastructure

The City of Chicago passed an **Energy Conservation Ordinance** on June 3, 2001 requiring all new and replaced roofs to meet minimum standards of solar reflectance and emissivity using ASTM testing methods. This requirement, which is being phased in, can be met by installing a green roof system.

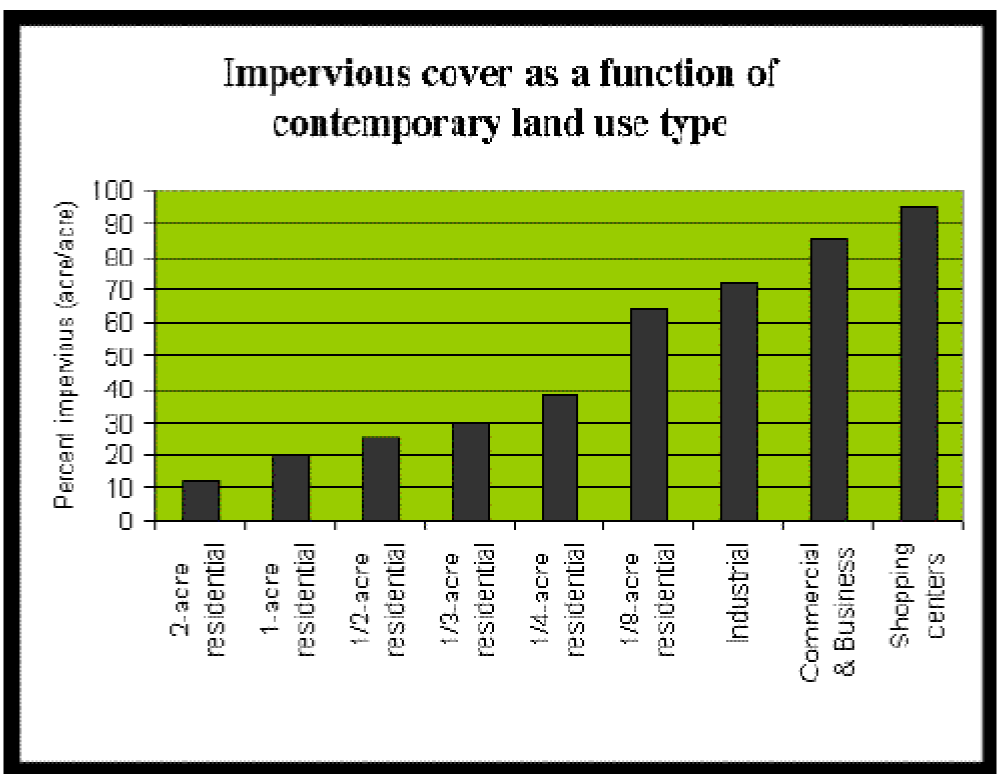
B. GreenRoofs

6.5 GreenRoof

Greenroofs reduce the volume of stormwater flowing into streams and drainage channels, resulting in the control of sediment transport and overall soil erosion. According to an article in the November/December 1998 issue of Erosion Control Magazine, the natural carpets provided by greenroofs protect both roofs and the soil below. Nitrogen, phosphorus and toxins can enter a vegetated stream as dissolved substances. Greenroofs' vegetated cover properties of friction, root absorption, clay, and soil organic matter can control these substances from entering a stream corridor (Dramstad, et al, 1996). In February of 1999, the International Erosion Control Association's Conference & Trade Exposition was held in Nashville, TN, and featured a training workshop and special section regarding the benefits and applications of roof greening systems. Thomas Roess of Strodthoff and Behrens GMBH of Germany presented on this subject, and is a frequent lecturer worldwide on greenroof technology.

Vegetation absorbs pollutants from rainwater, and greenroofs provide this same amenity. Heavy metals and nutrients found in stormwater are bound in the soil instead of being discharged into the groundwater or streams or rivers. Over 95% of cadmium, copper and lead and 16% of zinc can be taken out of rainwater. Nitrogen levels can also substantially fall (The London Ecology Unit, 1993).

Perhaps the greatest ecological function a greenroof can provide is its stormwater management capacity. Impervious cover has become a function of contemporary land uses. As a result of new land use practices, cities across the nation have developed over-stressed sewer systems with urgent stormwater management problems. According to analysis of Lansat Satellite data by NASA climate scientists, University of Georgia researchers and others, metro Atlanta is losing 50 acres of tree cover per day. From 1988 to 1998 the 13-county metro area lost approximately 190,000 acres of tree cover to development (Charles Seabrook, 1999). Lost green space is then a by-product of the proverbial asphalt jungle, and the inherent natural processes associated with natural areas are also lost. The chart below from Bruce Ferguson's *Introduction to Stormwater: Concept, Purpose, Design* (1998), shows the amount of impervious cover that development and the new impervious pavements produce.

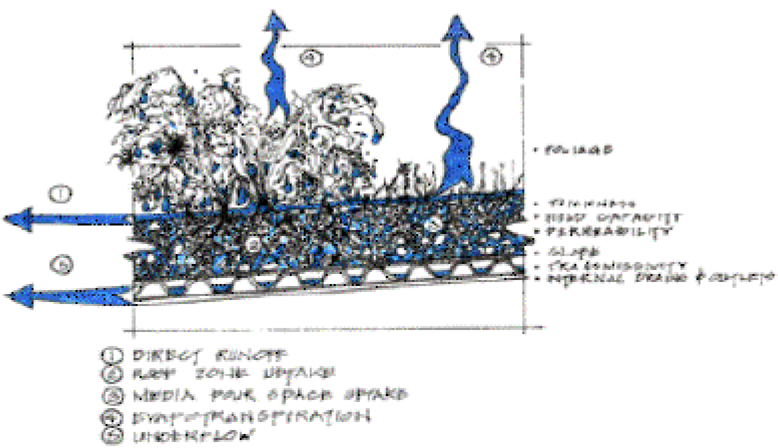


“We are obligated to restore the mechanisms of the earth’s self-maintaining balance. Runoff must be moderated, treated, and returned to its restorative path in the soil,” (Ferguson, 1998).

Source: ZinCo International 3/98 Brochure

On-site stormwater retention and runoff control from expansive roof surface areas of buildings can be accomplished through greenroofs. According to civil engineer Charlie Miller, Principal, of Roofscapes, Inc., “Vegetated roof covers may offer the only practical ‘at-source’ technique for controlling runoff in areas that already are highly urbanized.” The reversal of damage caused by uncontrolled storm water runoff and non-point source pollution is possible within our urbanized watersheds. He believes that the intelligent use of best management practices (BMPs) can result in significant improvements, as well as long-term savings to individuals and municipalities (**www.roofmeadow.com**).

Depending on rain intensity and greenroof soil depths, runoff can be absorbed between 15 to 90 %, thereby considerably reducing runoff and potential pollutants from traditional impervious roofing surfaces. Plants intercept and delay rainfall runoff and the peak flow rate, alleviating combined sewer overflows, and eventually return water to the surrounding atmosphere by evaporation and transpiration. Average runoff absorption rates are between 50 to 60% (**www.roofmeadow.com**).



Courtesy of Roofscapes, Inc.; **www.roofmeadow.com**

The control of stormwater runoff is achieved by mimicking natural processes by intercepting and delaying rainfall runoff. Greater grass & plant diversity provides better plant uptake and simple friction, which creates less erosion, and more water is retained on the greenroof surface. Stormwater Natural Processes Detail from **www.roofmeadow.com**.

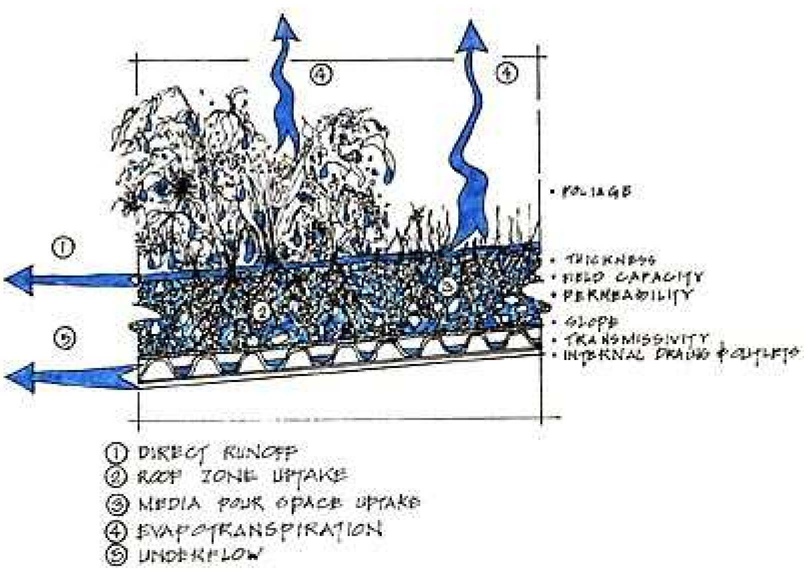
According to Charlie Miller, the installation of greenroofs is “a potential technique for relieving nuisance flooding and reducing hydraulic loads on combined storm sewer systems.” He contends that, “In addition to providing immediate relief for overburdened stormwater management facilities, the deployment of vegetated roof covers can help reduce the overall costs of infrastructure rehabilitation in our older cities.”

Possible impervious coverage restrictions may be reduced for developers who incorporate greenroofs into their site plan. Depending on local ordinances, greenroofs may be installed in lieu of conventional stormwater practices. They can significantly reduce the size, or even completely eliminate the necessity for unsightly, space-wasting, and expensive detention ponds or underground galleries (Roofscapes, Inc., 1998). Although hard to quantify, there is also potential for downstream stormwater treatment savings.

Water Benefit

Control of stormwater runoff is achieved by mimicking the processes that occur in nature, intercepting and delaying rainfall runoff by:

- Capturing and holding precipitation in the plant foliage
- Absorbing water in the root zone
- Slowing the velocity of direct runoff as it infiltrates through the layers of vegetated cover

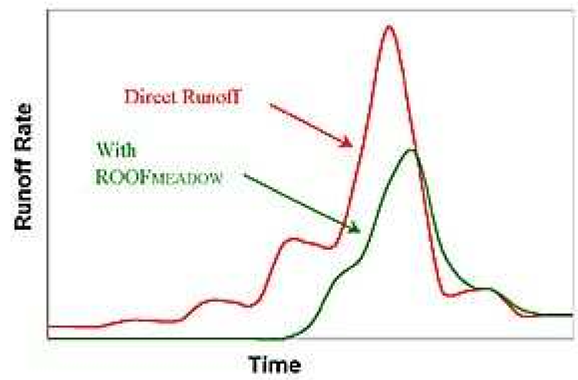


For small rainfall events, little runoff will occur and most of the precipitation will eventually return to the atmosphere by evaporation and transpiration. For larger storms, vegetated roof covers can significantly delay and attenuate the discharge of runoff from roofs.

Vegetated roof covers are effective methods of retarding runoff from roof surfaces during storms:

Compared to many other stormwater management practices, vegetated roof covers are unobtrusive, low maintenance, and reliable management systems. Vegetated roof covers are particularly effective when applied to extensive roofs, such as those that typify commercial and institutional buildings. They can be designed to achieve specified levels of stormwater runoff control, including reductions in:

- Total annual runoff volume (reductions of **50 to 60 percent** are common place for vegetated roof covers)
- Peak runoff rates for selected
- design storm events



Stormwater runoff for a 3.35-inch, 24-hour rainfall event. This Roofmeadow incorporated a 3-inch deep layer of growth media.
© Roofscapes, Inc.

6.6 URLs

http://peck.ca/grhcc/
http://greenroofs.com/
http://roofscapes.com

7 Chester

7.1 Definition (ordinance language)

Redevelopment (in Article II)

Reconstruction of an existing improved, developed property, as of the data of adoption of this Ordinance. This includes all projects creating over 2,000 s.f. of additional impervious cover.

7.2 Water Quality and Quantity Control Drainage Plan preparation Procedure (Ordinance language)

1) Applicant determines if development meet definition of “Redevelopment” per Article II.
2) If yes, applicant adjust pre-development RCN or C value based on curves present in Section 401 C and Appendix B.

7.3 Section 401 C (ordinance language)

The Chester Creek Stormwater Management Plan requires water quality and water quantity controls as illustrated on the flow chart shown in Figure 4-1 and detailed in Section 404. The flow chart illustrates a three-step hierarchical process.

4) Infiltration
5) Extended detention
6) Implementation of additional design control

Must evaluate the outcome of each step before processing to next.
Riparian buffers are required where applicable (404.A.2).

7.4 Appendix B (report)

Figure B-3 Redevelopment project runoff criteria adjustment for pre-development conditions

Concern was expressed that imposing the release rate criteria on redevelopment projects might serve as a disincentive for developers. Therefore, an approach was proposed that would reduce the level of control required on redevelopment projects. This was accomplished by developing a chart which allows modification of pre-development conditions for which the stormwater management plan would be prepared. This chart adjusts the pre-development RCN value or “C” value to reflect conditions less restrictive than “meadow on B class soils” based on the percentage of exiting impervious cover.

Comment: The figure development is ok. But the goal of “Back to the natural condition” will not be reached.

7.5 Section 403 C (ordinance language)

Redevelopment projects shall meet peak discharge requirements based on the adjusted runoff control number (RCN) or “C” value illustrated by Figure B-3 in Appendix B.

7.6 Section 405 B (ordinance language)

For the purpose of pre-development flow rate determination, undeveloped land shall be considered as “meadow” good condition, type “B” soils, (RCN=58, Rational “C”=0.12) unless the natural ground cover generates a lower curve number or Rational “C” value (i.e., forest). If a proposed development meets the definition of redevelopment as defined in Article II of this Ordinance, the applicant may adjust the pre-development RCN or “C” value based on the curves presented in Figure B-3.

APPENDIX F

DARBY-COBBS CREEK WATERSHED WATER BUDGET AND STORMWATER INFILTRATION REQUIREMENT ANALYSIS

1.0 Introduction

Under natural conditions, watersheds are in hydrologic balance; this means that the natural hydrologic cycle of rainfall, streamflow, and evapotranspiration are in equilibrium. The key to sustainable land development is to maintain this natural hydrologic regime as much as possible. The first step in accomplishing this is to develop an understanding of the watershed's water budget.

A water budget (or water balance) was used in 1944 by the meteorologist C. Warren Thornthwaite to refer to the balance between the income of water from precipitation and snow melt and the outflow of water by evapotranspiration, groundwater recharge and streamflow. The water balance has been used in a variety of situations, to predict human impact on the watershed hydrologic cycle, and has been refined many times. Although the predictions made using the water budget method may be approximate, it is sufficiently accurate to provide a basis for determining a management approach to sustaining the natural hydrologic conditions of a watershed.

In order to evaluate how this water budget can be managed, the watersheds or site specific annual water budget must be evaluated. The general equation of the annual water budget is:

$$P = R + WL \qquad \text{Equation 1}$$

where:

P = average annual precipitation (rain and snow)
R = average annual total runoff (overland surface runoff and groundwater discharge to base flow)
WL = average annual water loss (evaporation, transpiration and groundwater losses).

The total runoff value is composed of both overland surface runoff which occurs during rainfall events and infiltration which equates to groundwater discharge to streams which augments the base flow of streams in the watershed. For the water budget analysis, these two sources of flow were separated. Equation 1, therefore can be rewritten as

$$P = R_{osr} + R_e + WL \qquad \text{Equation 2}$$

where:
R_{osr} = overland surface runoff
R_e = groundwater recharge/discharge

The following sections provide a background for how these parameters were developed to analyze the water budget of the Darby-Cobbs watershed.

2.0 Prior Studies

Balmer and Davis (1996) had previously conducted a groundwater resource study for Delaware County, PA in which they studied three stream gauges in the Darby-Cobbs watershed. The gauges they analyzed were Darby Creek at Waterloo Mills near Devon, PA (01475300), Darby Creek near Darby, PA (01475510), and Cobbs Creek at Darby, PA (01475550).

Table 1 shows the total runoff and base flow of these three stream gauges determined in the study of Balmer and Davis. Based upon this information, they concluded that Cobbs Creek had the lowest ratio of base flow, which is most likely caused by an increased direct runoff from storm sewers, and therefore a lower groundwater recharge rate, in this highly urbanized watershed. Analysis of the water budget of this gauge would not be reflective of natural conditions of the watershed, which is the ideal goal for the water budget analysis. Therefore, the Cobbs Creek gauge was not further analyzed.

Table 1

Summary of Runoff and Base Flow for Dry (1981), Normal (1976) and Wet (1979) Years. Modified from Table 6 of WRR 66 (Balmer, 1996)

USGS Gauge Name and Number	Type of year	Discharge, in	Base flow, in
Darby Creek at Waterloo Mills Near Devon, PA 01475300	Dry	14.33	9.10
	Normal	22.98	18.51
	Wet	37.61	21.77
Darby Creek Near Darby, PA. 01475510	Dry	13.27	7.02
	Normal	22.64	16.27
	Wet	33.05	17.99
Cobbs Creek at Darby 01475550	Dry	15.15	5.70
	Normal	17.54	9.00
	Wet	29.54	14.66

Detailed hydrologic data including precipitation, streamflow including base flow from 1973 to 1982, were reported in the Balmer and Davis study at the Darby Creek at Waterloo Mills near Devon and the Darby Creek near Darby gauges. This data, provided in Table 2 along with the derived water losses, shows a lower percentage of base flow at the downstream station (Darby Creek near Darby) which is in an urbanized setting, when compared to the upstream station (Darby Creek at Waterloo Mills near Devon), which is in a more rural setting. Balmer and Davis concluded that the possible reasons for the lower percentage of base flow are more rainfall in the upper reaches of the basin, and more direct runoff due to urbanization in the lower reaches of the basins.

