Green City Clean Waters

The City of Philadelphia's Program for Combined Sewer Overflow Control

A Long Term Control Plan Update

Submitted by the Philadelphia Water Department
September 1, 2009

TABLE OF CONTENTS

Section 1: Introduction and Background

Section 2: Public Participation

Section 3: Characterization of Current Conditions

Section 4: Problem Analysis and Goal Setting

Section 5: Overview of the Long Term Control Plan Update (LTCPU)

Section 7: Water-Based Control Measures

Section 8: Infrastructure-Based Control Measures

Section 9: Development and Comparison of Alternatives

Section 11: Financial Capability

Section 12: Post-Construction Monitoring

References

LIST OF FIGURES

Section 4: Problem Analysis and Goal Setting

Section 5: Overview of the Long Term Control Plan Update (LTCPU)

Section 6: Land-Based Control Measures (Source Controls)

Section 8: Infrastructure-Based Control Measures

Section 9: Development and Comparison of Alternatives

Section 10: Recommended Plan Elements

Section 11: Financial Capability

LIST OF TABLES

Section 3: Characterization of Current Conditions

Section 4: Problem Analysis and Goal Setting

Section 5: Overview of the Long Term Control Plan Update (LTCPU)

Section 6: Land-Based Control Measures (Source Controls)

Section 7: Water-Based Control Measures

Section 8: Infrastructure-Based Control Measures

Section 9: Development and Comparison of Alternatives

Section 10: Recommended Plan Elements

Section 11: Financial Capability

SUPPLEMENTAL DOCUMENTATION

All Supplemental Volumes are located online at: http://www.phillywatersheds.org/ltcpu.

1 INTRODUCTION AND BACKGROUND

1.1 THE CITY OF PHILADELPHIA COMBINED SEWER OVERFLOW (CSO) LONG TERM CONTROL PLAN UPDATE (LTCPU)

The City of Philadelphia has undertaken an update to its CSO Long Term Control Plan (LTCP) commitment – first adopted in 1997. This LTCPU builds on the solid foundation established by the LTCP and furthers the City's commitment to watershed based planning and implementation. The Philadelphia Water Department (PWD) has adopted a restoration strategy that acknowledges the inseparable linkage between land use and water resource protection. When cities invest in green stormwater infrastructure and other innovative, cost-saving strategies to manage their stormwater, they are not only ensuring the rebirth of the ecological resources of the City's waterways but are also striving to provide a host of other environmental, social and economic benefits that will preserve the vitality of our nation's cities.

What is different about this LTCPU?
PWD's implementation approach has been developed to integrate the management of Philadelphia's watersheds into a larger context such that the program is designed to provide multiple benefits beyond the reduction of combined sewer overflows, so that every dollar spent provides a maximum return in benefits to the public and the environment. The City of Philadelphia's LTCPU seeks to meet the regulatory requirements of the National CSO Control Policy ("the Policy") through a comprehensive watershed-based approach, such that the CSO program is just one piece of their larger Integrated Watershed Management Planning Program. The Policy acknowledges the importance of watershed planning in the long-term control of CSOs and lays the groundwork for PWD's commitment to watershed-based planning as initiated in the City's original LTCP commitment in 1997. The City of Philadelphia's LTCPU is additionally fortified by the recent green infrastructure guidance and policy documents developed by the United States Environmental Protection Agency (US EPA). With this vision, the LTCPU takes the emphasis off of capital investments that are implemented out of the public view (*i.e.*, underground or in pipes) and instead focuses a program on specific benefits to the residents of the City of Philadelphia by restoring environmental amenities for our constituents and "greening" our City.

To that end, PWD has contracted with a top economic consulting firm to undertake what is called a "triple bottom line" analysis to assess the environmental, social, and economic benefits of the program. This triple bottom line accounting presents a means of expanding traditional cost-benefit analyses to take into account the additional ecological and social benefits in order to provide information for a more comprehensive cost and benefit analysis. Triple bottom line accounting attempts to describe the social and environmental impact of PWD's proposed infrastructure investment such that they can account for not only the water quality benefit that the infrastructure would produce, but also the additional environmental and societal benefits generated by the various implementation approaches. Understanding the full societal costs and benefits is important in justifying the program with the ratepayers, who will ultimately pay for this large public works project. In fact, PWD's *Green City, Clean Waters* program represents the largest green stormwater infrastructure program ever envisioned in this country.

Green City, Clean Waters is the vision developed by PWD to convey the goals of several long-term planning initiatives aimed at improving the environment of the Philadelphia area while addressing combined sewer overflow reductions. Central to all these planning programs is a commitment to greening, sustainability, open space, waterfront revitalization, outdoor recreation, and quality of life. Incidental to compliance with the policy is that this LTCPU will also help to further the challenge set forth in 2007 by the Mayor of Philadelphia, Michael A. Nutter that the City of Philadelphia becomes the "greenest city in America."

1.1.1 Philadelphia Water Department

PWD is well suited to undertake the development and implementation of a watershed approach to CSO control. PWD owns and operates the City of Philadelphia's sanitary sewers, storm sewers, combined sewers, and wastewater treatment plants. In cooperation with the Philadelphia City Planning Commission, PWD regulates stormwater management during the construction and post-construction phases of most development and redevelopment projects.

Through a reorganization in January 1999, PWD integrated three historically separated programs: Combined Sewer Overflow, Stormwater Management, and Source Water Protection. PWD's mission is to preserve and enhance the health of the region's watersheds through integrated wastewater and stormwater services and the adoption of a comprehensive watershed management approach that achieves a sensible balance between cost and environmental benefit and is based on planning and acting in partnership with other regional stakeholders.

PWD is committed to a balanced "land-water-infrastructure" approach to achieve its watershed management and CSO control goals. Where appropriate, this method includes infrastructure-based approaches, but focuses on implementation of a range of land-based stormwater management

PWD *Green City, Clean Waters* Vision:

PWD's vision *Green City, Clean Waters* is to unite the City of Philadelphia with its water environment, creating a green legacy for future generations while incorporating a balance between ecology, economics, and equity.

This long-term vision for the City of Philadelphia integrates CSO and water resources management into the socioeconomic fabric of the City by creating amenities for the people who live and work here. This vision includes:

- Large-scale implementation of green stormwater infrastructure to manage runoff at the source on public land and reduce demands on sewer infrastructure
- Requirements and incentives for green stormwater infrastructure to manage runoff at the source on private land and reduce demands on sewer infrastructure
- A large-scale street tree program to improve appearance and manage stormwater at the source on City streets
- Increased access to and improved recreational opportunities along green and attractive stream corridors and waterfronts
- Preserved open space utilized to manage stormwater at the source
- Converted vacant and abandoned lands to open space or redeveloped responsibly
- Restored streams with physical habitat enhancements that support healthy aquatic communities
- Additional infrastructure-based controls when necessary to meet appropriate water quality standards

techniques and physical reconstruction of aquatic habitats where appropriate. The ultimate goal of PWD's approach is to regain the resources in and around streams that have been lost due to urbanization, both within the City of Philadelphia and in the surrounding counties, while achieving regulatory compliance objectives in a cost-effective manner.

1.2 Evolution of PWD's CSO Implementation Commitments

In 1997 PWD committed to a LTCP that included a strategy to attain water quality improvement goals in three primary phases: aggressive implementation of a comprehensive program for Nine Minimum Controls (NMC); planning, design and construction of 17 capital projects that further enhance system performance and reduce CSO volume and frequency; and, commitment of up to $4 million in services and resources toward comprehensive watershed based planning and analyses that will identify additional, priority actions to further improve water quality in Philadelphia area water bodies. Within this section is a brief description of accomplishments based on these commitments set forth in the 1997 LTCP.

In preparation for the 1997 commitment, PWD submitted a "System Inventory and Characterization," to Pennsylvania Department of Environmental Protection (PADEP) and US EPA on March 27, 1995. This document included an inventory of overflow points and hydraulic control points. PWD also submitted a "System Hydraulic Characterization," to PADEP on June 27, 1995. This document included a system description, discussion of a technical approach to CSO modeling, and hydraulic analysis results. Both of these reports are available for download at http://www.phillyriverinfo.org/CSO.

1.2.1 Document Implementation of the NMC (Phase 1)

In the first phase of PWD's CSO strategy, and in compliance with its Non-Point Discharge Elimination System (NPDES) permits, PWD submitted "CSO Documentation: Implementation of Nine Minimum Controls," to the PADEP on September 27, 1995. The NMC are low-cost actions or measures that can reduce CSO discharges and their effect on receiving waters, do not require significant engineering studies or major construction, and can be implemented in a relatively short time frame. To provide information needed for the development of the NMC program, PWD instituted a $6.5 million project to upgrade its comprehensive system flow monitoring network. This program provides information necessary to identify and eliminate dry weather overflows, monitor system performance and operation, and configure and calibrate computer hydraulic models needed to develop the NMCs and long-term CSO control plans. This information provided the basis for the "System Hydraulic Characterization" report and provided the technical basis for the development of the NMC plan. The NMCs are:

1. Review and improvement of on-going operation and maintenance programs
2. Measures to maximize the use of the collection system for storage
3. Review and modification of PWD's industrial pretreatment program
4. Measures to maximize flow to the wastewater treatment facilities
5. Measures to detect and eliminate dry weather overflows
6. Control of the discharge of solid and floatable materials
7. Implementation of programs to prevent generation and discharge of pollutants at the source
8. Public notification of CSO impacts
9. Comprehensive inspection and monitoring programs to characterize and report overflows and other conditions in the combined sewer system

1.2.2 Technology Based Capital Improvements - Long Term CSO Control Plan (Phase 2)

The second phase of PWD's CSO strategy focused on technology-based capital improvements to the City's sewerage system to further increase its ability to store and treat combined sewer flow, reduce inflow to the system, eliminate flooding due to system surcharging, decrease CSO volumes and improve receiving water quality. This amounted to a commitment of just under $50 million. The recommended capital improvement program was the result of a detailed analysis of a broad range of technology-based control alternatives.

The capital improvement plan encompassed the three major areas of the City that are affected by CSOs: the Northeast, Southeast and Southwest Drainage Districts. Table 1-1 provides a status update on the 17 capital projects selected by PWD to provide significant CSO load reduction. The total expenditures toward implementation of these capital projects to date are in excess of $128 million.

Table 1-1 Summary of Phase II Capital Projects

Project	LTCP Estimated Costs (based on 1997 estimate costs)	Construction Costs (based on original contract)	Status
Real Time Control (RTC) Program			
RTC - Main Relief Sewer Storage (R-7 through R-12)	$650,000	$5,029,919	Completed in 2007
RTC - Tacony Creek Park Storage (T-14)	$450,000	$4,500,000	In-progress as of 2008
RTC - Rock Run Relief Sewer Storage (R-15)	$490,000	$3,665,000	Completed in 2008
Establish Real Time Control (RTC) Center	$350,000	$1,000,000	Completed in 2006
RTC & Flow Optimization (Southwest Main Gravity Interceptor, Cobbs Creek Cut-Off, and Lower Schuylkill West Side)	$1,750,000	$4,657,690	In-progress as of 2008
Outfall Elimination			
Eliminate Outfalls: Dobson's Run Phase I	$6,200,000	$7,040,000	Completed in 1998
Eliminate Outfalls: Dobson's Run Phase II & III	$12,400,000	$38,500,000	In-progress as of 2008
Eliminate Main & Shurs Overflow (R-20)	$12,000,000	$46,000,000*	In-progress as of 2001
Eliminate 32nd & Thompson Outfall (R-19)	$1,500,000	$2,400,000	Completed in 2003
Collection System Improvements			
Upgrade Frankford Siphon	$10,000	$50,000	Completed in 1997
Somerset Interceptor Sewer Conveyance Improvements	$300,000	$273,867	Completed in 1998
Cobbs Creek Low Level (CCLL) Conveyance Improvements	$444,000	$1,500,000	Completed in 2000
Cobbs Creek Low Level (CCLL) Control Project	$2,500,000	$3,647,540	Completed in 2000
Other Capital Programs and Projects			
WPCP Wet Weather Treatment Maximization Program	$150,000	$334,180	Completed in 2001

Project	LTCP Estimated Costs (based on 1997 estimate costs)	Construction Costs (based on original contract)	Status
Targeted Infiltration/Inflow Reduction Programs	$2,000,000	$13,610,000	On-going since 1999
Solids & Floatables Control Program	$380,000	$526,690	Completed in 2005 and On-Going
85% CSO Capture Pennypack Watershed (P1 through P5)	$230,000	$7,339,796	Completed in 2004
Total	**$41,804,000**	**$140,074,662**	

* Estimated cost to complete

1.2.3 Watershed-Based Planning and Implementation (Phase 3)

The third component of the City's 1997 CSO strategy involved a substantial commitment by PWD to watershed planning. This process was structured for the identification of long-term improvements throughout the watersheds, including identification of potential CSO controls, which would result in further improvements to water quality and, ultimately, the attainment of water quality standards. The need for this watershed initiative is rooted in the fact that prior to PWD's detailed watershed assessments, insufficient physical, chemical and biological information existed on the nature and causes of water quality impairments, sources of pollution, and appropriate remedial measures for these urban systems. The watershed planning included various tasks ranging from monitoring and resources assessment to technology evaluation and public participation. The watershed plan development process was detailed in the 1997 CSO LTCP as outlined as follows:

Step 1: Preliminary Reconnaissance Survey

- Data collection and assessment
- Preliminary water quality assessment
- Land use and resource mapping
- Inventory of point and non-point sources
- Definition of regulatory issues and requirements
- Preliminary biological habitat assessment
- Reconnaissance stream survey
- Preliminary problem assessment

Step 2: Watershed Work Plan and Assessment

- Monitoring, sampling and bioassessment
- Quality assurance/quality control and data evaluation
- Watershed modeling
- Waterbody modeling
- Problem definition and water quality goal setting
- Technology evaluation
- Economic assessment and funding requirements
- Public involvement
- Development of IWMP

Step 3: Watershed Plan Implementation

- Institutional arrangements
- Implementation programs
- Monitoring and measures of success

It is the advancement of this watershed approach that has afforded PWD with the experience and knowledge necessary to develop its current *Green City, Clean Waters* vision and this LTCPU commitment.

1.2.3.1 Integrated Watershed Management Plans, River Conservation Plans and Source Water Protection Plans

1.2.3.1.1 Integrated Watershed Management Plans (IWMPs)

The City of Philadelphia had originally committed to developing an IWMP for each of the 5 major waterways that drain to the City of Philadelphia, including the Cobbs, Tookany/Tacony-Frankford, Wissahickon, Pennypack and Poquessing in PWD's CSO and Stormwater Permits. This commitment has now been amended to include IWMP development for the in-City portions of the much larger Schuylkill and Delaware River Watersheds as well, so that all areas of the City are covered by watershed-based visions and implementation commitments.

PWD's IWMP planning process is based on a carefully developed approach to meet the challenges of watershed management in an urban setting. It is designed to meet the goals and objectives of numerous water resources related regulations and programs, and it utilizes adaptive management approaches to prescribe implementation recommendations. IWMPs focus on attaining priority environmental goals in a phased approach, making use of the consolidated goals of the numerous existing programs that directly or indirectly require watershed-based implementation. IWMPs are designed to meet the goals and objectives of numerous water resource related regulations and programs and draw from the similarities contained in many watershed-based planning approaches authored by the PADEP and the US EPA. Further, watershed planning is mandated by the CSO Policy and guidance documents and also is consistent with the Clean Water Act (CWA) and its regulations, as well as the priorities announced by US EPA's Office of Water (See EPA's Watershed Approach Framework, Office of Water, June 1996).

As PWD has developed IWMPs, a defined planning approach has evolved based on refinements that have come with each new watershed. Four major planning elements have been defined, each with multiple tasks specific to the needs of the given watershed as follows:

- Data collection, organization and analysis
- Systems description
- Problem identification and development of plan objectives
- Strategies, policies and approaches

These elements are captured within three planning steps documented in Figure 1-1.

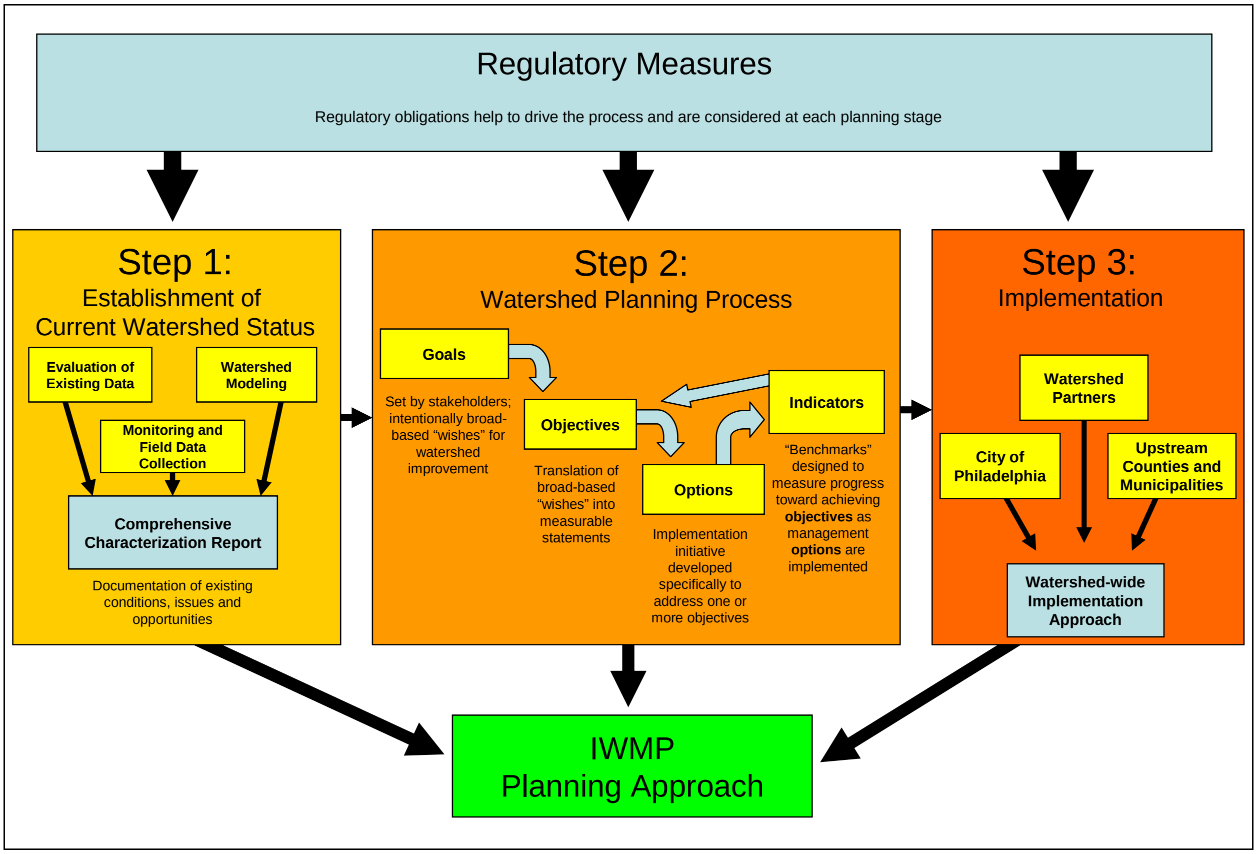


Figure 1-1 PWD's IWMP Development Process

Step 1: Establishment of Current Watershed Status

The first step in the planning process involves the collection and organization of existing and new data on surface water hydrology and quality, wastewater collection and treatment, stormwater control, land use, stream habitat and biological conditions, and historic and cultural resources in order to gain an understanding of what data already exists and where there may be gaps worth filling. Additionally, existing ordinances, regulations, and guidelines pertaining to watershed management at federal, state, basin commission, county, and municipal levels must be examined for coherence and completeness in facilitating the achievement of watershed planning goals. Data are collected from various agencies and organizations in a variety of forms, ranging from reports to databases and Geographic Information System (GIS) files.

The planning approach for an urban stream must focus on the relationship between the natural watershed systems (both groundwater and surface water) and the constructed systems related to land use that influence the hydrologic cycle, such as water supply, wastewater collection and treatment, and stormwater collection. A critical step in the planning process is to examine this relationship in all its complexity and to explore the adequacy of the existing regulatory structure at the federal, state, county, and municipal level to properly manage these natural and anthropogenic systems. Significant savings can be achieved through coordination of the programs and the development of one comprehensive plan for a watershed that meets multiple needs.

In urban watersheds, the natural systems are, by definition, influenced by the altered environment; existing conditions reflect these influences. It is not, however, always obvious which constructed systems are having the most influence or what that influence is. Analyzing and understanding the water resources and water supply/wastewater/stormwater facilities and their interrelationship provides a sound basis for subsequent planning, leading to the development of a realistic set of planning objectives. All data collected and analyzed lead to an understanding of the existing conditions within the watershed area – known as the systems description.

<u>Problem Identification</u>

Existing problems and issues of water quality, stream habitat, and streamflow related to the urbanization of the watershed can be identified through previously described analyses of:

- Prior studies and assessments;
- Existing data;
- New field data;
- Stakeholder input.

Problems and issues identified through data analysis must also be compared with those brought forward by stakeholders. Ultimately, this will allow the prioritization of goals based on scientifically justified issues in the watershed.

Step 2: Watershed Planning Process

<u>Development of Plan Goals, Objectives, Indicators and Options</u>

The development of a preliminary list of goals and objectives for the watershed can be initiated simultaneously with the development of the systems description. A watershed-wide goal setting process involves the development of a “base set” of goals for the region – incorporating when available all information produced by other plans and reports. A base set of goals are then presented to the stakeholder group for evaluation. A facilitated discussion is held during which the partners are invited to add to this list of goals and finally to adopt this master list as the initial goal set for the watershed area.

Often times, this stakeholder insight may reveal “information gaps” not addressed by problem analysis that requires additional data collection. Ultimately, with stakeholder collaboration, a final list of goals is established that should reflect the multitude of stakeholder interests in the watershed.

The following example clarifies the difference between a goal and an objective:

> **Goal:** These are to be general and not specifically measurable. Goals represent a series of “wishes” for the watershed.
>
> *e.g., Improve stream habitat and aquatic resources*
>
> **Objective:** Objectives translate the goal statements into measurable parameters. The objective should lead toward the establishment of a target value and could help to establish a trend over time. There can be multiple objectives for a single goal.
>
> *e.g., Restore “x” miles of stream channel and habitat using Natural Stream Channel Design (NSCD) principles* (Note: “x” to be filled in for the given watershed based on restoration needs)

Based on the preceding descriptions, each of the goals in the master list needed to be further evaluated and *translated* into objectives so that progress would be measurable as management options are implemented in the future.

As previously noted, the Systems Description results in the identification of existing problems within the watershed area; these problems are then presented to watershed stakeholders in order to re-evaluate the master list of goals and prioritize those that directly address problems identified.

> **Management Option:** A management option is a technique, measure, or structural control that addresses one or more objectives (e.g., a stormwater best management practice (BMP) that is installed, an ordinance that gets passed, an educational program that gets implemented).
>
> *e.g., Utilize NCSD principals to restore stream corridors*

Once the final list of goals and objectives are defined, each objective is evaluated for the identification of potential management options that could be implemented to achieve the given objective. The product of this process is a comprehensive list of potential options that will need to be individually evaluated for feasibility under the conditions of a given watershed area.

> **Indicator:** Indicators can be used to characterize the current condition of a watershed area and can be used to measure progress toward goals as management options are implemented.
>
> *e.g., Macroinvertebrate and fish population diversity*

A list of indicator measures is developed to address each of the objectives so that as management options are implemented, progress can be measured toward attainment of the watershed goal. An indicator has been developed for each of the watershed objectives.

<u>Screening of Management Options</u>
Clear, measurable objectives provide guidance for developing options designed to meet the watershed goals. Lists of management options are developed to meet each of the goals and objectives established for the watershed and once evaluated, only those options deemed feasible and practical are considered in the final list of management options. Options were developed and evaluated in three steps:

> **Development of a Comprehensive Options List:** Virtually all options applicable in the urban environment are collected. These options are identified from a variety of sources, including other watershed plans, demonstration programs, regulatory programs, literature, and professional experience.
>
> **Initial Screening:** Some options can be eliminated as impractical for reasons of cost, space required, or other considerations. Options that are already planned and/or committed to, are mandated by another program, or are agreed upon as vital are chosen for inclusion in the final list as not needing further evaluation. The remaining options are screened for applicability to

the watershed as well as for their relative cost and the degree to which they meet the project objectives. Only the most cost-effective options are considered further.

Detailed Evaluation of Structural Options: Structural best management practices for stormwater management are subjected to a modeling analysis as necessary to assess effects on runoff volume, peak stream velocity, and pollutant loads at various levels of coverage.

Step 3: Implementation Planning
Development of planning goals through the IWMP process led to the establishment of three targets for watershed improvement and restoration based on consideration of ecology and human health in dry weather. These targets were devised in light of the fact that achievement of the intent of the CWA – including the fishable and swimmable criteria would necessitate breaking the end goal into achievable pieces.

Additionally, through PWD's experience in working with stakeholder groups in goal prioritization and option evaluation, what often emerges is that stakeholder priorities differ from those identified by the data driven problem identification process, for example stakeholders might place priority on problems associated with aesthetics, litter, dumping, etc, as opposed to macroinvertebrate diversity. PWD's target based implementation approach is able to address and show progress toward achievement of high priority stakeholder concerns while simultaneously addressing the scientifically defined priorities.

Targets are specifically designed to help focus plan implementation. By defining these targets, and designing alternatives and an implementation plan to address the targets simultaneously, the plan will have a greater likelihood of success. They also make possible the realization of accomplishing measurable progress on some of the objectives within a relatively short time frame, providing positive incentive to the stakeholders to continue to support the initiative, while also providing immediate benefits to the residents of the watershed.

The three IWMP planning targets are defined as follows:

Target A: Improvement of Stream Quality, Aesthetics and Recreation During "Dry" Weather
Streams should be aesthetically appealing, free of unpleasant odors, be accessible to the public, and be an amenity to the community. Target A was defined with a focus on trash removal and litter prevention, and the elimination of sources of sewage discharge during dry weather. Access and interaction with the stream during dry weather has the highest priority, because dry weather flows occur about 60-65% of the time during the course of a year. These are also the times when the public is most likely to be near or in contact with the stream. The water quality of the stream in dry weather, particularly with respect to bacteria, should not be impacted by human contribution of bacteria.

Target B: Preservation and Enhancement of Healthy Living Resources
Improvements to the number, health, and diversity of the benthic macroinvertebrate and fish species needs to focus on habitat improvement and the creation of refuges for organisms to avoid high velocities during storms. Fluvial geomorphological studies, wetland and streambank restoration/creation projects, and stream modeling should be combined with continued biological monitoring to ensure that correct procedures are implemented to increase habitat heterogeneity within the aquatic ecosystem.

Improving the ability of an urban stream to support viable habitat and fish populations focuses primarily on the elimination or remediation of the more obvious impacts of urbanization on the stream. These include loss of riparian habitat, eroding and undercut banks, scoured streambed or excessive silt deposits, channelized and armored stream sections, trash buildup, and invasive species. Thus, the primary tool to accomplish Target B is stream restoration.

Target C: Improvement of Wet Weather Water Quality and Quantity
The third target is to restore water quality to meet fishable and swimmable criteria during wet weather. Improving water quality and flow conditions during and after storms is the most difficult target to meet in the urban environment. During wet weather, extreme increases in streamflow are common, accompanied by short-term changes in water quality. Where water quality and quantity problems exist, options may be identified that address both. Any BMP that increases infiltration or detains flow will help decrease the frequency of damaging floods; however, the size of such structures may need to be increased in areas where flooding is a major concern. (Reductions in the frequency of erosive flows and velocities also will help protect the investment in stream restoration made as part of the Target B.)

Target C must be approached somewhat differently from Targets A and B. Full achievement of this target means meeting all water quality standards during wet weather, as well as elimination of flood related issues. Meeting these goals will be difficult, expensive, and will require a long-term effort. A rational approach to achieve this target includes stepped implementation with interim goals for reducing wet weather pollutant loads and stormwater flows, along with monitoring for the efficacy of control measures.

1.2.3.1.2 River Conservation Plans (RCPs)

The Pennsylvania Rivers Conservation Program is administered by the Pennsylvania Department of Conservation and Natural Resources (PA DCNR). This program is intended to conserve and enhance river resources through locally initiated plans. PA DCNR provides Rivers Planning Project grants to groups seeking to develop a RCP for a given watershed area. This funding is for completion of a RCP via identification of significant natural, recreational and cultural resources. Issues, concerns and threats to river resources and values are determined locally as part of planning, as well as recommending methods to conserve, enhance and restore Pennsylvania's many streams and rivers. Once approved by the PA DCNR, RCPs are placed on the State Rivers Registry and become eligible for PA DCNR's implementation funding.

PWD has played the roll of both lead and supporting partner in RCP planning initiatives undertaken in the regional watersheds that drain to the City of Philadelphia (Table 1-2). These plans facilitate PWD's understanding of stakeholder interests and concerns and are extremely valuable in highlighting recreational opportunities and constraints within the watersheds. And, because these plans are often initiated at least a year or so before an IWMP process, they are instrumental with bringing grassroots partners into PWD's stakeholder partnerships (described in Section 1.2.3.2).

Table 1-2 Watershed Management Planning Status

Watershed	RCP	IWMP	Implementation Commitment Status
Delaware River (tidal, non-tidal)	Initiated in 2008 by PWD; to be completed 2010	Initiated in 2009	To be developed in 2009/2010
Cobbs Creek	Darby RCP completed in 2005 by Darby Creek Valley Association	Completed 2004	1st 5-year Implementation Plan developed and committed to; 2006-2011
Pennypack Creek	Completed in 2005 by PWD	Initiated in winter 2008, to be completed by 2010	To be developed 2010/2011
Poquessing Creek	Completed in 2007 by PWD	Initiated in 2009	To be developed 2011/2012
Schuylkill River (tidal, non-tidal)	Completed in 2001 by the Academy of Natural Sciences, Natural Lands Trust, and the Conservation Fund	Initiated in 2009	To be developed 2009/2010
Tacony-Frankford Creek	Completed in 2004 by PWD	Completed 2005	1st 5-year Implementation Plan developed and committed to; 2006-2011
Wissahickon Creek	Completed in 2000 by Fairmount Park Commission	Initiated in 2005, anticipated completion of planning process for City of Philadelphia portion of the watershed 2010.	1st 5-year Implementation Plan developed currently in development; it will cover time period from 2010-2015

1.2.3.1.3 Source Water Protection Plans (SWPPs)

The mission of PWD's Source Water Protection Program is to enhance, protect, and preserve the surface waters of the Schuylkill and Delaware Rivers to ensure a high quality and sustainable source of drinking water for future generations of Philadelphia residents. The accomplishment of this mission depends on a holistic watershed approach, a sense of common commitment and responsibility felt by all who work and reside in the watershed boundaries, and a respect for the interconnectedness between source water protection concerns, upstream land and water use, and the need to maintain a healthy aquatic ecosystem which nurtures habitat and inspires low-impact recreation. The program develops watershed protection plans, implements projects, and engages in public education programs to preserve, protect, and improve the water quality of both rivers.

In order to accomplish this mission, a 5-year strategy has been developed which is centered on the following categories:

1. Source Water Quality Enhancement and Protection – Activities that ensure long-term, sustainable improvements to the health of the Schuylkill River and Delaware River Watersheds
2. Early Warning Notifications and Event Communication – Efforts to improve notification and communication surrounding water quality events which may threaten water supply and recreational safety.

3. Drinking Water Treatment Support – Research on technologies and methods for treatment optimization, problem diagnosis, predictive analyses, vulnerability assessments, and improvements to local water quality.

PWD's Source Water Team completed a SWPP for the Schuylkill River Watershed in 2006 and for the Delaware River in 2007. PWD's source water assessment process has received an award from the US EPA and the PADEP has formally recognized both plans.

1.2.3.1.4 Additional Plans that Further the City's Greening Goals

A number of stakeholder groups and community development corporations (CDCs) have embarked on planning initiatives that also support the concept of "greening" the City of Philadelphia. Several of these larger plans are highlighted below, but PWD is also working with numerous stakeholders on identifying opportunities for collaborating and producing synergies by working together to accomplish our respective goals in plans both large and small.

Greenworks Philadelphia – the City's sustainability plan, released in April of 2009. This plan builds upon the work of the 2007 Local Action Plan for Climate Change that was produced by the Mayor's Sustainability Working Group – a task force of more than 50 municipal employees. The goal of that work group was to establish a plan to reduce greenhouse gas emissions by 10% by 2010. The Greenworks Philadelphia Plan considers sustainability through five goals including: energy, environment, equity, economy and engagement. Each of these goals has associated with it a number of measurable targets to be achieved by 2015. This plan also incorporates the goals of the City's soon-to-be-adopted open space plan – GreenPlan Philadelphia.

GreenPlan Philadelphia – the City's blueprint for sustainable open space, is Philadelphia's first comprehensive plan for its parks, recreation areas, and open space. GreenPlan Philadelphia will guide and inform decision-making about open space use, acquisition, development, funding, and management. It will ensure that open space continues to enhance the environmental, social, and economic well-being for the City of Philadelphia.

1.2.3.2 Creation of Watershed Partnerships and Stakeholder Networks

As previously described, central to PWD's comprehensive approach to urban water resources management is development of IWMPs. The IWMPs, developed in cooperation with stakeholder partnerships, are based on a carefully developed approach to meet the challenges of watershed management in an urban setting. Stakeholder support is critical to the ultimate success of a regional planning initiative. A diversity of stakeholder perspectives must be involved with the development of each stage in the planning process in order to ensure that the plan is representative of stakeholder interests. The watershed partnerships are designed to provide a forum for stakeholders to work together to develop strategies that embrace the dual focus of improving stream water quality and the quality of life within their communities. The partnership is charged with driving the process and ensuring that the process remains representative of the diversity of stakeholder perspectives. The partnerships discuss priorities and the actions necessary to make the plan successful. These actions become a part of the implementation strategy, and address the desire to improve the water and land environment through a number of avenues. The ultimate goal is to cultivate a partnership committed to implementing the plan once completed. Recognizing this, PWD has committed a great deal of resources toward establishing and supporting watershed-based stakeholder partnerships within each watershed where an IWMP is initiated.

At a minimum, PWD's watershed partnerships are comprised of representatives from each of the following: federal, state, and local government (both municipal and county) agencies, industries, local businesses, non-profit organizations and watershed residents, as well as additional interested stakeholders in the watershed.

PWD has initiated stakeholder partnerships in six of the watersheds that drains to the City of Philadelphia and also supported the large-scale Schuylkill Action Network and its "work groups". Information on each of these stakeholder partnerships is presented in Table 1-3.

1.2.3.3 Detailed Watershed-Based Monitoring and Assessment

As prescribed by the 1997 LTCP, PWD implements a detailed monitoring program in each watershed in which it develops an IWMP. This monitoring program includes chemical, biological and physical assessments to characterize the current state of the watershed and identify existing problems and their sources. The need for this watershed monitoring effort is rooted in the fact that prior to PWD's monitoring program, insufficient physical, chemical and biological information existed on the nature and causes of water quality impairments, sources of pollution, and appropriate remedial measures.

The purpose of the survey is to review existing information, gain a good, understanding of the physical, chemical and biological conditions of the water bodies, understand the character of the watershed land uses that will drive wet weather water quality conditions, and build a common understanding of these factors among all stakeholders. From this understanding more detailed monitoring, modeling, mapping, and analytical work can be better scoped and scheduled to meet the specific needs of the watershed.

Comprehensive Characterization Reports (CCRs)
A compendium document is produced following the analysis of all collected data for a given watershed; this CCR serves to document the watershed baseline health prior to implementation of any plan recommendations, allowing for the measure of progress as implementation takes place upon completion of the IWMP. The CCR is shared with watershed partners for comments and feedback.

CCRs have been completed for the Cobbs Creek Watershed in 2004, the TTF Creek Watershed in 2005 and the Pennypack Creek Watershed in 2009 (Table 1-4). These CCR documents are available on the partnership website at http://http://www.phillyriverinfo.org.

Table 1-3 PWD Supported Watershed Stakeholder Partnerships

Watershed Partnership	Initiated	Status and Accomplishments
Darby-Cobbs Watershed Partnership	1999	PWD continues to convene the Darby-Cobbs Watershed Partnership Steering Committee and Public Education and Outreach Committee on a quarterly basis. This partnership has collaborated on a number of on-the-ground implementation initiatives and demonstration projects including porous pavement installation at a municipal basketball court and a parking lot at a municipal complex, as well as the greening of a street that forms the “gateway” between the City of Philadelphia and Delaware County.
Tookany/Tacony-Frankford (TTF) Watershed Partnership	2000	As of 2007 this partnership had evolved into an independent 501(c)3 non-profit organization with a mission of implementing the IWMP for the TTF Watershed. This partnership has collaborated on a number of initiatives – including demonstration projects on the property of Awbury Arboretum as well as Cliveden Park and Waterview Recreation Center.
Pennypack Creek Watershed Partnership	2004	PWD originally initiated this partnership for the development of a RCP in 2004; this group has been re-convened in 2008 for the development of an IWMP.
Wissahickon Creek Watershed Partnership	2005	PWD initiated this partnership in 2005 for development of an IWMP for this watershed, which had recently been the recipient of a total maximum daily load (TMDL) for nutrients and siltation. PWD continues to convene the Wissahickon Watershed Partnership Steering Committee and Public Education and Outreach Committee. PWD has supported a number of watershed-wide data gathering and on-the-ground demonstration projects in this watershed. PWD will be putting together an implementation commitment to address the requirements of the siltation TMDL; over the coming months PWD will be finalizing their implementation commitments to this watershed
Poquessing Creek Watershed Partnership	2006	PWD initiated this stakeholder partnership in 2006 in support of the RCP planning process. That plan was completed and posted in 2008. PWD will be reconvening this stakeholder partnership in 2009 for the development of an IWMP.
Delaware Direct Stakeholder Partnership	2007	PWD initiated this stakeholder partnership in 2007 to support development of a RCP for the Delaware Direct drainage area of the City of Philadelphia. In 2009, PWD has requested that this stakeholder group remain on board to drive the development of an IWMP commitment for this watershed.
Schuylkill Action Network	2003	PWD has worked with the US EPA and PADEP as well as the Partnership for the Delaware Estuary to support large-scale stakeholder initiatives.

Table 1-4 Monitoring and Comprehensive Characterization Report Status for the City's Watersheds

Watershed	Preliminary Reconnaissance	Detailed Monitoring Program	CCR Production
Delaware River (tidal, non-tidal)	N/A*	N/A*	N/A*
Cobbs Creek	2000/2001	2003	2004
Tacony-Frankford Creek	2000/2001	2004	2005
Pennypack Creek	2002	2007-2008	2009
Schuylkill River (tidal, non-tidal)	N/A*	N/A*	N/A*
Poquessing Creek	2001	2008-2009	2010
Wissahickon Creek	2001	2005-2006	2006

* A CCR will not be produced for the Delaware and Schuylkill Rivers; monitoring and data collection are ongoing in both rivers.

1.2.3.4 Fluvial Geomorphologic Assessment (FGM) and Streamside Infrastructure Inventory

FGM

PWD has committed to completing a fluvial geomorphologic assessment for the five smaller planning watersheds that drain to the City of Philadelphia, including the Cobbs, TTF, Wissahickon, Pennypack and Poquessing. Due to the size of the Schuylkill and Delaware River Watersheds, FGM assessments will not be completed on them.

The purpose of conducting the fluvial geomorphologic assessment is to document existing conditions within the waterway using Rosgen methodologies to measure channel geometry and stability parameters to determine stream classification. Additionally, a comprehensive habitat survey is completed for each watershed. Together, the measured geomorphologic channel survey and the habitat survey provide the implementers of the IWMP with a baseline for evaluating effects of urbanization, a land use and/or planning tool, a rating method specific to the watershed, potential stream and habitat restoration sites, and appropriate potential restoration strategies. This tool has the potential to help outline high priority segments of the waterway for restoration.

Streamside Infrastructure Mapping

PWD has additionally committed to a streamside infrastructure inventory/mapping initiative that compliments the FGM assessment. This is a watershed-wide infrastructure process that includes field survey of the entire waterway from the headwater tributaries outside the City of Philadelphia through the mainstem and tributaries in the City to the confluence with the Delaware River. Data collected as a part of this inventory process includes points such as stormwater and sanitary sewers, manholes, dams, outfalls, pipes of any kind, culverts, abutments and constrictions. Data is collected using global positioning system (GPS) coordinates and plotted into various data layers.

This assessment process has helped to identify high priority restoration projects including sites where erosion has exposed infrastructure, making it vulnerable to large debris coming downstream during storm events.

All data collected outside the City of Philadelphia has been shared with the City's partner municipalities.

1.2.3.5 Wetlands Assessments

PWD has completed development of wetland assessments for the Cobbs, TTF, Pennypack and Poquessing Creek Watersheds. The purpose of the assessment is to evaluate existing wetlands, evaluate select stormwater outfalls, and identify potential wetland creation sites throughout these watersheds.

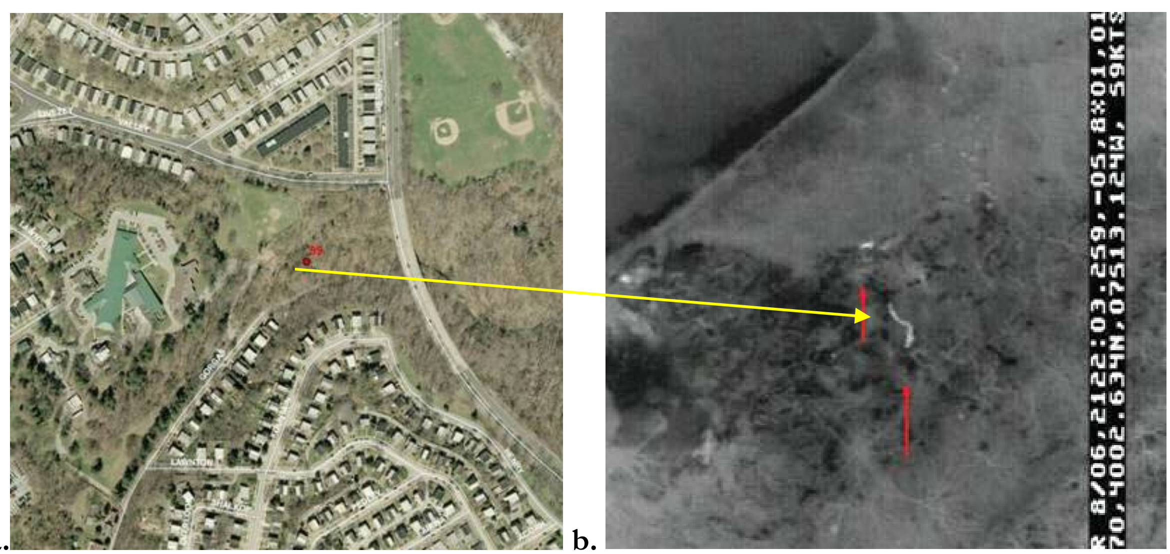
For the TTF Watershed, the assessment included the entire watershed drainage in Montgomery and Philadelphia Counties. In total, 79 sites were investigated for either the presence of wetlands or the potential for wetland creation. All sites investigated were located along one of the major waterways in TTF Watershed including tributaries. The assessment was conducted from 2001-2003 with the final report completed in 2006.

For the Cobbs Creek Watershed, the assessment included the entire watershed drainage in Delaware, Montgomery, and Philadelphia Counties. In total, 89 observation sites were investigated for either the presence of wetlands or the potential for wetland creation. All of the wetlands were located along one of the major waterways in Cobbs Creek Watershed or a tributary. Within the city limits, 11 sites were associated with wetlands. The assessment was conducted from 2001-2003 with the final report completed in 2006.

Completed wetland assessments are available online at http://http://www.phillyriverinfo.org.

1.2.3.6 Aerial Infrared Thermography

The purpose of this technology is to identify thermal anomalies potentially indicative of liquid contamination of the surface water. This technology utilizes aerial flyovers to pinpoint potential environmental problems such as discharges from stormwater outfalls, illicit connections to stormwater drainage systems, sanitary collection system failures/seepages, illegal dumping to streams/rivers, and other potential anomalies that may be contributing to the pollution of waterways. The resulting data set is compared with the infrastructure data in order to analyze the potential sources of thermal change in the waterway (Figures 1-2 and 1-3).

a.


b.

Figures 1-2(a) Aerial Photo and (b) Aerial Infrared Thermography Photo of Point 99

Figure 1-3 Point 99 – View from the Ground; Gorgas Run (Near the Intersection of Valley and Henry Ave)

PWD embarked on a demonstration initiative to pilot this technology in several of the City's waterways to assess its effectiveness in identifying "hot spots" for illicit cross connections and compromised infrastructure. The City initiated flyovers of the Wissahickon, Cobbs and TTF waterways in winter, 2006. Flyovers were conducted watershed-wide from headwaters outside the City of Philadelphia through the confluence with the Schuylkill/Delaware. Table 1-5 shows the extent of the findings of this initial demonstration initiative.

Table 1-5 Areas Surveyed with Aerial Infrared Thermography

Watershed	Area Surveyed
Tacony-Frankford Creek Watershed	Stream miles - 31 miles total (6 miles inside Philadelphia and 25 miles located outside of Philadelphia)
Wissahickon Creek Watershed	Stream miles - 125 miles total (21 miles inside Philadelphia and 103 miles located outside of Philadelphia)
Cobbs Creek Watershed	Stream miles - 17 miles total (10 miles inside Philadelphia and 7 miles located outside of Philadelphia)

As a result of the assessment, PWD tracked and inspected 43 anomalies that are within or in close proximity to City limits. Of these anomalies, only three were confirmed sewage leaks, others were determined to be encapsulated streams or spring fed. Analyzed data was packaged and shared with each of the municipalities outside the City of Philadelphia through the Watershed Partnerships.

Due to the low cost and high quality of data produced through this initial demonstration program, PWD has committed to replicating this program again in 2010. In 2010, the Cobbs, TTF and Wissahickon will be re-flown for a second round of data collection and the Pennypack and Poquessing Creek Watersheds will be assessed for the first time.

1.2.4 Stormwater Management Requirements and Incentives

1.2.4.1Stormwater Regulation Changes

The adoption of city-wide stormwater regulations as of January 1, 2006 enabled the City of Philadelphia to review plans for both new and redevelopment sites ensuring that water quality and quantity are part of the management plan. The regulations focus on the Post-Construction Stormwater Management Plan (PCSMP), which addresses more than the typical peak rate controls previously required. Through these regulations, stormwater management addresses smaller more frequent storms in terms of water quality volume and channel protection for all development projects throughout the City. Philadelphia's stormwater regulations are available online at http://www.PhillyRiverInfo.org.

The stormwater regulations have been enacted to address the following technical components:

> *Water Quality*: The first inch of precipitation over directly connected impervious cover must be recharged. Where recharge is not feasible or limited, then any remaining volume is subject to an acceptable water quality practice.
>
> *Channel Protection*: The 1-year, 24-hour storm must be detained and slowly released over a minimum of 24-hours and maximum of 72-hours.
>
> *Flood Control*: Watersheds that have been part of an Act 167 planning effort are to follow the model results for flood management districts.
>
> *Non-Structural Site Design*: Projects are required to maximize the site potential for stormwater management through appropriate placement and integration of stormwater management practices.

Implementation of the stormwater regulations will continue to improve stormwater quality and quantity impacts as redevelopment and development continues across the City. PWD is tracking the stormwater management practices implemented by private development to address the regulations. Of particular interest are green approaches that encourage the return of rainfall back to the hydrologic cycle through evapotranspiration or distributed infiltration.

The impact of the regulations in terms of total acres developed, area removed from contributing to the sewer system, volume of water quality managed, volume of stormwater infiltrated, increase in number of green infrastructure projects (*i.e.*, structural basins, green roofs, porous paving, and rain gardens) will be calculated and tracked.

1.2.4.2 Commitment to Act 167 Stormwater Management Planning

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 PADEP, municipalities and counties, and provides for enforcement and appropriations. The Act requires the PADEP 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.

Each county must, in consultation with its municipalities, prepare and adopt a stormwater management plan for each of its designated watersheds. 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 City of Philadelphia has taken the lead in the development of Act 167 Stormwater Management Plans for each of the watersheds that drain to the City, through the provision of staff resources and funding to ensure the creation of regional, watershed-based plans including:

- Cobbs Creek
- Darby Creek
- Delaware River
- Pennypack Creek
- Poquessing Creek
- Schuylkill River
- Tacony/Frankford Creek
- Wissahickon Creek

To that end, the City of Philadelphia supported the Delaware County Planning Department for the development of the Darby-Cobbs Act 167 Stormwater Management Plan – completed in 2004. The City of Philadelphia led the Act 167 Stormwater Management Planning Process for the Tookany/Tacony-Frankford Watershed – plan completed in 2008. Additionally, the City of Philadelphia signed a Phase 1 Agreement with the PADEP in July, 2008 committing to the completion of a city-wide Act 167 planning process. This city-wide Act 167 Plan will be largely based on the City of Philadelphia Stormwater Regulations. PWD is considering modifications to the current regulations, including to lower the threshold of disturbance that triggers the regulations for compliance with the regulations from the current level of 15,000 ft^2 to a level of disturbance of 5,000 ft^2. The city-wide plan will lay the groundwork for additional watershed-basin specific planning to be initiated including Pennypack Creek Watershed (initiated in fall 2008), the Poquessing Creek Watershed (to be initiated in fall 2009) and the Wissahickon Creek Watershed (to be initiated in fall 2010).

1.2.4.3 Storm Flood Relief Program

PWD has initiated a large-scale project to analyze and reduce property damage from flooding and basement backups including work on multiple fronts to both understand the causes of flooding as well as to start implementation of items that would be helpful to flood prone properties.

PWD has investigated, evaluated, analyzed, and looked for solutions to these problems. As part of this effort PWD has begun and will continue to:

- Inspect sewers in flood prone areas to determine if there are any obstructions and schedule appropriate maintenance where problems are found or schedule capital projects if structural problems are observed
- Collect and update data from property owners impacted by flooding
- Analyze the sewer system by hydraulically modeling the system to determine how the sewer system responds to storm events
- Coordinate with other government entities and enhance the legal framework for managing stormwater
- Provide possible remedies/solutions based upon the modeling information, which in turn is based on all of the data collected

Basement flooding has been brought to the highest priority for PWD. This is a complex problem without a quick fix, and will require a considerable amount of time and resources to analyze the problem, determine possible alternatives, and finally implement chosen solutions. PWD is committed to analyzing the problem, and searching for and implementing solutions. Information regarding flooding is critical to understanding the problem and finding the appropriate solution. A system has been developed to collect information from residents experiencing flooding; this information is used to better understand the sewer system and how it responds to wet weather events. Flood prone areas will be modeled, analyzed, and flood management solutions/alternatives will be identified.

1.2.4.4 Parcel-Based Billing – Rate Reallocation

Traditionally, PWD has recovered the costs for the operation and maintenance of its stormwater system components (pipes, storm drains, pump stations, treatment facilities, and billing) through a service charge related to the customers' water meter size. This method was considered a reasonable means to approximate the contribution of a property to stormwater runoff.

However, as the City's stormwater management costs have increased, it has become more important to recover the costs of management on a basis that is the most fair and reasonable to all properties that benefit from the sewer systems. In the 1990s, PWD convened a Citizens Advisory Group (CAC) to make a recommendation to the City about more equitable stormwater charges. After a two year deliberation, the CAC came to a consensus and recommended that PWD transition from a water meter-based stormwater management charge to one that was property based. At the time, PWD was unable to implement this recommendation due to technology limitations. That has since changed. Today, PWD has the information necessary to develop a more equitable program consistent with the principles recommended by the CAC, including GIS, detailed aerial photography, database coordinates, etc.

Based on recommendation of the 1996 Stormwater Citizens Advisory Council, the City has developed a stormwater charge with a formula based upon the gross size of a customer's property and the imperviousness of the property, as these two factors are most important in determining the stormwater runoff contribution of individual properties. Because the impervious factor is the most dominant factor in calculating stormwater runoff, the CAC recommended that 80% of the stormwater costs should be charged and recovered based on a property's impervious area and 20% of the stormwater costs should be based on the property's gross area.

The CAC also recognized that providing a detailed analysis of each of the City's 450,000 residential properties would be expensive and not provide a significant improvement in the fairness of property based charges. They recommended that the City's residential properties be treated as a single parcel with total gross area and impervious area factors. The total costs would be divided among all residences. This recommendation was implemented in the FY 2002 tariff and resulted in a decrease in stormwater costs to residences and other smaller meter customers.

However, at the time when the FY 2002 rates were being developed, the City did not have accurate or adequate parcel information to transition from a meter based charge to a property based stormwater charge among its larger customers. Accordingly, the meter based charge was maintained to distribute the stormwater-related costs among larger customers. In early 2006, PWD began the process of validating the City's parcel data information with the Board of Revision of Taxes database and orthographic (impervious) information. This information was available from the 2004 contracted flyover of the City. PWD staff can now analyze the approximately 40,000 non-residential accounts to determine, on an individual customer basis, the stormwater runoff contribution of each large customer parcel, in order to apply the 80/20 impervious/gross area formula. This work has been completed and is available for the next rate new tariff and planned for a multi-year period beginning in FY 2010.

PWD has proposed to transition stormwater charges among its large meter, non-residential customer base over a four year period beginning in FY 2010. This transition will result in more equitable stormwater charges that closely match the cost of managing stormwater runoff from each property. Current calculations show that the majority of large meter customers will see a reduction or otherwise minor impact on the stormwater component of their water and sewer bills. For those customers that will see noticeable increases in their stormwater fees, the department will identify opportunities on their property to decrease the amount of their impervious area and thus decrease their stormwater fees.

PWD has also evaluated properties that do not presently have a water/sewer account. These parcels also generate stormwater runoff that is managed by the City and therefore should be reasonably charged for such service. These current non-customers include parking lots, utility rights-of-way and vacant land. Current large meter customers have recognized this discrepancy, and in prior rate hearings have demanded that we charge parcels, such as parking lots, to share the cost burden of stormwater management. PWD applied the same 80/20 impervious/gross area formula to these properties to identify appropriate charges. Once the identification and corresponding stormwater calculations for these parcels are complete, stormwater costs can be spread out and shared over a larger customer base, resulting in a decrease for all current customers.

The CAC also encouraged the City to provide a means for customers to ease the burden of property based stormwater charges. Customers who have the ability to decrease the amount of directly connected impervious area (hard surfaces that direct runoff to the City's sewer system) on their property may do so using any number of stormwater management practices (rain gardens, infiltration islands, porous asphalt and sidewalks, vegetated swales, green roofs). Once a property has been retrofitted with any of these features, PWD would reevaluate its stormwater fees based on the 80/20 impervious/gross area formula.

A property based stormwater management charge will result in a fair "cost of service" that provides incentives for non-residential and stormwater only customers to incorporate green building practices, where practicable, into their sites. In addition, all customers will be more aware of the impact they have and the importance of urban stormwater management practices.

1.2.5 Commitment to Demonstration Projects

PWD's implementation commitment for each watershed with a completed IWMP includes a substantial commitment to demonstration projects in the first five years of the implementation planning cycle. These demonstration projects include both land based programs such as low impact development (LID) and stormwater BMPs as well as water based or in-stream work – aimed at restoring the habitat through NSCD principles.

LID/BMP Demonstration Projects

PWD has made a significant commitment to implementing land based demonstration projects within the City's urban drainage systems. This has been critical to PWD's understanding of the function and effectiveness of these practices under the specific conditions found within the City of Philadelphia. Table 1-6 lists the completed demonstrations projects led or substantially supported by PWD, implemented within the City of Philadelphia. Table 1-7 lists additional demonstration projects that PWD has planned and will be constructed in 2010.

Table 1-6 Completed-Land Based Demonstration Projects Led by PWD

Project Name	BMPs	Watershed
Columbus Square Streetscape	sidewalk planter	Delaware Direct
Liberty Lands	rain garden, cistern	Delaware Direct
Police Forensic Science Center Parking Lot	curbs cuts, vegetated swales	Delaware Direct
Models for Stormwater Management on Reclaimed Vacant Land (North Philadelphia) - PHS	retentive grading; vacant lot restoration	Delaware Direct
Herron Playground	basketball court subsurface infiltration	Delaware Direct
East Falls Parking Lot	bioinfiltration system	Schuylkill
School of the Future - Green Roof (PSD)	green roof, new construction	Schuylkill
School of the Future - Cistern/Reuse (PSD)	stormwater harvesting/reuse	Schuylkill
Wissahickon Charter School (WCS) Harmony Garden	rain gardens, porous pavers, subsurface infiltration	Schuylkill
47th & Grays Ferry - Street Runoff Rain Garden	rain garden; street runoff	Schuylkill - Tidal
Greenfield School	rain gardens, porous pavers, porous safety surface	Schuylkill - Tidal
Clark Park Basketball Court	subsurface infiltration; off-site runoff	Schuylkill - Tidal (Mill Creek)
Mill Creek Porous Basketball Courts	porous asphalt	Schuylkill - Tidal (Mill Creek)
Mill Creek Urban Farm	street inlet disconnection, vegetated swale, retentive grading, green roof, cistern	Schuylkill - Tidal (Mill Creek)
Mill Creek HOPE 6	subsurface pipe detention with slow release/infiltration	Schuylkill - Tidal (Mill Creek)
North 50th Street Projects	retentive grading; vacant lot restoration; rain barrels; street trees	Schuylkill - Tidal (Mill Creek)
West Mill Creek - Ogden/Ramsey Tree Trench	tree trench; porous pavers; modified street inlets to subsurface infiltration	Schuylkill - Tidal (Mill Creek)
Penn Alexander School	subsurface infiltration, pervious asphalt, rain garden	Schuylkill (Mill Creek)
Sulzberger Middle School Outdoor Classroom	disconnected rain leader, vegetated swale, rain barrel/cistern	Schuylkill (Mill Creek)
Awbury Arboretum	street run-off diversion, bioswale	Tacony-Frankford
Bureau of Laboratory Services: Turf to Meadow Conversion	native meadow; turf replacement	Tacony-Frankford
Cliveden Park Stormwater Project	vegetated extended detention basin; off-site runoff	Tacony-Frankford
Waterview Recreation Center	tree trench, street runoff diversion, disconnected rain leader, rain barrel cistern	Tacony-Frankford
Monastery Stables	basin modification, bioswales	Wissahickon
Saylor Grove Stormwater Treatment Wetland	stormwater wetland	Wissahickon
Springside School	disconnected rain leader, rain garden, planter box	Wissahickon
Allens Lane Art Center	Porous basketball court	Wissahickon

Table 1-7 Land-Based Demonstration Projects (Planned for Construction in 2010)

Project Name	BMPs	Watershed
Cobbs Creek Park / Blue Bell Tavern Rain Garden	trench drain, street inlet disconnection, vegetated swale	Cobbs
Bureau of Laboratory Services Green Streets	stormwater tree trenches, planters	Tacony-Frankford
Wakefield Park Street Runoff Diversion	trench drain, street inlet disconnection, vegetated swale, rain gardens	Tacony-Frankford
Harpers Hollow Street Runoff Diversion	trench drain, street inlet disconnection, vegetated swale, rain gardens	Tacony-Frankford
Kemple Park Street Runoff Diversion	trench drain, street inlet disconnection, vegetated swale, rain gardens	Tacony-Frankford
Belfield Green Street (Wister Woods)	trench drain, street inlet disconnection, vegetated swale, rain gardens	Tacony-Frankford
Awbury-Cliveden Model Neighborhood Green Streets	stormwater tree trenches, vegetated curb extensions	Tacony-Frankford
Queen Lane Green Street	vegetated curb extensions	Schuylkill
Belmont Treatment Plant Green Street	vegetated curb extensions, vegetated swale	Schuylkill
Barry Playground Green Streets	stormwater tree trench	Schuylkill - Tidal
Passyunk Avenue Rain Gardens	trench drain, street inlet disconnection, rain gardens	Schuylkill - Tidal
Cherry Street Connector	stormwater tree trench, rain garden vegetated swale, subsurface infiltration	Schuylkill - Tidal
Benjamin Franklin Parkway Green Street	street inlet disconnection, subsurface infiltration	Schuylkill - Tidal
Clemente Playground Green Streets	stormwater tree trenches, vegetated swale	Schuylkill - Tidal
Passyunk Square/South Philadelphia Model Neighborhood Green Streets	stormwater tree trenches, vegetated curb extensions	Schuylkill - Tidal
Lancaster Avenue Green Street	stormwater tree trenches, vegetated swale	Schuylkill - Tidal (Mill Creek)
Clark Park Green Streets	trench drains, vegetated swales, disconnected inlets, subsurface infiltration	Schuylkill - Tidal (Mill Creek)
39th & Olive Playground	stormwater tree trenches, porous surfaces, rain garden	Schuylkill - Tidal (Mill Creek)
Dickinson Square Green Street	stormwater tree trenches, planters	Delaware Direct
Columbus Square Rain Garden	rain garden, disconnected inlet	Delaware Direct
Columbia & Thompson Green Street Intersection	vegetated curb extensions	Delaware Direct
Big Green Block Green Streets	stormwater tree trenches	Delaware Direct
Bodine High School Green Streets	stormwater tree trenches	Delaware Direct
Hartranft School Green Streets	stormwater tree trenches	Delaware Direct
Welsh School Green Streets	stormwater tree trenches	Delaware Direct
Northern Liberties Model Neighborhood Green Streets	stormwater tree trenches, vegetated curb extensions	Delaware Direct

Rain Barrel Program:
Rain barrels are storage containers that collect rain water from downspouts. Downspouts lead the rain water from the roof to the ground or storm sewer. Rain barrels usually consist of a plastic storage container with lid, a system that diverts water into the barrel, an overflow that diverts water away from the house, a screen to keep out debris, and a water spigot to which a hose can attach. The rain barrel is connected to the downspout system, in order to capture and store some of the rain water. Figure 1-4 includes the images used to explain rain barrel installaion.

PWD has piloted a city-wide rain barrel giveaway program to provide rain barrels to residents free of charge after taking workshop, in order to promote the reduction of stormwater flows to our sewer system and creeks. The PWD Rain Barrel pilot project was initiated in 2002 in the TTF Watershed where PWD was able to give away 215 rain barrels to watershed residents. This program has now been expanded city-wide as of 2006, and to date, over 1,200 rain barrels have been given to residents.

Steps 1.  2.  3.  4. 

Figure 1-4 The Four Steps for Installation of a Rain Barrel as Presented at PWD Workshops

In order to receive their free rain barrel, Philadelphia residents must attend a training workshop to learn about the benefits of rain barrels as well as how to install and use them on their own properties.

For additional information, PWD has a website for this rain barrel program; it can be accessed at http://www.phillywatersheds.org/rainbarrel.

Stream Restoration
Through PWD's IWMP implementation commitments, the City has committed to the use of NSCD principles for the restoration of the mainstem (and tributaries where possible) of the Cobbs and TTF waterways.

PWD implemented their first stream restoration demonstration project on the Cobbs Creek at Marshall Road. This project involved the restoration of 900 linear feet of stream with the installation of j-hook vanes and rock vanes, constructed riffles, boulder bank stabilization, abutment removal and sewer protection. The restoration project at Marshall Road was a priority for PWD because the erosive flows within the creek had exposed the Cobbs Creek interceptor sewer, making it vulnerable to large debris that might be swept downstream with large storm events. This project was constructed in 2004. Figures 1-5, 1-6, and 1-7 show the Cobbs Creek before, during and after the Marshal Road restoration project.

Figure 1-5 Marshall Road Pre-Restoration (Note Exposed Interceptor)

Figure 1-6 Marshall Road Under Construction – 2004

Figure 1-7 Marshall Road Post-Construction – 2006

Watershed Mitigation Registry

Since 1997, the City of Philadelphia has invested millions of dollars in creating watershed management plans to advance the restoration of riparian environmental resources. This planning work identifies numerous stream and wetland enhancement opportunities, which are being compiled into a Watershed Mitigation Registry. Projects in the registry offer the potential to mitigate for wetlands and open water impacts that result from development and redevelopment.

Philadelphia's Watershed Mitigation Registry takes a watershed approach to aquatic resource protection by acknowledging the complex ecological relationships of the entire riparian corridor. This approach is consistent with federal guidelines for wetlands mitigation. Implementation of projects organized within a comprehensive watershed management framework would help achieve greater environmental benefit at reduced cost by addressing environmental, regulatory, and local community concerns in an integrated fashion.

The project registry is designed to function in a similar manner to wetland mitigation banks, with two important differences. Unlike mitigation banks that consist of completed wetland projects ready for purchase, the mitigation registry presents conceptual plans for projects ready to be designed and constructed. These plans encompass a range of riparian corridor improvements, including new and restored aquatic habitats, streambanks, wetlands, and flood and stormwater management. Although much research has been conducted to characterize the relative effectiveness of different wetlands in performing a range of environmental functions, no single method provides a technique for assessing the effectiveness of integrated riparian corridor improvements in mitigating impacts to wetlands from development and redevelopment projects.

Presently, the registry includes over 200 targeted stream and wetland improvement locations in the Philadelphia area. These targeted areas include potential stream restoration, stream daylighting, wetland enhancement/creation, and fish passage projects.

1.2.5.1 Establishment of the Waterways Restoration Team (WRT)

In 2003 PWD created the WRT, which consists of crews devoted to removing trash and large debris (*e.g.*, cars, shopping carts and appliances) from the streams and tributaries within the City. The team also performs restoration work around PWD's storm and combined sewer outfalls, eliminating plunge pools and streambanks eroded around outfall headwalls. The team works in partnership with Fairmount Park staff and the various "Friends of the Parks" groups to maximize resources and the positive impacts to our communities. The team performs stream clean up work in the City's streams – Cobbs, Wissahickon, Tacony, Pennypack, and Poquessing Creeks, and their tributaries, in addition to the Manayunk Canal. Table 1-8 lists a number of completed restoration and stabilization projects implemented by the WRT since their inception in 2003.

1.2.6 Additional Programs in Support of PWD's Watershed Planning Initiatives

PWD has developed a number of web-based tools and applications for the sharing of information about the City's watersheds, related programs, public events and ways to get involved with supporting the watershed approach. PWD has also created a number of web-based tools for tracking of water quality events and providing public notification of events when necessary.

Table 1-8 WRT Restoration Projects Completed or Planned as of April 2009

Project	Watershed	Constructed by WRT	Description
Pennypack Rock Ramp	Pennypack Creek	Yes	Improvement of fish passage
Indian Creek	Cobbs Creek	Yes	Interim stabilization implemented; future large-scale restoration project to be completed by a contractor
Wises Mill Run	Wissahickon Creek	Yes	Lower segment; interim stabilization
Gorgas Run	Wissahickon Creek	Yes	Interim stabilization; infrastructure protection with boulders
Crescentville Outfall	TTF Creek	Yes	Plunge pool removal and culvert restoration with boulders
Maxwell Place Outfall	Pennypack Creek	Yes	Plunge pool removal
Adams Ave Fish Ramp	TTF Creek	Yes	Improvement of fish passage
Awbury Stream Daylighting	TTF Creek	Yes	Phase I implementation; included development of a bioswale and daylighting of a spring/stream on Arboretum property
Bingham Street Sewer Crossing	TTF Creek	Yes	Plunge pool removal
Cobbs Creek 61st Street Repair	Cobbs Creek	Yes	Emergency streambank restoration after a sewer line rupture
Marshall Road Restoration Work	Cobbs Creek	Supported	Stream restoration where erosion had exposed a combined sewer interceptor
Rex Avenue Restoration	Wissahickon	Yes	Stabilization and habitat creation along the west bank of the Wissahickon Creek mainstem.
Carpenters Woods Outfalls	Wissahickon	Yes	Stabilization of stormwater outfalls including stream restoration using NSCD principles.

1.2.6.1 Watershed Information Center

The 1997 LTCP committed to the development of a watershed technology center that would utilize and extend the modeling, GIS and technology resources developed by PWD throughout its CSO planning effort. The watershed technology center was intended as a resource to facilitate the development and dissemination of information to others involved in watershed planning in the Philadelphia area watersheds. PWD has undertaken the development of this commitment, calling it the Watershed Information Center and has continued to evolve this system from a web resource intended to centrally locate technical, management, and administrative tools and capabilities to support those involved in watershed planning (Figure 1-8).

The goal of information center is to create a single, central location for the collection and dissemination of southeastern Pennsylvania watershed-related information. All plans, reports, meeting announcements, presentations, minutes produced by PWD and their watershed partnerships are posted on this site for public dissemination. The Watershed Information Center website can be accessed at http://www.phillyriverinfo.org.

The information center is continually evolving. A new website will be launched in the fall of 2009 at http://www.phillywatersheds.org, although the old URL will remain active. PWD also envisions a virtual technology center at the Fairmount Water Works Interpretive Center that will enable the department to share documentaries and presentations in each of the key components of our IWMPs.

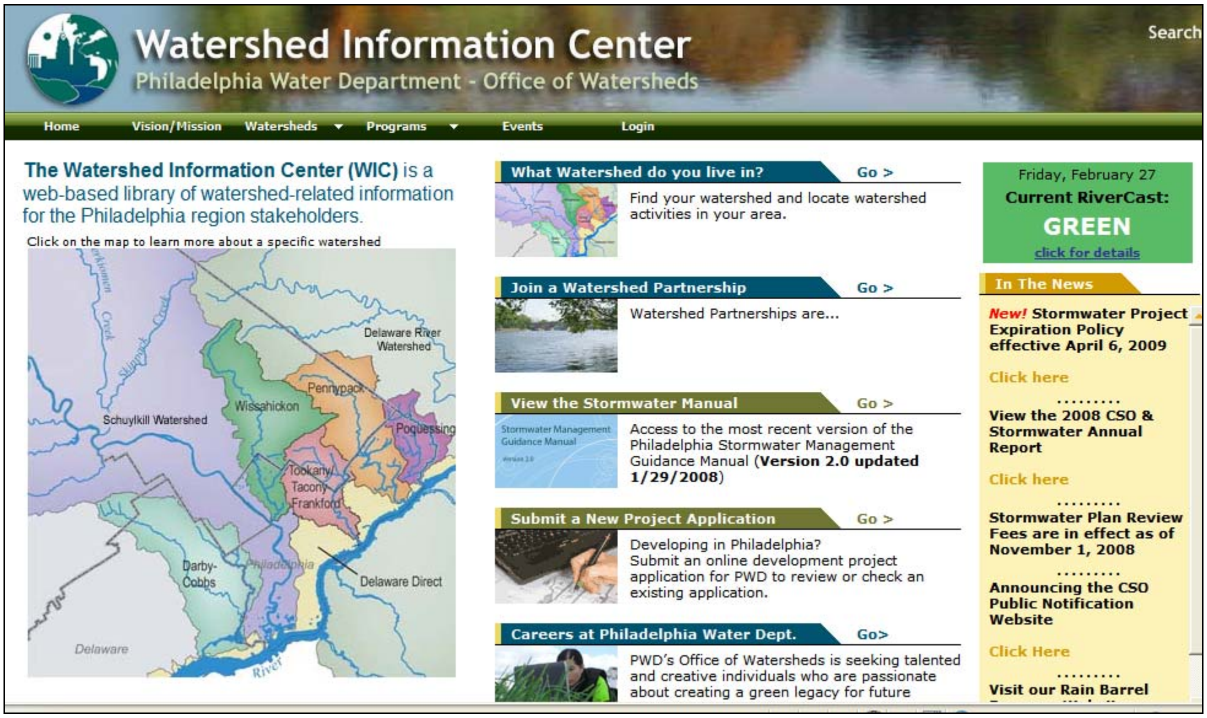


Figure 1-8 PWD's Watershed Information Center Website

1.2.6.2 The History of Philadelphia's Watersheds and Sewers

PWD has hired a historical research consultant to compile information on each of the City's watersheds, including the history of the sewer system – which often replaced many of the historic tributary streams to the larger stream systems. This fascinating information is presented to watershed partnerships as well as stakeholder public meetings, and often helps to present stakeholders with a more comprehensive understanding of the function of the complex system of pipes and sewers beneath the City. Figure 1-9 shows the homepage of the information available on PhillyH2O. com.

Historical presentations, articles, photos and additional content have been posted on the web and can be accessed at http://www.phillyh2o.org.

1.2.6.3 Establishment of Public Notification Systems

Early notification of changes in river water quality is important to public water suppliers with drinking water intakes on both the Schuylkill and Delaware Rivers, as well as to the public using the rivers for recreation. Several systems have been developed.

Delaware Valley Early Warning System (EWS)

The Delaware Valley EWS is an integrated monitoring, notification, and communication system designed to provide advance warning of surface water contamination events in the Schuylkill and lower Delaware River watersheds. The EWS was developed in 2002 with funding provided by the PADEP and the US EPA and was deployed as a fully functional system in 2004. PWD initiated the

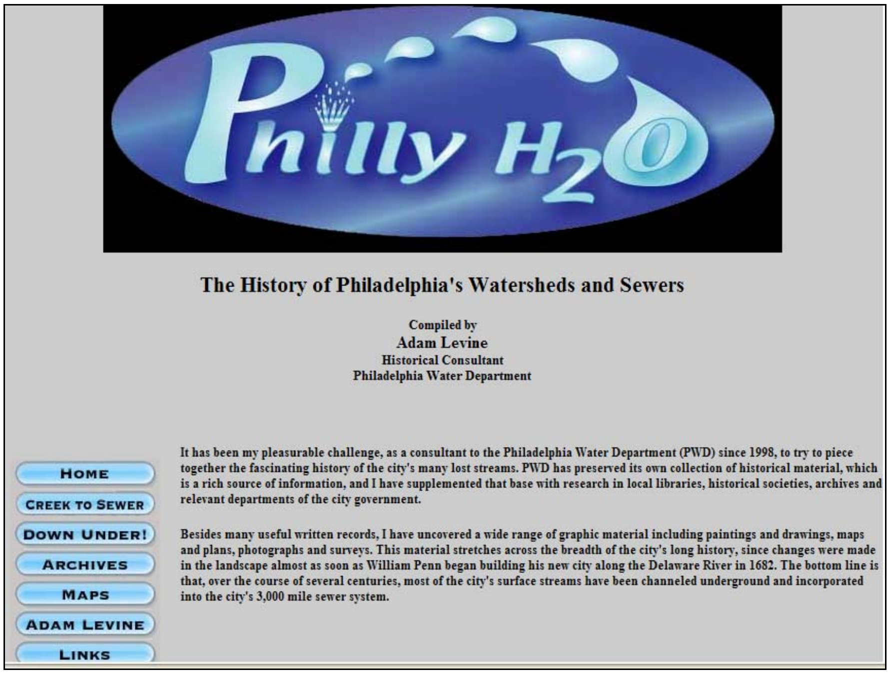


Figure 1-9 PhillyH2O Website Homepage

development of the EWS after identifying the need for such a system while collaborating with upstream treatment plant operators for the completion of the source water assessments for the Schuylkill and Lower Delaware Rivers between 1998 and 2000. The Delaware Valley EWS covers the entire length of the Schuylkill River as well as the Delaware River from Chester, PA (just downstream of Philadelphia) to the New York state boarder.