Table 2

Comparison of Precipitation, Total Runoff, and Base flow for Darby Creek at Waterloo Mills Near Devon and Darby Creek Near Darby from 1973 to 1982. (Modified from Table 7 of WRR 66, Balmer, 1996)

	Darby Creek at Waterloo Mills Near Devon, Pennsylvania 01475300				Darby Creek Near Darby, Pennsylvania 01475510			
Year	Precipitation[1] (inches)	Total Runoff (inches)	Base flow (inches)	Water loss[3] (inches)	Precipitation[2] (inches)	Total Runoff (inches)	Base flow (inches)	Water loss[3] (inches)
1973	52.14	33.76	23.17	18.38	46.06	36.57	21.91	9.49
1974	41.00	23.40	16.63	17.60	37.78	25.01	16.71	12.77
1975	56.86	28.75	19.53	28.11	52.13	30.27	19.22	21.86
1976	38.09	22.98	18.51	15.11	33.27	22.64	16.27	10.63
1977	50.89	17.85	12.41	33.04	49.42	16.59	9.68	32.83
1978	49.23	36.72	22.96	12.51	35.58	31.37	18.44	4.21
1979	64.34	37.61	21.77	26.73	52.79	33.05	17.99	19.74
1980	34.89	23.12	17.46	11.77	38.80	20.83	14.77	17.97
1981	42.37	14.33	9.10	28.04	37.83	13.27	7.02	24.56
1982	49.04	20.54	13.24	28.50	40.43	20.26	11.77	20.17
Mean	47.89	25.91	17.48	21.98	42.21	24.99	15.38	17.42

[1] Precipitation measured at the Devault and Conshohocken Stations.
[2] Precipitation measured at Philadelphia Airport.
[3] Differences between Precipitation and Total Runoff.

Based upon their observations, the stream gauge 01475300 (Darby Creek at Waterloo Mills near Devon) which is located in the upper portion of the Darby Creek Watershed, has a rural setting which is a less impacted by development within the watershed and therefore the hydrologic behavior is closer to natural conditions. The stream gauge records are continuous and record stream stage (elevation in feet) which can easily be converted to stream flow (in cubic feet per second, cfs) by knowing the cross sectional data and the elevation/flow relationship and the gauge (the “rating curve”). This gauge also has an extended period of record from 1972 through the current year. Knowing the drainage area to this gauge, approximately 5.15 square miles, the flow per square mile can be determined and then applied to other areas of the watershed. From this data, statistical frequency analyses can be applied to determine many useful hydrologic facts including the 100-year flow, mean annual flow, low flow, etc. Considering these factors, and the fact that flow at this gauge reflects more closely the natural hydrologic cycle of the watershed, the Waterloo Mills gauge was selected for the water budget analysis.

3.0 Water Budget Determination

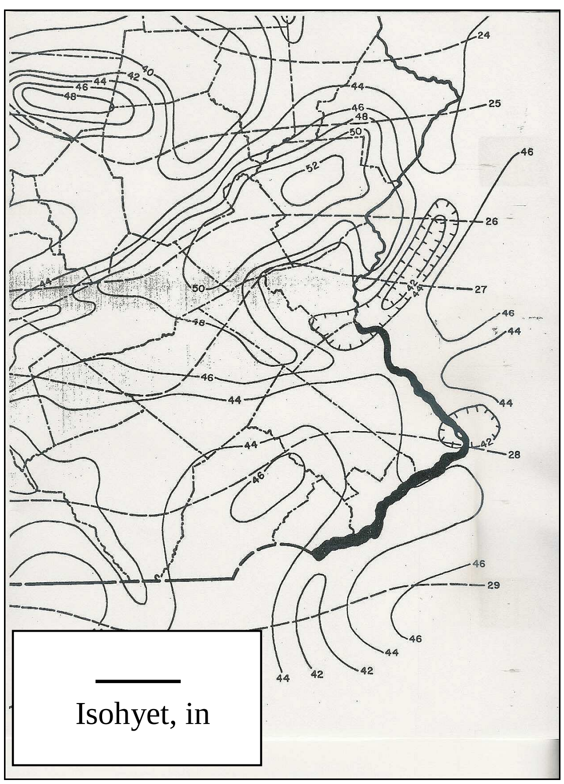
3.1 Average Annual Precipitation (P)

The average annual precipitation of Delaware County, PA was reported in the Balmer study as 43.46 inches (Balmer, 1996). Detailed precipitation records were collected at the Devault and Conshohocken rainfall gauging station from 1973 to 1982 and applied at the stream gauge station 01475300 (Darby Creek at Waterloo Mills near Devon). Similar rainfall data for were measured at the Philadelphia Airport and applied at the stream gauge station 01475510 (Darby Creek near Darby) as reported in WRR 66 (Balmer, 1996). Table 2, above, showed the precipitation range at these stations between is 34.89 and 64.34 inches. The average annual precipitation at the Waterloo Mills gauge was 47.89 inches (based upon the average precipitation measured at the Devault and Conshohocken Stations, Balmer, 1996). It was noted in the Balmer study that the precipitation at the upstream station (Darby Creek at Waterloo Mills near Devon), is greater than that at the downstream station (Darby Creek near Darby) in all years studied (1973-82). The average precipitation difference noted is about 13%.

As a second source of average annual precipitation data, Water Resources Bulletin No. 13 Floods in Pennsylvania (Flippo, 1977) was also referenced. The isohyets are based on U.S. Weather Bureau precipitation data for 1931-60. The average annual precipitation for the Darby-Cobbs watershed is in the range of 44 to 46 inches as shown in Figure 1.

Figure 1

Annual Precipitation Map of Northeast Pennsylvania (Flippo, 1977)
Isohyets are Based on U.S. Weather Bureau Precipitation Data for 1931- 1960.



As noted above, precipitation in the Darby-Cobbs Creek varies based upon location within the watershed. Therefore, the average annual precipitation selected for determining the water budget must be weighted carefully.

There are several rain gages around the watershed including Conshohocken, Montgomery Co. (36, 6927), Pheonixville, Chester Co. (36 1737), Chadds Ford, Delaware Co. (36 1342), Marcus Hook, Delaware Co. (36 5390), Philadelphia Airport, Philadelphia Co. (36 6889), and Devault, Chester Co. (36 2116). Table 3 presents the average annual precipitation of these gages for 1972-2000. The average precipitation of Darby-Cobbs watershed was also computed using Thiessen-weighted average. Thiessen-weighted average is a better measure where the rain gages is not uniform distributed and where has stronger precipitation gradients (Dunne, 1978). Figure 2 depicts the percentage of influence area within the watershed and average annual precipitation of each gage used in Thiessen-weighted average. Table 4 shows the calculation of the Thiessen-weighted average.

Table 3

Average Annual Rainfall (in) of Rain Gages Nearby the Darby-Cobbs Watershed from 1972 to 2000.

Rain Gage Name and Station Number	Average Annual Precipitation, in
Conshohocken, Montgomery Co. (36, 6927)	48.79
Pheonixville, Chester Co. (36 1737)	43.87
Chadds Ford, Delaware Co. (36 1342)	47.56
Marcus Hook, Delaware Co. (36 5390)	40.66
Philadelphia Airport, Philadelphia Co. (36 6889)	42.05
Devault, Chester Co. (36 2116)	43.72

Source: Middle Atlantic River Forecast Center, National Weather Service

Figure 2

Percentage of Influence Area within the Watershed for Each Rain gage Along with Average Annual Precipitation Used for Thiessen-Weighted Average Analysis.

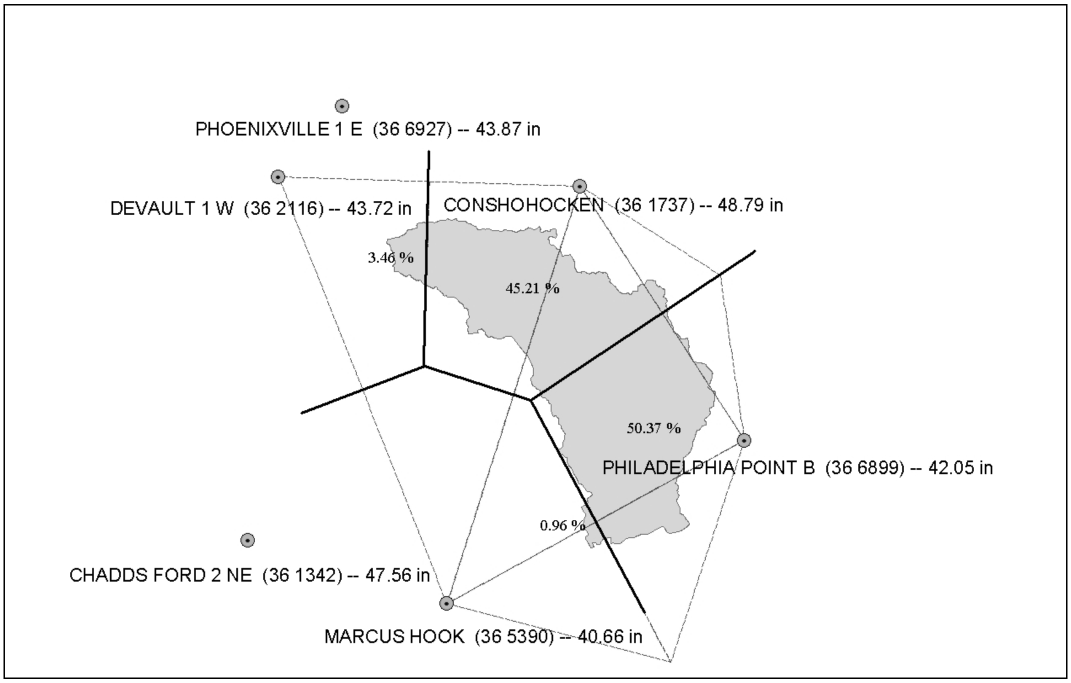


Table 4
Darby-Cobbs Watershed Area Average Precipitation Calculation Using Thiessen-Weighted Average

Rain Gage Name and Station Number	Average Annual Precipitation at Gage, in	Area of Polygon Within Watershed as a Percentage of Total Watershed Area, %	Rainfall Weighted by Fraction Area (Col. 1 x Col. 2)
Conshohocken (36, 6927)	48.8	45.21	22.06
Marcus Hook (36 5390)	40.7	0.96	0.39
Philadelphia Airport (36 6889)	42.1	50.37	21.18
Devault (36 2116)	43.7	3.46	1.51
Total		100	45.14 inches

This result is an average annual rainfall for the Darby-Cobbs watershed of 45.14 inches. ***Since this data is the most accurate for the watershed, and corresponds nicely with the other studies, 45.41 inches was adopted as precipitation (P) of Darby-Cobbs watershed.***

3.2 Average Annual Total Runoff (R) - Overland Surface Flow (R_{osr}) and Base Flow (R_e)

The average total runoff at the Darby Creek stream gauge at Waterloo Mills near Devon, as listed in Table 2, was reported as 25.91 inches (Balmer, 1996). This total runoff value is composed of both surface overland runoff which occurs during rainfall events and groundwater recharge/discharge which augments the base flow of streams in the watershed. For the water budget analysis, these two sources of flow were separated. In Table 2, Balmer (1996) reported the base flow at station 01475530 (Darby Creek at Waterloo Mills near Devon) from year 1973-82 to be 17.48 inches based upon the mean of the period of records.

USGS provides surface water data including annual statistics information. The average annual stream flow (total runoff) at Darby Creek at Waterloo Mills near Devon (01475530) from 1973-93 is 23.06 inches (8.75 ft^3/s) from USGS Surface Water data for Pennsylvania (USGS 2004). Table 5 presents the detail numbers and average.

Table 5

Annual Mean Stream Flow and Average Mean Stream flow for 1973-93 at Stream Gage Waterloo Mills Near Devon PA (01475300)

Year	Annual Mean Stream flow, ft^3/s	Annual Mean Stream Flow, in	Year	Annual Mean Stream flow, ft^3/s	Annual Mean Stream Flow, in
1973	11.40	30.05	1984	8.89	23.43
1974	8.19	21.59	1985	5.00	13.18
1975	12.00	31.63	1986	6.89	18.16
1976	7.33	19.32	1987	7.17	18.90
1977	8.70	22.93	1988	6.99	18.42
1978	12.20	32.16	1989	9.35	24.64
1979	16.20	42.70	1990	8.51	22.43
1980	5.96	15.71	1991	8.06	21.24
1981	5.86	15.45	1992	7.24	19.08
1982	7.98	21.03	1993	9.52	25.09
1983	10.30	27.15	Average	8.75	23.06

Source: USGS Surface Water data for Pennsylvania (USGS 2004).

Therefore, the total runoff (R) for Darby-Cobbs watershed was determined to be 23.06 inches.

To obtain the amount of the total runoff that is base flow (groundwater recharge), the USGS publication Water Resources Investigations Report (WRIR) 90-4161, "Base-Flow-Frequency Characteristics of Selected Pennsylvania Streams" (White, 1990), was reviewed. This report used computer-assisted empirical methods to separate the ground-water and surface-runoff components for streamflow stations in Pennsylvania. This analysis first determined the 2-, 5-, 10-, and 25-year base-flow-recurrence intervals for each station utilizing 2 methods; the local-minimum method and the fixed interval method. Table 6 summarizes the base flows found at the streamflow at the Waterloo Mills station near Devon, PA. (Station I.D. 01475300) for 1973-85.

The data in Table 6 can be plotted as shown in Figure 3 and then interpolated to obtain mean annual base flow. The mean base flow is the arithmetic mean of all annual base flows and has a recurrence interval equal to 2.33 years. From Figure 3, the mean annual base flow was determined from the average of the two methods as 0.69 mgd/mi^2.

Table 6

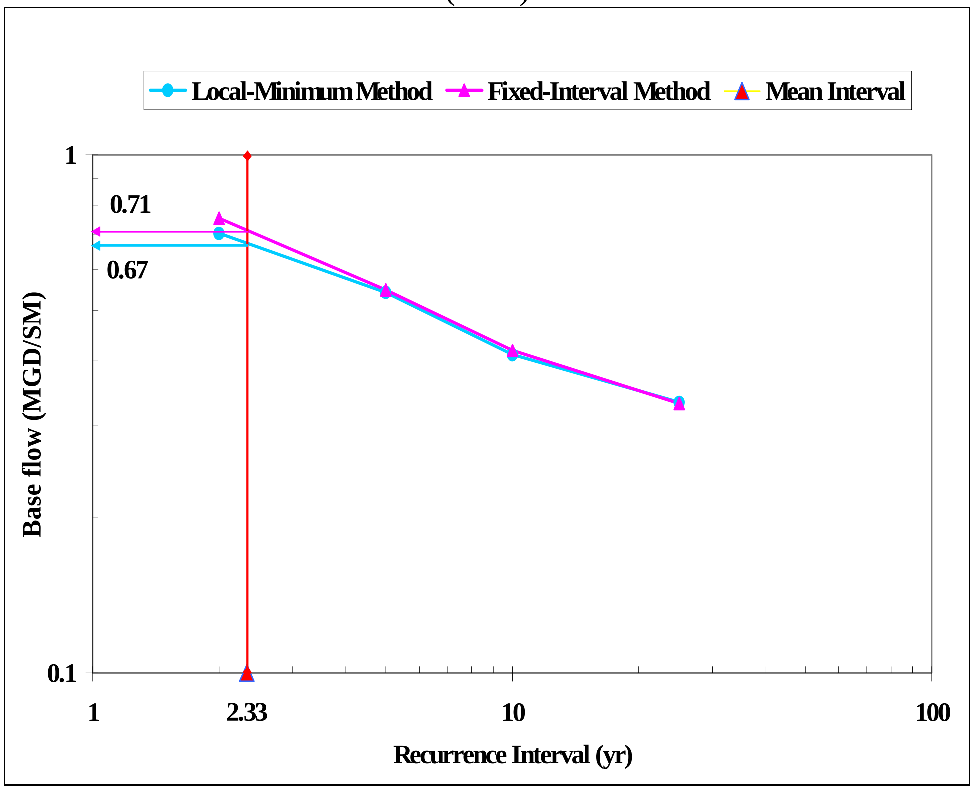
Base Flows for Selected Recurrence Intervals at Darby-Cobbs Watershed at Darby Creek At Waterloo Mills near Devon, PA for year 1973-85

	Darby Creek At Waterloo Mills near Devon, PA			
Recurrence Interval	Base Flow Estimate (Local-Minimum Method)		Base Flow Estimate (Fixed-Interval Method)	
Year	mgd/mi^2	In	mgd/mi^2	in
2	0.706	15	0.754	16
5	0.543	11	0.549	12
10	0.412	8.7	0.419	8.8
25	0.333	7.0	0.331	7.0

*mgd/mi^2: million gallon per day per square mile.
Source: USGS WRIR 90-4167, Base-Flow-Frequency Characteristics of Selected Pennsylvania Streams

Figure 3

Mean Base Flow at Darby Creek at Waterloo Mills near Devon, PA Using WRIR 90-4167 “Base-Flow-Frequency Characteristics of Selected Pennsylvania Streams” (1990)



This value was converted to inches as follows:

$$(0.69 \text{ mgd/ mi}^2) \times (1 \text{ ft}^3 / 7.481 \text{ gal}) \times (365\text{d/yr}) \times (1 \text{ mi}^2 / 640 \text{ ac}) \times (1 \text{ ac} / 43{,}560 \text{ ft}^2) \times (12 \text{ in /ft})$$

$$= 14.5 \text{ inches/year}$$

It was determined that a value of 14.5 inches for the 2.33- year base flow event. ***As a result, the mean groundwater recharge (R_e) rate was determined to be 14.5 inches per year.***

3.3 Water Loss (WL)

The most common mechanisms of surface water losses are due to evaporation and transpiration, typically referred to as evapotranspiration (ET). Evapotranspiration is the combination of water that is evaporated and transpired by plants as a part of their metabolic processes. Evapotranspiration is difficult to measure and therefore, very little data exists on it for this particular area. However, potential evapotranspiration (PET), or the maximum possible water loss, has been studied and can be used as a reference for estimation of ET losses.

Potential evapotranspiration was studies in the USGS Bulletin No. 13, Floods in Pennsylvania (Flippo, 1977). The potential evapotranspiration at the Darby-Cobbs watershed from Flippo report was found to be approximately 28.5 inches. Since the potential evaporation is the “potential” amount of water that would evapotranspirate, the PET value is typically a larger number than actual ET.

The Water Loss (WL) in Darby-Cobbs watershed can be calculated by subtracting total runoff (R) from the precipitation (P) which is equal to 22.08 inches (45.14 in – 23.06 in). Cross referencing 28.5 inches PET from (Flippo, 1977), the 22.08 inches ET is smaller less than the PET and concluding that 22.08 inches ET is a reasonable estimation.

For the Darby-Cobbs watershed, therefore, the Water Loss (WL) in the equations 1 and 2 is 22.08 inches.

3.4 Final Darby-Cobbs Water Budget

Based upon above analysis, the general water budget of Darby-Cobbs watershed, Equation 1, can be written as:

$$\begin{array}{ccccc} P & = & R & + & WL \\ 45.14 \text{ in} & = & 23.06 \text{ in} & + & 22.08 \text{ in} \end{array}$$

Overland surface runoff (R_{osr}) will therefore be the recharge (R_e) and Water Loss (WL) subtracted from the precipitation (P) or:

$$R_{osr} = P - R_e - WL$$
$$8.56 = 45.14\text{ in} - 14.5\text{ in} - 22.08\text{ in}$$

Therefore Equation 2, than can be rewritten as:

$$P = R_{osr} + R_e + WL$$
$$45.14\text{ in} = 8.56\text{ in} + 14.5\text{ in} + 22.08\text{ in}$$

In summary,

P = average annual precipitation: 45.14 inches
R = average annual total runoff: 23.06 inches
WL = average annual water loss: 22.08 inches
R_{osr} = overland surface runoff: 8.56 inches
R_e = groundwater recharge/discharge: 14.5 inches

4.0 Establishment of Infiltration Criteria to Recharge Baseflow

In order to evaluate the amount of rain storms that would have to be retained on a development site to maintain the natural hydrologic regime, an analysis of the rainfall patterns was performed. To do this analysis a rain gage's worth of precipitation data which had a total precipitation amount close to the average precipitation value for the Darby-Cobbs watershed, or 45.14 inches, was selected.

The long term record (1948-2001) of Chadds Ford (36 1342) has an annual average rainfall 45.05 inches. It is close to the average annual precipitation of the Darby-Cobbs watershed. Therefore, the rain gage, Chadds Ford, was used to construct a cumulative annual rainfall pattern, as shown in Figure 4.

In Figure 4, each rainfall event was sorted according to total daily precipitation, and then the average yearly accumulated precipitation was graphed as shown against daily precipitation.

From the previous analysis, it was shown that approximately 14.5 inches of precipitation would need to be infiltrated annually to maintain base flow in natural watershed conditions. Plotting this total annual rainfall amount on Figure 5, it can be shown that all daily rainfall events with precipitation 0.6 inches would need to be infiltrated to meet the 14.5 inches infiltration requirement.

Therefore, as development occurs in the watershed and impervious areas created by development begin to prohibit rainfall from infiltrating, 0.6 inches of rainfall would be required to be infiltrated from the impervious areas to replicate the natural hydrologic regime after development. The goal of the Darby Creek Plan is therefore to capture the rainfall from impervious areas into infiltration BMP and allow this rainfall to infiltrate so that it replicates the amount of water that would recharge the groundwater before the land mass was paved.

In the analysis of the Chadds Ford rain gage, 2450 of the 4487 storms which occurred are less than or equal to 0.6 inches. This represents approximately 55 % (2450/4487) of the rainstorms at Chadds Ford for 1948-2001. A plotting of each rainfall event which occurred in the analysis is shown in Figure 5.

Figure 4
Cumulative Annual Rainfall Patten for Darby-Cobbs Watershed

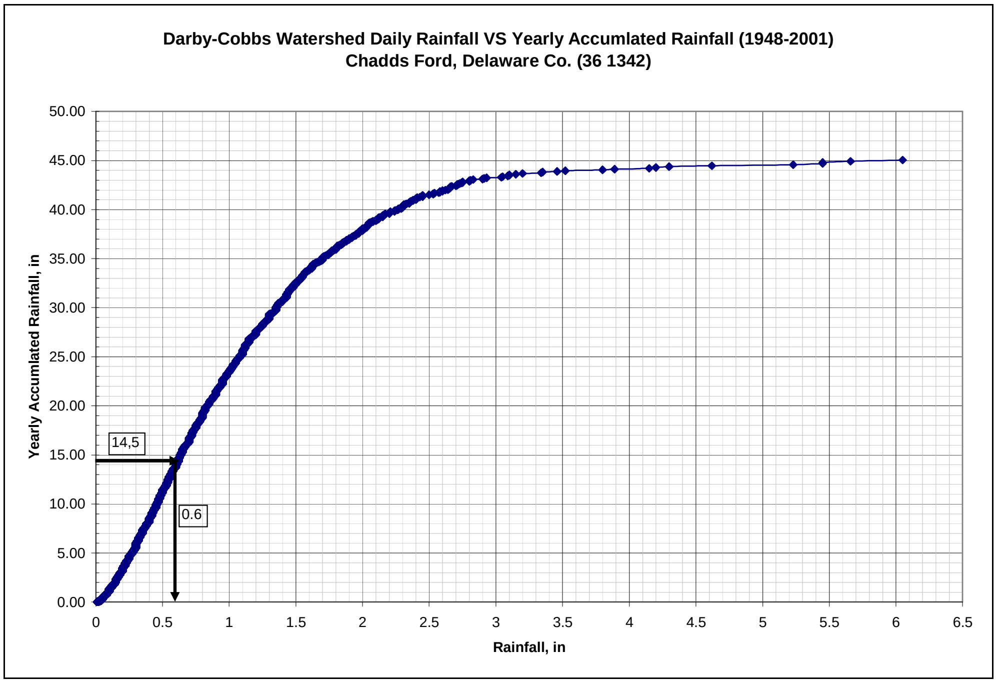
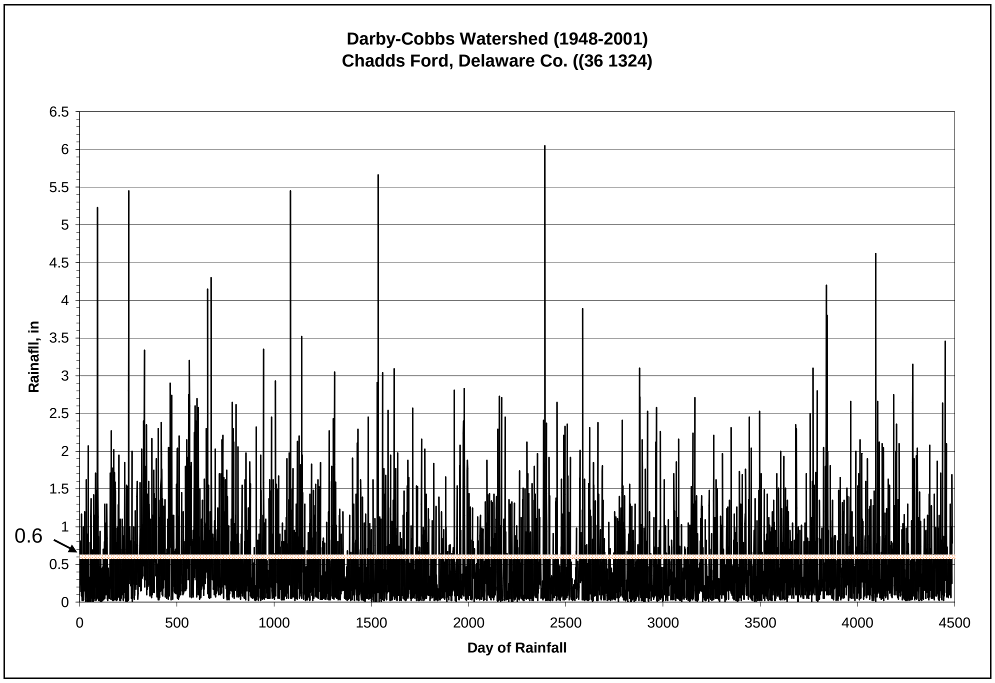


Figure 5
Rain Storms at Chadds Ford, Delaware, Co. (36 1342) for 1948-2001



From the previous discussion, we saw that collecting and infiltrating all rainfall events which resulted in 0.6 inches or less of rains would duplicate natural recharge of the baseflow. However, it is impossible to collect just those storms less than 0.6 inches to infiltrate as shown in Figure 5. The first 0.6 inches of every storm greater than 0.6 inches would also be collected and infiltrated resulting in a net infiltration value greater the previously determined 14.5 inches. The total number of rainfall events greater than 0.6 inches is 2037 (4487-2450) for 54 years of record (1948-2001). Then the average rainfall events greater than 0.6 inches is 38 (2037/54).

The breakdown of rain storms would therefore be as follows:

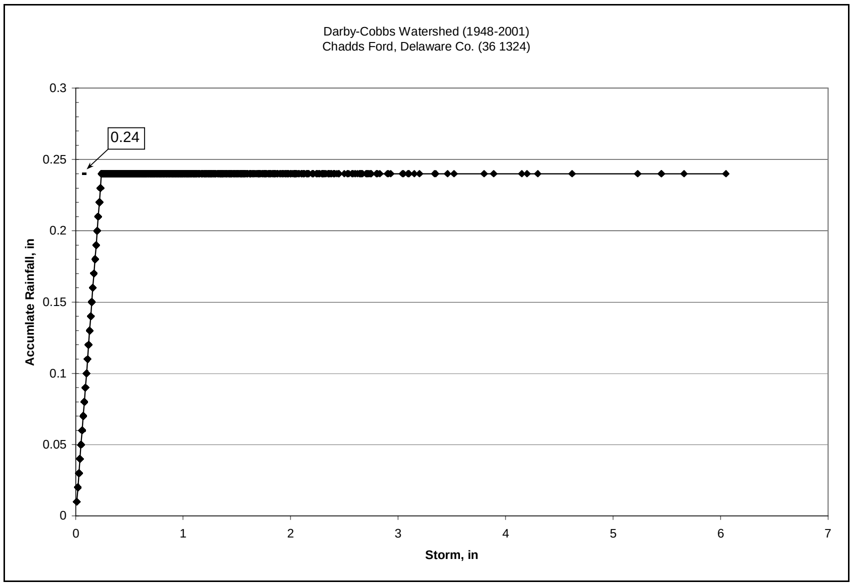
Total annual rainfall of storms less than 0.6 inches	14.5 inches
Total annual rainfall of the first 0.6 inches of storms greater than 0.6 inches (38 storms * 0.6 inches = 22.8 inches)	22.8 inches
Total annual rainfall amount of storms greater than 0.6 inches	7.7 inches
Total annual rainfall	45.0 inches

Therefore a rainfall threshold value was determined that would theoretically produce the 14.5 inch recharge value. This was accomplished by accumulating the all the rainfall from storms less than this threshold value plus the first portion of threshold value of all storms greater than the threshold value in an Excel spreadsheet until the 14.5 inches was obtained as shown graphically in Figure 6. The threshold value therefore turns out to be 0.24 inches.

Figure 6

Rainfall Threshold Value (0.24 inches) Determined in an Excel Spreadsheet Until

Recharge Volume 14.5 inches was obtained.



Therefore at first glance, this 0.6 inch value appears to be conservative, however, all the water that is infiltrated through an infiltration BMP will not recharge the groundwater.

5.0 Average Annual Water Loss from Infiltration / Retention Facilities that Will or May Not Enter the Groundwater.

There are several quantifiable and unquantifiable losses which will occur to the rainwater from the surface to the groundwater table.

5.1 Quantifiable Losses

5.1.1 Surface Water Losses

Surface (or depression) storage accounts for a large part of the surface losses. Surface storage is estimated based on the nature of the vegetation and ground surface (Chow, 1988). The surface storage ranges from 0.04 inches on steep, smooth hill slopes to 2 inches on agricultural lands of low gradient that have been furrowed to catch the water (Dunn, 1978). Much of the smaller storms will be contained in the puddles, ditches, pockets, and cracks of pavement (Ponce, 1989, and Dunn, 1978) and will not runoff to the infiltration structure. Although the exact amount will vary with type of material, pavement slope, etc. there is very little runoff from macadam surfaces from the 0.1 inch storm or less. There are 1217 storms of 0.1 inch or less for the period of record 1948-2001 (54 years). Totally these storms gives a rainfall amount of 66.33 inches. Therefore, dividing the total amount of rainfall by the number of years of record (66.33 inches / 54 years) gives an average annual surface storage of 1.2 inches for macadam surfaces. This amount would not reach the recharge facility.

5.1.2 Groundwater Losses

Once water is infiltrated into the subsurface, additional losses occur which prevent the infiltrated water from becoming a source which replenishes stream baseflow. One such loss is referred to as groundwater evapotranspiration. Groundwater evapotranspiration is the process that evapotranspiration occurs where the saturated zone (water table) close to the land surface (Sloto, 1994a). The moisture is extracted from below the water table and brought to the near-surface, where it either evaporates or is used by plants in transpiration. Losses to evapotranspiration are greatest during the growing season, May through October, and are particularly great in mid to late summer. The potential for groundwater evapotranspiration increases as the water table approaches the land surface, where the roots of plants can capture the water and soil capillaries can draw ground water nearer to the surface, allowing warm air to evaporate the water.

Two studies were performed in the region surrounding the Darby-Cobbs watershed to estimate the amount of losses which can be attributed to groundwater evapotranspiration. The first study focused on groundwater evapotranspiration in Chester and Northern Bucks Counties, Pennsylvania (Sloto, 2004, 1994a, 1994b, and 1990). In this study, simulations of hydrological budgets using a groundwater-flow model estimated groundwater evapotranspiration to be 2 in/yr. A second study of groundwater evapotranspiration by in the Piedmont geographic province determined a loss on the average of 5.5 in/yr (Sloto, 1994a, Olmsted 1962). Since the Darby-Cobbs watershed is located directly in the Piedmont Physiographic Province, a conservative loss value of 5.5 in/yr associated with groundwater evapotranspiration was adopted in this study.

5.2 Unquantifiable Losses

Some of the unquantifiable losses include:

- Underflow which is the transference of water from beneath one basin to another (i.e. outside of the Darby-Cobbs basin), and groundwater storage. Both parameters are difficult to estimate without a detailed hydrogeologic study performed within the study basin.
- Evaporation of the water in retention facilities.
- Removable of snow from the flow path that would otherwise get to the infiltration facility.
- Surface runoff on frozen ground from areas that would otherwise have infiltration.
- Horizontal conductivity in the vadose zone due to fractures (USGS, 2001a).
- Subsurface barriers such as subsurface ice layer and hardpans (USGS 2001b).

Although an exact number could not be determined, based upon best judgment, unquantifiable losses lumped together could range from 0 to 6 inches. It is almost impossible to determine an exact value without extensive data collection, well monitoring and hydrogeologic evaluations, therefore an estimate was required. To account unquantifiable losses mentioned previously, this study assumed these loss lumped together contribute the average of the estimated values stated above or 3 in/yr.

5.3 Final Losses from Retention / Infiltration Facility

As noted in Equation 1, above, WL consists of evaporation, transpiration, and groundwater losses. The average water loss value determined for the Waterloo Mills gauge station was approximately 22.08 inches. This water loss is composed of losses which occur both on the surface, such as evaporation and transpiration, and losses which occur in the groundwater table, such as groundwater evapotranspiration, underflow and groundwater storage. Both are explained below.

Hence, the total groundwater loss is estimated to be 11.8 in/yr as listed in the Table 7.

Table 7
Average Annual Water Losses for Infiltration

Water Lost	Amount (inches/yr)
Surface Depressions	1.2
Groundwater Evapotranspiration	5.5
Unquantifiable Losses	3
Total	9.7

Based upon the prior analysis, the total annual amount of infiltration necessary to replenish groundwater sources necessary for baseflow was 14.5 inches. To assure that the 14.5 inches is made available to runoff as base flow, the groundwater losses should be added to the base flow discharge amount. Therefore, the total annual volume which should be infiltrated to replenish base flow is then:

14.5 inches/yr + 9.7 inches/yr = 24.2 inches /yr.

Therefore a new rainfall threshold value was determined that would theoretically produce the 24.2 inch recharge value. This was accomplished by accumulating all the rainfall from storms less than this new threshold value plus the first portion of the new threshold value of all storms greater than the new threshold value in an Excel spreadsheet until the 24.4 inches of recharge value was obtained as shown graphically in Figure 7. The threshold value therefore turns out to be 0.513 inches. Table 8 explains the trail-and-error fitting approach to obtain the new threshold value. Due to the amount of data (1948-2001), only a portion of the data is presented in Table 8 to illustrated the concept of the approach.

The total Recharge Volume is the average of the sum of column "Rainfall Amount to be Accumulated". The individual value in that column is determined by comparing precipitation and the threshold value. If the precipitation is less than the threshold value, the rainfall amount to be accumulated is the amount of precipitation (data from ID 4487 to 1448 in Table 8) for storms less than threshold value, otherwise the accumulated rainfall is threshold value (data from ID 1447 to 1) for storms greater than threshold value. The goal of this approach is to find the appropriate threshold value in that the

Total Recharge Volume is equal to the recharge volume, 24.2 in. This is determined by adjusting the threshold value (0.513) in the spreadsheet and comparing it to the Total Recharge Volume in Table 8 (24.2). For this exercise, to satisfied the recharge value of 24.2 inches, a threshold value of 0.513 inches was obtained.

Figure 7

Rainfall Threshold Value (0.51 inches) Determined in an Excel Spreadsheet Until Recharge Volume 24.2 inches was obtained.