The EWS is comprised of four principal components:

1. EWS Partnership
2. Notification system
3. Monitoring network
4. Web-based database and portal

The EWS Partnership is comprised of stakeholders in the EWS and includes representatives from both public and private drinking water treatment plants in the coverage area, industries who withdraw water from the Schuylkill and Delaware rivers for daily operations, and representatives of government agencies from both PA and NJ. The notification system includes a spill model to track water quality changes and predict arrival times at intakes, and both automated telephone notification and web-based notification capabilities for intakes that are predicted to be affected by the water quality event. The monitoring network is comprised of on-line water quality and flow monitoring stations located at U.S. Geological Survey sites and water treatment plant intakes throughout both watersheds. The website and database portal are the backbone of the EWS and are fully integrated with the notification system and monitoring network.

The Delaware Valley EWS has become an international model for water quality early warning systems through its sophisticated integration of monitoring, notification, and website technologies, its usefulness for daily plant operations, and through the strength of its partner network.

RiverCast

The Schuylkill River, like all working rivers, is not a pristine body of water and is subject to contamination from many sources and activities that either discharge directly, or enter the river during rain events. Because rivers are vulnerable to such contamination, recreation in or upon any body of water has with it an inherent risk of illness and infection for the individual involved.

PWD developed a unique, web-based water quality forecasting system for the Schuylkill River called RiverCast. Based on real-time turbidity, flow, and rainfall data, it provides up-to-the-hour public service information on the estimated current fecal coliform concentrations in the river and the acceptable types of recreation based on those conditions. The system is designed to maximize accuracy while avoiding recommendations that suggest water quality is better than it is likely to be (avoidance of false positives). The Philly RiverCast operates for the stretch of the river between Flat Rock Dam and Fairmount Dam (Figure 1-10). The Philly RiverCast can be accessed at: http://www.phillyrivercast.org/

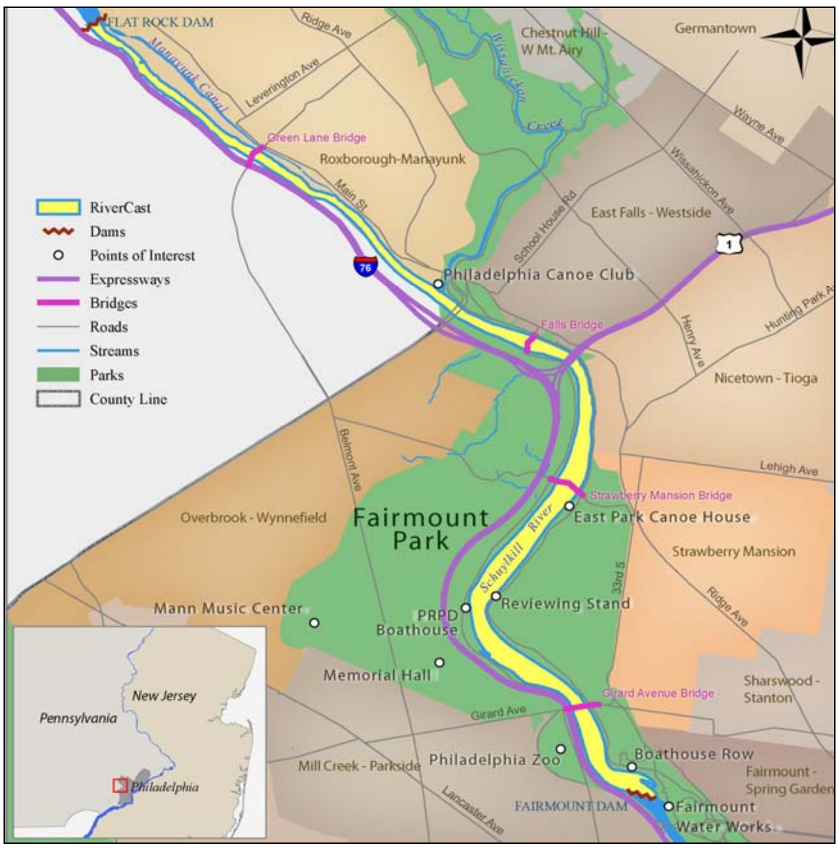


Figure 1-10 RiverCast Coverage Zone Map

CSOcast

In order to expand upon the public notification program established through the RiverCast, PWD has developed another internet-based notification system called CSOcast, which reports on the overflow status of combined sewer outfalls throughout the combined sewer system. The purpose of this notification system is to alert the public of possible CSOs from Philadelphia's combined sewer system outfalls. When a combined sewer outfall is overflowing, and up to a period of 24 hours following the rainfall event, it is unsafe to recreate in the water body due to possible pollutant contamination. The data on the website is updated daily.

PWD has maintained an extensive flow monitoring network since 1995. The level sensors record data throughout the combined sewer system. PWD currently operates and maintains monitoring equipment at, or near, the 164 CSOs throughout the City. This public notification system is based on PWD analysis of monitoring network data which is used to determine the likelihood of combined sewer overflows.

Flow monitoring data presented on this webpage is validated with the Philadelphia watershed and wastewater conveyance model. The model was developed through US EPA's Storm Water Management Model (SWMM). Real time rainfall data is taken from the PWD rain gage network and run through the SWMM model to estimate where and when overflows are occurring. Model output is then used to validate the monitoring data, ensuring a second level of accuracy. The data on this site is updated daily. If an outfall reports that no overflow is occurring, but it is still raining, there is the potential that an overflow is indeed occurring. It is always safest to avoid aquatic recreation during rainfall events.

When users visit the website, they will see a series of gray circular points as well as triangles on the map of Philadelphia. The gray circular points indicate an outfall location. The triangles indicate overflow status, where "green" indicates that no overflow has occurred in the past 24 hours, "yellow" indicates that an overflow has occurred in the past 24 hours, and "red" indicates that the outfall is currently overflowing (Figure 1-11). The CSOcast can be accessed at: http://www.phillywatersheds.org/csocast/

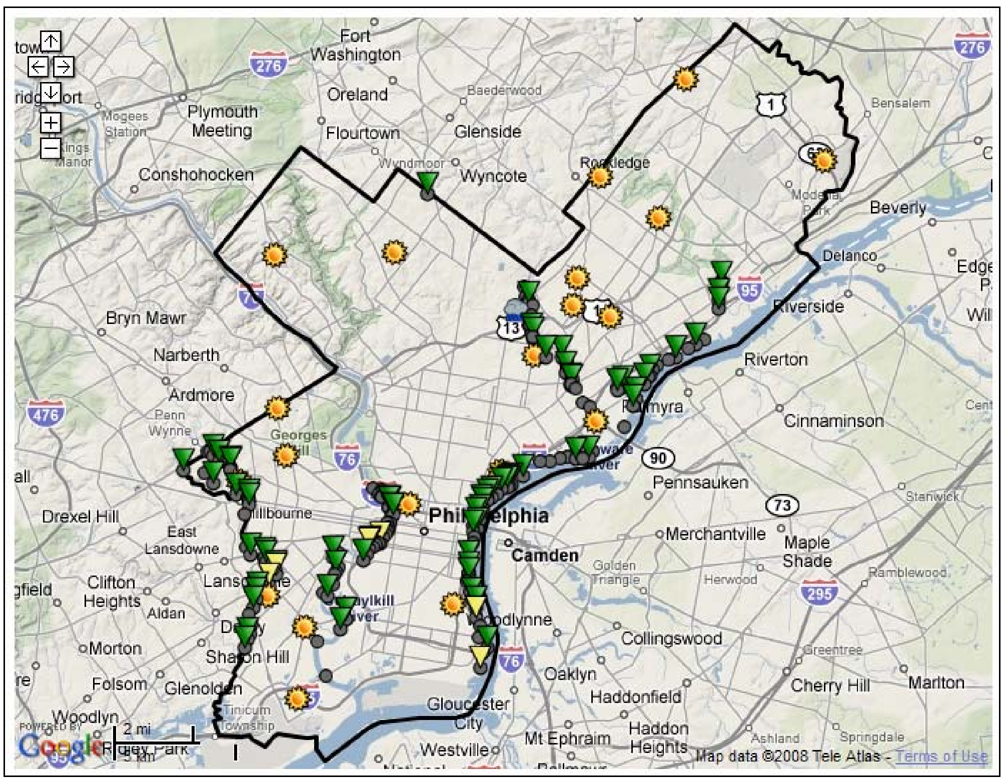


Figure 1-11 Image of CSOcast Website

1.3 PWD LTCPU

For the past decade, PWD has been creating, testing and implementing new integrated strategies which promote the economic and social growth of the City while meeting the environmental, ecological and business missions of the utility. In August 2008, PWD entered into a consent order and agreement with the PADEP, which reiterated the process for development of an update to PWD's LTCP commitments as originally included in PWD's NPDES permit. This LTCPU represents the plan as set forth by PWD to address their obligations under the CWA for the combined sewer system within the City of Philadelphia.

Our strategy is to implement the goals of our long-term planning initiatives with a focus on improving the water resources and revitalizing the City of Philadelphia. Commitments made in this plan will lay the foundation for a sustainable Philadelphia by greening our neighborhoods, restoring our waterfronts, improving our outdoor recreation spaces, and enhancing our quality of life.

2 PUBLIC PARTICIPATION

"I love the idea! Please give us a greener Philadelphia. It would make us healthier and happier all around."

- Response on the Philadelphia Water Department's "Green Neighborhoods through Green Streets Survey." The question asked, "*Are you in favor of greening?*"

2.1 INTRODUCTION

2.1.1 Overwhelming Public Support

The participants in the Philadelphia Water Department's (PWD's) *Green City, Clean Waters* public participation program overwhelmingly favor the sentiment expressed in the above quote – green stormwater infrastructure (such as street tree trenches, sidewalk planters and vegetated bump-outs) is more desirable over gray stormwater infrastructure (such as, sewer separation, tunnels, and dams) as the preferred approach to controlling Combined Sewer Overflows (CSOs) in Philadelphia. In fact, over ninety-two percent of the more than 730 survey respondents reacted positively to the green stormwater infrastructure approach. This desire for green stormwater infrastructure is echoed throughout all components of PWD's *Green City, Clean Waters* public participation program and confirms the wishes expressed over the past *ten years* by PWD's long-standing watershed partners during the watershed management planning process. The benefits associated with a more environmentally-sensitive approach to improving the health of the region and the City's waterways are almost universally understood. The citizens, partners and stakeholders that we have met and worked with believe that the benefits derived from a green approach contribute towards the creation of healthier watersheds, communities, and parks which transform into desirable places for individuals to live, work, and play.

Watershed partners value safe access to a clean stream where they can fish and relax. Likewise, City residents that participated in the *Green City, Clean Waters* programs, value a tree-lined street as it provides shade, cools the air and beautifies the block, making it more enjoyable to live on such a street. Ultimately, PWD's watershed stakeholders desire an approach to protecting and preserving the region and the City's waterways that can promote multiple community benefits, creating truly sustainable watersheds and cleaner waterways for the City of Philadelphia and its upstream neighbors.

2.1.2 The Demand

In recent months, the PWD has seen the desire for green stormwater infrastructure rapidly evolve into a *demand* by residents of CSO-impacted areas. Through PWD's Model Neighborhoods initiative, PWD has received approximately 750 signatures to date (from March – July 2009), from residents petitioning for Green Streets. These residents want PWD to install green stormwater infrastructure on their block, in order to serve as a model green neighborhood in the City. The demand for Green Streets is so high that has begun to exceed PWD's capacity to implement them. This initiative is a true testament to the overwhelmingly positive response the City is receiving from its citizens, regarding green stormwater infrastructure.

2.1.3 Partnerships, Plans and Participation

In addition to City residents, PWD understands that relationships with watershed stakeholders – upstream, as well as downstream - are critical to facilitating successful watershed management plans and the implementation of these plans. The City also recognizes that it is vital for its citizens to understand the benefits and costs associated with controlling Combined Sewer Overflows (CSOs) and the importance of active citizen participation in the decision-making process associated with the CSO Long Term Control Plan Update (LTCPU). As a result, PWD offers an extensive partnership program and public participation program, as detailed below.

2.1.4 Watershed Goals

Through the watershed management planning process, a critical component of active watershed partnership involvement with the City's upstream neighbors is *goal-setting*. During this phase of the watershed management planning process, watershed partners work closely with PWD on ranking their wishes for the watershed. In doing so, a final list of goals that reflects the multitude of stakeholder interests in the watershed is established.

Over the past ten years, the watershed-based goal-setting process initiated through IWMP development has taught PWD that our watershed stakeholders generally consider all watershed management goals of almost equal importance; there is no goal with a clear higher priority over others (Figure 2-1). The *Green City, Clean Waters* program aligns with this equal prioritization by addressing all aspects of watershed management instead of focusing solely on selected in-stream water quality parameters.

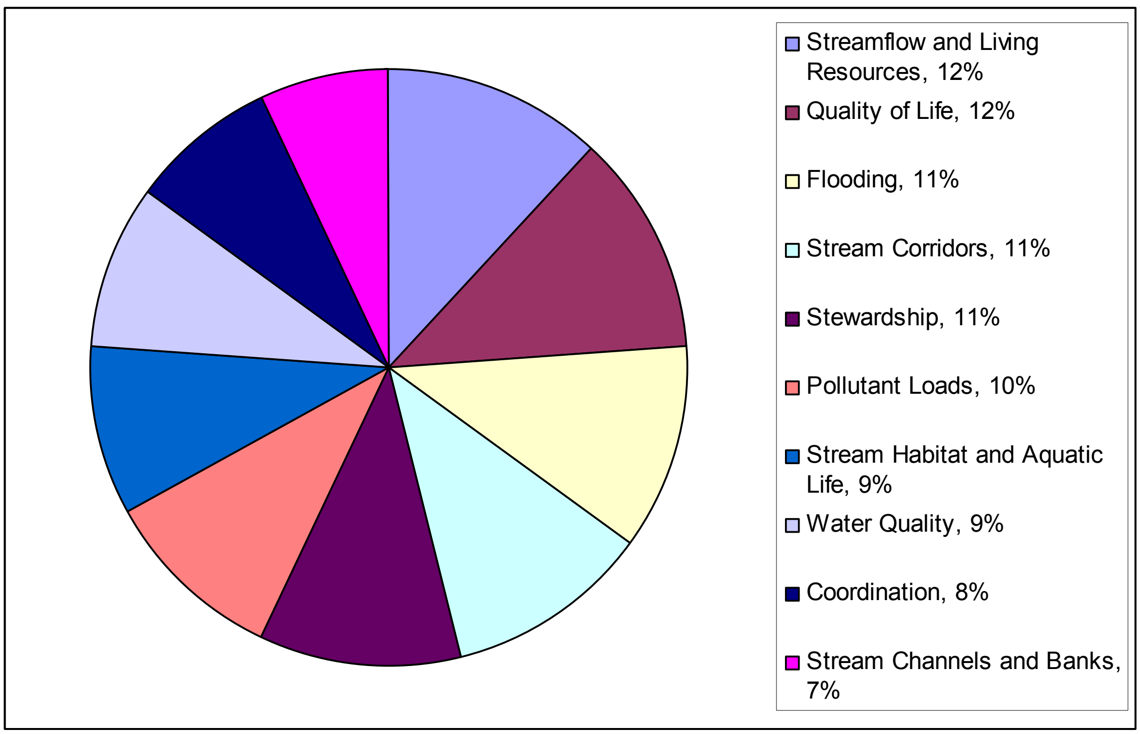


Figure 2-1: Distribution of weight percentages amongst watershed goals as prescribed by watershed partners Source: Data based on the goal-setting process for the development of the Cobbs Creek Integrated Watershed Management Plan, 2003

Eroded parks and streambanks, a lack of aquatic habitat, culverted and concreted stream sections, trash and odors in the parks and streams, a lack of safe recreation, concerns about security and a need for environmentally sound development – all of these are conditions the watershed partners want addressed under the prioritized goals. The wishes of the watershed partners are clear – they unanimously desire communities where opportunities exist for fishing, hiking and birding in a safe park, along a clean creek, surrounded by native wildflowers and other components of a healthy stream buffer, which can protect rich and diverse aquatic life in their streams. These are the goals the watershed partners believe will lead the watersheds to attain water quality and water quantity improvements, a healthier natural environment and a better quality of life for the people who live, work and play in the watersheds.

2.1.5 Education and Outreach

In recognizing that active citizen engagement in Philadelphia is critical to the success of the CSO LTCPU, PWD has also offered a variety of education and outreach programs over the past twenty years that target the residents of the City and foster public awareness and facilitate public involvement. Most recently, innovative CSO-related outreach programs are offered *in addition* to public meetings and have garnered much attention. Through the Model Neighborhoods program, fourteen communities are currently selecting the first four blocks in their respective neighborhoods that they want to green with green stormwater infrastructure in an effort to serve as the City's model green neighborhoods. The City has also hosted the first-of-its-kind *Green City, Clean Waters* Art Exhibit, featuring artwork by local artist, Bill Kelly, in addition to informational posters on the LTCPU and its green stormwater infrastructure alternatives. The Green Neighborhoods through Green Streets survey is circulating throughout the City and on on-line blogs, gauging attitudes and opinions on Green Streets, while educating survey-takers on the green stormwater infrastructure elements highlighted in the survey. Friends abound on PWD's *Green City, Clean Waters* Facebook wall, where approximately 200 members can find public meeting announcements, view images of Green Streets and provide feedback.

2.1.6 Diversified Partnership and Public Participation are Keys to Success

PWD believes that its commitment to its diverse watershed partners, including the residents of the City, is critical to the success of the LTCPU. Detailed components of the recent CSO LTCPU programs are listed below.

2.1.6.1 LTCPU Public Participation Program

A targeted LTCPU Public Participation Program was developed to foster public awareness on CSOs and to facilitate public involvement in the decision-making process associated with the LTCPU.

2.1.6.2 LTCPU Public Participation Program Team (Team)

A LTCPU Public Participation Program Team (Team), comprised of PWD staff and consultants, was assembled to develop and produce communication strategies, materials, and events, aimed at educating the affected public on Combined Sewer Overflows (CSOs) and the LTCPU, using a variety of methods to reach different segments of the population. Furthermore, the Team is tasked with documenting all activities resulting from the public participation process.

2.1.6.3 *Green City, Clean Waters*

At the outset of the development of the LTCPU Public Participation Program, the Public Participation Program Team set out to label the LTCPU in a manner that better connected the plan to its target audience: the affected public. As a result, the LTCPU is also referred to as the *Green City, Clean Waters* program. The Team referred to it as such when referencing the LTCPU in a public context and in all communication materials in order to better capture the attention of its target audience.

The Public Participation section of the report summarizes the public participation activities conducted to reach the affected public on CSOs and the LTCPU. It also includes the activities carried out to gain input from the affected public, while also listing the materials and comments received throughout the public participation process on the development of the LTCPU.

2.2 PUBLIC INVOLVEMENT DURING THE DEVELOPMENT OF THE DRAFT LTCPU

"This LTCP is the greatest investment -- more than $1 Billion -- that we will see in our lifetimes to redress the "sins of the past" against our neighborhoods, rivers and streams. This investment will launch the transformation of our City into the "Green ... Towne" that our founder envisioned!

-Patrick Starr, Senior Vice President, Pennsylvania Environmental Council

2.2.1 Advisory Committee

The Public Participation Program Team assembled a diverse group of stakeholders to comprise the *Green City, Clean Waters* Advisory Committee. The committee consists of key City, state and community representatives (including civic organizations in neighborhoods affected by sewage backups during intense rainstorms), as well as leaders of local, regional and national environmentally -minded organizations. Targeted efforts were made to invite civic leaders of the impacted neighborhoods (and who represent ratepayers), industrial users, and organizations that represent people that live near and use the impacted areas. A majority of the representatives that actively participate on the advisory committee belong to organizations whose missions concentrate on civic and environmental issues.

The *Green City, Clean Waters* Advisory Committee is responsible for providing oversight and guidance to the PWD throughout the development of the LTCPU, along with providing input specifically on the development of the communication strategies, on public information and on outreach materials. All advisory committee invitees were sent an advisory committee introductory packet, including an appeal letter, a meeting agenda, two informational backgrounders and directions to the first meeting. View Supplemental Volume 1 for Advisory Committee Invite Packet.

The *Green City, Clean Waters* Advisory Committee were convened during key stages of the LTCPU. After the initial kick-off meeting, held in the fall of 2007, the committee met twice per year. Members of the advisory committee also met with PWD staff outside of regularly scheduled advisory committee meetings to further discuss communication strategies and outreach materials, and to get feedback on specific interests. Advisory committee members were also invited to attend public meetings.

2.2.1.1 Advisory Committee Membership

The representative organizations that serve on the *Green City, Clean Waters* Advisory Committee are listed in Table 2-1.

Table 2-1 Advisory Committee Organizations

Type of Group	Organization
Business	• Building Industry Association
Citizen Groups	• Northern Liberties Neighborhood Association • Passyunk Square Neighbors Association • Washington West Civic Association
Interest Groups	• Community Legal Services, Inc. • Delaware River City Corporation • Impact Services Corporation • PennFuture (Next Great City) • Pennsylvania Environmental Council • Tookany/Tacony-Frankford Watershed Partnership • Schuylkill River Development Corporation • Sierra Club
Regulatory Agencies	• Pennsylvania Department of Environmental Protection (PADEP)
Local Government Agencies	• Fairmount Park Commission • Mayor's Office of Sustainability • Philadelphia Water Department

2.2.1.2 Advisory Committee Meetings

The *Green City, Clean Waters* Advisory Committee meetings are listed in Table 2-2. The agendas, presentations, sign-up sheets and comments from each meeting may be viewed in Supplemental Volume 1.

Table 2-2 Advisory Committee Meetings

Green City, Clean Waters **Advisory Committee**			
Meeting:	**1**	**2**	**3**
Date:	November 13, 2007	February 20, 2008	October 8, 2008
Time:	10:00am - 12:00pm	10:00am - 12:00pm	10:00am - 12:00pm
Place:	Fairmount Water Works Interpretative Center, Philadelphia	Fairmount Water Works Interpretative Center, Philadelphia	Fairmount Water Works Interpretative Center, Philadelphia
Number of Attendees:	9	8	16
Topics Covered:	Purpose and role of the advisory committee	Purpose and role of the advisory committee	Water quality characterization
	Overview on CSOs	Feedback on the public meeting presentation	Problem analysis
	Assessment of Philadelphia's combined sewer system	Presentation on Philly RiverCast	Goals developed for each targeted watershed
	Regulatory context of the LTCPU	Presentation on plans for Philly CSOCast	Presentation on Philly CSOCast
	Watershed management approach to CSO control		Preview of *Green City, Clean Waters* Exhibit (Refer to Section 2.2.3 for exhibit description)

Green City, Clean Waters Advisory Committee			
Meeting:	**1**	**2**	**3**
	CSO-related outreach materials/projects developed to date		
	Next steps for CSO-related public outreach		
	Timeline for future meetings and meeting topics		
General Feedback:	When presenting to the public, use less technical jargon and more images; relay problems and solutions; and demonstrate to the public why they should care.	Demonstrate what individuals (public) can do to make a difference; take extra time to explain combined sewers, separate sewers and stormwater runoff and the impacts on streams.	Create incentives for commercial and residential properties to go green; ensure communication with properties that will be affected by rate allocation; provide more details on CSO Cast; tell us more about sizing gray infrastructure and tidal influences.

Table 2-2 Advisory Committee Meetings cont'd

Green City, Clean Waters Advisory Committee		
Meeting:	**4**	**5**
Date:	April 9, 2009	August 5, 2009
Time:	10:00am - 12:00pm	10:00am - 12:00pm
Place:	Fairmount Water Works Interpretative Center, Philadelphia	Fairmount Water Works Interpretative Center, Philadelphia
Number of Attendees:	8	12
Topics Covered:	Public meeting presentation on CSO – control options & alternatives	How do we promote the final public meetings?
		Any final feedback to incorporate in the draft and CSO LTCPU?
General Feedback:	Use less technical jargon when presenting to the public. The presentation is too balanced regarding the green and gray infrastructures.	Promote through press and all partners. This plan is a model for all cities!

2.2.1.3 Targeted Advisory Committee Meetings

The Public Participation Program Team met with advisory committee members outside of the regularly scheduled advisory committee meetings to further discuss communication strategies and outreach materials. The Team also met with other stakeholders that were targeted for specific feedback, such as the Commercial Customer Forum Committee. These sub-committee meetings enabled the City to get specific feedback from residents or customers with specific interests in PWD's operations and services. The meetings are listed in Table 2-3.

Table 2-3 Targeted Advisory Committee Meetings

Targeted Advisory Committee Meetings		
Meeting:	1	2
Date:	December 12, 2007	March 5, 2008
Time:	10:00am - 11:30am	10:00am - 11:30am
Place:	Philadelphia Water Department, Philadelphia	Philadelphia Water Department, Philadelphia
Attendees:	Business Industry Association (BIA)	Pennsylvania Environmental Council
	PWD	Passyunk Square Civic Association
Topics Covered:	Public outreach strategy for first public meeting and review of materials produced to date in preparation for the first public meeting	Public outreach strategy for first public meeting and review of materials produced to date in preparation for the first public meeting
	Feedback on communications strategy	Feedback on communications strategy

2.2.2 Public Meetings

The *Green City, Clean Waters* public meetings were held during key points in the development of the LTCPU in order to keep the public apprised of the plan as it progressed and, in turn, for the City to get feedback from the public on the development of the LTCPU. Effort was made to engage a full range of stakeholders; including rate payers, industrial users, and communities that live near and use the affected areas. A detailed record of the public meetings, including the number of people attending, all comments made by attendees and responses to all comments, is included in Supplemental Volume 1.

2.2.2.1 Notification

Notifications and advertisements for the public meetings are disseminated via the following media:

- Newspapers: Notices of public meetings were published at least one week prior to each public meeting. Public meetings were advertised in the following newspapers as shown in Figure 2-2 (View Supplemental Supplemental Volume 1 for more notices and ads).

    - Chestnut Hill Local
    - Germantown Courier
    - Mt. Airy Independent
    - Mt. Airy Times Express
    - North Star
    - Philadelphia Daily News
    - Philadelphia Inquirer
    - South Philadelphia Review
    - The Philadelphia Tribune
    - Westside Weekly

- Internet Websites: Notices of public meetings were also placed on the following websites:
    - PWD's LTCPU Program website: http://www.phillyriverinfo.org/csoltcpu
    - Philadelphia Tribune – http://www.phillytribune.com

- Germantown Courier – http://www.Germantowncourier.com
- Mt. Airy Times - http://www.mtairytimesexpress.com/
- Philadelphia Inquirer/Daily News – http://www.philly.com (Green Section)
- Penn Praxis - http://www.design.upenn.edu/pennpraxis/
- This Week in Philly – http://www.thisweekinphilly.com
- Northeast Philly – http://www.nephillyonline.com
- Northern Liberties Neighbors Association – http://www.nlna.org
- Philly 1 – http://www.philly1.com
- Green Philly Blog – http://www.greenphillyblog.com
- Yahoo – http://www.upcoming.yahoo.com
- Twitter – http://www.twitter.com

- Radio:
  - KYW 1060AM
  - The Public Eye News WPEB 88.1FM

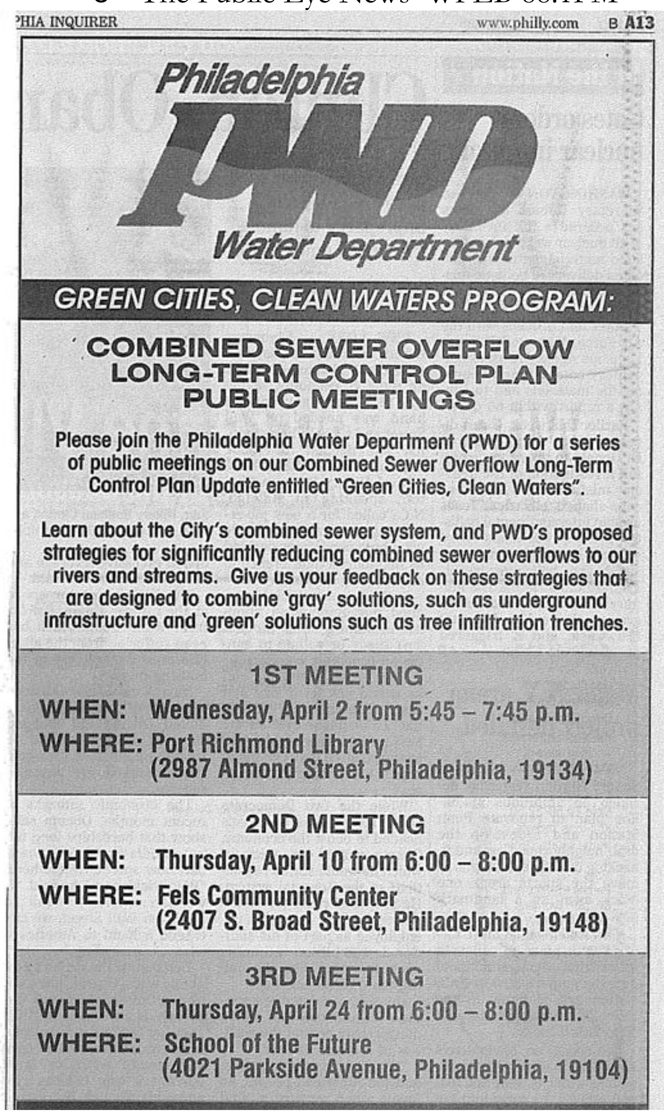


Figure 2-2 Public Notice

- Watershed Partnership Listservs and Advisory Committee Listservs: Notice of all public meetings was distributed through the following listservs via e-mail announcements.
    - Tookany/Tacony Frankford Watershed Partnership
    - Darby-Cobbs Watershed Partnership
    - Delaware Direct Watershed Partnership
    - Pennypack Watershed Partnership
    - Schuylkilll Action Network

- Flyer: A flyer was created for the second, third and fourth series of public meetings. The flyers were placed in popular neighborhood locations (See Supplemental Volume 1 for flyers).

2.2.2.2 Public Meetings, Series #1

The *Green City, Clean Waters* public meetings are held in different locations throughout the City of Philadelphia in order to maximize the likelihood of attendance for residents from across the City (Figure 2-3 and 2-4). The public meetings are listed in Table 2-4. A detailed record of the public meetings, including the number of people attending, all comments made by attendees and responses to all comments, agendas, presentations, and sign in sheets may be viewed in Supplemental Volume 1.

The first series of public meetings included a unique informational display, referred to as the *Green City, Clean Waters* Information Fair (Figure 2-2). The fair was set up at each venue. (For details on the Information Fair, view section 2.2.5).

Figure 2-3 *Green City, Clean Waters* Information Fair

Figure 2-4 Public Meeting

The first series of public meetings covered the following topics:

- History of Philadelphia's waterways and current status of the waterways
- Combined sewer systems
- The CSO Long Term Control Plan and the National CSO Control Policy
- Introduction to CSOs per watershed
- Nine Minimum Controls
- Capital projects
- Philadelphia's Integrated Watershed Management Approach

- Watershed partnerships
- How You Can Make a Difference
- Profiles of CSO peer cities and their approach to CSO control
- Gray (traditional infrastructure) approach
- Green stormwater infrastructure approach

Table 2-4 Public Meetings, Series #1

Green City, Clean Waters Public Meetings, Series #1			
Meeting:	**1**	**2**	**3**
Date:	April 2, 2008	April 10, 2008	April 24, 2008
Time:	6:00 p.m. – 8:00 p.m.	6:00 p.m. – 8:00 p.m.	6:00 p.m. – 8:00 p.m.
Place:	Port Richmond Library, Philadelphia	FELS Community Center, Philadelphia	School of the Future, Philadelphia
Number of Attendees:	10	6	19
General Feedback:	Generally, the participants posed questions, regarding PWD's proposed tank in the area; on whether gray water systems are illegal; and provided comments on green stormwater infrastructure being a better approach and on the locations of storage tanks or diversion systems.	The participants made remarks, regarding the importance of showing specific examples of green stormwater infrastructure projects and using local project examples, so that the public can better relate to the projects.	The participants asked questions, regarding building code changes, the impacts of greening on the residential water bills, and the importance of working with neighborhood groups to maintain green stormwater infrastructure projects, in addition to the importance of educating children in school about green projects.

2.2.2.3 Public Meetings, Series #2

The second series of public meetings was also held in locations throughout the City of Philadelphia in order to maximize the likelihood of attendance for residents from across the City. The meetings are listed in Table 2-5. A detailed record of the public meetings, including the number of people attending, all comments made by attendees and responses to all comments, agendas, presentations, and sign in sheets may be viewed in Supplemental Volume 1.

The second series of public meetings kicked off at the Fairmount Water Works Interpretive Center. At this site, the *Green City, Clean Waters* Exhibit was on display. Meeting participants were encouraged to tour the exhibit and the other displays in the Interpretive Center. This exhibit was also advertised at the other meeting sites. (For more details on the exhibit, view section 2.2.5)

The second series of public meetings covered the below topics:

- PWD's mission & responsibilities
- *Green City, Clean Waters* vision
- Review of combined sewer systems and the National CSO Control Policy
- Overview of Gray (traditional infrastructure) and Green approach and examples of each approach
- Mayor's Priorities

- Integrated Watershed Management Approach & Partnerships
- Existing watershed problems and conditions
- The way in which the Long Term Control Plan Update addresses the watershed problems

Table 2-5 Public Meetings, Series #2

Green City, Clean Waters Public Meetings Series #2			
Meeting:	**1**	**2**	**3**
Date:	October 23, 2008	December 4, 2008	December 10, 2008
Time:	6:30pm - 8:30pm	5:30pm - 7:30pm	6:00pm - 8:00pm
Place:	Fairmount Water Works Interpretative Center, Philadelphia	Cobbs Creek Community Environmental Education center, Philadelphia	Center in the Park, Philadelphia
Number of Attendees:	13	14	20
General Feedback:	The participants asked questions, regarding incentives for residential/commercial properties; communication with the larger parcels that will be affected by the rate reallocation; modeling gray infrastructure; and tidal influences on the drinking water intake on the Delaware River.	The participants asked questions, regarding the function of a tank; the longevity of gray infrastructure; models and maintenance of porous asphalt; stormwater regulations; and about CSO LTCPU plans in other cities.	The participants asked questions, regarding how project sites are selected; the reasons behind residents paying for stormwater impacts, and about how other CSO cities manage with their gray projects.

2.2.2.4 Public Meetings, Series #3

The third series of public meetings was also held in locations throughout the City in order to maximize the likelihood of attendance for residents from across the City. The meetings are listed in Table 2-6. A detailed record of the public meetings, including the number of people attending, all comments made by attendees and responses to all comments, agendas, presentations, and sign in sheets may be viewed in Supplemental Volume 1.

The third series of public meetings involved a component of a survey, titled, "Combined Sewer Overflow (CSO) -Control Approach Survey" (See Supplemental Volume 1). The responses on the survey were overwhelmingly positive – favoring green stormwater infrastructure over gray infrastructure. Table 2-7, 2-8 and 2-9 provide the feedback from the survey.

The third series of public meetings covered the below topics:

- Options for CSO-Control
- Alternatives for CSO-Control
- Approaches to CSO-Control
- Survey on CSO-Control Approach

Table 2-6 Public Meetings, Series #3

Green City, Clean Waters Public Meetings Series #3			
Meeting:	**1**	**2**	**3**
Date:	June 2 2009	June 4 2009	June 10 2009
Time:	6:00pm - 8:00pm	6:00pm - 8:00pm	6:00pm - 8:00pm
Place:	Fels South Philadelphia Community Center, Philadelphia	Waterview Recreation Center, Philadelphia	Northern Liberties Community Center, Philadelphia
Number of Attendees:	7	9	14
General Feedback:	See Table 2-7	See Table 2-8	See Table 2-9

Table 2-7 CSO Control Survey Results, Public Meeting, Series #3, FELS Center

FELS Center			
Do you like this strategy?	**What do you like about the strategy?**	**What concerns do you have about this strategy?**	**Any additional information?**
Yes	Makes sense!	Some Concerns about maintaining curb openings, planters, water collection units, but I'm sure they will be maintained.	
Absolutely, all-green is utopian (after all the most cost-effective), green is probably the most practical and a huge improvement over the current situation	I love the idea of replacing with more porous material. Love the Model Neighborhood approach	Cooperation from the government, narrow-minded individuals, companies, corporations. What is being done to convince, train and persuade?	How can I help? How can PWD and LoMo work together? Who pays for what?
Yes	Works well with future plans of developing the City neighbors, parts, commercial industries and business.	The cost	
I strongly prefer the all green approach, while I understand the seeming necessity of the plan mentioned above.	I like the cost-effectiveness of this plan vs. an all-gray approach, which does not offer any of the socioeconomic benefits.	Can't think of any at this time.	Perhaps offering greening solutions and tips on billing statements for residents who cannot attend community meetings but are interested in green approach.
Yes! I have been studying green infrastructure economics & the PWD's strategy is probably the most progressive program for stormwater management. I want to see it implemented across the City.	The fact that PWD has used triple bottom line accounting to prove the value of Green Infrastructure. Also, that PWD is holding presentations like this for public education, input and feedback.	How are we going to pay for it as a City? How can we implement this strategy over as a short amount of time as possible?	More information on the model neighborhood program and getting our blocks involved in green infrastructure renovations on our homes and streets.

Table 2-8 CSO Control Survey Results, Public Meeting, Series #3, Waterview Recreation Center

Waterview			
Do you like this strategy?	**What do you like about the strategy?**	**What concerns do you have about this strategy?**	**Any additional information?**
Yes	It captures the water at or near the source which prevents or helps to prevent problems as water travels through sewer system to reduce stress on the system.	Convincing the gov't that this investment will be beneficent in the short and long tem	
	Lowering crime, prettier neighborhood	Tailor it more to homeowners; Use more pictures	
Yes	All	Not a thing	Get the word out more
I endorse the green approach for the clear social & environmental benefits. The cost savings and improved quality of life in a greener Philly	The increased air quality, health benefits, recreation opportunities in the green solutions.	How to build public support for letting PWD green their blocks. It will be a significant communication and public involvement challenge	Have some case studies available about the commercial and industries. Handouts no more needed in the presentation. Is there a film or short documentary about a model neighborhood here on Philly?
Yes, with more incentives $ for the individual property owners	It has a more sustainable methodology to a long term problem.	[My concern is] that the solutions are not geared or focused on the individuals own home/property.	Producing a model neighborhood in Philadelphia that can be visited.
Love it	I like the whole idea of the greening of Philadelphia. There are so many benefits to the *Green City, Clean Waters* initiative.	[My concern is] obtaining support from local residents, businesses, organizations and government agencies. But keep up the good work - the more you educate people about this program, the more positive feedback.	Great presentation! Very interesting and informative. Thanks.
Yes	most of green improvements	more knowledge in areas (urban)	Put into schools and organizations
Yes	Reality	Traditional business men might block the City plans if they're gonna lose profit	Stick to the plan

Do you like this strategy?	What do you like about the strategy?	What concerns do you have about this strategy?	Any additional information?
yes	This presentation was very informative. I didn't really understand the issues before. Green is the best approach.	My concern is that more people need to be informed so then a greater support and participation.	
yes, it's great	Greening space is always good. Ancillary benefits of green infrastructure are also great. It's the environmental approach.	No grey water plan, which would lower sewer stress. Residences should have rate incentive to manage the first inch.	More info on impact. For example, how many square feet of green roof per mile do you need to reduce x% of stormwater events. Also, how much work do you have to do on private land?
Absolutely	Increased green - trees, plants, etc. improved environment - healthier waterways	Maintenance - Who will maintain the garden? Is it PWD or neighbors?	Could the presentation be available online (maybe shorter) so people who are busy can watch it when they have free time.
Absolutely! No more gray - Green, Green, Green	All the benefits, triple bottom line return to green away from more infrastructure and enormous pipes.	Maintenance	Timeline
Yes, I think it is great.		Long term maintenance, who is responsible? May be difficult to get some communities on board with maintaining these features.	It would be helpful to see examples on how effective the "green approach" has been in the past. For example, how do you measure the amount of runoff captured? Flow meters? Water quality sampling?
I love it very much. The added benefits of greening (health, performance, ecological, monetary) make it the obvious choice.	See before	Changing public perception	The current state of water resources - running out, polluted and undervalued

Table 2-9 CSO Control Survey Results, Public Meeting, Series #3, Northern Liberties Community Center

Northern Liberties Community Center			
Do you like this strategy?	**What do you like about the strategy?**	**What concerns do you have about this strategy?**	**Any additional information?**
Yes	Everything sounds like a no-brainer.	Will these spaces become breeding areas for the mosquitoes?	
Yes	Aesthetics and cost	Convincing row house Philadelphians that it will work	How to hook-up a rain barrel; how will the City handle the additional leaves, horticultural involvement, etc.
Yes	The multitude of benefits of greening. Reduced stormwater runoff, increased aesthetics, air quality improvement reduction of waste diverted to the Delaware river	none	
It is a wonderful and natural process	I didn't hear much because I was late, however, I read about it (not much). I understand that the strategy presented is more complex and thorough than some	I cant say since I didn't hear the entire presentation	No
Questionable need more info	good presentation	need more info	need more info
yes	Balance, presentation of alternatives, figures. But needs to be 20 min shorter	Overestimates Philadelphians willingness to embrace change. For example, god luck putting cut outs and trees in St. Monica's	where people park too deep for blocks
yes	beauty of landscape in City; protects rivers and streams		
yes	Reality	Traditional business men might block the City for they lose profit	stick to the plan
yes	This presentation was very informative. I didn't really understand the issues before. Green is the best approach.	My concern is that more people need to be informed so then a greater support and participation.	

Do you like this strategy?	What do you like about the strategy?	What concerns do you have about this strategy?	Any additional information?
yes, it's great	Greening space is always good. Ancillary benefits of green infrastructure are also great. It's the environmental approach.	No grey water plan, which would lower sewer stress. Residences should have rate incentive to manage the first inch.	More info on impact. For example, how many square feet of green roof per mile do you need to reduce x% of stormwater events. Also, how much work do you have to do on private land?
Absolutely	Increased green - trees, plants, etc. improved environment - healthier waterways	Maintenance - Who will maintain the garden? Is it PWD or neighbors?	Could the presentation be available online (maybe shorter) so people who are busy can watch it when they have free time.
Absolutely! No more gray - Green, Green, Green	All the benefits, triple bottom line return to green away from more infrastructure and enormous pipes.	maintenance	Timeline
Yes, I think it is great.		Long term maintenance, who is responsible? May be difficult to get some communities on board with maintaining these features.	It would be helpful to see examples on how effective the "green approach" has been in the past. For example, how do you measure the amount of runoff captured? Flow meters? Water quality sampling?
I love it very much. The added benefits of greening (health, performance, ecological, monetary) make it the obvious choice.	see above	changing public perception	The current state of water resources - running out, polluted and undervalued

2.2.2.5 Public Meetings, Series #4

The fourth series of public meetings were held primarily outdoors – at green stormwater infrastructure demonstration sites, located throughout the City, in order to maximize the likelihood of attendance for residents from across the City. In order to drum up attention for the public meetings, the *Green City, Clean Waters* Exhibit is traveling throughout the City, serving to educate and to promote the final round of public meetings and the LTCPU Summary Report. Along with the exhibit, Green Stormwater Infrastructure fact sheets are available along with comments sheets for participants to leave comments. Table 2-10 lists the venue sites hosting the exhibit. The meetings are listed in Table 2-11. A detailed record of the public meetings, including the number of people attending the meetings, all comments made by attendees and responses to all comments, agendas, presentations, and sign in sheets may be viewed in Supplemental Volume 1.

Comments on the exhibit may also be viewed in Supplemental Volume 1.The focus of the fourth series of public meetings is the LTCPU Summary Report. The report will be shared with the participants. PWD will walk them through the report. Also, PWD will highlight the local model green stormwater infrastructure demonstration project on-site. PWD plans to solicit final comments from participants.

The fourth series of public meetings will cover the below topics:

- LTCPU Summary Report
- Feedback on the Summary Report
- Model green stormwater infrastructure demonstration project

Table 2-10 *Green City, Clean Water*s Exhibit

***Green City, Clean Waters* Exhibit**			
Exhibit	**Date**	**Time**	**Location**
1	July 21- August 21, 2009	Tuesday – Saturday 10:00pm - 5:00pm Sunday 1:00pm – 5:pm	Fairmount Water Works Interpretive Center, Philadelphia
2	July 20 -24, 2009	Monday – Friday 10:00am - 1:00pm	Northern Liberties Community Center, Philadelphia
3	July 27-31, 2009	Monday and Wednesday 12:00pm - 8:00pm Tuesday, Thursday and Friday 10:00am – 5:00pm	Walnut Street West Library, Philadelphia
4	August 3-7, 2009	Monday – Friday 7:00am - 9:00pm	Waterview Recreation Center, Philadelphia
5	August 10-14, 2009	Monday – Friday: 9:00am - 9:00pm	Columbus Square Recreation Center, Philadelphia
6	August 17-21, 2009	Monday – Thursday: 9:00am - 9:00pm Friday: 9:00am – 6:00pm	Parkway Central Library, Philadelphia

Table 2-11 *Green City, Clean Water* Public Meetings, Series #4

***Green City, Clean Waters* Public Meetings, Series #4**				
Meeting:	1	2	3	4
Date:	August 18 2009	August 19 2009	August 20 2009	August 25 2009
Time:	6:00pm - 8:00pm	6:00pm - 8:00pm	6:00pm - 8:00pm	6:00pm - 8:00pm
Place:	Waterview Recreation Center, Philadelphia	Northern Liberties Community Center, Philadelphia	Columbus Square Recreation Center, Philadelphia	Mercy Hospital, Philadelphia
Number of Attendees:	15	34	20	25
General Feedback:	Very Positive. View section 2.5.1 for testimonials from public meetings.	Very Positive. View section 2.5.1 for testimonials from public meetings.	Very Positive. View section 2.5.1 for testimonials from public meetings.	Very Positive. View section 2.5.1 for testimonials from public meetings.

2.2.2.6 Targeted Public Meetings

Components of the *Green City, Clean Waters* presentations and materials prepared for the LTCPU public meetings were also presented at the following meetings:

Table 2-12 Targeted Public Meetings

Targeted Public Meetings			
Event	**Date**	**Place**	**Address**
Citizen's Advisory Committee (CAC) Meeting	February 15, 2008	Philadelphia Water Department	1101 Market St. Philadelphia
South Philadelphia Storm Flood Relief Civic Meeting	April 24, 2008	Maria Goretti High School	1736 S 10th St. Philadelphia
Penn Praxis "10 Action Steps" event	May 26, 2008	Seaport Museum	Penn's Landing, Philadelphia
Rally Around Green Streets with State Senator Fumo	June 12, 2008	Columbus Square & Liberty Lands Park	N 3rd St Philadelphia
Green City, Clean Waters Exhibit Opening and Artist Reception for Bill Kelly	October 16, 2008	Fairmount Water Works Interpretative Center,	640 Waterworks Drive Philadelphia
Columbus Square Storm Flood Relief Civic Meeting	October 27, 2008	Columbus Square Recreation Center,	12th & Wharton Sts. Philadelphia
Washington West Storm Flood Relief Civic Meeting	October 29, 2008	Jefferson Hospital,	111 South 11th Street Philadelphia

2.2.3 Watershed Partnerships

Stakeholder buy-in is critical to informing the PWD approach to implementing CSO-control alternatives. A diversity of stakeholder perspectives is considered in the development of each stage in the planning process of the LTCPU in order to ensure that the plan is representative of stakeholder interests. Through this approach, a green stormwater infrastructure program would be built based on the public demand for it. Recognizing this, the PWD has helped to develop stakeholder watershed partnerships for each watershed that drains to the City of Philadelphia through its integrated watershed planning approach. The purpose of each watershed partnership is to share resources and expertise among partners and to coordinate information with other municipalities within the same watershed. The ultimate goal of the watershed planning approach is to cultivate partnerships committed to implementing the watershed management plans once completed.

2.2.3.1 Tookany/Tacony-Frankford Watershed Partnership

In 2000, the PWD launched the Tookany/Tacony-Frankford Watershed Partnership (TTF) with its partners, as an effort to connect diverse stakeholders as neighbors and stewards of the watershed. The partnership was integral in developing the Tookany/Tacony-Frankford Integrated Watershed Management Plan (TTF IWMP).

In 2005, the TTF Partnership formally incorporated as an independent non-profit, composed of environmental organizations, community groups, government entities, and other watershed stakeholders. Now the Partnership has embarked on implementing the TTF IWMP and advancing a wide range of initiatives for the good of the watershed.

The mission of the TTF Watershed Partnership is:
"*To increase public understanding of the importance of a clean and healthy watershed; to instill a sense of appreciation and stewardship among residents for the natural environment; and to improve and enhance our parks, streams, and surrounding communities in the Tookany/Tacony-Frankford Watershed.*"

A range of public education and outreach activities and events have resulted from the watershed planning approach in the Tookany/Tacony-Frankford Watershed. Please refer to Table 2-13 for a description of the events and activities that took place through the watershed planning approach, which occurred prior to the updating of the Long Term Control Plan in 2008.

The below activities and events cover components of the LTCPU and/or the topic of "watershed management" in the Tookany/Tacony-Frankford Watershed, from the inception of the update of the LTCP in early 2008 alone:

Table 2-13 Tookany/Tacony-Frankford Watershed Partnership Outreach Events

Tookany/Tacony-Frankford (TTF) Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Number Served**
Watershed Lessons	Taylor Elementary School	January 22, 2008	One 45 minute watersheds lesson co-taught with Awbury Arboretum's Director of Outreach and Public Programs. Watersheds lesson included the "Curly the Catfish" activity (importance of clean water and good stewardship).	54 third graders during school time
Watershed Lessons	Emlen Elementary School (Upshal & Chew)	March 12, 2008	One 45 minute watersheds lesson co-taught with Awbury Arboretum's Director of Outreach and Public Programs. Watersheds lesson included the "Curly the Catfish" activity (importance of clean water and good stewardship).	15 7th graders, 15 3rd graders, 15 2nd graders after school
"Stormwater Management for Business" Lecture	Elkins Park Rotary Club	March 12, 2008	30 minute presentation on ways businesses can help manage stormwater and reduce non-point source pollution. Main presentation given by PWD's Watersheds Program coordinator.	11 Rotary Club Members (adults)
"Stormwater Management for Business" Lecture	Cheltenham/ Rockledge Rotary Club	March 20, 2008	31 minute presentation on ways businesses can help manage stormwater and reduce non-point source pollution. Main presentation given by PWD's Watersheds Program coordinator.	26 Rotary Club Members (adults)

Tookany/Tacony-Frankford (TTF) Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Number Served**
Wingohocking Creek Watershed Historic Stream Mystery Tour	TTF Watershed	April 5, 2008	The Wingohocking Creek, the largest creek in the City to be encapsulated in a sewer, ran from the top of East Mt Airy, through Germantown, to Juniata Park. In the four hours of the tour, we'll cover some natural history and a lot of human history, concentrating on the important role of man-made drainage structures in the development of the City.	33 participants
		October 11, 2008		26 participants
		December 18, 2008		12 participants
Rain Barrel Workshop	Glenside-Weldon Elementary School	April 16, 2008	Rain Barrel Workshop	61 families
Stream Cleanup	Wall Park	April 19, 2008	Volunteer stream clean up day. 28 bags of trash collected 12 evaluation forms completed	12 adults, 3 children
Rain Barrel Workshop	Cedarbrook Middle School	April 26, 2008	Rain Barrel Workshop	79 families
TOXTOUR w/ Christopher Swain	Cedarbrook Middle School	April 27, 2008	Hosted Christopher Swain Arranged volunteers and assisted with e-waste collection (950 lbs) Unattended TTF Watershed display table	15 adults
TOXTOUR school visit	Cedarbrook Middle School	April 28, 2008	Christopher spoke to 7 classes about clean water issues and e-waste	4adults, 150 children (7th graders)
Mt. Airy Day	Cliveden Historic Site (6401 Germantown Ave)	May 3, 2008	Shared a display table with Awbury Arboretum Talked to adults about the TTF Watershed information Did the Nature's Filter activity with children	30 children, 15 adults
Jenkintown Fair		May 10, 2008	Hosted TTF display table Talked to adults about the TTF Watershed information	23 adults, 1 child
Park Clean Up and Invasive Removal	Tacony Creek Park (Snake Road by I and Ramona)	May 14, 2008	Frankford high School City Year students collected trash and removed invasive in Tacony Creek Park, led by Jackie Olson, FPC	4 Frankford High School Students, 3 City Year Leaders (college age)
TTF Watershed Bus Tour	Multiple sites in the TTF Watershed	June 27, 2008	5-hour bus Tour of 7 demonstration sites across the TTF Watershed	25 adults, 11 speakers

Event Title:	Location	Date:	Description	Number Served
Model Neighborhood Presentation	Chew & Belfield Organization - 1124 Chew Avenue	August 18, 2008	2 hour meeting with neighborhood block captains, Renovo Developers, Mt Airy USA and Awbury Arboretum. The sole agenda item was the Model Neighborhood Project. Sarah described the program and then a long discussion followed in which feedback and suggestions about neighborhood improvement were given.	11 adults
Belfield Block Party	6424 Belfield	August 23, 2008	Hosted a TTF display table with Model Neighborhood information highlighted. 2.5 hours	15 adults, 2 teens
Volunteer Work Day in Tacony Creek Park	Tacony Creek Park in Rising Sun and Olney	August 26, 2008	In collaboration with Fairmount Parks Commission, removed invasive species and trash from Tacony Creek Park for 3 hours with Red Cross volunteers	4 adults, 4 teens
Watershed Lessons, Academy for Middle Years	Awbury Arboretum	August 27, 2008	Taught a Watershed lesson while touring the Arboretum property. Focused on the onsite stormwater management demonstration projects.	6 adults, 50 7th-graders
Rain Barrel Workshop	Waterview Recreation Center	September 11, 2008	Hosted Rain Barrel Workshop taught by PWD staff Porous pavement demonstration by PHS staff Model neighborhood presentation by TTF	48 families
Model Neighborhood Presentation	Chew & Belfield Organization - Corner of Chew and Belfield	September 16, 2008	Presented the Model Neighborhood Project to residents of Chew and Belfield neighborhood as part of their monthly block meeting. Surveys about neighborhood improvement were distributed.	24 adults, 1 teen
Coast Day	Penn's Landing	September 20, 2008	Hosted a TTF display table with Awbury Arboretum. Did the “What’s Your Watershed Address?” with hundreds of children and adults using large-scale street/watershed maps. 4 hours	approx. 200 adults and children
Model Neighborhood Presentation	Chew & Belfield Organization - E. Herman St. near Chewfield Avenue	September 22, 2008	Presented the Model Neighborhood Project to residents of E. Herman Street as part of their monthly block meeting. Project ideas were shared verbally and surveys about neighborhood improvement were completed	18 adults

Event Title:	Location	Date:	Description	Number Served
Senior Environment Fair	Center in the Park, Senior Environment Corps	September 26, 2008	Hosted a TTF display table with Model Neighborhood information highlighted. Surveys about neighborhood improvement were distributed. 5 hours.	50 adults
Stream Clean Up	Wall Park	September 28, 2008	Volunteer neighborhood clean up day. 16 evaluation forms completed and 20 bags of trash collected. 20 bags of trash collected 16 evaluation forms	9 adults, 12 children
Neighborhood Clean Up	1124 Chew Avenue (Chew and Walnut Lane)	October 11, 2008	Volunteer neighborhood clean up day. 11 tons of trash 15 evaluation forms completed	19 adults, 5 children
Neighborhood Clean Up	Whitaker and F St	November 8, 2008	Volunteer clean up day run by PA clean ways in collaboration with PWD, Streets Department, Penn DOT, FPC, and TTF. 231, 860 lbs (115.93 tons)	38 volunteers
TOXTOUR school visit	High School of the Future	December 3-7, 2008	Christopher Swain, swimmer conservationist presented his work at numerous schools throughout Cheltenham and Philadelphia. He spoke about clean water issues, his past work swimming rivers to raise awareness, his upcoming swim (1000+ miles down the Atlantic Coast from Boston to Washington DC), and the problems associated with common e-waste disposal techniques.	60 HS students
	Arcadia University			15 college students, 1 adult
	Cheltenham high School			58 HS Students
	Elkins Park Elementary			25 6th graders
	Cedarbrook Middle School			210 7th and 8th graders
	Glenside Elementary			350 K-4th graders
TOXTOUR, Ethical Electronics Recycling Event	Cedarbrook Middle School	December 6, 2008	Hosted a drive to collect used electronics for ethical recycling at a fee of $1/lb. 10,524.7lbs of e-waste collected $1000 proceeds to TTF 150 contacts added to mailing list	150 families

2.2.3.2 Darby Cobbs Watershed Partnership

In 1999, the Darby Cobbs Watershed Partnership (DCWP) was initiated in an effort to connect residents, businesses, and government as neighbors and stewards within the vast drainage area. Over the course of the last nine years, this partnership has provided a driving force for stakeholder planning and implementation of the Darby Cobbs Integrated Watershed Management Plan (DC IWMP).

The Darby Cobbs Watershed Partnership (DCWP) mission is:
"To improve the environmental health and safe enjoyment of the Darby Cobbs Watershed by sharing resources through cooperation of the residents and other stakeholders in the Watershed. The goals of the initiative are to protect, enhance, and restore the beneficial uses of the Darby-Cobbs waterways and riparian areas."

A range of public education and outreach activities and events have resulted from the watershed planning approach in the Darby Cobbs Watershed. Please refer to Table 2-14 for a description of the events and activities that took place through the watershed planning approach, which occurred prior to the updating of the Long Term Control Plan in 2008.

The below activities and events cover components of the LTCPU and/or the topic of "watershed management" in the Darby Cobbs Watershed, from the inception of the update of the LTCP in early 2008 alone:

Table 2-14 Darby Cobbs Watershed Partnership Outreach Events

Darby Cobbs Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Number Served**
Second Ward porous Basketball Court hoops Challenge	Second Ward playground in Upper Darby Township, PA	September 9, 2007	In celebration of the porous pavement basketball court, an Enviroscape demonstration was set up, along with an awards ceremony to honor the Darby Cobbs Watershed Partnership.	25 participants
25th Annual Darby Creek Valley Association Stream Clean Up	77 square miles of the Darby Watershed	April 25, 2008	Help continue the "Ribbon of GREEN" from Tinicum to Tredyffrin	
Indian Creek East Branch Walking and Bus tour	Friend's Central School (1101 City Ave., Wynnewood	May 17, 2008	This event involved a bus/walk tour of stormwater Best Management Practices (BMP) projects and stream restoration projects, along with presentations by project leaders on the visited sites. Lunch was included.	20 participants
Free Rain Barrel Workshop	Christ Lutheran Church (7240 Walnut St, Upper Darby)	May 29, 2008	This Rain Barrel Workshop provided a brief overview of the rainwater cycle, the importance of stormwater management at the property level, and how to install and use a rain barrel. The first 50 households that pre-registered for the workshop received a free rain barrel. This event was offered to residents of the Darby-Cobbs Watershed.	45 participants
Delaware County Riverfront Ramble	Along the Delaware Riverfront	September 20, 2007	This day included community service events, education, other activities, dining and fireworks in honor of the river 30+ contacts made from this event	

Darby Cobbs Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Number Served**
Clean Up in Morris Park	Papa Playground (Lansdowne Ave and 68th St.)	September 20, 2007	A community clean up took place in the park	40+ volunteers
Thinking Like a Watershed	Ridley Creek State Park	November 4, 2008	The purpose of this workshop was to educate participants about watersheds and how to enhance the beneficial features of an urban system. This free one day workshop was intended for teachers of grades four through eight. Participants enjoyed the hands-on activities offered through this workshop, which included trudging through the stream and receiving in-class instructions while participating in activities.	9 School teachers

2.2.3.3 Delaware Direct Watershed Partnership

The Delaware Direct Watershed Partnership was formed in the fall of 2007 to support the River Conservation planning process for the Delaware Direct River Conservation Plan. A myriad of stakeholders are involved– non-profits, state and local government, in addition to community representatives. Each of the stakeholders represents a current planning initiative, such as the GreenPlan Philadelphia, the Central Delaware Master Plan, and the DRBC Water Resources Plan, among others. Through the Partnership, the representatives come together in a coordinated manner to communicate the best possible method to achieve protection of the natural resources and their sustainability in the urbanized Delaware Direct Watershed.

The below meetings and events involved components of the LTCPU and/or the topic of "watershed management" in the Delaware Direct Watershed:

Table 2-15 Delaware Direct Watershed Partnership Outreach Events

Delaware Direct Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Result**
Pulaski Pier River Conservation Plan Workshop #1	Pennsylvania Horticultural Office (PHS) Office, Philadelphia	April 30, 2008	Research and problem-solving session on Pulaski Pier as a park, wetland and riparian restoration park expansion	35 attendees representing 26 organizations
21st Century Parking Solutions River Conservation Plan Workshop #2	Philadelphia Seaport Museum, Philadelphia	July 4, 2008	Research and problem-solving session on 21st century parking solutions	32 attendees representing 17 organizations and businesses

Delaware Direct Watershed Partnership Outreach Events				
Event Title:	**Location**	**Date:**	**Description**	**Result**
Green and Complete Streets River Conservation Plan Workshop #3	Penn Treaty Park, Philadelphia	July 31, 2008	research and problem solving session on green and complete streets	39 attendees representing 27 organizations and businesses
Healthy Neighborhoods River Conservation Plan Public Meeting #1	Center for Architecture, Philadelphia	12/4/2008	Rather than a traditional lecture format, the meeting plan provided for a series of activities and one-to-one discussions. The open house format allowed for drop in visitations over a several hour time frame.	Estimated 60 attendees from surrounding watershed and neighborhoods

2.2.3.4 Schuylkill Action Network (SAN)

The Schuylkill Action Network (SAN) was initiated in 2003 as a joint collaborative network supported by the US EPA, PADEP and City of Philadelphia along with numerous partners from throughout the Watershed.

The purpose of the Schuylkill Action Network is: *"To improve the water resources of the Schuylkill River Watershed by working in partnership with state agencies, local watershed organizations, water suppliers, local governments, and the federal government to transcend regulatory and jurisdictional boundaries in the implementation of protection measures."*
Although the City of Philadelphia has long been a leading supporter of the Schuylkill Action Network and an active partner in the events and activities taking place throughout this large drainage basin, the events and activities relevant to the portion of the watershed that lies within the City of Philadelphia are in their inception. The Environmental Committee of the Schuylkill River Development Corporation (SRDC) will be charged with reviewing the Integrated Watershed Management Plan associated with the in-City portion of the Schuylkill Watershed. Through the development of the goals and the implementation of the plan, the public participation events and activities will emerge.

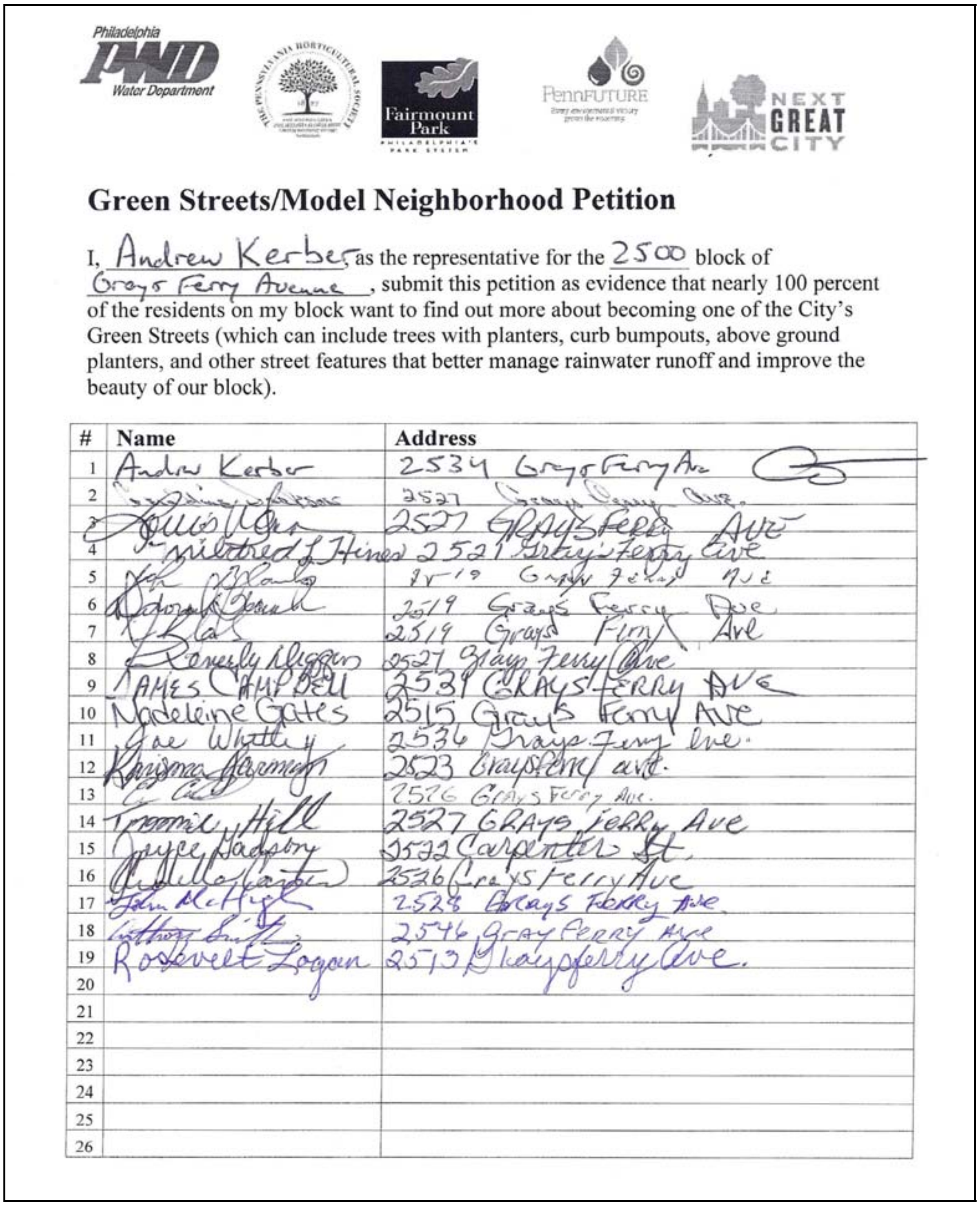
2.2.4 Existing Educational Programs

The PWD offers a variety of educational programs that target the residents of the City and upstream watershed partners.

2.2.4.1 Model Neighborhoods

In recent months, the PWD has seen the desire for green stormwater infrastructure rapidly evolve into a *demand* by residents of CSO-impacted areas. Through PWD's Model Neighborhoods initiative, PWD has received approximately 750 signatures to date (from March – July 2009), from residents petitioning for Green Streets. These residents want PWD to experiment with green stormwater infrastructure on their block, in order to serve as a model green neighborhood in the City. Currently, the demand for Green Streets is so high that it has exceeded PWD's capacity to implement them. This initiative is a true testament to the overwhelmingly positive response the City is receiving from its citizens, regarding green stormwater infrastructure. View Figure 2-5 for an example of a Green Streets/Model Neighborhoods Petition and view Supplemental Volume 1 for copies of the petitions received to date.

The Model Neighborhoods initiative is a new program (as of January, 2009). It is the result of the PWD partnership with Citizens for Pennsylvania's Future and the Next Great City coalition, Fairmount Park, Pennsylvania Horticultural Society and a diverse number of civic representatives, among other City department staff and environmentally-minded partners. The goal of the initiative is to transform the neighborhoods of Philadelphia into model green communities that manage stormwater in innovative ways. These neighborhoods will showcase green stormwater infrastructure elements, such as street tree trenches, sidewalk planters, and vegetated bump outs/curb extensions. The program is currently targeting four blocks in approximately fourteen willing neighborhoods in the City of Philadelphia, helping these communities become models for green stormwater infrastructure projects. The ultimate goal is to design projects that will manage stormwater runoff on one greened acre of each participating neighborhood. Design and construction of the green stormwater infrastructure elements will take place in the first year of the program for the first three targeted neighborhoods - Northern Liberties, Passyunk Square and Awbury/Cliveden.



Philadelphia Water Department | Fairmount Park | PennFUTURE | Next Great City

Green Streets/Model Neighborhood Petition

I, Andrew Kerber, as the representative for the 2500 block of Grays Ferry Avenue, submit this petition as evidence that nearly 100 percent of the residents on my block want to find out more about becoming one of the City's Green Streets (which can include trees with planters, curb bumpouts, above ground planters, and other street features that better manage rainwater runoff and improve the beauty of our block).

#	Name	Address
1	Andrew Kerber	2534 Grays Ferry Ave
2	[illegible]	2527 Grays Ferry Ave.
3	[illegible]	2527 Grays Ferry Ave
4	Mildred L. Hines	2521 Grays Ferry Ave
5	[illegible]	2519 Grays Ferry Ave
6	[illegible]	2519 Grays Ferry Ave.
7	[illegible]	2519 Grays Ferry Ave
8	Beverly Higgins	2527 Grays Ferry Ave.
9	James Campbell	2531 Grays Ferry Ave
10	Madeleine Gates	2515 Grays Ferry Ave
11	Joe Whitley	2536 Grays Ferry Ave.
12	[illegible]	2523 Graysferry ave.
13	[illegible]	2526 Grays Ferry Ave.
14	Tommie Hill	2527 Grays Ferry Ave
15	[illegible]	2532 Carpenter St.
16	[illegible]	2526 Grays Ferry Ave
17	John McHugh	2528 Grays Ferry Ave
18	Anthony Smith	2546 Gray Ferry Ave
19	Roosevelt Logan	2513 Graysferry Ave.
20		
21		
22		
23		
24		
25		
26		

Figure 2-5 Green Streets/Model Neighborhoods Petition

The Model Neighborhoods program requires a great deal of public outreach in order to generate public awareness and enthusiasm for green stormwater infrastructure components. The civic partners representing each neighborhood are pivotal to the success of each community, as they initiate the grass-roots civic engagement process that leads a neighborhood to become considered for this program. Table 2-16 lists the current Model Neighborhoods and partners.

Table 2-16 Model Neighborhoods and Civic Partners

Location	Civic Partner
Passyunk Square	Passyunk Square Civic Association
Awbury/Cliveden	Tookany/Tacony-Frankford (TTF) Watershed Partnership
Northern Liberties	Northern Liberties Neighbors Association
Pennsport	Pennsport Civic Association
New Kensington/ Fishtown	New Kensington CDC
Point Breeze	South Philadelphia Homes, Inc./ Newbold/Redevelopment Authority (RDA)
North Philadelphia	Associación Puertorriqueños en Marcha (APM)
Manayunk	Manayunk Development Corp/ Roxborough CDC
East Falls	East Falls Development Corporation
Lower Moyamensing	Lower Moyamensing Civic Association
Cobbs	Cobbs Creek CDC
Haddington	Haddington CDC
Gray's Ferry	South of South Neighborhood Association (SOSNA)
Allegheny West	Allegheny West Civic

A number of Model Neighborhoods educational materials and programs have been developed with additional outreach tools currently in production. Fairmount Park has led a series of free walks in the Model Neighborhoods, titled "Tree Walk on Your Blocks" in Northern Liberties, Passyunk Square and Awbury/Cliveden. They have also offered a free summer environmental education program for children in Model Neighborhoods titled, H2O & You, Trees are Terrific and Steppin into Nature. By September, 2009, these summer programs are projected to reach approximately 1,175 children, along with 91 adults, in the first three targeted Model Neighborhoods - Northern Liberties, Passyunk Square and Awbury/Cliveden. Fairmount Park has also produced a number of informational fact sheets and handouts, regarding tree care and maintenance. View Table 2-13 for examples of the Model Neighborhoods education materials and Supplemental Volume 1 for all materials.

PWD has developed a Model Neighborhoods overview brochure, informational handouts on trees and laterals, along with other outreach materials (See Table 2-17). Photo simulations of green stormwater infrastructure elements have been created for each of the first three neighborhoods - Northern Liberties, Passyunk Square and Awbury/Cliveden. The photo simulations depict a street before and after the implementation of green stormwater infrastructure projects, providing strong visuals to help residents better visualize a Green Street in their neighborhood. PWD is also currently working on creating a Model Neighborhoods Kit. The kit will serve as an orientation packet for Model Neighborhoods civic partners, including an array of materials to best prepare civic leaders reaching out to residents for Model Neighborhoods support. View Figure 2-6 for an example Green Street photo simulation and Supplemental Volume 1 for other simulations.

Before

After

Figure 2-6 Example of Model Neighborhoods Photo Simulation Set (3rd and Brown Streets, Northern Liberties)

Table 2-17 Examples of Model Neighborhoods Educational Materials

Model Neighborhoods Educational Materials			
Three Typical Stormwater Management Project		Sidewalk Trees and House Sewer Laterals	
Model Neighborhoods Brochure		Street Trees in Philadelphia Background Information	
Model Neighborhoods Tree Walk on your Block		Summer Outreach Programs for Camps	
Philadelphia Street Trees		Before and After Photo Simulation	

2.2.4.1.1 PENNVEST

The City of Philadelphia was approved for a $30 million loan administered by PENNVEST (Pennsylvania Infrastructure Reinvestment Authority) in April, 2009. These funds are dedicated to the implementation of innovative, green stormwater infrastructure projects throughout Philadelphia. PENNVEST funds will cover the cost of the first year of Model Neighborhoods projects, along with installation of green stormwater infrastructure in conjunction with PWD's planned water and sewer replacement work, along with interagency cooperation with Streets Department to identify opportunities for green streets implementation within the CSS drainage area.

2.2.4.2 Green Neighborhoods through Green Streets Survey

"How beautiful everything is! 100% behind this effort in all ways!"

- Response on the Philadelphia Water Department's "Green Neighborhoods through Green Streets Survey." The question asked, "*Are you in favor of greening?"*

PWD developed a qualitative survey titled, Green Neighborhoods through Green Streets. The purpose of the survey is to understand how the targeted audience (City residents) feels about green stormwater infrastructure elements, such as Green Streets (*e.g.*, likes and dislikes), and to get the survey-taker to start thinking about green stormwater infrastructure in Philadelphia neighborhoods through images, therefore making the survey an educational tool, as well as serving as qualitative research. View Figure 2-7 for sample question from Green Neighborhoods through Green Streets Survey.

Over ninety-two percent of the 734 survey responses to date are in favor of a green stormwater infrastructure-based approach. A longer on-line survey was posted on City and partner websites, in addition to a PWD - hosted Facebook page, partner sites and other websites. Representatives from every zip code in the City (except for one) participated in the survey. View Tables 2-18 and 2-19 for sample survey results (March – August, 2009) and view Supplemental Volume 1 for all survey results and the Green Neighborhoods through Green Streets (complete) Survey.

1. After viewing each set of images below, are you in favor of greening in your neighborhood?

□ Yes
□ No

a) What do you like about the images?

b) What don't you like about the images?