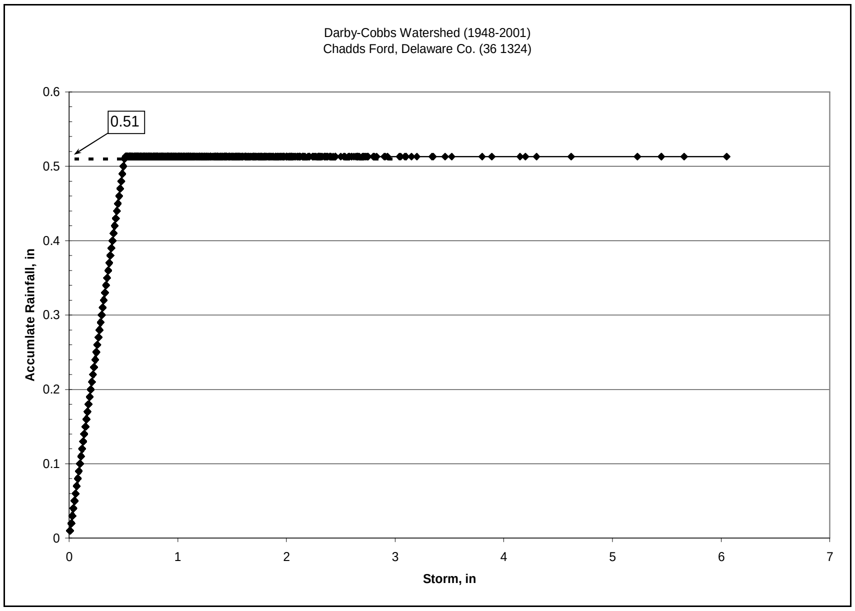


Table 8

Trail-and-Error Fitting Approach to Obtain the New Threshold Valve (0.51 in) in that the Recharge Value is Equal to 24.2 inches. Only Portion of Data is Presented to Illustrated the Concept.

		Threshold Value (in)	0.51
		Total Recharge Volume (in)	24.2
ID	Precipitation	Rainfall Amount to be Accumulated	
4487	0.01	0.01	
4486	0.01	0.01	
4485	0.01	0.01	
4484	0.01	0.01	
4483	0.01	0.01	
	Etc., etc., etc.		

1469	0.5	0.5	
1468	0.5	0.5	
1467	0.5	0.5	
1466	0.51	0.51	
1465	0.51	0.51	
1464	0.51	0.51	
1463	0.51	0.51	
1462	0.51	0.51	
1461	0.51	0.51	
1460	0.51	0.51	
1459	0.51	0.51	
1458	0.51	0.51	
1457	0.51	0.51	
1456	0.51	0.51	
1455	0.51	0.51	
1454	0.51	0.51	
1453	0.51	0.51	
1452	0.51	0.51	
1451	0.51	0.51	
1450	0.51	0.51	
1449	0.51	0.51	
1448	0.51	0.51	
1447	0.52	0.513	
1446	0.52	0.513	
1445	0.52	0.513	
1444	0.52	0.513	
1443	0.52	0.513	
1442	0.52	0.513	
1441	0.52	0.513	
1440	0.52	0.513	
Etc., etc., etc.			
5	5.23	0.513	
4	5.45	0.513	
3	5.45	0.513	
2	5.66	0.513	
1	6.05	0.513	

6.0 Conclusions

Rounding up for conservatism, a justifiable recharge rate adopted for the Darby-Cobbs watershed is 0.5 inches (rounded from the 0.51 inch value) from all proposed impervious area. Therefore based upon this analysis, it was determined that infiltrating 0.5 inches from impervious area for each event would accomplish the goal of maintaining the recharge value in the water budget of the watershed.

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APPENDIX G

WATER QUALITY VOLUME ANALYSIS

Introduction

Several methods exist for the determination of the appropriate water quality volume to use in the design of Best Management Practices for addressing water quality issues related to stormwater management. Methods promoted by Pennsylvania, Maryland and New Jersey are investigated in this report. A brief description of these methods and summary comparison of these methods is provided below, with detailed calculations provided in the appendices.

Methods Summary

<u>Method 1</u> (2- Year Post Development Runoff to 1- Year Pre Development Rate)

This method incorporates the analysis of pre development conditions when determining the water quality volume for design of BMPs and requires the designer to reduce the 2-year post development runoff rate to the 1- year pre development runoff rate. Additional requirements include the retention of the 1- year post development runoff volume for a minimum of 24- hours to encourage settling of pollutants within the water column.

The water quality volume (WQv) was determined by calculating the pre and post development runoff hydrographs for the design storms. Then the complete 2- year runoff hydrograph under post development conditions and a target outflow rate (based upon the 1- year pre development hydrograph) were utilizing to calculate the volume required based upon the SCS TR-55 (1986) method for determining storage volumes for detention basins.

<u>Method 2</u> (Maryland WQv Equations – using Pennsylvania Rainfall depths)

This method utilizes an equation (Table 2.1) developed for the Maryland 2000 Stormwater Design Manual. The equation is based on a volumetric runoff rate and rainfall depth (based on capturing and treating the 90^{th} percentile storm). The volumetric runoff rate is calculated from a regression analysis performed on rainfall-runoff volume data from a number of cities nationwide, and is considered an adequate short cut method for runoff volume calculation for small storm events typically analyzed for stormwater quality calculations. Rainfall depths for the 90^{th} percentile storm event were derived from the Pennsylvania Association of Conservation District (PACD) Handbook of Best Management Practices in Pennsylvania (Table 5.2).

<u>Method 3</u> (1.25- inch, 2- hour Rainfall Event – NJDEP)

This method was developed for the New Jersey BMP Manual (Draft Version dated January 2003) and calls for addressing 1.25- inches of rainfall over a 2- hour storm event for water quality BMP Design.

The water quality volume (WQv) was determined by calculating the entire runoff volume underneath the post development 1.25- inch, 2- hour runoff hydrograph. To accomplish this, the SCS TR-55 (1986) method for determining basin storage volume was utilized with an allowable outflow of 0.00 cfs.

Method 4 (1 inch of rainfall – Darby-Cobbs Watershed, Pennsylvania)

The required Water Quality Volume (WQv) is the storage capacity needed to capture and to treat a portion of stormwater runoff from the developed areas of the site produced from 1 inch of rainfall. The following calculation formula is to be used to determine the water quality storage volume, (WQv), in acre-feet of storage for the Darby-Cobbs watershed:

$$WQv=[(P)(Rv)(A)]/12$$

Where:

WQv = Water Quality Volume (acre-feet)
P = One (1) inch of Rainfall
A = Area of the project contributing to the water quality BMP (acres)
Rv = 0.05 + 0.009(I) where I is the percent of the area that is impervious surface (impervious surface/A)*100)

Summary Comparison

A sample site was selected for analysis of the three methods described above. The following table summarized site parameters for pre and post development conditions.

Parameters	Pre Development	Post Development
Area (acres)	10.724	10.724
Land Cover	Woods – Grass Combination (Fair Conditions)	1/3 – 1/4 acre Residential Lot Subdivision
Hydrologic Soil Group	C	C
TR-55 Runoff CN	76	82
Time of Concentration (min)	10.7	5.0
% Impervious	0	24.14
PDT-IDF Rainfall Region	4	4

A summary of resulting Water Quality Volumes (WQv) to be used in design of Best Management Practices is shown in the table below.

	WQv (Sq. feet)	WQv (acres)
Method 1	19,776	0.4540
Method 2	20,286	0.4657
Method 3	5,889	0.1352
Method 4	10,511	0.2413

Appendix 1
(Method 1)

Appendix 2
(Method 2)

Appendix 3
(Method 3)

Appendix 4
(Method 4)

APPENDIX H

RAINFALL ANALYSIS SUMMARY

Revised 11/26/03

Introduction

A rainfall study was conducted for the Darby-Cobbs Creek Watershed using available NOAA climatological data. Both daily and extreme event precipitation were examined. Recommended runoff capture values for the Darby-Cobbs Creek Watershed were developed that are substantially smaller then that contained within the Pennsylvania BMP Manual (PACD 1998). The extreme event results are not as clear, leading to the recommendation that designers continue to use the Pa-IDF curves (PennDot 1986).

Data Sources

All climatological data for the region was obtained through the NOAA National Climatic Data Center. This data is available electronically, and was downloaded using the internet. Recording gages that are available in this manner include the Philadelphia Airport, Chadds Ford, Conshocken, Glassboro (NJ), Marcus Hook, and Phoenixville. Of these gages, only the airport gage is directly located in the watershed. A limitation of the data source is the restriction to daily versus 24 hour reporting. Thus a storm that begins at 10:00 PM and lasts through the next morning is recorded as two storms not one. This limitation mostly impacts the extreme value reporting.

Daily Rainfall Analysis

Daily rainfall values were collected for all stations for the period of 1948 – 2001. While all stations experienced some errors due to equipment break down and losses, the number of recorded rain events were high. For example the Philadelphia Airport gage recorded 6236 rain events ranging from .01 to 6.43 inches. This same gage had only 37 “errors’ in 19512 days. Except for the Glassboro gage which had a shorter record, the other gages recorded between 4500 and 5500 rain events each.

The data was manipulated in an Excel XP spreadsheet to ascertain the percent rainfall and rainfall capture curve for each gage. Percent rainfall is defined for the purposes of this study as the percent of the yearly volume that falls in storms equal or less then that daily rainfall volume. Rainfall Capture is defined as the amount of the yearly rainfall “captured” when facilities are designed for a set rainfall volume. For example the Pennsylvania BMP manual Appendix F gives the value of .83” as the volume needed to make up 60% of the yearly precipitation (PACD 1998). To develop the rainfall capture for the Darby-Cobbs Creek Watershed, first the daily rainfall for each gage was sorted, and the total rainfall over the entire period of record was determined. Second, the total record capture volume was found for daily capture values ranging from .5 to 3.0

inches (increments of .25”). To determine the total record capture value for a daily capture value of 1”, all daily rainfalls less then or equal to one inch were summed, and then the first 1” of each storm exceeding one inch were added. Results of all gages are shown below in Table 1 and Figure 1.

	Daily Rainfall Capture - Inches										
	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
Station											
Phoenixville	61.1	74.7	83.4	89.1	92.7	95.0	96.6	97.6	98.3	98.8	99.1
Conshocken	63.6	76.9	85.1	90.2	93.4	95.5	96.8	97.7	98.3	98.8	99.1
Chadds Ford	58.8	72.5	81.5	87.6	91.7	94.4	96.2	97.4	98.2	98.7	99.0
Marcus Hook	63.1	76.7	85.0	90.0	93.0	95.1	96.4	97.2	97.7	98.1	98.4
Phil Airport	64.9	78.0	85.9	90.8	93.9	95.9	97.2	98.0	98.5	98.8	99.1
Glassboro	62.2	75.8	84.4	89.7	93.0	95.2	96.6	97.6	98.3	98.7	99.1
Average	**62.3**	**75.8**	**84.2**	**89.5**	**93.0**	**95.2**	**96.6**	**97.6**	**98.2**	**98.7**	**99.0**
Average (C, MH, PA)	63.9	77.2	85.3	90.3	93.4	95.5	96.8	97.6	98.2	98.6	98.9
	Percent Daily Rainfall Capture - 1948 - 2001										

Table 1 – Overall Runoff Capture Results

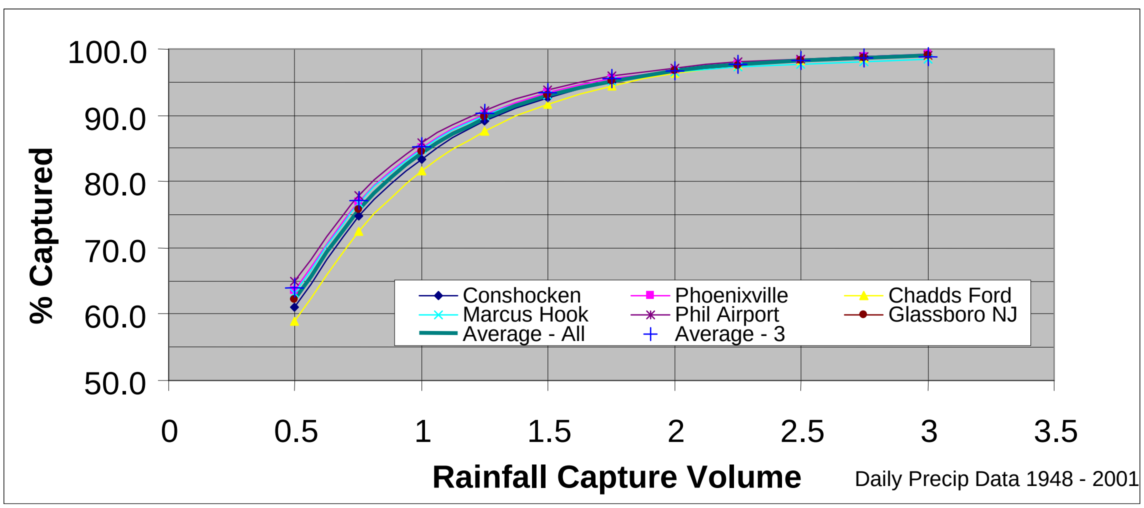


Figure 1 - Rainfall Capture Results

While the similarity of all the gages was impressive, it was decided to concentrate on the nearest three gages to the watershed, Conshocken, Marcus Hook and the Philadelphia Airport. Philadelphia Airport is at the south eastern corner of the watershed, with Marcus Hook just below it. Conchocken is above the North West corner of the watershed. The average of these three (labeled as Average - 3) is shown more clearly in Figure 2. Note that a fourth order polynomial fits the data with an R squared of .9998 (This equation is only appropriate between the values of .5 – 3.0 inches), and that the average of these three stations indicates a significantly higher capture rate then that indicated by the Pennsylvania BMP Manual.

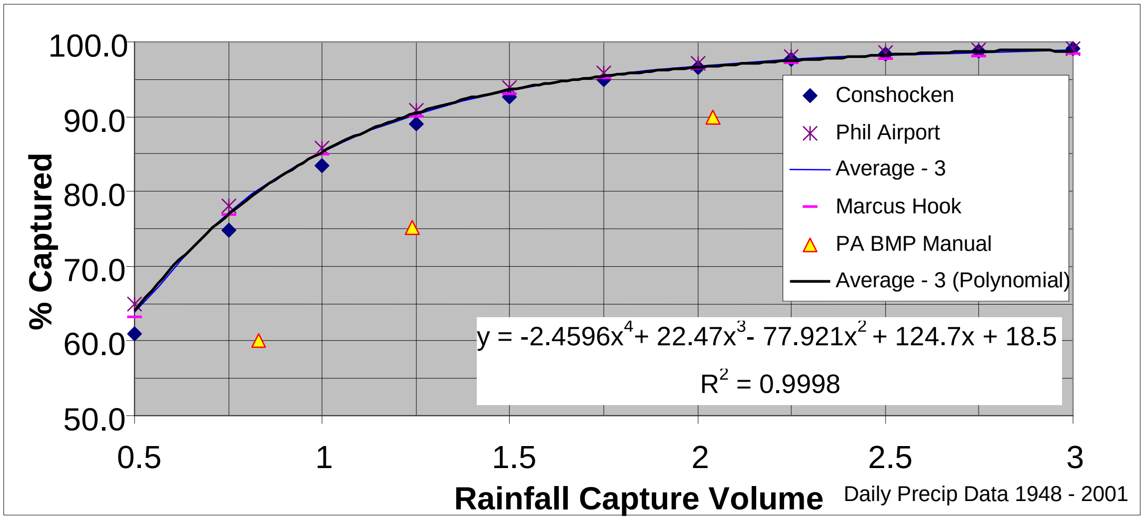


Figure 2 - Select 3 Stations Rainfall Capture

Using this equation, the volume necessary to capture a specified percent of the rainfall for the watershed was developed as shown below in Table 2.

% Capture	60	65	70	75	80	85	90	95	98	99
Volume (in)	<.5	0.52	0.60	0.71	0.83	0.99	1.22	1.68	2.41	3.00

Table 2 – Capture Rainfall - Three Station Average

Comparison of the Capture, and Percent Rainfall values are shown in Table 3. Note the similarity of the percent rainfall to that of the Pa BMP manual. The Maryland values are more confusing. From a presentation from the Maryland Department of the Environment, they listed the rainfall from eastern cities as 1.2" for the 90% Rainfall event, and they state that to capture 1 inch is approximately 95% of the yearly rainfall. These values are lower, but the method used by MDE is not clear.

Percent	Pa BMP Manual Region - 5	Darby Percent Rainfall	Darby Capture Rainfall
0.60	0.83 in	1.00 in	<.50
0.75	1.24 in	1.38 in	.71
0.90	2.04 in	2.10 in	1.22

Table 3 - Percent vs Capture Rainfall

Estimation of the error contained within these numbers is extremely difficult to enumerate. First there is error introduced when the raingages fail during rainfall events. The worst of the 3 selected gages missed less then 5% of the rainfall events over the period, and the overall average was greater then 98% successful. This error is deemed insignificant due to the long period of record. The next source of error is that the data period is based on a calendar day. Thus, a rainfall event occurring overnight may be split into two day storms, overstating the capture volume. This error would only count for storms close to the volume of the desired rate. For example, if a .5" storm was split over two days, no error would be introduced for any capture volume of .5" and above. Also the mass of the rainfall volume occurs in smaller storms. For the Philadelphia Airport gage, 62% of the rainfall over the entire period occurs in rainfalls measuring 1" or less, 90% in 2 inches or less, 96% in 3 inches or less. This leads to the conclusion that as runoff capture volume increases, the volume associated with the error decreases, and the overall error rate is not significant.

In conclusion we recommend the Rainfall Capture values be used for the Darby-Cobbs Creek Watershed.

Extreme Value Rainfall

Annual Climatological Summaries were collected for four area stations. These stations included the Chadds Ford (1945–2001), Philadelphia Airport (1948-2001), Conshocken (1931-2001), and Marcus Hook (1931-2001). Each summary provided the rate and volume of the Maximum observed daily rainfall event for the year. In addition, hourly rainfall was available for the Philadelphia Airport gage. This allowed for comparisons between maximum day and max 24 hour recordings.

A Log Pearson Type III analysis (Viesman 1996) was conducted for each station. This procedure is commonly recommended for extreme value precipitation studies. The data was also plotted on probability paper using a Gumbel plotting procedure method. Values were determined for the 2 – 100 year storms.

The first step was to compare the difference between the Philadelphia Airport Maximum day and Maximum 24 hour recording period. As expected, the maximum 24 hour results were slightly higher, as shown in Table 3 and Figure 3 below. The difference also was higher for the larger storms, as would be expected. A "delta" was created in order to adjust the other stations for comparison purposes. Note that the 50 year value was raised slightly to create a progression. Note that both curves are less then Pa- IDF curves for region 5 (PennDot 1986).