Figure 2-7 Green Neighborhoods through Green Streets Survey Sample Question (Images from Wallace Roberts & Todd, LLC)

Table 2-18 Green Neighborhoods through Green Street Survey - Popular Responses

Green Neighborhoods through Green Streets Survey – Popular Responses			
	On-line	**Hardcopy**	**Overall**
Likes	Most respondents stated that they were in favor of greening. Popular quotes: “trees and plants add beauty to the block” and “it makes the neighborhood more safe and more inviting”	Respondents generally are in favor of greening. Popular quotes: “we want more trees” and “greening makes the block more attractive”	92% responded positively towards greening 15% specifically mentioned that greening will “beautify” the neighborhood 14% specifically stated that they “want more trees” + “liked/loved trees”
Dislikes	Most popular comments: “who will maintain this?” and “limited space available for greening on some sidewalks”	Most popular concerns: “trash and foliage come with greening” and “damage to sidewalks, home foundations or pipes due to tree roots”	23% of the respondents are worried about maintenance-related issues 60% have concerns about greening
Total Responses	438	296	734 (Total)

Table 2-19 Green Neighborhoods through Green Streets Feedback

Survey Quotes
Amazing; I think it's a no-brainer!
Bring it on... beautifying the neighborhoods, making better use of public space -- brings communities together, etc.
Greening makes the world a better, happier place.
All of it. More trees & green!
How beautiful everything is! 100% behind this effort in all ways!
I LOVE IT - what a great plan!
I love the idea! Please give us a greener Philadelphia. It would make us healthier and happier all around.
I strongly support it. In addition to what it does for storm water, it's prettier, shadier, and people are less likely to throw trash on it.
Yes, yes, a thousand times yes! We need more street trees. The corner bump-outs with trees would be WONDERFUL for overall look-and-feel in the neighborhoods (and the traffic calming benefits would be nice as well. I'm not sure where the second set of photos is, exactly, but it would be a nice improvement.
Love that there would be shade along the sidewalk, especially during the summer months when I am walking with my kids. The trees and green areas make the places seem more welcoming. And the fact that it would help with stormwater runoff is a real plus!
I LOVE THE GREEN NEIGHBORHOODS... GOOD ENERGY...A VIBRANCY... A POSITIVE FEEL!
"AFTER" images - the street views look fresher & softer; more friendly & vibrant. They indicate a community where the residents are glad to be living.
Things are prettier, more sustainable, shows community pride, [and] make the City beautiful.
Everything!!! Increase worth of home, cleaner air, calmer environment, shade in the summer.
What’s not to like? It’s a no-brainer.
I love plants, trees and greenery. I feel more at peace near nature.
I’m a big greening advocate do I’m totally on-board with all of these project proposals.
This work needs to be done in all neighborhoods.

2.2.4.3 Facebook

The PWD has a Facebook page and Facebook wall dedicated to the *Green City, Clean Waters* program (Figure 2-8). Facebook (a free-access social networking website) enables PWD to reach out to an audience that may otherwise not choose to become familiarized with its programs. Friends abound on PWD's *Green City, Clean Waters* Facebook wall, where approximately 200 members can find public meeting announcements, view images of Green Streets and where visitors can leave comments on the City's green stormwater infrastructure approach. The Facebook page also hosts the Green Neighborhoods through Green Streets survey. . To access PWD's Facebook page, visit http://www.facebook.com/green.cities.clean.waters. View Supplemental Volume 1 to view images of the Facebook page and wall.

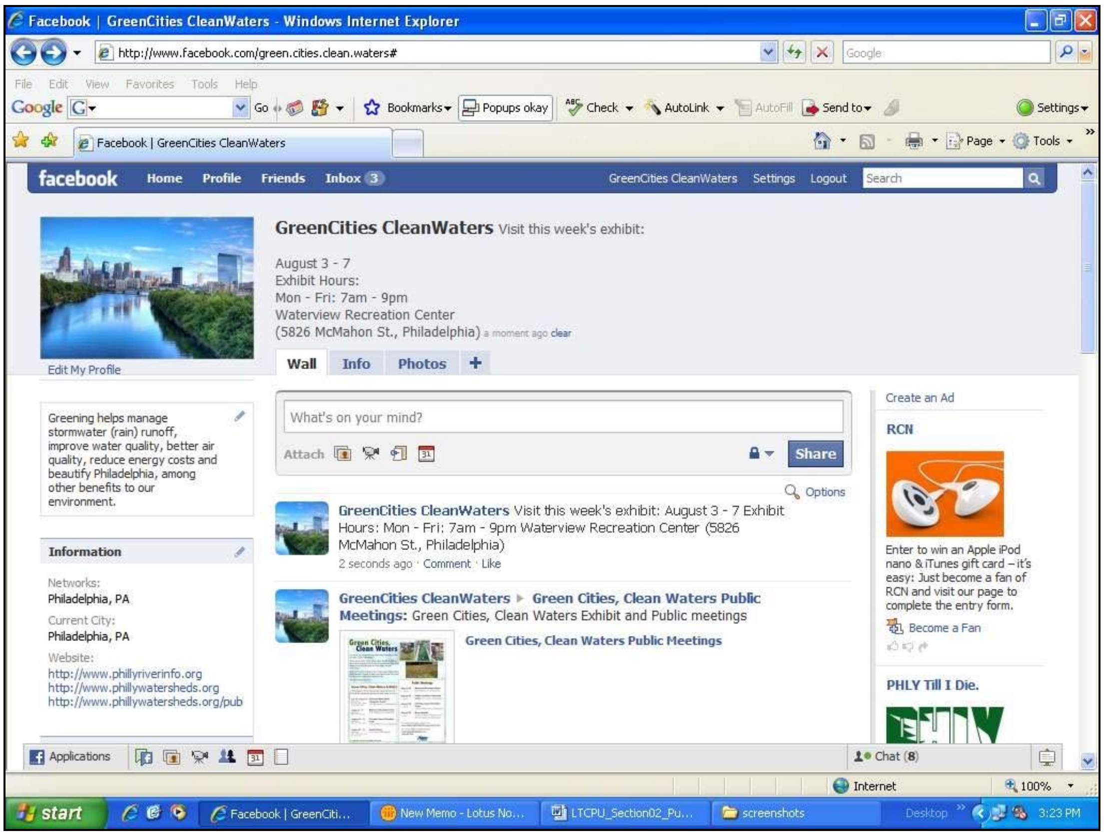


Figure 2-8 Facebook Screenshot

2.2.4.4 Watershed Partnership Story

A Watershed Partnership Story is in the process of being developed to tell the story of the watershed partnership approach through a short presentation, geared to different audiences, such as a municipal audience or environmentally-minded audience. This presentation will provide PWD with an opportunity to relay its watershed management and partnership messages in a short, yet visual manner, while also serving to connect with potentially new partners as well.

2.2.4.5 Green Stormwater Infrastructure Tours

The PWD regularly offers tours to highlight local examples of green stormwater infrastructure. Table 2-20 lists the tours held in 2008 and 2009.

Table 2-20 Green Stormwater Infrastructure Tours

Date	Event	Number of Attendees	Description
April 6, 2008	Historic Mill Creek Watershed Tour	35	As part of a larger tour organized for a University of Pennsylvania landscape architecture class that focused on the Mill Creek Watershed, students toured the Mill Creek Farm, Mill Creek Playground, Sulzberger Outdoor Classroom, Blackwell Homes, and Penn-Alexander School.
May 3, 2008	Clean Water, Green City Tour	20	Presented with White Dog Café, a tour to highlight projects that link environmental vision with economic health, and quality of life with the sustainability of our City. Sites included Waterworks Interpretive Center, Awbury Arboretum, Saylor Grove, and Penn-Alexander School.
Sept. 10, 2008	Philadelphia Green Infrastructure Tour	10	Organized for a group from New York City Parks, Conservation District, and Dept. of Environmental Protection, sites included Wissahickon Charter School, Waterview Recreation Center, Cliveden Park, Saylor Grove, and Allens Lane Arts Center.
Oct. 3, 2008	GreenPlan Philadelphia Tour	45	Organized as part of the American Society for Landscape Architects national conference, the tour highlighted several greening and vacant land management sites that integrated stormwater management, including Liberty Lands, N. 3rd Street Corridor, and North Central Philadelphia vacant land stormwater management sites.
May 5, 2009	Historic Mill Creek Watershed Tour	35	As part of a larger tour organized for a University of Pennsylvania landscape architecture class that focused on the Mill Creek Watershed, students toured the Mill Creek Farm, Mill Creek Playground, Blackwell Homes, Penn-Alexander School, and Clark Park.
June 10, 2009	US EPA National Stormwater Coordinators Meeting Tour	40	As part of a national US EPA meeting, the tour illustrated PWD's green infrastructure program and highlighted innovative projects and partnerships. Sites included Liberty Lands, Thin Flats, Greensgrow Farm, model neighborhoods (Northern Liberties, New Kensington, and APM), Saylor Grove, and Wise's Mill.

2.2.4.6 Water Quality Council

The Water Quality Council is made up of a diverse group of individuals concerned about water quality and watershed issues. The council is comprised of private citizens, representatives from watershed non-profit groups, Friends groups, and city and state representatives. The Water Quality Council has been meeting since 1995. Currently, the council members meet approximately four times per year. The council members meet to learn about current innovative PWD projects from PWD staff and about other environmentally-related issues from local watershed leaders. Most importantly, however, the meetings provide an opportunity for the PWD staff and other watershed leaders to hear from the council members (who represent the public) about their concerns. These meetings also enable the members to explore opportunities to collaborate with the Department on projects in their respective watersheds. In turn, PWD gets valuable feedback from the council members on PWD's emerging projects and initiatives and gets to hear directly from the council members on what the needs of the local representatives are in the City.

2.2.4.7 Storm Flood Relief

Since 2005, the PWD has been planning for storm relief in neighborhoods where basement backups are occurring. This Storm Flood Relief Program involves revamping the City's sewer system to reduce future waste water basement backups. Property owners in South Philadelphia, Northern Liberties, Washington Square West and Kensington have complained of basement backups, mainly between 2005 through 2006 – a period of intense rain fall. This program was developed in response to these complaints. Although the PWD has been meeting with the public since 2005 on Storm Flood Relief, Table 2-21 lists the Storm Flood Relief public meetings that were held as of January, 2008 – when the Storm Flood Relief Program public meetings overlapped with the targeted CSO LTCPU Public Participation Program.

Table 2-21 Storm Flood Relief Meetings

Meeting	Date	Place
So. Philly Storm Flood Relief (SFR)	April 24, 2008	Maria Goretti HS
Columbus Square	October 27, 2008	Columbus Square Rec Center
Washington West SFR	October 29, 2008	Jefferson Hospital
Passyunk Civic SFR	April 7, 2009	Passyunk Civic Meeting Site
Washington Ave. SFR	May 6, 2009	Washington Ave. Meeting Site
Washington Ave. SFR	May 28, 2009	Italian Market

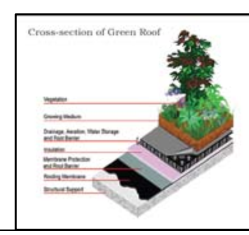
2.2.5 Public Information

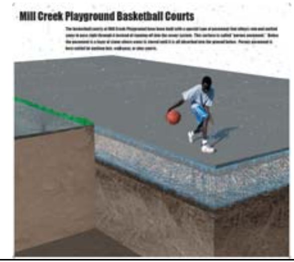
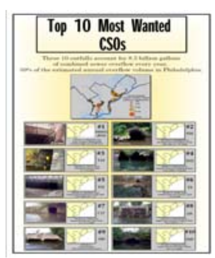
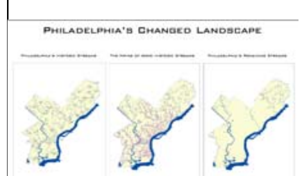
In recognizing that active citizen engagement in Philadelphia is critical to the success of the LTCPU, the PWD targets the residents of the City and upstream the watershed partners in a variety of public forums to foster public awareness and facilitate public involvement.

2.2.5.1 Green City, Clean Waters Information Fair

A *Green City, Clean Waters* Information Fair was displayed during select public meetings. The Fair included a table-top display with posters on CSO LTCPU-related projects, fact sheets on projects designed and/or implemented by PWD to address CSO discharges, other educational materials and a demonstration rain barrel. Table 2-22 lists samples of the materials from the *Green City, Clean Waters* Information Fair. View Supplemental Volume 1 for all Information Fair materials.

Table 2-22 *Green City, Clean Waters* Information Fair Materials

Green City, Clean Waters Information Fair Materials				
Backgrounder (enhanced fact sheet): The CSO Long Term Control Plan - History and Background			Illustration: Green Roof Cross-Section	
Fact Sheet: Tacony Creek Storage			Illustration: Venice Island's Green Roof Pumping Station	

Green City, Clean Waters Information Fair Materials			
Fact Sheet: Waterways Restoration Team		Mill Creek Recreation Center's Porous Basketball Court –	
Fact Sheet: Real Time Control Center		Poster: Rain Barrels	
Fact Sheet: Main Relief		Fact Sheet: Marshall Road Creek Restoration	
Fact Sheet: Penn Alexander's Stormwater Management BMPs		Guide: Saylor Grove Stormwater Wetland Tour Guide	
Brochure: Floatables Skimming Vessels		Poster: Top 10 CSO's of Philadelphia	
Guide: Homeowner's Guide to Stormwater Management Manual		Poster: Philadelphia's Changing Streams	

2.2.5.2 Green City, Clean Waters Exhibit

The LTCPU Public Participation Team developed a one-of-a-kind informational exhibit and art exhibit. The two shows made up the *Green City, Clean Waters* Exhibit, which were displayed at the Fairmount Water Works Interpretive Center (in Philadelphia) for approximately one month (October 10, 2008 – November 7, 2008). The purpose of the combined exhibit was to unite art with educational information on CSO controls in order to raise awareness on the LTCPU. The goal of this approach was to target a new audience and to capture the attention of the general public through art, providing a gateway to the informational displays.

While the *Green City, Clean Waters* Exhibit was displayed at the Fairmount Water Works Interpretive Center, over a month-long period, roughly 992 visitors had a direct experience with the artwork and the messages portrayed through the informational displays. The exhibit also received media coverage on the local television CBS News affiliate and in local newspapers, such as the Philadelphia Inquirer and the City Paper, in addition to other media (See Supplemental Volume 1 for media coverage documentation and month-long sign up sheet.)

The artistic component of the exhibit was comprised of artwork (photography and jars) from artist and educator, Bill Kelly. Mr. Kelly specializes in depicting nature in an urban context. He was commissioned to interpret the *Green City, Clean Waters* program through an artistic eye. Bill Kelly used recycled mason jars, filled with water, plants and photography to interpret the CSO LTCPU. The unique exhibit also included photographs of the jars. His work was funded through a Coastal Non-Point Pollution Program grant through the Pennsylvania Department of Environmental Protection's Coastal Zone Management Program and the National Oceanic and Atmospheric Administration (NOAA). (See Figure 2-9, Figure 2-10 and Supplemental Volume 1. for examples of Bill Kelly's artwork).

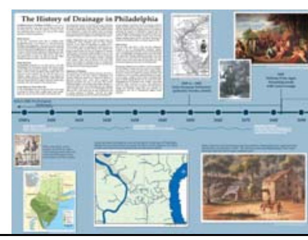
The informational component of the exhibit was made up of a variety of posters that relayed CSO-related and watershed-related information, in addition to displaying a rain barrel. The informational posters are also currently circulating throughout the City, drumming up excitement for the final round of public meetings in August, 2009 (View Table 2-10 for the traveling exhibit locations). The informational posters are listed in Table 2-23. (See Supplemental Volume 1 for examples of the informational posters).

An artist reception was held on October 16, 2008, at the Fairmount Water Works Interpretive Center, to celebrate the opening of the *Green City, Clean Waters* Exhibit. The reception also gave the Public Participation Program Team an opportunity to discuss the material behind the informational posters (the CSO LTCPU) with the attendees. Approximately 77 individuals attended the artist reception. (See Supplemental Volume 1 for reception invitation flyer and reception sign-up sheet.)

Figure 2-9 Sample of Bill Kelly Art

Figure 2-10 Sample of Bill Kelly Art

Table 2-23 ***Green City, Clean Waters*** **Exhibit Informational Posters**

Green City, Clean Waters **Exhibit Information Posters**	
Green City, Clean Waters ~ PWD's Combined Sewer Overflow Long Term Control Plan (an introduction to the CSO LTCPU)	
History of Drainage in Philadelphia (historical timeline)	
What the City and its Partners are Doing (examples of local demonstration projects that manage stormwater through "green" approach)	
What You Can Do (examples of projects property owners can take on to manage stormwater in environmentally-friendly manners	

2.2.5.3 Fairmount Water Works Interpretive Center

The Fairmount Water Works Interpretive Center (FWWIC) is PWD's renowned education center, located on the banks of the Schuylkill River in Philadelphia. The Center tells the story of the Schuylkill River and its human connections throughout history. Innovative exhibits and interactive educational programs meld the history, technology and science, providing education on the many issues facing the regions' urban watersheds.

The mission of the Center is to: *"educate citizens to understand their community and environment, especially the urban watershed, know how to guide the community and environment in the future, and understand the connections between daily life and the natural environment."*

Since opening its doors in October, 2003, the FWWIC has seen over 150,000 visitors tour the center, participate in its programs, sign up for educational events and online updates.

During a typical week, the FWWIC hosts 450 visitors, three school groups (elementary or middle school classes), two independent organizations (charter school, community centers), and two special events (evening with a visiting environmental author or lecturer, weekend film preview, *e.g.*, Liquid Assets).

In 2008, approximately 37,177 individuals visited the FWWIC. The breakdown of visitors is listed in Table 2-24.

Table 2-24 2008 Fairmount Water Works Interpretive Center Visitors

2008 Fairmount Water Works Interpretative Center Visitors	
School Groups	113 classes, totaling 6,843 students
Teacher Trainings	3 multi-day workshops with 33 teachers
Summer Camps	24 multi-day summer camps with 851 environmental campers
Special Exhibits	6 multi-month exhibits, including the *Green City, Clean Waters* CSO Long Term Control Plan Update Exhibit
New Programs	9 events, including the World Water Day Celebration
Visiting Authors, Lecturers, Environmental Leaders	4 new education programs, including "Seeing is Believing: A Drop in the Bucket," a career- based laboratory program for high school students
Community Programs	70 community programs, reaching 4,739 individuals
General Visitors	18,985
2008 Total Visitors	**37,177**

2.2.5.4 Stormwater Best Management Practices (BMP) Recognition Program

In 2005, PWD and partners developed the Stormwater Best Management Practices (BMP) Recognition Program to recognize developers, engineers, architects, and others that are designing and implementing innovative and environmentally-friendly stormwater Best Management Practices (BMPs) in southeastern Pennsylvania. Projects, such as rain gardens, green roofs, infiltration swales, and treatment wetlands - stormwater management systems based on nature's best designs are recognized to provide inspiration for future similar projects in the region. The number of submissions has grown steadily every year. Approximately eighty submissions have been received to date. The awaredees are listed in Table 2-25 –Stormwater BMP Recognition Program Awards.

A certificate is distributed to each awardee to recognize their good work. Each certificate recipient is also provided with an opportunity to present their awarded project at an event, such as the Urban Watersheds Revitalization Conference. The recognized projects are also promoted in the PWD Water Wheel (newsletter), distributed to over a half million residents and businesses in Philadelphia and on the website (http://www.stormwaterbmp.org).

Table 2-25 Stormwater BMP Recognition Program Awards

Stormwater BMP Recognition Program Awards	
Awardee	**Project**
AD Marble & Company	Evaluation of Potential Improvements within the Cobbs Creek Corridor: Marshall Road to Cobbs Creek Golf Club
Andropogon Associates & Friends of Wissahickon	Valley Green ~ Environmental Restoration Program
Andropogon Associates, Ltd.	Thomas Jefferson University Plaza
Awbury Arboretum Association	Awbury Arboretum Watershed Restoration Project
Cahill Associates	Porous Asphalt Parking Lot for the Morris Arboretum, University of Pennsylvania
	John Heinz National Wildlife Refuge at Tinicum
	Innovative Stormwater Management and Education at the K-8 Penn-Alexander School
	Demonstration of Innovative Stormwater Management Using Porous Pavement and Rain
	Gardens in an Urbanized Setting (Wayne Art Center)
Cheltenham Township	Leaf Leachate Stormwater Management Waverly Road Leaf Composting Facility
Community Design Collaborative	Haven in the Goodlands
	Overbrook Environmental Education Center
CSA Group, Inc.	School of the Future
Fairmount Park Commission	Monastery Stables Runoff Control Project
Friends Center Corporation	Friends Center Urban Water Management
F.X. Browne, Inc.	Stony Creek Farms Age-Qualified Residential Development
	F.X. Browne Constructed Stormwater Wetland
Gladnick Wright Salameda	Swarthmore College Science Center
Gilmore & Associates	Chatham Financial Corporate Headquarters
Green Valleys Association	Porous Parking & Bioretention
Hunt Engineering Company	Smith Memorial Playground
Interface Studio LLC	Sheridan Street Housing
	Third Street Condominiums
Johnson & Johnson	Pharmaceutical Research and Development Spring House Road Property
Kling	Ortho McNeil Springhouse
	Centocor Horsham
Lower Merion Environmental Advisory Council	Riverbend Environmental Education Center
Lower Merion Township	Aqua America Headquarters
Lower Providence Township	Image
Onion Flats	Rag Flats
Pennoni Associates, Inc.	3925 Walnut Street Mixed Use Facility

Stormwater BMP Recognition Program Awards	
Awardee	**Project**
Pennsylvania Horticultural Society	Tree Vitalize
	Models for Stormwater Management on Vacant Land
Roofscapes, Inc. (Lifetime Achievement Award)	Philadelphia Fencing Academy
The Enterprise Center Community Development Corporation	The Plaza at Enterprise Heights
The Schuylkill Center for Environmental Education	Green Roof Installation
Upper Darby Township and Cahill Associates	Second Ward Park
Upper Perkiomen High School (UPHS)	UPHS Stormwater BMPs
Upper Providence Township	Black Rock
UC Green	Lower Mill Creek Stormwater Management Demonstration Garden
Ursinus College Environmental Studies Program	Design of an Extended-detention Wet-pond Retrofit for Ursinus College
Villanova University Stormwater Partnership	Villanova University Bioinfiltration BMPs
Wallace, Roberts & Todd, LLC	Mill Creek Hope VI Project
Warrington Environmental Advisory Committee	Igoe, Porter, Wellings Memorial Field
Wissahickon Charter School	Harmony Garden
Wissahickon Valley Watershed Association	Sandy Run

2.2.5.5 Urban Watersheds Revitalization Conference

"The conference was one of the best I've been to in 25 years. Such a wide cross-section of people but all of us focused on the same city-improving agenda. Thanks for your efforts in making it happen."

- Comment from 2008 "Greening Our Streets" Conference participant

Since 2005, the PWD, along with its partners, has hosted an annual conference, titled the Urban Watersheds Revitalization Conference. The event gives PWD an opportunity to explore current watershed-related themes that are relevant to the City of Philadelphia and the suburban communities that drain to the City. The conference is held at different locations every year and it targets the urban and suburban (or mostly developed) communities in southeastern Pennsylvania. The audience is diverse – comprised of local planners, engineers, municipal representatives, community activists, among others. The event is offered at a nominal fee or it is free of charge.

Details on the conferences held in the past two years are listed in Table 2-26. Flyers may be viewed in Supplemental Volume 1.

Table 2-26 2007 & 2008 Urban Watersheds Revitalization Conference

Urban Watersheds Revitalization Conference		
Conference Theme:	Greening Our Streets	Stormwater Management Regulations & Requirements
Date:	October 31, 2008	May 3, 2007
Time:	8:30am - 3:30pm	8:30am - 3:30pm
Location:	The Great Hall, Community College of Philadelphia, Spring Garden Street, Philadelphia	Kanbar Center, Philadelphia University, School House Lane, Philadelphia
Number of participants:	175	131
Result:	Many participants remarked on it being a very successful conference (see above quote).	Feedback from the participants was positive.
Promotional Material:	View Supplemental Volume 1	View Supplemental Volume 1

2.2.6 Floatables Control Outreach ~ Skimming Vessel and Pontoon Vessel

The reduction in floatables on the Schuylkill and Delaware Rivers in Philadelphia improves both water quality and aesthetics. The use of a skimmer vessel and pontoon vessel allows for mobile control programs capable of managing debris at various locations, increasing the effectiveness of this control measure. In addition, the boats are visible controls, therefore increasing public awareness and education of the impacts of floatables.

The vessels are used for clean up and serve as public relations tools at local events on the river, such as the Schuylkill Regatta, an annual sailing event. For more details on the performance of the vessels, please refer to Section 1 and Section 10 of this report.

The skimming vessel participated in several public events during 2007 and 2008. In addition to cleaning the tidal portions of the Delaware and Schuylkill Rivers, the PWD plans to continue to use the skimming vessel as a tool for public awareness and outreach.

In 2007 and 2008, the vessel participated in the following events, by conducting clean-ups while these outdoor activities occurred:

- Demonstrations for students on the Schuylkill River (2007)
- Coast Day (2007)
- 4th of July (2007)
- Dedication Ceremony of the new fireboat, Independence (2007)
- Penn's Landing Safe Boating Day (2008)
- Fairmount Water Works Shad Tour (2008)
- Maritime Charter School (Frankford Arsenal Dock Demonstrations) (2008)
- Bartram Gardens Dock (Demonstration for Teachers) (2008)

The pontoon vessel also participated in public events in 2008, including the Philly Spring Clean-Up and the Earth Day Clean-Up at Lloyd Hall. Public awareness is one of the many benefits resulting from the work conducted by the vessels.

2.2.7 Signage, Websites & Informational Materials

2.2.7.1 CSO Outfall Notification Signage

The PWD produced CSO outfall notification signs to educate the public of the potential hazards associated with primary contact with creeks and rivers during and shortly after wet weather events. The signs (Figure 2-11) were placed at outfalls that are accessible by the public. In addition to warning the public, the text in the signs state that the PWD be notified if overflows occur during dry weather (an emergency call –in number is provided on the sign). The text is in English and Spanish.

CSO Outfall Notification Signage Text:

No Swimming at Any Time
Sewer Overflows

During and immediately after rain, polluted water flows from these pipes or nearby pipes. To protect your health, do not come in contact with rivers and streams during this time.

For more information on how to protect our waterways, visit www.phila.gov/water.

Please report flows from pipes during dry weather to PWD's Hotline: 215-685-6300.

Figure 2-11 CSO Outfall Notification Signage

The CSO Outfall Notification Signage was a pilot project aimed at determining if outfall signs were a feasible way to accomplish public notification of combined sewer overflows. The PWD, in conjunction with the Fairmount Park Commission, installed thirteen signs at CSO outfalls in the City. Locations for placement of the signs were selected based on factors such as high visibility, known recreational areas, and volume of the combined sewer overflow. Installation of the CSO signs was conducted in the summer of 2007 and a survey of the sites was completed in October, 2007. During this survey, each of the sites where the CSO signs were installed was visited and photos were taken to document the status of the signs that were installed. The survey of the sites determined that several of the signs were removed or vandalized. Of the thirteen signs that were installed, five of them were vandalized or removed during the short amount of time between installation and the survey. Although signs are seen as a simple, low-cost, visual way to raise awareness of Combined Sewer Overflows, this pilot project has highlighted the difficulties in using signs as a public notification system in Philadelphia due to the poor sustainability (See Figure 2-12 and Figure 2-13).

Figure 2-12 Vandalized CSO Notification Sign

Figure 2-13 Missing CSO Notification Sign

2.2.7.2 CSO Identification Signage

The PWD also produced CSO identification signs, which were installed at each of the City's CSO outfalls, with the exception of eight sites that were difficult to reach. The identification signs include an outfall ID number (See Figure 2-14). The identification signs are useful when the public is reporting a problem at an outfall, as they are able to accurately identify the outfall due to this signage. The identification sign helps alleviate communication problems between the public and the PWD responders. Unlike the CSO Notification Signage, the CSO identification signs have not been vandalized

Figure 2-14 CSO Identification Signage

2.2.7.3 Websites

The PWD created multiple websites as educational tools dedicated to watershed management. A CSO LTCPU website was also created and devoted exclusively to CSO issues. View Section 2.24 for the *Green City, Clean Waters* Facebook page and wall.

2.2.7.3.1 PhillyRiverInfo

http://www.phillyriverinfo.org

As presented in Section 1, this website offers detailed information on Philadelphia's watersheds and partnerships. The website offers resources to the public including educational material and announcements of upcoming watershed-related events and projects (See Figure 2-15). The PhillyRiverInfo site also allows residents of 10 counties in Southeastern Pennsylvania to find their watershed from one of the seven that drains to Philadelphia by typing in their street address.

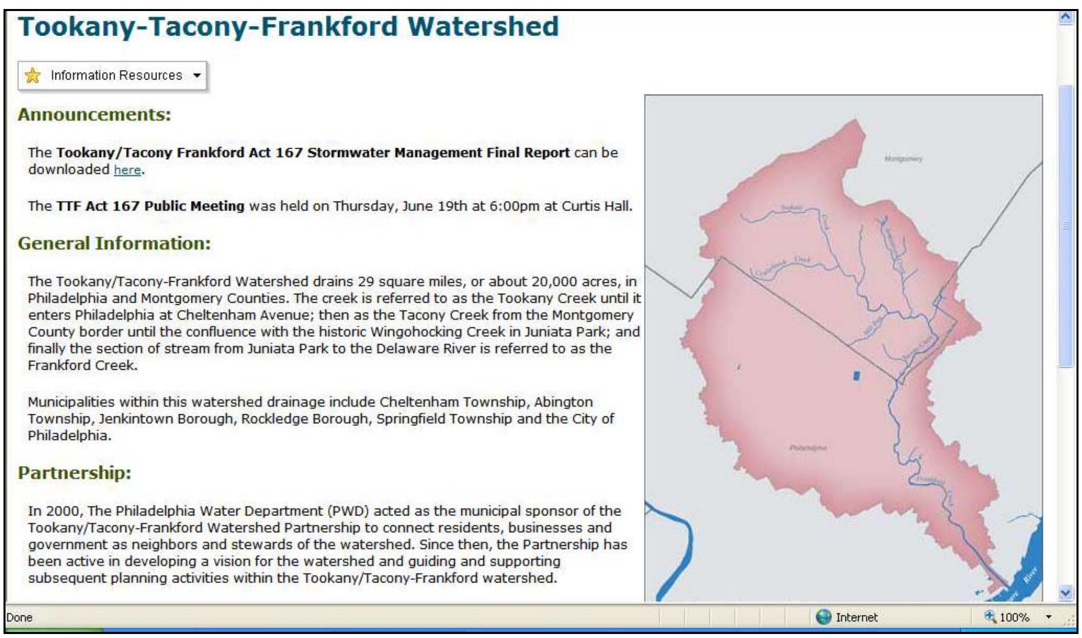


Figure 2-15 Example of public information on PhillyRiverInfo

2.2.7.3.2 Green City, Clean Waters (CSO Long Term Control Plan Update)

http://www.phillyriverinfo.org/csoltcpu

An offshoot of PhillyRiverInfo, this website focuses exclusively on the *Green City, Clean Waters* Program (CSO Long Term Control Plan Update) (See Figure 2-16). One can find details on the nature of CSOs, the LTCPU, the history of CSOs, and public events, among other CSO-related information.

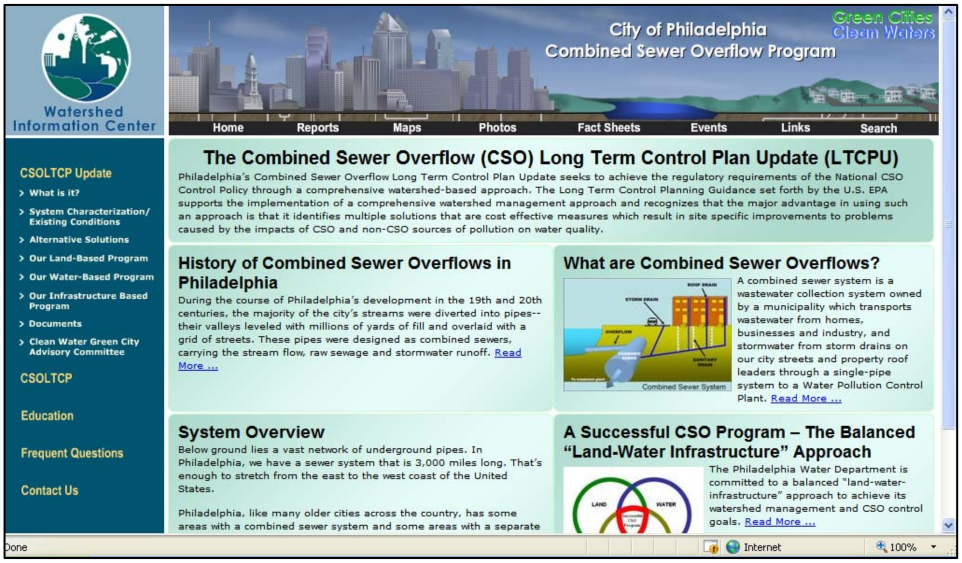


Figure 2-16 ***Green City, Clean Waters*** **(**LTCPU**) Website**

2.2.7.3.3 RiverCast

http://www.phillyrivercast.org

As described in Section 1, The Philly RiverCast is a forecast of water quality that predicts potential levels of pathogens in the Schuylkill River between Flat Rock Dam and Fairmount Dam (*i.e.*, between Manayunk and Boathouse Row). One would visit this site to find out the daily RiverCast prediction and to learn more about water quality (See Figure 2-17).

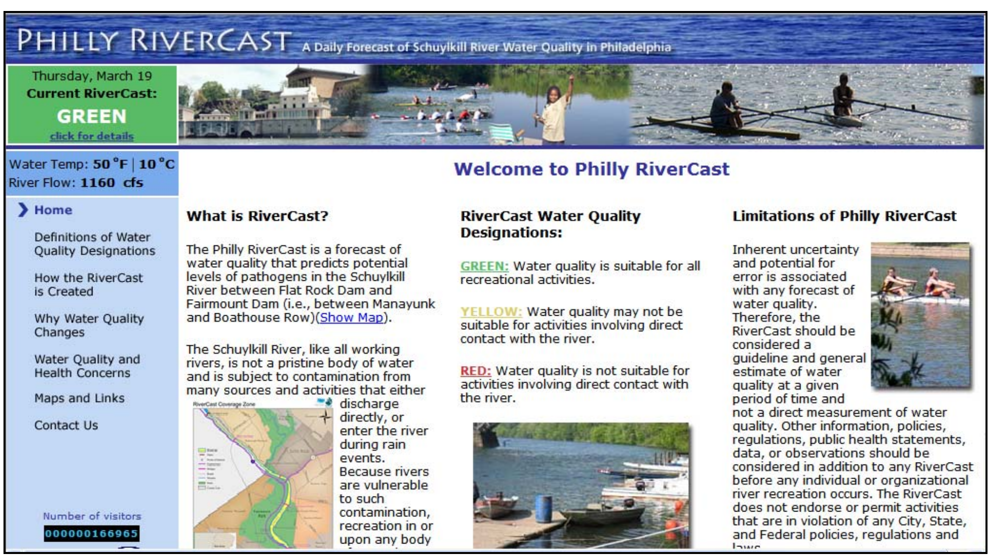
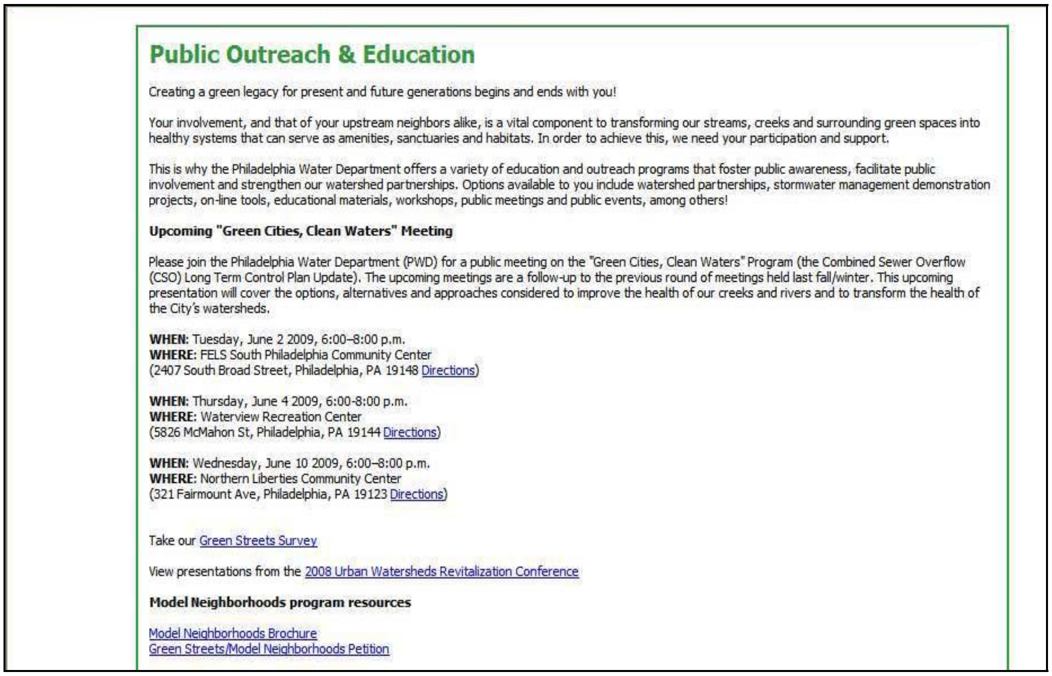


Figure 2-17 PWD's RiverCast Website

2.2.7.3.4 Public Outreach & Education

http://www.phillywatersheds.org/public

This website is dedicated to promoting PWD's educational programs and opportunities (See Figure 2-18). Options available include watershed partnership projects, educational materials, public meeting and event announcements, among others.



Public Outreach & Education

Creating a green legacy for present and future generations begins and ends with you!

Your involvement, and that of your upstream neighbors alike, is a vital component to transforming our streams, creeks and surrounding green spaces into healthy systems that can serve as amenities, sanctuaries and habitats. In order to achieve this, we need your participation and support.

This is why the Philadelphia Water Department offers a variety of education and outreach programs that foster public awareness, facilitate public involvement and strengthen our watershed partnerships. Options available to you include watershed partnerships, stormwater management demonstration projects, on-line tools, educational materials, workshops, public meetings and public events, among others!

Upcoming "Green Cities, Clean Waters" Meeting

Please join the Philadelphia Water Department (PWD) for a public meeting on the "Green Cities, Clean Waters" Program (the Combined Sewer Overflow (CSO) Long Term Control Plan Update). The upcoming meetings are a follow-up to the previous round of meetings held last fall/winter. This upcoming presentation will cover the options, alternatives and approaches considered to improve the health of our creeks and rivers and to transform the health of the City's watersheds.

WHEN: Tuesday, June 2 2009, 6:00–8:00 p.m.
WHERE: FELS South Philadelphia Community Center
(2407 South Broad Street, Philadelphia, PA 19148 Directions)

WHEN: Thursday, June 4 2009, 6:00-8:00 p.m.
WHERE: Waterview Recreation Center
(5826 McMahon St, Philadelphia, PA 19144 Directions)

WHEN: Wednesday, June 10 2009, 6:00–8:00 p.m.
WHERE: Northern Liberties Community Center
(321 Fairmount Ave, Philadelphia, PA 19123 Directions)

Take our Green Streets Survey

View presentations from the 2008 Urban Watersheds Revitalization Conference

Model Neighborhoods program resources

Model Neighborhoods Brochure
Green Streets/Model Neighborhoods Petition

Figure 2-18 Public Outreach and Education Website

2.2.7.3.5 CSOcast

http://www.phillywatersheds.org/csocast

The CSOcast is PWD's latest effort in demonstrating the overflow status of the City's 164 Combined Sewer Outfalls. CSOcast informs the public whether CSOs are occurring or are suspected to have occurred within the last 24 hours (See Figure 2-19). It is updated twice daily with information from PWD's extensive sewer monitoring network.

Phillywatersheds.org
CSOcast
Rain Barrel Workshops
Find Your Watershed

Philadelphia Combined Sewer Overflow Public Notification System

The purpose of this notification system is to alert the public of possible Combined Sewer Overflows (CSOs) from Philadelphia's combined sewer system outfalls.

Background

During dry weather, the combined sewer system and waste water treatment plants have the capacity to transport and treat all the sanitary sewage entering the system. However, when flow in the sewer increases as a result of rainfall and/or snowmelt, the treatment plants may reach their capacity. When system capacity is reached, the sewer system allows for combined sewage to discharge to nearby waterbodies from CSOs to prevent and protect neighborhoods and these waste water plants from flooding.

No Swimming at Any Time
Sewer Overflows

CSO Signage, installed at outfall locations

When a combined sewer outfall is overflowing, and up to a period of 24 hours following the rainfall event, it is unsafe to recreate in the waterbody due to possible pollutant contamination. Viewing this website before potential water contact is highly recommended.

To see ways Philadelphia is working to reduce and eliminate CSOs click here!

How It Works

Philadelphia Water Department (PWD) has maintained an extensive flow monitoring network since 1995. The level sensors record data throughout the combined sewer system. PWD currently operates and maintains monitoring equipment at, or near, the 164 CSOs throughout the city. This public notification system is based on PWD analysis of monitoring network data which is used to determine the likelihood of combined sewer overflows.

Flow monitoring data presented on this webpage is validated with the Philadelphia watershed and wastewater conveyance model. The model was developed through U.S. EPA's Storm Water Management Model (SWMM). Real time

Done
Internet
100%

Figure 2-19 PWD's CSOcast Website

2.2.7.3.6 Rain Barrel Program

http://www.phillywatersheds.org/rainbarrel

The PWD is providing rain barrels to residents of Philadelphia's watersheds free of charge, in order to promote the reduction of stormwater flows to our sewer system and creeks (See Figure 2-20). To receive a rain barrel, one must attend a rain barrel workshop to be educated on the installation and use of the rain barrel. Rain barrel workshops are held in locations around the City throughout the year. Through this website, one can view when a workshop is being held in watersheds throughout the region.

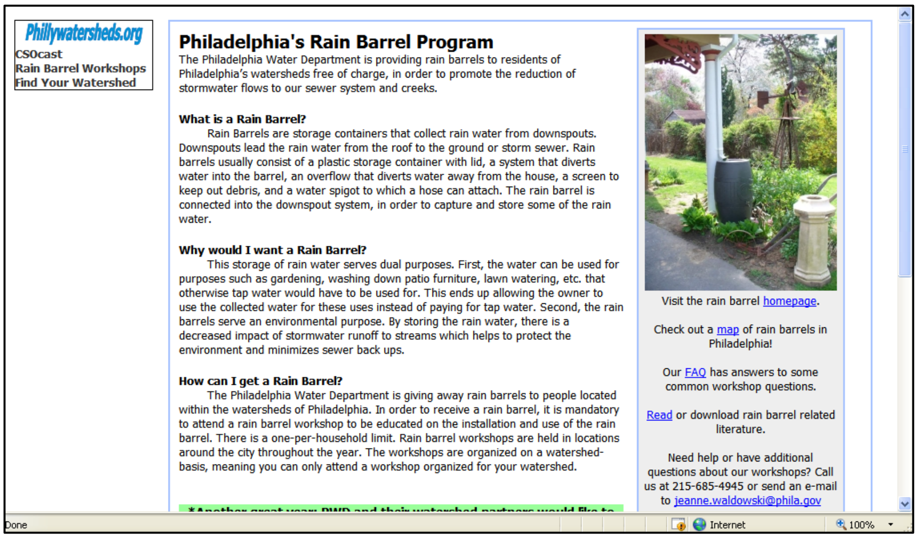


Figure 2-20 PWD's Rain Barrel Program Website

2.2.7.3.7 Handout Materials

CSO LTCPU Backgrounders

The eight page Backgrounders are handouts designed for a general audience (the CSO affected public) and serve to provide an overview of the LTCPU. These documents provide information on the history, background and approach taken by the City to control CSOs. The Backgrounders are distributed to our watershed partners, the LTCPU Advisory Committee and to the public at all public meetings and public events. The documents are also available through the LTCPU website. View Supplemental Volume 1 for copies of the Backgrounders. The Backgrounders cover the themes in Table 2-27.

Table 2-27 CSO LTCPU Backgrounders

Backgrounder I	The CSO Long Term Control Plan – History & Background
Backgrounder II	The CSO Long Term Control Plan Update – Clean Water Benefits & The Balanced Approach
Backgrounder III	Current Status of Our Waterways

Bill stuffers/waterwheels (Newsletters)

The bill stuffers and Water Wheels are newsletters inserted into the water bill of the estimated one-half million customers of the PWD. The bill stuffers and Water Wheels listed in Table 2-28 have been developed under the CSO LTCPU Public Participation Program and have also been distributed throughout the City at advisory committee meetings, public meetings, and at other public events. View Supplemental Volume 1 for copies of the newsletters.

Table 2-28 Bill Stuffers & Waterwheels

Newsletter Title	Newsletter Description
Bill Stuffer I: The Combined Sewer Overflow Program: A Long Term Control Plan for Our Rivers in addition to Clean Water, Green City: Long Term Control Plan Update.	This publication covers an introduction to the CSO LTCPU and the goals of the PWD in controlling CSOs.
Water Wheel I: CSO Public Notification Means You're in the Know	This publication aims to notify the public of the CSO public notification system and covers the commonly asked questions about CSO-affected waters.
Water Wheel II (in Water Quality Report): *Green City, Clean Waters Program*	This publication covers the history of CSOs and includes a CSO Notification Card cut-out.
Water Wheel III: Clean Waters, Green Cities – Neighborhood-Friendly Solutions	This publication covers the PWD's Green Streets Program.
Water Wheel IV: Green Cities, Clean Waters – Tookany/Tacony-Frankford Creek	This publication covers the Integrated Watershed Management Plan for the Tookany/Tacony-Frankford Watershed.

2.3 Public Involvement During Release of Draft CSO LTCPU

"I have attended many meetings of the PWD concerning the CSO long term Plan. As a resident and business owner in Philadelphia I am proud that PWD came up with a solution to our stormwater needs that has such a broad positive effect. As a citizen of the planet, I am inspired by PWD's vision. Their thinking is cutting edge and in my experience they have the will, strategy and expertise to implement this plan effectively. I fully support this project."

-Dr. Terrie Lewine, Northern Liberties – Statement made at *Green City, Clean Waters* Public Meeting, Series #4)

2.3.1 Distribution of Information

PWD plans to provide copies of the Draft LTCPU Summary Report to the public in the last round of public meetings. PWD will also distribute the Summary Report to key locations, such as libraries, in each targeted watershed, in addition to partner organization centers, such as the Awbury Arboretum. Table 2-29 lists the targeted locations. The Draft LTCPU Summary Report will also be available on-line - on PWD's CSO LTCPU website (http://www.phillyriverinfo.org/csoltcpu).

Table 2-29 Targeted Locations for Draft LTCPU Summary Report Distribution

Targeted Locations for Draft CSO LTCPU Distribution	
Frankford Library	4634 Frankford Ave, Philadelphia
Ogontz Avenue Revitalization Corporation	1536 Haines St, Philadelphia
Wissahickon Environmental Center Tree House	300 Northwestern Ave. Philadelphia
Center in the Park	5818 Germantown Ave. Philadelphia
FELS Community Center	2407 S. Broad Street Philadelphia
Port Richmond Library	2987 Almond Street Philadelphia
Fairmont Waterworks Interpretive Center	Waterworks Drive and Kelly Drive Philadelphia
Aubury Arboretum	One Awbury Road Philadelphia
Free Library of Philadelphia	1314 Locust St. Philadelphia
South Philadelphia Library	1700 S Broad St. #2 Philadelphia
Cobbs Creek Community Environmental Education Center	700 Cobbs Creek Parkway, Philadelphia

2.3.2 Media Publicity

PWD plans to notify the public of the availability of the Draft LTCPU Summary Report through a public notice process, conducted via newspaper announcements, internet websites, television and radio public service announcements, partnership e-mail listservs, and through the CSO LTCPU Advisory Committee. View Section 2.2.2. (Public Meetings) for the list of media outlets targeted for outreach for the release of the Draft LTCPU Summary Report. View Supplemental Volume 1 for all notices.

2.4 Opportunities for Public Comment on Draft CSO LTCPU Summary Report

Figure 2-21 Northern Liberties Community Center August 2009 Public Meeting

Opportunities for public comment on the draft LTCPU Summary Report will be made possible through:

- Mail letters to Joanne Dahme, Public Affairs Division, 5th Floor, 1101 Market Street, Philadelphia, PA 19107
- E-mail: Questions@phillywatersheds.org
- Fax: 215-685-6043
- *Green City, Clean Waters* Facebook Wall: http://www.facebook.com/green.cities.clean.waters
- *Green City, Clean Waters* Public Meetings
- Comments sheets left at libraries and other centers of distribution that will host the Draft LTCPU Summary Report

2.5 PUBLIC COMMENTS ON DRAFT CSO LTCPU

2.5.1 Comments on Draft CSO LTCPU Summary Report

The Draft LTCPU Summary Report was distributed during the final round of public meetings (Series 4). A list of the comments that have been received by members of the public thus far follows.

- *"This plan is great! It is positive for our neighborhood and for our people. Greening can improve the way people behave and act."* (John Donlen, Fishtown Resident)

- *"You're not trying to solve it all with one answer. The different projects are not going to be buried or hidden underground. The projects are going to be visible and they are going to provide amenities to us and lots of solutions. There's a big difference between raising our kids in a place surrounded by pavement versus green. This plan is wonderful!"* (John Donlen, Fishtown Resident)

- *"After hearing about this plan, I am much more appreciative of the work that the City is doing. We need to get this out there!"* (Don McGuire, Ph.D., Mt. Airy Resident)

- *"This plan will protect our streams, rivers and the underground structures. It has to be a good thing!"* (Harold Carter, Germantown Resident)

- *"It's great, but throw us a bone! Create more incentives for residents to do greening."* (Janet Boys, Mt. Airy Resident)

- *"I support this plan because I believe it is vital to our health and welfare. I appreciate how well founded the proposed project is based on good research. I would like the plan to be implemented completely and soon."* (Margaret Judd, Northern Liberties Resident)

- *"I fully support the PWD, its CSO LTCPU and commend PWD for its creative approach."* (Eugene Swggnot, Northern Liberties Resident)

- *"This program is a must for the good of the entire city of Philadelphia. There is much talk regarding, "greening." But this project is instrumental to the very core values our President speaks of. As one citizen, I* *cast my vote of confidence to the Philadelphia Water Department."* (James Harrison, Northern Liberties Resident)

- *"I see this project is long-term and pretty ambitious, and I assume you will be needing a large workforce to accomplish these goals. If I wanted to work for this project, what should I do? I completely support your efforts and would like to offer my help, even voluntarily, to accomplish this."* (Ernesto Canal, Northern Liberties Resident)

- *"This is a very exciting plan of action. In addition to all of its environmental benefits, it brings a certain urban-natural vitality to the city and its management of water runoff!"* (Harry Kyriakodis, Esq., Northern Liberties Resident)

- *"I would like to support the PWD project [plan]. It is a very interesting idea that could create a better environment in the city… I feel that one of my dreams regarding the city is coming true! Thank you!"* (Cinzia Sevignani, Ph.D., South Philadelphia)

- *"I am excited about this plan! It makes so much sense to recycle rain water in this way and reduce the heat pocket in the City. The benefits to the City are so varied and all the areas of influence (like parking, roofs, streets, schools, open space and industry, etc.) individually can be used to spur each other on to make a really <u>major</u> impact! Go Philly Go! Thanks to PWD for moving forward on this! <u>I'm a "PIMBY" – Please in my back yard</u>!"* (Mary Stumpf, South Philadelphia Resident)

- *"What's not to like? We're transforming concrete and black top into a green oasis!"* (Diane Mayer, Pennsport Resident)

- *"This plan is so exciting, the timing is right and our City needs a kick in the pants to move forward with clean water initiatives!"* (Jessica Mammarella, South Philadelphia Resident)

- *"Thank you for the thoughtful & exciting presentation tonight at Columbus Square Park. PWD's plan to green Philadelphia is the most exciting & encouraging initiative my husband & I have seen in our 30 plus years in Philadelphia… Because of these initiatives our neighborhood has blossomed with young families interested in calling this neighborhood their home."* (Norma Gottlieb & Mark Brown, Columbus Square)

- *"This is the way to go! Green Streets, Parks, Green Pathways!"* (Jim Campbell, SOSNA)

- *"The Green City, Clean Waters Plan is long overdue and will be a plus for our City and neighborhoods. I'm looking forward to seeing the further greening of my community!"* (Patricia Funaro, Columbus Square)

- *Green City, Clean Waters Plan… with public policy that connects us, our homes and streets to our natural shared resources… Public Health Policy at its best!* (Susan Patrone, Columbus Square)

2.5.2 Approach to Addressing Comments on Draft CSO LTCPU Summary Report

PWD will respond to questions and comments presented at public meetings. PWD is also prepared to answer questions received via mail, e-mail, fax, the Facebook Wall, and comments left on comments sheets at libraries and other centers of distribution in the City.

2.6 FUTURE PUBLIC PARTICIPATION

PWD is committed to working with the public on the planning, design and construction of CSO control projects.

PWD plans to hold an additional public meeting (Series 4) on August 25 2009, to distribute the CSO LTCPU Summary Report. All comments received at this meeting will be submitted to the PADEP and US EPA.

All public participation projects have and will continue to be designed to educate the affected public about the CSO LTCPU and CSO control projects, to get feedback from the affected public on the CSO LTCPU and CSO control projects and their results, and to partner with neighborhood residents before, during and after the implementation of CSO controls, in addition to reporting progress on the results of the public participation projects to them.

The watershed partnerships will continue to expand, as well as Model Neighborhoods, among other public participation programs. PWD will continue to evolve its public participation program in order to get a step closer to the best methods, preferred tools, key tactics and target audiences to focus its CSO LTCPU-related and CSO control-focused program messages. New initiatives will also continue to unfold. Currently, a Faith-Based Initiative is underway, where PWD and the Mayor's Office of Faith-Based Initiatives are partnering in a more focused manner with diverse faith-based organizations throughout the City on green stormwater infrastructure. See Supplemental Volume 1 for outreach materials in development.

The PWD's commitment to its watershed partners and the citizens of the City will enable the programs that support the LTCPU to continue to grow and expand.

3 CHARACTERIZATION OF CURRENT CONDITIONS

As prescribed by the 1997 LTCP, PWD has committed to a detailed watershed-based monitoring program in the Cobbs and Tookany/Tacony-Frankford (TTF) Creek Watersheds. This monitoring program includes chemical, biological and physical assessments to characterize the current state of the watershed and identify existing problems and their sources. The need for this detailed watershed monitoring program was rooted in the fact that insufficient physical, chemical and biological information existed on the nature and causes of water quality impairments, sources of pollution, and appropriate remedial measures prior to PWD's watershed based assessment.

Through this assessment process, PWD has sought to gain a good understanding of the physical, chemical and biological conditions of the water bodies, understand the character of the watershed land uses that will drive wet weather water quality conditions, and build a common understanding of these factors among all stakeholders. A compendium document is produced following the analysis of all collected data; this Comprehensive Characterization Report (CCR) assessment serves to document the watershed baseline health prior to implementation of any plan recommendations, allowing for the measure of progress as implementation takes place upon completion of the plan. The CCR is shared with watershed partners for comments and feedback.

CCRs have been completed for the Cobbs Creek Watershed in 2004, the TTF Creek Watershed in 2005 and the Pennypack Creek Watershed in 2009 (Section 1, Table 1.4). These CCR documents are available on the partnership website at www.phillyriverinfo.org. Data related to the Cobbs and TTF Watersheds within this section have been pulled from these CCRs. Data related to the Schuylkill and Delaware River Watersheds have been assembled from a number of sources including PWD sampling locations, the United States Geological Survey (USGS) gage stations and the Delaware River Basin Commission (DRBC) monitoring locations.

In order to further understand the complex nature and causes of water quality impairments, PWD has continued to monitor and model the collection system within Philadelphia. This section additionally presents information characterizing Philadelphia's network of sewer systems, regulating structures, drainage districts, contributing watersheds and outlying community municipalities, precipitation data collection and analysis and the collection of water quantity and quality information.

3.1 MONITORING AND DATA COLLECTION

Data collection and monitoring is an essential component to appropriately develop and analyze alternatives for the LTCPU. The collected data is organized, assessed for errors and analyzed using a variety of models, tools and methods. The sections below present data necessary to the LTCPU development process and how it was collected. More information specific to the models, methods and tools used to analyze the data is available in Section 5.

3.1.1 Overview of Input Data Collection

The development of the LTCPU required extensive data collection and analysis. The data collection and analysis included characterization of the City's local climate through precipitation data sources; analysis, collection and correct representation of existing infrastructure data; analysis of the contribution of contaminants and flow data with established flow metering programs; analysis of the topography through extensive use of Geographic Information Systems analyses; analysis and collection of socioeconomic status and the cost for improving the infrastructure. The following sections discuss how this data was collected and the sources used to characterize the City for the LTCPU.

3.1.2 Meteorological Monitoring Data

Precipitation data are a fundamental component of a Combined Sewer System monitoring program required to calibrate and validate CSO models and develop design conditions needed for characterizing the CSS and estimating CSO statistics. Both long-term temporal rainfall data and event based rainfall data synchronized with CSS flow monitoring are needed to appropriately calibrate and characterize the CSS. There are three primary sources of precipitation data used in the CSO Program.

- National Weather Service (NWS) operated Philadelphia International Airport (PIA) surface observation station
- PWD's city-wide rain gage network
- Calibrated radar rainfall estimates

3.1.2.1 PIA Precipitation Data Sources

NWS gage at the Philadelphia International Airport (PIA), located in southwestern Philadelphia, has over 100 years of hourly precipitation data; the period of record runs from January 3, 1902 through the present. An annual online subscription is maintained by PWD for the Philadelphia International Airport station (PIA) that allows the download of monthly Edited Local Climatological Data published by the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center. The reports are downloaded on a monthly basis when made available - typically four to six weeks behind the end of the current month. Along with hourly rainfall data, the report includes snowfall, temperature, wind speed, atmospheric pressure and other relevant and useful climatological data.

3.1.2.2 PIA Precipitation Data Processing and QA/QC

The NWS applies quality assurance procedures to the PIA data internally prior to its release, therefore, no quality assurance protocols are proposed for the PIA data.

3.1.2.3 PWD Precipitation Data Sources

PWD maintains a rain gage network consisting of 24 tipping bucket rain gages located throughout the City that record rainfall depths (minimum recorded depth of 0.01 inches) in 2.5-minute increments. The PWD data is considered reliable from 1990-present, with all 24 gages replaced with heated units beginning in the year 2004 in order to allow for accurate measurement of frozen precipitation events. The raw 2.5-minute tipping bucket rain gage data is extracted from a link to the PWD Collector System's real-time control unit (RTU) database which collects data directly via automatic telephone polling of the gages.

The approximate locations of the 24 PWD rain gages are presented in Figure 3-1. The total number of rain gages within each watershed is shown in Table 3-1.

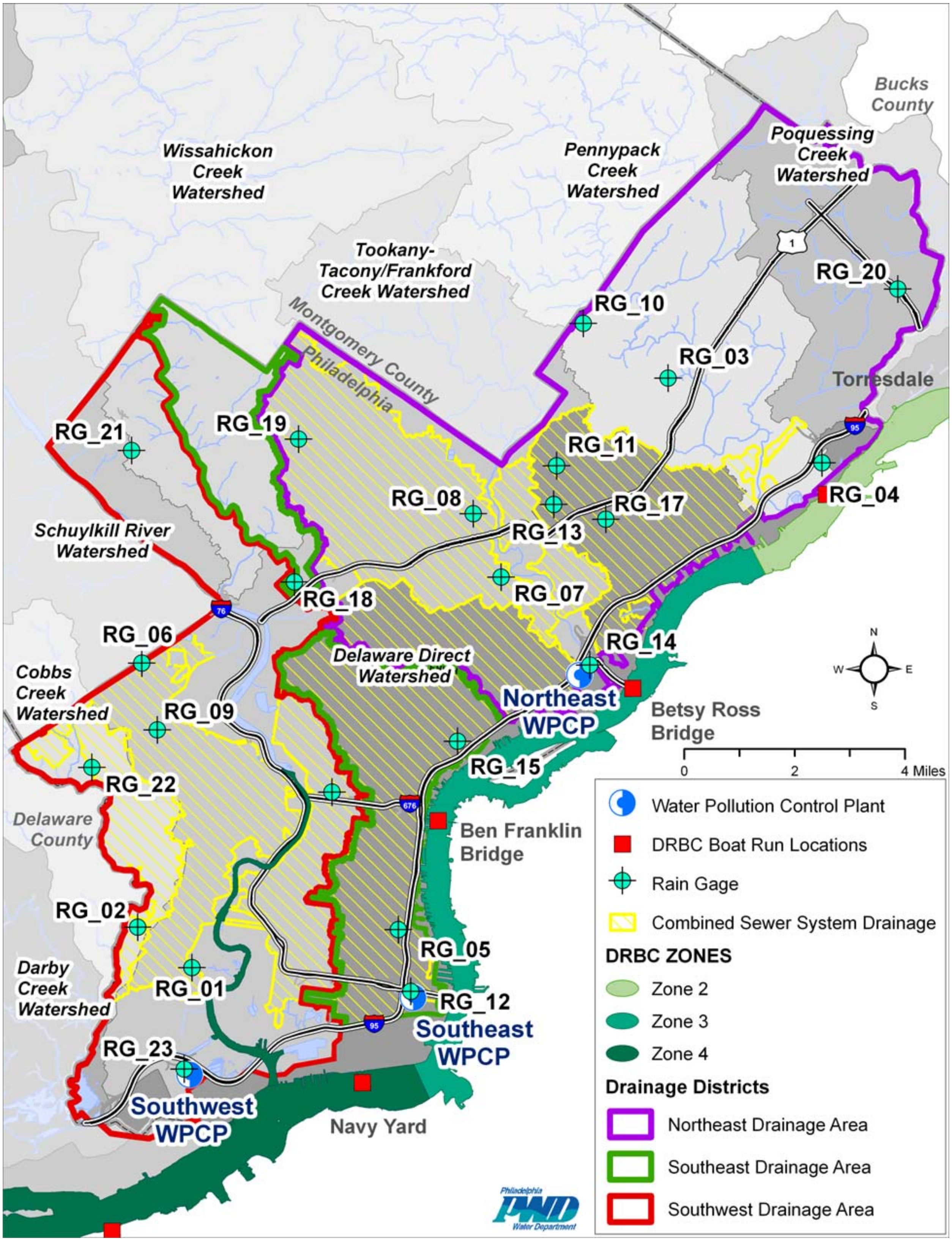


Figure 3-1 PWD Rain Gage Locations and Combined Sewer Drainage Areas

Table 3-1 Number of PWD Rain Gages within each Watershed

Watershed	Total Number of Rain Gages
Delaware River	10
Schuylkill River	7
Darby-Cobbs Creek	2
Tookany/Tacony Frankford Creek	5

3.1.2.4 PWD Precipitation Data Processing and QA/QC

The PWD raw 2.5-minute data are summed to fixed 15-minute intervals. QA/QC of this data is performed on a monthly basis by visual inspection using comparison of data across the network in order to identify and flag missing or questionable data. Flagged data are then filled with coincident data from the six nearest gages using inverse distance squared weighting.

On an annual basis, daily rainfall totals for each gage are compared to the network mean using double mass and cumulative residual time series plots in order to identify changes in non-climatic biases at the gages. In this way, gage malfunctions not readily apparent from initial visual inspection of the raw gage data can be identified. Furthermore, bias adjustment periods are identified for each gage and along with comparisons to radar rainfall estimates obtained for a 15-month period of the gage record, a bias adjusted rainfall record is produced for each gage location. Detailed descriptions of the tools and methods of the precipitation bias adjustment are available in Section 5.

3.1.2.5 Calibrated Radar Rainfall Data Sources

Due to the fact that storm events are inherently variable and do not evenly distribute rainfall spatially or temporally, PWD obtained discrete measurements of rainfall intensity during storm events targeted for wet weather sampling. For each 15-minute interval, RADAR tower-mounted equipment measured high frequency radio wave reflection in the atmosphere as a series of relative reflectivity measurements for individual 1 km^2 blocks. This information was used along with PWD rain gage network data to generate gage calibrated RADAR rainfall estimates and provided to PWD and is further discussed in Section 5.2.1.

The National Weather Service's Next Generation Weather Radar (NEXRAD) program generates products used for estimating spatially variable rainfall data. Several vendors offer gage adjusted radar-rainfall data. PWD rain gage data are used to calibrate NEXRAD data in order to create a detailed and accurate rainfall record that preserves the total rainfall volume reported at the gages while incorporating the spatial variability provided by the NEXRAD data. Detailed rainfall records for areas outside of the City are required for calibration of rainfall dependent inflow and infiltration (RDII) from sanitary sewers contributing flows to the CSS, as well as for watershed modeling performed as part of Phase III of the CSO LTCP. In addition, increased spatial resolution of rainfall data within the City can improve model accuracy as the models are refined with further shed sub-delineation.

The PWD has purchased calibrated radar rainfall data as follows:

1. NEXRAIN Corporation provided 18 months of 15-minute 2 x 2 km grid gage calibrated radar rainfall data covering 399 square miles including the PWD service area plus all surrounding

contributory watershed areas. This data was acquired for use in calibration of PWD CSO, Cobbs Creek restoration, and Main and Shurs models. The time periods covered include:

- 12- month period from September 1st, 1999 through August 31st, 2001
- 4-month period from March 1st, 2002 through June 30th, 2002
- 2 months containing historic rainfall events: July 1994 and October 1996

2. Vieux & Associates provided event based 15-minute 1 x 1 km gage calibrated radar rainfall data covering the PWD service area plus the Tacony-Frankford and the Darby-Cobbs Watersheds. This data was acquired for the wet weather water quality monitoring program and the calibration of open channel flow models and as part of the Tacony-Frankford and Darby-Cobbs Watershed management plans. The time periods covered include:
    - Spring 2003 (4 events): May 2nd, 5th, 7th and 16th
    - Summer 2003 (5 events): July 10th, 23rd and 24th ; September 13th and 23rd
    - Fall 2003 (1 event): October 14th
    - Summer 2004 (2 events): July 7th and August 30th

3. Vieux & Associates provided 21 months of continuous 1-hour 4 x 4 km calibrated radar rainfall data covering the Lower Delaware River Basin for the period July 1st 2001 through March 31st 2003. This data was acquired for calibration of the Delaware River Basin PCB loading model.

3.1.2.6 Radar Rainfall Data Processing and QA/QC

The vendor evaluates the NEXRAD radar reflectivity data and makes corrections for anomalies such as beam blockages and ground clutter. PWD approved, 15-minute unfilled data – which is randomly missing or errant data due to data collection errors that have not been filled in or adjusted using averaging techniques – are provided to the vendor for calibration of the radar rainfall estimates using mean field bias adjustments. The vendor also evaluates the rain gage data and removes questionable gage data from the calibration process.

3.1.3 Municipal Collector Sewer System Data

PWD maintains the following primary sources of flow and level monitoring data for its municipal sewer collection system:

- Water Pollution Control Plant (WPCP) Influent
- Permanent Collection System Level Monitoring
- Portable Flow and Level Monitoring
- Outlying Community Contributing Flow Meter
- National Oceanographic and Atmospheric Agency (NOAA) Tide

To efficiently analyze these data a variety of tools and models were used, including SHAPE and RTK spreadsheet tools created specifically for the LTCPU. Details of these tools are available in Section 5.

3.1.3.1 Water Pollution Control Plant (WPCP) Influent Data

All three WPCPs record influent flow and level/depth data in daily and hourly time increments. PWD WPCP daily qualitative data - unusual color or odors of influent flow - and quantitative data -

flow level, pH, total suspended solids, fecal coliform, biological oxygen demand, and chlorine residual - are reported to regulatory agencies in monthly Discharge Monitoring Reports (DMR). The data in the DMRs exist in digital format and are accessible through MS EXCEL.

The Central Schuylkill Pumping Station (CSPS) records influent flow and level data in 20-minute intervals in digital format (EXCEL). Pumping rates are recorded for each of the six pumps and level data is recorded for the North and South shafts of the Central Schuylkill Siphon.

3.1.3.2 Permanent Collection System Level Monitoring

PWD maintains real-time sewer monitors in the combined sewer system at regulator locations and system hydraulic control points. The regulator chamber level monitors are typically located in the trunk sewer just above the regulator and in the outfall pipe itself. Hydraulic control point level monitors are generally located in interceptor sewers upstream of confluence points, and in trunk sewers at diversion structures. These level monitors are used for system operation and control, as well as, identification of combined sewer overflows, and for determining head losses and hydraulic grade lines used for calibration and validation of system hydraulic models.

3.1.3.3 Portable Flow and Level Monitoring

Monitoring of combined sewer flow is critical to establish a baseline for the urban water budget, against which future progress can be measured. Hydrologic and hydraulic computer models are calibrated to these measured flows so that they accurately represent baseline conditions. Rain that falls in the urban environment can take one of three main pathways – interception by vegetation or depression storage on impervious surfaces, leading to eventual evaporation; infiltration into soil, leading to eventual uptake and transpiration by plants, or continuation to groundwater recharge; or direct runoff to the combined sewer system. Of these three pathways, stormwater flows in the combined sewer system are the easiest to monitor. Measured flows are separated into their components – base wastewater flow, groundwater inflow, and stormwater – using tools described in Section 5.

The PWD portable flow and level monitoring program, initiated in July 1999, deployed flow meters throughout targeted Philadelphia sewershed areas to quantify wastewater flow through sanitary sewers and characterize the tributary sewersheds. This work continued through 2004 with a primary focus on flow monitoring of sanitary sewersheds in order to characterize rainfall dependent inflow and infiltration rates, as well as base wastewater and ground water infiltration rates from service areas both within and outside the City of Philadelphia. Approximately 56 locations were monitored over this period (1999-2004) with deployment durations ranging from two months to over three years.

Beginning in 2005, portable flow and level-only monitoring was performed at three (3) sanitary sewer locations selected to support the monitoring of an extreme wet weather sanitary sewer overflow upstream of the Upper Delaware Low Level Interceptor. In addition, sixteen (16) flow and nine (9) level only monitoring locations were selected in targeted combined sewer storm flood relief areas that are experiencing basement flooding caused by sewer backups.

During the spring of 2006, CSL services were contracted to deploy portable flow monitors in targeted combined sewer storm flood relief areas with a focus on locations surrounding flow splits between CSO regulator drainage basins. Approximately twenty (20) locations were deployed as part of this work.

Additional flow monitoring was performed for calibration and verification of detailed CSS models used for characterizing the response of the system to wet weather under current conditions and for the evaluation of the performance benefit of proposed LTCP projects.

Monitors are generally left in place until a sufficient duration of dry weather days and a sufficient number and range of smaller and larger rain events are captured. The monitors are then removed and reinstalled at other selected sewer sites to maximize the coverage of the PWD service area. Because variability is generally greater from storm to storm rather than between locations, it is desirable to monitor a set of representative locations continuously over the duration of the monitoring program.

Metering location, monitoring period and type are shown in Table 3-2 with locations and contributory areas shown on the map in Figure 3-2. Similarly, Table 3-3 gives location and meter details for the fall 2005 and spring 2006 storm flood relief deployments with locations and contributory areas shown on the map in Figure 3-3.

Table 3-2 Metering Location IDs, Type and Deployment Dates for PWD Portable Flow Monitoring Program

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
005	Level and Flow	Sanitary	NE	9,382	8/10/99 - 6/13/00
012	Level and Flow	Sanitary	NE	630	8/12/99 - 4/28/00
014	Level and Flow	Sanitary	NE	181	8/12/99 - 4/28/00
015	Level and Flow	Sanitary	NE	191	8/10/99 - 4/10/00
018	Level and Flow	Sanitary	NE	355	8/30/99 - 6/12/00
019	Level and Flow	Sanitary	NE	381	8/9/99 - 11/3/99
023	Level and Flow	Sanitary	NE	402	8/9/99 - 4/27/00
027	Level and Flow	Sanitary	NE	353	8/12/99 - 4/27/00
029	Level and Flow	Sanitary	NE	266	8/9/99 - 11/3/99
030	Level and Flow	Sanitary	NE	276	8/12/99 - 4/27/00
031	Level and Flow	Sanitary	NE	383	8/10/99 - 6/19/00
032	Level and Flow	Sanitary	NE	263	9/20/99 - 6/28/00
040	Level and Flow	Sanitary	SW	4,895	8/11/99 - 9/10/01
041	Level and Flow	Sanitary	SW	6,079	11/2/99 - 9/24/01
043	Level and Flow	Sanitary	NE	2,416	11/3/99 - 2/14/00
044	Level and Flow	Sanitary	NE	1,986	11/3/99 - 6/12/00
045	Level and Flow	Sanitary	SW	42	3/10/00 - 8/31/00
046	Level and Flow	Sanitary	SW	117	5/4/00 - 4/24/01
047	Level and Flow	Sanitary	SW	148	5/4/00 - 9/27/01
048	Level and Flow	Sanitary	SE	897	5/3/00 - 10/10/00

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
049	Level and Flow	Sanitary	SE	1,784	4/28/00 - 9/24/01
051	Level and Flow	Sanitary	SW	5,358	5/3/00 - 2/14/01
052	Level and Flow	Sanitary	SE	278	5/3/00 - 9/14/00
055	Level and Flow	Sanitary	SW	235	6/12/00 - 10/10/00
056	Level and Flow	Sanitary	SW	187	6/13/00 - 4/24/01
057	Level and Flow	Sanitary	SW	164	6/13/00 - 9/10/01
058	Level and Flow	Sanitary	SW	105	6/23/00 - 9/27/01
060	Level and Flow	Sanitary	SE	1,818	6/28/00 - 9/27/01
070	Level and Flow	Sanitary	NE	276	10/5/00 - 9/26/01
071	Level and Flow	Sanitary	SE	711	10/13/00 - 4/23/01
072	Level and Flow	Sanitary	NE	301	11/13/00 - 9/27/01
073	Level and Flow	Sanitary	SW	68	2/13/00 - 9/10/01
074	Level and Flow	Sanitary	SW	90	2/16/01 - 4/24/01
075	Level and Flow	Sanitary	NE	179	5/16/01 - 9/26/01
076	Level and Flow	Sanitary	NE	196	5/18/01 - 9/26/01
077	Level and Flow	Sanitary	NE	162	7/11/01 - 9/10/02
078	Level and Flow	Combined	SW	116	9/21/01 - 9/11/02
079	Level and Flow	Combined	SW	117	10/11/01 - 9/10/02
080	Level and Flow	Sanitary	SW	252	10/16/01 - 9/23/02
081	Level	Sanitary	SW	715	1/23/02 - 5/6/02
082	Level and Flow	Combined	SW	203	2/16/02 - 9/10/02
083	Level and Flow	Combined	SW	20	10/17/02 - 5/2/05
084	Level and Flow	Combined	SW	25	10/18/02 - 5/2/06
085	Level and Flow	Combined	SW	99	10/24/02 - 07/29/04
088	Level and Flow	Sanitary	NE	338	4/25/03 - 6/24/03
090	Level and Flow	Sanitary	NE	359	8/31/04 - 7/25/07
091	Level and Flow	Combined	SW	29	7/07/04 - 3/9/06
092	Level and Flow	Sanitary	NE	257	9/15/04 - 5/4/05
095	Level and Flow	Sanitary	NE	3,543	6/08/04 - 9/19/07
096	Level and Flow	Sanitary	NE	12,985	6/03/04 - 9/18/2007
097	Level and Flow	Sanitary	NE	273	10/01/04 - 5/4/2005
098	Level and Flow	Sanitary	NE	12,960	4/06/05 - 9/18/07
099	Level and Flow	Combined	SW	24	9/9/05 - 9/4/07
100	Level	Combined	SW	42	9/23/05 - 7/24/06
101	Level	Combined	SW	80	9/12/05 - 2/26/07
102	Level	Combined	SW	214	9/28/05 - 7/18/06
103	Level	Combined	SW	148	9/23/05 - 7/24/06
104	Level and Flow	Combined	SW	82	9/23/05 - 3/8/07

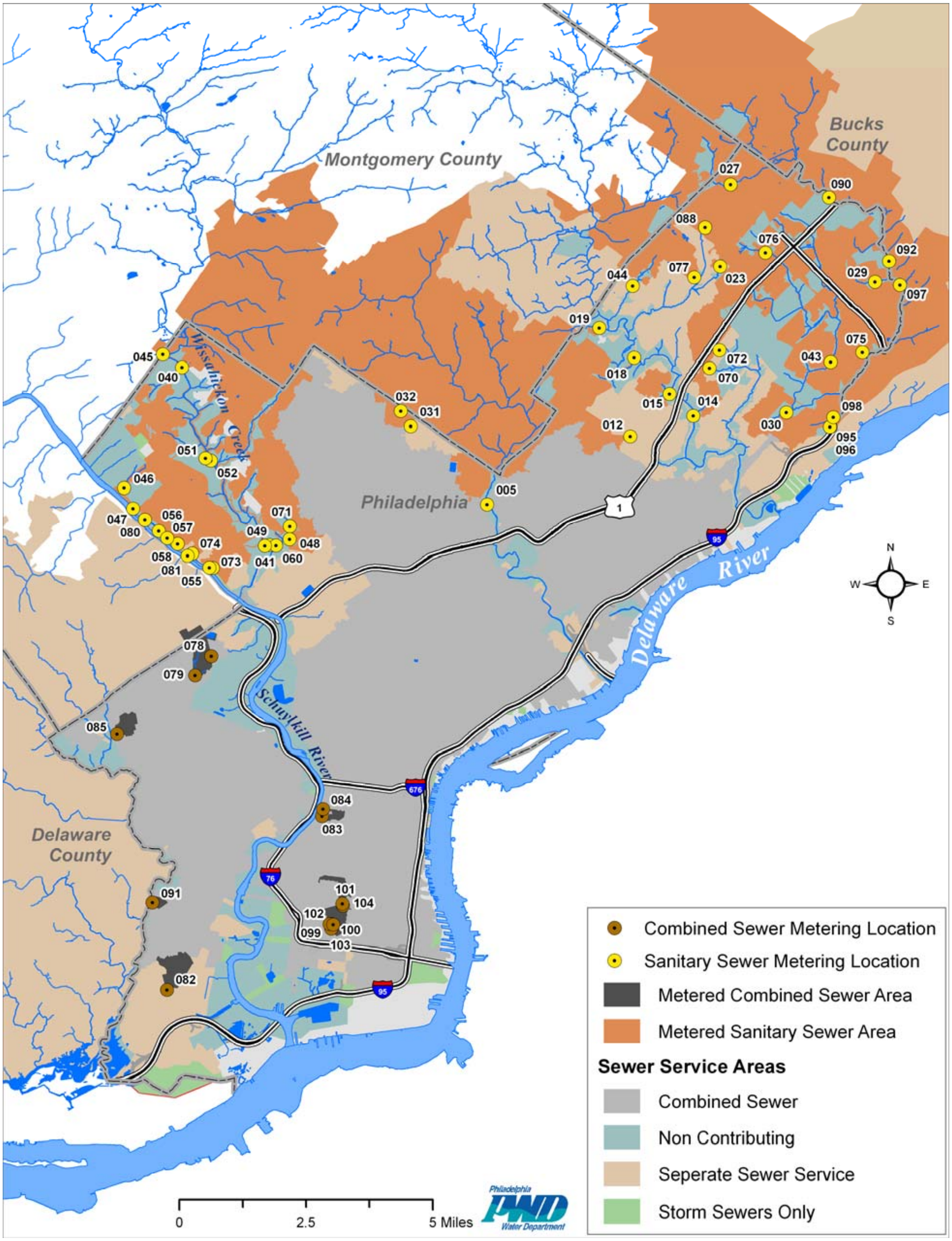


Figure 3-2 PWD Portable Flow Monitoring Program Metering Locations

Table 3-3 Fall 2005 and Spring 2006 Deployment Dates, Locations and Meter IDs for Targeted Storm Flood Relief Areas

Meter ID	Measurement Type	Location	Date Installed	Deployment Phase
S42-130	Level and Flow	Passyunk Avenue	11/1/2005	Fall 2005
D68-1505	Level and Flow	Passyunk Avenue	11/7/2005	Fall 2005
D68-430	Level Only	Passyunk Avenue	9/20/2005	Fall 2005
D68-135	Level and Flow	Passyunk Avenue	11/1/2005	Fall 2005
D68-85	Level and Flow	Passyunk Avenue	9/21/2005	Fall 2005
D66-1625	Level and Flow	Tasker Street	10/10/2005	Fall 2005
D66-125	Level and Flow	Tasker Street	10/18/2005	Fall 2005
D54-3890	Level and Flow	Washington West	9/19/2005	Fall 2005
D54-3320	Level and Flow	Washington West	9/19/2005	Fall 2005
D54-95	Level and Flow	Washington West	10/10/2005	Fall 2005
D54-80	Level Only	Washington West	9/21/2005	Fall 2005
D54-70	Level Only	Washington West	9/19/2005	Fall 2005
D45-3620	Level Only	Northern Liberties	9/20/2005	Fall 2005
D45-1660	Level and Flow	Northern Liberties	9/19/2005	Fall 2005
D45-1415Y	Level Only	Northern Liberties	11/1/2005	Fall 2005
D45-445	Level Only	Northern Liberties	9/21/2005	Fall 2005
D45-165	Level Only	Northern Liberties	11/1/2005	Fall 2005
D45-80	Level Only	Northern Liberties	9/20/2005	Fall 2005
D44-75	Level Only	Northern Liberties	9/20/2005	Fall 2005
S42-130	Level and Flow	Passyunk Avenue	4/25/2006	Spring 2006
D68-85	Level and Flow	McKean & Snyder	4/25/2006	Spring 2006
D68-135	Level and Flow	McKean & Snyder	5/8/2006	Spring 2006
D66-1585	Level and Flow	Tasker Street	4/25/2006	Spring 2006
D66-140	Level and Flow	Tasker Street	4/25/2006	Spring 2006
D54-70	Level and Flow	Washington West	4/21/2006	Spring 2006
D54-3890	Level and Flow	Washington West	4/24/2006	Spring 2006
D54-3653	Level and Flow	Washington West	4/24/2006	Spring 2006
D54-15	Level and Flow	Washington West	5/18/2006	Spring 2006
D45-70	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-610	Level and Flow	Northern Liberties	4/21/2006	Spring 2006
D45-510	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-490	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-450	Level and Flow	Northern Liberties	5/19/2006	Spring 2006
D45-45	Level and Flow	Northern Liberties	5/5/2006	Spring 2006
D45-3705	Level and Flow	Northern Liberties	4/21/2006	Spring 2006
D45-1425	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D44-75	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D39-110	Level and Flow	Northern Liberties	4/21/2006	Spring 2006

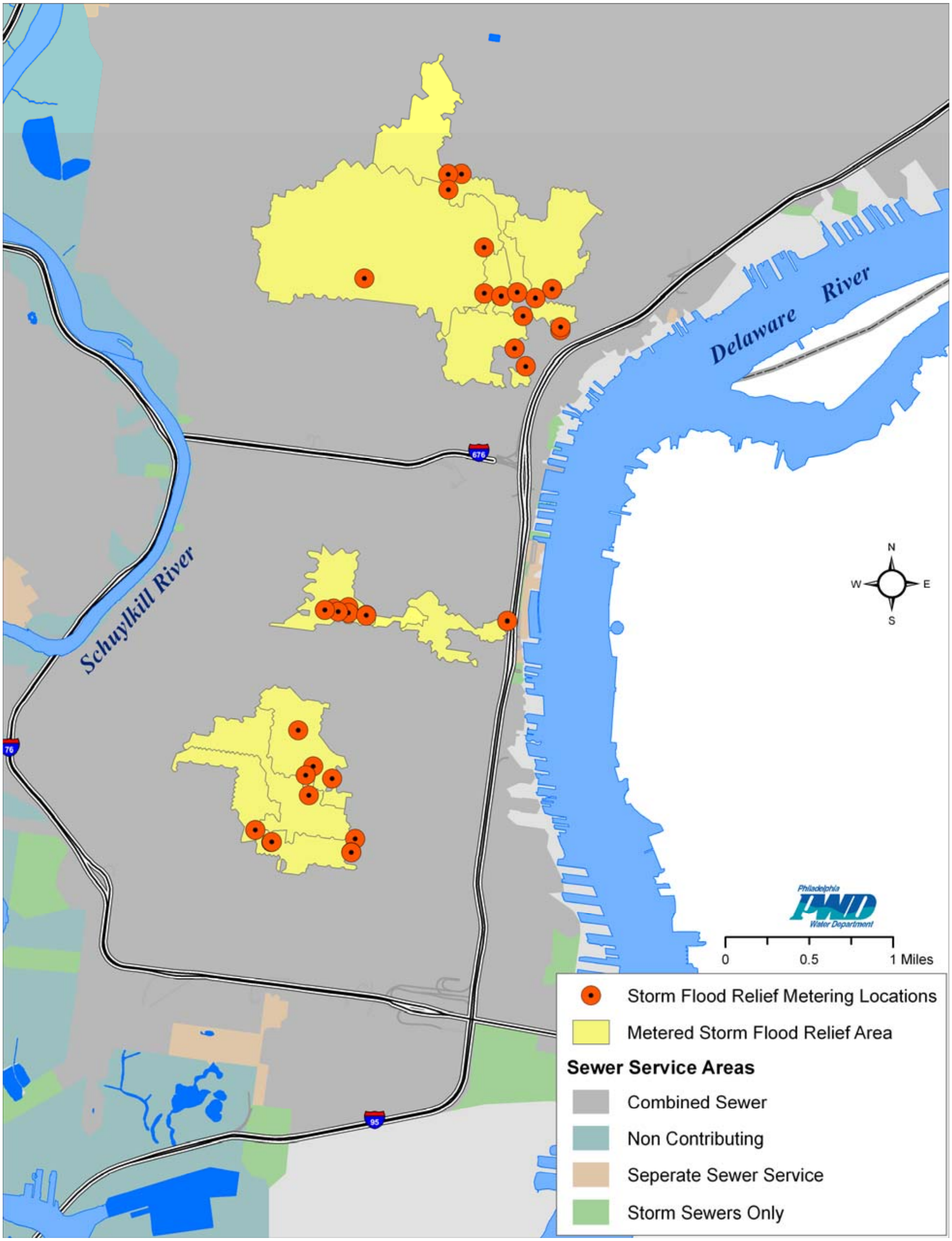


Figure 3-3 PWD Targeted Storm Flood Relief Monitoring Program Meter Locations

Portable Flow Monitoring Data Processing and QA/QC
Flow monitoring field personnel install and maintain depth and velocity recording monitors and upload hydraulic data, via a laptop computer, on a bi-weekly basis throughout the monitoring period. All deployed monitors have data uploaded in a period of 2 – 3 days. Obtaining and recording field-measured depth, velocity, and flow points are vital in verifying the monitoring equipment is properly calibrated and providing reliable results. During the site visits, field calibration measurements are taken at various times of the day and under various ranges of depths and flows to check and verify the equipment is functioning correctly. Wastewater depths are measured from the crown of the pipe using a ruler. Average velocities through the pipe are measured using a hand-held portable velocity meter. Several of the field calibration events for each meter location take place in high flow periods during wet weather, at locations where it a measurement may be safely obtained by the crew during the wet weather event. The calibration data and observed discrepancies are documented by field crews in a field log and submitted along with interrogated data from every deployed site. After several site visits, the field-measured flow points are used to establish a depth versus flow relationship and rating curves used in quality assurance procedures.

The monitored data are transferred from the field to the Office of Watersheds Server on a bi-weekly basis where they undergo a comprehensive QA/QC review process. Several procedures have been formulated and implemented for reviewing the portable flow monitoring data, assessing its accuracy, and making any required adjustments. Time-series plots and scatter-plots of the raw monitored data are produced to facilitate initial investigations of the flow and level trends at each of the monitoring locations.

The QA/QC methods and procedures implemented in the PWD Flow Monitoring Program assist the data analyst in reviewing the monitored flow data and identifying errors. Subsequently, procedures were developed and implemented to correct erroneous data. Two categories or types of data errors were detected, random errors and systematic errors.

Random errors are typically caused by temporary hydraulic conditions or sensor problems that usually lasted less then an hour. Since randomly errant data points usually were surrounded by reliable data points, both depth and velocity errors could be corrected by matching the adjacent data. The corrections are made by observing the reliable depths, velocities, and flows from the adjacent monitored data, observing the trends, and applying linear interpolations between the adjacent data points to determine the appropriate value for the incorrect data point(s).

Systematic errors are typically caused by long-term hydraulic conditions, sensor fouling, improper calibrations, and/or equipment failures that can last several hours, several days, or even several weeks in extreme cases. Systematic errors in depth measurement usually can not be corrected. When depth sensors are fouled or fail for long durations, there are usually no reliable means by which to recover or correct the lost or errant data. Detected errant data are flagged for unacceptable quality, regarded as data gaps, and not used in the subsequent data analyses. However, systematic errors in velocity measurement usually can be corrected as long as the corresponding depth measurements are reliable. Systematic errors may be corrected by using the envelope curve(s) from the scatter-plots to mathematically define the typical depth-flow relationships (rating curves) at the monitoring site. The rating curve can then be applied to the level data to obtain an estimate of the flow.

To quantify RDII, a four-step process is used to perform dry weather and wet weather flow analyses of the monitored sewer system flow data. The analyses are performed using the CDM SHAPE software, which is further discussed in Section 5. The four-step procedure used to perform the RDII analyses on the monitored data is listed below and described in the following paragraphs.

- Flow data preparation
- Precipitation data preparation
- Dry weather flow evaluations and determination of base flow quantities
- Hydrograph decomposition to determine rainfall derived inflow and infiltration (RDII) quantities in sanitary sewers and stormwater runoff loading in combined sewers

Flow Data Preparation:
After initial QA of monitored flow data, the data are entered into the CDM SHAPE software and reviewed to confirm that it was complete, properly formatted, and compatible with the requirements of the subsequent RDII analysis processes, which is discussed in greater detail in Section 5. The review also includes error checking, identifying data gaps, and filling in periods of missing data.

Precipitation Data Preparation:
The monitored rain gage data is reviewed to confirm that it was complete and met the requirements of the RDII analysis process. To quantify RDII, there must be a corresponding rainfall data point for each wastewater flow data point. The review includes error checking and filling in periods of missing data with corresponding data from adjacent gages.

Dry Weather Flow Evaluations:
After the data entry, format conversions, and reviews of the flow and precipitation data are completed, dry weather analyses are performed to quantify base wastewater flow (BWWF), ground water infiltration (GWI), and rainfall dependant inflow and infiltration (RDII). The specifics of this analysis and the models employed are available in Section 5. The analyses consist of identifying days within the monitoring period of record that are not affected by a rainfall event. The method also eliminates other atypical days in which the dry weather flows may have been affected by holidays or other special events. Mean maximum, minimum, and average daily flows for the selected dry weather days are computed and used to identify GWI and BWWF. Average weekday and weekend dry weather flow hydrographs are computed and used in subsequent analysis processes to determine the RDII flows during rainfall events.

Hydrograph Decomposition:
The average daily dry weather flow (ADDWF) hydrographs calculated by the program are then used to quantify RDII volumes for each of the storms that occurred during the flow monitoring period. The first step in the analysis is to manually adjust GWI rates to account for seasonal variations. The seasonal adjustments are based on the assumption that the difference between monitored flows and the computed ADDWF hydrograph should be approximately zero before and after a storm. RDII volumes and peak flows for individual storm events are calculated by subtracting the seasonally adjusted dry weather flow hydrograph (wastewater plus GWI) from the total monitored flow (wastewater plus GWI plus RDII). The subtraction process is called hydrograph decomposition. For each monitored storm, the total rainfall volume over the monitored sewershed area, the storm-induced RDII volume, and the total R-value are computed. The total R-value is defined as the ratio

of the calculated RDII volume to the rainfall volume over the sewered area, expressed as a percent. An R-value of 0.07 indicated that 7 percent of the total monitored rainfall volume that fell over the sewershed area made its way into the sewer system.

Additionally, the service area tributary to each monitor site is delineated to obtain accurate estimates of service populations and areas.

Dry Weather Flow Characterization:
Average dry weather flow patterns are identified using the CDM SHAPE software. Initially, days are automatically excluded from the average daily dry weather flow calculations based on selected rainfall amounts for the given day as well as each of the two preceding days to account for residual influences from previous storm events and snow melt. In addition, days are automatically excluded based on a selected number of standard deviations from the mean. Further manual selection of dry weather days are performed based on a consistent diurnal cycle typical for the tributary sewershed area. Time series plots of flow and precipitation are generated for each individual day within the period of record. Dry weather flow calculations are performed separately for weekdays and weekends due to the fact that base wastewater flow patterns will differ for the two. The monitoring locations are analyzed on a monthly basis to characterize seasonal variations.

The average daily dry weather flows consist of total domestic wastewater, commercial and industrial flow, ground water infiltration, and direct stream inflow flowing through the sewer. Dry weather flows are quantified with respect to population and tributary sewershed acreage to provide a basis of comparison amongst all monitored sites. Additionally, the SHAPE software is used to calculate average daily maximum and minimum flows during dry weather to illustrate the magnitude of fluctuation for diurnal flow. The average daily minimum flow rate is used to estimate the quantity of ground water infiltration that is conveyed through the system (assuming a negligible quantity of early morning commercial/industrial activity).

Extreme Event Analysis:
Once the monitor has been removed and all available data has undergone QA/QC protocols, the five largest (peak, not volume) RDII responses for the period of record at each monitoring site are identified and the maximum hourly-sustained peak flows, total rainfall depth, unit per capita and per acre flows are calculated. Extreme events can provide valuable insight into sewer hydraulics during surcharged conditions. The flow and rainfall data for these events is used to identify the potential for sanitary sewer overflows in a given monitor location.

Portable Flow Monitoring Data Storage
The quality checked and corrected monitored data, along with the monthly raw and corrected plots for each site are kept in a Microsoft Excel workbook for each quarter year. A Microsoft Access database is also maintained that contains all corrected flow monitoring data with flagging to identify corrected or removed data. This database is maintained as a source of flow data for use in subsequent analyses. The CDM SHAPE software generates Microsoft Access databases that are maintained for each flow monitoring site. In addition, a Microsoft Access database is maintained containing the results of all wet and dry weather flow analyses performed using the CDM SHAPE software.

Arcview point and polygon coverages are maintained indicating the monitor location and contributing area, respectively.

3.1.3.4 Outlying Community Contributing Flow Meter

Permanent flow meters are installed at major points of connection for municipalities contributing sanitary sewage to the PWD system. PWD has also performed portable flow monitoring of all non-metered outlying community points of connection with the City of Philadelphia, when seventeen sanitary sewer locations were monitored for two months during the fall of 2004. In addition, portable flow monitoring was provided by Bensalem Township beginning in August 2004 for each of its fifteen points of connection to the City. The outlying community meter locations are listed in Table 3-4 and shown along with contributing areas on the map in Figure 3-4.

Table 3-4 Outlying Community Permanent and Portable Metering Chamber IDs and Locations

Sewer District	Meter IDs	Townships	Interceptor Systems	Number of Meters
NE	MA1, MA2, MA3, MA4, MB1, MBE1, MBE2, MBE3, MBE4, MBE5, MBE6, MBE7, MBE8, MBE9, MBE10, MBE11, MBE12, MBE13, MBE14, MBE15, MBE16, MC1, MC2, MC3, MC4, MC5, MC6, MC7, MLM1, MLM2, MLM4, MLM5, MSH1	Abington, Bucks County, Bensalem, Cheltenham, Lower Moreland, Lower Southampton	PP, UDLL, POQ, FHL, Upper PP	33
SE	MS1, MS6	Springfield	WHL	2
SW	MD1, ML1, ML2, ML3, ML4, ML5, ML6, ML7, MS2, MS3, MS4, MS5, MS7, MS8, MUD1-N, MUD1-O, MUD1-S	Delaware Co., Lower Merion, Springfield, Upper Darby	CCHL, WHL, WLL, SWMG, DELCORA	17

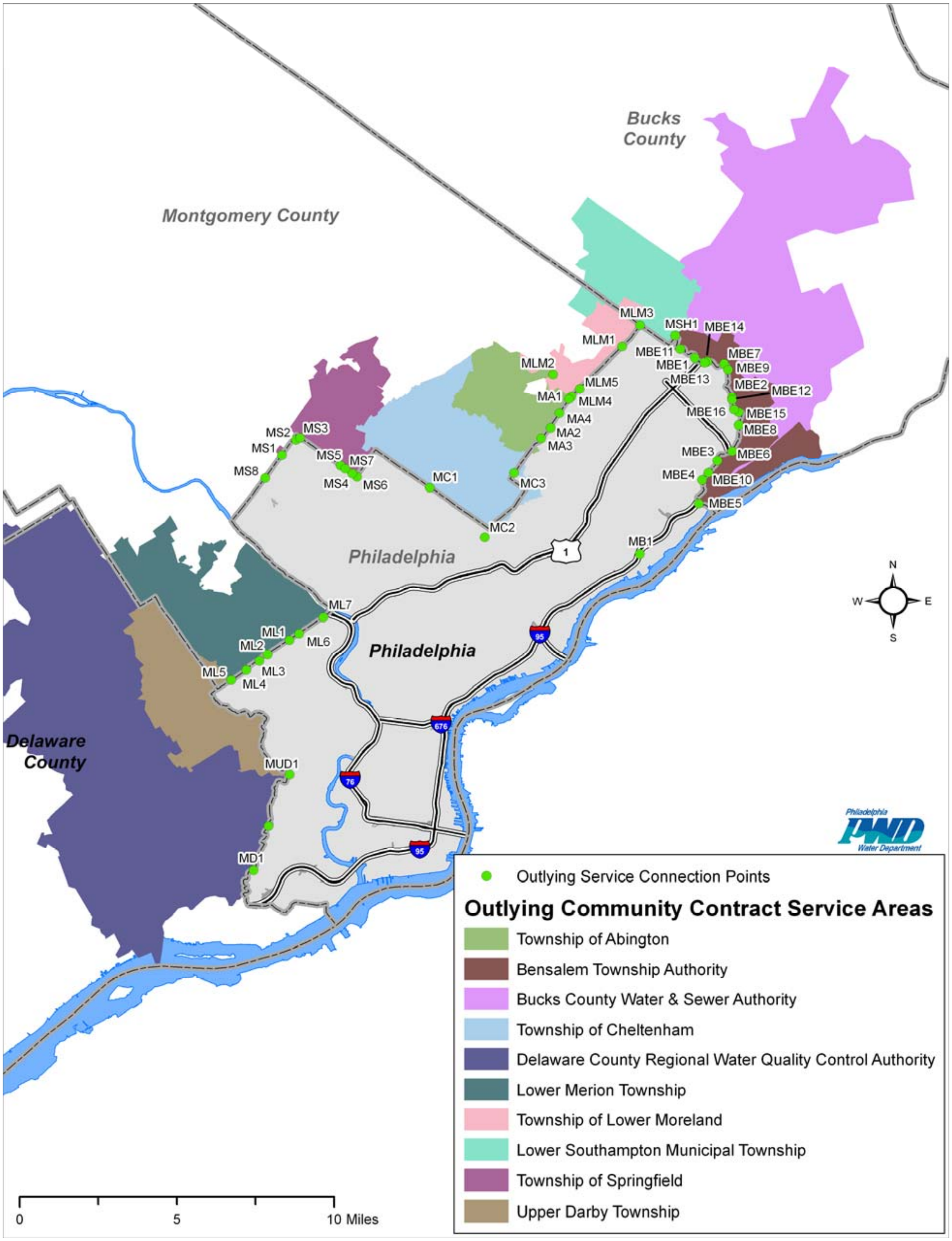


Figure 3-4 PWD Outlying Community Contract Service Areas and Connection Locations

3.1.3.5 National Oceanographic and Atmospheric Agency (NOAA) Tide

NOAA maintains hourly tidal data for the Delaware River station # 8545240 (USCG station at Washington Ave). Data is available in a preliminary form (most recent) and a verified form after NOAA performs quality assurance measures to ensure data integrity. NOAA verified hourly water level data is downloaded, converted to City datum, and interpolated to 15-minute intervals. Three sets of data are created from this to estimate three different tidal zones accounting for shifting tidal boundaries using a water-level offset and the time it takes the tide to affect the various zones based on distance upstream from the gage station.

Tidal boundary conditions are needed because many of the CSO regulator outfalls are located in tidal waters and are equipped with flap gates to prevent tidal inflows to the collection system. The tidal boundary condition in turn determines the effective overflow elevation for these regulators.

3.1.3.6 Ongoing Combined Sewer System Monitoring

Monitoring of combined sewer system wet and dry weather water quality and quantity will continue over the implementation period in order to track the performance of LTCPU control measures over time, including implementation of the NMCs, as well as, to refine hydrologic and hydraulic models of the system.

The continued monitoring of fixed long-term monitoring locations within the combined sewer system is important for tracking system performance over time in terms of dry and wet weather flow and pollutant loadings. The primary sources for continued monitoring at fixed long-term locations are:

- Water Pollution Control Plant (WPCP) influent flow data including hourly flow quantities and daily water quality monitoring of suspended solids, biological oxygen demand, fecal coliform
- Outlying community metering chamber flow data
- Permanent metering of water levels at CSO regulators, along interceptors, and in key locations that control the hydraulic grade line in the system
- Pumping station records

In addition to these sources of fixed long-term monitoring locations, a portable flow monitoring program will continue to be implemented.

Each interceptor system will be individually targeted for flow monitoring investigations aimed at identifying representative locations highly suitable for flow monitoring. Some of the larger CSO basins may call for monitoring of multiple smaller sub-sewershed basins or warrant investigating alternative portable high-rate metering technology or permanent meter installation.

Primary flow monitoring locations should also target key hydraulic control points coordinated with permanent metering programs as part of automated and real time CSS operation decision support systems.

Secondary flow monitoring should continue in selected sanitary and combined sewer areas identified in support of LTCP projects, extreme wet weather sanitary overflows, combined sewer storm flood relief projects, planning unit development, wet weather flow capacity evaluations, inflow and infiltration reduction programs, and watershed monitoring programs.

Flow Monitor Deployment Frequency and Duration
Maintaining long-term continuous primary flow monitoring stations in ideal representative priority locations is desirable to track the CSS performance improvement over time, and because the CSS response to wet weather conditions is generally greater over the range of events experienced than it is between locations across the CSS. Long-term continuous monitoring of select locations is also valuable for estimating inter-annual base groundwater inflow and infiltration rates, and relating short-term monitoring results with long-term average hydrologic conditions.

Secondary monitoring locations are deployed on a rotating basis in continued support of CSS remediation projects and investigations. Installed monitors are generally left in place until a sufficient number of dry weather days and rainfall events are captured, including storms of varying intensity, total volume, and antecedent dry periods. The monitors are then removed and reinstalled at other selected sewer sites to maximize the coverage of the PWD service area.

3.1.4 Receiving Water Monitoring

3.1.4.1 Overview
Comprehensive assessments of waterways are integral to planning for the long-term health and sustainability of water systems. PWDconsiders such assessments essential to measure the spatial and temporal differences within each watershed and to compare differences between watersheds. The watershed approach is used for monitoring in order to investigate the multiple sources of degradation which include stormwater and CSOs. While developing a comprehensive baseline condition in each watershed, the PWD can also measure the water quality and water quantity effects of the programs. Finally, the watershed approach to monitoring raises the awareness in Southeastern Pennsylvania of the impact that land development activities are having on waterbody health. By measuring all factors that contribute to supporting fishable, swimmable, and drinkable water uses, appropriate management strategies can be developed for each watershed land area that Philadelphia shares. The results of these monitoring efforts are reported in Section 3.4.2.

From 1999 to 2008, PWD has implemented a comprehensive watershed assessment strategy, integrating biological, chemical and physical assessments to provide both quantitative and qualitative information regarding the aquatic integrity of the Philadelphia regional watersheds. This information is being used to plan improvements to the watersheds in the Southeast Region of Pennsylvania.

In addition to discrete chemical sampling, PWD incorporated *in situ* continuous water quality monitoring at strategic locations within each watershed as part of the 1999-2008 comprehensive monitoring strategy. Using submerged instruments, dissolved oxygen, temperature, pH, conductivity, depth (stage) and turbidity were logged at 15-minute intervals. The instruments were deployed for approximately two weeks, retrieved and replaced with fresh calibrated instruments in order to produce nearly seamless temporal and spatial data.

Biological, physical and chemical sampling and monitoring follow the quality management procedures and Standard Operating Protocols (SOPs) as prepared by the Philadelphia Water Department's Bureau of Laboratory Services (BLS). These documents cover the elements of quality assurance, including field and laboratory procedures, chain of custody, holding times, collection of blanks and duplicates, and health and safety.

In addition to discrete and continuous sampling, the third water quality component of PWD's comprehensive monitoring strategy 1999-2008 was collecting water samples during wet weather flows. Automated samplers were strategically placed in locations throughout the watershed and used to collect samples during runoff producing rain events. This automated system obviated the need for staff to manually collect samples, thereby greatly increasing sampling efficiency. Automated samplers were programmed to commence sampling with a small (0.1 ft.) increase in stage. Once sampling was initiated, a computer-controlled peristaltic pump and distribution system collected grab samples at 30 min. to 1 hr. intervals, the actual interval being adjusted on a site by site basis according to "flashiness". Adjustment of the rising-limb hydrograph sampling interval allows optimum characterization of water quality responses to stormwater runoff and wet weather sewer overflows (Figure 3-5). Due to sample volume restrictions, fewer chemical analyses are performed on samples collected in wet weather.

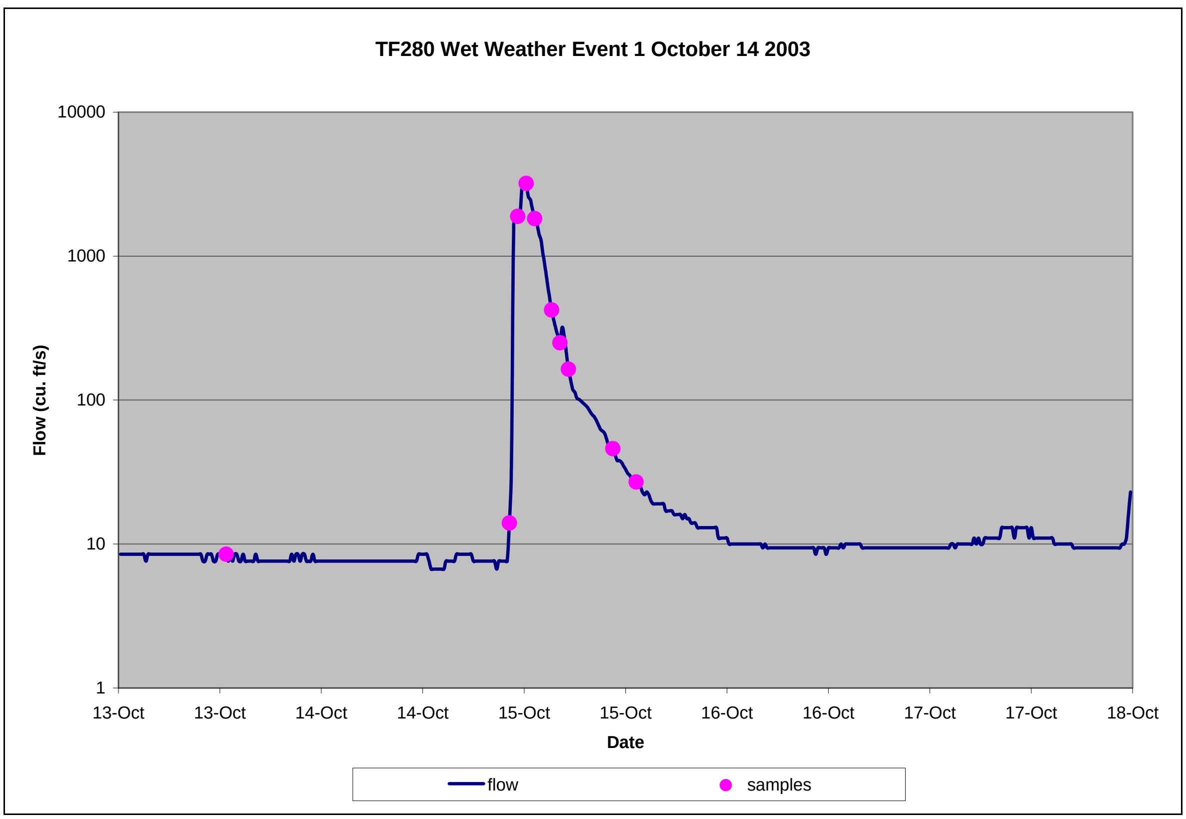


Figure 3-5 Hydrograph Showing Complete Capture of the October 14, 2008 Wet Weather Event from an Automatic Sampler in the Tookany/Tacony-Frankford Creek

PWD integrated biological assessments into the monitoring strategy for the IWMPs as a means of characterizing health of biological communities, identifying potential physical impairments or chemical stressors, and as a "baseline" for measuring the effects of future restoration projects. The biological monitoring protocols employed by PWD are based on methods developed by the United States Environmental Protection Agency (Barbour et al. 1999) and the Pennsylvania Department of Environmental Protection. These procedures are as follows:

- EPA Rapid Bioassessment Protocol III and PADEP ICE (Benthic Macroinvertebrates)
- EPA Rapid Bioassessment Protocol V (Fish)
- EPA Rapid Periphyton Assessment (Algae)
- EPA Physical Habitat Assessment

From 1999 through 2008, PWD has sampled fish communities throughout each of Philadelphia's watersheds using USEPA Rapid Bioassessment V Methods (RBP V).

From 2002 through 2008, PWD collected algal periphyton samples from a small number of sites in selected watersheds using components of USEPA Rapid Bioassessment Protocol 6.1 (laboratory-based approach). Algal periphyton are collected from natural substrates and biomass is estimated based on a quantitative chlorophyll-a and total chlorophyll analysis. Periphyton sampling is performed primarily to address the question of whether anthropogenic nutrient sources are causing eutrophication, which may result in violations of water quality criteria for dissolved oxygen, pH, and have adverse effects on aquatic food webs. Large concentrations of chlorophyll indicate excessively dense algal growth, which may partially explain observed aquatic life impairments.

Habitat assessments are conducted at each monitoring site based on the Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (Barbour *et al.*, 1999). Reference conditions are used to normalize the assessment to the "best attainable" situation. Habitat parameters are separated into three principal categories: (1) primary, (2) secondary, and (3) tertiary parameters:

- Primary parameters are those that characterize the stream "microscale" habitat and have greatest direct influence on the structure of indigenous communities.
- Secondary parameters measure "macroscale" habitat such as channel morphology characteristics.
- Tertiary parameters evaluate riparian and bank structure and comprise three categories: (1) bank vegetative protection, (2) grazing or other disruptive pressure, and (3) riparian vegetative zone width.

A description of the models and tools developed to facilitate analysis of receiving water quality is presented in Section 5.

3.1.4.1.1 Cobbs Creek and Tacony-Frankford Creek

PWD had planned and carried out an extensive sampling and monitoring program to characterize conditions in the Darby-Cobbs Creek Watershed and in the Tacony-Frankford Creek Watershed. The program includes hydrologic studies, water quality monitoring, biological assessments, habitat investigations, and fluvial geomorphologic modeling. These investigations, combined with considerable urban planning and community stewardship efforts, have culminated in the Cobbs

Creek Integrated Watershed Management Plan (CCIWMP) and the Tookany/Tacony-Frankford Integrated Watershed Management Plan (TTFIWMP). Comprehensive watershed assessments conducted in 1999 and 2003 informed the decision-making and prioritization processes of the plan. Future assessments will complement state water quality criteria by providing a scientific means to measuring improvements once restoration activities are implemented.

3.1.4.1.2 Tidal Schuylkill and Delaware Rivers

Water quality and hydrological data used to characterize wet and dry weather conditions of the tidal Schuylkill and Delaware Rivers were obtained from the U.S. Geologic Survey (USGS), the Delaware River Basin Commission (DRBC), the Philadelphia Water Department The monitoring programs target different features of the tidal Delaware River Estuary, and when analyzed together, they present a complete picture of the wet and dry weather hydrologic conditions within and bordering Philadelphia.

USGS water quality monitoring in the Delaware Estuary is a part of the National Water Information System that records the physical and chemical characteristics of waters across the U.S. The data from five USGS monitoring stations are used in this characterization of the tidal Schuylkill and Delaware Rivers.

The DRBC is a regional governing body created in 1961 to regulate the water resources of the Delaware River Basin. DRBC activities include water quality protection, water supply allocation, regulatory review, water conservation, watershed planning, and drought management. DRBC monitors the water quality of the Delaware River through its Boat Run Monitoring Program. Six Boat Run sampling locations in the tidal Delaware River are examined in addition to the USGS locations.

PWD operates extensive water monitoring programs that support the drinking water treatment, stormwater management, and wastewater treatment functions of the utility. A number of PWD monitoring programs are used in this application to characterize the dry and wet weather water quality of the tidal Schuylkill and Delaware Rivers. Tidal Schuylkill River data include the results from an Office of Watersheds dry and wet weather sampling program between 2005 and 2006 and a continuous deployment of Sondes in the tidal Schuylkill from 2007-2009. The Bureau of Laboratory Services records tidal Delaware River data at the Baxter Water Treatment Plant intake located in the Torresdale section of Philadelphia. The Baxter intake data tracks water quality conditions in the tidal Delaware River which is the source water supply to Philadelphia and surrounding municipalities.

3.1.4.2 Historical Data

3.1.4.2.1 Tacony-Frankford Creek

From 1971 to 1980, PWD and the USGS established six stream gauging stations in Tacony-Frankford Watershed and conducted monthly water quality sampling at five of these locations. Monthly water quality samples were collected at each site and analyzed for conductivity, BOD_5, total phosphate, ammonia, nitrite, nitrate, and fecal coliform. The program collected about ten years of monthly samples. Figure 3-6 shows the locations of the monitoring stations from the PWD/USGS Cooperative Program.

PWD and the USGS augmented the existing stream gage network in the watershed as part of the Cooperative sampling program, establishing three new stream gages from 1971 to 1973. A gage was established at Castor Avenue in 1982, which is the only gage still in operation. However, PWD and USGS have re-established the former gage at the City line. Table 3-5 contains summary information for each of the six gauging stations for their respective periods of record.

Table 3-5 Periods of Record for Flow and Water Quality Data

Station ID	Location	Quality Data (Period)	Streamflow Data (Period)
01467089	Frankford Creek at Torresdale Ave.	10/9/67 - 3/7374	10/1/64 - 6/29/82, 5/14/82 – 6/29/82
01467087	Frankford Creek at Castor Ave.*	9/24/25 - 8/24/76	7/1/82 - 9/30/03
01467086	Tacony Creek at County Line*	11/9/67 - 10/1/73	10/1/65 - 11/17/88
01467085	Jenkintown Creek At Elkins Park		10/01/73 - 9/30/78
01467084	Rock Creek above Curtis Arboretum near Philadelphia	10/4/71 - 10/1/73	5/1/71 – 9/30/78
01467083	Tookany Creek near Jenkintown		10/1/73 - 9/30/78
	*Active Gage		

In general, the majority of the historical data are available from STORET, USEPA's water quality database. For the Tookany/Tacony-Frankford Watershed, data were from the PWD/USGS Cooperative Program, "Urbanization of the Philadelphia Area Streams."

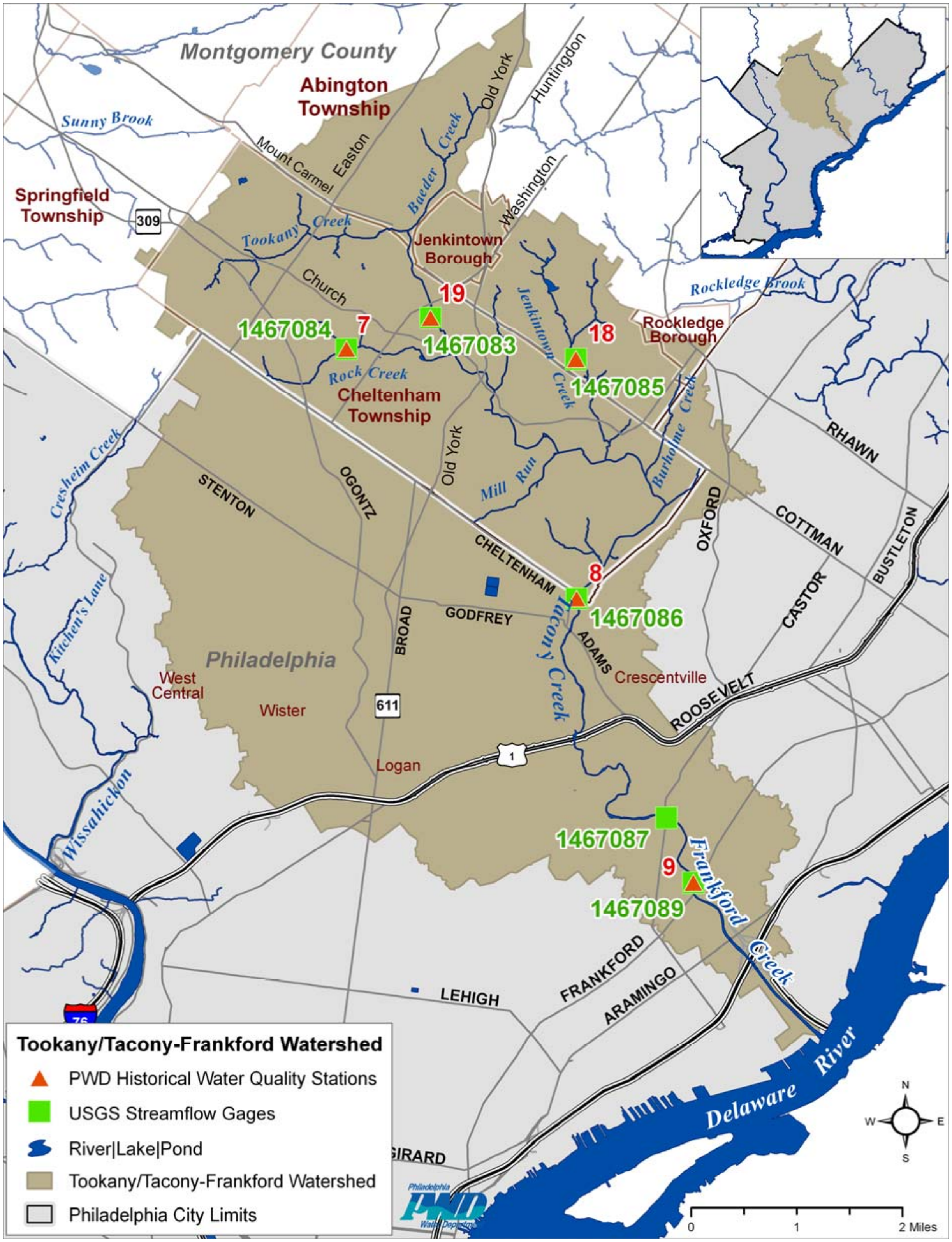


Figure 3-6 PWD/USGS Cooperative Program Water Quality Stations in the Tookany/Tacony-Frankford Watershed

3.1.4.2.2 Cobbs Creek

In the early 1970s, the Philadelphia Water Department began a study in cooperation with the USGS titled, "Urbanization of the Philadelphia Area Streams." The purpose of this study was to quantify the pollutant loads in some of Philadelphia's streams and possibly relate the degradation in water quality to urbanization. The study included four locations in Darby-Cobbs Watershed (Figure 3-7). Water quality monitoring at the four stations in Cobbs Creek began in 1967, but was eventually terminated by 1983. Similarly, measurements of streamflow commenced in 1964 and were discontinued at all locations by 1990.

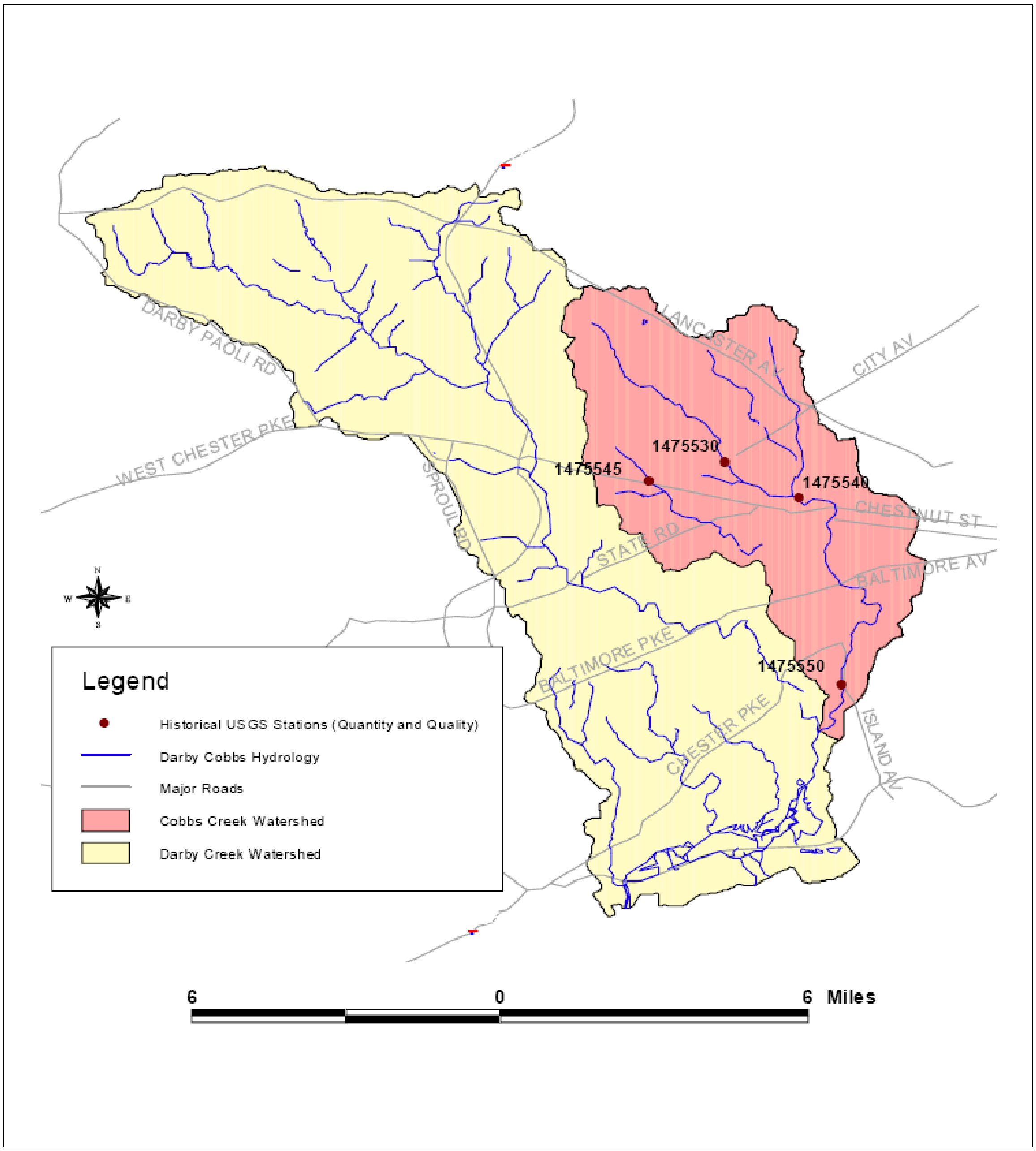


Figure 3-7 Historical USGS Monitoring Locations in Darby-Cobbs Watershed

3.1.4.2.3 Tidal Schuylkill and Delaware Rivers

The USGS and DRBC play central roles in monitoring the water quality of the Delaware Estuary. The DRBC boat run program began in the late 1960s and collects water quality data from the center channel of the main stem Delaware River and Delaware Bay. These stations extended from RM 127.5, a short distance south of Trenton, New Jersey, to South Brown Shoal in Delaware Bay at RM 6.5, near the bay mouth, and throughout the Philadelphia segment of the Delaware River. The stations are plotted on an estuary map in Figure 3-8 and listed by RM and geographic coordinates in Table 3-6. Data categories include routine pollutants: bacteria and radioactivity; heavy metals; algae and organic carbon; and oxygen demand. Additional surveys for other pollutants are performed on an as needed basis.

In the vicinity of Philadelphia, all but three historic USGS stations collect water quality and/or streamflow data. Presented below in Table 3-6 are the descriptions of these stations.

Table 3-6 Tidal Schuylkill and Delaware River Historic Monitoring Locations

Station ID	Location	Quality Data (Period)	Streamflow / Gage Data (Period)
01464600	Delaware River at Bristol, PA	10/1/54 - 11/26/80	NA
01475200	Delaware River at Paulsboro, NJ	5/22/80 – 11/26/80	12/20/86 – 1/11/88
01474500	Schuylkill River at Philadelphia, PA	10/31/25 – 2/9/04	**

NA – Not applicable because data was never recorded
** Ongoing data collection

Figure 3-8 DRBC Boat Run Monitoring Locations

3.1.4.3 Recent Data

3.1.4.3.1 Tacony-Frankford

Tables 3-7 and 3-8 summarize the types, amounts, and dates of sampling and monitoring performed by PWD, PA DEP, and USGS. A river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. The naming convention includes three or four letters and three or more numbers which denote the watershed, stream, and distance from the mouth of the stream. For example, site TFJ110 is named as follows:

- "TF" indicates the Tookany/Tacony-Frankford Watershed
- "J" indicates Jenkintown Creek, a tributary to Tookany Creek
- "110" places the site 1.10 miles upstream of the confluence of Jenkintown Creek and Tookany Creek

Table 3-7 Summary of Physical and Biological Sampling and Monitoring Tookany/Tacony-Frankford Watershed

		Physical			Biology			
	USGS		USGS	USGS Annual	PWD			PA DEP
Site Name	Gage	Stream Name	Daily Flow	Peak Flow	RBP III*	RBP V**	Habitat	
	1467089	Frankford Creek	1965-1982	1966-1980				
TF280	1467087	Tacony Creek	1982-Present	1982-Present				
TF324		Tacony Creek			November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	
TF396		Tacony Creek			Mar-04	Jun-04	Mar-04	
TF500		Tacony Creek			November 2000 March 2004	Jun-04	November 2000 March 2004	
TF620	1467086	Tacony Creek	1965-1986; 2005-2009	1966-1985	November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	1999
TF760		Tookany Creek			Nov-00		Nov-00	
TF827		Tookany Creek			Mar-04	Jun-04	Mar-04	
TF975		Tookany Creek			November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	

		Physical			Biology			
	USGS		USGS	USGS Annual	PWD			PA DEP
Site Name	Gage	Stream Name	Daily Flow	Peak Flow	RBP III*	RBP V**	Habitat	
TF1120	1467083	Tookany Creek	1973-1978	1974-1978	November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	
TF1270		Tookany Creek			Mar-04		Mar-04	1999
TFU010		Unnamed Tributary			Mar-04		Mar-04	1999
TFJ013		Jenkintown Creek			Mar-04		Mar-04	1999
	1467085	Jenkintown Creek	1973-1978	1974-1978				
TFJ110		Jenkintown Creek			Nov-00		Nov-00	
TFM006		Mill Run			Mar-04		Mar-04	
TFR064		Rock Creek			Mar-04		Mar-04	1999

* EPA Rapid Bioassessment Protocol III Benthic Macroinvertebrates
** EPA Rapid Bioassessment Protocol V Ichthyofaunal (Fish)

A range of water quality samples were collected between 1999 and 2004 at 9 sites in the watershed. The sites are listed in Table 3-8 and are shown on Figure 3-9. Three different types of sampling were performed as discussed below. Parameters were chosen based on state water quality criteria or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-9.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings:

- Data collected during the previous five years may be considered to represent current conditions
- At least ten temporally independent samples should be collected and analyzed for a given parameter
- "A two-year minimum data set is recommended to account for inter-year variation, and the sample set should be distributed over a minimum of two seasons to account for inter-seasonal variation."
- "No more than two-thirds of the samples should be collected in any one year."
- "Samples collected fewer than four days apart at the same riverine location should be considered one sample event."
- "Samples collected within 200 meters [about 0.1 miles] of each other will be considered the same station or location." This convention was followed except where two sampling sites were chosen to represent conditions upstream and downstream of a modification such as a dam

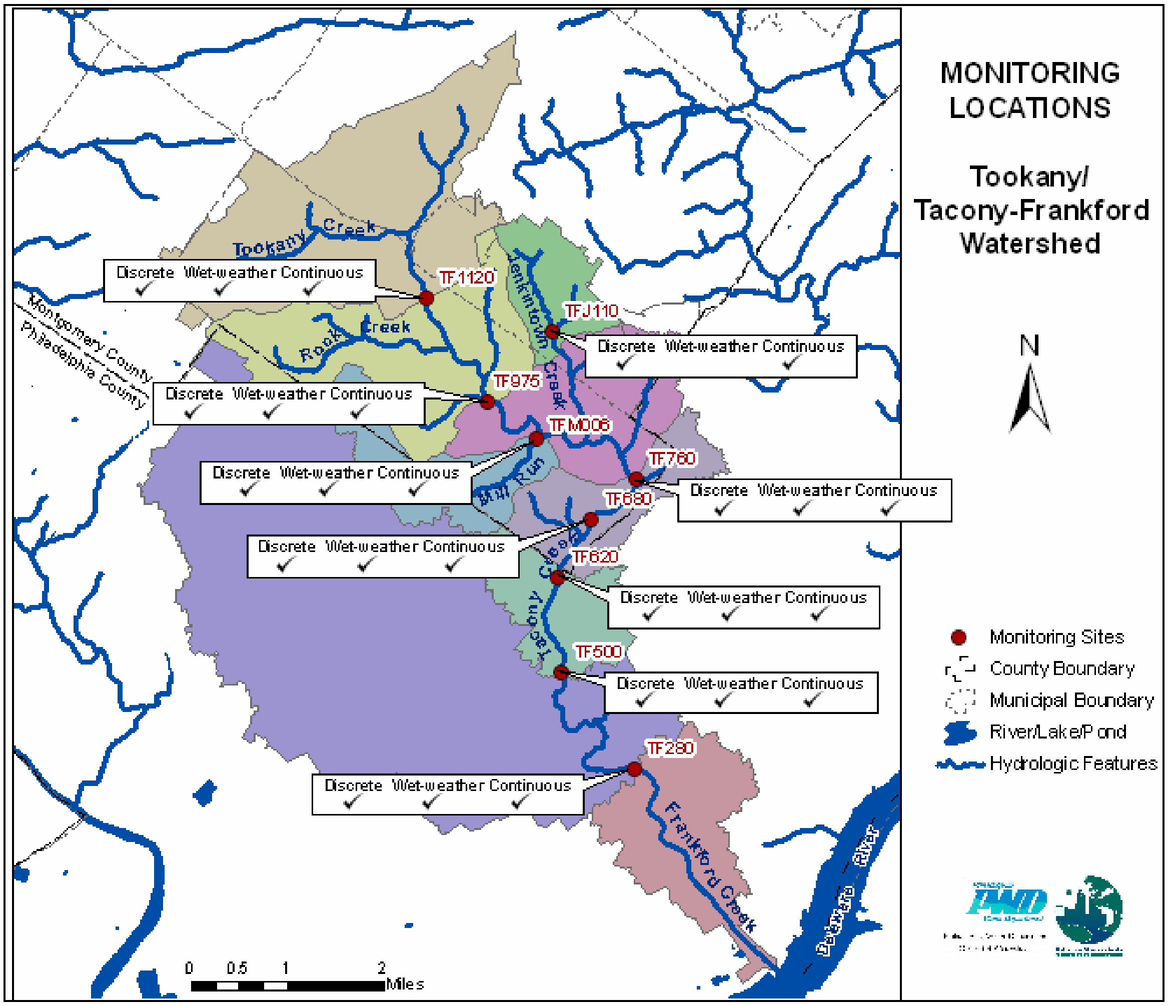


Figure 3-9 Water Quality Sampling Sites in Tookany/Tacony-Frankford Watershed

Table 3-8 Summary of Water Quality Sampling and Monitoring in the Tookany/Tacony-Frankford Watershed

Site	USGS Gage	Discrete	Continuous (hrs)	Wet Weather
TF280	1467087	32 samples 6/29/2000 - 9/2/2004	11109	12 periods 3/19/2001 - 9/1/2004
TF500		25 samples 6/29/2000 - 8/26/2004	3335.5	2 periods 5/21/2001 - 11/1/2002
TF620*	1467086	27 samples 6/29/2000 8/26/2004	9972.5	13 periods 10/15/2002 - 3/7/2003
TF680*		4 samples 7/27/2004 - 9/2/2004		9 periods 5/1/2003 - 9/1/2004
TF760		22 samples 6/29/2000 - 8/26/2004	1701.25	2 periods 5/21/2001 - 11/1/2002
TF975		27 samples 6/29/2000 - 9/2/2004	6298	12 periods 10/29/2002 - 9/1/2004
TF1120	1467083	24 samples 6/29/2000 - 9/2/2004	6462.75	10 periods 10/15/2002 - 9/1/2004
TFJ110	1467085	21 samples 6/29/2000 - 8/26/2004	2593.25	
TFM006		16 samples 11/29/2001 - 9/2/2004	2543.25	2 periods 7/7/2004 - 9/1/2004

* Sites TF620 and TF680 were combined for analysis in many instances.

Table 3-9 Water Quality Parameters Sampled in the Tookany/Tacony-Frankford Watershed

Parameter	Units	Discrete	Wet Weather	Continuous
Physical Parameters				
Temperature	deg C	X	X	X
pH	pH units	X	X	X
Specific Conductance	µMHO/cm @ 25C	X	X	X
Alkalinity	mg/L	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
Oxygen and Oxygen Demand				
DO	mg/L	X	X	X
BOD_5	mg/L	X	X	
BOD_{30}	mg/L	X	X	
$CBOD_5$	mg/L	X	X	
Nutrients				
Ammonia	mg/L as N	X	X	
TKN	mg/L	X	X	
Nitrite	mg/L	X	X	
Nitrate	mg/L	X	X	
Total Phosphorus	mg/L	X	X	
Phosphate	mg/L	X	X	
Metals				
Aluminum (Total)	mg/L	X	X	
Aluminum (Dissolved)	mg/L	X	X	
Calcium (Total)	mg/L	X	X	
Cadmium (Total)	mg/L	X	X	
Cadmium (Dissolved)	mg/L	X	X	
Chromium (Total)	mg/L	X	X	
Chromium (Dissolved)	mg/L	X	X	
Copper (Total)	mg/L	X	X	
Copper (Dissolved)	mg/L	X	X	
Fluoride (Total)	mg/L	X	X	
Fluoride (Dissolved	mg/L	X	X	
Iron (Total)	mg/L	X	X	
Iron (Dissolved)	mg/L	X	X	
Magnesium (Total)	mg/L	X	X	
Manganese (Total)	mg/L	X	X	
Manganese (Dissolved)	mg/L	X	X	
Lead (Total)	mg/L	X	X	
Lead (Dissolved)	mg/L	X	X	
Zinc (Total)	mg/L	X	X	
Zinc (Dissolved)	mg/L	X	X	
Biological				
Total Chlorophyll	µg/L	X	X	
Chlorophyll-*α*	µg/L	X	X	

Parameter	Units	Discrete	Wet Weather	Continuous
Fecal Coliform	CFU/100mls	X	X	
E. coli	CFU/100mls	X	X	
Osmotic Pressure	mOsm	X		
Miscellaneous				
Phenolics	mg/L	X	X	

3.1.4.3.2 Cobbs Creek

3.1.4.3.2.1 Water Quality Sampling and Monitoring (1999-2000)

Tables 3-10 and 3-11 summarize the types, amounts, and dates of sampling and monitoring performed through 2000 by PWD, PADEP, and USGS in a cooperative effort. As in the Tookany/Tacony-Frankford Watershed, a river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. For example, site DCC-110 is located as follows:

- "DC" stands for the Darby-Cobbs Watershed
- "C" stands for Cobbs Creek
- "110" places the site 1.10 miles upstream of the mouth of Cobbs Creek, where it flows into Darby Creek

For dissolved oxygen, discrete sampling is not sufficient to characterize the condition of the stream. The magnitude of the diurnal pattern exhibited by DO is an indicator of the amount of algal activity in the stream, and the minimum DO occurs in darkness when sampling is impractical. For this reason, PWD monitored dissolved oxygen on a continuous basis at several sites in the Cobbs Creek system as part of the 1999 comprehensive assessment (Table 3-11).

A range of water quality samples were collected between 1999 and 2001 at eleven sites in the watershed. The sites are listed in Table 3-12 and are shown on Figure 3-10. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-13.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings.

Table 3-10 Summary of Physical and Biological Sampling and Monitoring in Darby-Cobbs Watershed through 2000

Site ID	USGS Gage	PWD Geomorph.	USGS Daily Flow	USGS Annual Peak Flow	PWD RBP III	PWD RBP V	PWD Habitat	PADEP
DCC-110	01475550	Assessments were performed at cross-sections located throughout the system	1964-1990	1964-1990	December 1999		December 1999	
DCC-175						April 2000		
	01475548		2005-2009	2006-2008				
DCC-455					December 1999		December 1999	
DCC-505						April 2000		
	01475540		1964-1973	1965-1971				
DCC-770	01475530		1964-1981; 2004-2009	1965-2008			December 1999	
DCC-820						April 2000		
DCC-865					December 1999		December 1999	
DCD-765	01475510		1964-1990	1964-1990				
	01475545		1972-1978	1972-1978				
DCD-1170								
DCD-1570								
DCD-1660								
	01475300		1972-1997*	1972-1996				
STA01 – STA12								1995-1996
DCI-010								
DCI-135					December 1999		December 1999	
DCIW-010					December 1999		December 1999	
DCIW-100						April 2000		
DCIW-185					December 1999		December 1999	
DCM-300								
DCN-010								
DCN-185					December 1999		December 1999	
DCN-215						April 2000		
DCS-170								

* Provisional data are available up to the present.

Table 3-11 Summary of Water Quality Sampling and Monitoring in Darby-Cobbs Watershed through 2000

		Chemical		
	USGS	PWD		
Site ID	Gage	Discrete	Continuous	Wet Weather
DCC-110	01475550	14 samples 5/11/99-6/29/00	3379 hrs	3 periods 5/23/00-7/28/00
DCC-115			951 hrs	
DCC-175				
DCC-455		10 samples 5/11/99-7/20/99	3176 hrs	
DCC-505				
	01475540			
DCC-770	01475530	10 samples 5/11/99-7/20/99	2486 hrs	
DCC-820				
DCC-865				
DCD-765	01475510	12 samples 5/11/99-6/12/00	1854 hrs	3 periods 5/23/00-7/28/00
	01475545			
DCD-1170		10 samples 5/11/99-7/20/99		
DCD-1570		10 samples 5/11/99-7/20/99		
DCD-1660		4 samples 6/1/00-7/13/00	2645 hrs	1 period 7/27/00-7/28/00
	01475300			
STA01 - STA12				
DCI-010		10 samples 5/11/99-7/20/99		
DCI-135				
DCIW-010				
DCIW-100				
DCIW-185				
DCM-300		10 samples 5/11/99-7/20/99		
DCN-010		10 samples 5/11/99-7/20/99	167 hrs	
DCN-185				
DCN-215				
DCS-170		10 samples 5/11/99-7/20/99		

Table 3-12 Water Quality Sampling Sites in Darby-Cobbs Watershed 1999-2000

Cobbs Creek	Darby Creek	Tinicum
Mainstem	**Mainstem**	**MuckinpattisCreek**
DCC110	DCD765	DCM300
DCC455	DCD1570	
DCC770	DCD1660	
Naylors Run		**Stony Creek**
DCN010		DCS170
Indian Creek		
DCI010		

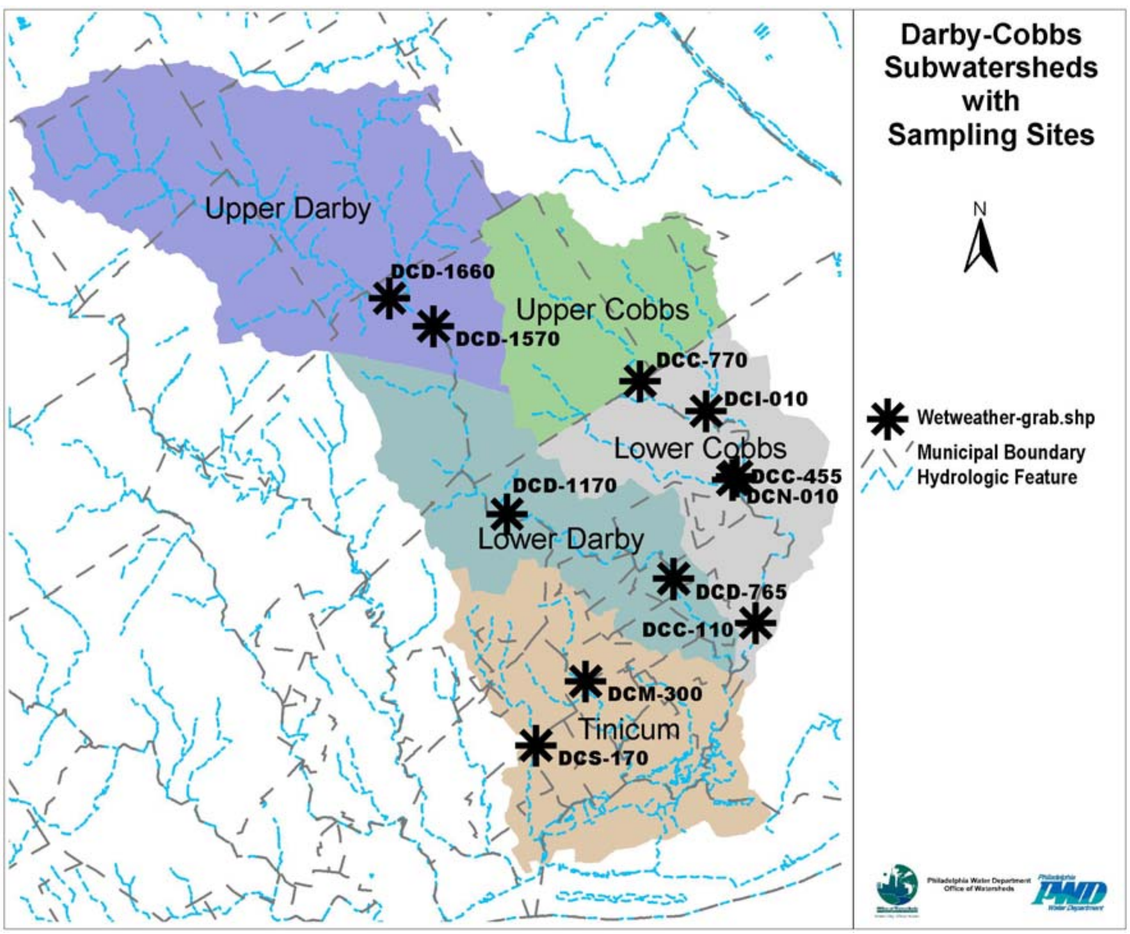


Figure 3-10 Darby-Cobbs Watershed 1999-2000 Water Quality Sampling Sites

Table 3-13 Darby-Cobbs Watershed Water Quality Parameters Sampled 1999-2000

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg. C	X	X	X
pH	none	X	X	X
Specific Conductance	uS/cm	X	X	X
Alkalinity	mg/L as CaCO3	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
OXYGEN AND OXYGEN DEMAND				
DO	mg/L	X	X	X
BOD5	mg/L	X	X	
BOD30	mg/L	X	X	
CBOD5	mg/L	X		
NUTRIENTS				
Total Ammonia	mg/L as N	X	X	X*
Nitrate	mg/L as N	X	X	X*
Nitrite	mg/L as N	X	X	X*
TKN	mg/L as N	X	X	
Phosphate	mg/L as P	X	X	
Total Phosphorus	mg/L	X	X	
METALS				
Aluminum	mg/L	X	X	
Calcium	mg/L	X	X	
Cadmium	mg/L	X	X	
Chromium	mg/L	X	X	
Copper	mg/L	X	X	
Fluoride	mg/L	X	X	
Iron	mg/L	X	X	
Dissolved Iron	mg/L	X		
Magnesium	mg/L	X	X	
Manganese	mg/L	X	X	
Lead	mg/L	X	X	
Zinc	mg/L	X	X	
BIOLOGICAL				
Chlorophyll A	ug/L	X	X	
Total Chlorophyll	ug/L	X	X	
Fecal Coliform	/100 mL	X	X	
E. coli	/100 mL	X	X	
Osmotic Pressure	mosm	X	X	
MISCELLANEOUS				
Phenolics	mg/L	X	X	

* Results did not pass quality assurance but may have some value as a relative measure.

3.1.4.3.2.2 Water Quality Sampling and Monitoring (2003)

Since the 1999 comprehensive assessment, the understanding of the watershed has been advanced by numerous studies and modeling exercises, funded largely by the Commonwealth of Pennsylvania (e.g., Acts 167, 104b3 and 537). The PWD Watershed Sciences Group 2003 comprehensive assessment was designed to further investigate and characterize the Darby-Cobbs Watershed. Locations of the 27 water quality sampling sites for 2003 are depicted in Figure 3-11. Sites DCC770, DCC455, DCC208, DCD1570, DCD1170, DCD765, DCI010 and DCN010 were included in PWD's baseline chemical assessment of Darby-Cobbs Watershed in 1999. Sites in the Tinicum sub-basin (DCM300 and DCS170) were sampled in 1999 but not in 2003. A single new site (DCD1660), located on Darby Creek upstream of its confluence with Ithan Creek was added for 2003. Figure 3-11 displays locations of these monitoring sites, as well as the type of assessments performed (i.e., discrete chemical, RBP III, habitat, RBP V, or tidal assessments).

Tables 3-14 and 3-15 summarize the types, amounts, and dates of sampling and monitoring performed by PWD, PADEP, and USGS during 2003.

A range of water quality samples were collected during 2003 at eleven sites in the watershed. The sites are listed in Table 3-14 and are shown on Figure 3-11. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-16.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings:

Table 3-14 Summary of Physical and Biological Sampling and Monitoring in Darby-Cobbs Watershed 2003

Site ID	Waterbody	Chemical	PWD		Tidal
			RBP III / Habitat	RBP V	
DCC037	Cobbs				X
DCC1003	Cobbs		X		
DCC208 (DC-06N)	Cobbs	X	X	X	
DCC455 (DC-07)	Cobbs	X	X	X	
DCC770 (DC-10)	Cobbs	X			
DCC793	Cobbs		X	X	
DCD0765 (DC-03)	Darby	X	X	X	
DCD053	Darby				X
DCD100	Darby				X
DCD1105	Darby		X	X	
DCD1170 (DC-04)	Darby	X			

Site ID	Waterbody	Chemical	PWD		Tidal
			RBP III / Habitat	RBP V	
DCD1570 (DC-05)	Darby	X	X	X	
DCD1660 (DC-12)	Darby	X	X		
DCD1880	Darby		X	X	
DCD2138	Darby		X	X	
DCD310	Darby				X
DCD390	Darby				X
DCD480	Darby				X
DCD550	Darby				X
DCD630	Darby				X
DCI010 (DC-09)	Indian	X	X	X	
DCIC007	Indian		X		
DCIE186	East Branch of Indian		X		
DCIW177	West Branch of Indian		X		
DCLD034	Little Darby		X		
DCN010 (DC-08)	Naylors	X	X		
DCN208	Naylors		X		

Table 3-15 Summary of PWD Water Quality Sampling and Monitoring in Darby-Cobbs Watershed 2003

Site Name	Discrete	Continuous	Wet Weather
DCC208 (DC-06)	13 Samples 2/13/03-9/4/03	792.75 hrs	4 Periods 7/21/03 - 9/14/03
DCC455 (DC-07)	13 Samples 2/13/03-9/4/03	793 hrs	4 Periods 7/21/03 - 9/14/03
DCC770 (DC-10)	13 Samples 2/13/03-9/4/03	793 hrs	4 Periods 7/21/03 - 9/14/03
DCD765 (DC-03)	13 Samples 2/13/03-9/4/03	793.25 hrs	4 Periods 7/21/03 - 9/14/03
DCD1170 (DC-04)	12 Samples 2/13/03-9/4/03		
DCD1570 (DC-05)	12 Samples 2/13/03-9/4/03		
DCD1660 (DC-12)	13 Samples 2/13/03-9/4/03	792 hrs	4 Periods 7/21/03 - 9/14/03
DCI010 (DC-09)	12 Samples 2/13/03-9/4/03		
DCN010 (DC-08)	12 Samples 2/13/03-9/4/03		

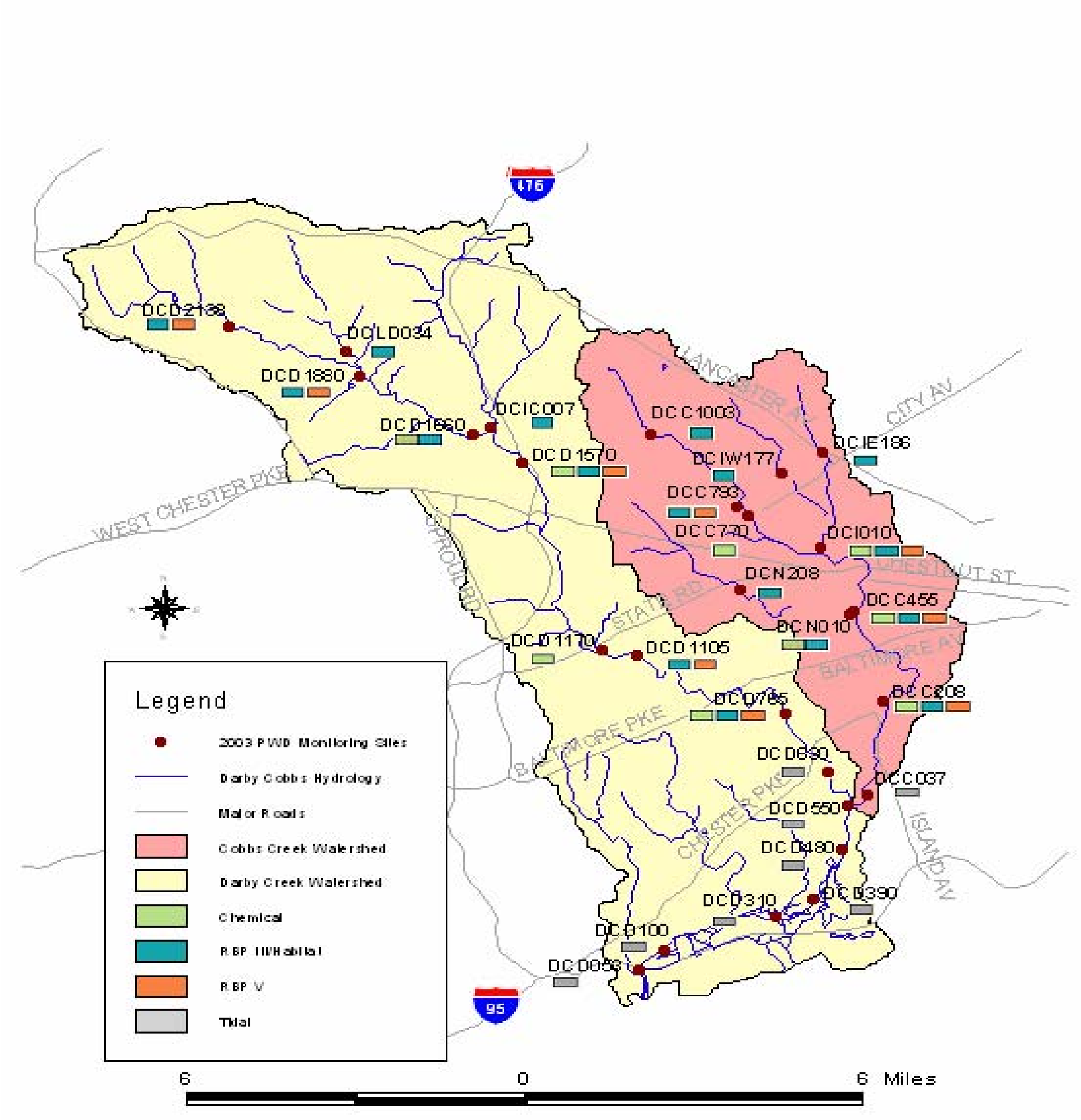


Figure 3-11 PWD Monitoring Locations in Darby-Cobbs Watershed (2003)

Table 3-16 Water Quality Parameter Sampled in Darby-Cobbs Watershed 2003

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg C	X	X	X
pH	pHU	X	X	X
Specific Conductance	uS/cm	X		X
Alkalinity	mg/L	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
OXYGEN AND OXYGEN DEMAND				
DO	mg/L	X	X	X
BOD5	mg/L	X	X	
BOD30	mg/L	X	X	
CBOD5	mg/L	X		
NUTRIENTS				
Nitrate	mg/L	X	X	
Nitrite	mg/L	X	X	
TKN	mg/L	X	X	
Total Phosphorus	mg/L		X	
METALS				
Aluminum	mg/L	X	X	
Calcium	mg/L	X	X	
Cadmium	mg/L	X	X	
Chromium	mg/L	X	X	
Copper	mg/L	X	X	
Fluoride	mg/L	X	X	
Iron	mg/L	X	X	
Dissolved Iron	mg/L	X		
Magnesium	mg/L	X	X	
Manganese	mg/L	X	X	
Lead	mg/L	X	X	
Zinc	mg/L	X	X	
BIOLOGICAL				
Chlorophyll A	ug/L	X		
Fecal Coliform	#/100 mls	X	X	
E. coli	#/100 mls	X	X	
Osmotic Pressure	milliosmoles	X		
MISCELLANEOUS				
Phenolics	mg/L	X		

3.1.4.3.3 Tidal Delaware River

Tidal Delaware River water quality monitoring is conducted by three complementary monitoring efforts on behalf of DRBC, USGS, and PWD. The locations of sampling sites are shown in Figure 3-12.