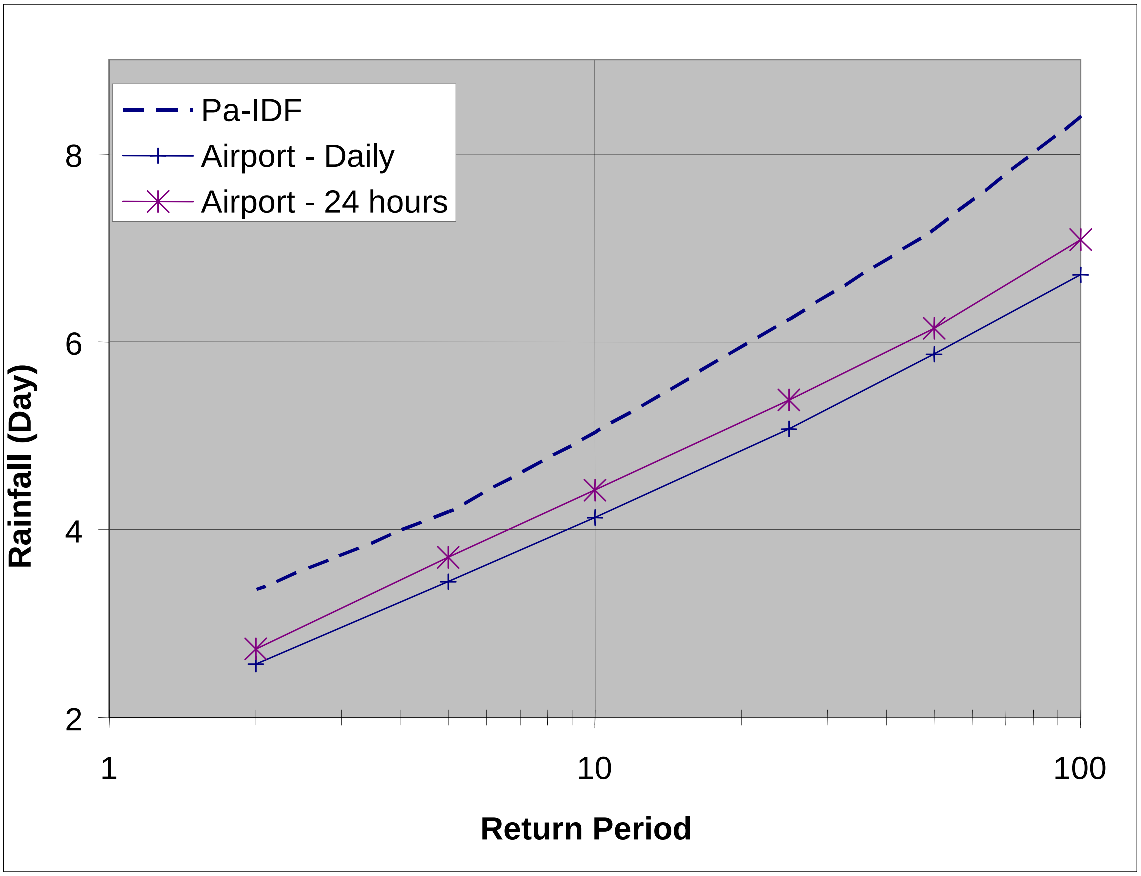


Figure 3. Philadelphia Airport – 24 Hour Versus Maximum Day.

Exceedence Probability	Return Period	Max 24 Hour Phila Airport Inches	Max Day Phila Airport Inches	Difference Inches	Delta Inches
0.01	100	7.09	6.72	0.37	0.37
0.02	50	6.13	5.86	0.27	0.35
0.04	25	5.37	5.07	0.30	0.30
0.10	10	4.41	4.12	0.29	0.29
0.20	5	3.71	3.45	0.26	0.26
0.50	2	2.73	2.57	0.16	0.16

Table 3 - Philadelphia Airport - Max Day Vs. 24 hour

Next all area stations were examined. Chadds Ford was eliminated as it was farther away from the Darby-Cobbs Creek Watershed, and to be consistent with the daily rainfall study. Figure and Table 5 present these results. Note the difference between the Marcus Hook and Philadelphia Airport results, even though these gages are relatively close in proximity.

		Max Day					Adjusted	
Exceedence	Return	Phila Airport	Conshocken	Marcus Hook	Average	Delta	Average	PaIDF
Probability	Period	Inches	Inches	Inches	Inches	Inches	Inches	
0.01	100	6.72	6.93	9.76	7.80	0.37	8.17	8.40
0.02	50	5.86	6.01	7.82	6.57	0.35	6.92	7.20
0.04	25	5.07	5.17	6.23	5.49	0.30	5.79	6.24
0.10	10	4.12	4.15	4.54	4.27	0.29	4.56	5.04
0.20	5	3.45	3.44	3.51	3.47	0.26	3.72	4.20
0.50	2	2.57	2.49	2.37	2.47	0.16	2.63	3.36

Table 5 – Extreme Event Analysis

The next step in the analysis was to use the guidance in Bulletin 17B of the US Water Resources Council (Viessman 1996) to examine the gages for outliers of the data record. This analysis indicated that Hurricane Floyd was an outlier for the Marcus Hook and Conshocken gage , and should be dropped from the data. Outlier is defined by Viessman (1996) are storms “outside the trend of the rest.” Table and Figure 6 present these results.

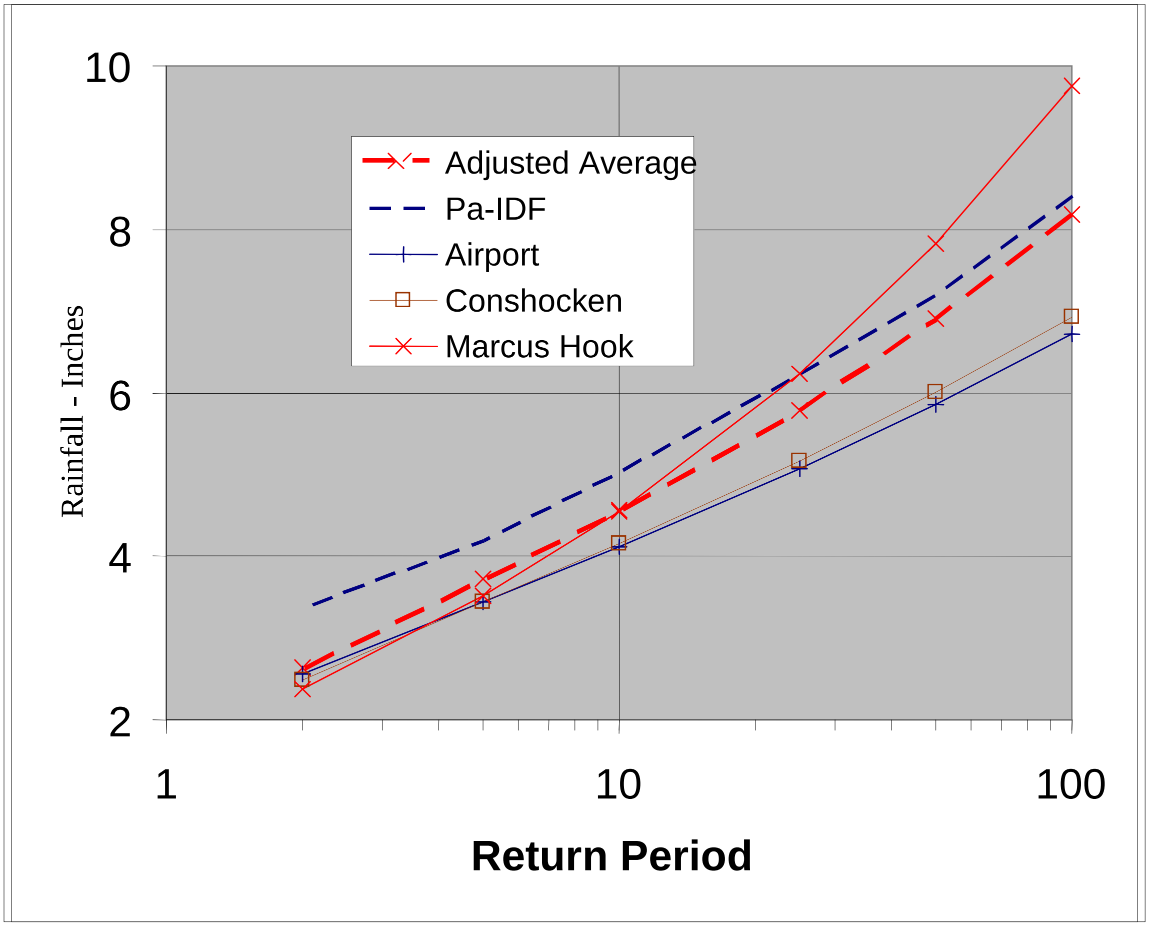


Figure 5 – Extreme Event Analysis

		Max Day					Adjusted	
Exceedence	Return	Phila Airport	Conshocken	Marcus Hook	Average	Delta	Average	PaIDF
Probability	Period	Inches	Inches	Inches	Inches	Inches	Inches	
0.01	100	6.72	6.20	8.45	7.12	0.37	7.49	8.40
0.02	50	5.86	5.45	6.91	6.07	0.35	6.42	7.20
0.04	25	5.07	4.75	5.62	5.15	0.30	5.45	6.24
0.10	10	4.12	3.90	4.21	4.08	0.29	4.37	5.04
0.20	5	3.45	3.28	3.34	3.36	0.26	3.61	4.20
0.50	2	2.57	2.45	2.34	2.45	0.16	2.61	3.36

Table 6 – Extreme Event Analysis Adjusted for Outliers

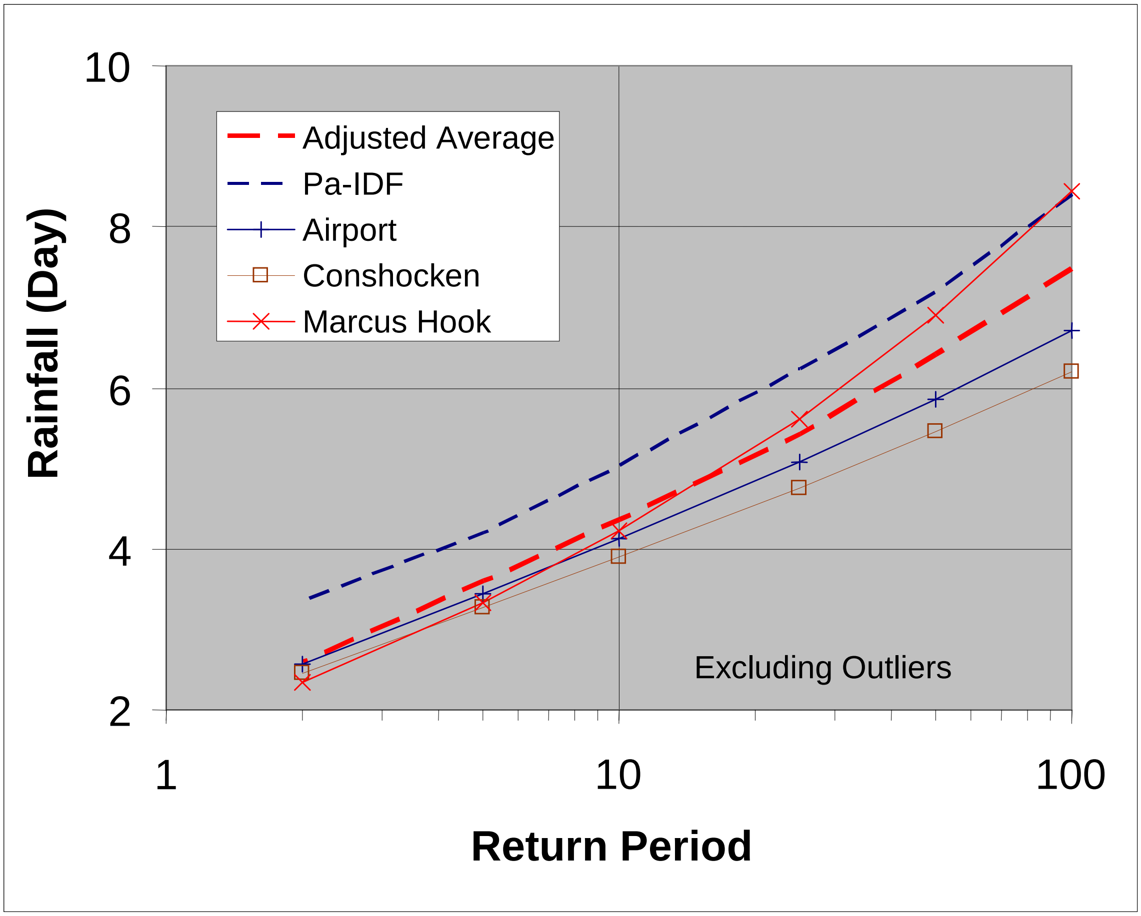


Figure 6 Extreme Event Analysis Adjusted for Outliers

These results are not nearly as clear as the daily statistics. The Marcus Hook gage has recorded higher extreme events then the other stations. Hurricane Floyd (which was considered an outlier) this gage recorded 4 inches more rain then the Philadelphia Airport. This climate influence can not be discounted, but it also represents a minority portion of the watershed. It is reasonable to use the current standard Pa-IDF curves. Note that the 2 year Penndot IDF value is similar to the 5 year storm average for this work.

Conclusion

Specific runoff capture curves are developed to be used for infiltration or water quality design. These values are smaller then those recommended by the Pennsylvania BMP Manual. Comparison is difficult as we could not find how the runoff capture values were determined. As the numbers presented here focus on the Darby-Cobbs Creek Watershed, they should be more accurate. Due to the data problems identified using the day vs 24 hour storm, a slightly higher value should be used for design to compensate for this error.

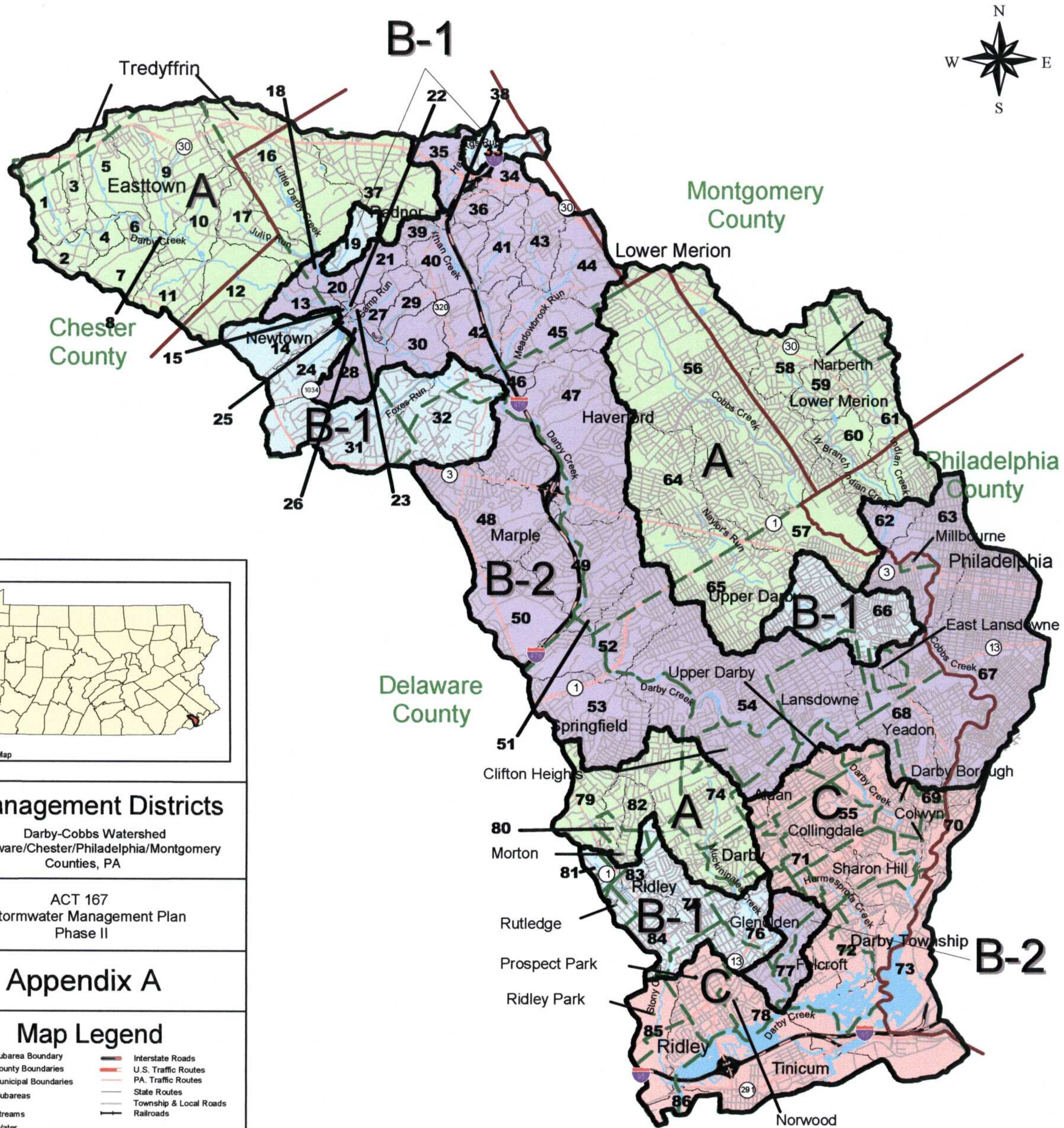
The study also has found that the climatological record is very different between the immediately adjacent gages surrounding the Darby-Cobbs Creek Watershed. It seems appropriate to continue using the Penndot IDF curves to be consistent with surrounding communities. There is danger that the true 2 year storm is overestimated, leading to streambank erosion. This should be considered when developing final recommendations.

Aaron et al. 1986 Field Manual of Pennsylvania Department of Transportation Storm – Duration – Frequency Charts – PA-IDF Penndot – FHWA.