The DRBC Boat Run monitoring program locations used to characterize the receiving waters are limited to the monitoring stations nearest Philadelphia. Only six of twenty-two DRBC Boat Run stations are included in the following assessment of receiving waters due to their locations far upstream and downstream of Philadelphia. DRBC Boat Run stations and the River Mile locations are presented in Table 3-17 below.

Table 3-17 DRBC Boat Run Stations

Station ID	River Mile	Station Name
332052	87.9	Paulsboro, New Jersey
892065	93.2	Philadelphia Navy Yard
892071	100.2	Ben Franklin Bridge
892070	104.75	Betsy Ross Bridge
892077	110.7	Torresdale (Baxter Water Treatment Plant)
892080	117.8	Burlington Bristol Bridge

The parameters collected at each of the Boat Run stations include:

- Acidity as $CaCO_3$
- Alkalinity, Hydroxide as $CaCO_3$
- Chloride
- Chromium, hexavalent
- Copper
- Dissolved oxygen (DO)
- Dissolved oxygen saturation
- Enterococcus Group Bacteria
- Escherichia coli
- Fecal Coliform
- Hardness, carbonate
- Nitrogen, ammonia (NH3) as NH3
- Nitrogen, Kjeldahl
- Nitrogen, Nitrate (NO3) as NO3
- Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N
- Nitrogen, Nitrite (NO2) as NO2
- pH
- Phosphorus as P
- Phosphorus, orthophosphate as P
- Sodium
- Solids, volatile
- Solids, suspended
- Specific conductance
- Temperature, air
- Temperature, water
- Turbidity
- Zinc

DRBC also conducts specialized monitoring programs at some locations for a range of contaminants including pesticides and toxic compounds such as benzene, TCE, methyl bromide, and MTBE.

The locations of USGS gages supporting the analysis of receiving waters extend through the Delaware Estuary from north of Philadelphia to the mouth of the Delaware Bay. The USGS gage descriptions and parameters collected are presented below in Table 3-18.

Table 3-18 USGS Gage Descriptions

Station ID	Location	Water Quality Parameters
01467200	Delaware River at Ben Franklin Bridge at Philadelphia	Specific Conductance pH Water Temperature Dissolved Oxygen
01477050	Delaware River at Chester, PA	Specific Conductance pH Water Temperature Dissolved Oxygen
01464600	Delaware River at Bristol, PA	Specific Conductance pH Water Temperature Dissolved Oxygen
01412350	Delaware Bay at Ship John Shoal Lighthouse, NJ	Specific Conductance Water Temperature
01482800	Delaware River at Reedy Island Jetty, DE	Specific Conductance pH Water Temperature Dissolved Oxygen

PWD monitoring of the tidal Delaware River is conducted by the Bureau of Laboratory Services at the intake to the Baxter Water Treatment Plant. The Baxter intake monitoring program assesses the raw water quality of the Delaware River in support of treatment decisions made in order to produce high quality drinking water. Monitoring of the intake is conducted daily, weekly, bi-weekly, or monthly depending upon the relationship of the parameter to treatment processes and ongoing research needs.

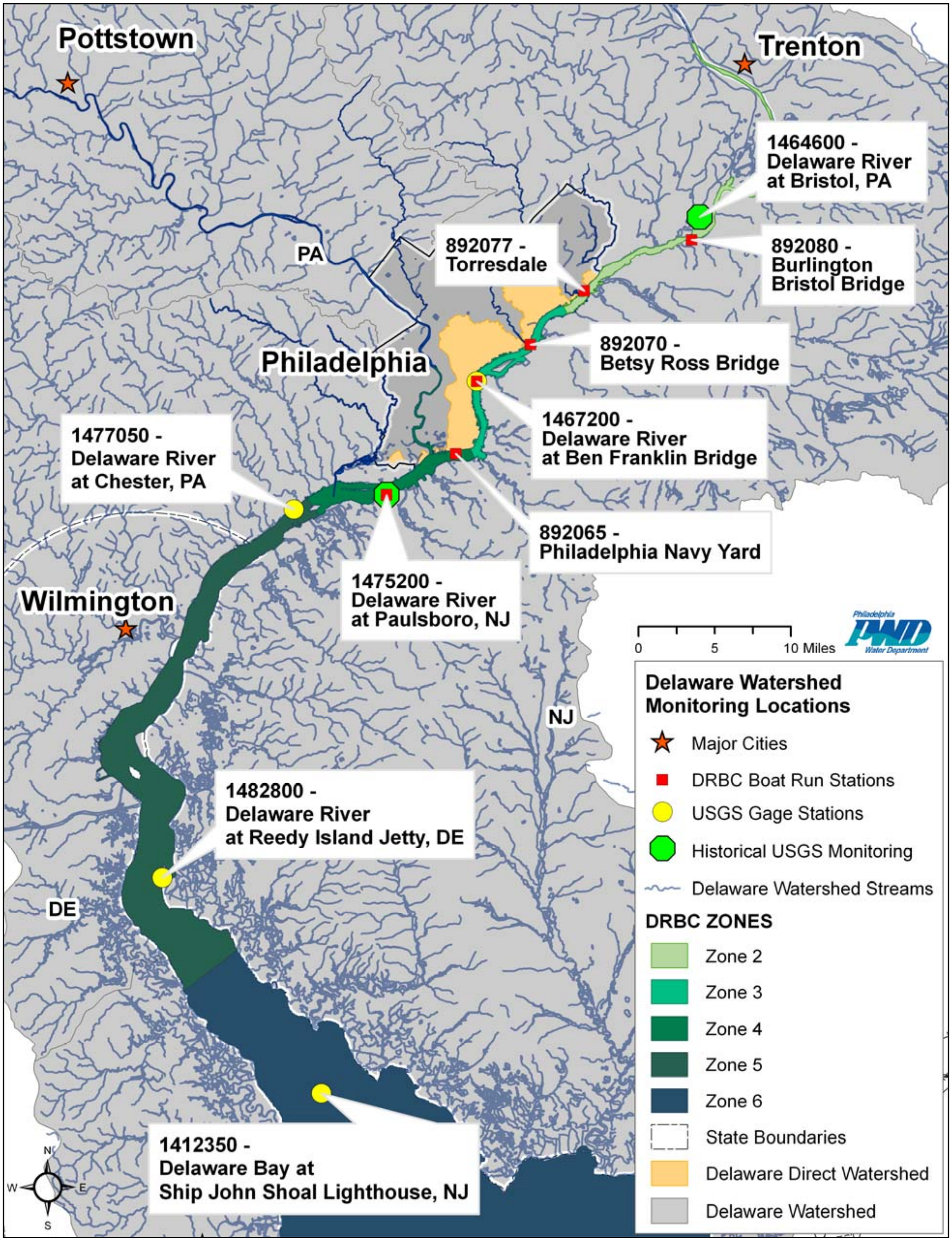


Figure 3-12 Monitoring Locations Used to Characterize Water Quality in the Delaware River

3.1.4.3.4 Tidal Schuylkill River

Table 3-19 summarizes the types, amounts, and dates of sampling and monitoring performed by PWD and USGS through the monitoring period. The locations of monitoring sites are depicted on Figure 3-13. A river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. For example, site SCH-789 is located as follows:

- "SCH" stands for the Schuylkill River Watershed
- "789" places the site 7.89 miles upstream of the mouth of the Schuylkill River, where it flows into the Delaware

A range of water quality samples were collected during the monitoring period at six sites in the watershed. The sites are listed in Table 3-19 and are shown on Figure 3-13. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-20.

Table 3-19 Summary of Water Quality Sampling and Monitoring in Tidal Schuylkill River

Site Name	USGS Gage	Chemical		
		PWD		USGS
		Wet Weather	Continuous	Discrete
SC136		7 Periods 4/20/2005-5/15/2007		
SCH587		7 Periods 4/20/2005-5/15/2007		
SCH791		7 Periods 4/20/2005-5/15/2007		
	1474500			945 Samples 10/31/1925 to 9/2/2004
SCHU823			3,597.25 hrs	
SCH048			1,297.5 hrs	

Table 3-20 Water Quality Parameters Sampled in Tidal Schuylkill River

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg C	X	X	X
pH	pHU	X	X	X
Specific Conductance	uMHO/cm @25C	X	X	X
Alkalinity	ug/L	X	X	
Turbidity	NTU	X	X	X
OXYGEN AND OXYGEN DEMAND				
DO	ug/L	X	X	
BOD5	mg/L	X		
CBOD5	mg/L	X		
NUTRIENTS				
Total Ammonia	mg/L as N	X		
Nitrate	mg/L as N & ug/L	X	X	
Nitrite	mg/L as N & ug/L	X	X	
TKN	ug/L		X	
Phosphate	mg/L	X		
Total Phosphorus	ug/L		X	
METALS				
Aluminum	ug/L	X	X	
Calcium	mg/L & ug/L	X	X	
Cadmium	ug/L	X	X	
Chromium	ug/L	X	X	
Copper	ug/L	X	X	
Fluoride	mg/L & ug/L	X	X	
Iron	ug/L	X	X	
Dissolved Iron	ug/L		X	
Magnesium	mg/L & ug/L	X	X	
Manganese	mg/L & ug/L	X	X	
Lead	ug/L	X	X	
Zinc	ug/L	X	X	
BIOLOGICAL				
Chlorophyll A	mg/m^2	X		
Fecal Coliform	#/100 mls	X	X	
E. coli	#/100 mls		X	

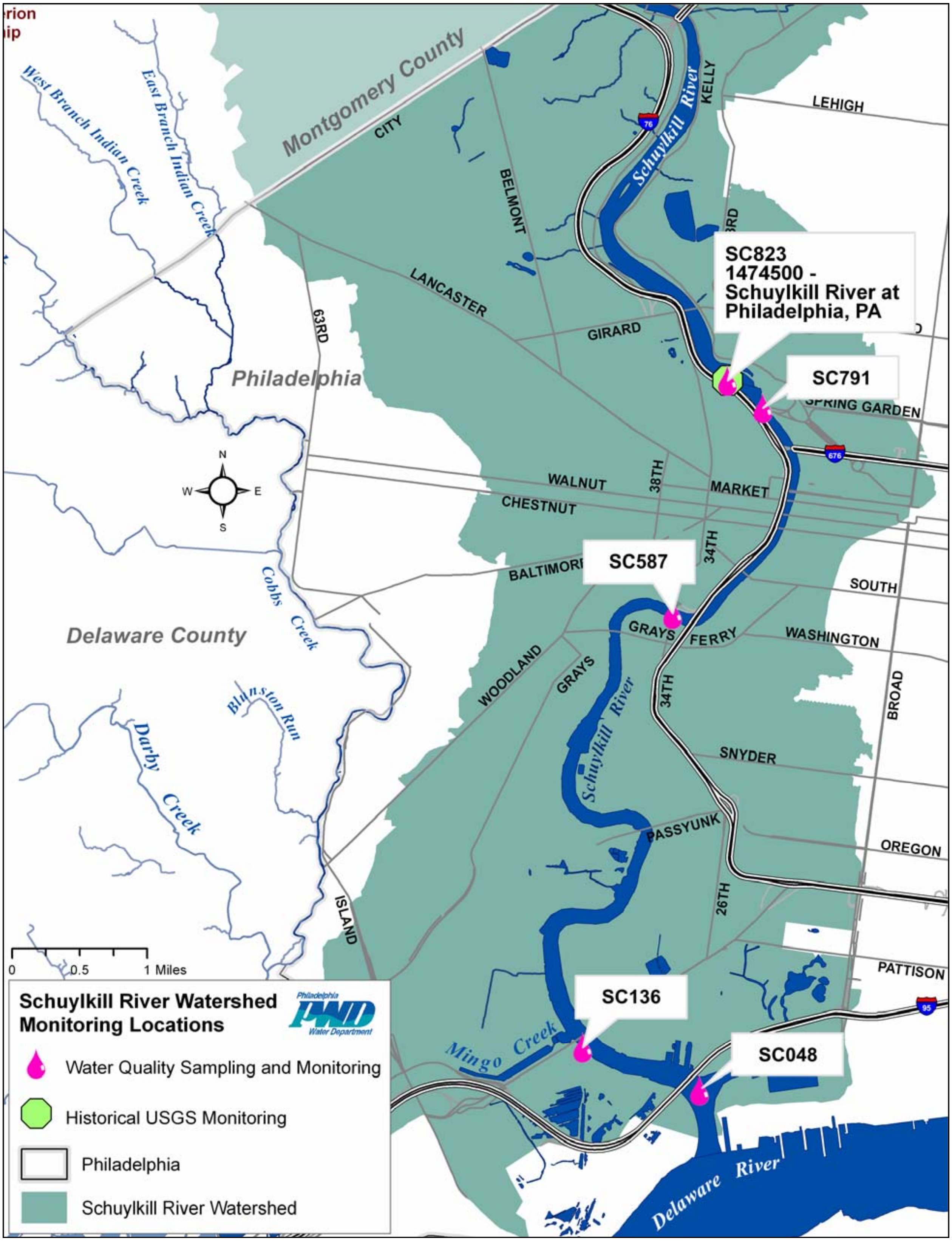


Figure 3-13 USGS and PWD Monitoring Locations in the Schuylkill River

Hydrologic monitoring of the Schuylkill and Delaware Rivers at Philadelphia is conducted mainly at two non-tidal USGS gages; 01474500 Schuylkill River at Philadelphia, and 01463500 Delaware River at Trenton. Sites 01474500 and 01463500 are the most downstream streamflow monitoring locations on the two largest freshwater inputs to the Delaware River Estuary.

3.1.4.4 Continued Monitoring of Receiving Water

PWD will continue to monitor the receiving waters with the watershed approach throughout the implementation phase of the LTCPU. The focus of this monitoring will be to further characterize certain watersheds conditions and to continue collecting water chemistry at USGS stations. The methods and scheduling of all future sampling will be based on the evolving watershed management planning process. All monitoring used for adaptive management of LTCPU implementation is discussed in Section 11.

On-going Monitoring of Tookany/Tacony-Frankford and Cobbs Creek Watersheds

Throughout the LTCPU implementation period (2009-2029), PWD will continue water chemistry assessment activities for the purpose of maintaining a consistent record of data. Assessment will be guided by recognition of the fact that water quality changes dramatically during wet weather. Water quality assessment will advance the understanding of wet weather effects on stream water quality as well as the stormwater and sewer infrastructure. Aligned with LTCPU targets A, B, and C, PWD's water quality assessment strategy has been designed to facilitate separate analyses of dry weather (*i.e.*, baseflow) and wet weather water quality conditions. This program has evolved over time, as personnel and technological advancements have improved PWD abilities to collect more data from an increasing number of sampling locations in a more efficient manner. Automated sampling, in particular, has greatly increased the temporal resolution of stormwater sampling at multiple sampling locations for a single storm event.

Of the 39 water quality parameters regularly sampled during PWD baseline and comprehensive assessments (1999-2009), some have been identified as potentially contributing to water quality problems. However, many parameters are not typically present in concentrations that would cause concern. Furthermore, changes to analytical methods and regulatory requirements and the desire to remain up-to-date with best practices encourage frequent re-evaluation of the suite of chemical parameters to be sampled during various monitoring activities. By tailoring the group of chemical parameters monitored to project goals, PWD hopes to increase sampling efficiency. When fewer parameters are sampled, a smaller volume is required for each sample, increasing the number of samples that can be collected. This philosophy is especially beneficial in automated wet weather sampling programs. The parameters selected for the initial phase of monitoring are presented in Table 3-21.

Dry Weather Water Chemistry Assessment

Surface water grab samples will be collected quarterly at ten Philadelphia area USGS gage stations in dry weather, baseflow conditions in order to build upon a long term record of water quality trends over time. Sample results from the previous monitoring period will be summarized in PWD NPDES Annual Report. Two of the USGS gages sampled are located in Cobbs Creek Watershed and two are located in Tookany-Tacony/Frankford Watershed. In both watersheds, the upstream USGS gage is located at or near the Philadelphia County line, while the downstream gage is located within the downstream-most non-tidal segment of the creek

Surface water grab samples will also be collected for the purpose of updating water quality indicator status from the Tookany/Tacony-Frankford Creek and the Cobbs Creek Integrated Watershed Management Plans. PWD will sample watersheds on a rotational basis, following the same order as monitoring for the original baseline characterizations. For example, Cobbs Creek samples will be collected at sites DCC208, DCC455, and DCC770 (Figure 3-11) in dry weather baseflow conditions during spring and summer seasons of a designated year within the initial implementation phase. Water quality analysis results will be published in a watershed indicator status update report for the Cobbs Creek. The Tookany/Tacony-Frankford Creek will be the next watershed sampled at sites TF280, TF620, TF975, and TF1120 (Figure 3-9) during spring and summer seasons in order to characterize water quality for a watershed indicator status update report for the Tookany/Tacony-Frankford Watershed.

Wet Weather Targeted Water Chemistry Assessment
Wet weather water quality assessment is an important component of PWD Comprehensive Watershed Assessments, which provide the technical basis for Integrated Watershed Management Plans and IWMP update reports for water quality indicators (Target C). Wet weather targeted water chemistry assessment will be conducted with automated water sampling equipment during four runoff-producing wet weather events during a given year following the same watershed assessment rotation as proscribed in the Integrated Watershed Management process. The Cobbs Creek watershed will be monitored first followed by The Tookany/Tacony-Frankford Watershed. Monitoring locations will be similar to the sites listed above in the Dry Weather Water Chemistry Assessment.

Continuous Water Chemistry Assessment
PWD provides ongoing support to the USGS to collect continuous water quality data at ten locations within Philadelphia's watersheds, addressing both dry and wet water quality. PWD staff are currently responsible for installing and maintaining water quality monitoring instruments (YSI 6600, 6600 EDS and 600 XLM sondes) which measure dissolved oxygen, temperature, pH, conductivity, depth (stage) and, optionally, turbidity at 30-minute intervals. Sondes are connected to USGS transmitters uploading data to the USGS National Water Information System (NWIS) at least every four hours. Continuous data, including intervals during which water quality exceeded PADEP criteria, are summarized for each gage in PWD Combined Stormwater NPDES Annual Report.. Sondes deployed in urban environments require frequent cleaning and maintenance. Field meter readings and Winkler titration dissolved oxygen tests are performed on a regular weekly basis and following a significant wet weather event.

In addition to the permanent continuous water quality monitoring at USGS gages 01467087 and 01467086, PWD will monitor continuous water quality in the Tookany/Tacony-Frankford Watershed using *in situ* continuous water quality monitoring equipment at sites TF975 and TF1120 (Figure 3-9) from March to December 2013.

Table 3-21 Parameters Analyzed for PWD Water Chemistry Assessment Programs

Parameter	Units	Dry Weather Assessment	Wet Weather Assessment	Continuous Assessment
Alkalinity	mg/L			
Ammonia	mg/L as N			
BOD5	mg/L			
Calcium	mg/L			
Specific Conductance	µS/cm	X		X
Enterococcus	CFU/100mL	X	X	
E. coli	CFU/100mL	X	X	
Fecal Coliform	CFU/100mL	X	X	
Hardness	mg/L $CaCO_3$			
Magnesium	mg/L			
Nitrate	mg/L	X	X	
Nitrite	mg/L			
Orthophosphate	mg/L	X	X	
Dissolved Oxygen	mg/L	X		X
pH	pH units	X		X
Total Phosphorus	mg/L		X	
Suspended Solids	mg/L	X	X	
Total Solids	mg/L		X	
Temperature	°C	X		X
TKN	mg/L		X	
Turbidity	NTU		X	X

On-going Monitoring of the Tidal Rivers

PWD is currently developing an assessment program for the tidal river segments within Philadelphia. This program will include the collection of discrete dry weather samples, wet weather samples, and continuous monitoring at USGS gages and sondes deployed in the Tidal Schuylkill. PWD will continue to monitor water quality in the Tidal Schuylkill for the purposes of further characterizing baseline conditions. Other studies will be conducted as needed and likely focus on the tidally-influenced tributaries since previous studies focused on non-tidal portions of these watersheds. PWD will continue to use DRBC Boat Run data to assess the water quality in the Delaware River.

All sampling and monitoring will continue to follow the Standard Operating Protocols (SOPs) as prepared by the Philadelphia Water Department's Bureau of Laboratory Services (BLS). These documents cover the elements of quality assurance, including field and laboratory procedures, chain of custody, holding times, collection of blanks and duplicates, and health and safety. These procedures may evolve as our understanding of the watersheds and science change and technology for sampling and analysis advance.

3.1.5 PWD Interceptor System and Regulator Structure Data

Data collection of the Philadelphia interceptor systems and regulator structures as used for development of the LTCPU were compiled using the return plans, design and as-built drawings provided by the Engineering Records Viewer (ERV) maintained by PWD, model pipe and node layers provided by a GIS database maintained by OOW, drainage plats and regulator structure inspection reports.

3.1.6 Geographic Information System (GIS) Data

In 2005 PWD completed a data conversion project resulting in the creation of GIS coverages for all of the City's water, sewer, and high pressure fire infrastructure. The conversion project consisted of extracting data from over 250,000 engineering documents stored in digital format and indexed by location. Project execution occurred in three phases: Initiation, Pilot and Production. The Initiation Phase included a series of workshops designed to ensure the conversion process properly utilized the 85 different types of source documents maintained by the department. It also included customization of data conversion tools to meet the project's data specifications, the development of a detailed conversion work plan, and conversion of the data for a 2-block area within the City. The Pilot Phase included further definition of the project's data dictionary and conversion tools and applied both to data from 2 of the City's 121 map tiles. The final phase, Production, included conversion of the remaining tiles and the establishment of links between the GIS data and legacy databases related to valves, hydrants and storm sewer inlets.

The project was supported through the use of customized conversion tools for data collection, data scrubbing, data entry, graphical placement, and quality control. Conflicts and anomalies in the data were tracked using a web-based tool and database. PWD expects to utilize the GIS coverages as the foundation for many of their operations including maintenance management, capital improvements, and hydraulic modeling. A list of GIS data used to support the LTCPU process includes:

- Land use data from the DVRPC
- Geology data
- Detailed information on size and types of impervious cover
- Rain gage, flow monitoring, and receiving water monitoring sites
- Sewer system information (manholes, pipes, regulator structures, outfalls)
- Drainage areas to individual regulator structures
- Hydrography
- Soil type
- Public property (Philadelphia Streets Department, Philadelphia Water Department, School District of Philadelphia, Fairmount Park Commission, Philadelphia Department of Recreation, etc.)
- Land surface slope
- Vacant and abandoned lands
- Aerial photos
- PWD's Engineer Records Viewer, georeferenced contract and construction drawings.
- U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing)
- General base layers prepared by the City of Philadelphia Department of Technology

One of the most important GIS data layers produced from the updated data conversion, which was used throughout the development process of the LTCPU, was the impervious surfaces analysis. The impervious area analysis was necessary to more accurately determine the benefit of implementing green infrastructure into the City by determining the extent to which green infrastructure could be feasible for the City of Philadelphia specifically. A brief account of how the impervious data used to characterize the impervious area throughout the City of Philadelphia was produced and the governing criteria for that process using the above mentioned GIS utilities and tools is provided in the following sub-section. Soil type analysis was also conducted using GIS capabilities and is discussed briefly below.

Determining soil types was also fundamental to correctly characterizing the City's current hydrologic condition. GIS was used to analyze soil characteristics and define soil types. Based on the GIS data layers, it was found that most of Philadelphia lies within the Coastal Plain Physiographic Province with the northwest portion of the City and a small section of the northeast extending into the Piedmont Uplands section of the Piedmont Physiographic Province. Elevations in the Coastal Plain range from 10 feet mean sea level (msl) along the Delaware River, to slightly more than 40 feet (msl) at the northwest edge of the Province. The Piedmont Uplands Section ranges from 40 feet (msl) at the Coastal Plains Section to approximately 150 feet (msl). The soil coverage in the Philadelphia service area is categorized into two types:

- C2a: Chester-Glenelg Association – Soils formed in materials igneous and metamorphic rocks
- E3a: Howell-Fallsington Association – Soils formed in unconsolidated water alluvial materials

The soils associated with the Piedmont Uplands Section primarily have a B-type hydrologic rating and, therefore, moderate rates of infiltration can be expected. This section has slopes averaging from 15-20 percent, and soil depths of 50-70 inches. Soils associated with the Coastal Plain Province are influenced by their substrate of marine clay and sand, and slow infiltration rates can be expected. Note that most of the combined sewer area in the PWD service area is densely developed and highly impervious. Therefore, the soils in this area are primarily disturbed urban land, and the drainage to the combined sewer system is dominated by the imperviousness of the drainage area.

GIS Impervious Area Analysis

Impervious surface information was obtained from the 2004 Sanborn planimetric layer maintained by the Office of Watersheds. This layer is known to contain some inaccuracies but is the best information on impervious surfaces currently available. Impervious surface classifications in the layer were grouped into three broad categories (buildings, parking, streets/sidewalks). Pervious surfaces and surfaces with no or limited green stormwater infrastructure potential (e.g., bridges, water bodies) were excluded from the analysis with the exception of bridges on interstate highways, which were included in the analysis.

For subsequent hydrologic model simulation analyses and alternatives analysis, it was necessary to determine the impervious area within each shed modeled for the City. Boundaries were determined for lands owned and maintained by the following City departments and other City entities: PWD, Recreation, the School District and the Fairmount Park Commission. A number of the above listed

GIS layers were intersected with the 2004 planimetric layer to allocate area to each of the above public entities, a private land category and vacant lands and homes. Once these categories were identified, the amount of impervious cover for each shed was summed based on the three broad categories previously mentioned (buildings, parking and streets/sidewalks).

This impervious data were used as the foundation from which many LID analyses were conducted for the LTCPU.

3.1.7 Improvement Cost Data

Source Controls

Costs for stormwater controls are site-specific. PWD's approach is to compile a number of real post-construction stormwater management plans submitted to PWD by developers required to comply with the City's stormwater regulations. These projects include a range of drainage areas, densities, and control requirements. Using quantities from the plans and realistic local unit costs, PWD estimated the marginal cost to the developer of complying with the stormwater ordinance. The marginal cost is the cost in addition to traditional development. For example, demolition typically should not be included, but excavation and hauling of material needed to build a subsurface basin should be included. Costs on each site are expressed as a range to represent uncertainty.

Costs are expressed in terms of cost per unit area of impervious cover on the site before redevelopment. This range of costs per unit area was scaled to give an estimate over a given drainage area undergoing redevelopment.

Infrastructure Options

PWD developed an Alternative Costing Tool (ACT) for cost estimating of infrastructure options. Costs are based on quantities of labor and materials required for construction. Additional costs for design, geotechnical investigations when needed, and operations and maintenance are added and expressed as a present value. Unit costs are based on a combination of local experience, site specific factors, and best professional judgment. These estimates are suitable for the long-term planning level. More precise cost estimates will be required in the facilities planning and design phases. The ACT is discussed in greater detail in Section 5.

3.1.8 Socio/Economic Data

The following Socio/Economic Analysis (Tables 3-22 and 3-23) used geographic and demographic data from the U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) database. These files contain local and state political boundaries, rivers and waterways, roads and railroads, and census block and block group boundaries for demographic analysis. Additional demographic data are discussed in the watershed Comprehensive Characterization Reports.

3.1.8.1 Tacony-Frankford Watershed

Figure 3-14 and Figure 3-15 show there is a distinct contrast in the socio-economic status between areas in the Tookany/Tacony-Frankford Watershed that lie within the City of Philadelphia and those in surrounding municipalities in Montgomery County. Average Housing Unit Value within the TTF Watershed within Philadelphia is $58,605 and in Montgomery County is $164,340. Median

Household Income in the TTF Watershed within Philadelphia is $32,654 and in Montgomery County is $66,708.

3.1.8.2 Cobbs Creek Watershed

Figure 3-16 and Figure 3-17 show there is a distinct contrast in the socio-economic status between areas in the Cobbs Creek Watershed that lie within the City of Philadelphia and those in surrounding municipalities in Delaware and Montgomery Counties. Average Housing Unit Value within the Cobbs Creek Watershed within Philadelphia is $47,397 and in Delaware and Montgomery Counties, the average is $212,410. Median Household Income in the Cobbs Creek Watershed within Philadelphia is $30,240 and in Delaware and Montgomery Counties, the average is $75,668.

3.1.8.3 Tidal Delaware River Watershed

Figure 3-18 and Figure 3-19 illustrate the socio-economic status in the Delaware Direct Watershed. Average Housing Unit Value within the Delaware Direct Watershed is $55,908 and Median Household Income is $38,934, the highest in Philadelphia.

3.1.8.4 Schuylkill River Watershed

Figure 3-20 and Figure 3-21 illustrate the socio-economic status in the Combined Area in the Schuylkill Watershed. Average Housing Unit Value within the Combined Area in the Schuylkill Watershed is $60,869, the highest in Philadelphia and Median Household Income is $25,756.

Table 3-22 Mean Home Value (MHV) in Philadelphia Watersheds

Watershed	MHV	MHV within Philadelphia	MHV in other Municipalities
Tookany-Tacony Frankford	$111,472	$58,605	$164,334
Cobbs Creek	$157,406	$47,397	$212,410
Delaware Direct	$55,908	$55,908	N.A.
Schuylkill	$60,869	$60,869	N.A.

Table 3-23 Mean Household Income (MHI) in Philadelphia Watersheds

Watershed	MHI	MHI in Philadelphia	MHI in Outside Municipalities
Tookany-Tacony Frankford	$49,681	$32,654	$66,708
Cobbs Creek	$60,526	$30,240	$75,668
Delaware Direct	$38,934	$38,934	N.A.
Schuylkill	$25,756	$25,756	N.A.

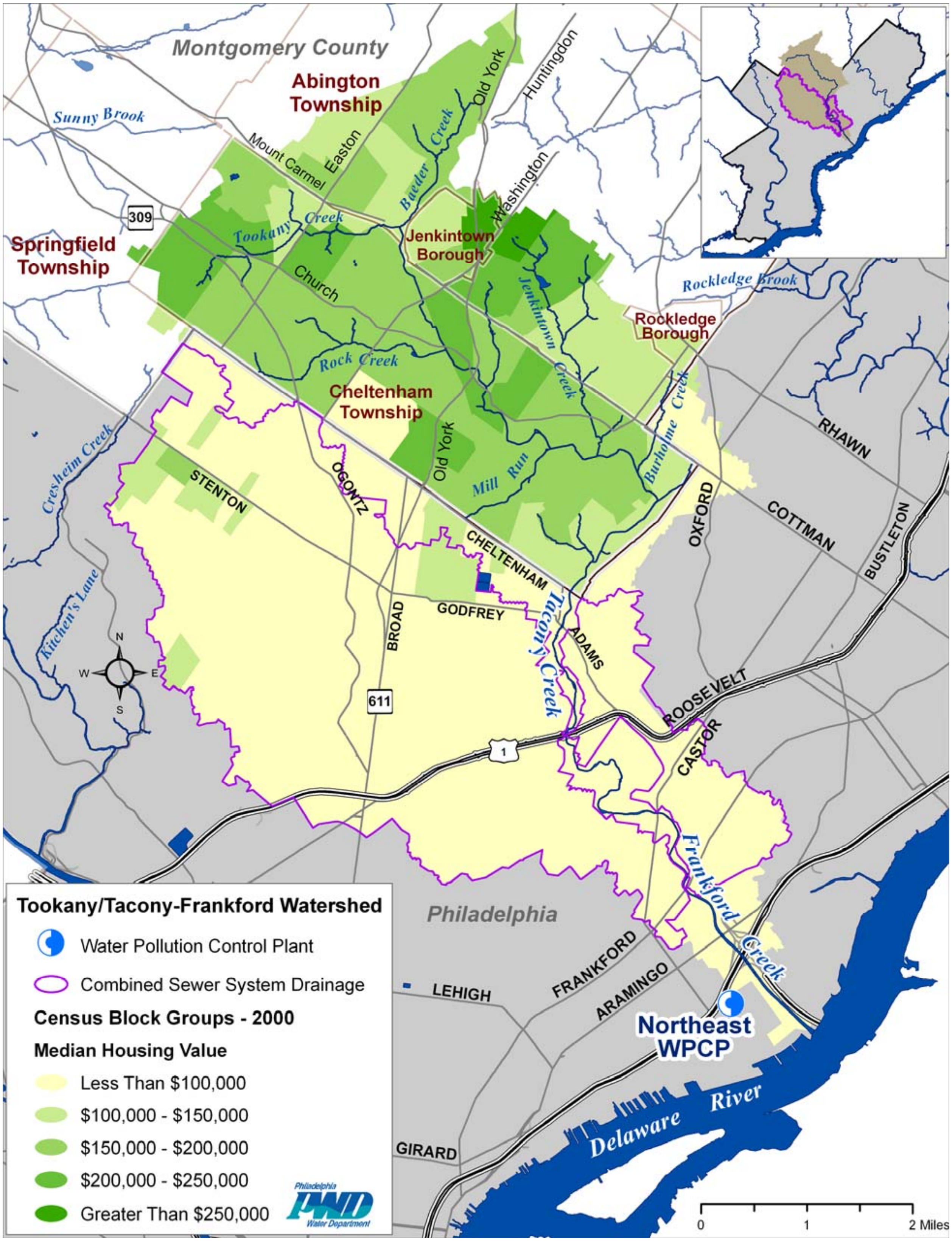


Figure 3-14 Mean Home Value in Tookany/Tacony-Frankford Watershed

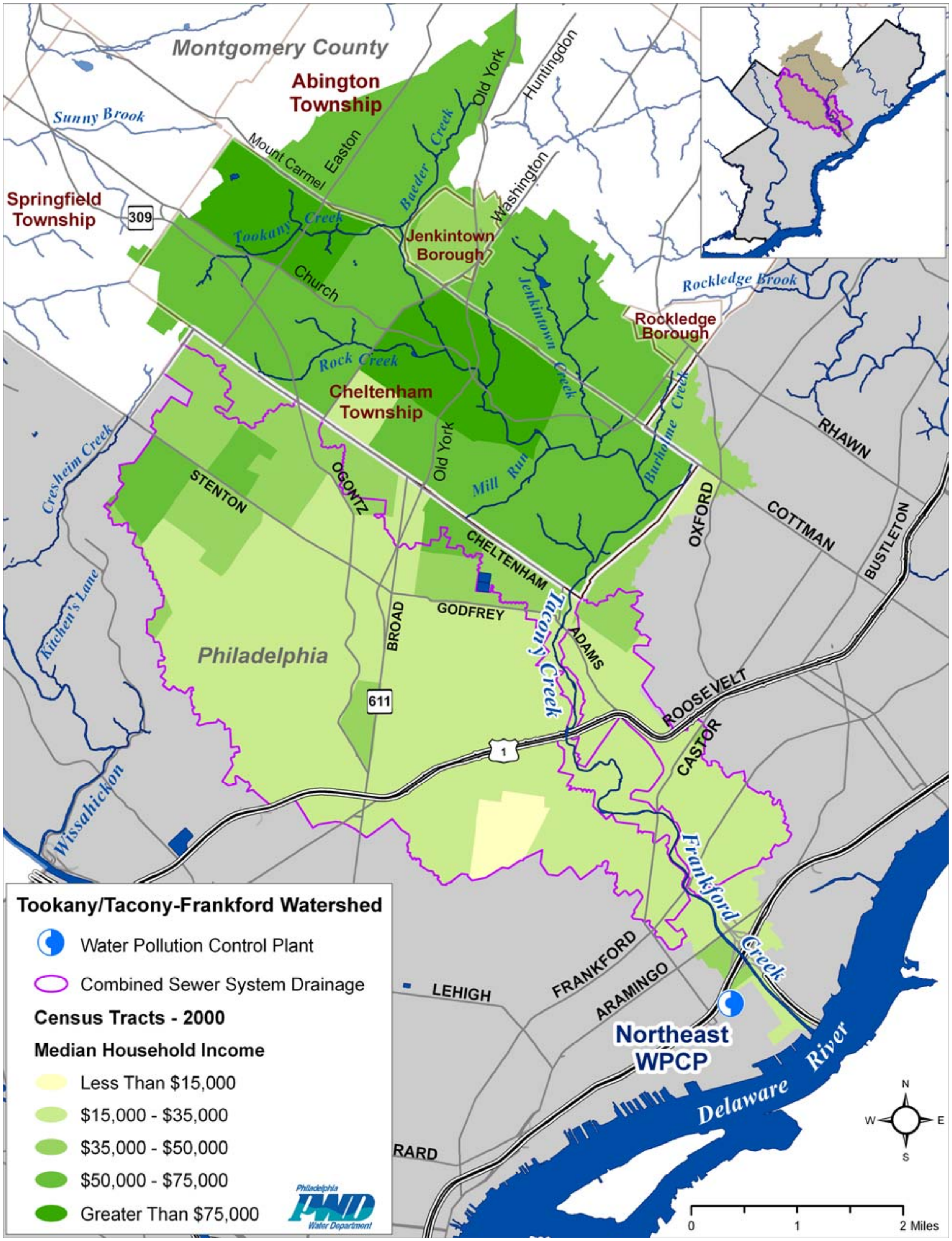


Figure 3-15 Median Household Income in Tookany/Tacony-Frankford Watershed

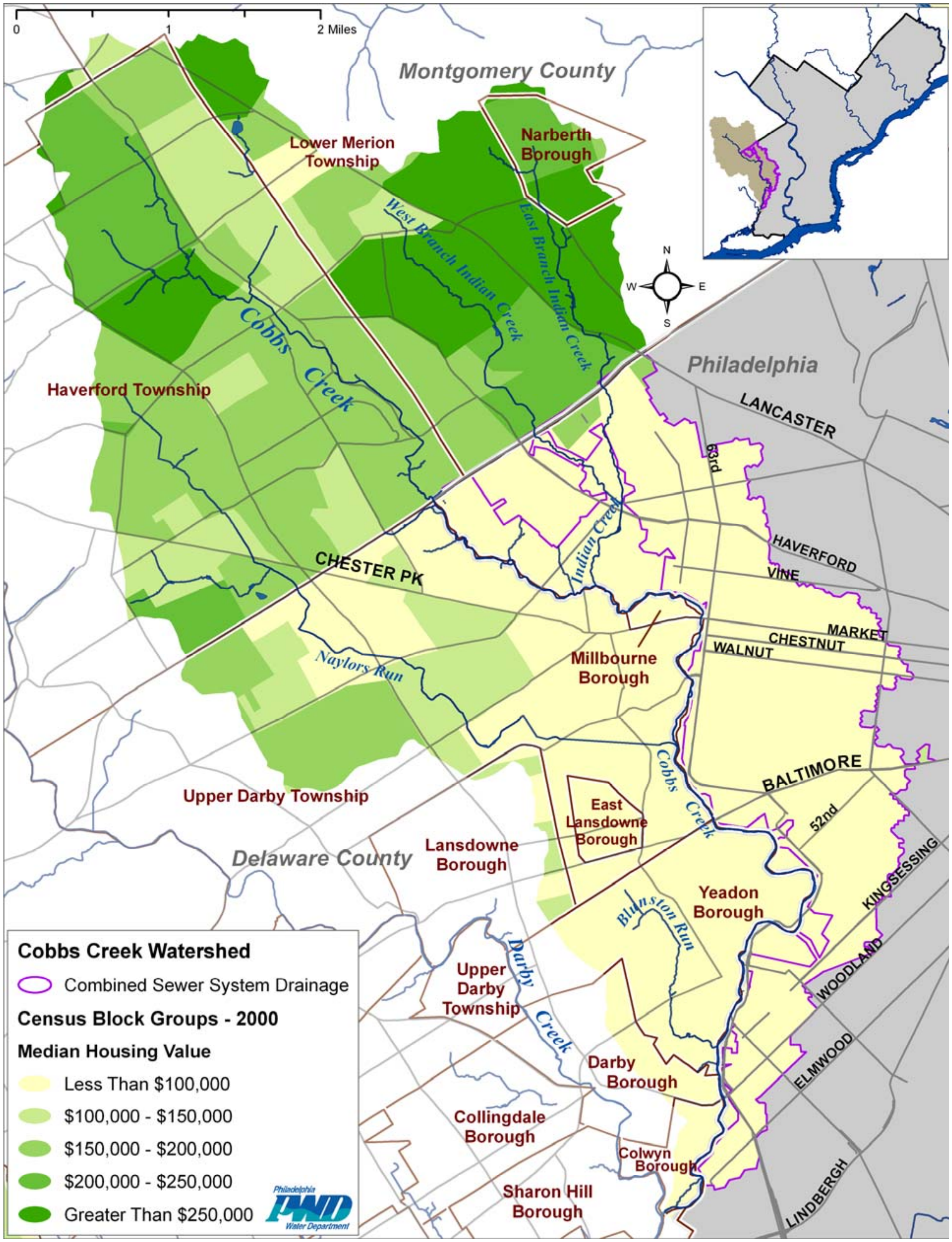


Figure 3-16 Mean Home Value in Cobbs Creek Watershed

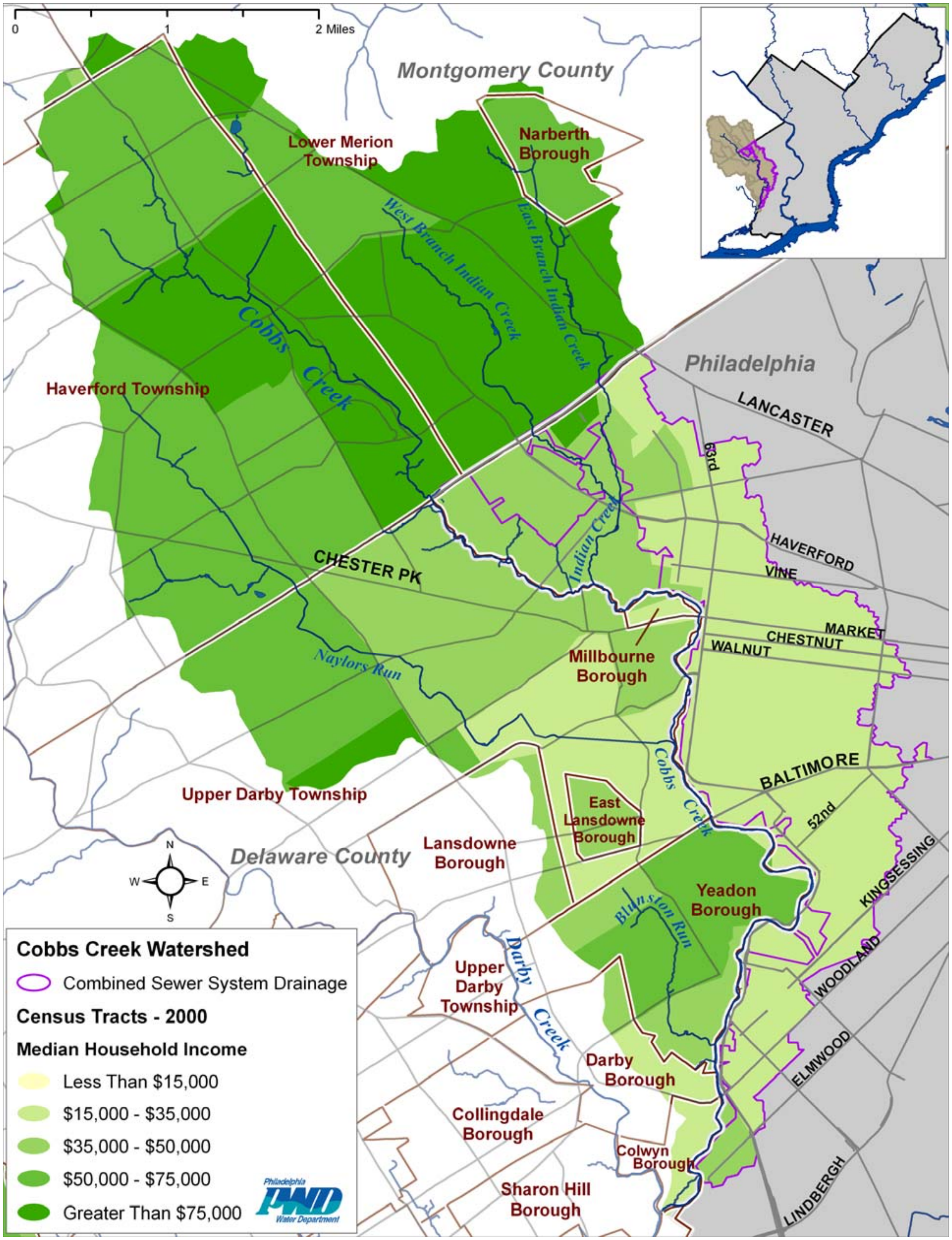


Figure 3-17 Median Household Income in Cobbs Creek Watershed

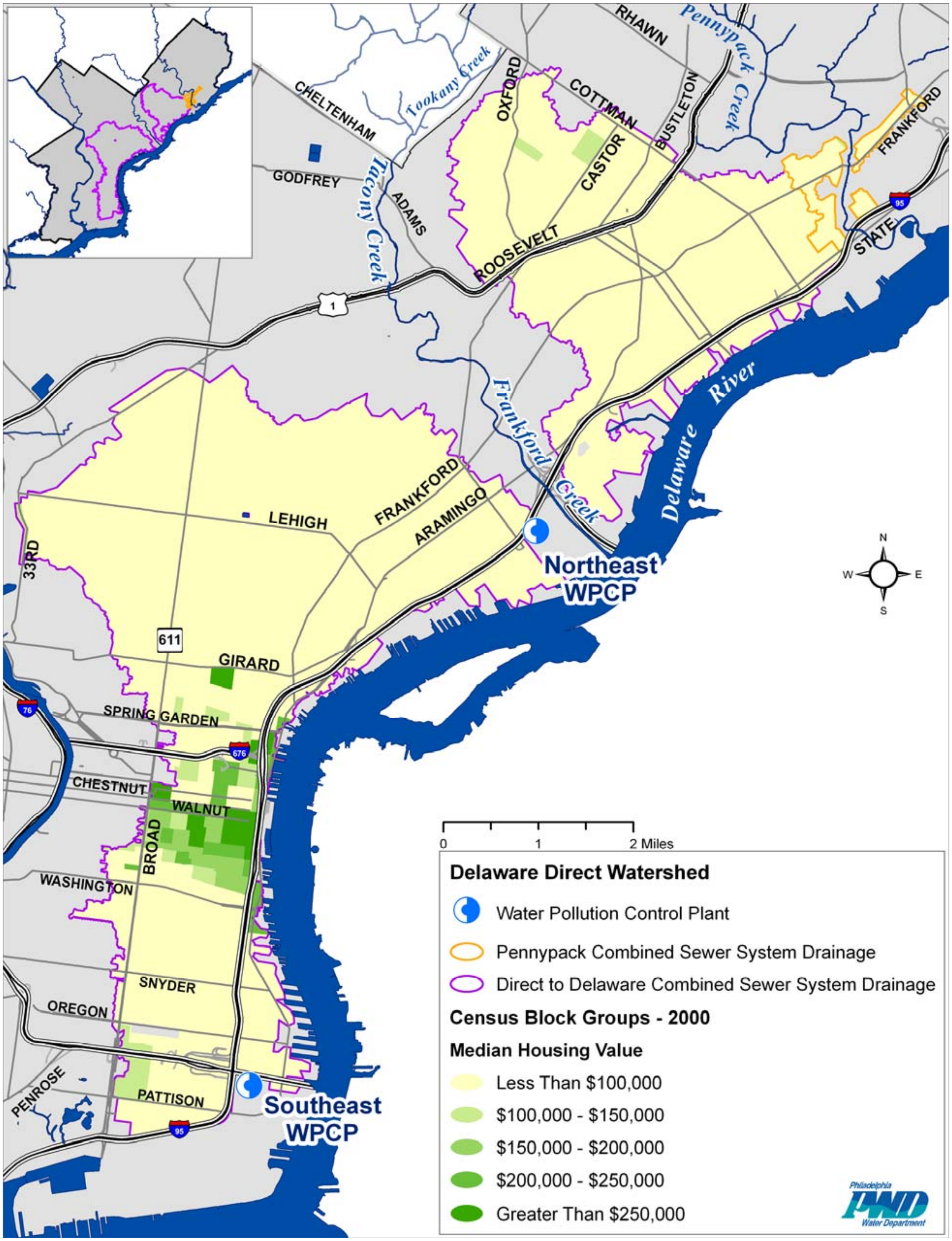


Figure 3-18 Mean Home Value in the Delaware Direct Watershed

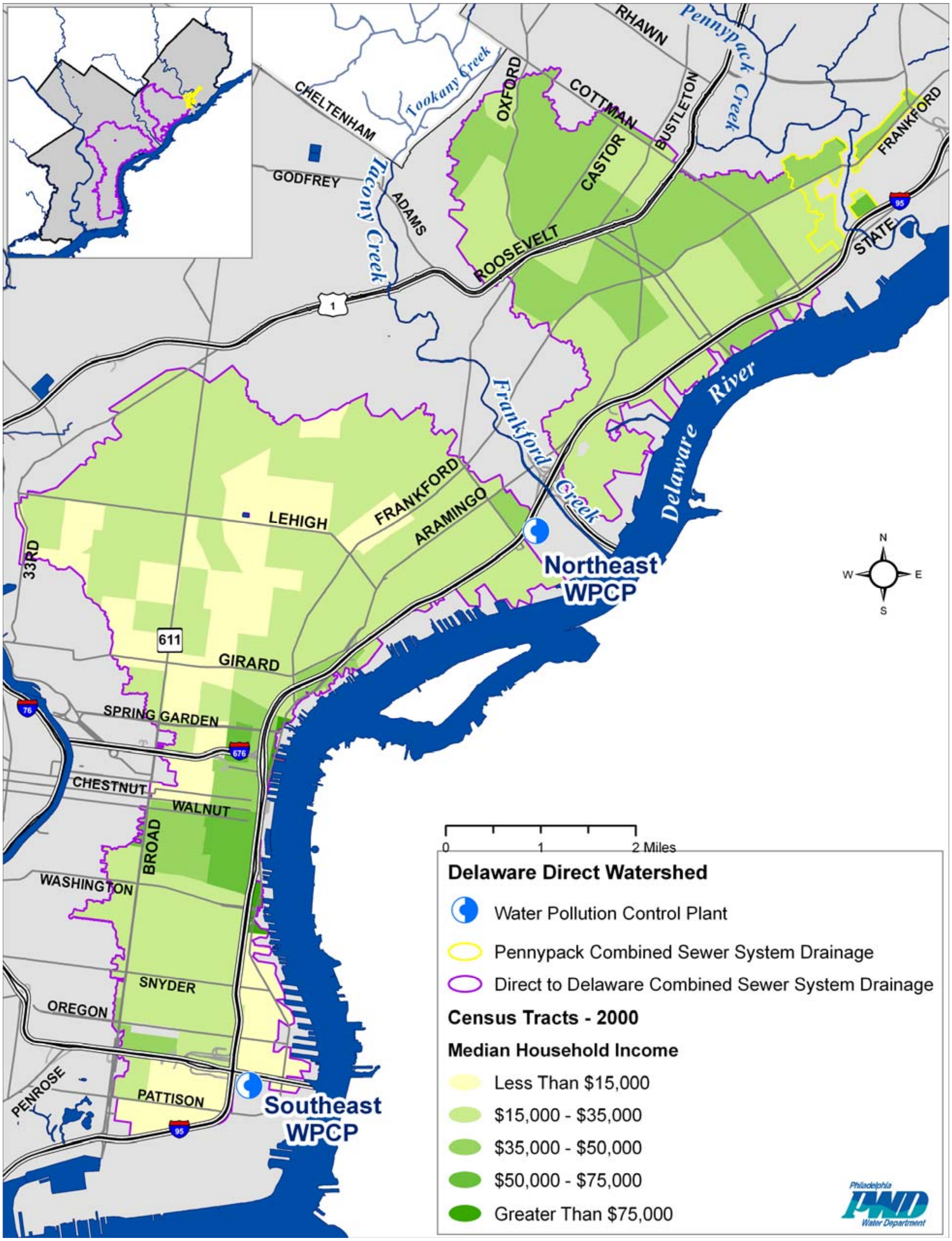


Figure 3-19 Median Household Income in the Delaware Direct Watershed

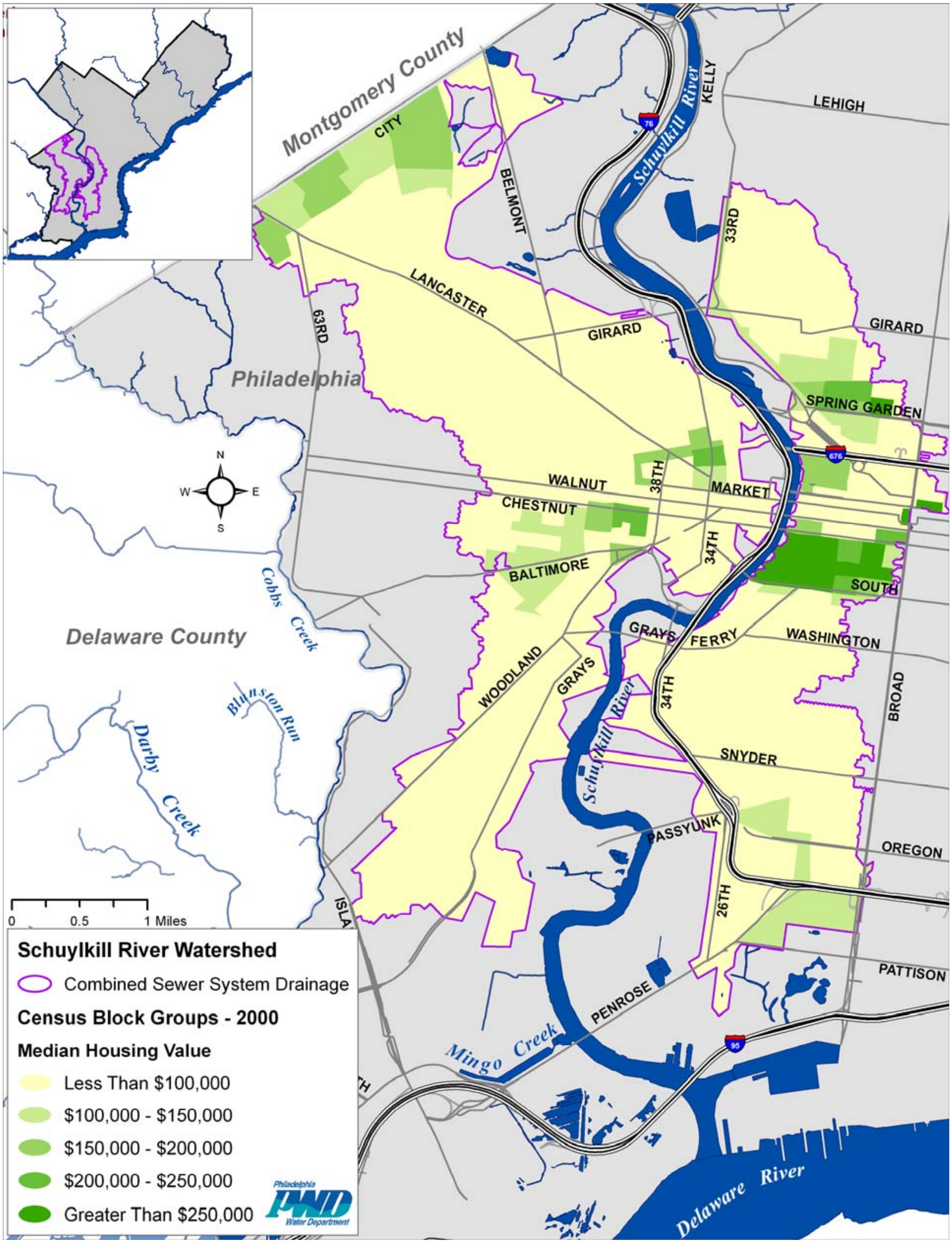


Figure 3-20 Mean Home Value in the Schuylkill River Watershed

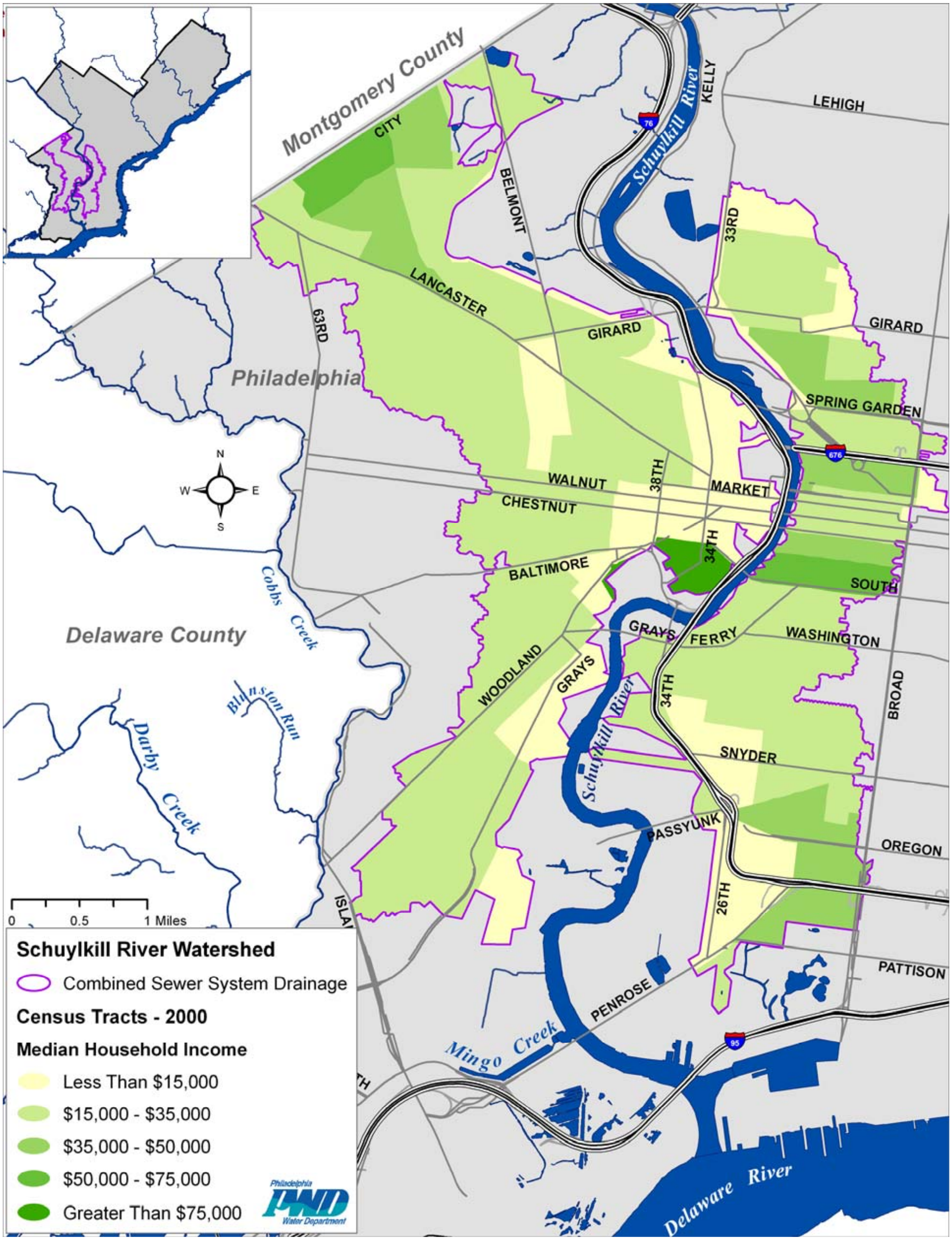


Figure 3-21 Median Household Income in the Schuylkill River Watershed

3.2 PWD WASTEWATER COLLECTION AND TREATMENT SYSTEM

3.2.1 Contributing Area Description

Service Area Description

The greater Philadelphia area is the fifth largest urban population center in the United States, and the City of Philadelphia has a population of nearly 1.5 million and a total land area of 136 square miles. Of this area, approximately 64 square miles are served by combined sewers carrying a mix of domestic and industrial wastewaters, which are combined with stormwater runoff during wet weather, and approximately 42 square miles are served by separate sanitary sewers which carry wastewater only. PWD operates three water pollution control plants (WPCPs): Northeast, Southeast, and Southwest. In addition, the department operates the system of branch sewers, trunk sewers, regulator chambers, and interceptor sewers that convey the combined wastewater to the WPCPs.

The PWD wastewater service area consists of the entire City of Philadelphia, as well as outlying communities and authorities that discharge wastewater to the WPCPs. The ten municipalities and authorities that have discharge agreements with the City are:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bensalem, Bristol, Falls, Lower Wakefield, Lower Southampton, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham
- The Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence.
- The Township of Lower Merion
- Township of Lower Moreland and the Lower Moreland Township Authority
- Lower Southampton Municipal Authority
- Township of Springfield, Montgomery County
- Upper Darby Township and Haverford Township

The City of Philadelphia is bounded by the Delaware River on the east and south, and by the suburban communities of Bucks, Montgomery and Delaware counties on the west, north, and east. Combined Sewer Overflows discharge to the Delaware and Schuylkill Rivers and to the Cobbs, Frankford, Old Frankford, Pennypack, Tacony, West Branch Indian and East Branch Indian Creeks. Figure 3-22 shows the City of Philadelphia and the combined sewer drainage areas in the PWD system.

Drainage Area Delineation

The drainage basin sub areas are the smallest units used to determine how flow enters into the collection system. The drainage areas were digitized from the PWD drainage plats, currently maintained by Collection Systems Support: Drainage Information Unit. Prior to digitizing, each plat was reviewed to determine if it should be subdivided for modeling purposes and to identify the point where flow enters the collection system. Subdivisions are marked on the existing drainage plat so that PWD will be able to maintain the model in future years. Information is stored in a geographic information system (GIS).

3.2.2 Collection System Configuration

This section describes the configuration, current capacity, CSO response to rainfall and the existing conditions of the water pollution control plants for each district. A variety of models and tools were used to represent and analyze the CSS for the LTCPU, including SWMM4, NetStorm, a number of proprietary spreadsheet analysis tools specific to the City of Philadelphia and this LTCPU and SAS software. These models and tools are discussed in greater detail in Sections 5.

Description of Collection System

The PWD service area is divided into three drainage districts: Northeast, Southeast, and Southwest (Figure 3-22). Each of these drainage districts conveys flow to the respective WPCP of the same name. These three drainage basins are hydraulically independent except during conditions of high flow, when cross connections in the trunk sewer system allow conveyance of some flow between drainage districts.

Each drainage district contains a variety of sewers types – trunks, storm relief, combined, separate sanitary and interceptors – throughout the City as shown in Figure 3-22. This network of sewers collects stormwater and wastewater and conveys the flow to regulator chambers located throughout the CSS. Flow passing through the regulator chambers is conveyed to the WPCPs. During many rainfall events the regulating chambers divert excess flow that cannot be treated at the WPCPs to overflow outfalls or storm relief diversion chambers to prevent combined sewer backups.

PWD design criteria for the combined sewers are based on an empirical expression relating design rainfall intensity to the estimated basin time of concentration. This intensity is used in the Rational Method with an estimate of the runoff coefficient (C) and the size of the drainage area to obtain a design flow rate. Standard sewer design methods using the continuity and Manning's equation for flow were then applied in determining the size, grade, design depth, and other sewer system characteristics for the combined sewer system.

A brief description of the collection systems for each drainage district follows.

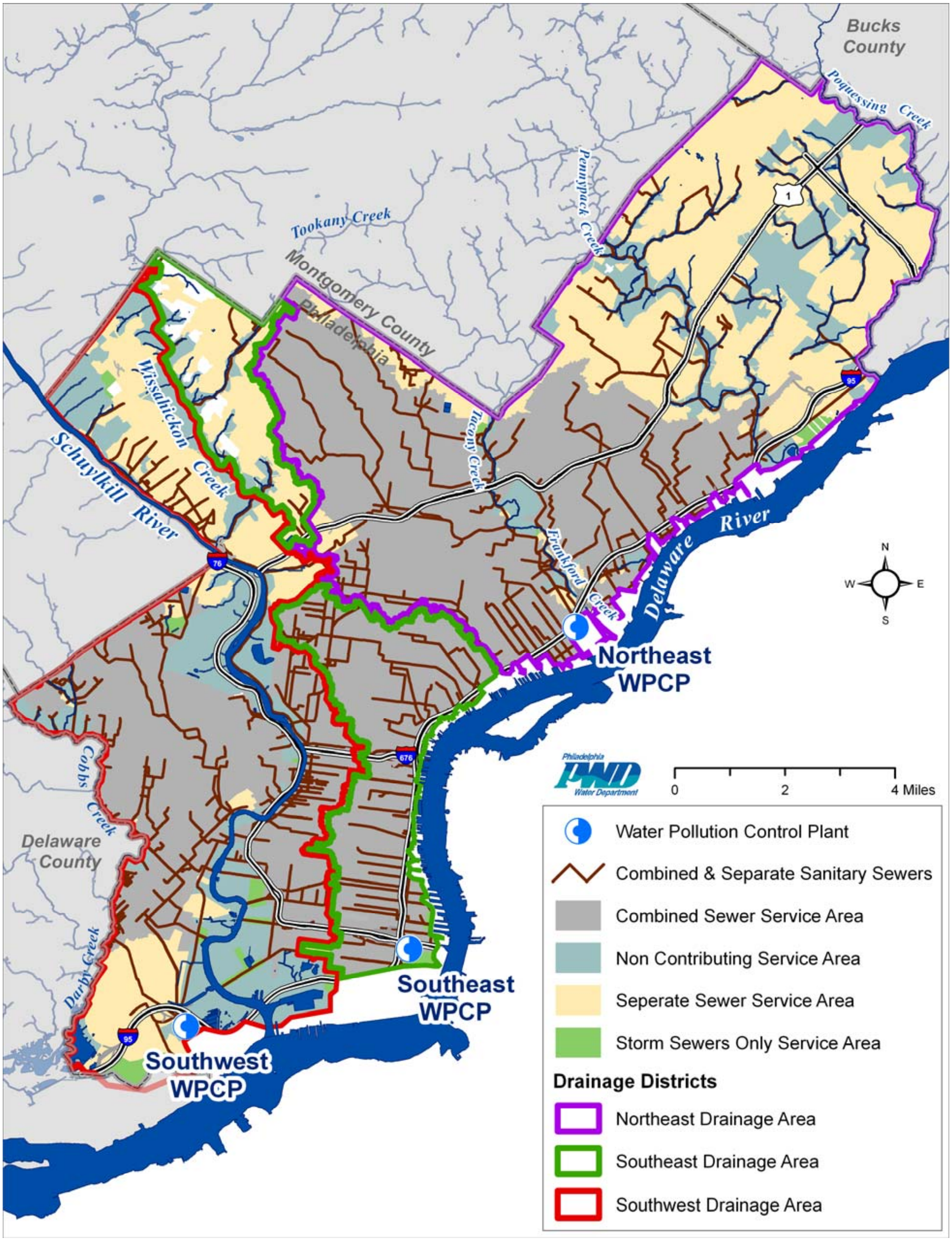


Figure 3-22 Philadelphia Sewer Area with Drainage Districts Boundaries

3.2.2.1 Northeast Drainage District

Figure 3-23 shows the collection system for the Northeast drainage district. This figure depicts the combined and separate sanitary sewer interceptors, as well as the location of the CSO regulators and major hydraulic control points – strategic flow control points in the sewer system where flow is redirected using weirs or in cases of extreme wet weather. Suburban communities served by the Northeast WPCP include:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bristol, Falls, Lower Wakefield, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham
- Township of Lower Moreland
- Lower Southampton Township

The Northeast drainage district serves an in-City population of approximately 752,000 and conveys flows to two hydraulically independent interceptor systems. The low level system includes the Upper Delaware Low Level (UDLL), Upper Frankford Low Level (UFLL), Lower Frankford Low Level (LFLL), Pennypack (PP), and Somerset Low Level (SOM). These interceptors convey wastewater and stormwater to the WPCP where it is pumped into the preliminary treatment building. The Pennypack and Lower Frankford Low Level interceptors are tributary to the Upper Delaware Low Level, which conveys flow to the Northeast WPCP through Junction Chamber A (JCA) to the preliminary treatment building (PTB) for screening and pumping. The Somerset and Upper Frankford Low Level interceptors combine outside of the WPCP at Diversion Chamber A (DivA), at which point flows are metered and conveyed through the JCA to the preliminary treatment building for screening and pumping. The high level interceptor system consists of the Tacony (TAC) interceptor and the Frankford High Level (FHL) interceptor. The Tacony interceptor conveys flows to the Frankford High Level interceptor. The Frankford High Level conveys flows into the WPCP by gravity.

Upper Delaware Low Level

The UDLL interceptor originates in the northeast region of Philadelphia near the confluence of the Poquessing Creek and the Delaware River. Two sanitary sewer interceptors contribute flow here, the Byberry Interceptor and the Poquessing Interceptor, in addition to a metered flow from Bensalem Township. Bensalem, Southampton and Lower Moreland Townships also contribute flows to the PWD system through the Poquessing Interceptor. Wastewater flow from Bucks County enters the UDLL interceptor just upstream of Pennypack Creek through a 42 inch force main. The interceptor flows southwest, parallel to the Delaware River until it reaches the NE WPCP. Table 3-24 lists the combined sewer regulators on the UDLL.

The Pennypack (PP) interceptor conveys flows from Holmes Avenue in northeast Philadelphia to the UDLL interceptor on the south side. The Pennypack interceptor receives sanitary flows from several small interceptor systems and metered flow from Abington. Table 3-24 lists the combined sewer regulators on the Pennypack interceptor.

The Lower Frankford Low Level (LFLL) lies between the Delaware Expressway and the UDLL interceptor. It conveys flows from Church Street on the southwest and Bridget Street on the northeast to the junction with the UDLL near Margaret and Garden Streets. Table 3-24 lists the combined sewer regulators on the LFLL.

Somerset/Upper Frankford Low Level
The Somerset Low Level (SOM) interceptor originates near Somerset Street and conveys flow along the Delaware River northeast into the NE WPCP. The UFLL interceptor begins near Wyoming and Castor Streets, and conveys flows southeasterly toward the WPCP, parallel to New Frankford Creek. The UFLL interceptor combines with the Somerset interceptor near Luzerne and Richmond Streets at Diversion Chamber A. Table 3-24 lists the combined sewer regulators on the Somerset and upper Frankford Low Level interceptors.