Pennsylvania Association of Conservation Districts 1998. Pennsylvania Handbook of Best Management Practices for Developing Areas, Harrisburg PA

Viessmanm W. Jr, Lewis, G. 1996 Introduction to Hydrology, Harper Collins

Maps Appendix



Location Map

Management Districts

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Appendix A

Map Legend

- Subarea Boundary
- County Boundaries
- Municipal Boundaries
- Subareas
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

Note:

Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
DRGs - USGS
Subareas - BLE

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World Wide Web : http://www.borton-lawson.com

Prepared By: CGF | Check By:
Project Number: 99613.01 | Date of Plot: December 2003

Management Districts Legend

	Design Storm Proposed Conditions	Reduce To	Design Storm Existing Conditions
A	2 - Year 5 - Year 10 - Year 25 - Year 100 - Year		1 - Year 5 - Year 10 - Year 25 - Year 100 - Year
B-1	2 - Year 10 - Year 25 - Year 50 - Year 100 - Year		1 - Year 5 - Year 10 - Year 25 - Year 100 - Year
B-2	2 - Year 5 - Year 25 - Year 50 - Year 100 - Year		1 - Year 2 - Year 5 - Year 10 - Year 100 - Year
C*	Provisional Discharge District (see notes below *)		

* If storms greater than the 2 - year storm cannot be conveyed to a stream or watercourse in a safe manner, then District A requirements shall apply. (See model ACT 167 Stormwater Management Ordinance, Article III Section 308 for details.)

In addition to the Management District Criteria above, the groundwater recharge (Section 305), water quality (Section 306), and streambank erosion (Section 307) requirements shall also apply to all Management Districts within the Darby-Cobbs Watershed.

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Location Map

Base Map

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-1A

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

Prepared For:
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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE

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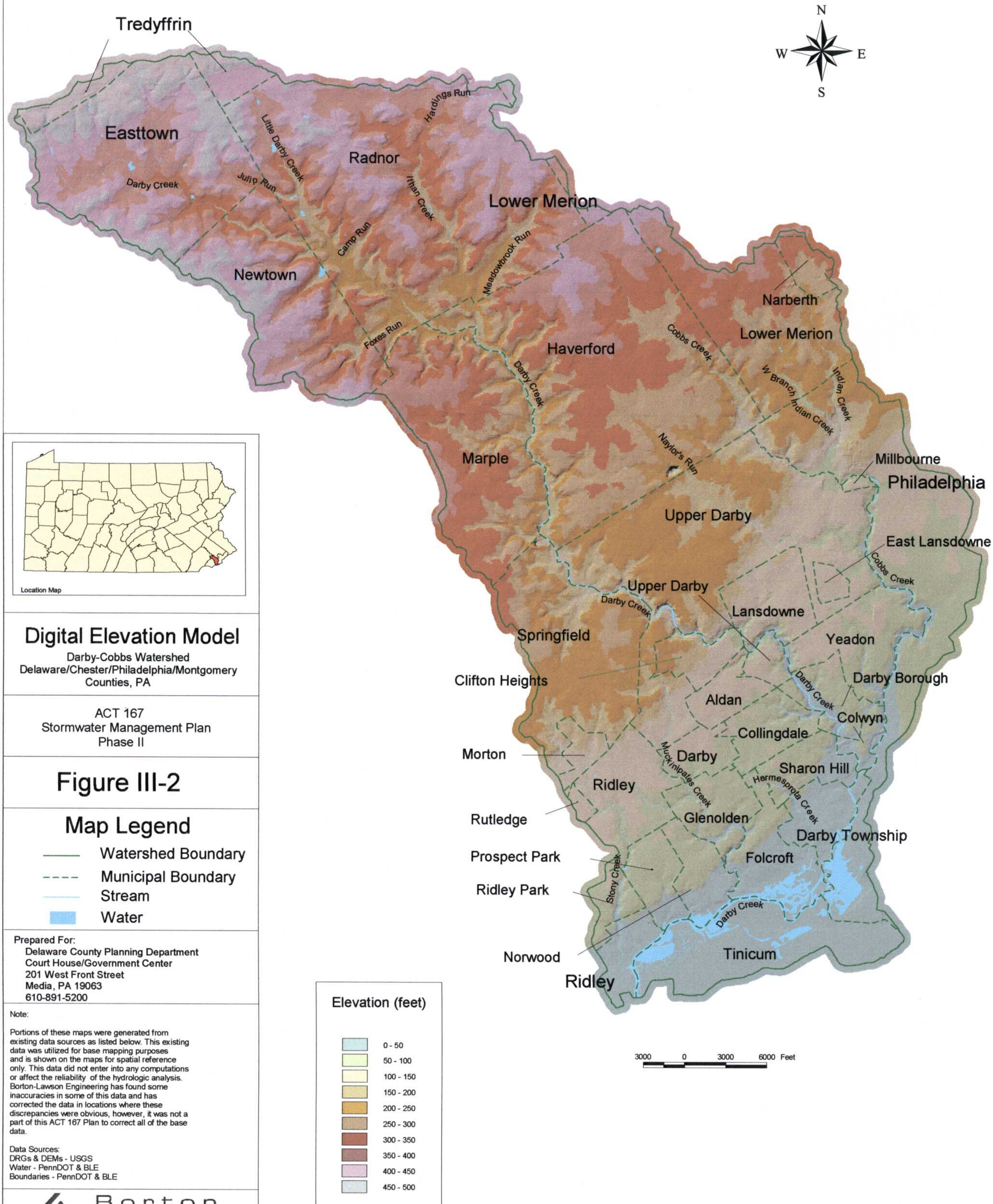
Prepared By: SJD
Check By:
Project Number: 99613.01
Date: 12/13/2004

file: p:\99613\00\data\gis\avprojects\wshed.apr\Base Map



Digital Elevation Model

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-2

Map Legend

- Watershed Boundary
- Municipal Boundary
- Stream
- Water

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Media, PA 19063
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Note:

Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
DRGs & DEMs - USGS
Water - PennDOT & BLE
Boundaries - PennDOT & BLE

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Prepared By: SJD	Check By:
Project Number: 99613.01	Date: 12/13/2004

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Soil Associations

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-3

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

SOIL ASSOCIATIONS

- NESHAMINY-LEHIGH-GLENELG
- CHESTER-GLENELG-MANOR
- URBAN LAND-WESTBROOK-PITS

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Soils - NRCS, STATSGO

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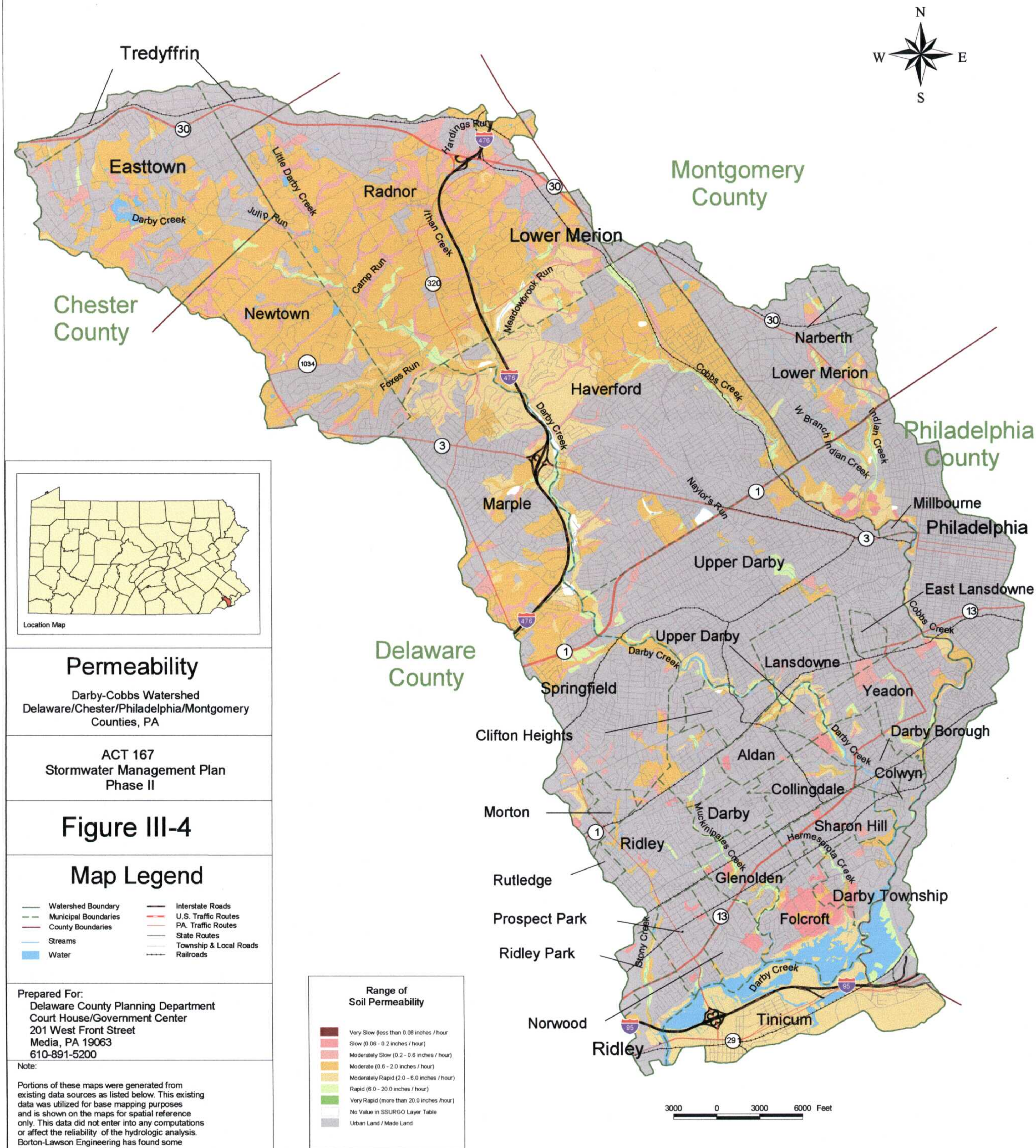
file: p:\99613\00\data\gis\avprojects\wshed.apr\Soil Associations



Permeability

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-4

Map Legend

Watershed Boundary	Interstate Roads
Municipal Boundaries	U.S. Traffic Routes
County Boundaries	PA. Traffic Routes
Streams	State Routes
Water	Township & Local Roads
	Railroads

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Soils - NRCS

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Project Number: 99613.01	Date: 12/13/2004

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Location Map

Erodible Soils

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-5

Map Legend

Watershed Boundary	Interstate Roads
Municipal Boundaries	U.S. Traffic Routes
County Boundaries	PA. Traffic Routes
Streams	State Routes
Water	Township & Local Roads
	Railroads

SOIL ERODIBILITY

- SLIGHT
- MODERATE
- SEVERE
- MADE/URBAN LAND

MADE/URBAN LAND based on NRCS SSURGO data

3000 0 3000 6000 Feet

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Data Sources:
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Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Soils - NRCS

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Hydrologic Soil Groups

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-6

Map Legend

Watershed Boundary	Interstate Roads
Municipal Boundaries	U.S. Traffic Routes
County Boundaries	PA. Traffic Routes
Streams	State Routes
Water	Township & Local Roads
	Railroads

Soil Groups

- A - sand, loamy sand, or sandy loam
- B - silt loam or loam
- C - sandy clay loam
- D - clay loam, silty clay loam, sandy clay, silty clay, or clay

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Soils - NRCS

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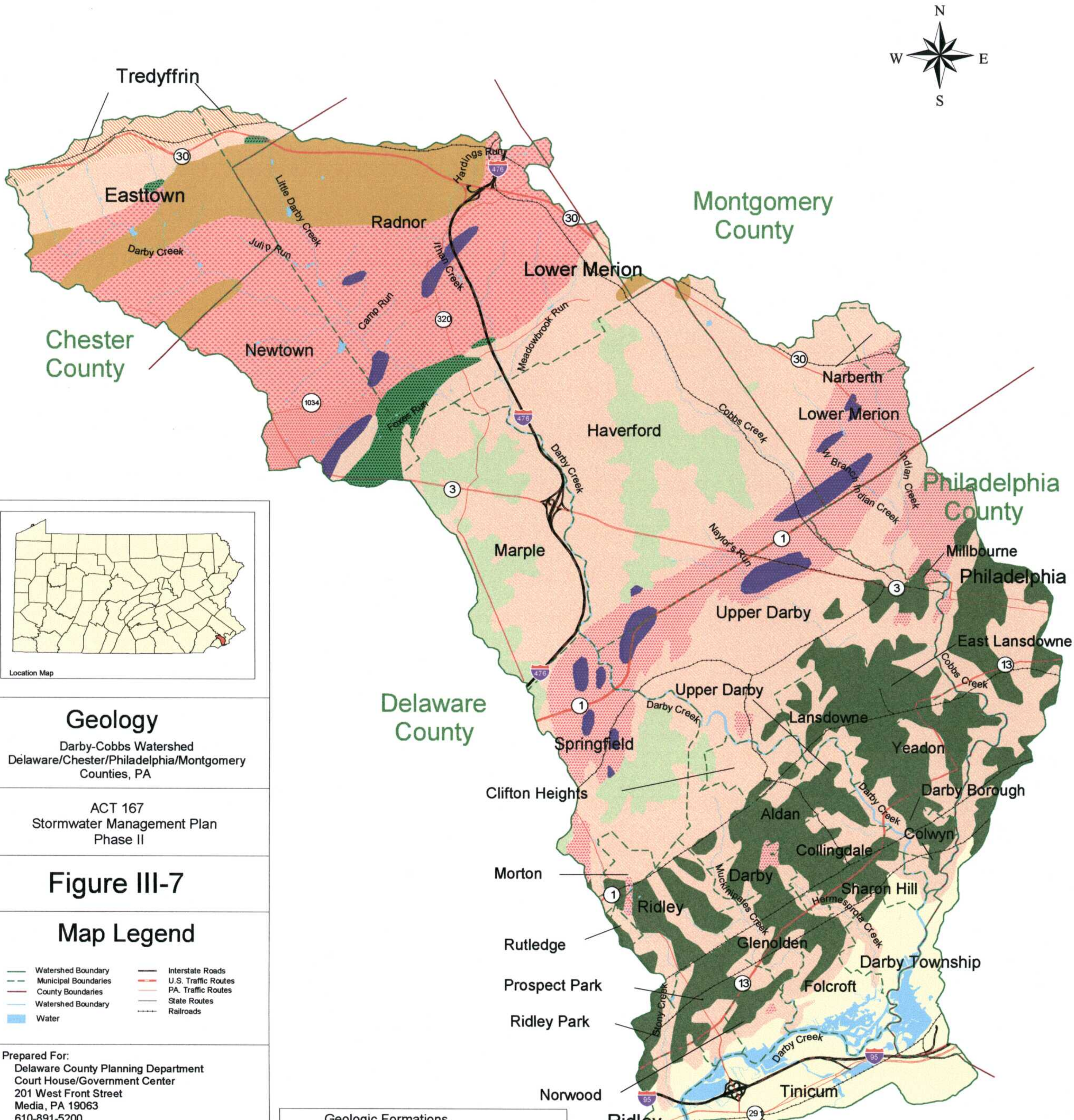

Geology

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-7

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Watershed Boundary
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Railroads

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Geology - PASDA

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Project Number: 99613.01
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Geologic Formations

- Bryn Mawr Fm - High level of terrace deposits; reddish-brown gravelly sand and some silt. Age uncertain.
- Felsic Gneiss, Hornblende bearing - Light, medium grained; includes rocks of probable sedimentary origin
- Felsic Gneiss, Pyroxene bearing - Light, medium grained; includes rocks of probable sedimentary origin
- Granite Gneiss and Granite - Includes Springfield Granodiorite (granitized Wissahickon)
- Mafic Gneiss, Hornblende bearing - Dark, medium grained; includes rocks of probable sedimentary origin
- Felsic Gneiss, Pyroxene bearing - Dark, medium grained; includes rocks of probable sedimentary origin
- Pensauken and Bridgeton Formations - Undifferentiated Dark reddish brown, cross-stratified, feldsparthic quartz sand and some thin beds of fine gravel and rare layers of clay or silt
- Serpentine - Includes serpentine, steatite and other products of alteration of peridotites and pyroxenites
- Trenton Gravel - Gray or pale reddish brown, very gravelly sand interstratified with crossbedded sand and clay-silt beds
- Wissahickon Formation (Albite-Chlorite Schist) - Includes "Octoraro Schist", phyllite, some hornblende gneiss and granitized members
- Wissahickon Formation (Oligioclase Mica Schist) - Includes some hornblende gneiss, some augen gneiss, and some quartz-rich and feldspar-rich members due to various degrees of granitization

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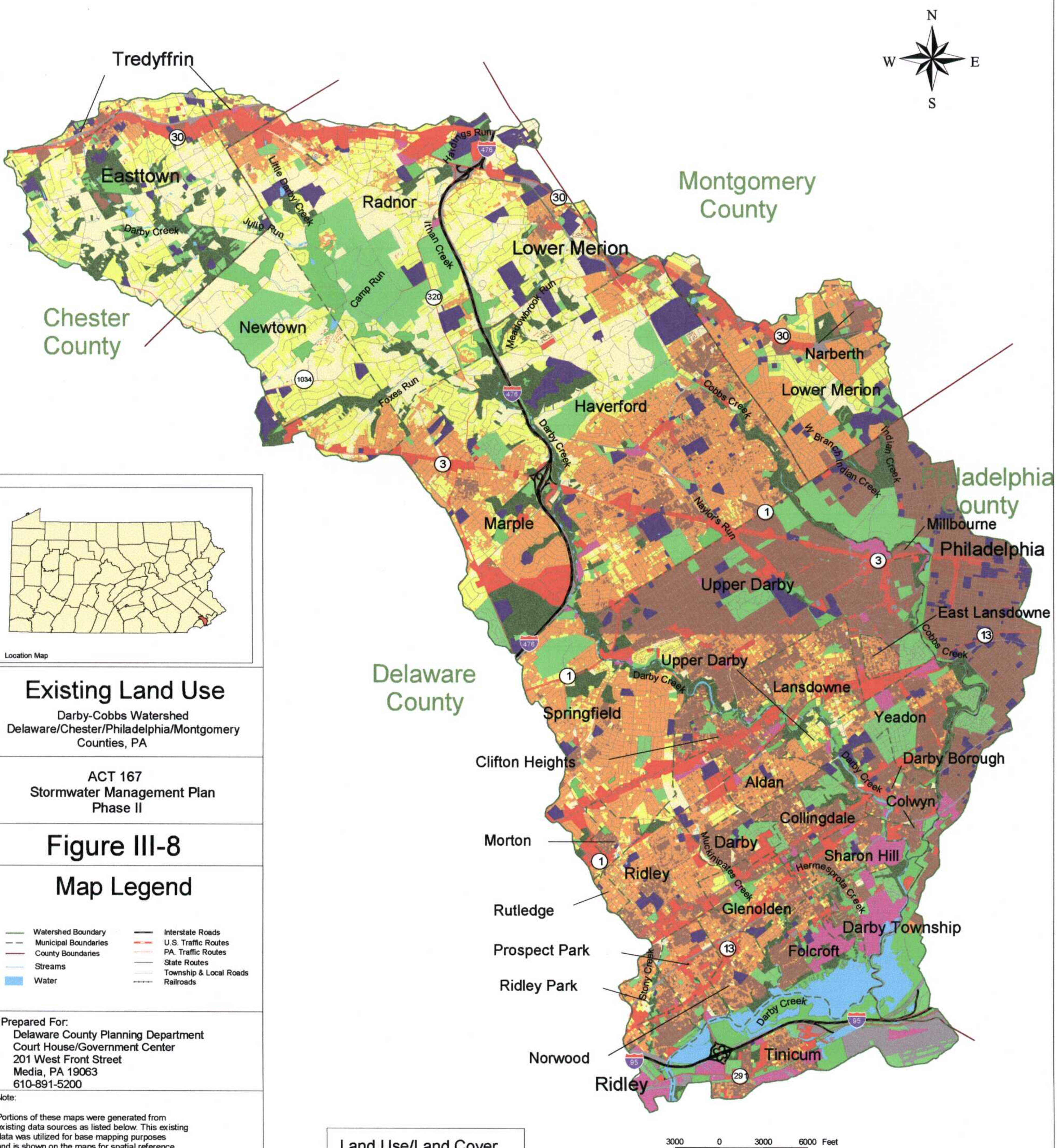

Existing Land Use

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-8

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

Land Use/Land Cover

- COMMERCIAL
- FOREST
- MEADOW
- OPENSPACE
- FARMSTEAD
- INDUSTRIAL
- INSTITUTIONAL
- GRAVEL
- PAVED
- R-A (1/8 Acre or less)
- R-B (1/8 to 1/3 Acre)
- R-C (1/3 to 1 Acre)
- R-D (1 to 4 Acres)

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Existing Land Use - DCPC, CCPC, MCPC, BLE

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Project Number: 99613.01 | Date: 12/13/2004

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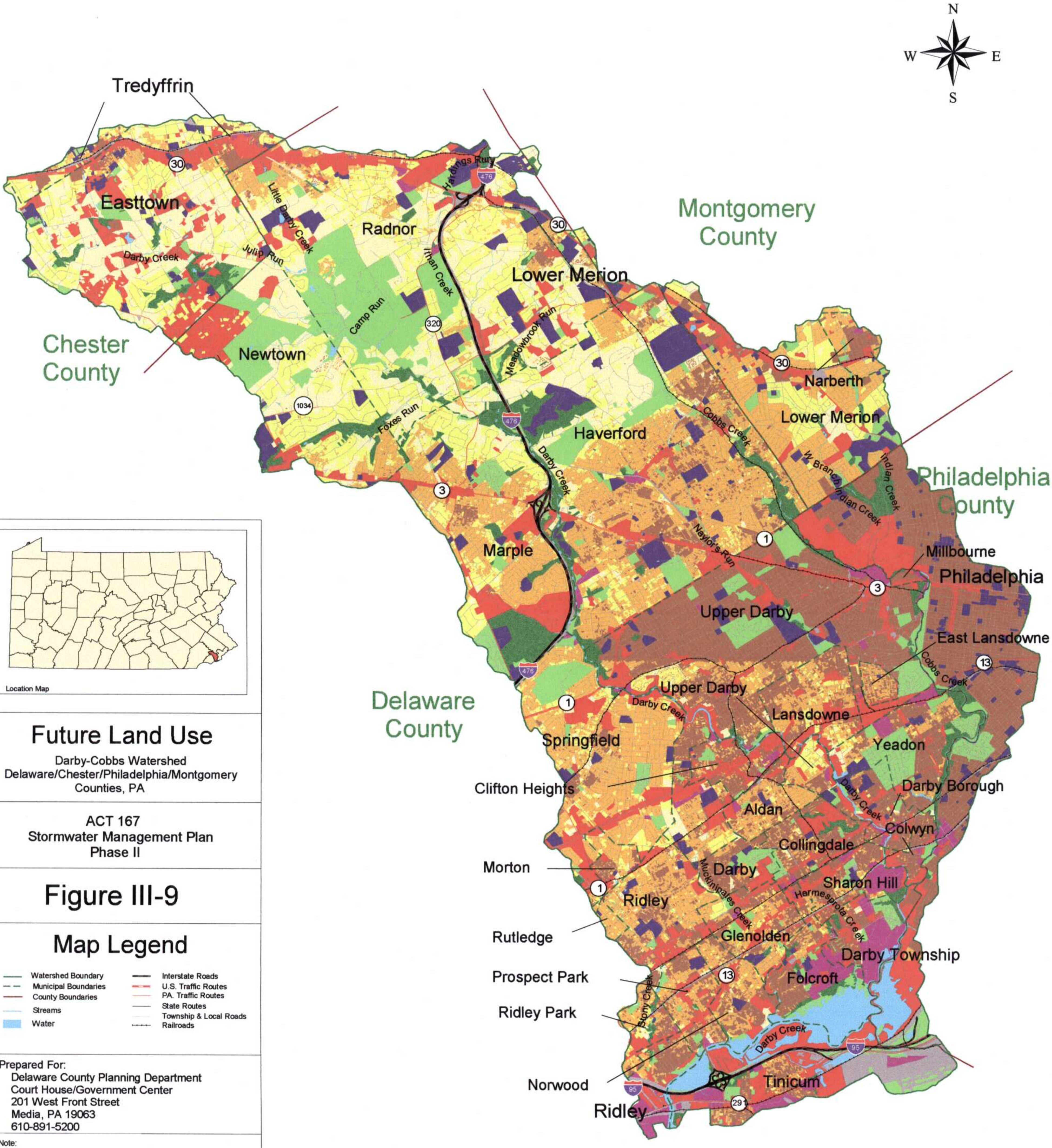

Location Map

Future Land Use

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-9

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Future Land Use - DCPD & BLE

Land Use/Land Cover

- COMMERCIAL
- FOREST
- OPENSPACE/MEADOW
- FARMSTEAD
- INDUSTRIAL
- INSTITUTIONAL
- GRAVEL
- PAVED
- R-A (1/8 Acre or less)
- R-B (1/8 to 1/3 Acre)
- R-C (1/3 to 1 Acre)
- R-D (1 to 4 Acres)
- WATER

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Project Number: 99613.01
Date: 12/13/2004

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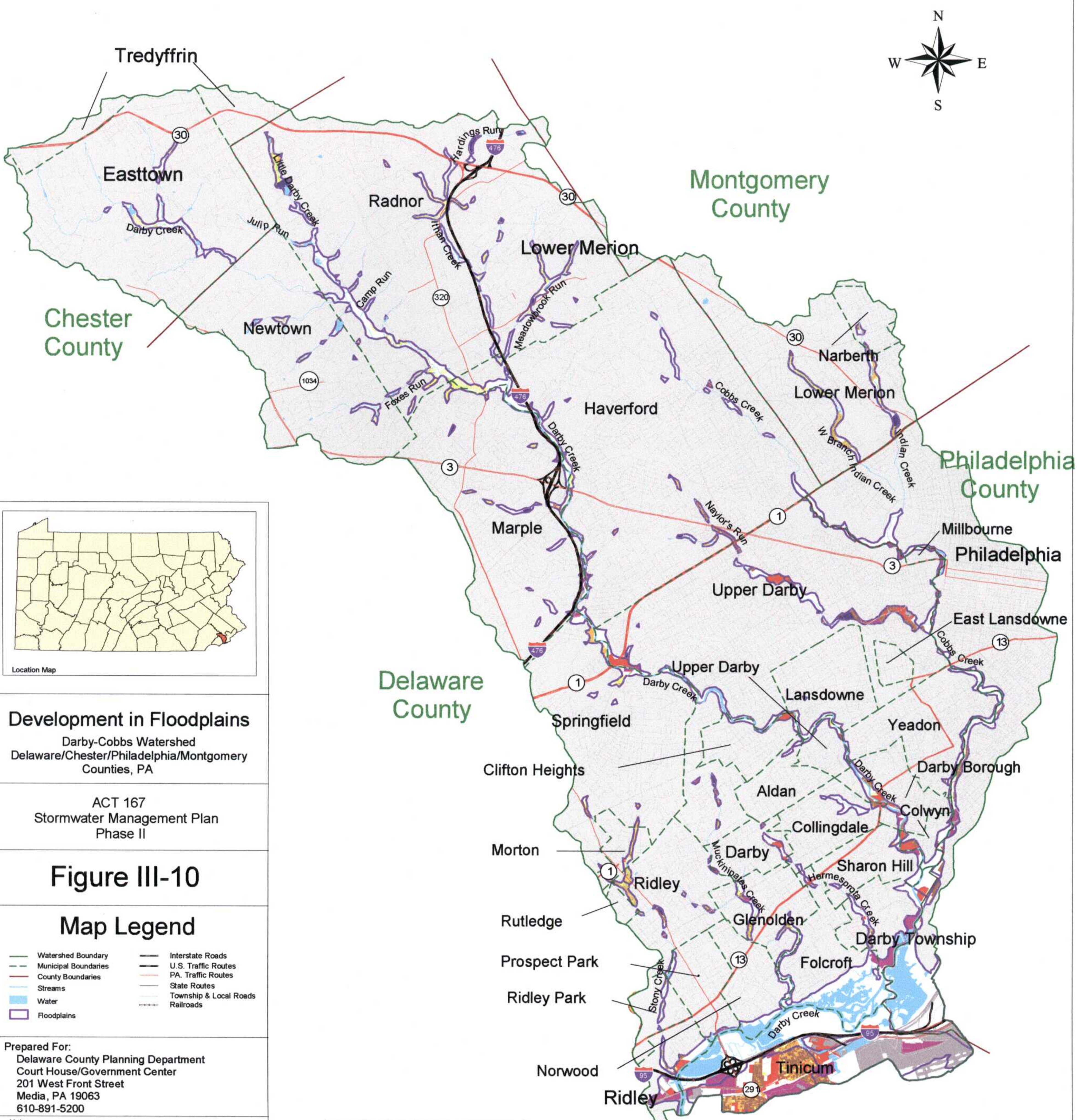

Location Map

Development in Floodplains

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-10

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Streams
- Water
- Floodplains
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

Land Use/Land Cover

- COMMERCIAL
- FARMSTEAD
- INDUSTRIAL
- INSTITUTIONAL
- GRAVEL
- PAVED
- R-A (1/8 Acre or less)
- R-B (1/8 to 1/3 Acre)
- R-C (1/3 to 1 Acre)
- R-D (1 to 4 Acres)
- UNDEVELOPED

NOTE:
The light gray area is outside the floodplains.

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Floodplains - FEMA
Existing Land Use - DVRPC

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Date: 12/13/2004

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Location Map

Obstructions

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-12

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

Obstructions

- Able to pass 100YR Flow
- Able to pass 50YR flow
- Able to pass 25YR flow
- Able to pass 10YR flow
- Able to pass 5YR flow
- Able to pass 2YR flow
- UNDERSIZED
- NO DATA

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
DRGs - USGS
Obstructions - DCPD & BLE

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Location Map

Problem Areas

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-13

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads
- Problem Areas / Points
- Stream Bank Erosion Area

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
DRGs - USGS
Problem Areas - DCPD & BLE

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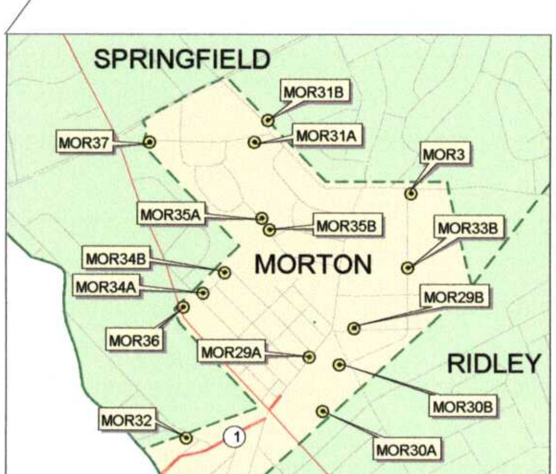

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Project Number: 99613.01
Date: 12/13/2004

file: p:\99613\00\data\gis\avprojects\wshed.apr\ Problem Areas

Flood and Stormwater Facilities

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-14

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
DRGs - USGS
Problem Areas - DCPD & BLE

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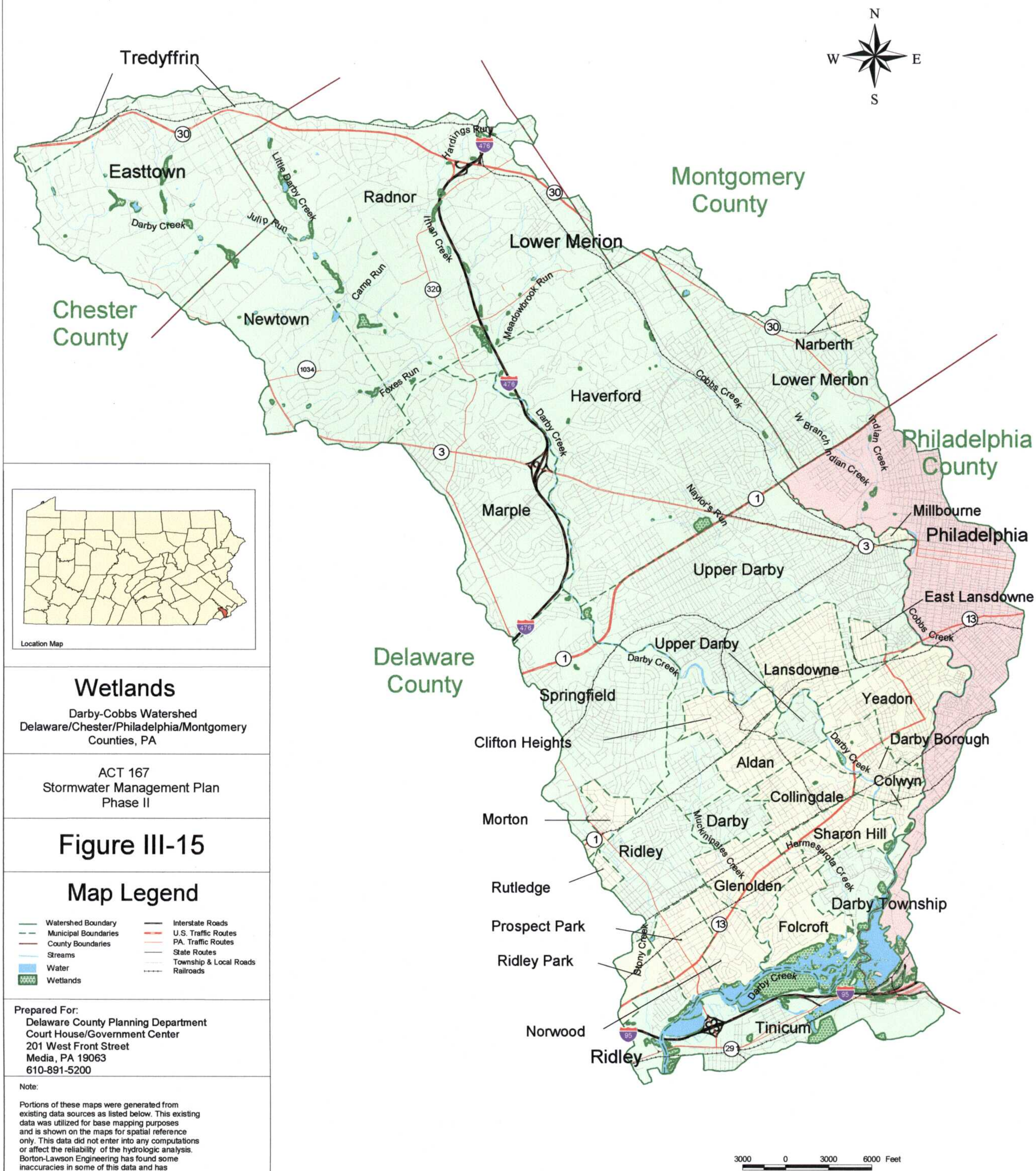
Project Number: 99613.01	Date: 12/13/2004

Flood and Stormwater Facilities

- Existing Flood Control Project
- Proposed Flood Control Projects
- Existing Stormwater Control Facilities
- Proposed Stormwater Control Facilities
- Existing Stormwater Collection System
- Present and Protected Development in the Flood Hazard Area
- Proposed Stormwater Collection Systems

Note: Most locations identified on Forms C - J as submitted by municipalities.
Some detention basins were field located by others .
Facilities in close proximity may appear to overlap or be double labeled.

file: p:\99613\00\data\gis\avprojects\wshed.apr\ Figure III-12b Flood and Stormwater Facilities



Wetlands

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery
Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-15

Map Legend

- Watershed Boundary
- Municipal Boundaries
- County Boundaries
- Streams
- Water
- Wetlands
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Municipal Boundaries - PennDOT & BLE
Wetlands - NWI