Tacony/Frankford High Level
The Tacony (TAC) and FHL interceptors combine to convey flows from near Cheltenham Township southeasterly along the Tacony and New Frankford Creeks to the NE WPCP. The Tacony interceptor runs along the Tacony Creek to where the FHL interceptor begins at the Frankford Grit Overflow Chamber (R_18) located near Hunting Park Avenue and Castor Street. From here, the FHL interceptor conveys flow to the "O" Street and Erie Avenue Diversion Chamber (H_22), where flows split into parallel sewers. The parallel sewers convey wastewater and stormwater along Frankford Creek by gravity into the NE WPCP. Table 3-24 lists the combined sewer regulators on the Tacony and Frankford High Level interceptors. Table 3-25 lists ranges of interceptor sewer diameters in the Northeast drainage district by interceptor system

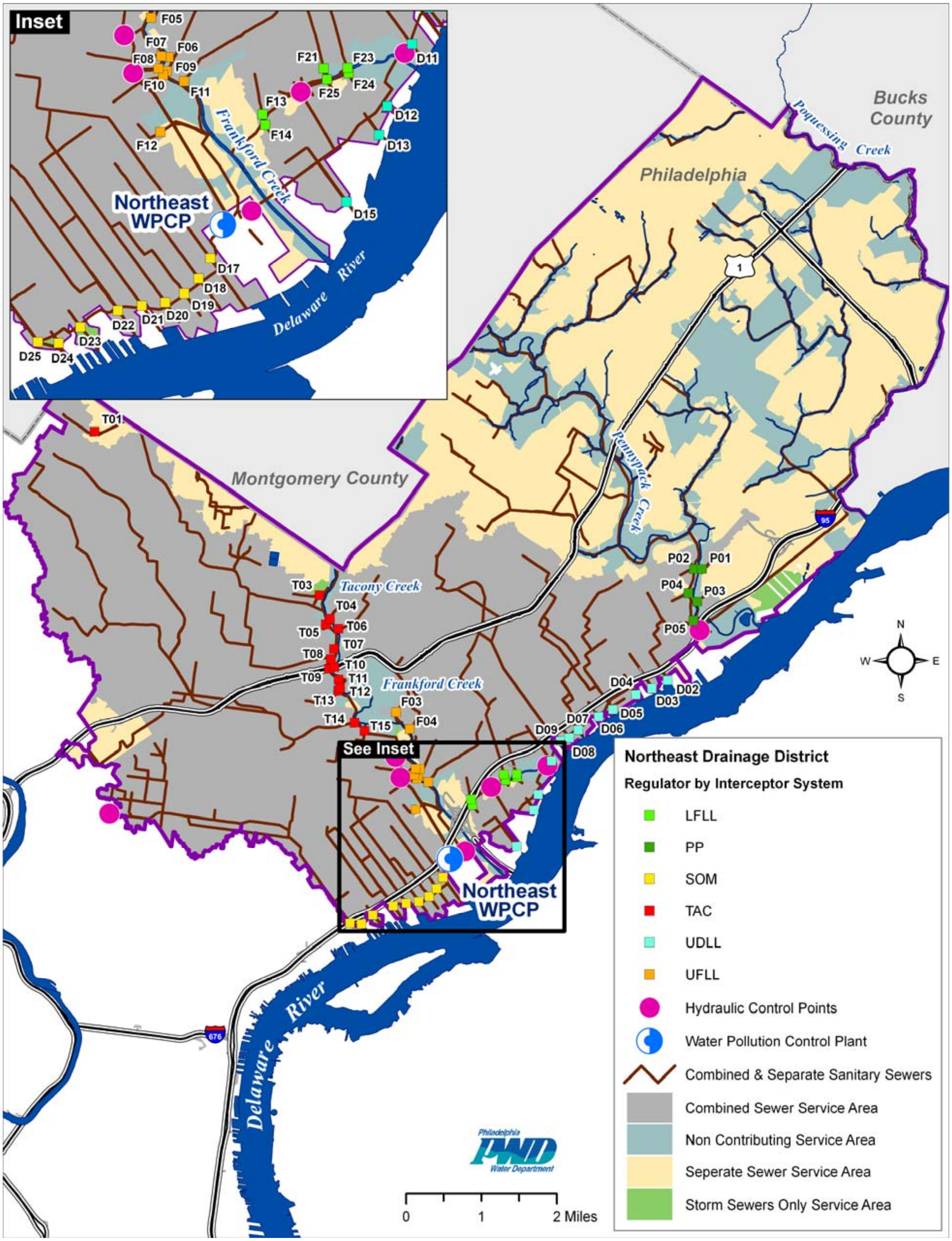


Figure 3-23 Northeast Drainage District Collection System

.Table 3-24 Northeast Drainage District CSO Regulators (NPDES Permit # PA 0026689)

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
D_17	D_17	2	SOM	Castor Ave. and Balfour St	Brown & Brown
D_18	D_18	3	SOM	Venango St. NW of Casper St.	Brown & Brown
D_19	D_19	4	SOM	Tioga St. NW of Casper St.	Brown & Brown
D_20	D_20	5	SOM	Ontario St. NW of Casper St.	Brown & Brown
D_21	D_21	6	SOM	Westmoreland St. NW of Balfour	Brown & Brown
D_22	D_22	7	SOM	Allegheny Ave. SE of Bath St	Water Hydraulic-Sluice Gate
D_23	D_23	8	SOM	Indiana Ave. SE of Sedgwick	Slot
D_24	D_25	10	SOM	Cambria St. E of Melvale St.	Slot
D_25			SOM	Somerset St. E of Richmond St.	Brown & Brown
D_02	D_02	11	UDLL	Cottman St. SE of Milnor St.	CC-Sluice Gate
D_03	D_03	12	UDLL	Princeton Ave SE of Milnor St.	CC-Sluice Gate
D_04	D_04	13	UDLL	Disston St. SE of Wissinoming	Brown & Brown
D_05	D_05	14	UDLL	Magee St. SE of Milnor St.	CC-Brown & Brown
D_06	D_06	15	UDLL	Levick St. SE of Milnor St.	Water Hydraulic-Sluice Gate
D_07	D_07	16	UDLL	Lardner St. SE of Milnor St.	CC-Sluice Gate
D_08	D_08	17	UDLL	Comly St. SE of Milnor St.	Water Hydraulic-Sluice Gate
D_09	D_09	18	UDLL	Dark Run La and Milnor St	CC-Sluice Gate
D_11	D_11	19	UDLL	Sanger St. SE of Milnor St.	CC-Sluice Gate
D_12	D_12	20	UDLL	Bridge St. SE of Garden St.	Brown & Brown
D_13	D_13	21	UDLL	Kirkbride St. and Delaware Ave.	Water Hydraulic-Sluice Gate
D_15	D_15	22	UDLL	Orthodox St. and Delaware Ave.	CC-Sluice Gate
P_01	P_01	23	PP	Frankford Ave. and Asburner St	Slot
P_02	P_02	24	PP	Frankford Ave. and Holmesburg	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
P_03	P_03	25	PP	Torresdale Ave. NW of	Slot
P_04	P_04	26	PP	Cottage Ave. and Holmesburg	Slot
P_05	P_05	27	PP	Holmesburg Ave. SE of	Slot
T_01	T_01	28	TAC	Williams Ave. SE of Sedgwick	Manual-Sluice Gate
T_03	T_03	29	TAC	Champlost Ave. W of Tacony Cr.	Slot
T_04	T_04	30	TAC	Rising Sun Ave. E of Tacony Cr.	Slot
T_05	T_05	31	TAC	Rising Sun Ave. W of Tacony Cr.	Slot
T_06	T_06	32	TAC	Bingham St. E of Tacony Cr.	Manual-Sluice Gate
T_07	T_07	33	TAC	Tabor Rd. W of Tacony Cr.	Slot
T_08	T_08	34	TAC	Ashdale Sr. W of Tacony Cr.	Manual-Sluice Gate
T_09	T_09	35	TAC	Roosevelt Blvd. W of Tacony Cr.	Slot
T_10	T_10	36	TAC	Roosevelt Blvd. E of Tacony Cr.	Slot
T_11	T_11	37	TAC	Ruscomb St. E of Tacony Cr.	Slot
T_12	T_12	38	TAC	Whitaker Ave. E of Tacony Cr.	Slot
T_13	T_13	39	TAC	Whitaker Ave. W of Tacony Cr.	Slot
T_14	T_14	40	TAC	I St. and Ramona St.	2-Manual-Sluice Gate
T_15	T_15	41	TAC	J St. and Juniata Park	Slot
F_03	F_03	42	UFLL	Castor Ave and Unity Street	Slot
F_04	F_04	43	UFLL	Wingohocking St. SW of Adams	Water Hydraulic-Sluice Gate
F_05	F_05	44	UFLL	Bristol St. W of Adams Ave.	Water Hydraulic-Sluice Gate
F_06	F_06	45	UFLL	Worrel St. E of Frankford Cr.	Dam
F_07	F_07	46	UFLL	Worrel St. W of Frankford Cr.	Water Hydraulic-Sluice Gate
F_08	F_08	47	UFLL	Torresdale Ave. and Hunting Park	Water Hydraulic-Sluice Gate
F_09	F_09	48	UFLL	Frankford Ave. NE of Frankford	Water Hydraulic-Sluice Gate
F_10	F_10	49	UFLL	Frankford Ave. SW of Frankford	Water Hydraulic-Sluice Gate
F_11	F_11	50	UFLL	Orchard St. S of Vandyke St.	Water Hydraulic-Sluice Gate
F_12	F_12	51	UFLL	Sepviva St. NE of Butler St.	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
F_13	F_13	52	LFLL	Duncan St. Under I-95	Brown & Brown
F_14	F_13	52	LFLL	Bristol St. NW of Belgrade	Brown & Brown
F_21	F_21	54	LFLL	Wakeling St. NW of F-25	Brown & Brown
F_23	F_23	55	LFLL	Bridge St. NW of Creek Basin	Water Hydraulic-Sluice Gate
F_24	F_24	56	LFLL	Bridge St. SE of Creek Basin	Water Hydraulic-Sluice Gate
F_25	F_25	57	LFLL	Ash St. W of Creek Basin	CC-Brown & Brown
R_13	D_FRW	58	UDLL	Wakeling Relief Sewer	Dam
R_14			UDLL	Wakeling Relief Sewer	Dam
R_15	T_RRR	59	TAC	Rock Run Storm Flood Relief Sewer	Dam
R_18	F_FRFG	60	FHL	Frankford High Level Relief Sewer	Dam

Table 3-25 Interceptor Sewer Systems in the Northeast Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Upper Delaware Low Level	7.0	4 - 12.25
Pennypack Low Level	3.0	1.67 - 6
Lower Frankford Low Level	1.0	1 - 5
Somerset Low Level	2.1	4 by 4 - 5 by 5.5
Upper Frankford Low Level	2.5	1.67 - 4.5
Tacony High Level	3.5	3 - 8.5
Frankford High Level	3.0	5.5 - 11 by 8.5

3.2.1.2 Southeast Drainage District

Figure 3-24 shows the collection system for the Southeast drainage district. This figure depicts the combined sewer and separate sewer interceptors, as well as the location of the CSO regulators and major hydraulic control points. The only suburban community served by the Southeast WPCP is Springfield Township.

The Southeast drainage district serves an in-City population of approximately 279,000 and conveys flows to the two combined sewer interceptors, the Lower Delaware Low Level (LDLL) and Oregon Avenue (O) interceptors. The Oregon Avenue Interceptor combines with the LDLL upstream from the Southeast WPCP pumping station, which lifts the wastewater from both interceptors into the preliminary treatment building.

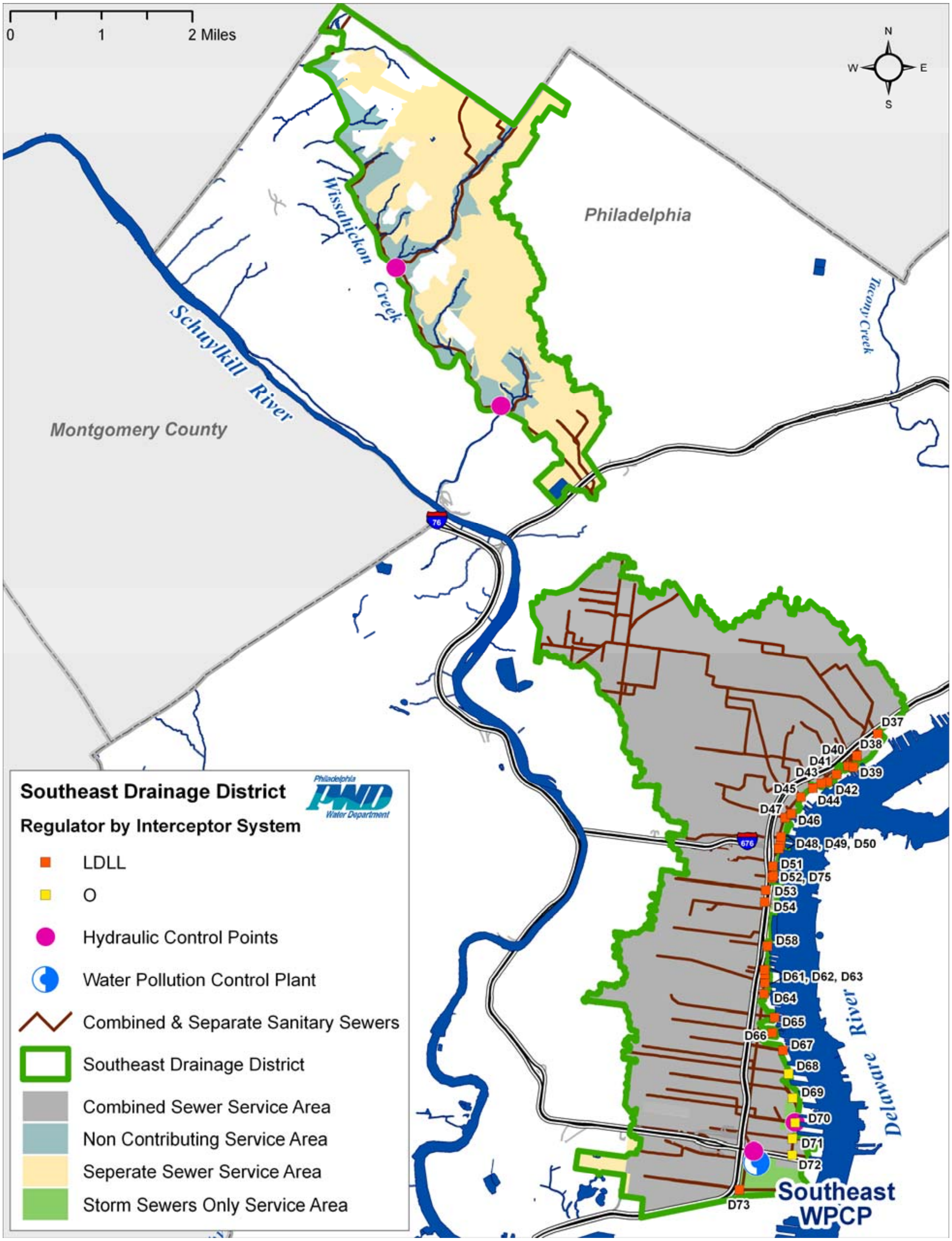


Figure 3-24 Southeast Drainage District Collection System

Lower Delaware Low Level
The LDLL interceptor begins in central Philadelphia at the intersection of Dyott Street and Delaware Avenue. The LDLL heads south along the Delaware River and combines with the Oregon Avenue interceptor at Oregon Avenue and Swanson Street. Separate sanitary wastewater flows from the Wissahickon High Level, Monoshone and Cresheim Valley interceptors, including flow from areas outside the City, are collected by the LDLL. Table 3-26 lists the combined sewer regulators on the LDLL.

Oregon Avenue
The Oregon Avenue interceptor runs on Delaware Avenue from Snyder Avenue to Packer Avenue, with a portion between Jackson Street and Snyder Avenue on River Street. Wastewater flows to the intersection of Oregon and Delaware Avenues where it heads west along Oregon Avenue to Swanson Street and feeds into the LDLL. Table 3-26 lists the combined sewer regulators on the Oregon Ave. Interceptor.

Table 3-27 lists ranges of interceptor sewer diameters in the Southeast Drainage district by interceptor system.

Table 3-26 Southeast Drainage District CSO Regulators (NPDES Permit # PA 0026662)

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
D_37	D_37	36	LDLL	Cumberland St.and Richmond St.	Brown & Brown
D_38	D_38	2	LDLL	Dyott St and Delaware Ave	Brown & Brown
D_39	D_39	3	LDLL	Susquehanna Ave SE of Beach	Brown & Brown
D_40	D_40	4	LDLL	Berks St. SE of Beach St	Slot
D_41	D_41	5	LDLL	Palmer St. SE of Beach St	Brown & Brown
D_42	D_42	6	LDLL	Columbia Ave. SE of Beach St	Slot
D_43	D_43	7	LDLL	Marlborough St. and Delaware	Slot
D_44	D_44	8	LDLL	Shackamaxon St. E of Delaware	Brown & Brown
D_45	D_45	9	LDLL	Laurel St. SE of Delaware Ave	Brown & Brown
D_46	D_46	10	LDLL	Penn St. and Delaware Ave	Slot
D_47	D_47	11	LDLL	Fairmount Ave. W of Delaware	Brown & Brown
D_48	D_48	12	LDLL	Willow St. W of Delaware Ave	Brown & Brown
D_49	D_49	13	LDLL	Callowhill St. and Delaware Ave.	Brown & Brown
D_50	D_50	14	LDLL	Delaware Ave N of Vine St	Brown & Brown
D_51	D_51	15	LDLL	Race St. W of Delaware Ave	Brown & Brown
D_52	D_52	16	LDLL	Delaware Ave. and Arch St	Brown & Brown
D_53	D_53	17	LDLL	Market St and Front St	Brown & Brown
D_54	D_54	20	LDLL	Front St S of Chestnut St	Brown & Brown
D_58	D_58	21	LDLL	South St and Delaware Ave	Brown & Brown
D_61	D_61	22	LDLL	Catherine St. E of Swanson St	Brown & Brown
D_62	D_62	23	LDLL	Queen St E of Swanson St	Brown & Brown

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
D_63	D_63	24	LDLL	Christian St W of Delaware Ave	Brown & Brown
D_64	D_64	25	LDLL	Washington Ave E of Delaware	Brown & Brown
D_65	D_65	26	LDLL	Reed St E of Delaware Ave	Brown & Brown
D_66	D_66	27	LDLL	Tasker St E of Delaware Ave	Brown & Brown
D_67	D_67	28	LDLL	Moore St E of Delaware Ave	Brown & Brown
D_73	D_73	33	LDLL	Pattison Ave and Swanson St	Brown & Brown
D_68	D_68	29	O	Snyder Ave and Delaware Ave	Brown & Brown
D_69	D_69	30	O	Delaware Ave N of Porter St	Brown & Brown
D_70	D_70	31	O	Oregon Ave and Delaware Ave	Brown & Brown
D_71	D_71	32	O	Bigler St and Delaware Ave	Brown & Brown
D_72	D_72	34	O	Packer Ave E of Delaware Ave	Brown & Brown

Table 3-27 Interceptor Sewer Systems in the Southeast Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Lower Delaware Low Level	5.0	3 - 11
Oregon Avenue	1.5	2.5 - 4

3.2.1.3 Southwest Drainage District

Figure 3-25 shows the collection system for the Southwest drainage district. This figure depicts the combined sewer and separate sewer interceptors, as well as the location of the CSO regulators and major hydraulic control.

The Southwest drainage district serves an in-City population of approximately 451,000 and conveys flows to the combined sewer interceptors of the Central Schuylkill East Side (CSES), Central Schuylkill West Side (CSWS), Lower Schuylkill East Side (LSES), Southwest Main Gravity (SWMG), Cobbs Creek High Level (CCHL), and Cobbs Creek Low Level (CCLL). The CSES, CSWS, and LSWS interceptors are all tributary to the Central Schuylkill Pumping Station (CSPS), which pumps to the upstream end of the SWMG. The CCHL is also tributary to the SWMG which conveys flow by gravity to the Southwest WPCP preliminary treatment building. Wet weather flow in excess of treatment capacity of regulators along the SWMG overflows to the LSWS regulators which delivers flow to the Southwest WPCP pumping station. The Southwest WPCP pump station receives additional flow from the CCLL and lifts the wastewater from these interceptors into the preliminary treatment building to be combined with the flow from SWMG and the DELCORA force main for screening. The Southwest drainage district collects separate sanitary wastewater flows from the Wissahickon Low Level and Upper Schuylkill interceptors, including large areas outside the City. The suburban communities served by the Southwest WPCP are:

- Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence
- Lower Merion Township

- Springfield Township
- Upper Darby Township and Haverford Township

Cobbs Creek High Level
The CCHL interceptor begins in the westernmost sections of Philadelphia along Cobbs and Indian Creeks. Several small interceptors consolidate to form the main interceptor that runs parallel to Cobbs Creek. This interceptor, which once continued south along Cobbs Creek, heads east in the Cobbs Creek High Level Cutoff sewer along 60th Street until it combines with the SWMG interceptor. Table 3-28 lists the combined sewer regulators on the CCHL.

Southwest Main Gravity
The SWMG interceptor begins at the force main from the Central Schuylkill Pumping Station and continues south to the Southwest WPCP. A tributary interceptor, which conveys flow from the Mill Creek drainage basin, enters the main SWMG interceptor at 47th Street and Grays Ferry Avenue. Wastewater from DWOs of regulators S_50 and S_51 is pumped to the SWMG interceptor by the 42nd Street pumping station. The CCHL interceptor combines with the SWMG at 60th Street and Grays Avenue. The SWMG interceptor enters a dispersion chamber near the intersection of 70th Street and Dicks Avenue and becomes a triple barrel parallel sewer, which conveys the wastewater directly into the Southwest WPCP without additional inflows. There are gates on each of the three pipes at this dispersion chamber with automatic controls enabling selected barrels to be closed during dry weather or for service as needed.. Table 3-28 lists the combined sewer regulators on the SWMG. Five CSO regulating chambers, S_34, S_39, S_40, S_43, and S_47, are hydraulic control points that regulate flow to the SWMG and overflow to regulators along the LSWS interceptor. Additionally, two more regulators, S_27 and S_28, are hydraulic control points that regulate flow to the SWMG and overflow to S_50.

Central Schuylkill East Side
The CSES interceptor begins at the downstream end of the Upper Schuylkill separate sanitary sewer interceptor. The CSES travels along the east bank of the Schuylkill River, collecting combined sewer flows from regulators including the Main Relief real time control sewer storage structure. The CSES combines with the LSES prior to flowing under the Schuylkill River at the Central Schuylkill Siphon. Table 3-28 lists the combined sewer regulators on the CSES.

Central Schuylkill West Side
The CSWS conveys flow north of the Spring Garden Street Bridge to the Central Schuylkill Pumping Station (CSPS). It travels along the west bank of the Schuylkill River and combines with outflow from the Central Schuylkill Siphon at the CSPS. Table 3-28 lists the combined sewer regulators on the CSWS.

Lower Schuylkill East Side
The LSES intercepts flow at 26th and Penrose Avenue and conveys flow north to the CSPS. The LSES combines with the CSES at the upstream end of the Central Schuylkill Siphon prior to flowing under the Schuylkill River. Table 3-28 lists the combined sewer regulators on the LSES.

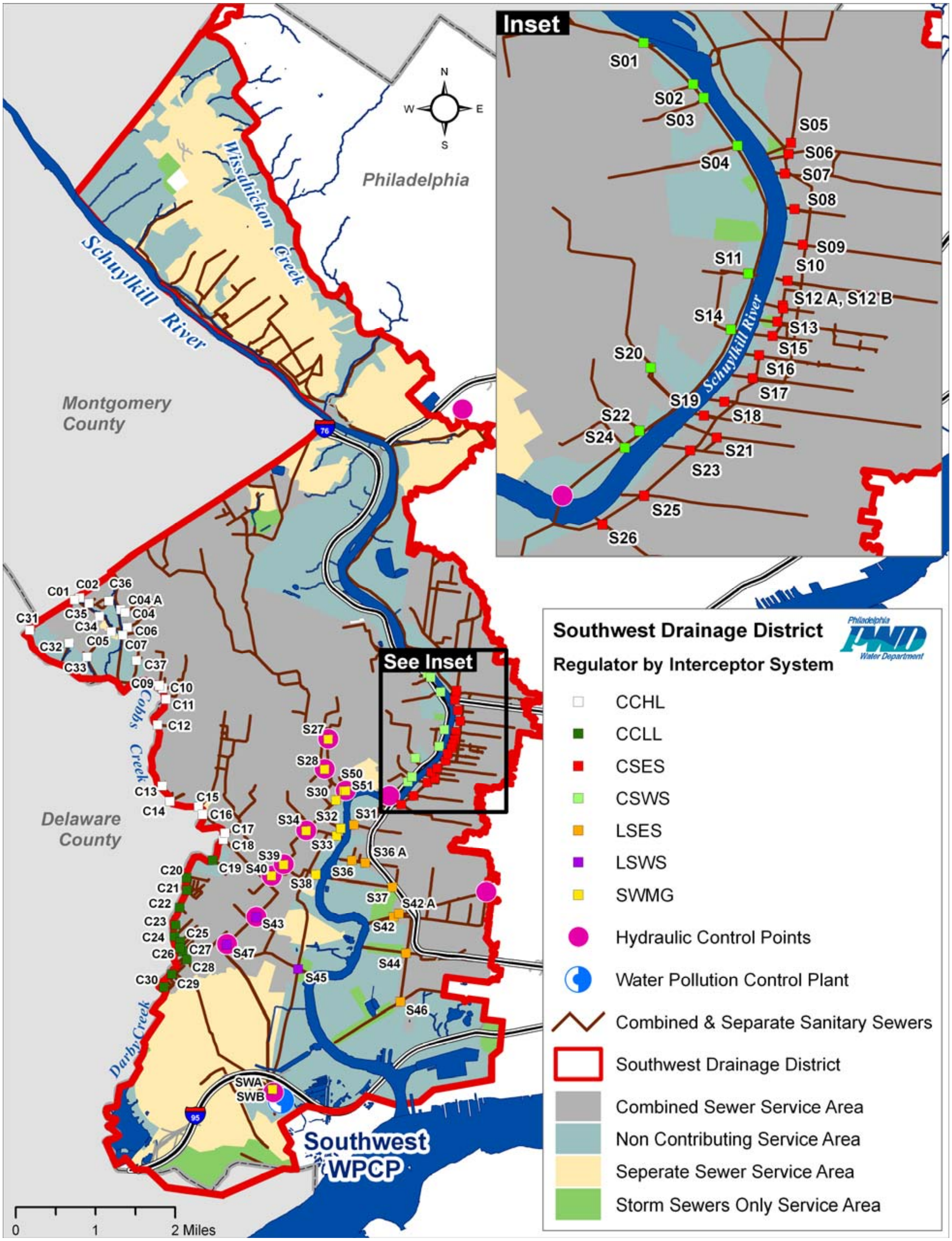


Figure 3-25 Southwest Drainage District Collection System

Cobbs Creek Low Level

The CCLL interceptor system consists of two distinct segments – the continuation of the Cobbs Creek Interceptor south of the high-level cutoff, and the 80th Street and Island Road Interceptor. The interceptor originally discharged directly to Cobbs Creek, but the 80th Street and Island Road Interceptor was later built to convey this flow to the Southwest WPCP pumping station. There are no regulators or overflow structures along this interceptor, with the exception of the Eagle Creek emergency relief sewer serving the pumping station. Table 3-28 lists the combined sewer regulators on the CCLL.

Lower Schuylkill West Side

This interceptor lies east of the SWMG line and west of the Schuylkill River. It services four regulator structures (S-32, S-33, S-38, and S-45). Three of the regulators (all except S-32) receive overflows from the SWMG system, in addition to controlling their own tributary areas. Flow from the LSWS combines with flow from the CCLL at the Southwest WPCP pump station where three Archimedes positive displacement pumps lift and deliver it to the pretreatment building where it is combined with SWMG and DELCORA Force Main flow for screening at the PTB. Table 3-28 lists the combined sewer regulators on the LSWS.

Table 3-29 lists ranges of interceptor sewer diameters in the Southwest drainage district by interceptor system.

Table 3-28 Southwest Drainage District CSO Regulators (NPDES Permit # PA 0026671)

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
S_05	S_05	9	CSES	24th St. 155' S. of Park Towne	Brown & Brown
S_06	S_06	10	CSES	24th St. 350' S. of Park Towne	Brown & Brown
S_07	S_07	11	CSES	24th St. and Vine St	Brown & Brown
S_08	S_08	12	CSES	Frace St W of Bonsall St	Brown & Brown
S_09	S_09	13	CSES	Arch St W of 23rd St	Brown & Brown
S_10	S_10	14	CSES	Market St 275' W of 23rd	Water Hydraulic-Sluice Gate
S_12	S_12A	15	CSES	24th St N of Chestnut St Bridge	Slot
S_12A	S_12A	15	CSES	24th St under Chestnut St Bridge	Slot
S_13	S_13	16	CSES	Sansom St W of 24th St	Slot
S_15	S_15	17	CSES	Walnut St W of 24th St	Brown & Brown
S_16	S_16	18	CSES	Locust St and 25th St	Brown & Brown
S_17	S_17	19	CSES	Spruce St and 25th St	Slot
S_18	S_18	20	CSES	Pine St W of Taney St	Brown & Brown
S_19	S_19	21	CSES	Lombard St W of 27th St	Brown & Brown
S_21	S_21	22	CSES	South St E of 27th St	Dam
S_23	S_23	23	CSES	Schuylkill Ave and Bainbridge	Brown & Brown
S_25	S_25	24	CSES	Schuylkill Ave and Christian St	Brown & Brown
S_26	S_26	25	CSES	Ellsworth St. W of Schylkill Ave	Brown & Brown
S_01	S_01	26	CSWS	West River Dr 1600' NW Spring	Brown & Brown

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
S_02	S_02	27	CSWS	West River Dr 375' NW Spring	Brown & Brown
S_03	S_03	28	CSWS	Spring Garden St. W of	Slot
S_04	S_04	29	CSWS	Schuylkill Expressway 600' NW	Brown & Brown
S_11	S_11	30	CSWS	Market St W of Schuylkill	Dam
S_14	S_14	31	CSWS	Schuylkill Expy Under Walnut St	Brown & Brown
S_20	S_20	32	CSWS	440' NNW of South St	Brown & Brown
S_22	S_22	33	CSWS	660' S of South St. E of Penn	Brown & Brown
S_24	S_24	34	CSWS	1060' S of South St. E of Penn	Brown & Brown
C_01	C_01	51	CCHL	City Line Ave 100' S of Creek	Slot
C_02	C_02	52	CCHL	City Line Ave and 73rd St	Slot
C_04	C_04A	82	CCHL	Malvern Ave and 68th St	Slot
C_04A	C_04A	82	CCHL	68th St. NW of Mavern Ave	Slot
C_05	C_05	54	CCHL	Lebanon Ave SW of 73rd St	Slot
C_06	C_06	55	CCHL	Lebanon Ave and 68th St	Slot
C_07	C_07	56	CCHL	Landsdowne Ave and 69th St	Slot
C_09	C_09	57	CCHL	64th St and Cobbs Cr.	Slot
C_10	C_10	58	CCHL	Gross St and Cobbs Cr.	Slot
C_11	C_11	59	CCHL	63rd St S of Market St	Slot
C_12	C_12	60	CCHL	Spruce St at Cobbs Cr	Slot
C_13	C_13	61	CCHL	62nd St at Cobbs Cr.	Slot
C_14	C_14	62	CCHL	Baltimore Ave and Cobbs Cr.	Slot
C_15	C_15	63	CCHL	59th St and Cobbs Creek	Slot
C_16	C_16	64	CCHL	Thomas Ave and Cobbs Cr.	Slot
C_17	C_17	65	CCHL	Beaumont St and Cobbs Creek	Slot
C_18	C_18	41	CCHL	60th St. at Cobbs Cr Parkway	Slot
C_31	C_31	66	CCHL	Cobbs Cr. Park S of City Line	Slot
C_32	C_32	72	CCHL	Cobbs Creek Parkway & 77th St	Slot
C_33	C_33	67	CCHL	Brockton Rd and Farrington Rd.	Slot
C_34	C_34	68	CCHL	Woodcrest Ave and Morris Park	Slot
C_35	C_35	69	CCHL	Morris Park W of 72nd St. and	Slot
C_36	C_36	70	CCHL	Woodbine Ave S of Brentwood	Slot
C_37	C_37	71	CCHL	Cobbs Creek Parkway S of 67th	Slot
C_19	C_19	42	CCLL	Cobbs Cr. And 62nd Thru	Slot
C_20	C_20	43	CCLL	65th St and cobbs Cr. Parkway	Slot
C_21	C_21	44	CCLL	68th St and Cobbs Cr. Parkway	Slot
C_22	C_22	45	CCLL	70th St and Cobbs Cr. Parkway	Slot
C_23	C_23	46	CCLL	Upland St Cobbs Cr. Parkway	Slot
C_24	C_25	47	CCLL	Greenway Ave and Cobbs Cr.	Slot
C_25	C_25	47	CCLL	Woodland Ave and Cobbs Cr.	Slot
C_26	C_28A	78	CCLL	Saybrook Ave and Island Ave	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
C_27	C_28A	78	CCLL	Paschall Ave and Island Ave	Slot
C_28A	C_28A	78	CCLL	Island Ave SE of Glenmore Ave	Dam
C_29	C_29	49	CCLL	Claymount St and Grays Ave	Slot
C_30	C_30	50	CCLL	77th St W of Elmwood Ave	Slot
S_31	S_31	2	LSES	Reed St and Schuylkill Ave	Brown & Brown
S_35	S_36A	3	LSES	35th St and Mifflin St	Slot
S_36	S_36A	3	LSES	36th St and Mifflin St	Slot
S_36A	S_36A	3	LSES	34th St and Mifflin St	Brown & Brown
S_37	S_37	4	LSES	Vare Ave and Jackson St	Brown & Brown
S_42	S_42	5	LSES	Passyunk Ave and 29th St	Brown & Brown
S_42A	S_42A	6	LSES	Passyunk Ave and 28th St	Brown & Brown
S_44	S_44	7	LSES	26th St 700' N off Hartranft St	Brown & Brown
S_46	S_46	8	LSES	Penrose Ave and 26th St	Brown & Brown
S_32	S_32	37	LSWS	49th St S of Botanic St	Slot
S_33	S_33	38	LSWS	51st St and Botanic St	Brown & Brown
S_38	S_38	39	LSWS	56th St E of P&R RR	Brown & Brown
S_45	S_45	40	LSWS	67th St E of P&R RR	Brown & Brown
S_30	S_30	35	SWMG	46th St and Paschall Ave	Slot
S_50	S_50	36	SWMG	43rd St Se of Woodland Ave	Brown & Brown
S_51	S_51	36	SWMG	42nd St SE of Woodland Ave	Slot
R_7	S_FRM	75	CSES	16th Street and Clearfield Street	Dam
R_8	S_FRM	75	CSES	22nd Street and Dauphin Street	Dam
R_9	S_FRM	75	CSES	22nd Street and Berks Street	Dam
R_10	S_FRM	75	CSES	22nd Street and Montgomery Ave	Dam
R_11	S_FRM	75	CSES	24th Street and North College Ave	Dam
R_11A	S_FRM	75	CSES	23rd Street and North College Ave	Dam
R_12	S_FRM	75	CSES	23rd Street and North College Ave	Dam
R_1	C_FRTR	83	CCHL	56th Street and Locust Street	Dam
R_1A	C_FRTR	83	CCHL	56th Street and Locust Street	Dam
R_2	C_FRTR	83	CCHL	56th Street and Spruce Street	Dam
R_3	C_FRTR	83	CCHL	56th Street and Spruce Street	Dam
R_4	C_FRTR	83	CCHL	56th Street and Pine Street	Dam
R_5	C_FRTR	83	CCHL	56th Street and Cedar Avenue	Dam
R_6	C_FRTR	83	CCHL	56th Street and Webster Street	Dam
R_24	C_FRA	84	CCHL	Arch Street and Cobbs Creek	Dam

Table 3-29 Interceptor Sewer Systems in the Southwest Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Cobbs Creek High Level	7.1	1 - 8
Southwest Main Gravity	10.1	5.5 - 14
Central Schuylkill East Side	2.5	5.5 - 8.5
Central Schuylkill West Side	2.0	2.5 - 4.5
Lower Schuylkill East Side	2.8	3 - 5.5
Cobbs Creek Low Level	2.0	2.5 - 4
Lower Schuylkill West Side	3.5	1.75 - 5

3.2.3 Current Collection System Capacities

This section presents the results of the LTCPU collection system models to study the maximum theoretical flows that can be delivered to each of the water pollution control plants. Scenarios were analyzed for each drainage district model (NE, SE and SW) and peak flows observed. The study was conducted as a part of the LTCPU to identify the maximum flow that can be delivered to each of the treatment plants regardless of their treatment capacity so as to study the conveyance limits of each sewer system.

3.2.3.1 Northeast Drainage District

The Northeast drainage district consists of the Northeast High Level system and the Northeast Low Level system. The Northeast Low Level system pumps flow into the NE WPCP from the Somerset (SOM), Upper Frankford Low Level (UFLL), and the Upper Delaware Low Level (UDLL) interceptors. The Northeast High Level system delivers flow to the Northeast WPCP by gravity from the Frankford High Level Interceptor (FHL) through a double barrel sewer. Presently only one of the barrels is in service and the other barrel is closed.

Table 3-30 presents the estimated maximum potential flow conveyed to the NE WPCP through each interceptor system based on model simulation results from running the combined Northeast High and Low Level simplified model using the September 28, 2004 rainfall. This event produced the largest peak flows based on continuous simulation of existing conditions for the years 2002 through 2004 and can be considered representative of expected peak hydrologic response.

Table 3-30 Northeast Drainage District Estimated Maximum Potential Flow Delivery to the WPCP through Existing Interceptor Systems

Interceptor system	Peak Flow (cfs)	Peak Flow (MGD)	Notes
FHL	124	80	- Includes head losses between R18 and PTB - Only One Barrel in Service
UFLL	63	41	Free Outfall Upstream of Diversion Chamber A (DivA)
UDLL	504	326	Free Outfall at Junction Chamber A (JCA) with Grit
SOM	94	61	Free Outfall Upstream of Diversion Chamber A (DivA)
Total	**786**	**508**	

3.2.3.2 Southeast Drainage District

The Southeast WPCP receives flows from two interceptor systems, the Lower Delaware Low Level (LDLL) and the Oregon Avenue (O) interceptor systems. The Oregon Avenue interceptor is a tributary to the Lower Delaware Low Level system. All the flows that come to the SE WPCP are pumped. The simplified SE drainage district model with median runoff and baseflow estimates was used for simulating the ramp rainfall. The ramp rainfall had a total rainfall of 79 inches falling over 48 hours with a peak intensity of 2.5 inches per hour sustained over 24 hours. The ramp rainfall was used to simulate maximum potential flows throughout the system. To determine the unrestricted maximum flow that may be delivered to the plant by the LDLL and O interceptors, the boundary conditions due to the pump at the SE WPCP were removed. The results are presented in Table 3-31.

Table: 3-31 Estimated Maximum Potential Flow Delivery to the SE WPCP

Scenario no.	Description	SE Total (cfs)	SE Total (mgd)
1	SE model using ramp rainfall with SE pump replaced by a free outfall	638	412
* SE flow is the sum of Lower Delaware Low Level and Oregon Ave interceptor systems.			

3.2.3.3 Southwest Drainage District

The Southwest WPCP receives low-level flows from the screw pumps which pump flows from the Cobbs Creek Low Level and Lower Schuylkill West Side Interceptors. SW High-level (SWHL) flows are delivered to the SW WPCP from the DELCORA Force Main and the SW Main Gravity Triple Barrel. The Triple Barrel conveys flows by gravity from the Cobbs Creek High Level and the SW Main Gravity Interceptors. The SW Main Gravity Interceptor also receives flows that are pumped through the Central Schuylkill Pump Station (CSPS) from the Upper Schuylkill East Side, Central Schuylkill East Side, Central Schuylkill West Side, and Lower Schuylkill East Side Interceptors.

The following maximum flow scenario is analyzed for the Southwest drainage district:
LTCPU SW drainage district model with the rainfall ramp described above in the Southeast section was used for the simulation. DELCORA is removed from the system in order to eliminate competition with the SW Main Gravity Triple Barrel for capacity at the plant. The SWHL immediately downstream of the Triple Barrel is modeled as unrestricted to allow the maximum amount of flow through the pipes and the Low Level Screw pumps are disconnected to remove the boundary conditions at the plant – which limit the flow conveyed to the plant – allowing for maximization of flow delivery. The results are presented in Table 3-32.

Table: 3-32 Estimated Maximum Potential Flow Delivery to the SW WPCP Through Existing Interceptor Systems

Scenario No.	Description	SW Low Level (mgd)	SW High Level (mgd)	Total (mgd)
1	Southwest model with median runoff and baseflow estimates using ramp rainfall with DELCORA removed, a free outfall for SWHL immediately downstream of the Triple Barrel, and the Low Level screw pumps replaced by a free outfall.	278	478 *	756
* Not achievable through gravity flow - free outfall at WPCP				

3.2.4 Wastewater Treatment Plant Descriptions

Stress testing and hydraulic model evaluations were conducted for each of PWD's three WPCPs in order to determine current maximum reliable capacities of plant unit processes and to identify cost effective improvements capable of increasing peak wet weather capacities of the existing facilities.

- CH2MHILL, 2001 Stress Testing of the Northeast WPCP, Prepared for the Philadelphia Water Department. December
- CH2MHILL, 2001 Stress Testing of the Southeast WPCP, Prepared for the Philadelphia Water Department. December
- CH2MHILL, 2001 Stress Testing of the Southwest WPCP, Prepared for the Philadelphia Water Department. December

3.2.4.1 Northeast Water Pollution Control Plant

The Northeast WPCP influent flow is conveyed by the Frankford High Level (FHL), Upper Frankford Low Level (UFLL), Somerset (SOM) , and the Upper Delaware Low Level (UDLL) interceptors while the plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-33. The sludge produced during the treatment process is treated on site and the final product is moved to the BRC center for composting.

Table 3-33 Summary of NE WPCP Unit Processes

Unit Process	Number	Description
Bar Screen	7	Width = 8ft, single-rake front cleaned, 1-in. opening
	1	Width = 8ft, multiple-rake front cleaned, 5/8-in. opening
Low-Level Pumps	6	Centrifugal Pumps
		Q = 85 mgd, at 55-ft head
Grit Removal	4	Rectangular detritors
		Length = 55ft, width = 55ft, SWD = 7.5ft, volume = 22,690 ft^3 (each)
Influent Flow Meter	2	Venturi - 48 inch - Set 1 primary clarifiers
	1	Venturi - 66 inch - Set 2 primary clarifiers

Unit Process	Number	Description
Primary Clarifiers	8 (Set 1)	Length = 240ft, width = 65ft, SWD = 10ft
		Surface area = 15,600ft^2, weir length = 450ft (each)
		C and F sludge mechanism, influent end hopper
	4 (Set 2)	Length = 250ft, width = 125ft, SWD = 10ft
		Surface area = 31,250ft^2, weir length = 900ft (each)
		C and F sludge mechanism, influent end hopper
Aeration Basin	7	Four-pass - through flow only
		Length = 371ft, width = 87ft, SWD = 15ft, volume = 3.286mg (each)
		Operate with selector
Blowers	4	Centifugal Q = 35,000 acfm
	2	Centifugal Q = 27,000 acfm
Diffusers	Fine bubble	Ceramic; 12,000 per tank
Secondary Settling Tanks	8 (Set 1)	Length = 214ft, width = 75ft, SWD = 11ft
		Surface area = 16,100 ft^2, weir length = 869ft (each)
		Gould-type central hopper, C&F sludge mechanism
	8 (Set 2)	Length = 231ft, width = 70ft, SWD = 13ft
		Surface area = 16,200ft^2, weir length = 860ft (each)
		Gould-type central hopper, C&F sludge mechanism
Chlorine Contact Chamber	2	Three-pass serpentine flow
		Length = 300ft, width = 84ft, SWD = 11ft, volume = 2.06mg
		Chlorine gas solution feed
Sludge Thickening	12	Dissolved air flotation
Anerobic Digesters	8 (Set 1)	Digesters - Diameter = 110ft, SWD = 30ft, volume = 300,000ft^3 (each)
		Sludge transfer tanks
		Volume = 1.5 mg (each)
		Diameter = 96ft, SWD = 26ft

A summary of NEWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-34. Since July 2000, PWD has received and implemented revised NPDES permits that are used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as follows:

- If a calendar month includes one or more days where flow exceeds 315mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the daily monitoring report (DMR).
- If a calendar month includes one or more days where flow exceeds 315mgd, a value of 86 percent may be used for those days for the purpose of calculating average monthly

BOD_5 percent removal. The actual BOD_5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.

- When daily flows exceed 315mgd, the average monthly and average weekly TSS and BOD_5 mass loadings for those days may be calculated by using the lesser of the actual load or the permit's allowable average monthly and average weekly limit, respectively. The actual TSS and BOD5 loadings associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-34 NPDES Permit Requirements

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	42000	63600	-	
	Percent Removal	%	86			
TSS	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	52540	78810	-	
	Percent Removal	%	85			
Flow		mgd	210		315	420

A maximum instantaneous treatment capacity was estimated during the 2001 stress test that was performed on the NEWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-35 below.

Table 3-35 NE WPCP Treatment Capacity Assessment

Unit Process	Estimated Capacity (mgd)	Criteria
Pumping and Screening	500 mgd - screening and raw sewage pumping capacity	
	Low-Level interceptor[1] - 375 mgd	Observed capacity of pumps
	High-Level interceptor - 125 mgd	Observed maximum flow
Grit Removal	525 mgd - grit removal[2]	SOR - 58,000 gpd/ft^2
Primary Treatment	460 mgd - existing	Based on allowable SOR
	505 mgd - modified inlet baffle	SOR - 2,500 gpd/ft^2
	567 mgd - improved sludge pumping	SOR - 2,800 gpd/ft^2
	710 mgd - potential	SOR - 3,500 gpd/ft^2
	Set 1[3] - 273 mgd (existing)	2,500 gpd/ft2 - test results
	Set 2[3] - 187 mgd (existing)	2,000 gpd/ft2 - test results
	Set 2 - 235 mgd (modified inlet baffle)	2,500 gpd/ft2 - test results

Unit Process	Estimated Capacity (mgd)	Criteria
Aeration Basins	N/A - no change to organic loading patterns	
Secondary Clarifiers	270 - 380 mgd - existing condition	Long-term monitoring results
	440 mgd - improved flow/solids distribution between clarifiers	Based on allowable SOR - 1,800 gpd/ft^2
	322 mgd - mixed liquor concentration 2,000 mg/L	Based on allowable SLR - 30 lbs/day/ft^2
Chlorine Contact Chamber	430 mgd - meeting disinfection requirements at current flows	
	800 mgd - volume of chlorine basin and plant outfall	HRT- 15 minutes

[1]Based on one pump and one screen out of service: Rated capacity of raw sewage pumps – 85mgd at 55 feet TDH, Observed maximum capacity 75 mgd, Channel velocity of screens – 0.41 ft/s at 5 ft channel depth.
[2]Based on removal of 60 mesh (0.25mm) particles
[3]Based on one clarifier out of service

A sustainable flow analysis was performed on the NEWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined that the performance of the secondary clarifiers would determine the final effluent quality of the NEWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-36 below.

Table 3-36 NE WPCP NPDES Permit Requirements and Results of the Sustainable Flow Analysis

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow Based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	Mgd	420			375
Maximum Week Limits	Mgd		320	305	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	63600			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	78810			
Maximum Monthly Limits	Mdg	210	260	235	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	42000			
BOD_5 Percent Removal	%	86			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	52540			
TSS Percent Removal	%	85			

3.2.4.2 Southeast Water Pollution Control Plant

The Southeast WPCP influent flow is generated by the Lower Delaware Low Level interceptor while the plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-37. The sludge from the primary clarifiers is piped for further treatment to SWWPCP sludge handling facility.

Table 3-37 Summary of Unit Processes SE WPCP

Unit Process	Number	Description
Coarse Screens	2	Width = 6.5 ft, single-rake front cleaned
Low-Level Pumps	6	Centrifugal pumps; 3 VSD, 3 constant speed
		Design Q = 70 mgd, at 45-ft head
Bar Screens	6	Width = 6.5 ft, 75 percent inclined, 1-inch opening
Grit Removal	6	Grit channels
		Length = 140 ft, width = 10 ft, SWD = 10 ft, volume = 14,000 ft3 (each)
Flocculation Pre-aeration	2	Aerated channel
		Length = 225 ft, width = 28 ft, SWD = 13 ft, volume = 81,900 ft3 (each)
Primary Clarifier	4	Length = 250 ft, width = 125 ft, SWD = 12 ft
		Surface area = 31,250 ft2, weir length = 635 ft (each)
		C&F sludge mechanism, influent end hopper
Flow Spit Chamber	24	Gates at 60-inch weir length
		6 gates for 2 aeration basins
Aeration Basin	8	Four-pass - through flow only
		Length = 210 ft, width = 52.5 ft, SWD = 14.3 ft, volume 1.18 mg (each)
		Operate with first pass as selector
Aeration System	4	1 @ 40 Hp, 3 @ 30 Hp (per basin)
Secondary Settling Tanks	12	Length = 214 ft, width = 68 ft, SWD = 11 ft
		Surface area = 14,552 ft2
		Weir length = 784 ft (each)
		Gould-type central hopper, C&F mechanism
Effluent Pumps	5	Q = 70 mgd at 11 head, VSD 3 units

A summary of SEWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-38. Since August 2000, PWD has received and implemented revised NPDES permits that are used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as follows:

- If a calendar month includes one or more days where flow exceeds 168mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- If a calendar month includes one or more days where flow exceeds 168mgd, a value of 86 percent may be used for those days for the purpose of calculating average monthly

BOD5 percent removal. The actual BOD5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.

- When daily flow exceeds 168mgd, the TSS and BOD5 mass loadings for those days may be omitted from the average monthly and average weekly mass loading calculations, in accordance with the requirements of the Delaware River Basin Commission for Zone 3 of the Delaware Estuary. The actual TSS and BOD5 loadings associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-38 NPDES Permit Requirements SE WPCP

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	19,650	29,475		
	Percent Removal	%	86			
TSS	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	28,025	42,035		
	Percent Removal	%	85			
Flow		mgd	112		168	224

A maximum instantaneous treatment capacity was estimated during the 2001 stress test performed on the SEWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-39 below.

Table 3-39 Treatment Capacity Assessment SE WPCP

Unit Process	Estimated Capacity (mgd)	Criteria
Pumping and Screening	286	Observed maximum flow
	240 [1] - 1 coarse screen partially blocked	Observed maximum flow
	200 [2] - 1 wet well out of service	Observed maximum flow
Grit Removal	350 [3] - 1 channel out of service	
Primary Treatment	225 mgd[4] - existing condition (hydraulic limitations)	2,400 gpd/ft^2 - test results
	260 mgd[4] - new launders	2,800 gpd/ft^2 - SW test results
	330 mgd[4] - improved sludge pumping	3,500 gpd/ft^2 - potential
Aeration Basins	N/A	
	No change in organic loading pattern	

Unit Process	Estimated Capacity (mgd)	Criteria
Secondary Clarifiers	200 mgd[4] - existing (sludge bulking incidence)	Long-term monitoring results
	330 mgd[4] - current mixed liquor concentration	Based on allowable SOR of 1,800 gpd/ft^2
	236 mgd[4] - mixed liquor concentration 2,000 mg/L	Based on allowable SLR or 30 lbs/day
Effluent Pump Station	280 mgd[5] (1 pump out of service)	70 mgd per pump
Disinfection	395 mgd - volume of plant outfall	HRT - 15 minutes

[1]Based on one screen partially blocked
[2]Based on one screen (1/2 of wet well) out of service
[3]Based on removal of 60 mesh (0.25 mm) particles
[4]Based on one clarifier out of service
[5]Based on 1 pump out of service rated capacity of pumps 70 mgd

A sustainable flow analysis was performed on the SEWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined the performance of the secondary clarifiers would determine the final effluent quality of the SEWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-40 below.

Table 3-40 NPDES Permit Requirements and Sustainable Flow Analysis for SE WPCP

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	mgd	168			190
Maximum Week Limits	mgd		195	165	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	29,475			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	42,035			
Maximum Monthly Limits	mgd	112	150	125	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	19,650			
BOD_5 Percent Removal	%	86			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	28,025			
TSS Percent Removal	%	85			

3.2.4.3 Southwest Water Pollution Control Plant

The Southwest SWWPCP influent flow is generated by three sources; Southwest Main Gravity Triple-barrel sewer, Low-level pump station and DELCORA Force Main. The plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-41. The SWWPCP system contains a solids handling facility that treats the solids from the plant and also the solids from the SEWPCP. This system contains a dissolved air flotation sludge thickener and an anaerobic digester which create compost out of the waste activated sludge (WAS) from the two WPCPs.

Table 3-41 Summary of Unit Processes SW WPCP

Unit Process	Number	Description
Influent Flow Meter	1	Parshall flume - low-level gravity sewer
	3	Venturi - high-level gravity sewer
	1	Venturi - DELCORA forcemain
Low-Level Pumps	6	Archimedes screw (operating 2 in series)
		Q = 32 mgd, diameter = 8.5 ft, head = 22 ft (each), 42 ft total
Bar Screens	5	Width = 6 ft, 84^o incline, front cleaned, 1-in. opening
	1	Width = 6 ft, 84^o incline, front cleaned, 5/8-in opening
Grit Removal	4	Rectangular Detritor
		Length = 60 ft, width = 60 ft, SWD = 8 ft
Flocculation (Pre-aeration)	1 (west)	Length = 127.25 ft, width = 28.75 ft, SWD = 12 ft,
		Volume = 43,900 ft^3
	1 (east)	Length = 127.24 ft, width = 28.75 ft, SWD = 12 ft,
		Volume = 43,900 ft^3
Primary Clarifiers	5	Length = 250 ft, width = 125 ft, SWD = 12 ft
		Area = 31,250 ft2, weir length = 1,008 ft (each)
		C and F sludge mechanism, influent end hopper
Flow Split Chamber	36	Gates of 86-in. weir length
		6 gates for 2 aeration basins
Aeration Basin	10	Four-pass - through flow only
		Length = 160 ft, width = 40 ft, SWD = 17 ft
		Operate with first pass as selector - seasonally
Aeration System	2	Cryogenic, 90lb O2 per day
	40	125 hp, 100 hp, 75 hp, 60 hp (per basin)
Secondary Settling Tanks	20	Length = 260 ft, width = 76 ft, SWD = 11 ft
		Weir length = 816 ft (each)
RAS Pumps		Chain and flight sludge mechanism
	30	Q = 6.2 mgd, 3 pumps for 2 clarifiers
Effluent Pumps	5	Q = 115 mgd, hp = 500, VSD 3 units
DAF	8	Length = 70 ft, width = 18 ft, SWD = 12 ft
Anaerobic Digesters	12	Diameter = 110 ft, SWD = 30 ft, volume = 2.1 mg (each)
	1	Sludge storage tanks

A summary of SWWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-42. Since July 2000, PWD has received and implemented revised NPDES permits used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as fallows:

- If a calendar month includes one or more days where flows exceed 300mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- If a calendar month includes one or more days where flows exceed 300mgd, a value of 89.95 percent may be used for those days for the purpose of calculating average monthly BOD5 percent removal. The actual BOD5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- When daily flows exceed 300mgd, the TSS and BOD5 mass loadings for those days may be omitted from the average monthly and average weekly mass loading calculations. The actual TSS and BOD5 loading associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-42 NPDES Permit Requirements SW WPCP

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45		60
	Mass Loading	lbs/day	21,650	32,475	-	
	Percent Removal	%	89.25			
TSS	Concentration	mg/L	30	45		60
	Mass Loading	lbs./day	50,040	75,060	-	
	Percent Removal	%	85			
Flow		mgd	200		300	400

A maximum instantaneous treatment capacity was estimated during the 2001 stress test performed on the SWWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-43 below

Table 3-43 Treatment Capacity Assessment

Unit Process	Estimated Capacity (mgd)	Criteria
Preliminary Treatment	540 mgd - screening and raw sewage pumping capacity Low level interceptor [1] - 64 mgd High level interceptor - 475 mgd	 Rated capacity of pumps Observed maximum flow
Grit Removal	625 mgd - grit removal [2]	SOR - 58,000 gpd/ft^2

Unit Process	Estimated Capacity (mgd)	Criteria
Primary Treatment	250 mgd [3] - with BRC solids 350 mgd [3] - with BRC solids 440 mgd [3] - without BRC solids	Based on allowable SOR - 2,000 gpd/ft^2 Based on allowable SOR - 2,800 gpd/ft^2 Based on allowable SOR - 3,500 gpd/ft^2
Aeration Basins	N/A no change to organic loading patterns	
Secondary Clarifier	675 mgd 3 - existing 550 mgd 3 - mixed liquor concentration 2,000 mg/L 350 mgd 3 - mixed liquor concentration 3,000 mg/L	Based on allowable SOR - 1,800 gpd/ft2 Based on allowable SLR - 30 lbs/day/ft2 Based on allowable SLR - 30 lbs/day/ft2
ES station	460 mgd 4 (1 pump out of service)	115 mgd rated capacity
Chlorination	830 mgd - volume of plant outfall	HRT - 15 minutes

[1] Based on design capacity of 32mgd for each pump, with one pump out of service
[2] Based on unit out of service
[3] Based on one clarifier out of service
[4] Based on one pump out of service

A sustainable flow analysis was performed on the SWWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined the performance of the secondary clarifiers would determine the final effluent quality of the SWWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-44 below.

Table 3-44: NPDES Permit Requirements and Results of the Sustainable Flow Analysis SW WPCP

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	Mgd	400			320
Maximum Week Limits	Mgd		380	225	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	32,475			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	75,060			
Maximum Monthly Limits	Mgd	200	288	175	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	21,650			

			Maximum Sustainable Flow based on SOR		
BOD_5 Percent Removal	%	89			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	50,040			
TSS Percent Removal	%	85			

1 - BOD_5 limits based on old permit, plant now monitors $cBOD_5$ for compliance

3.2.5 Current Collection System CSO Response to Rainfall

The response of the current combined sewer collection system to wet weather events is characterized in terms of the average annual volume of wet weather flow captured and treated, and the volume overflowed to receiving waters. Percent capture, defined as the fraction of wet weather combined sewer flow that is captured and treated, is also commonly used to characterize the performance of the combined sewer collection system. Table 3-45 presents wet weather performance measures estimated for each watershed based on system hydrologic and hydraulic model simulations for a typical year precipitation record using a low and a high range of estimated hydrologic parameters.

Table 3-45 Combined Sewer System Wet Weather Characterization of Current Conditions

Watershed	Captured Volume (MG)	Overflow Volume (MG)	Capture %
Cobbs	1,713 - 1,971	651 - 1,015	66% - 72%
Delaware	9,629 - 11,068	4,133 - 6,737	62% - 70%
Schuylkill	5,757 - 5,740	2,204 - 3,463	62% - 72%
TTF	3,221 - 3,945	3,319 - 4,659	46% - 49%
System-Wide	20,320 - 22,724	10,307 - 15,873	59% - 66%

The frequency of combined sewer overflows is also a measure of system wet weather performance and is presented in Figure 3-26 as box and whisker plots for each watershed under existing conditions. The plot shows the range of overflow frequencies that occur among different combined sewer outfalls within each watershed. The average annual overflow frequency for each outfall is based on model simulations for the typical year precipitation record and is determined as the average of the low and high hydrologic parameter estimates. The annual number of overflows is seen to vary significantly between regulators within each watershed.

Wet weather performance is detailed further with regulator specific information in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

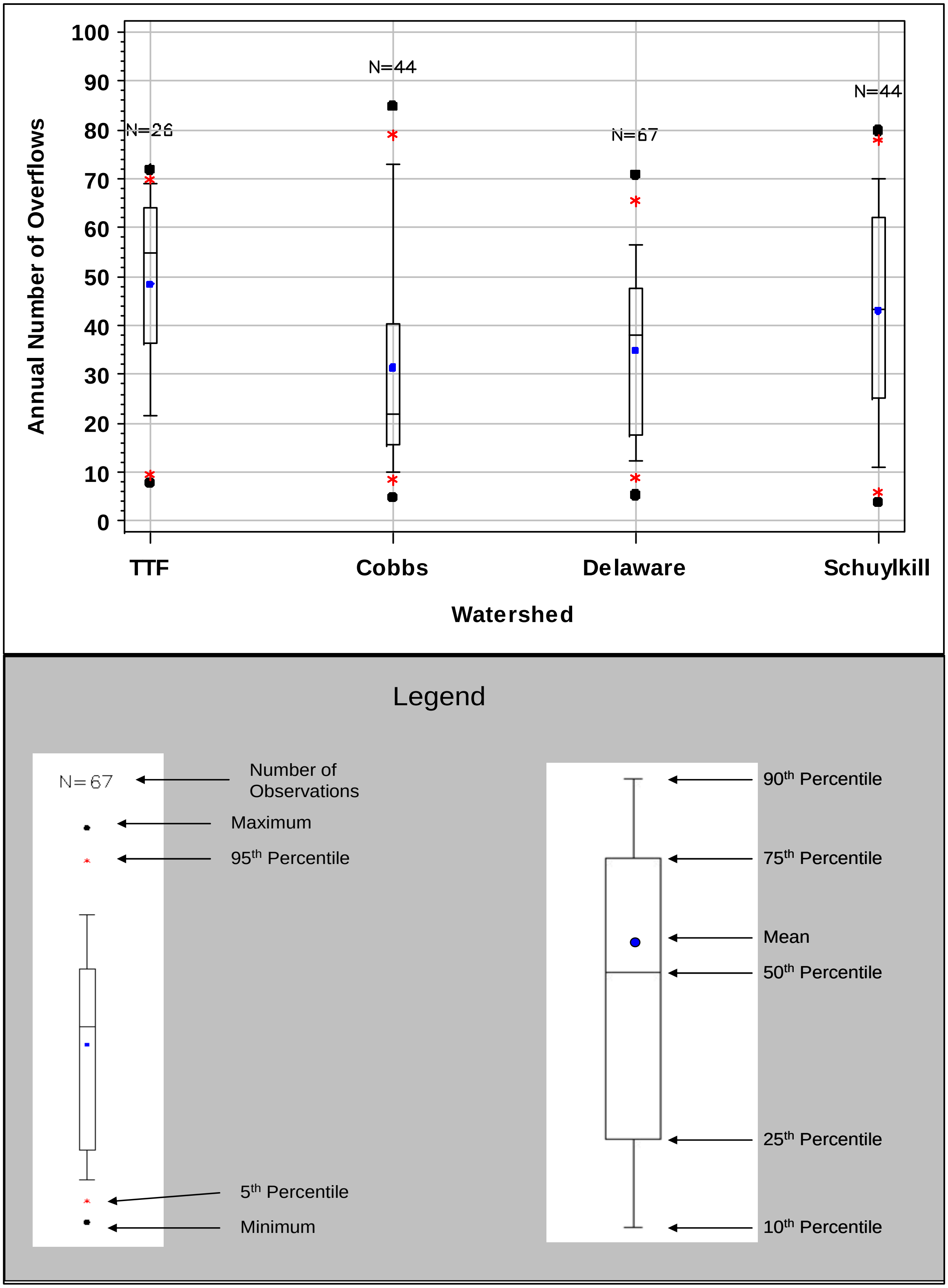


Figure 3-26 Average Annual Regulator Overflow Frequency by Watershed for Existing Conditions (Average of Low and High Uncertainty Range Using Typical Year Rainfall)

3.3 CONTRIBUTING MUNICIPALITIES

3.3.1 Contributing Area Description

This section provides additional details on metered flows for those communities contributing sanitary sewage, inflow, and infiltration to the PWD collection system. These communities, as listed in the previous section, are:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bensalem, Bristol, Falls, Lower Wakefield, Lower Southampton, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham and Abington Township and Jenkintown Borough
- The Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence.
- Township of Lower Merion
- Township of Lower Moreland and the Lower Moreland Township Authority
- Lower Southampton Municipal Authority and Upper Southampton Township
- Township of Springfield, Montgomery County and Whitemarsh and Upper Dublin Township
- Upper Darby Township and Haverford Township

PWD has entered into agreements with the municipalities, townships and authorities outside the City of Philadelphia (wholesale purchasers) to provide for the receipt, conveyance, treatment and disposal of wastewater and its by-products. In addition to water quality loading limits, the agreements provide maximum average annual or daily flow limits and instantaneous peak flow limits. The average long-term flow limits are based on the portion of secondary treatment capacity being reserved for the wholesale purchaser, while the instantaneous peak flow limit is established to limit the amount of wet weather inflow and infiltration entering the City in order to assure adequate wet weather conveyance and treatment capacity will be available. Chronically exceeding peak flow limits requires an accepted plan of action to eliminate the flow exceedances within a specified time period or financial penalties will be imposed upon the wholesale purchaser to encourage proper maintenance and rehabilitation of their community sanitary sewer collection system in order to mitigate the sources of excessive wet weather inflow and infiltration.

Table 3-48 provides details for each community being serviced by the NE WPCP including service area and population, maximum contractual flow limits, and connection points. The relative location of each community to the City boundary is shown in Figure 3-4.

Table 3-46 Summary of Outlying Communities Contributing to the Northeast Drainage District

Northeast Drainage District						
Community	Cheltenham Township	Abington Township	Bensalem Township	Bucks County	Southampton Township	Lower Moreland Township
Population	58,871	14,605	22,317	94,261	24,662	6,287
Area (acres)	8,855	4,489	5,143	24,990	6,411	1,917
Watershed	Tacony-Frankford Creek	Pennypack Creek	Poquessing Creek	Neshaminy Creek and Delaware River	Poquessing Creek	Pennypack Creek and Poquessing Creek
Downstream Combined Sewer Interceptor	Frankford High Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level
Connection Points	MC_1, MC_2, MC_3	MA_1, MA_2, MA_3, MA_4	MBE_1, MBE_2, MBE_3, MBE_4, MBE_5, MBE_6, MBE_7, MBE_8, MBE_9, MBE_10, MBE_11, MBE_12, MBE_13, MBE_14, MBE_15, MBE_16	MB_1	MSH_1, MSH_2	MLM_1, MLM_2, MLM_3, MLM_4, MLM_5, MLM_6, MLM_7
Contractual Flows						
Peak (MGD)	13.41	5.974	7.584	54.962	10.205	5.795
Daily (MGD)	-	4.453	-	37	-	2.9
Annual (MGD)	-	-	6.133	24	7.14	1.45

Table 3-49 provides details for each community being serviced by the SW WPCP and the SE WPCP including service area and population, maximum contractual flow limits, and connection points.

Table 3-47 Summary of Outlying Communities Contibuting to the Southwest and Southeast Drainage Districts

Southwest and Southeast Drainage Districts				
Community	Lower Merion Township	Upper Darby Township	DELCORA	Springfield Township
Population	53,861	96,784	468,801	21,640
Area (acres)	10,079	7,659	45,771	4,804
Watershed	Schuylkill River	Darby Creek and Cobbs Creek	Cobbs Creek	Wissahickon Creek
Downstream Combined Sewer Interceptor	Southwest Main Gravity and Cobbs Creek	Cobbs Creek High Level	DELCORA Force Main	Central Schuylkill East Side and Lower Delaware Low Level
Connection Points	ML_1, ML_2, ML_3, ML_4, ML_5, ML_6, ML_7	MUD_1N, MUD_1S, MUD1_O	MD-1	MS_1, MS_2, MS_3, MS_4, MS_5, MS_6, MS_7, MS_8
Contractual Flows				
Peak (MGD)	20.39	22.61	100	4.22
Daily (MGD)	14.5	-	75	-
Annual (MGD)	-	17	50	4.2

A summary of the preliminary peak wet weather flows contributed by the above listed municipalities are available in Table 3-50 and 3-51 below. These flows have undergone a preliminary QA process, but the numbers have not been finalized.

Table 3-48 Outlying Community Permanent Meter Flow Summary

Permanent Meter Flows (1/1/2000 - 3/31/2005)				
Meter ID	Drainage District	Average Daily Dry Weather Flow (mgd)	Peak 15-Minute Flow (mgd)	Wet / Dry Ratio
MA2	NE	1.50	4.94	3.3
MB1	NE	17.14	84.58	4.9
MBE5	NE	0.63	4.68	7.4
MBE6	NE	0.78	3.49	4.5
MBE7	NE	0.22	1.61	7.4
MC1	NE	0.50	2.93	5.8
MC2	NE	15.89	33.27	2.1
MC3	NE	0.04	0.23	6.3
MD1	SW	33.27	81.69	2.5
ML1	SW	1.09	2.99	2.7
ML3	SW	0.44	1.88	4.3
ML4	SW	3.89	14.40	3.7
ML5	SW	0.60	1.99	3.3
ML6	SW	0.10	0.59	5.8
ML7	SW	0.19	1.39	7.4
MLM1	NE	0.13	1.86	14.0
MLM2	NE	1.18	4.39	3.7
MS2	SW	1.22	7.50	6.2
MS3	SW	0.84	6.00	7.1
MS6	SW	0.43	1.98	4.7
MSH1	NE	5.63	25.00	4.4
MUD1-N	SW	6.57	20.10	3.1
MUD1-S	SW	5.03	38.50	7.7

Table 3-49 Outlying Community Temporary Meter Flow Summary

Meter ID	Drainage District	Average Daily Dry Weather Flow (mgd)	Peak 15-minute Flow (mgd)	Wet / Dry Ratio	Temporary Monitor Data Period
MA1	NE	0.009	0.043	4.8	11/15/04 - 1/16/05
MA3	NE	0.495	0.877	1.8	11/16/04 - 2/18/05
MA4	NE	0.063	0.204	3.2	11/15/04 - 1/16/05
MBE1	NE	0.121	1.313	10.9	8/1/2004 - 12/31/2004
MBE2	NE	0.332	1.464	4.4	8/1/2004 - 12/31/2004
MBE3	NE	0.035	0.480	13.7	8/1/2004 - 12/31/2004
MBE4	NE	0.163	1.888	11.6	8/1/2004 - 12/31/2004
MBE8	NE	0.379	1.771	4.7	8/1/2004 - 12/31/2004
MBE9	NE	0.381	1.689	4.4	8/1/2004 - 12/31/2004
MBE10	NE	0.067	0.444	6.7	8/1/2004 - 12/31/2004
MBE11	NE	0.014	0.174	12.7	8/1/2004 - 12/31/2004
MBE12	NE	0.150	0.620	4.1	8/1/2006 - 11/12/2006
MBE13	NE	0.013	0.152	11.5	8/1/2006 - 11/12/2006
MBE14	NE	0.017	0.392	22.8	8/1/2006 - 11/12/2006
MBE15	NE	0.010	0.104	10.8	8/1/2006 - 11/12/2006
MBE16	NE	0.130	1.320	10.2	9/3/2006 - 12/1/2006
ML2	SW	0.043	0.524	12.2	11/12/04 - 1/18/05
MLM3	NE	0.037	0.126	3.4	11/24/04 - 3/06/05
MLM4	NE	0.035	0.080	2.3	11/30/04 - 2/07/05
MS1	SE	0.134	0.822	6.1	11/12/04 - 1/18/05
MS4	SW	0.108	0.319	2.9	11/16/04 - 1/18/05
MS5	SW	0.106	0.380	3.6	11/12/04 - 1/26/05
MS7	SW	0.013	0.066	4.9	11/12/04 - 1/18/05
MSH2	NE	0.041	0.431	10.5	10/25/2006 - 1/25/2007

3.4 Regional Watershed and Receiving Water Characterization

3.4.1 Receiving Water Quality Standards and Use Designations

Information on segments considered impaired, causes of impairment, and TMDL status were obtained from the 2008 Pennsylvania Integrated Water Quality Monitoring and Assessment Report. Additional information on PADEP's plans for TMDL development was obtained from their "Six-Year Plan for TMDL Development".

The water quality in the Delaware River and its tidal tributaries are regulated by standards set specifically for the Delaware Estuary. The DRBC uses water quality zones which dictate the designated use and water quality standards for each segment of the river (DRBC, 2008a).
The Delaware River is assessed every two years by the DRBC for Support of Designated Uses.

Information on fish consumption advisories was obtained from PADEP (last revised July 17, 2006), New Jersey DEP (issued 2006), and USEPA's national listing of fish advisories (current as of December 2004).

3.4.1.1 Tacony-Frankford Creek

Designated Uses

Title 25, Chapter 93 of the Pennsylvania Code assigns water quality standards to each reach of a water body. Water quality standards consist of designated uses, water quality criteria, and an antidegradation requirement. Except when otherwise specified, the statewide water uses set forth below apply to all surface waters.

- Aquatic Life
- WWF Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
- Water Supply
- PWS Potable Water Supply
- IWS Industrial Water Supply—Use by industry for inclusion into nonfood products, processing and cooling.
- LWS Livestock Water Supply—Use by livestock and poultry for drinking and cleansing.
- AWS Wildlife Water Supply—Use for waterfowl habitat and for drinking and cleansing by wildlife.
- IRS Irrigation—Used to supplement precipitation for growing crops.
- Recreation
- B Boating—Use of the water for power boating, sail boating, canoeing and rowing for recreational purposes when surface water flow or impoundment conditions allow.
- F Fishing—Use of the water for the legal taking of fish. For recreation or consumption.
- WC Water Contact Sports—Use of the water for swimming and related activities.
- E Esthetics—Use of the water as an esthetic setting to recreational pursuits.

Use Attainment Status and Total Maximum Daily Load Development

Use attainment status listed by PADEP for the non-tidal Tacony-Frankford Creek is shown in Table 3-50. Reaches of this creek are listed as impaired by causes related to the quantity and velocity of discharge: municipal point sources, urban runoff, storm sewers, flow variability, flow variations, and associated habitat alterations. These physical alterations lead to impairment but are not considered pollutants as defined by the Clean Water Act, and do not by themselves require a TMDL. It is important to note that the Frankford Creek is a tidal tributary to the Delaware River of the Tidal Delaware River as described in Section 3.4.1.3.

The PADEP categorized the aquatic life impairments of the TTF Creek on the list 4c, Streams Impaired by Pollution not Requiring a TMDL. The Fish Consumption impairment is listed as category 5. A TMDL is planned for PCBs in the TTF Watershed, but it is not clear on the timeframe of this TMDL development.

Table 3-50 Philadelphia Impaired Streams in the Tacony-Frankford Creek Watershed

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Tacony Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	1.34	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		
			Water/Flow Variability	Urban Runoff/ Storm Sewers		
			Flow Alterations	Urban Runoff/ Storm Sewers		
Frankford Creek (Rising Sun Ave. to Aramingo Ave.)	Aquatic Life	Impaired	Other Habitat Alterations	Urban Runoff/ Storm Sewers	3.93	2002
Frankford Creek (Aramingo Ave. to confluence)	Fish Consumption	Impaired	PCBs	Source Unknown	1.59	2006
Tributaries						
Burholme Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	0.94	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		
Tookany Creek, unnamed tributary	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	0.40	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		

3.4.1.2 Cobbs Creek

Designated Uses

Title 25, Chapter 93 of the Pennsylvania Code assigns water quality standards to each reach of a water body. Except when otherwise specified, the statewide water uses set forth below apply to all surface waters.

Use Attainment Status and Total Maximum Daily Load Development
Use attainment status listed as category 5 by PADEP for Cobbs Creek is shown in Table 3-51. Reaches are listed as impaired by causes related to the quantity and velocity of discharge: municipal point sources, urban runoff, storm sewers, flow variability, flow variations, and associated habitat alterations. These physical alterations lead to impairment but are not considered pollutants as defined by the Clean Water Act, and do not by themselves require a TMDL. Cobbs Creek is listed for "siltation" related to these same physical factors. Because Siltation/sediment is considered a pollutant requiring a TMDL, it is unclear at this time when the TMDL will be developed. PADEP is currently updating its process for producing TMDLs and tentatively scheduled the Cobbs Creek TMDL for the year 2015.

Fish Consumption Advisories
No fish consumption advisories have been issued by PADEP for the non-tidal portions of Cobbs Creek..

3.4.1.3 Tidal Delaware and Tidal Schuylkill Rivers, Including Tributaries

Designated Uses
Water quality standards for the tidal Delaware River and tidal portions of tributaries, including the entire length of the Schuylkill River within the combined sewer service area, are assigned by the Delaware River Basin Commission. The Delaware Direct includes Zones 2, 3 and 4. The Schuylkill River drains to the Delaware River in Zone 4. Zone 5 is included in the reporting of designated use since it is downstream of the City of Philadelphia and the CSO receiving waters.

<u>Zone 2</u>
Zone 2 is that part of the Delaware River extending from the head of tidewater at Trenton, New Jersey, R.M. (River Mile) 133.4 (Trenton-Morrisville Toll Bridge) to R.M. 108.4 below the mouth of Pennypack Creek, including the tidal portions of the tributaries thereof. It is important to note that the tidal portion of the Pennypack Creek is included in Zone 2 of the Delaware River.

The quality of Zone 2 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment,
   b. industrial water supplies after reasonable treatment,
   c. agricultural water supplies;
2. a. maintenance and propagation of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation;
4. a. navigation.