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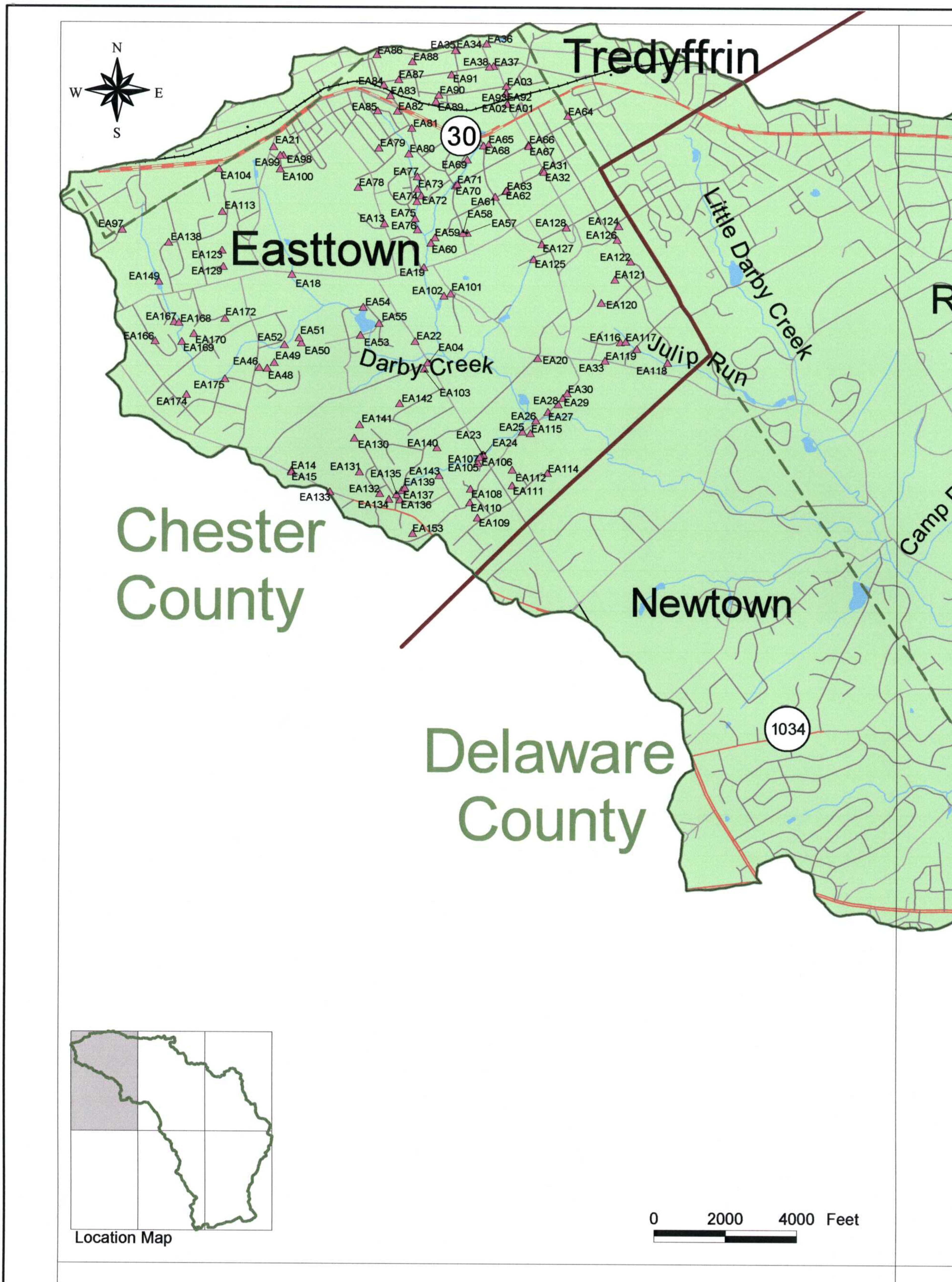

OUTFALLS

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-16A

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Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads
- Outfalls

Note:

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Outfalls - Individual Municipalities

Borton Lawson ENGINEERING

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World Wide Web : http://www.borton-lawson.com

Prepared By: SJD

Check By:

Project Number: 99613.01

Date: 12/10/2004

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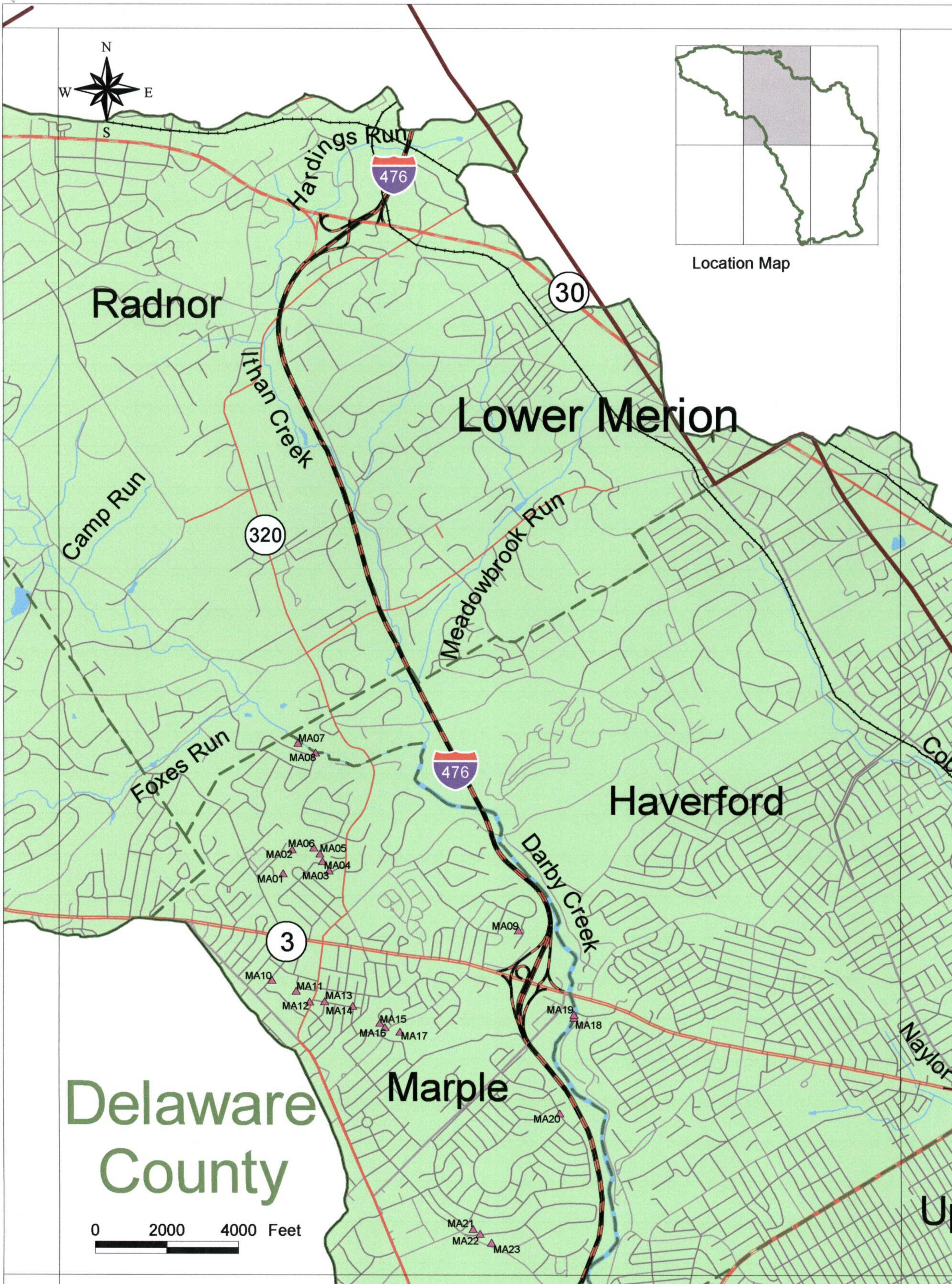

OUTFALLS

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-16B

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads
- Outfalls

Note:

Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Outfalls - Individual Municipalities

Borton Lawson ENGINEERING

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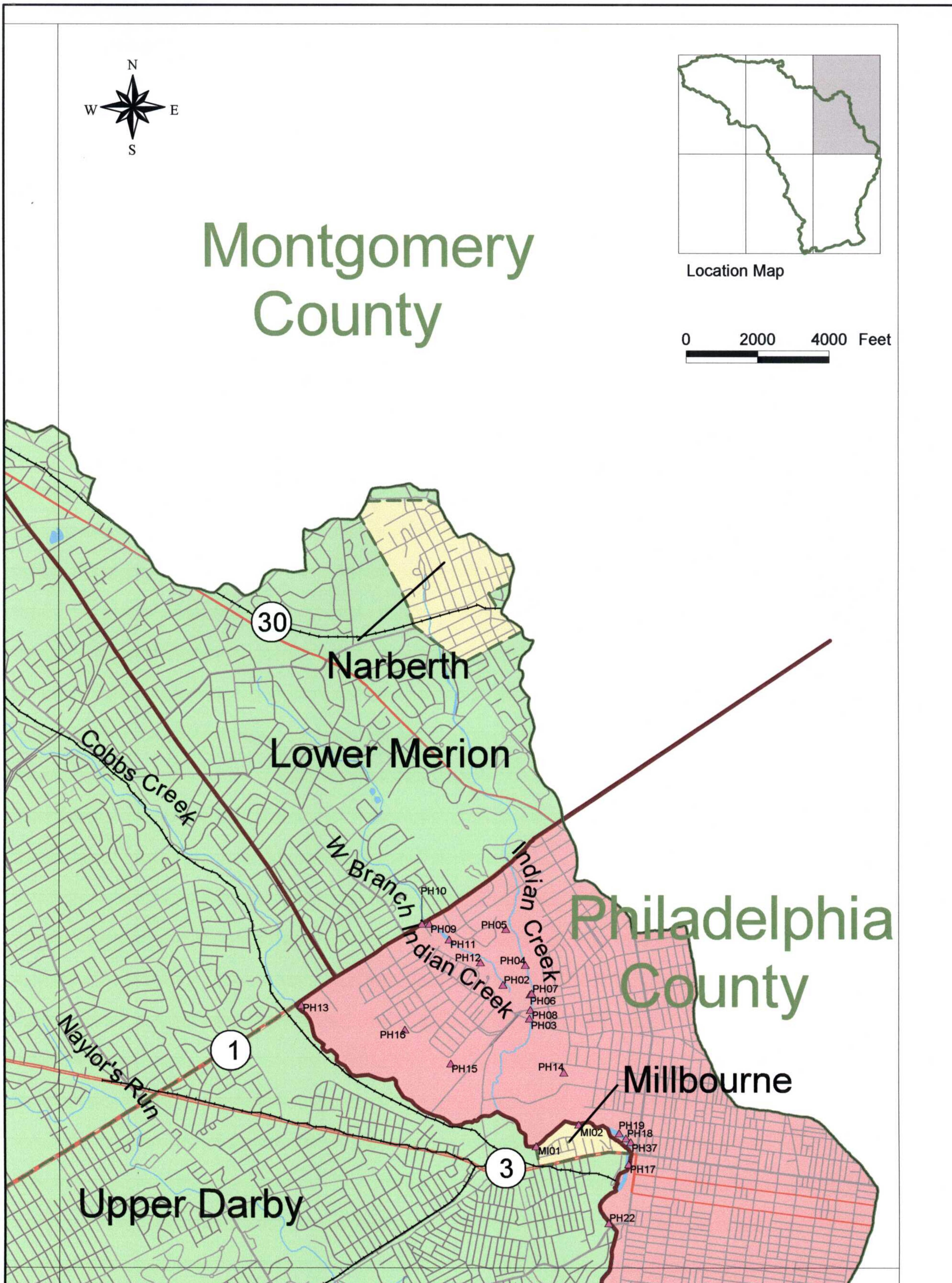
Prepared By: SJD
Check By: [signature]

Project Number: 99613.01
Date: 12/10/2004

file: p:\99613\00\data\gis\avprojects\wshed(final).apr\Outfalls



OUTFALLS

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-16C

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads
- Outfalls

Note:

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Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Outfalls - Individual Municipalities

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Prepared By: SJD
Check By:
Project Number: 99613.01
Date: 12/10/2004

file: p:\99613\00\data\gis\avprojects\wshed(final).apr\Outfalls

OUTFALLS

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-16D

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
- Railroads
- Outfalls

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Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Outfalls - Individual Municipalities

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World Wide Web : http://www.borton-lawson.com

Prepared By: SJD
Check By:
Project Number: 99613.01
Date: 12/10/2004

file: p:\99613\00\data\gis\av\projects\wshed(final).apr\Outfalls

OUTFALLS

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure III-16E

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

Map Legend

- Watershed Boundary
- County Boundaries
- Municipal Boundaries
- Cities
- Townships
- Boroughs
- Streams
- Water
- Interstate Roads
- U.S. Traffic Routes
- PA. Traffic Routes
- State Routes
- Township & Local Roads
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Note:

Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
Roads - PennDOT & BLE
Water - PennDOT & BLE
Boundaries - PennDOT & BLE
Outfalls - Individual Municipalities

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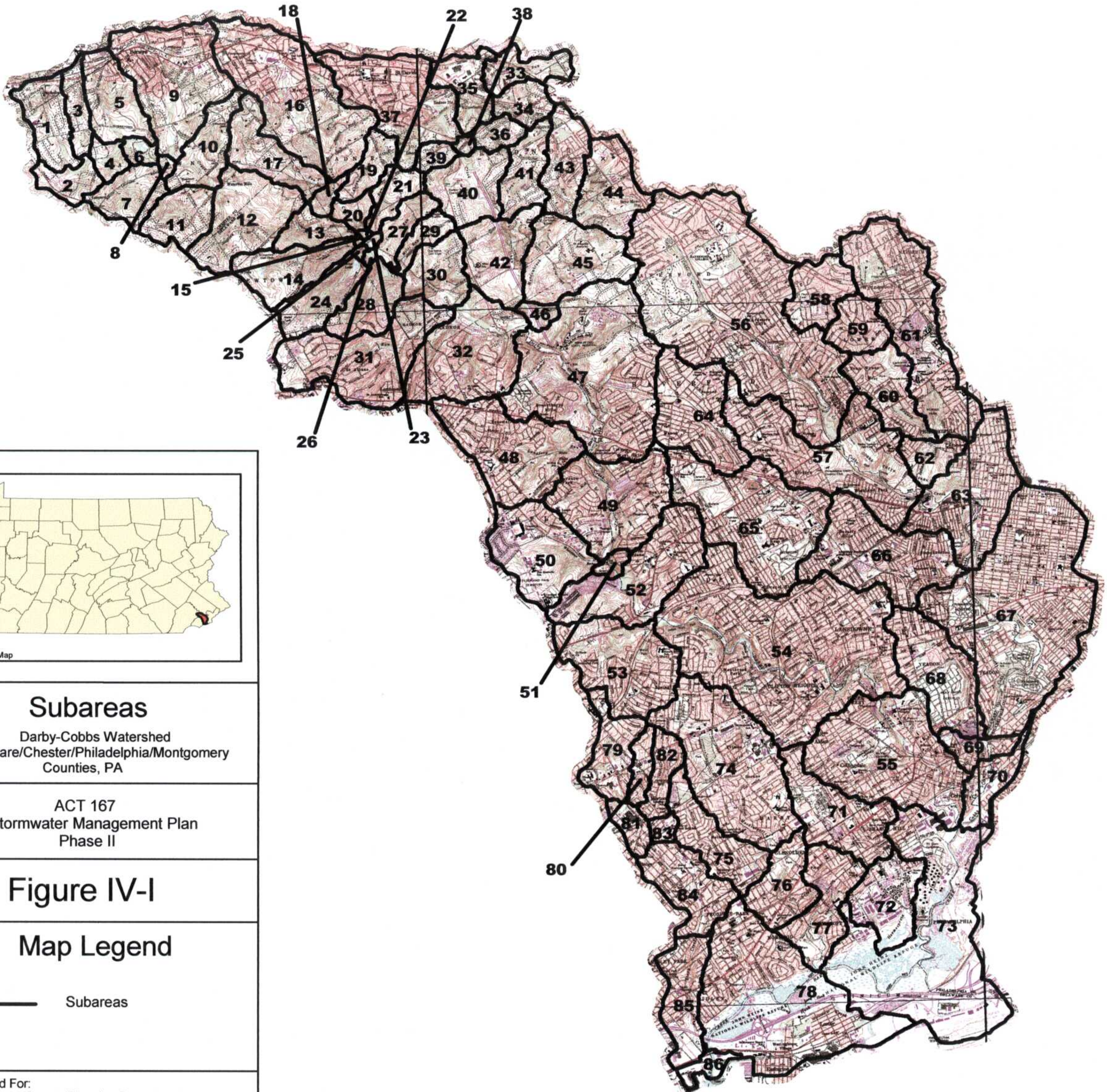
Prepared By: SJD

Check By:

Project Number: 99613.01

Date: 12/10/2004

File: p:\99613\00\data\gis\av\projects\wshed(final).apr\Outfalls



Subareas

Darby-Cobbs Watershed
Delaware/Chester/Philadelphia/Montgomery
Counties, PA

ACT 167
Stormwater Management Plan
Phase II

Figure IV-I

Map Legend

Subareas

Prepared For:
Delaware County Planning Department
Court House/Government Center
201 West Front Street
Media, PA 19063
610-891-5200

3000 0 3000 6000 Feet

Note:

Portions of these maps were generated from existing data sources as listed below. This existing data was utilized for base mapping purposes and is shown on the maps for spatial reference only. This data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of this data and has corrected the data in locations where these discrepancies were obvious, however, it was not a part of this ACT 167 Plan to correct all of the base data.

Data Sources:
DRGs - USGS
Subareas - BLE

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Bath, PA 18014
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World Wide Web : http://www.borton-lawson.com

Prepared By: CGF
Check By:
Project Number: 99613.01
Date of Plot: July 1, 2003

file: p:\99613\01\data\gis\arcinfo\wshed.apr\Subareas