Table 3-51 Philadelphia Impaired Streams in the Cobbs Creek Watershed

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Cobbs Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source; Urban Runoff/Storm Sewers		
Tributaries						
East Branch Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	2.04	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source, Urban Runoff/Storm Sewers		
Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	2.04	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source, Urban Runoff/Storm Sewers		
Naylors Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source ; Urban Runoff/Storm Sewers		
West Branch Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		

Zone 3

Zone 3 is that part of the Delaware River extending from R.M. 108.4 to R.M. 95.0 below the mouth of Big Timber Creek, including the tidal portions of the tributaries thereof. It is important to note that the tidal portion of the Frankford Creek is included in Zone 3 of the Delaware River.

The quality of Zone 3 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment,
   b. industrial water supplies after reasonable treatment,
   c. agricultural water supplies;
2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation - secondary contact;
4. a. navigation.

<u>Zone 4</u>
Zone 4 is that part of the Delaware River extending from R.M. 95.0 to R.M. 78.8, the Pennsylvania-Delaware boundary line, including the tidal portions of the tributaries thereof. It is important to note that the tidal potion of the Schuylkill River is included in Zone 4.

The quality of Zone 4 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment;
2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation - secondary contact above R.M. 81.8,
   b. recreation below R.M. 81.8;
4. a. navigation.

<u>Zone 5</u>
Zone 5 is that part of the Delaware River extending from R.M. 78.8 to R.M. 48.2, Liston Point, including the tidal portions of the tributaries thereof.

The quality of waters in Zone 5 shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment;
2. a. maintenance of resident fish and other aquatic life,
   b. propagation of resident fish from R.M. 70.0 to R.M. 48.2,
   c. passage of anadromous fish,
   d. wildlife;
3. a. recreation;
4. a. navigation.

Use Attainment Status and Total Maximum Daily Load Development
Table 3-52 shows the results of the 2008 Assessment for the Water Quality Zones within the Delaware Direct Watershed. The colors are used to summarize the zones and designated use. If two or more uses/zones are not supporting the heading is colored red. If one zone/use is not

supporting, the heading is colored orange. If all zones support the designated use, the heading is colored green.

Table 3-52 DRBC Integrated Assessment Summary

Zone	Designated Use				Final 2008 Assessment Category
	Aquatic Life	Recreation	Drinking Water	Fish Consumption	
2	Not Supporting	Supporting	Supporting	Not Supporting	5
3	Supporting	Supporting	Supporting	Not Supporting	4A
4	Not Supporting	Supporting	Not Applicable	Not Supporting	5
5	Not Supporting	Supporting	Not Applicable	Not Supporting	4A

4A: A TMDL to address a specific segment/pollutant combination has been approved or established
5: Available Data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.
Source: DRBC, 2008b

Use attainment status listed by PADEP for segments of the Delaware and Schuylkill Rivers intersecting Philadelphia County is shown in Table 3-53. Listed sources of impairment include industrial and municipal point sources, metals, urban runoff, storm sewers, and flow variability. The science behind impairment by PCBs is well documented. However, the scientific basis for impairments caused by metals and priority organics is unclear.

In December 2003, USEPA Regions II and III issued Total Maximum Daily Loads for polychlorinated biphenyls (PCBs) for Zones 2 - 5 of the Tidal Delaware River. The TMDL established waste load allocations (WLAs) for point sources in each zone, including continuous point sources, municipal separate storm sewer systems (MS4s), and combined sewer systems. The TMDL also assigned load allocations to nonpoint sources and to runoff from contaminated sites.

PWD has agreed to a good faith commitment to reduce discharges of PCBs from the Northeast Water Pollution Control Plant, Southeast Water Pollution Control Plant and Southwest Water Pollution Control Plant to the Delaware Estuary through the Pollutant Minimization Plan (PMP) process in accordance with the Delaware River Basin Commission PMP Rule 4.30.9. The PCB pollution minimization plan was submitted in September of 2005 and is implemented through the Operations Division.

A TMDL for the Pennypack Creek is planned, but it is unclear at this time if the tidal portion of the creek will be included and when the TMDL will be produced.

A TMDL was produced in 2007 for PCBs in the tidal Schuylkill River. The Pollution Minimization Plan described above also manages PCBs in the tidal Schuylkill River within the City of Philadelphia. No other TMDLs are planned for the Schuylkill River Watershed within Philadelphia at this time.

Table 3-53 Delaware and Schuylkill Rivers Impaired Reach Status Under PADEP Integrated List

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Delaware River	Fish Consumption	Impaired	Source Unknown - PCB	Unknown	21.87	1996
Schuylkill River	Fish Consumption	Impaired	PCB	Unknown	17.32	1998
Schuylkill River (City line to Penrose Ave.)	Aquatic Life	Supporting	-	-	15.14	NA
Schuylkill River (Falls Bridge to Roosevelt Blvd.)	Potable Water Supply	Supporting	-	-	0.31	NA
Tributaries						
Tidal Pennypack Creek	Aquatic Life	Impaired	Priority Organics	Industrial Point Source	3.07	1998
			Organic Enrichment/Low D.O.	Municipal Point Source		1998
Tidal Pennypack Creek	Potable Water Supply	Impaired	Pathogens	Municipal Point Source	3.07	1998
Old Frankford Creek	Fish Consumption	Impaired	Source Unknown - PCB	Unknown	0.83	1996
Dobsons Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	0.99	2002
Gulley Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	0.03	2002
Manayunk Canal	Aquatic Life	Supporting	-	-	1.35	NA
Schuylkill River, unnamed trib	Aquatic Life	Impaired	Water/Flow Variability	Removal of Vegetation, Road Runoff	0.72	2002
			Siltation	Removal of Vegetation, Road Runoff		2002
Schuylkill River, 6 unnamed tribs	Aquatic Life	Impaired		Urban Runoff/ Storm Sewers - Water/Flow Variability	2.93	2002
Schuylkill River, unnamed trib	Aquatic Life	Supporting	-	-	1.55	NA
Shaw Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers, Road Runoff	0.74	2002
			Siltation	Urban Runoff/Storm Sewers, Road Runoff		2002

Fish Consumption Advisories
In the late 1980s, the states of Delaware, New Jersey and Pennsylvania began issuing fish consumption advisories for portions of the Delaware Estuary due to elevated concentrations of PCBs measured in fish tissue. Today, the states' advisories cover the entire estuary and bay. The advisories range from a no-consumption recommendation for all species taken between the C&D Canal and the Delaware-Pennsylvania border to consumption of no more than one meal per month of striped bass or white perch in Zones 2 through 4 (EPA, 2003). PADEP and NJDEP have issued fish consumption advisories for the Delaware and Schuylkill Rivers as shown in Table 3-54. These advisories identify PCBs as a pollutant of concern in fish tissue. An NJDEP advisory issued in 2004 identifies dioxin as a pollutant of concern. While NJDEP advisories recommend high-risk individuals limit consumption of certain species due to mercury exposure, these recommendations are similar to those imposed nationwide for all freshwater fish. It is important to note that the differences in fish consumption advisories in the Delaware River from Pennsylvania and New Jersey are based on the methodology used to assess risk, not by the levels of contamination found in fish tissue.

3.4.2 Receiving Water Quality and Watershed Characterization

This section describes the baseline conditions of the receiving waters and watersheds. The watershed descriptions characterize both CSO and non-CSO sources of pollution and the status of watershed characterization. A detailed summary of water quality analysis includes chemical and biological data. Finally, a brief description of aquatic habitat conditions is also included to summarize overall water quality health in terms of its ability to support of aquatic life.

As discussed in Section 1, the Philadelphia Water Department is committed to managing CSOs through a watershed approach. Complete characterization of the receiving watersheds has been conducted in a series of Comprehensive Characterization Reports (CCRs). CCRs are completed for the TTF and Darby-Cobbs Creek Watersheds. Although the findings of the CCRs are summarized in this section of the LTCPU, these documents extensively describe in greater detail the land use, geology, soils, topography, demographics, meteorology, hydrology, water quality, ecology, pollutant loadings, and fluvial geomorphology in the watersheds. Additionally, the Philadelphia Water Department has developed Integrated Watershed Management Plans (IWMPs) to utilize the baseline data published in the CCRs in order to guide informed decision making for the CSO program and other watershed restoration efforts. The status and dates of publishing of these reports are explained and referenced in the following section for each receiving watershed.

The Tidal Delaware and Schuylkill Rivers are also receiving waters. This section of the LTCPU documents results from water quality monitoring in Philadelphia sections of these rivers relevant to CSOs. As explained earlier in Section 3, much of these data come from the USGS, the Delaware River Basin Commission, and supplemental PWD monitoring. Based on this continuing effort to characterize these two large rivers, PWD is currently developing IWMPs for the Philadelphia portion of the Delaware River Basin and the Schuylkill Watershed.

Table 3-54 Fish Consumption Advisories for the Tidal Delaware and Schuylkill Rivers

Issued By	Water Body	Area Under Advisory	Species	Meal Frequency		Contaminant
				General Population	High-Risk Individual	
PADEP 2006	Delaware Estuary, including the tidal portion of all PA tributaries and the Schuylkill River to the Fairmount Dam (Bucks, Philadelphia, and Delaware Counties)	Trenton, NJ-Morrisville, PA Bridge to PA/DE border	white perch	1 meal/month	not specified	PCB
			channel catfish			
			flathead catfish			
			striped bass			
			American eel	no consumption		
			carp			
PADEP	Schuylkill River (Chester, Montgomery, and Philadelphia Counties)	Black Rock Dam to Fairmount Dam in Philadelphia	carp	no consumption	not specified	PCB
			channel catfish	1 meal/month		
			flathead catfish			
PADEP	Schuylkill River (Berks, Chester, Montgomery, and Philadelphia Counties)	Felix Dam above Reading to Fairmount Dam	American eel	no consumption	not specified	PCB
			white sucker	1 meal/month		
NJDEP * 2004	Delaware River (Burlington County)	Trenton to Camden	largemouth bass	not specified	1 meal/week	Mercury
			white catfish	not specified		
NJDEP * 2004	Delaware River (Camden and Gloucester Counties)	Camden to Delaware/NJ state line	wtriped hybrid bass	not specified	1 meal/week	Mercury
NJDEP * 2004	Delaware River, including all tributaries up to the head of tide	from Easton(PA)/Phillipsburg(NJ) to PA/DE border	striped bass**	varies by subpopulation	no consumption	Dioxin
			channel catfish	6 meals/yr		
			American eel	varies by subpopulation		
			striped bass	varies by subpopulation		PCBs (Total)
			channel catfish	6 meals/yr		
			American eel	varies by subpopulation		

* NJDEP advisories are listed in EPA's National Listing of Fish Advisories (2004), but not found in NJDEP's listing (2006).

** A commercial fishing ban has been imposed on this species.

3.4.2.1 TTF Watershed Characterization

The Tacony and Frankford Creeks receive combined sewer overflows. Both creeks are part of the TTF Watershed (Figure 3-27). A Comprehensive Characterization Report (CCR) was completed for the TTF Watershed in August 2005. The CCR fully documents the baseline conditions and lays the groundwork for future CSO planning and watershed management. The Integrated Watershed Management Plan guides the Philadelphia Water Department's efforts to restore and protect the designated uses. The IWMP and CCR can both be located at http://www.phillyriverinfo.org. Table 3-55 includes the titles and links to other reports that can be referenced for more detailed characterization of the TTF Watershed.

The breakdown by sewer type is as follows:

- Combined sewer areas make up 9,800 acres, or 47% of the drainage area.
- Separate sewers, including areas outside of the City of Philadelphia, account for 9,200 acres or 44% of the drainage area.
- Non-contributing sewers make up 1,900 acres or 9% of the drainage area.

Table 3-55 Existing Documents Relevant to Characterization of the TTF Watershed

File Name	Year Published
Tacony-Frankford Act 167 Final Report	2008
Tacony FGM Report	2007
Southeast Regional Wetland Inventory and Water Quality Improvement Initiative	2006
TTF Integrated Watershed Management Plan	2005
TTF Comprehensive Characterization Report	2005
Tacony-Frankford River Conservation Plan	2004
Tacony-Frankford Watershed Historical Overview of the Philadelphia Section	2003
Baseline Biological Assessment of Mill Run Report	Draft, 2002
Biological Assessment of the Tacony-Frankford Watershed Report	2000

Municipalities and Demographics

The TTF Watershed is located in Montgomery County and Philadelphia County and covers a total of approximately 29 square miles, or about 20,000 acres. Figure 3-27 includes the watershed boundaries, hydrologic features, and municipal boundaries that are important to visualize in order to understand the character of the TTF Watershed.

Land Use

The TTF drainage area is a highly urbanized watershed. The lower reaches are primarily dominated by row homes in Philadelphia County, and the less densely populated upper reaches contain mostly single-family homes in Montgomery County. The combined sewer area within the TTF Watershed is 58% residential, 45% of the area consists of homes. This leads to an average population density in the combined area of 17,342 people per square mile (Figure 3-28). Figure 3-29 illustrates the land use of the Combined Sewer Area within the TTF Watershed is primarily residential and commercial. According to the CCR and TTFIWMP, the TTF Watershed is covered by more than 41% of impervious surfaces. The combined sewer area within the watershed is 62%. The population of the entire drainage area, based on 2000 census data, is approximately 331,400 people.

Pollution Sources

In addition to CSO discharges to Frankford Creek from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. The waters in the drainage area receive point source discharges including CSOs and other urban and suburban stormwater, sanitary sewer overflows, and industrial storm, process, and cooling waters. Non-point sources in the watershed include atmospheric deposition, overland runoff from urban and suburban areas, and potentially some remaining individual on-lot domestic sewage systems discharging through shallow groundwater.

More detailed information including watershed geology, hydrology, topography, wetlands, infrastructure features, history, cultural features, zoning, and ordinances can be found in the TTF CCR.

Receiving Waterbody Characterization

The receiving creek is referred to as the Tookany Creek until it enters Philadelphia at Cheltenham Avenue. It is then called the Tacony Creek from that Montgomery County border until the confluence with the historical Wingohocking Creek in Juniata Park. The section of stream from Juniata Park to the Delaware River is referred to as the Frankford Creek, portion of which is underlain by a concrete channel. The lower portion of the Frankford Creek is tidally influenced from the Delaware Estuary.

The streams in the western portion of the watershed are contained in pipes and combined sewer infrastructure. Historic streams, including the Wingohocking Creek, Rock Run, and Little Tacony Creek, were encapsulated in combined sewers to facilitate the development of this watershed in the early twentieth century. Combined sewers convey sanitary waste, as well as stormwater to the City's wastewater treatment facilities. The total number of stream miles in this watershed is 14.4 miles in the mainstem creek and approximately 31.9 miles of encapsulated tributaries.

3.4.2.1.1 TTF Creek Hydrologic Characterization

Components of the Urban Hydrologic Cycle

One way to develop an understanding of the hydrologic cycle is to develop a water balance. The balance is an attempt to characterize the flow of water into and out of the system by assigning estimated rates of flow for all of the components of the cycle. It is also important to understand that the natural water cycle components including precipitation, evapotranspiration (ET), infiltration, stream baseflow, and stormwater runoff must be supplemented by the many artificial interventions related to urban water, wastewater, and stormwater systems. A water balance conducted for the TTF Watershed is summarized in this section of the LTCPU and fully described in detail in the TTF CCR.

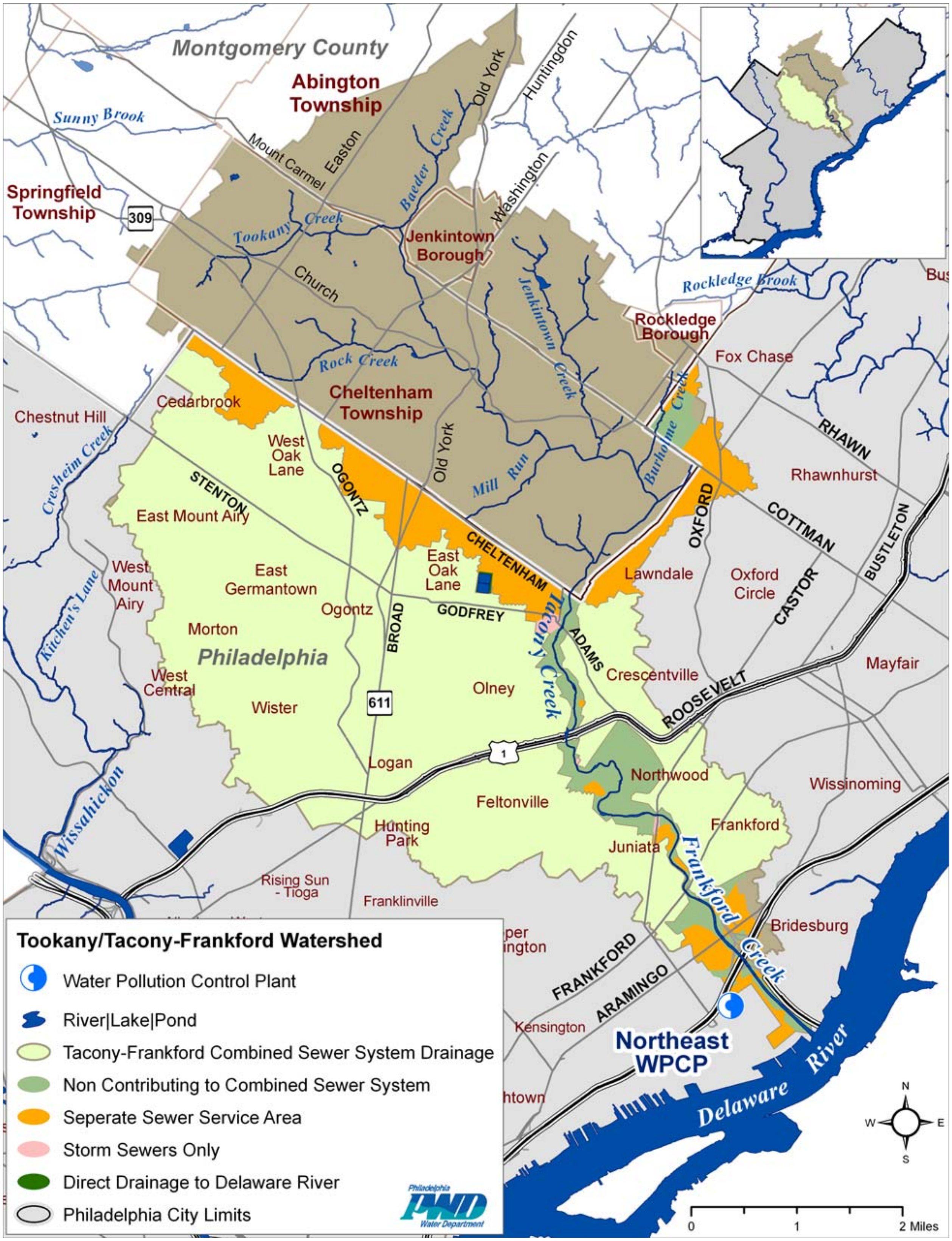


Figure 3-27 The TTF Watershed

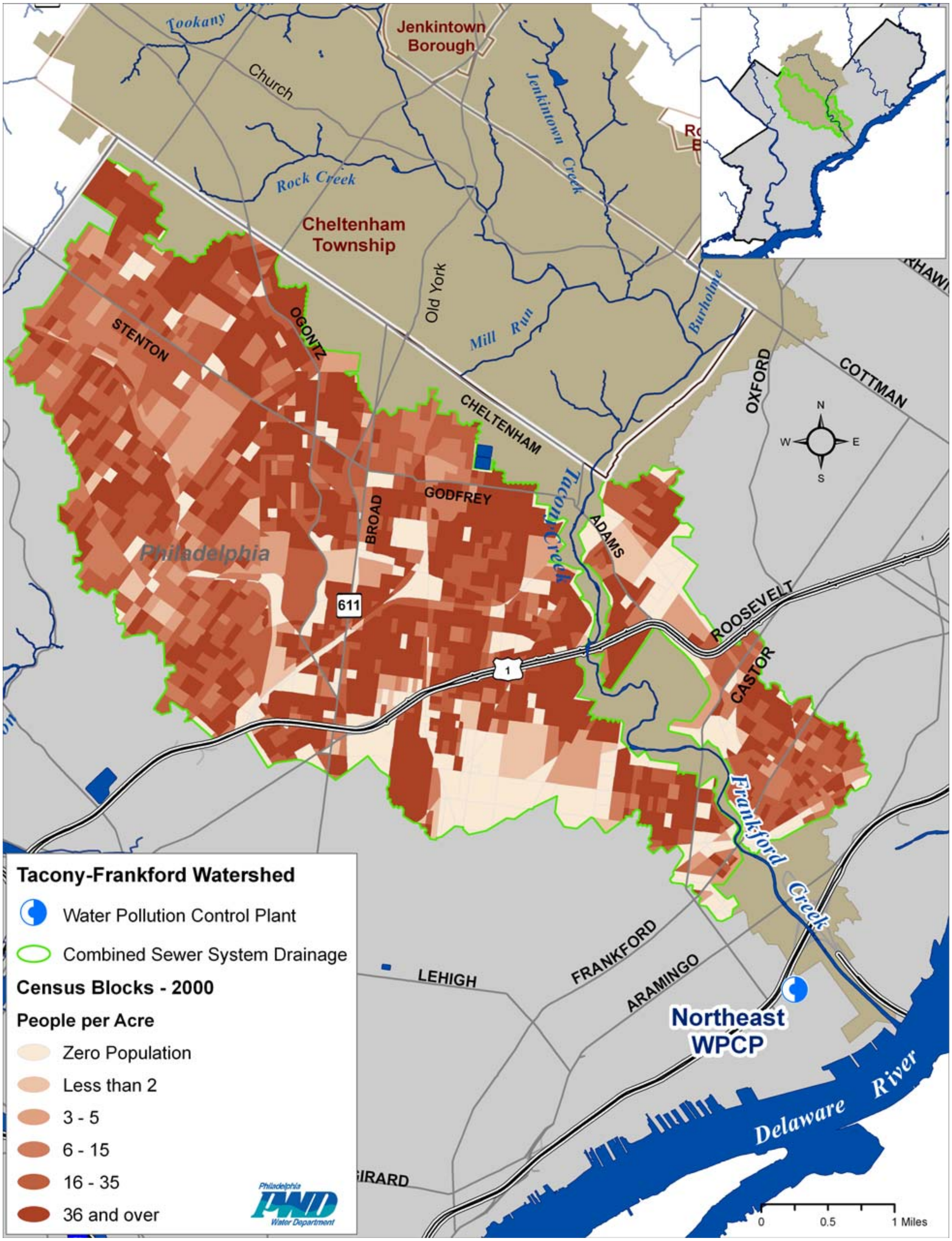


Figure 3-28 Population Density in the TTF Watershed

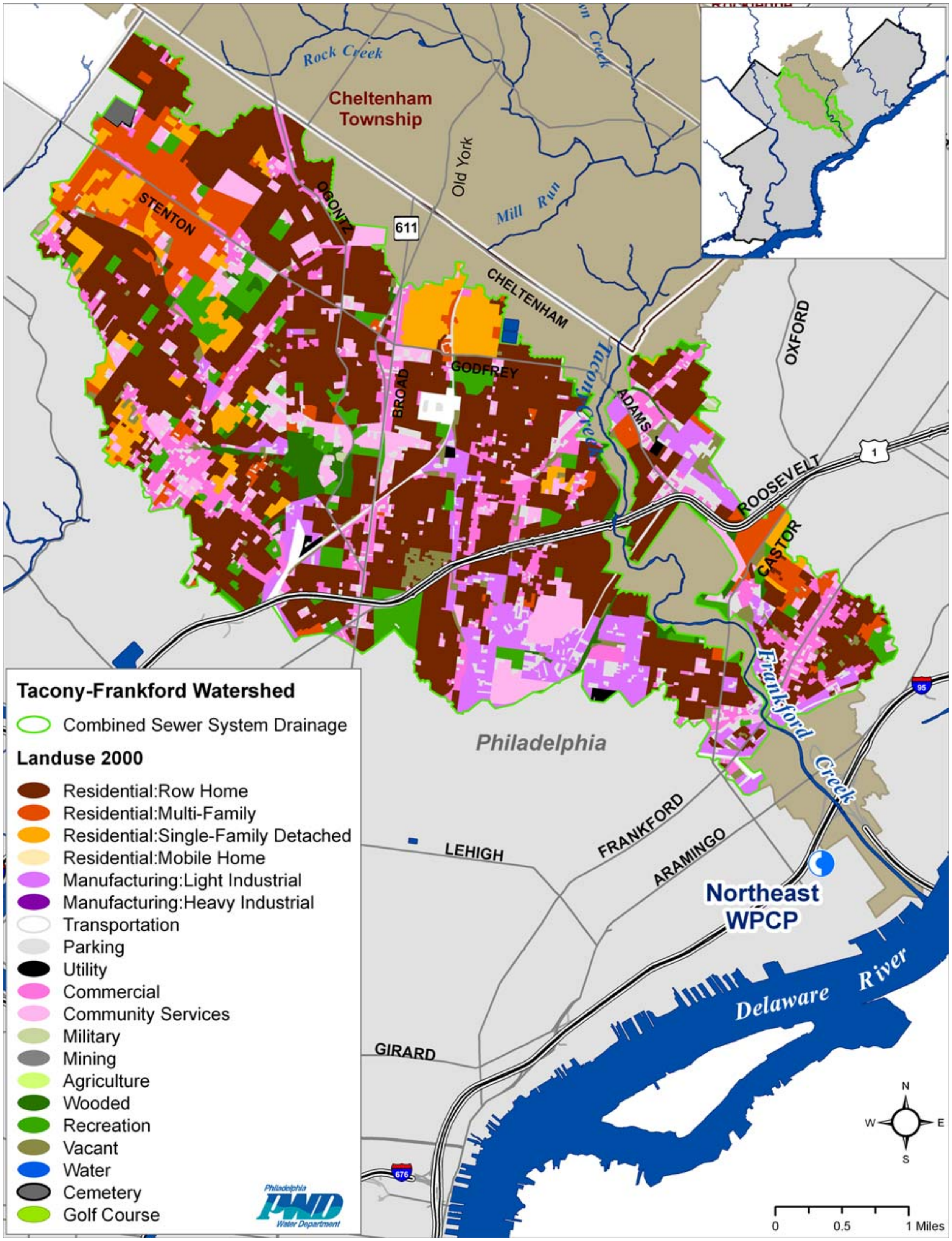


Figure 3-29 Land Use in the Combined Sewer Areas of the TTF Watershed

TTF Creek Water Cycle Component Tables

The relevant components of the urban water cycle have been estimated for the TTF Watershed. Outside Potable Water (OPW) is assumed to balance Outside Wastewater Discharges (OWD), with stormwater and CSO's considered as part of the Runoff component of the water cycle. Table 3-56 shows the results of the analysis, first in inches per year, then in million gallons per day. The inches per year figure simply takes all the flows over an average year, and divides by the area of the watershed. The million gallons per day table takes all the flows over an average year, and divides by 365 days to get an average day value.

Table 3-56 Water Budget Components in the TTF Creek (TTF CCR, Section 4.2, Table 4.3, Page 4-11)

	Period of Record	Inflow		Outflow		
		P	EDR	RO	BF	ET+Error
Component (in/yr)	1982 – 2002	42.1	0.085	11.4	7.06	23.7
Component (MGD)	1982 – 2002	66.1	0.134	17.9	11.1	37.3

*Period of Record applies to Runoff and Baseflow.

** Precipitation uses 100 year rainfall record.

- ***ET*** is the evaporation and transpiration of water and is used to close the equation. It thus contains the sum of errors of the other terms as well as the estimated ET value.
- ***EDR*** is the estimated domestic recharge from private septic systems,
- ***RO*** is the surface water runoff component of precipitation,
- ***BF*** is the median baseflow of streams,
- ***P*** is the average precipitation at the Philadelphia gage,

Hydrograph Decomposition Analysis

Areas and Gages Studied

The TTF Creek Watershed is highly urbanized and contains a large proportion of impervious cover. The hydrologic impact of urbanization can be observed through analysis of streamflow data taken from USGS gages. Table 3-57 lists six gages with available data, including their locations, periods of record, and drainage areas.

Baseflow Separation

Baseflow due to groundwater inflow is the main component of most streams in dry weather. Baseflow slowly increases and decreases with the elevation of the shallow aquifer water table. In wet weather, a stormwater runoff component is added to the baseflow. Estimation and comparison of these two components can provide insights into the relationship between land use and hydrology in urbanized and more natural systems.

Baseflow separation was carried out following procedures similar to those found in the USGS "HYSEP" program. A summary of the HYSEP procedure can be found in the TTF CCR.

Table 3-57 Data Used for Baseflow Separation of TTF Creek (TTF CCR, Section 4.3.2, Table 4-5, Page 4-15)

Gage	Name	Period of Record (yrs)	Drainage Area (mi^2)	N (days)	2N* (days)
01467083	Tacony Creek near Jenkintown	6	5.25	1.39	3
01467084	Rock Creek above Curtis Arboretum near Philadelphia	8	1.15	1.03	3
01467085	Jenkintown Creek At Elkins Park	6	1.17	1.03	3
01467086	Tacony Creek at County Line	24	16.6	1.75	3
01467087	Frankford Creek at Castor Ave.	21	30.4	1.98	3
01467089	Frankford Creek at Torresdale Ave.	18	33.8	2.02	5

The interval 2N* used for hydrograph separations is the odd integer between 3 and 11 nearest to 2N. N is calculated based on watershed area.

Summary Statistics

The results of the hydrograph decomposition exercise support the relationships between land use and hydrology discussed above. For convenience, the flows in Table 3-58 are expressed as a mean depth (flow per unit area) over a one-year time period. Table 3-58 shows streamflow statistics for French Creek as representative of a minimally impaired stream, compared to the six gages of the TTF Watershed. The degree of urban impact to baseflow and runoff can be seen in this table. The upstream portions of the watershed still show reasonable levels of baseflow, similar to those of French Creek (in the 12-13 inch per year range). In the downstream segments of Frankford Creek, baseflow is significantly reduced due to the high degree of impervious cover. Looking at baseflow as a percentage of total flow, the same pattern is evident, however, the effects of urbanization in the upstream areas is more evident using this way of measuring, because it accounts for the higher unit area total flow of the TTF Watershed compared with French Creek. The table also indicates the elevated runoff due to urbanization (as a percentage of total rainfall). Again, runoff is generally higher in the downstream areas, and lower in the upstream areas.

As expected, the quantity of stormwater runoff on a unit-area basis follows patterns of impervious cover in the drainage area. The French Creek Watershed, the least developed, has the smallest amount of stormwater runoff both as an annual mean quantity (7.4 in) and as an annual mean percent of rainfall (17%). As expected, the more highly-developed downstream Frankford Creek has the most runoff both as an annual mean quantity (14.9 in) and as an annual mean percent of rainfall (34%). Mean runoff from Frankford Creek is twice the mean runoff in the French Creek basin. The more upstream gages in the Tacony and Tookany have intermediate quantities of stormwater runoff.

Table 3-58 Annual Summary Statistics for Baseflow and Stormwater Runoff (TTF CCR, Section 4.3.2, Table 4-6, Page 4-17)

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	12.9	20.8	5.8	3.8	7.4	15.4	2.9	3.1
Frankford Creek 01467089	7.9	11.5	3.5	2.1	14.9	21.3	8.0	4.3
Frankford Creek 01467087	7.1	13.0	4.5	2.2	11.4	20.3	6.2	3.5
Tacony Creek 01467086	12.6	18.1	7.5	3.2	9.2	13.2	5.2	2.3
Jenkintown Creek 01467085	14.0	18.6	9.5	4.0	9.0	12.0	5.1	2.7
Rock Creek 01467084	12.6	17.0	9.4	3.0	14.9	20.5	10.2	3.6
Tacony Creek 01467083	13.5	18.0	10.8	2.9	10.3	13.6	6.7	2.6

	Baseflow (% of Annual Rainfall)				Runoff (% of Annual Rainfall)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	31%	44%	15%	7%	17%	30%	7%	5%
Frankford Creek 01467089	18%	24%	9%	4%	34%	46%	21%	7%
Frankford Creek 01467087	18%	25%	11%	4%	29%	39%	17%	6%
Tacony Creek 01467086	29%	40%	19%	6%	21%	27%	13%	3%
Jenkintown Creek 01467085	32%	38%	19%	8%	20%	23%	15%	3%
Rock Creek 01467084	28%	36%	19%	6%	33%	41%	21%	7%
Tacony Creek 01467083	31%	36%	22%	6%	24%	31%	20%	5%

	Baseflow (% of Annual Total Flow)				Runoff (% of Annual Total Flow)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	64%	75%	53%	5%	36%	47%	25%	5%
Frankford Creek 01467089	35%	48%	27%	5%	65%	73%	52%	5%
Frankford Creek 01467087	38%	49%	26%	6%	62%	74%	51%	6%
Tacony Creek 01467086	58%	67%	48%	5%	42%	52%	33%	5%
Jenkintown Creek 01467085	61%	68%	50%	7%	39%	50%	32%	7%
Rock Creek 01467084	46%	61%	36%	7%	54%	64%	39%	7%
Tacony Creek 01467083	57%	63%	51%	5%	43%	49%	37%	5%

3.4.2.1.2 TTF Water Quality Analysis

PWD collected water quality data from 2000 through 2004 for sampling locations in the non-tidal portion of the TTF Watershed. From 2007 through 2008 water quality data was monitored at two USGS stations in the Watershed. Tables 3-59 thru 3-64 provide a basic, statistical profile of the data from this recent water quality monitoring program. Tables 3-59 to 3-60 provide data from the discrete monitoring program and Tables 3-61 to 3-64 provide data from the continuous monitoring program.

Sample results were compared to relevant PADEP general water quality criteria to provide an indication of which parameters might need further investigation. Applicable relevant standards include water uses to support a potable water supply, recreation and fish consumption, human health, and aquatic life to support warm water fishes. The Target values are explained in the discussion of individual parameter. Parameters highlighted in yellow are considered potential problem parameters because 2-10% of the samples exceeded the target value. Parameters highlighted in red are considered problem parameters with more than 10% of the samples exceeded the target value. For a detailed analysis comparing historical water quality data with more recent data, including modified Tukey box plots, refer to Appendix A of the TTF CCR.

Wet weather is characterized using the 9 PWD operated rain gages in the TTF drainage district. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The monitoring methods including rain gage locations and PWD water quality monitoring locations are previously described in detail in Section 3.1.

Discussion of Possible Parameters of Concern

The following analysis of water quality data is focused on parameters that were listed in USEPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value) or "parameter of potential concern" (2-10% samples exceeding target value) in the TTF Watershed on Tables 3-59 through 3-64. The water quality criteria or target value is discussed in each parameter analysis.

pH

Water quality criteria established by PADEP regulate pH to a range of 6 to 9 in Pennsylvania's freshwater streams (Commonwealth of Pennsylvania, 2001). Direct effects of low pH on aquatic ecosystems have been demonstrated in streams affected by acid mine drainage (Butler et al. 1973) and by acid rain (Sutcliff and Carrick 1973). Aquatic biota may also be indirectly affected by pH due to its influences on other water quality parameters, such as ammonia (NH_3). As pH increases, a greater fraction of ammonia N is present as un-ionized NH_3 (gas). For example, NH_3 is approximately ten times as toxic at pH 8 as at pH 7. Extreme pH values may also affect solubility and bioavailability of metals (e.g., Cu, Al), which have individually regulated criteria established by PADEP.

Based on sampling by the Philadelphia Water Department (PWD) during 2000 – 2004, pH is not considered a parameter of concern in the TTF Watershed (<2% of samples exceeded standards). However, it is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan.

Continuous pH data show that pH fluctuations most often occur at highly productive sites with abundant periphytic algae (Figure 3-30). Pronounced diurnal fluctuations in pH were observed at site TF620, and occasionally at site TF280. These sites occasionally exceeded water quality criteria by exceeding pH 9.0; minimum pH standards were rarely exceeded. pH at shadier sites (i.e., TF500 and sites upstream of site TF680) was probably less strongly influenced by metabolic activity and fluctuations in pH appeared noticeably damped as a result. Algal densities and stream metabolism effects on stream pH are discussed further in section 5.4, Stream Metabolism of the TTF Creek Watershed Comprehensive Characterization Report.

Table 3-59 Dry Weather Water Quality Summary (2000-2004) - Parameters with Standards (TTF CCR Section 5.2, Table 5-4, Page 5-7)

Parameter	Standard	Target Value	Units	No. Obs	Percentiles 0	25	50	75	90	100	No. Exceed-ing	% Exceed-ing
Al	Acute Maximum	0.75	mg/L	149	0.00100	0.0200	0.0370	0.0610	0.0980	0.574	0	-
Al	Chronic Maximum	0.087	mg/L	149	0.00100	0.0200	0.0370	0.0610	0.0980	0.574	15	10.1
Alkalinity	Minimum	20	mg/L	130	21.0	65.0	72.0	77.0	81.0	89.0	0	-
BOD_{30}	No Standard	--	mg/L	98	2.00	3.41	4.15	5.24	8.10	100	--	--
BOD_5	No Standard	--	mg/L	130	0.300	2.00	2.00	2.00	2.19	20.4	--	--
Conductivity **	No Standard	--	µS/cm	142	227	411	508	605	697	1225	--	--
Diss Cd	Acute Maximum	* 0.0043	mg/L	83	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cd	Chronic Maximum	* 0.0022	mg/L	83	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Acute Maximum	0.0016	mg/L	46	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Chronic Maximum	0.01	mg/L	46	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cu	Acute Maximum	* 0.013	mg/L	74	0.00200	0.00400	0.00500	0.00500	0.00600	0.0220	0	-
Diss Cu	Chronic Maximum	* 0.009	mg/L	74	0.00200	0.00400	0.00500	0.00500	0.00600	0.0220	1	1.4
Diss Fe	Maximum	0.3	mg/L	110	0.0195	0.0500	0.0505	0.0770	0.133	0.587	3	2.7
Diss Pb	Acute Maximum	* 0.065	mg/L	65	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Pb	Chronic Maximum	* 0.0025	mg/L	65	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Zn	Acute Maximum	* 0.120	mg/L	73	0.00100	0.00700	0.0100	0.0170	0.0220	0.0260	2	2.7
Diss Zn	Chronic Maximum	* 0.120	mg/L	73	0.00100	0.00700	0.0100	0.0170	0.0220	0.0260	3	4.1
DO **	Instantaneous Minimum	4	mg/L	133	2.45	8.78	10.1	13.0	14.5	16.2	2	1.5

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
DO **	Minimum Average	5	mg/L	133	2.45	8.78	10.1	13.0	14.5	16.2	3	2.3
E. coli	No Standard	--	/100mL	144	10.0	145	290	500	1800	36000	--	--
F	Maximum	2	mg/L	130	0.0783	0.100	0.110	0.125	0.168	0.374	1	0.8
Fe	Maximum	1.5	mg/L	161	0.0294	0.0820	0.133	0.264	0.513	1.58	1	0.6
Fecal coliform	Swimming Season Dry weather Maximum	200	CFU/ 100mL	77	90.0	420	700	2600	5200	47000	71	92.0
Fecal coliform	Non-swimming Season Dry weather Maximum	2000	CFU/ 100mL	77	10.0	80.0	200	390	742	3200	3	3.9
Hardness	No Standard	--	mg/L	86	32.4	164	178	192	200	214	--	--
Mn	Maximum	1	mg/L	161	0.00490	0.0200	0.0380	0.0560	0.0840	0.167	0	-
NH_3	Maximum	(pH dependent)	mg/L	103	0.100	0.100	0.100	0.100	0.200	1.13	0	-
NO_2	No Standard	--	mg/L	133	0.0100	0.0500	0.0500	0.0500	0.0500	0.287	--	--
Nitrate+Nitrite	Maximum	10	mg/L	133	0.399	2.15	2.53	2.89	3.33	3.64	0	-
NO3	No Standard	--	mg/L	133	0.277	2.11	2.49	2.85	3.28	3.59	--	--
pH **	Maximum	9	--	132	6.85	7.35	7.52	7.64	7.76	8.03	0	-
pH **	Minimum	6	--	132	6.85	7.35	7.52	7.64	7.76	8.03	0	-
PO_4	No Standard	--	mg/L	133	0.0400	0.100	0.100	0.100	0.100	0.208	--	--
TDS	Maximum	750	mg/L	92	160	273	318	381	441	643	0	-
Temp **	Maximum	(varies)	°C	129	0.100	5.50	16.1	20.2	21.8	27.6	9	7.0
TKN	No Standard	--	mg/L	124	0.00	0.300	0.350	0.500	0.616	1.83	--	--
TN	No Standard	--	mg/L	124	0.869	2.21	2.50	2.91	3.08	3.98	--	--

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exced-ing	% Exceed-ing
					0	25	50	75	90	100		
TOC	No Standard	--	mg/L	8	1.23	1.30	1.58	1.84	1.99	1.99	--	--
Total Chlorophyll	No Standard	--	mg/L	33	0.750	1.35	1.79	3.96	5.99	12.8	--	--
TP	No Standard	--	mg/L	138	0.00100	0.0500	0.0505	0.0860	0.163	0.691	--	--
TSS	No Standard	--	mg/L	104	1.00	1.00	1.00	2.00	3.00	24.0	--	--
Turbidity	Maximum	100	NTU	154	0.207	0.533	0.657	0.96	2.09	7.76	0	-

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L
** These values are hand probe readings taken at the time of grab sampling.

Table 3-60 Wet Weather Water Quality Summary (2000-2004) - Parameters with Standards (TTF CCR sec 5.2 table 5.5, page 5-9)

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
Al	Maximum	0.75	mg/L	552	0.00167	0.0710	0.171	0.586	2.16	19.3	120	21.7
Alkalinity	Minimum	20	mg/L	562	14.0	43.0	56.5	70.0	77.0	91.0	7	1.2
BOD30	No Standard	--	mg/L	150	1.96	4.57	6.29	10.9	21.3	125	--	--
BOD5	No Standard	--	mg/L	567	1.95	2.00	3.45	6.62	14.4	147	--	--
Conductivity **	No Standard	--	µS/cm	243	76	249	381	516	658	1897	--	--
Diss Cd	Acute Maximum	* 0.0043	mg/L	194	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Acute Maximum	0.0016	mg/L	76	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cu	Acute Maximum	* 0.013	mg/L	81	0.00200	0.00500	0.00700	0.00800	0.0110	0.0150	6	7.4
Diss Fe	Maximum	0.3	mg/L	199	0.0240	0.0640	0.0970	0.156	0.229	0.701	11	5.5
Diss Pb	Acute Maximum	* 0.065	mg/L	76	0.00100	0.00100	0.00100	0.00100	0.00100	0.00300	0	-
Diss Zn	Acute Maximum	* 0.120	mg/L	56	0.00300	0.00650	0.0110	0.0170	0.0260	0.263	1	1.8
DO**	Minimum Average	4	mg/L	232	1.99	8.06	9.21	11.3	13.1	17.3	6	2.6
DO**	Instantaneous Minimum	5	mg/L	232	1.99	8.06	9.21	11.3	13.1	17.3	4	1.7
E. coli	No Standard	--	/100mL	628	0.00	1500	4700	20000	69000	1820000	--	--
F	Maximum	2	mg/L	564	0.0675	0.0980	0.104	0.121	0.151	0.888	0	-
Fe	Maximum	1.5	mg/L	610	0.0403	0.224	0.419	1.27	4.20	50.0	139	22.8
Fecal coliform	Swimming Season Wet weather Maximum	200	CFU/100mL	532	10	1900	6250	30000	107900	1820000	516	97.0
Fecal coliform	Non-swimming Season	2000	CFU/100mL	141	20	390	4100	19000	32000	91000	94	67.0

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
	Wet weather Maximum											
Hardness	No Standard	--	mg/L	468	0.710	94.1	127	162	182	282	--	--
Mn	Maximum	1	mg/L	611	0.00760	0.0370	0.0710	0.139	0.283	3.05	13	2.1
NH3	Maximum	(pH dependent)	mg/L	196	0.100	0.100	0.113	0.205	0.398	2.98	0	-
NO2	No Standard	--	mg/L	604	0.0100	0.0500	0.0500	0.0500	0.0760	0.366	--	--
Nitrate+Nitrite	Maximum	10	mg/L	604	0.3000	1.10	1.72	2.22	2.51	3.32	0	-
NO3	No Standard	--	mg/L	604	0.249	1.02	2.19	1.65	2.47	3.27	--	--
pH**	Maximum	9	--	238	6.61	7.23	7.39	7.53	7.64	8.01	0	-
pH**	Minimum	6	--	238	6.61	7.23	7.39	7.53	7.64	8.01	0	-
PO4	No Standard	--	mg/L	603	0.0400	0.100	0.100	0.100	0.100	0.423	--	--
TDS	Maximum	750	mg/L	184	56	159	231	308	398	1054	2	1.1
Temp **	Maximum	(varies)	°C	238	0.500	8.00	13.9	19.8	21.7	24.7	6	2.5
TKN	No Standard	--	mg/L	524	0.154	0.500	0.752	1.21	2.97	15.9	--	--
TN	No Standard	--	mg/L	524	0.0560	2.09	2.57	3.06	4.27	17.1	--	--
TOC	No Standard	--	mg/L	5	1.35	1.51	1.54	1.82	1.83	1.83	--	--
Total Chlorophyll	No Standard	--	mg/L	76	0.660	1.44	2.37	4.93	17.1	83.3	--	--
TP	No Standard	--	mg/L	601	0.00100	0.0670	0.114	0.255	0.557	3.45	--	--
TSS	No Standard	--	mg/L	188	1.00	1.00	2.60	10.0	54.5	408	--	--
Turbidity	Maximum	100.0	NTU	579.0	0.2	1.8	4.8	12.0	35.1	379.0	13.0	2.2

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness
** These values are hand probe readings taken at the time of grab sampling.

Table 3-61 Continuous Water Quality Data (2001-2004) - Parameter with Standards (TTF CCR Section 5.2, Table 5.6, Page 5-11)

Parameter	Standard	Period	No. Obs.	No. Exceed	% Exceeding	% Meeting
Sonde DO avg	Daily Average Minimum	03/20/01 - 10/05/04	1540	29	1.9	98
Sonde DO min	Daily Minimum	03/20/01 - 10/05/04	1540	104	6.8	93
Sonde Temp	Maximum	03/20/01 - 10/05/04	177208	23350	13	87
Sonde pH mean	Maximum	03/20/01 - 10/05/04	2003	1	0.05	99.95
Sonde pH mean	Minimum	03/20/01 - 10/05/04	2003	1	0.05	99.95

Table 3-62 Continuous Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	11664	2.00	3.10	4.50	6.60	8.90	11.2	15.8	2171	18.6
DO	01467086	Instantaneous Minimum	4	mg/L	24201	0.0500	5.90	7.10	8.90	10.9	12.7	18.23	460	1.9
DO	01467087	Daily Minimum	5	mg/L	287	2.31	3.33	4.37	6.19	8.47	10.7	14.5	95	33.3
DO	01467086	Daily Minimum	5	mg/L	517	0.597	6.46	7.48	8.85	10.9	12.0	15.0	10	1.9

Table 3-63 Continuous Wet Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	5314	2.00	2.90	3.90	5.70	8.40	11.0	15.8	1353	25.5
DO	01467086	Instantaneous Minimum	4	mg/L	12442	0.05	5.44	6.64	8.36	10.4	12.4	17.9	441	3.5
DO	01467087	Daily Minimum	5	mg/L	161	2.40	3.13	4.18	5.54	8.38	10.5	14.1	65	40.4
DO	01467086	Daily Minimum	5	mg/L	307	0.597	6.05	6.92	8.25	10.9	12.1	15.0	10	3.3

Table 3-64 Continuous Dry Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	6350	2.00	3.60	5.30	7.10	9.10	11.3	15.2	818	12.9
DO	01467086	Instantaneous Minimum	4	mg/L	11759	0.730	6.40	7.65	9.46	11.2	12.9	18.2	19	0.2
DO	01467087	Daily Minimum	5	mg/L	126	2.31	3.52	5.04	7.00	8.47	11.0	14.5	30	23.8
DO	01467086	Daily Minimum	5	mg/L	210	6.31	7.42	8.19	9.34	10.9	11.9	13.4	0	0

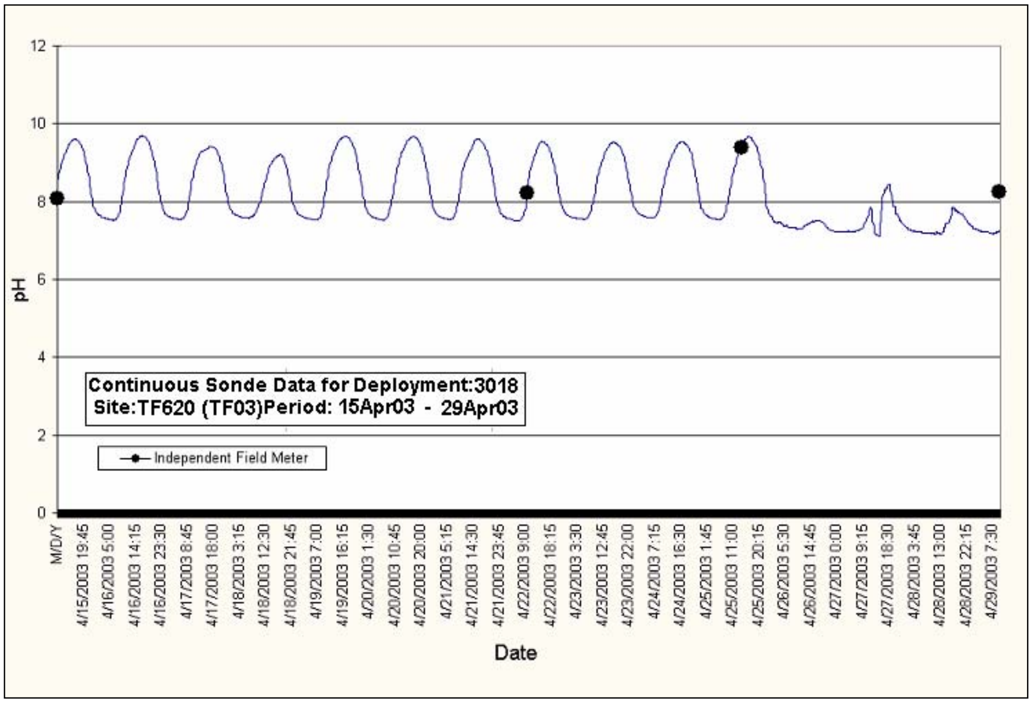


Figure 3-30 pH- From CCR (TTF CCR Section 5.3.3, Figure 5-3, Page 5-15)

Biochemical Oxygen Demand (BOD)
As warm stream water has a limited capacity for DO, excess BOD may preclude warm water streams from meeting WQ criteria despite re-aeration due to diffusion and algal production of DO.

Evaluation of BOD_5 results in a watershed where most sources exhibit spatial and temporal variability is difficult. The BOD_5 test provides little information when samples are dilute (Method Reporting Limit= 2mg/L), which is often the case in dry weather samples from streams lacking point source discharges or other sources of organic enrichment (87% of dry weather samples and 28% of wet weather samples had BOD_5 concentration below reporting limits). Analysts must also determine an appropriate series of dilution ratios without *a priori* knowledge of the sample's potential to deplete oxygen. For this reason, 4% of samples were reported as minimum values (*i.e.*, actual values were known to be greater than the value reported but the dilution sequence did not allow computation of an actual value); all samples in which BOD_5 concentration were reported as minimum values were collected in wet weather.

As BOD_5 concentration data were affected by a large number of imprecise values, nonparametric statistics were used in comparing between sites and evaluating wet weather effects. In the latter analysis, data from all sites were combined, non-detects were included as half the method reporting limit (MRL), and minimum values were included as if they were actual values. BOD_5 concentration was found to be significantly greater in wet weather than in dry weather (Mann-Whitney U test, $Z_{2,689}$ = -7.27, p<0.001), and there was a significant effect of site in wet weather (Kruskal-Wallis ANOVA, $H_{8,565}$= 73.32, p<0.001, which is likely due to frequent CSO discharge at site TF280 (mean wet weather BOD_5 11.79±18.22). Though the sampling effort was not equal across sites, mean wet weather BOD_5 data suggest CSO discharge at site TF620/680 (5.98±6.55mg/L) and occasional SSO discharge or other sources of organic enrichment at sites TFM006 (7.21±7.84mg/L), TF975 (4.95±5.74mg/L) and TF1120 (4.13±3.89mg/L) (Figure 3-31).

Table 3-65 Sonde Parameters of Concern in the TTF Watershed by site (2001-2004) (TTF CCR Section 5.3.1, Table 5.7, Page 5-12)

Site	Parameter	Standard	Ref	Dry Weather			Wet Weather			Comments
				No. Obs.	No. Exceed	% Exceed	No. Obs.	No. Exceed	% Exceed	
TF280	Sonde DO	5mg/L daily avg. 4mg/L min		17492	1243	7.1	16617	1798	11	Potential Concern
	Sonde Turbidity		8.05 NTU	5192	1045	20	7074	3563	50	Concern
TF500	Sonde DO	5mg/L daily avg. 4mg/L min		5125	0	0	3378	261	7.7	Potential Concern
	Sonde Turbidity		8.05 NTU	2579	10	0.39	1647	396	24	Concern
TF620	Sonde Turbidity		8.05 NTU	5298	244	4.6	7083	1727	24	Concern
	Sonde pH	6-9 inclusive		19380	598	3.1	20510	155	0.76	Potential Concern
TF760	Sonde Turbidity		8.05 NTU	3623	732	20	2710	1411	52	Concern
TF975	Sonde Turbidity		8.05 NTU	9328	360	3.9	9333	2972	32	Concern
TF1120	Sonde Turbidity		8.05 NTU	8972	561	6.3	8862	2722	31	Concern
TFJ110	Sonde Turbidity		8.05 NTU	550	0	0	894	251	28	Concern
TFM006	Sonde Turbidity		8.05 NTU	2412	40	1.7	3191	863	27	Concern
7th and Cheltenham	Sonde Turbidity		8.05 NTU	963	1	0.10	182	37	20	Concern

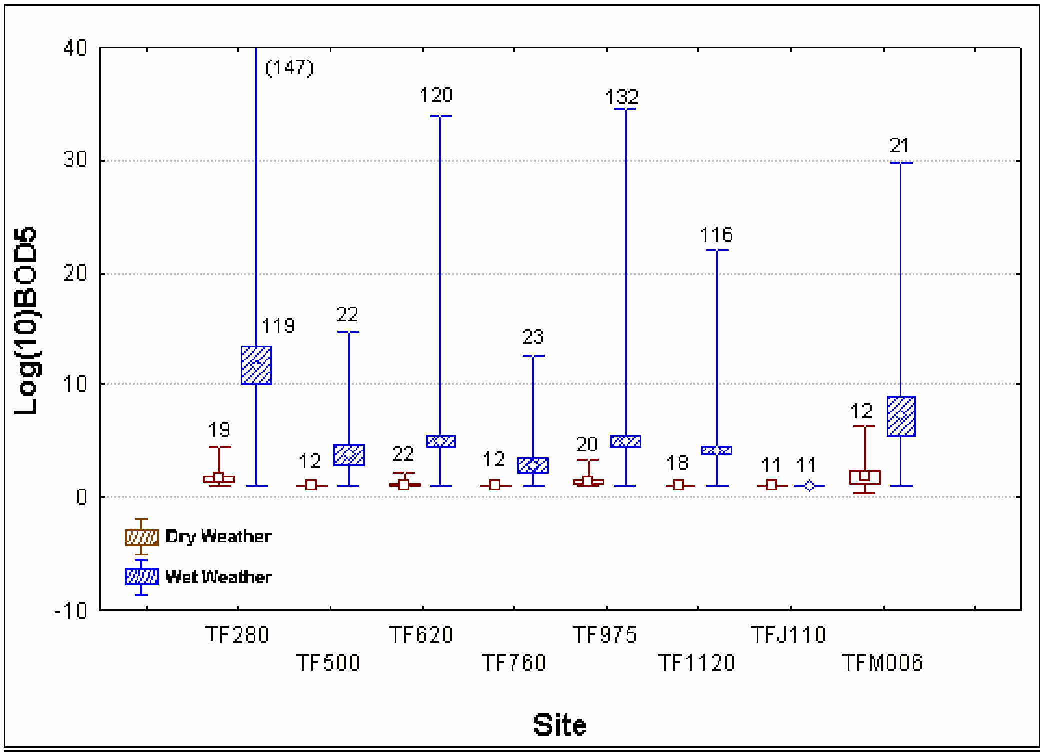


Figure 3-31 Five Day BOD of Samples Collected From Eight Sites in TTF Watershed in Dry and Wet Weather (TTF CCR Section 5.3.2, Figure 5.2, Page 5-14)

Dissolved Oxygen

The PADEP has established criteria for both instantaneous minimum and minimum daily average DO concentration. Criteria are intended to be protective of the types of aquatic biota inhabiting a particular lake, stream, river, or segment thereof. TTF Watershed is considered a Warm Water Fishery (WWF) that cannot support salmonid fish year-round. Furthermore, the stream is not considered appropriate for a put-and-take fishery (i.e., stocking trout to provide recreational opportunities). PADEP water quality criteria, therefore, require that minimum DO concentration in a WWF not fall below 4 mg/L and that daily averages remain at or above 5 mg/L.

Based on sampling by the Philadelphia Water Department during 2000-2004, DO is considered to be a parameter of potential concern because water quality criteria were exceeded (Tables 3-61 through 3-63). Based on these results, dissolved oxygen is a parameter of concern at USGS station 01467087 (Castor Avenue) and a potential concern at USGS station 01467086 (Adams Avenue).

When interpreting continuous DO data, one must keep in mind that in situ DO probes can only measure dissolved oxygen concentration of water in direct contact with the probe membrane. Furthermore, to obtain accurate measurements, DO probes should be exposed to flowing water or probes themselves must be in motion. Conditions found in urban areas (e.g., severe flows, infrastructure effects, debris accumulation, vandalism, etc.) complicated installation, and it was not always possible to situate instruments in ideal locations. Local microclimate conditions surrounding probes and biological growth on probes themselves probably contributed to errors in measurement. Often Sondes situated in subtly different areas of the same stream site to exhibit marked differences in DO concentration due to flow, shading, and local microclimate differences.

DO concentrations in the TTF Watershed were found to be highly variable, both seasonally and spatially, but in general, DO was controlled by temperature, natural community metabolism and inputs of combined sewage and untreated stormwater. As cold water has a much higher capacity for DO than warm water, DO violations were generally restricted to the warmer months. This appears to occur at site TF280, but DO suppression also was observed at site TF500 (Table 3-65). Pronounced diurnal fluctuations in DO concentration were observed at sites TF280, TF1120, and TF620/680; most other sites showed only moderate fluctuation due to biological activity. Effects of stream metabolism on DO concentration are addressed in more detail in the TTF Comprehensive Characterization Report.

Continuous water quality data indicated that certain sites in the TTF experience diurnal fluctuations in DO and pH that can be reduced in magnitude following storm events (Figure 3-32), generally within 3 miles of the confluence with the Delaware River. As TTF Watershed was not found to have large dry weather concentrations of chlorophyll in the water column that would be indicative of suspended phytoplankton, it was hypothesized that these pronounced fluctuations were due largely to periphytic algae.

Supporting this conclusion are observed reductions in the magnitude of fluctuations during and immediately after storms and increases in water column chlorophyll-a during storm events observed at some sites. The latter effect is difficult to characterize, as the degree to which chlorophyll-a increased in wet weather is believed to have been affected by algal density, predominant growth form, and stream velocity.

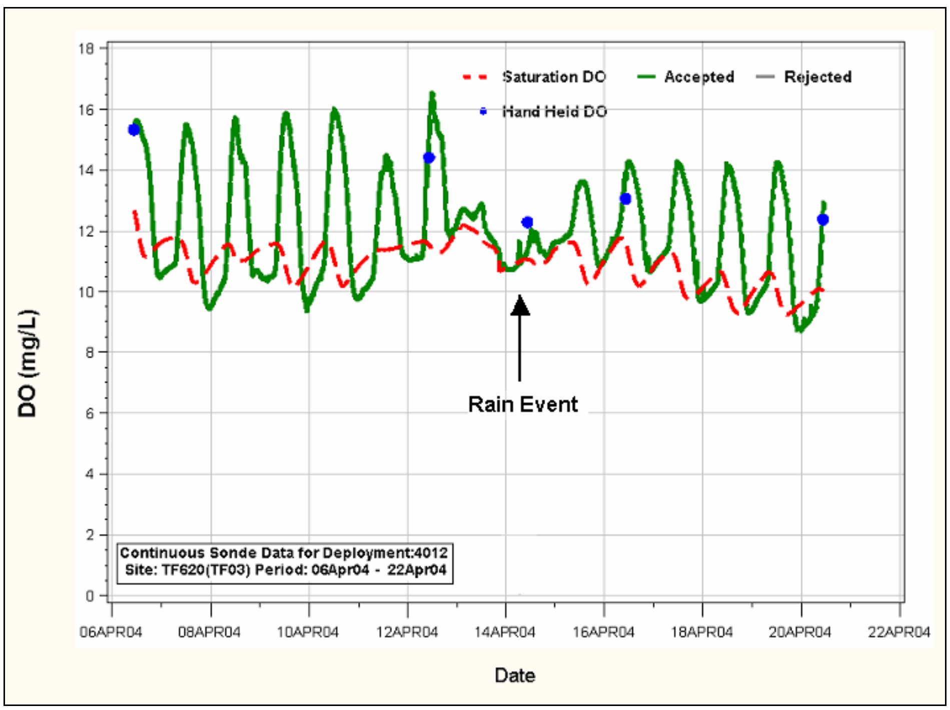


Figure 3-32 Continuous Plot of Water Column Dissolved Oxygen Concentration at Site TF620, April 2004 (TTF CCR Section 5.4, Figure 5.16, Page 5-41)

Relation of Algal Activity to Dissolved Oxygen Concentration

DO concentrations often strongly reflect autotrophic community metabolism and in turn, affect the heterotrophic community structure as a limiting factor for numerous organisms. Stream sites that support abundant algal growth often exhibit dramatic diurnal fluctuations in dissolved oxygen concentration. Algal photosynthesis infuses oxygen during the day (often to the point of supersaturation), while algae and heterotrophic organisms remove oxygen throughout the night. Diurnal fluctuations are more pronounced in the summer months than the autumn and winter months as colder water has a greater capacity for DO and biological metabolic activity is generally regulated by temperature.

Mainstem sites on Tacony and Frankford Creeks experience pronounced diurnal fluctuations in dissolved oxygen (DO) concentrations. When biological activity is high, DO concentrations may fall below the state-regulated limit of 4 mg/L., generally in the stretch of river within 6 miles of the confluence with the Delaware River and common within the lower three miles of the confluence (i.e., downstream of site TF500). Dry weather dissolved oxygen suppression tends to occur at night and is likely caused by respiration of algae and microbial decomposition of algae and other organic constituents in the absence of additional photosynthetic oxygen production.

Following storm events, amplitude of daily DO fluctuations was reduced. DO concentrations may decrease sharply upon increase in stage, but it was difficult to determine how much of these instantaneous decreases were due to DO probe membrane fouling (Figure 3-33). It was hypothesized that anoxic effluent from storm sewers contributes to a sudden reduction in water column DO, but modeling of CSO discharge DO concentrations indicated that the discharge alone could not account for the observed DO reductions. BOD and SOD may have increased due to organic matter present in sewage. Mean BOD_5 was substantially higher at TF280 than at TF620 (Figure 3-33), although numerous samples were below reporting limits. Additionally, the scouring effect of high flows reduces algal biomass, and the oxygen produced through photosynthesis and consumed through respiration is reduced. As algal biomass accrues following scouring events, peak DO concentrations and range of diurnal fluctuations return to pre-flow conditions (Figure 3-34).

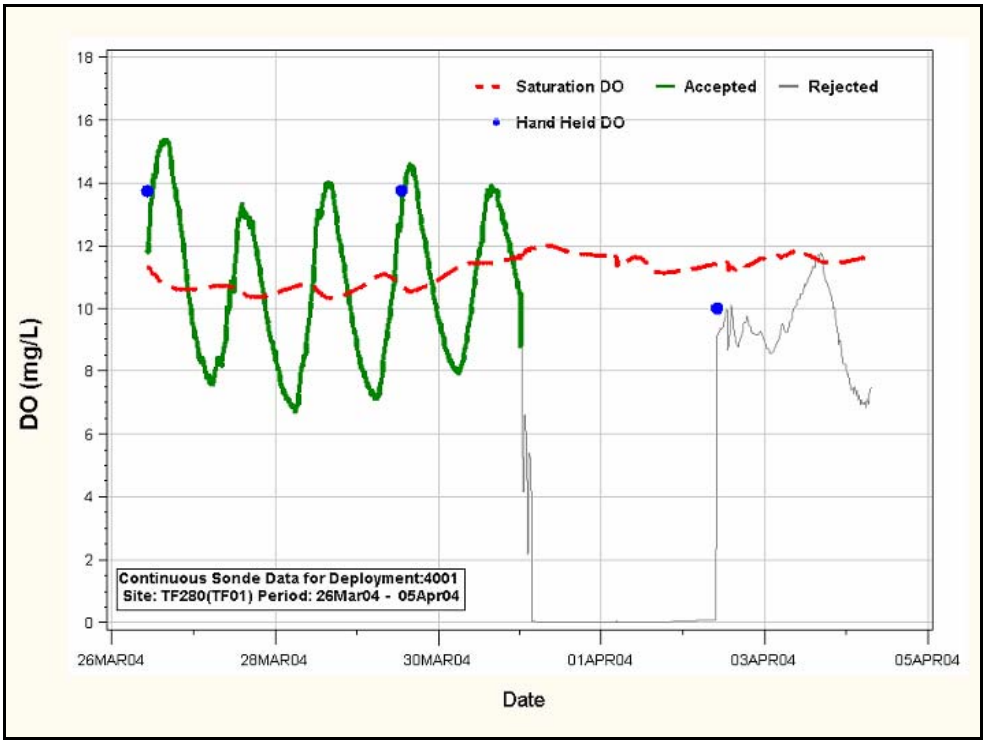


Figure 3-33 Continuous plot of Dissolved Oxygen Concentration at Site TF280 Showing DO Probe Failure (TTF CCR Section 5.4.1, Figure 5.19, Page 5-44)

Algal biomass at site TF280 was lower than at site TF620 further upstream. However, TF620 exhibits a higher mean DO and less pronounced diurnal fluctuations suggesting that the relationship between biomass and primary production is not straightforward. It is hypothesized that in dry weather the algae in combination with the residual effects of anoxic effluent, BOD and SOD accounts for the greater fluctuations in DO at site TF280. Further confounding the interpretation of this data is the fact that the sonde at site TF280 is located within a stagnant pool, the only location offering enough depth to allow the instrument to remain submerged at baseflow. Conversely, sonde locations at site TF620/680 are exposed to more streamflow, which replenishes the water surrounding the DO probe more frequently and helps keep the DO membrane itself from accumulating algae and debris. Microclimate conditions surrounding the DO probe membrane probably partially explain the difference in DO fluctuations observed between these two sites.

Future Investigation of Dissolved Oxygen Conditions in the Tacony and Frankford Creeks
The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the lower Tacony Creek and the Frankford Creek are not well understood at this juncture. Efforts to better understand the dissolved oxygen situation in Philadelphia's streams continue including, in addition to ongoing continuous long-term monitoring, process studies conducted for PWD by the USGS. The USGS is conducting a study to calculate the rate at which the atmosphere replenishes the creek with oxygen. The collection of that data, combined with local measurements of sediment oxygen demand and biochemical oxygen demand, are intended to better quantify the factors that contribute to dissolved oxygen conditions in the stream.

Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from dischargers to the Tookany

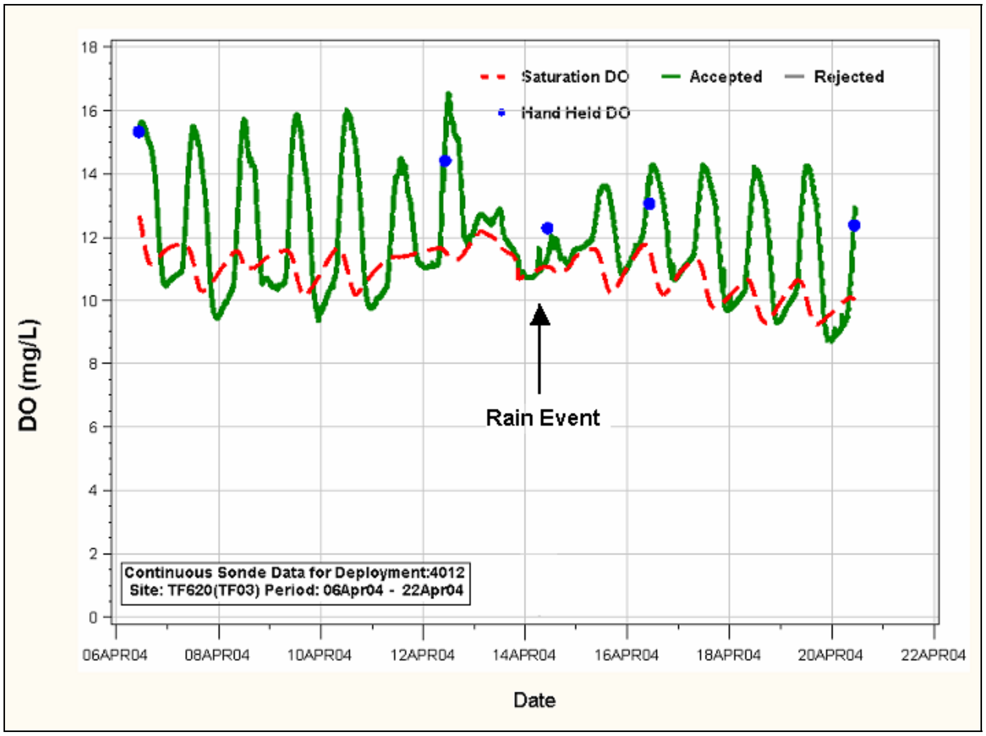


Figure 3-34 Continuous plot of Dissolved Oxygen Concentration at site TF280 returning to pre-flow conditions

Creek and other upstream tributaries. If a relationship between loadings and the dissolved oxygen conditions is suspected, informational total maximum daily loads will be investigated for the watershed. Progress and results of the monitoring and process studies, the revised loading work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Conductivity and Total Dissolved Solids

PADEP's established maximum criterion for an instantaneous maximum concentration of Total Dissolved Solids (TDS) is 750 mg/L. The criterion is intended for waterways that are used as potable water supplies (PWS).

Conductivity and TDS are measures of the concentration of ions and solids dissolved in water. TDS is an empirical laboratory procedure in which a water sample is filtered and dried to yield the mass of dissolved solids, while conductivity is a measure of the ability of water to conduct electricity over a given distance, expressed as microsiemens (µS)/cm (corrected to 25ºC) (Greenberg et al. 1993). With sufficient data, a good relationship between conductivity and TDS can be established. Waters containing large relative proportions of organic ions (e.g., bog or wetland samples containing organic acids) generally have less conductivity for equivalent TDS concentration than waters containing primarily inorganic ions.

Dissolved ion content is perhaps most useful in determining the start of wet weather events at ungaged water quality monitoring stations. Conductivity probes are generally simple in design, robust, and very accurate. They are extremely sensitive to changes in flow, as stormwater (diluent) usually contains smaller concentrations of dissolved ions than stream baseflow. A notable exception to this rule concerns the application of ice melt chemicals to roads (primarily Sodium, Magnesium, and Potassium salts). When present in runoff or snowmelt, these substances can cause large increases in ionic strength of stream water. Though some formulations may increase levels of Chloride, PADEP WQ criteria for Chloride (maximum 250mg/L) are intended to protect water supplies, and aquatic life effects have not been reliably demonstrated at moderate levels typically experienced in streams.

Conductivity ranged from 227 to 1225 µS/cm during dry weather sampling and 76 to 1897 µS/cm. TDS samples ranged from 160 to 643 mg/L in dry weather and 56 to 1054 mg/L during wet weather. Two wet weather samples exceeded the TDS target value of 750 mg/L, but neither Conductivity or TDS are considered parameters of concern or potential concern. It is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan.

Total Suspended Solids

There is no established state standard for Total Suspended Solids (TSS) but it is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan. Sediment transport in small streams is dynamic and difficult to quantify. Numerous factors can affect a stream's ability to transport sediment, but generally sediment transport is related to streamflow and sediment particle size. Stable streams are generally capable of maintaining equilibrium between sediment supply and transport, while unstable streams may be scoured of smaller substrate particles or accumulate fine sediments. The latter effect is particularly damaging to aquatic habitats. PADEP has identified the cause of impairment in TTF Watershed to be a combination of "Water/Flow Variability", "Flow Alterations", and "Other Habitat Alterations". "Siltation" was not listed as a cause of impairment, but the effects of sediment deposition, where and when they occur, are probably addressed by "Other Habitat Alterations".

Water sampling techniques that are adequate to characterize most water quality parameters (e.g., grab samples, automated sampling) are not generally appropriate for evaluating sediment transport in fluvial systems (Edwards and Glysson 1988); errors related to sampling technique should preclude computation of sediment transport during severe storm events that mobilize large streambed particles. TSS concentration (Log transformed) was significantly greater in wet weather than in dry weather ($F_{2,286}= 8.72$, $p<0.001$).

Maximum daily TSS concentration (log transformed) was found to be significantly positively correlated to average daily streamflow at site TF280 ($r(33)= 0.85$, $p<0.001$, (Figure 3-35) and instantaneous TSS concentration (log transformed) was positively significantly correlated with instantaneous discharge at all gaged sites in the PWD historical water quality database (unpublished data). These comparisons of TSS concentration to stream discharge supported the use of TSS concentration as a surrogate measure of the intensity of streamflow and the presence of eroded soil and streambed particles for the purpose of comparing concentrations of certain water quality parameters (i.e., Phosphorus, Nitrate, toxic metals) with intensity of streamflow and soil erosion at stations where USGS gages have been eliminated.

Turbidity

Turbidity is a measure of the light scattering properties of particles suspended in water. In streams, turbidity can come from many sources, but the chief cause of increased turbidity is suspended sediment. While a correlation between turbidity and TSS certainly exists, the relationship between turbidity and TSS may differ between water bodies and even among different flow stages/seasons in the same waterbody due to sediment characteristics. Consistently turbid waters often show impairment in aquatic communities. Light penetration is reduced, which may result in decreased

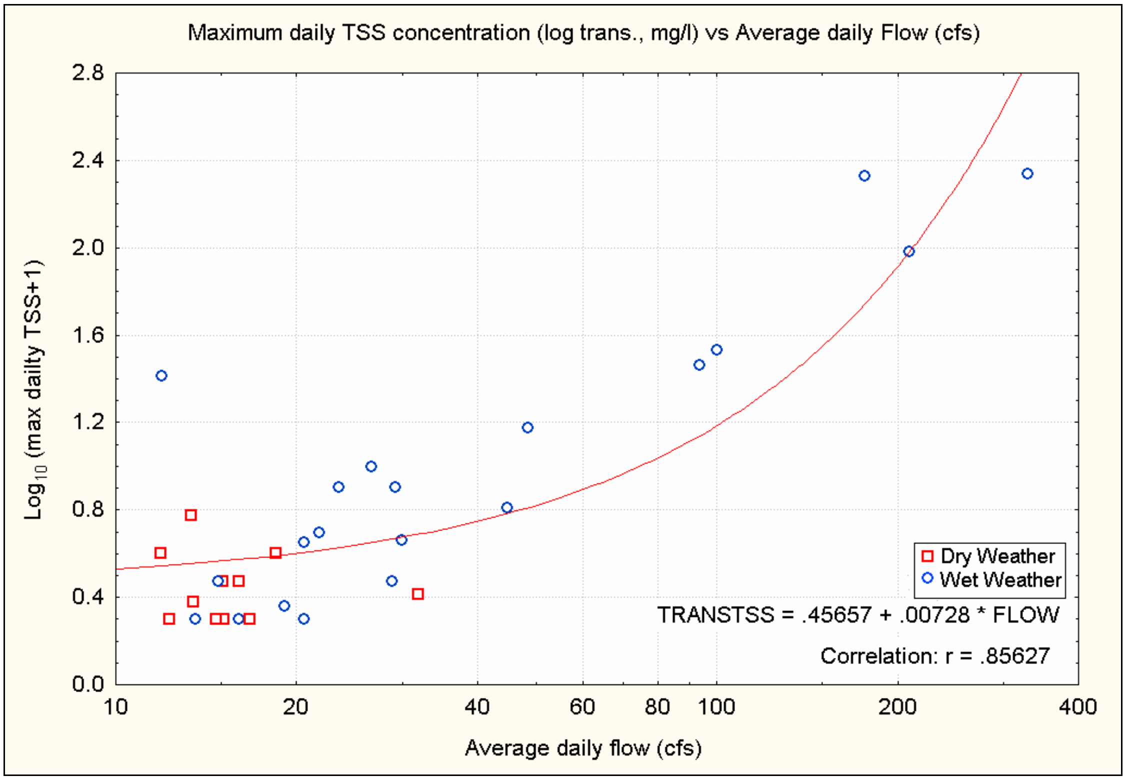


Figure 3-35 Maximum Daily Total Suspended Solids Concentration and Corresponding Average Daily Flow at site TF280 (TTF CCR section 5.3.6.1 figure 5.6 page 5-22)

algal production; suspended particles can clog gills and feeding apparatus of fish, benthic invertebrates, and microorganisms. Feeding efficiency of visual predators may also be reduced.

PADEP WQ criterion for turbidity is a maximum of 100 NTU. Discharge of substances that produce turbidity are also specifically prohibited and, General Water Quality Criteria (Title 25, Section 93.6) specifically prohibit substances attributable to any point or non-point source in concentrations inimical or harmful to aquatic life. Turbidity is considered a parameter of potential concern since it exceeded the 100 NTU standard in 2.2% of wet weather samples.

Nutrients

Phosphorus

Phosphorus (P) concentrations are often correlated with algal density and are used as a primary indicator of cultural eutrophication of water bodies. N:P ratio analysis strongly suggests that P is the limiting macronutrient in the TTF Watershed. Readily available dissolved orthophosphate (PO_4) was only detected in 5 of 129 total samples collected in dry weather, and in 55 of 584 wet weather samples, so nutrient analyses considered only total P concentrations (TP). TP includes some smaller fraction of P that is considered to be bioavailable, or readily usable by stream producers. Bioavailable P (BAP) includes soluble reactive P (SRP) and, depending on other factors, some portion of particulate inorganic P. Furthermore, some producer taxa can produce endogenous alkaline phosphatases and obtain P that is not normally available.

The TTF Watershed has not been listed by PADEP as impaired due to nutrients, and no WQ criteria exist for TP or PO_4. For the TTFIWMP, TP concentrations were evaluated using a frequency distribution approach. Data were compiled for reference reaches in USEPA Ecoregion

IX, subregion 64 (75th percentile of observed data=140 µg/L). This reference value is considerably greater than the mesotrophic/eutrophic boundary for TP suggested by Dodds et al. (1998) (i.e., 75 µg/L). Dry weather TP concentrations were usually below both reference values.

Total P concentration was below reporting limits in 58 of 135 samples collected in dry weather, but in only 87 of 555 wet weather samples. Elevated dry weather TP concentration was observed at sites TF280 and TFM006, possibly due to dry weather sewage inputs. Log-transformed Mean TP concentration was significantly greater in wet weather than in dry weather ($F_{2,183}=1.55$, $p=0.008$), so stream producers in the TTF Watershed are generally exposed to somewhat constant TP concentrations punctuated with episodic inputs of greater TP concentration due to runoff and erosion. Point sources of P include CSO and SSO discharges, contributing large amounts of phosphorus where and when they occur.

P readily adsorbs to soil and sediment particles and is generally less mobile in soils than nitrogen compounds. Potential non-point sources of P are decomposing organic matter in or near the stream, runoff from industrial parks, golf courses, agriculture and residential areas, and inorganic P adsorbed to soil particles that are washed into the stream by erosive forces. In fact, soil erosion may be the greatest source of P in separate-sewered portions of TTF. TP concentration was significantly positively correlated with TSS concentration, (Log transformed, $r(183)=0.60$, $p<0.001$) (Figure 3-36). Wet weather phosphorus inputs, however, are coupled with physical disturbances (e.g., hydraulic shear stress, other abrasive forces, reduced light availability). These stressors respond to changes in flow in a non-linear fashion. Some taxa have the ability to store intercellular reserves of inorganic nutrients ("luxury consumption") when concentrations exceed immediate demands. It is thus very difficult to estimate P concentrations available to stream producers and draw conclusions about stream trophic status.

<u>Ammonia</u>

Ammonia, present in surface waters as un-ionized ammonia gas (NH_3), or as ammonium ion (NH_4^+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH_3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH_3, although at the expense of increased NO3 concentration. PADEP WQ criteria for NH_3 reflect the relationship between stream pH, temperature, and ammonia speciation/ dissociation. Ammonia toxicity is inversely related to hydrogen ion [H^+] concentration; an increase in pH from 7 to 8 increases NH_3 toxicity by approximately an order of magnitude. At pH 9.5 and above, even background concentrations of NH_3 may be toxic.

Historic data comparisons show that, in the watershed overall, NH_3 concentrations have decreased significantly compared to samples collected from 1970 to 1980 (F2,1001=6.18, $p<0.001$). Dry weather NH_3 concentrations, in particular, have improved dramatically. For example, in samples collected from 1970 to 1980, there was no significant difference in NH_3 concentrations between dry and wet weather samples at site TF280 (F2,99=1.19, $p=0.77$), suggesting that sewage inputs were common at this site regardless of weather.

Though no dry weather samples collected from the TTF Watershed from 2000-2004 contained NH_3 concentration in excess of 0.8 mg/L and there were no violations of WQ criteria, 20 of 87 samples were above reporting limits, suggesting occasional inputs of untreated sewage, anoxic conditions, or the presence of other decomposing organic material. Site TF280 was responsible for most of these

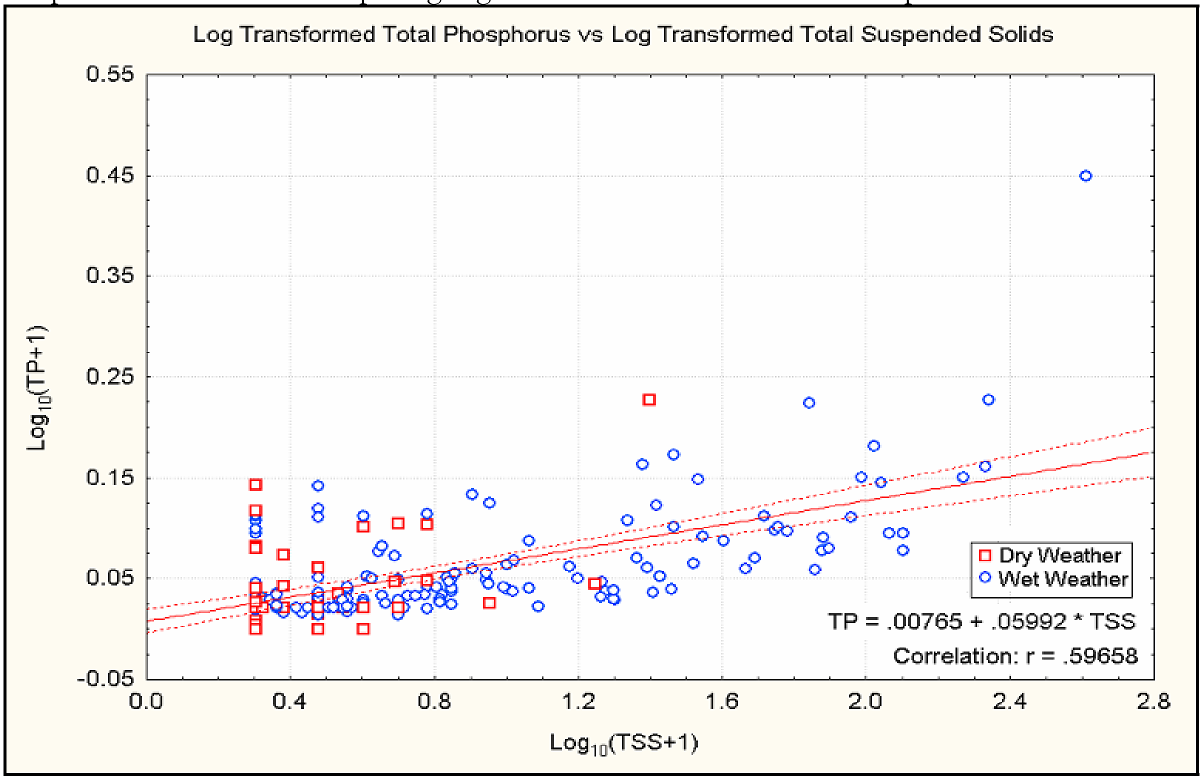


Figure 3-36 Scatterplot of Paired Total Phosphorus and Total Suspended Solids Concentrations of Samples Collected from 8 Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.1, Figure 5.13, Page 5-36)

observations, and is believed to be the site most seriously affected by dry weather sewage inputs and anoxic conditions. Target A of the TTFIWMP is directed at further reducing dry weather sewage inputs through source track-down and infrastructure repair/improvements.

NH_3 concentration of sites within TTF Watershed (log-transformed, all sites combined) was significantly higher in wet weather than in dry weather ($F_{2,710}$=2.30, p=.0047). NH_3 concentration was above detection limits in 211 of 436 total wet weather samples, though all samples with concentrations greater than 0.8mg/L were collected at site TF280.

There were no violations of WQ criteria due to the fact that pH remained near neutrality at the time samples were taken. Algal activity was observed to cause pH fluctuations, particularly at site TF620 in spring 2003. When severe, these fluctuations in pH caused NH3 WQ criteria to decrease to within the range of values observed at other times. The NH3 sampling regime was not ideal for identifying possible violations of WQ standards as discrete interval grab samples were collected in the morning, while daily pH maxima were typically reached in afternoon/early evening hours. NH3 was not considered a problem parameter since the standard was never exceeded.

<u>Nitrite</u>

As an intermediate product in the oxidation of organic matter and ammonia to nitrate, nitrite (NO_2) is seldom found in unimpaired natural waters in great concentrations provided that oxygen and nitrifying bacteria are present. For this reason, NO_2 may indicate sewage leaks from illicit connections, defective laterals, or storm sewer overflows and/or anoxic conditions in natural waters.

NO_2 was detected in only 14 dry weather samples collected from the TTF Watershed; most of these observations were at site TF280 and most were collected prior to 2004. Comparison to data collected from 1970-1980 showed that the incidence of Nitrite detections in dry weather has been drastically reduced, suggesting fewer dry weather sources of sewage and/or reduced severity of anoxic conditions.

NO_2 concentrations were greater than reporting limits more frequently in wet weather (129 of 585 total samples) than in dry weather, but contribution of NO2 to total inorganic nitrogen was usually small and concentrations of many samples were estimated to be half the detection limit for the purpose of evaluating nutrient ratios. Large numbers of samples below detection limits prevented the use of parametric statistical methods to evaluate weather effects. Mann-Whitney U test analysis showed significantly greater NO_2 concentration (log transformed, samples below MRL included as half the MRL) in wet weather than in dry weather ($Z2,717 = -2.75$, $p<0.005$).

<u>Nitrate</u>

Concentrations of nitrate (NO3) are often greatest in watersheds impacted by (secondary) treated sewage and agricultural runoff, but elevated NO3 concentrations in surface waters may also be attributed to runoff from residential and industrial land uses, atmospheric deposition and precipitation (e.g., HNO3 in acid rain) and decomposing organic material of natural or anthropogenic origin. Nitrate is a less toxic inorganic form of N than ammonia and serves as an essential nutrient for photosynthetic autotrophs. Availability of inorganic N can be a growth-limiting factor for producers, though usually only in oligotrophic (nutrient-poor) lakes and streams or acidic bogs.

PADEP has established a limit of 10 mg/L for oxidized inorganic N species (NO3 + NO_2) (Commonwealth of Pennsylvania, 2001). This limit is based on public water supply use and intended to prevent methemoglobinemia, or "blue baby syndrome", and eutrophication of natural water bodies. Waters of the Commonwealth that have been determined to be impaired due to excess nutrients have Waste Load Allocations (WLA) determined through the Total Maximum Daily Load (TMDL) process; TTF Watershed has not been listed as impaired due to nutrient enrichment. For the TTFIWMP, Inorganic N concentrations were evaluated using a frequency distribution approach. Data were compiled for reference reaches in USEPA Ecoregion IX, subregion 64 (75th percentile of observed data=2.9mg/L). This reference value is considerably greater than the mesotrophic/eutrophic boundary for Total N suggested by Dodds et al. (1998) (i.e., 1.5 mg/L TN). However, based on PADEP standards, Inorganic N is not considered to be a problem parameter since the standard was never exceeded.

Dry weather NO_3 concentrations in the TTF Watershed are almost always found between the two aforementioned reference points (i.e., between 1.5 mg/L and 2.9 mg/L). NO_3 concentrations typically decreased in wet weather. Mean NO_3 concentration (log transformed, all sites combined) was significantly lower in wet weather than in dry weather ($F^2,180=1.70$, $p<0.001$), and NO_3 was significantly negatively correlated with TSS concentration (Log transformed $r(182)= -0.55$, $p<0.001$, Figure 3-37). This relationship demonstrates dilution by stormwater and is the reverse of the phenomenon observed with P concentration. However, other forms of N (i.e., TKN, NH_3, NO_2) tended to increase in concentration in wet weather. Nutrient dynamics and relationships to autotrophic community production are addressed in greater detail in section 5.4, Stream Metabolism of the TTF Watershed Comprehensive Characterization Report.

Unusual dry weather samples were collected from site TF280 on July 7, 2004 and TFM006 on August 30, 2004 in which NO3 concentration seemed diluted compared to most other dry weather baseflow samples. In the first case, accompanying data showed increases in TKN and NO_2, as would be expected under anoxic conditions, but DO suppression could not be verified due to probe failure. In the second case, TKN was slightly elevated for a dry weather sample, but NO_2 was below reporting limits and no DO data were available.

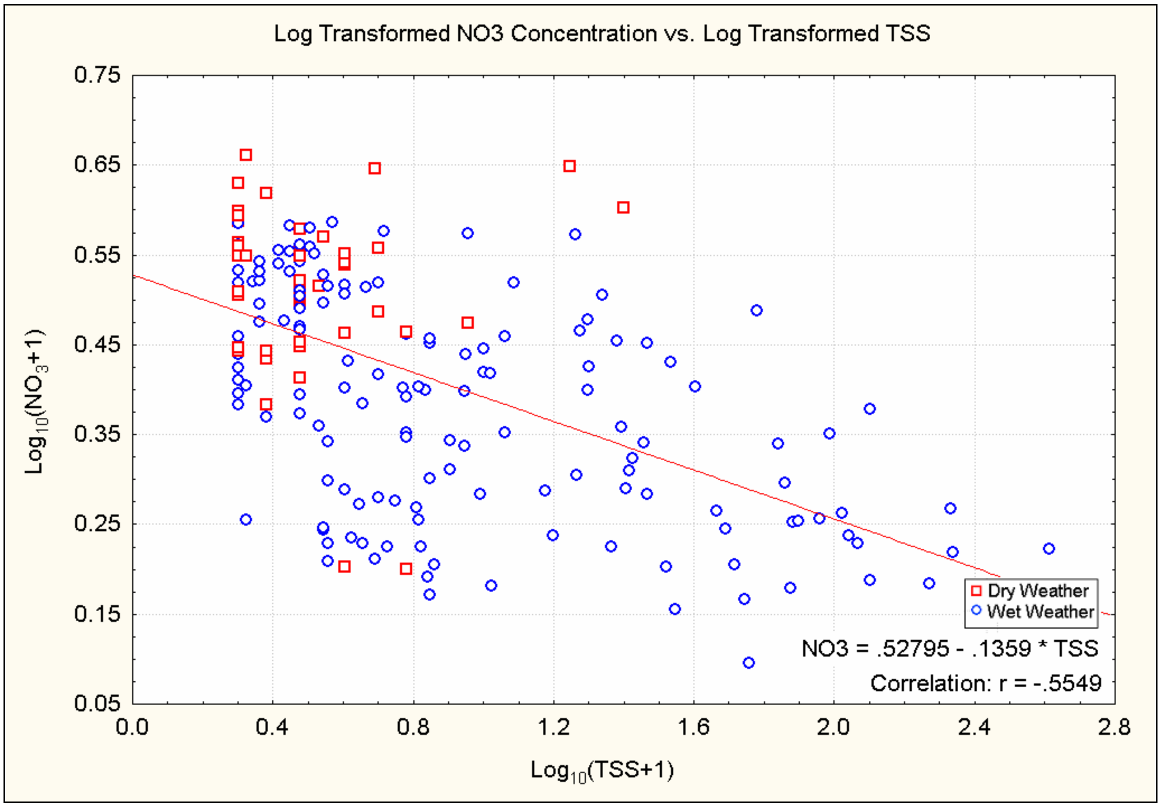


Figure 3-37 Scatterplot of Paired Nitrate and Total Suspended Solids Concentrations of Samples Collected from Eight Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.4, Figure 5.14, Page 5-39)

Total Kjeldahl Nitrogen

The Total Kjeldahl Nitrogen (TKN) test provides an estimate of the concentration of organically-bound N, but actually measures all N present in the tri-negative oxidation state. Ammonia must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters. Sampling results suggest the most important source of organic N is sewage inputs from CSO and SSO discharge. Log-transformed Organic N concentration was significantly greater in wet weather than in dry weather ($F_{2,654}=14.04$, $p<0.001$). Organic N was also significantly positively correlated with fecal coliform bacteria concentration, $r(647)=0.70$, $p<0.001$ (Figure 3-38). As most organic N loadings to the watershed occur in wet weather, this N is probably transported out of the system and into the Delaware estuary before exerting nitrification DO demand or becoming available for uptake by algae.

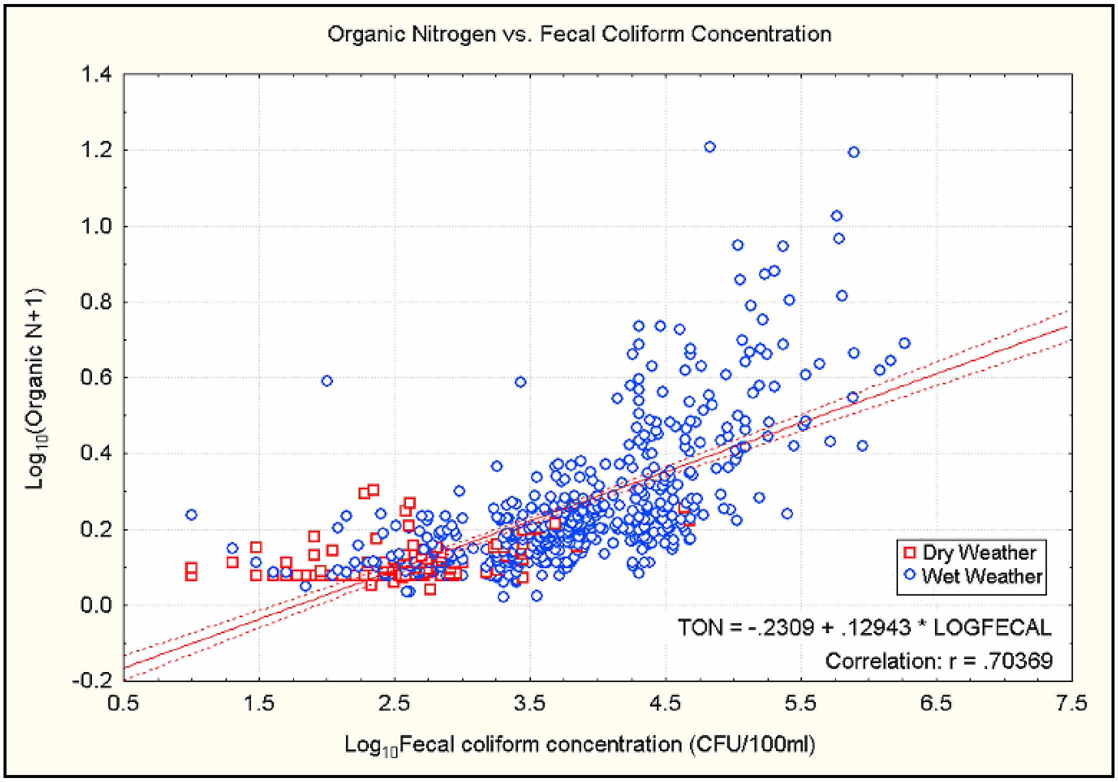


Figure 3-38 Scatterplot of Organic Nitrogen and Fecal Coliform Bacteria Concentrations of Samples Collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.5, Figure 5.15, Page 5-40)

TKN exceeded the 0.675 mg/L US EPA standard during both dry and wet weather, but is not considered a parameter of concern since there is no state standard.

Nutrient Limitation Effects on Primary Production

Nutrients are arguably the most important factor dictating algal standing crop, primary production, and community composition with examination of the nutrient-algae relationship requiring both an autecological and community-level approach (Borchardt 1996).

Nutrients can be a limiting factor to algal growth. In any given scenario, only one nutrient can limit algal growth for a given species at a time, although, at the community level, this rule does not apply where different species might be limited by different nutrients. Growth rates are not affected by nutrient concentrations alone. Light and temperature can affect nutrient uptake rates (e.g.,Falkner et al. 1980, Wynne and Rhee 1988), and more nutrients are often needed when light and temperature conditions are less than ideal (Goldman 1979, Rhee and Gotham 1981a,b, Wynne and Rhee 1986, van Donk and Kilham 1990). Additionally, nutrient uptake rates can vary depending on nutrient conditions. In steady-state growth conditions, the rate of nutrient uptake is equivalent to the rate at which nutrients are used in growth. However, cells may take up fewer or greater amounts of nutrients (for example, during nutrient pulses) and alter the nutrient ratios within the cell (Borchardt 1996).

The relationship between nutrients and algal biomass is complicated by numerous factors and findings are not consistent across ecoregions and waterbody types. Typically, nutrient enrichment stimulates periphyton growth in lotic systems and many studies have shown strong relationships between nutrient concentrations and algal biomass (e.g., Jones et al. 1984, Welch et al. 1988, Kjeldsen 1994, Chetelat et al. 1999, Francouer 2001). However, other studies have shown no relationship between biomass and nutrient concentration (Biggs and Close 1989, Lohman et al. 1992). Periphyton standing crop can be highly variable (Morin and Cattaneo 1992) and other factors (described in subsequent sections) may override nutrient effects.

Of the necessary components for algal growth, nitrogen and phosphorus are likely to be growth-limiting in aquatic systems (Wetzel 2001) although carbon (Fairchild et al. 1989, Fairchild and Sherman 1993), trace metals (Winterbourn 1990), organic phosphorus (Pringle 1987) and silicates (Duncan and Blinn 1989) have also been implicated in limiting algal growth. Based on periphyton-nutrient studies, phosphorus is typically the limiting nutrient in the northern US (see Borchardt 1996 for review) while nitrogen has been shown to be limiting in the southwest (Grimm and Fisher 1986, Hill and Knight 1988a, Peterson and Grimm 1992) and Ozark (Lohman et al. 1991) regions.

In an effort to develop a practical system of stream classification based on nutrient concentrations similar to those used for lakes, Dodds et al. (1998) examined the relationship between chl-a (mean and maximum benthic chl-a and sestonic chl-a) and total nitrogen (TN) and total phosphorus (TP) in a large, global dataset. They defined the oligotrophic-mesotrophic boundary by the lower third of the distribution of values with mean and maximum benthic chl-a concentrations of 20 mg/m2 and 60 mg/m2, respectively; and TN and TP concentrations of 700 μg/L and 25 μg/L, respectively. The mesotrophic-eutrophic boundary was represented by the upper third of the distribution of values with mean and maximum benthic chl-a concentrations of 70 mg/m2 and 200 mg/m2, respectively; and TN and TP concentrations of 1500 μg/L and 75 μg/L, respectively. Other recent studies examining specific chl-a-nutrient relationships include Dodds et al. (1997), Biggs (2000), Francouer (2001), Dodds et al. (2002a, b), Kemp and Dodds (2002).

<u>N:P Ratio</u>

Although nitrogen and phosphorus are the nutrients commonly limiting algal growth, the concentrations required to limit growth are less clear. Concentrations of phosphorus ranging from 0.3-0.6 μg PO4-P/L have been shown to maximize growth of benthic diatoms (Bothwell 1988) but higher concentrations have been needed in filamentous green algal communities (Rosemarin 1982), and even higher concentrations (25-50 μg PO4-P/L) as algal mats develop (Horner et al. 1983, Bothwell 1989). Nitrogen has been shown to limit benthic algal growth at 55 μg NO3-N/L (Grimm and Fisher 1986) and 100 μg NO3-N/L (Lohman et al. 1991). In the past, the Redfield ratio (Redfield 1958) of cellular carbon, nitrogen, and phosphorus at 106:16:1 has been used to determine nutrient limitation. In benthic algae studies, ambient N:P ratios greater than 20:1 are considered phosphorus limited whereas those less than 10:1 are considered nitrogen limited. Nutrient limitation analysis was focused on steady state (i.e., dry weather) conditions because these are the conditions under which limitation is most likely to affect periphyton communities.

Combining the above frameworks, most samples collected from sites in the TTF Watershed in dry weather would be considered P-limited, mesotrophic with respect to TP, and eutrophic with respect to TN. A small number of samples would be considered not strongly limited by N or P and eutrophic with respect to both macronutrients. Sites TF500, TFJ110, and TF1120 were P-limited and never had TP concentrations exceeding the mesotrophic/eutrophic boundary of .075mg/L. TF620 was P-limited and not eutrophic for all but one sample which was considered co-limited and eutrophic. TF760 was always P-limited and did not have eutrophic concentrations of P in all but one sample. Two sites, TF280 and TFM006, were P-limited and had TP concentrations above the eutrophic boundary more often than not. The latter two sites also had other indicators of sewage (e.g., fecal coliform bacteria) elevated in concentration in dry weather.

Sites TF280 and TF620 had similar mean TN values (2.59 ±0.49mg/L and 2.77± 0.45mg/L respectively), but mean dry weather TP concentration at site TF280 was significantly greater than at site TF620 ($F(47)= 9.35$ $p=0.0002$). Given the greater TP concentration, one might expect greater algal biomass at site TF280. However, observed biomass was consistently smaller at site TF280 than at site TF620, which indicates that other parameters such as light, disturbance, grazing and scouring are controlling algal biomass.

<u>Flow Effects on Stream Nutrient Concentrations</u>

Stream nutrient concentrations in TTF are dynamic. Macronutrients of greatest concern exhibited different responses to wet weather. NO_3 concentrations were relatively stable and adequate for abundant algal growth during dry weather and diluted in wet weather (mean NO3 concentration 2.37mg/L ±0.65, and 1.49mg/L ±0.70, respectively). Conversely, other forms of N (i.e., NH3, NO_2, TKN) generally increased in concentration during wet weather, which is likely due to CSO and SSO discharge as well as presence of other organic constituents in stormwater runoff. Nitrate (NO_3) and ammonium ions (NH^{4+}) forms are generally bioavailable, but other forms are not available for algal growth. Total organic nitrogen concentration (TON; calculated as TKN minus NH_3) showed a significant positive correlation with fecal coliform concentration, suggesting that sewage is a primary source of organic loading to the watershed ($r(648)=0.70$, $p<0.001$).

Phosphorous concentration followed a pattern similar to NH_3 and TON, increasing in wet weather (Figure 3-36). This increase was likely due to CSO and SSO discharge, runoff, and soil erosion. Particle size mobilization and transport, traditionally related to flow by entrainment velocity curves (i.e. Shields curve), may determine the effective P loading for a given sediment load. Smaller particles, due to their greater relative surface area, can absorb relatively more P than larger particles. Smaller particles are also generally more readily eroded and entrained in stormwater flow than larger particles.

Smaller storm events in TTF thus probably contribute more to eutrophication than larger events. For example, if smaller sediment particles adsorb more P than larger particles as has been suggested, P loading becomes less efficient as larger particles are entrained in runoff. As shear stresses increase, streambank materials comprise a greater proportion of the sediment load. These particles are likely more similar to the soil parent material (i.e., lower in P concentration) than more superficial soils layers that tend to incorporate more organic material. Furthermore, NH_3 showed a significant positive correlation with TSS ($r(380)=0.46$, $p<0.001$), but the greatest concentrations of NH_3 were observed accompanying moderate TSS concentrations, suggesting that NH_3 concentration increases immediately due to sewage inputs but is diluted by stormwater in larger, more severe storm events (Figure 3-39).

In addition to the decrease in relative bioavailability that accompanies high flows; physical stressors probably impose limits on the degree to which stream producers can take advantage of these increased concentrations. As flows increase, a greater proportion of the total nutrient load is transported out of the system, a greater proportion of the total load is inaccessible to producers, and much of the photosynthetic biomass (filamentous green algae and their associated epiphytes in particular) may be sloughed away and transported out of the system.

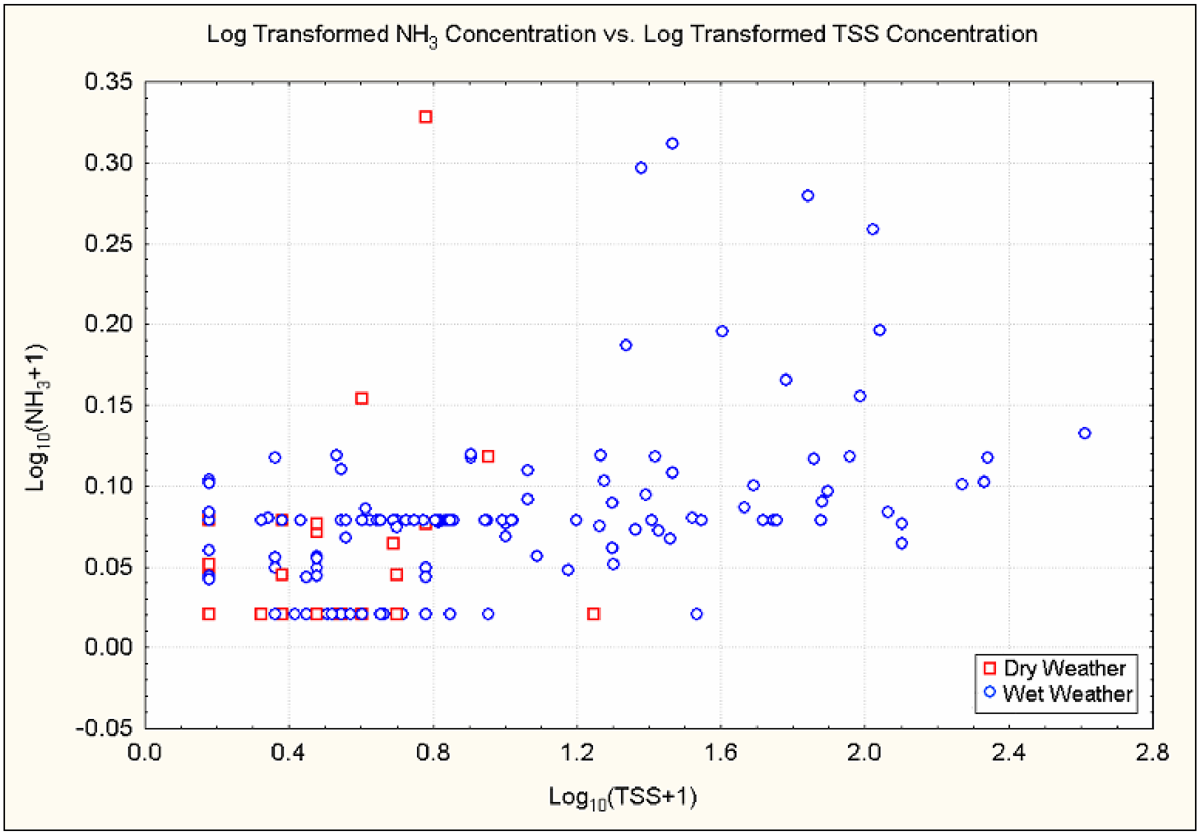


Figure 3-39 Scatterplot of Log-Transformed Ammonia and Total Suspended Solids Concentration of Samples Collected from Eight sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.4.2.2, Figure 5.20, Page 5-49)

In areas served by combined sewers, the relative impact of small, intense storms is magnified. CSO discharge is minimally diluted by stormwater in the initial overflow phase, or "first flush". If nutrients present in these overflows can become deposited along with sediment or rapidly taken up by stream producers, discharges of short duration, particularly in which shear stresses do not result in major sloughing of algal communities, may have far-reaching consequences for stream nutrient dynamics and aquatic biota. A greater benefit may result from reducing frequency, number, and volume of small CSO discharges rather than attempting to capture releases from larger events.

Metals

Iron and Manganese

Iron (Fe) and Manganese (Mn) are generally not toxic in streams, but are regulated in waters of the Commonwealth of Pennsylvania for public water supply (PWS) protection (Commonwealth of Pennsylvania, 2001) because excess concentrations of these metals can cause color, taste, odor, and staining problems in drinking water and industrial applications. The Pennsylvania Department of Environmental Protection (PADEP) has established criteria for a 30 day average as total recoverable maximum concentration for Fe. PADEP water quality criteria requires that the concentration of the 30 day average of Fe not exceed 1.5 mg/L. PADEP water quality criteria requires that the concentration of Mn as total recoverable not exceed 1 mg/L. Both elements are essential nutrients for all life and relatively abundant in the soils and surface geology of the TTF Watershed. Fe is particularly abundant (at approximately 5% of the Earth's crust it is second only to Aluminum in abundance among metals) and was detected in 746 of 761 samples collected from the TTF Watershed. Mn was less abundant but nevertheless detected in 745 of 762 samples. Presence of these metals in surface water samples may be natural- related to weathering of rock and soils- or due to stormwater runoff and ferrous materials in contact with the stream (e.g., pipes and metal debris).

Fe was not considered a parameter of concern in dry weather because the maximum standard of 1.5 mg/L as total recoverable was only exceeded in 0.60% of samples; however, Fe was considered a parameter of concern in wet weather because the standard was exceeded in 23% of the samples. Mn was not considered a parameter of concern in dry weather because the maximum standard of 1 mg/L as total recoverable was never exceeded; however, Mn was considered a parameter of potential concern in wet weather because the standard was exceeded in 2.1% of the samples. Neither Fe nor Mn are toxic to aquatic life at concentrations observed, and these constituents cannot be responsible for observed impairments in aquatic communities.

Toxic Metals

Toxic metals have been recognized as having the potential to create serious environmental problems even in relatively small concentrations (Warnick and Bell 1969, LaPoint et al. 1984, Clements et al. 1988). As such, their presence in waters of the Commonwealth, treatment plant effluents, and other permitted discharges is specially regulated by Pennsylvania Code Title 25, Chapter 16-Toxic Substances Criteria. Considerable research over the past two decades has been directed at understanding the ecotoxicology of heavy metals (e.g., biological pathways, physical and chemical mechanisms for aquatic toxicity, thresholds for safe exposure both acute and chronic, roles of other water quality constituents in bioavailability of toxic metals, etc.).

It is now widely accepted that dissolved metals best reflect the potential for toxicity to organisms in the water column, and many states, including PA, have adopted dissolved metals criteria (40 CFR 22227-22236). As many metals occur naturally in various rocks, minerals, and soils, storm events can expose and entrain soil and sediment particles that naturally contain metals. These inert particles are removed when samples are filtered for dissolved metals analysis (Greenberg et al. 1992). Total recoverable metals samples are digested and acidified to liberate organically-bound and complexed metals, but this process may also solubilize metals in inorganic and particulate states that are stable and inert under normal stream conditions, overestimating the potential for toxicity.

However, since it is not possible to filter samples collected with automatic sampling equipment immediately after collection, PWD has collected a greater number of total metals samples than dissolved metals samples. In order to ensure an adequate number of dissolved samples, particularly in wet weather, samples were collected from site TF280 during wet weather on two dates in summer 2004. Samples were collected manually by pumping through the automatic sampling tubing and apparatus and filtered immediately after collection. Site TF280 was sampled to conservatively direct sampling effort to the drainage that would be expected to contain the most potential sources of urban wet weather runoff pollution.

Analysis of paired dissolved/total metals concentration data suggests that most metals are generally found in considerably greater concentrations when total metals are measured, particularly in wet weather. Since dissolved metals concentrations are usually small or undetectable in both dry and wet weather, the potential for heavy metal toxicity in TTF, at least for water column organisms, is believed to be low. Sediment and pore water conditions may result in greater concentrations or otherwise contribute to increased potential for toxicity to benthic organisms within stream sediment microhabitats, but these effects remain poorly defined and are difficult to measure. Total recoverable metals results and comparisons to discontinued total metals water quality criteria are included herein as a reference measure of the potential for sediment metal loading and metals loading to the Delaware estuary from Philadelphia's urban stormwater; though it is believed that, for at least some metals, samples more closely reflect natural soil and geologic features than water pollution.

With the exception of Al and hexavalent Cr, PA WQ criteria are based on hardness (as $CaCO_3$), to reflect inverse relationships between hardness and toxicity that exist for most metals (Figure 3-40). While these criteria are much improved over simple numeric criteria, they fail to describe the complex interactions between dissolved metals and other water constituents and physicochemical properties (e.g., Dissolved Organic Carbon, pH, temperature, and ions other than Ca and Mg,). Hardness-based criteria may represent an intermediate step between simple numeric criteria and criteria based on more complex water quality models (i.e., Biotic Ligand Model), drafts of which have been recently been presented by USEPA.

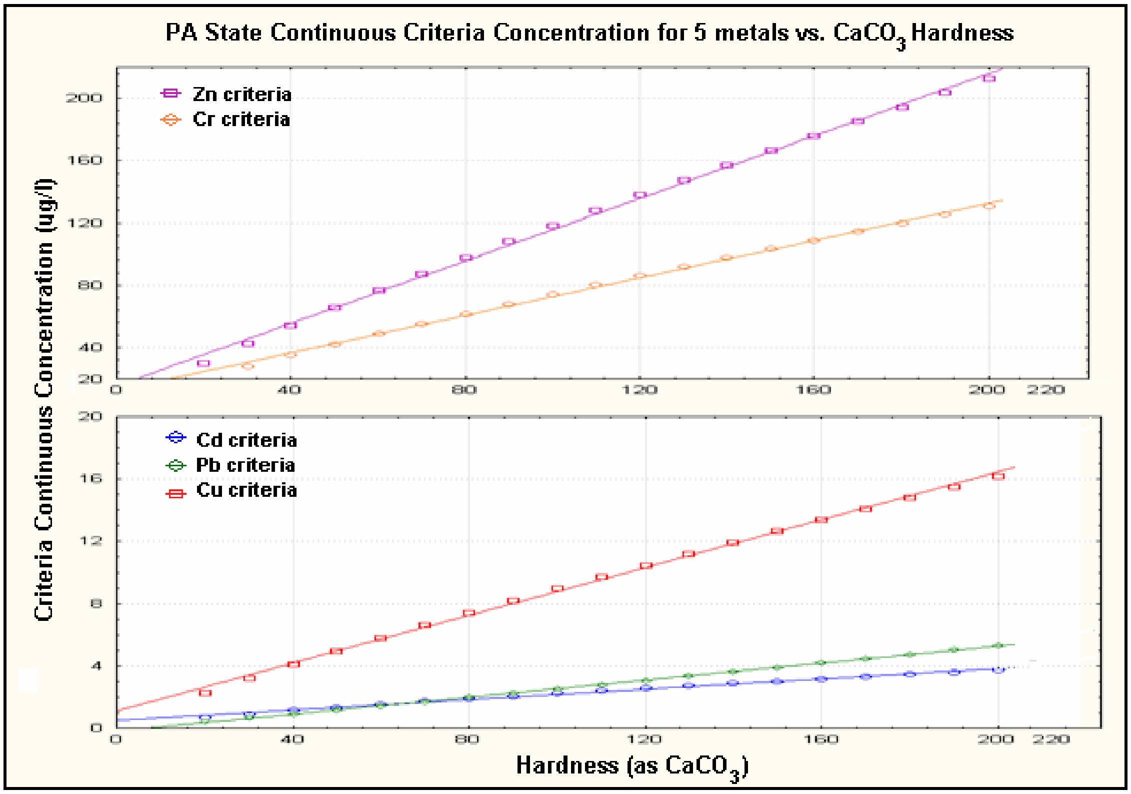


Figure 3-40 PADEP Hardness-based Criteria Continuous Concentrations for Five Toxic Metals (TTF CCR Section 5.3.7, Figure 5.7, Page 5-26)

Aluminum

The PADEP has established criteria for maximum concentrations for aquatic life acute exposure that states that the concentration of Al should not exceed 0.75 mg/L (National Recommended Water Quality Criteria, 2006). The USEPA requires that the concentration of Al should not exceed 0.087 mg/L for aquatic life chronic exposure. Water column Al concentrations were significantly higher in wet weather than in dry weather (Mann-Whitney test $Z_{2,699} = -13.28$, $p<.05$), which may be due to both natural and anthropogenic sources. Examination of paired dissolved and total recoverable Al concentrations from 45 samples collected from TTF shows that while total recoverable Al concentrations may often exceed 100 μg/L in wet weather, dissolved Al is rarely present in similar concentrations (Figure 3-41). This finding suggests that most Al is present in particulate form.

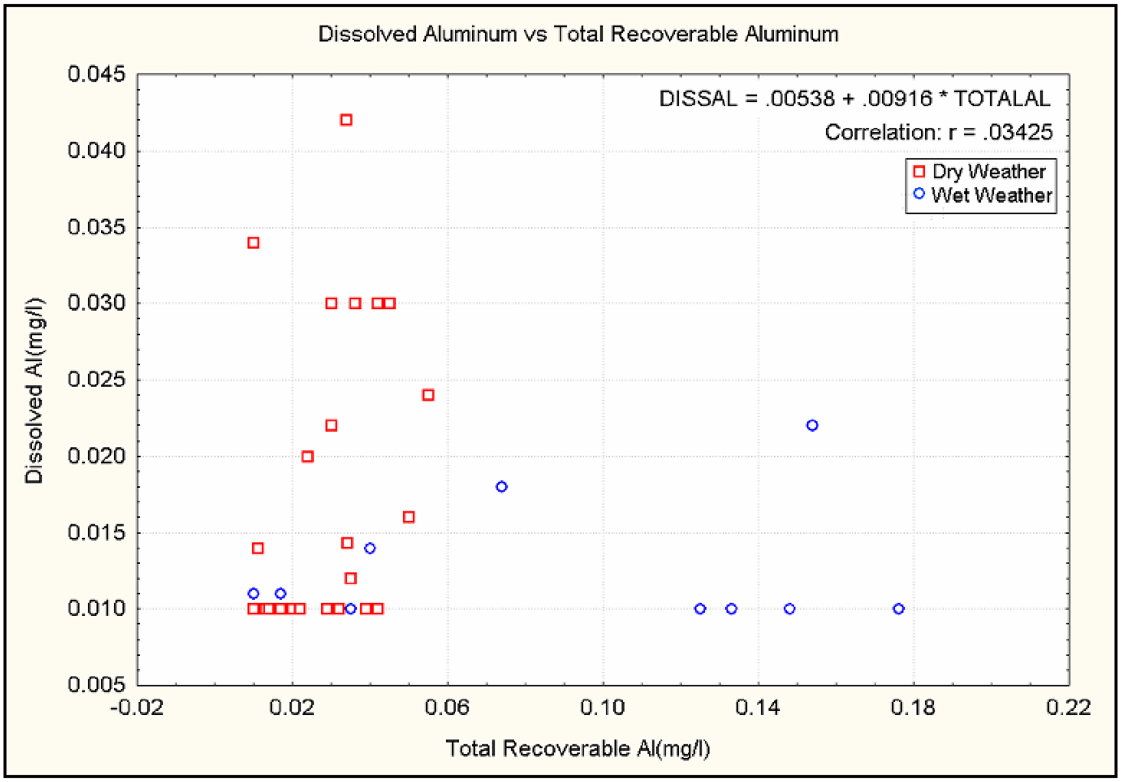


Figure 3-41 Scatterplot of Paired Dissolved Aluminum and Total Recoverable Aluminum Concentrations of Samples Collected from Eight Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.7.1, Figure 5.8, Page 5-27)

Al was detected in 643 of 701 samples from TTF (Table 3-66). Though 120 of 135 samples collected in wet weather were found to be in violation of water quality criteria, violations occurred with similar relative frequency in dry and wet weather because wet weather samples were much more numerous overall and dry weather criteria are far more stringent than wet weather criteria (87 μg/L and 750 μg/L, respectively).

The strong correlation between Al and TSS (Figure 3-42) suggests that most of the Al present in wet weather water samples may be due to suspended particulate Al. However, wet weather suspended solids loads consist of a mixture of urban stormwater, eroded upland soils, and streambank particles. It is impossible to determine individual Al contributions of these sources. State water quality criteria for Al are based upon total recoverable fractions rather than dissolved, partially because under experimental conditions, Brook Trout (Salvelinus fontinalis) experienced greater mortality with increased total Al concentration despite constant levels of dissolved Al (the form of particulate Al present in this experiment was Aluminum hydroxide, and experimental pH was low). Furthermore, USEPA has documented HQ waters that exceed WQ standards for Al (63FR 68353-68364). Al found in natural streams may be predominantly mica and clays, which are inert under normal stream conditions. As the TTF Watershed is rich in both mica and clay soils, and rarely experiences pH < 6.0, other factors should probably be ruled out before attributing biological impairment to Al toxicity.

Table 3-66 Summary of Toxic Metals Samples Collected in Dry and Wet Weather and Corresponding Number of Samples Found to have Concentrations Below Reporting Limits (TTF CCR Section 5.3.7.1, Table 5-12, Page 5-27)

Parameter	Number of Dry Samples	Number of Dry Non-Detects	Number of Wet Samples	Number of Wet Non-Detects
Total Al	149	22	552	36
Dissolved Al	55	26	12	7
Total Cd	129	129	605	560
Dissolved Cd	83	83	194	194
Total Cr	102	82	548	267
Dissolved Cr	46	45	76	76
Total Cu	154	0	609	0
Dissolved Copper	74	0	81	0
Total Pb	146	113	605	123
Dissolved Pb	65	65	76	59
Total Zn	143	8	528	6
Dissolved Zn	66	12	56	6

Al was not considered a parameter of concern in dry weather for aquatic life acute exposure because the water quality standard of 0.75 mg/L was never exceeded, however, Al was considered a parameter of concern in wet weather for aquatic life acute exposure because the standard was exceeded in 21.7% of the samples. Al was considered a concern in dry weather for aquatic life chronic exposure because the standard of 0.087 mg/L was exceeded in 10.1% of the dry weather samples.

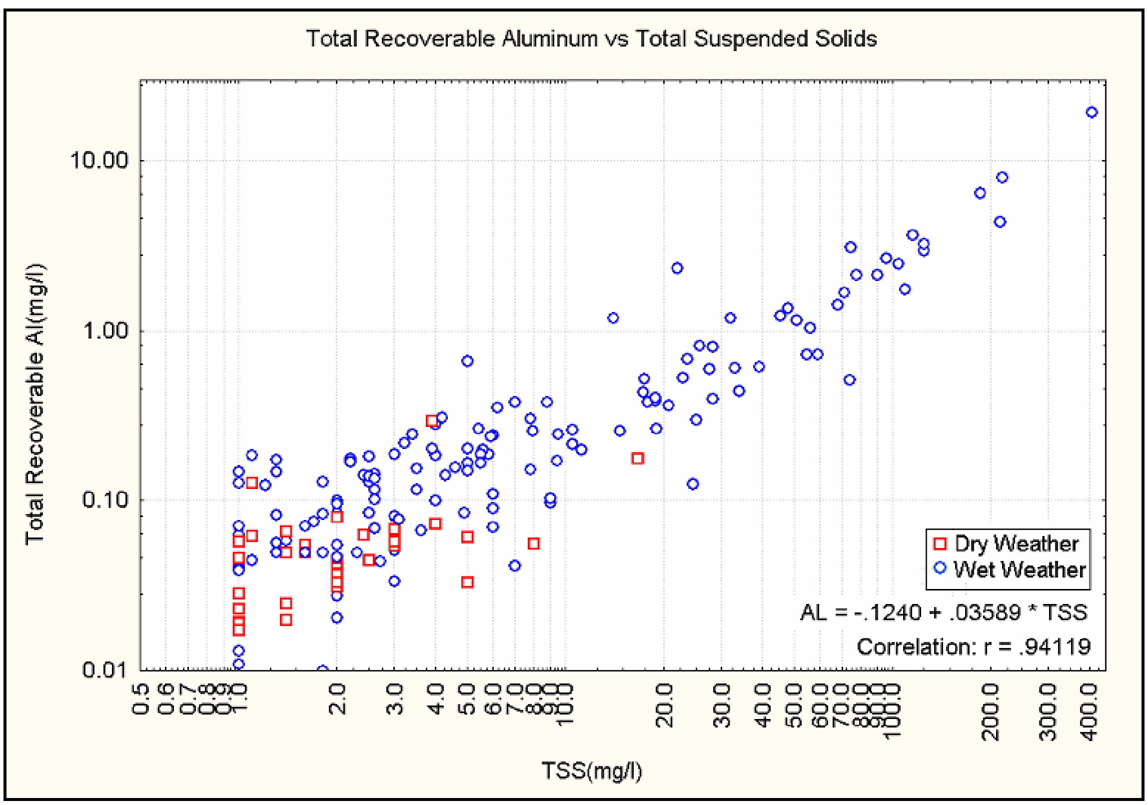


Figure 3-42 Scatterplot of Paired Total Recoverable Aluminum and Total Suspended Solids concentrations of samples collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.1 figure 5.9 page 5-28)

Copper

The PADEP has established Copper (Cu) concentration criteria for aquatic life acute exposure and aquatic life chronic exposure. Both criteria require a hardness correction. The standards that are stated below were calculated with 100 mg/L of $CaCO_3$ hardness. PADEP water quality criteria require that the concentration of dissolved Cu should not exceed 0.013 mg/L for the aquatic life acute exposure standard and 0.009 mg/L for the aquatic life chronic exposure standard. The USEPA also has an established criterion for maximum dissolved Cu concentration for human health standards of 1 mg/L, but there is equivalent state standard. Based on PADEP standards, Dissolved Cu is not considered a parameter of concern in dry weather for aquatic life acute exposure and aquatic life chronic exposure because the standards were all exceeded less than two percent of the time. Dissolved Cu is considered a parameter of potential concern in wet weather for aquatic life acute exposure because the standard was exceeded in 7.4% of the samples.

Cu was always detectable in TTF; all of the 763 samples collected in 2000-2004 had Cu concentration above reporting limits. Basic statistics for Total Cu and Dissolved Cu appear in Table 3-66 and outliers excluded from subsequent analyses are tabulated in Appendix D of the TTF CCR. Contamination was suspected in two samples where the ratio of dissolved to total Cu exceeded 2:1, and also in a dry weather sample at site TF500 where Total Cu concentration was 102 μg/L. Some samples lacked hardness data, so conservative hardness values were substituted for the purpose of comparing observed dissolved Cu to WQ criteria. These substitute hardness values were mean hardness minus one standard deviation, calculated separately for dry and wet weather (hardness data aggregated for all sites and dates).

In 2004, PWD reinstated separate determinations of total and dissolved fractions on metals samples collected as part of the discrete interval sampling program. PWD also conducted two rounds of intensive metals sampling during wet weather at site TF280, which is believed to be the most chemically impaired non-tidal site in the watershed. As of May 2005, 152 paired dissolved and total copper results were available. The ratio of dissolved Cu to total recoverable Cu was significantly higher in dry weather samples than in wet weather samples (t-test, $F(2,148)=2.809$, $p=.000039$). Furthermore, there was no strong relationship between dissolved and total recoverable Cu in wet weather samples (Figure 3-43). Despite total recoverable concentrations that ranged up to 200 μg/L, maximum observed concentration of dissolved Cu was 22 μg/L.

As Cu strongly associates with sediment, pore water/sediment toxicity should not be ignored as a potential stressor to benthic invertebrates. The only sensitive taxa that were consistently collected throughout the watershed (though densities were low) were tipulid larvae; these relatively large larvae are shredders, and enshroud themselves in leaf packets. A diet and microhabitat rich in organic acids may confer resistance to heavy metal pollution. Mayflies, on the other hand, have been characterized as very sensitive to metals pollution (Clements et al. 1988, Clements et al. 1990) and the obvious disparity between TTF sites and reference sites with respect to number and abundance of mayfly taxa may be attributable to heavy metal pollution. Sediment metals concentrations and reference site chemistry data are needed before any conclusions can be drawn.

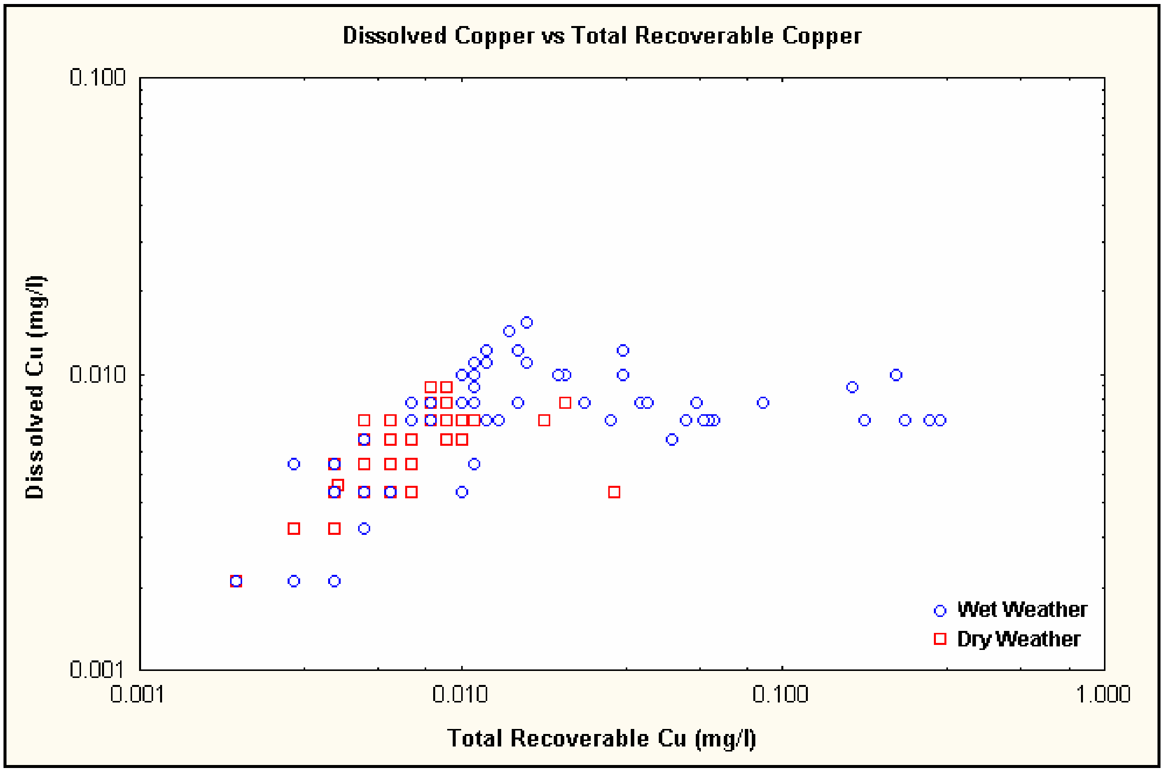


Figure 3-43 Paired Dissolved and Total Recoverable Copper Concentration of Samples Collected from 8 Sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.4 figure 5.10 page 5-31)

Cu toxicity was also investigated using the Biotic Ligand Model (BLM) (DiToro et al. 2001). Data were lacking for some model input parameters, so conservative values were substituted. Many water chemistry parameters can affect Cu toxicity, particularly other ions and organic molecules that tend to compete with gill ligand bonding sites for available Cu. Figure 3-44 illustrates the effects of pH and temperature on Cu bioavailability and toxicity. BLM data were used only to determine whether Cu toxicity could affect the biology of TTF Watershed, not to develop alternative water quality criteria. USEPA is in the process of developing new WQ criteria for Cu incorporating the BLM with appropriate margins of safety for protecting aquatic life.

The BLM was used to determine the LD50 of dissolved copper to Fathead Minnow (Pimephales promelas), and two cladoceran microcrustaceans (Ceriodaphnia dubia, and Daphnia pulex). For most parameters data entered into the model came from samples collected from TTF Watershed. Data from each sample were entered into the model as a separate case and the LD50 of Cu was determined for each case. When data from TTF Watershed were not available estimates from nearby streams were used. Parameters for which estimates were used included: (Dissolved Organic Carbon) DOC, Percent of DOC contributed by Humic Acids, Potassium, and Chloride. DOC competes for Cu with gill ligand sites and is positively correlated to the LD50 of Cu, therefore a conservative estimate of 2.9 mg/L from French Creek was used in place of 5.4 mg/L , an estimate given for PA streams (USEPA document #822-B-98-005). Due to the lack of DOC characterization data, ten percent was used for the relative proportion of DOC made up by Humic acids as recommended by the model documentation (DiToro et al. 2001). Model input values for Potassium (K) were estimated by averaging potassium values from Pickering Creek, Trout Creek, and Wissahickon Creek, though K currently has no direct effect on metal toxicity in the BLM.

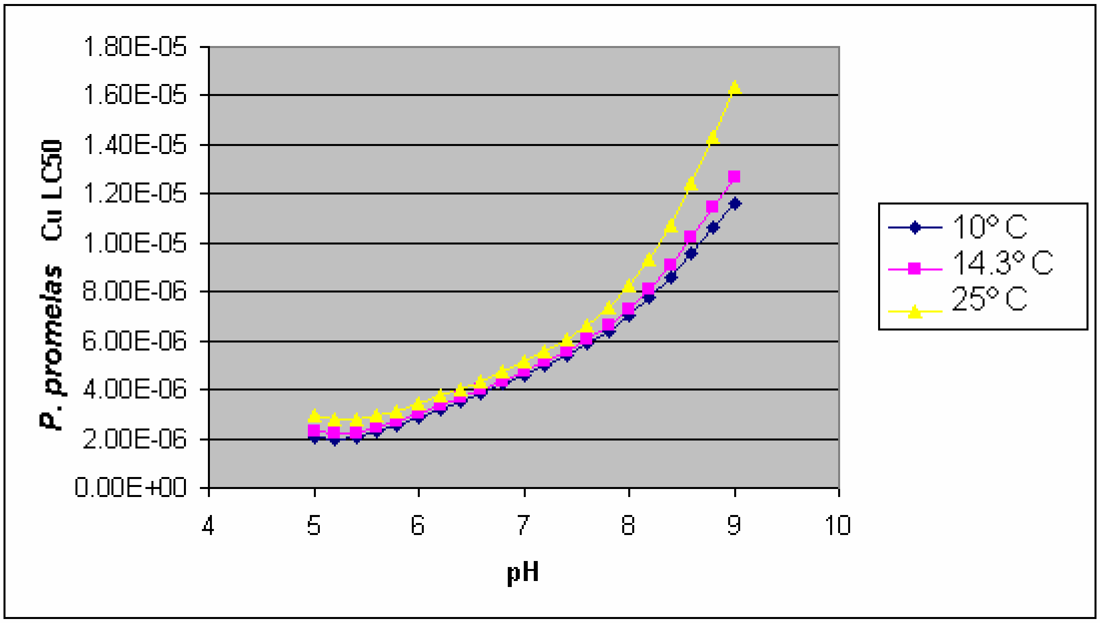


Figure 3-44 Effects of pH and Temperature on Copper Toxicity to Fathead Minnows (TTF CCR section 5.3.7.4 figure 5.11 page 5-32)

Chloride model input values were calculated by averaging values from Pickering Creek and Trout Creek. When comparing dissolved Cu concentrations from Tookany/Tacony-Frankford Watershed to predicted LD50, the predicted LD50 concentration was reduced by an order of magnitude (margin of safety). Even with this margin of safety, no sample had dissolved Cu concentration above the LD50 for any of the target organisms.

Zinc

The PADEP has established criteria for both aquatic life acute exposure and aquatic life chronic exposure. Both aquatic life acute exposure and aquatic life chronic exposure require a hardness correction. The standards that are stated below were calculated with 100 mg/L of CaCO3 hardness. The criteria requires that the concentration of dissolved Zn not exceed 0.12 mg/L for the aquatic life acute exposure and 0.12 mg/L for the aquatic life chronic exposure. The USEPA has an established maximum criterion for dissolved Zn concentration for human health standards of 5 mg/L, but there is no equivalent state standard. Based on the state standards, Dissolved Zn is considered a parameter of potential concern in dry weather for both aquatic life acute exposure and aquatic life chronic exposure because the standards were exceeded in 2.7% and 4.1% of the dry weather samples, respectively. Dissolved Zn is not considered a parameter of concern in wet weather for aquatic life acute exposure because the standard was exceeded in less than 2% of the samples.

Zn is usually present in surface waters of TTF; only 14 of 671 individual total recoverable Zn samples and 18 of 122 dissolved Zn samples from TTF had Zn below reporting limits (Table 3-66), though concentrations were relatively small.

In the TTF Comprehensive Characterization Report, contamination was suspected in four sets of samples collected in 2004, where dissolved concentrations were consistently greater than total recoverable concentrations in 30 of 32 samples (Figure 3-45). Dates and sample information for these sample dates are summarized in Appendix D of the TTF CCR. Of 15 dissolved Zn samples exceeding WQ criteria, 14 are likely to have been affected by contamination. If these samples are

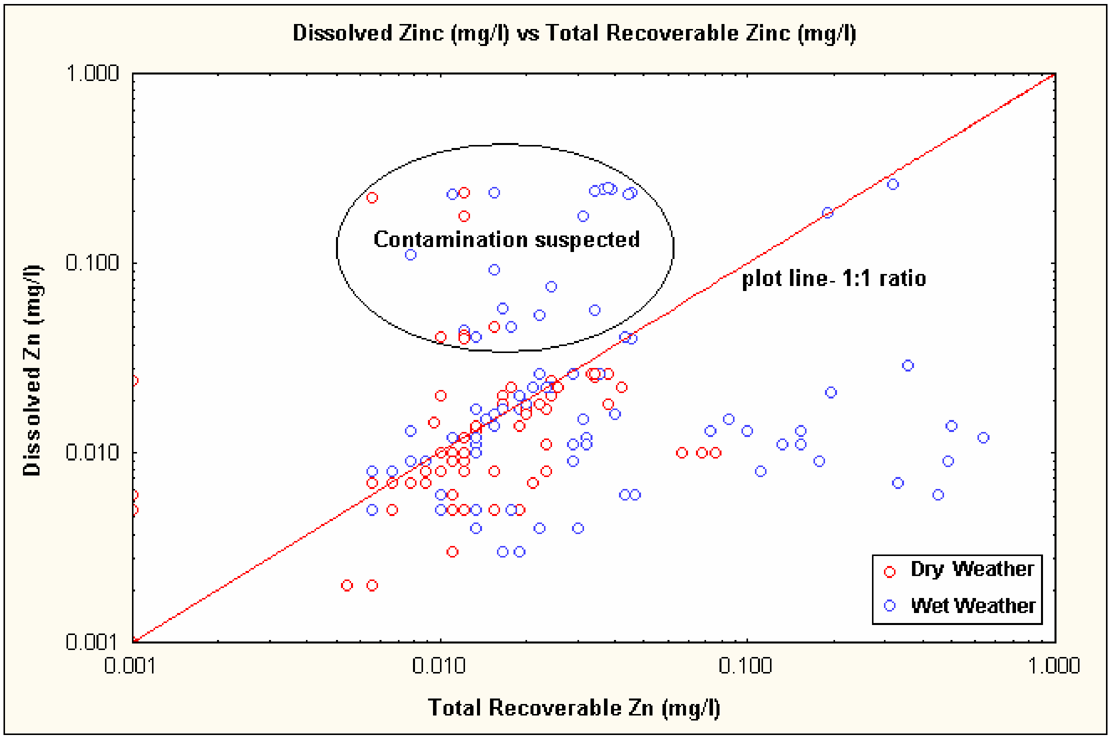


Figure 3-45 Paired Total Recoverable and Dissolved Zinc Concentrations of Samples collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.6 figure 5.12 page 5-34)

ignored, dissolved Zn/total recoverable Zn ratios more closely mirror those of other metals (i.e., higher in dry weather than in wet weather).

Discrepancies occurred with both dry and wet weather samples. Bench sheets did not indicate any problems with samples or the instrumentation, and all QC checks were passed. As samples were preserved and stored, the PWD Bureau of Laboratory Services (BLS) was able to re-analyze these samples, obtaining similar results. The analyst visually confirmed the presence of settled solids in sample containers used for total recoverable metal, while sample containers used for dissolved metals were visually clear. A series of subsequent filter blank trials showed filters used to prepare dissolved metals samples may have leached Zn, but the magnitude of the difference in total and dissolved concentrations was much too great to be explained by filter contamination. The source of contamination remains unknown.

The BLM was used to estimate the toxicity of dissolved Zn to Fathead Minnows (Pimephales promelas), rainbow trout (Oncorhynchus mykiss), and cladoceran (Daphnia magna). Input data were compiled or estimated in the same manner as dissolved copper model input data. An order of magnitude safety factor was applied to the LD50 concentrations generated by the model and the resulting concentration was compared with dissolved zinc data collected from the TTF Watershed. Even with this safety margin, no observed dissolved Zn concentrations exceeded the calculated LD50 for the studied organisms.

Fecal Coliform and E. coli Bacteria

The PADEP has established maximum concentration criteria for fecal coliform during both swimming season and non-swimming season of 200 CFU/100mL and 2000 CFU/100mL, respectively. Based on data from numerous sources (e.g., USEPA, USGS, USDA-NRCS, volunteer monitoring organizations, etc.), it appears likely that many, if not most, southeastern PA streams would be found in violation of water quality criteria for fecal coliform bacteria concentration during the swimming season given sufficient sampling effort. PWD has expended considerable resources toward documenting concentrations of fecal coliform bacteria and *E. coli* in Philadelphia's watersheds. The sheer amount of data collected allows for more comprehensive analysis and a more complete picture of the impairment than does the minimum sampling effort needed to verify compliance with water quality criteria. In keeping with the organizational structure of the watershed management plan, fecal coliform bacteria analysis has been separated into dry (Target A) and wet weather (Target C) components, defined by a period with at least 48 hours without rain as measured at the nearest gage in PWD's rain gage network.

Dry Weather Fecal Coliform Bacteria (Target A)
Fecal coliform was considered a parameter of concern during the dry weather non-swimming season because the standard of 2000 CFU/100mL was exceeded in 3.9% of the samples. In the swimming season, Fecal coliform was considered a parameter of concern because the standard of 200 CFU/100mL was exceeded in 92% of the samples.

The geometric mean of 63 fecal coliform bacteria concentration samples collected from TTF Watershed in dry weather during the non-swimming season from 2000-2004 did not exceed 2000 CFU/100 mL (Table 3-67). Only one sample, collected from site TF280, exceeded 2000 CFU/100 mL (estimated fecal coliform concentration 2100 CFU/100mL). In contrast, dry weather geometric mean fecal coliform concentration exceeded water quality criteria of 200 CFU/100 mL during the swimming season at all sites except TFJ110 (Table 3-68). An improvement in mean fecal coliform concentration can be seen in both swimming and non-swimming season when data from 2000-2004 is compared to historical data from 1970-1980 (t-test $F_{2,140}= 5.6$, $p <0.05$; $F_{2,163} =3.76$, $p <0.05$ respectively).

Table 3-67 Fecal Coliform Concentration (CFU/100mL) Dry Weather Non-swimming Season (1 Oct. - 30 Apr.) (TTF CCR section 5.3.4.1 table 5.8 page 5-17)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	9	600	286	290	30	2100	777
TF500	8	468	226	330	10	1500	500
TF620	10	259	187	225	30	550	187
TF760	8	139	83	105	10	390	129
TF975	9	408	312	450	90	900	276
TF1120	9	229	186	200	40	410	131
TFJ110	6	55	42	65	10	90	34
TFM006	4	293	231	210	100	650	244

Collectively, mean fecal coliform bacteria concentration of sites in the City of Philadelphia were significantly higher during the swimming season than during the non-swimming season ($F_{2,68}= 1.48$, $p=.000016$). Sites in Montgomery County follow the same temporal pattern and have a significantly higher mean during the swimming season ($F_{2,64}=1.83$, $p <0.05$).

Table 3-68 Fecal Coliform Concentration (CFU/100mL) Dry Weather Swimming Season (1 May - 30 Sept.) (TTF CCR section 5.3.4.1 table 5.9 page 5-17)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	12	1474	773	425	190	4800	1591
TF500	6	2655	2003	2300	800	6900	2261
TF620	15	833	700	700	340	2700	644
TF760	5	562	514	440	300	1000	275
TF975	13	1620	1130	860	450	6000	1652
TF1120	11	632	541	450	260	1500	409
TFJ110	4	175	173	185	130	200	31

Wet Weather Fecal Coliform Bacteria Concentration (Target C)

Fecal coliform is considered a parameter of concern in wet weather during both the swimming and non-swimming season because the standard was exceeded in 97% and 67% of the samples, respectively.

Wet weather fecal coliform concentration of 480 samples collected during the swimming season (i.e., 5/1 - 9/30) and 140 samples collected during the non-swimming season were estimated. Geometric mean fecal coliform concentration of all samples collected in wet weather during the swimming season exceeded the 200 CFU/100mL water quality criterion (Figure 3-46, Table 3-69). All sites except TFJ110 had geometric mean fecal coliform concentration greater than $3x10^3$ CFU/100mL. Sites TF280 and TFM006 showed evidence of severe wet weather sewage impacts (estimated geometric mean fecal coliform concentration 23,773 and 13,787 CFU/100mL respectively).

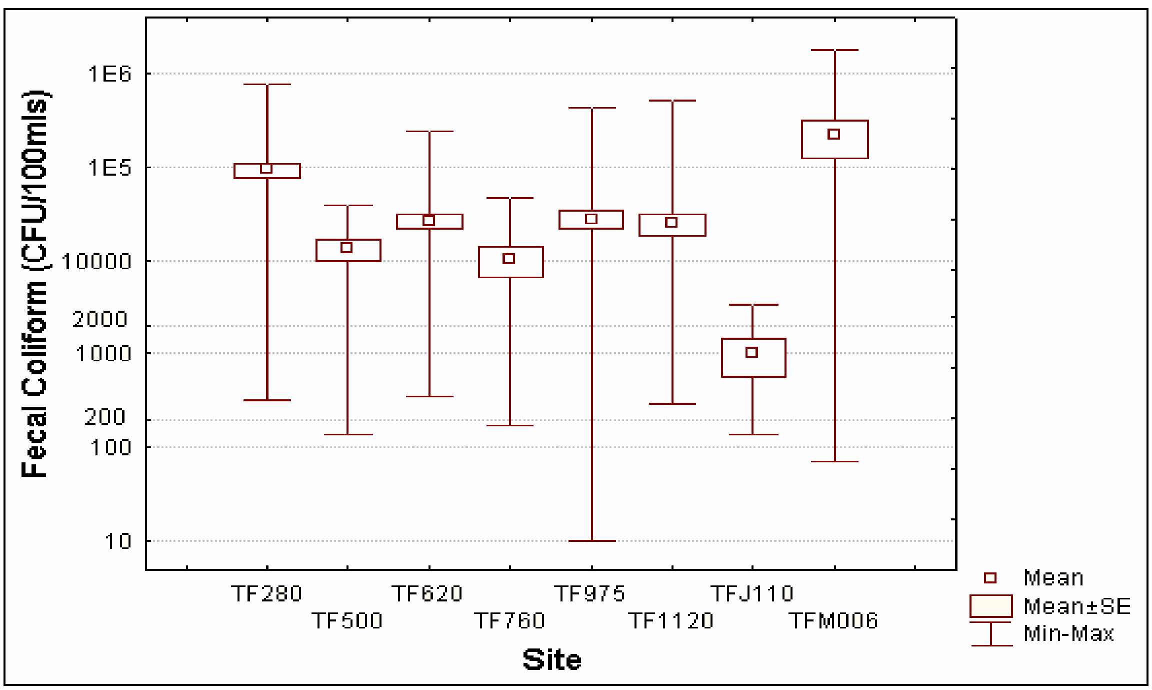


Figure 3-46 Fecal Coliform Bacteria Concentrations of Samples Collected from 8 sites in TTF Watershed in Wet Weather during the Swimming Season, 2000-2004 (TTF CCR section 5.3.4.2 figure 5.4 page 5-18)

Table 3-69 Fecal Coliform Concentration (CFU/100mL) Wet Weather, Swimming Season (1 May - 30 Sept.) (TTF CCR section 5.3.4.2 table 5.10 page 5-19)

	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	104	95132	23774	32000	320	780000	163153
TF500	14	13766	6199	8500	140	40000	13323
TF620	98	27064	8808	8250	350	250000	44437
TF760	14	10446	3357	2950	170	48000	14147
TF975	107	28750	7275	6500	10	430000	61335
TF1120	110	25256	5503	4850	290	520000	66313
TFJ110	8	1004	580	455	140	3500	1219
TFM006	27	223534	15049	11200	70	1820000	497239

Surface water samples collected at site TFM006 in dry weather (n=6) do not indicate severe problems, however, results from a targeted wet weather sampling event 8/30/04-9/1/04 suggest that sewage impacts in wet weather are still a serious problem at this stormwater outfall (Figure 3-47). Source(s) of these sewage inputs remain unknown. PWD's Waterways Restoration Team completed a streambank restoration project at this outfall in 2005, and removal of a large plunge pool was one component of the restoration design. It is hoped that reduction of stagnant water will reduce the influence of small wet weather sewage impacts on dry weather fecal coliform concentrations.

Mean wet weather fecal coliform concentration during the swimming season was significantly greater than that of the non-swimming season both within the City of Philadelphia ($F_{2,316}$= 1.11, p <0.05) and in Montgomery County ($F_{2,302}$= 1.35, p= 0.002). However geometric mean fecal coliform concentrations during the non-swimming season exceeded 2,000 CFU/100mL at sites TF280, TF500, TF620, TF975 and TF1120 (Table 3-70). Although few samples were collected in wet weather during the non-swimming season, Sites TFM006 (geometric mean 137, n=2) and TFJ110 (geometric mean 51, n=3) did not exceed water quality standards. Improvements in mean fecal coliform concentration were observed in both the swimming (historical n=22, modern n=482) and non-swimming season when data from 2000-2004 was compared with historical data from 1970-1980 (t-test $F_{2,502}$=1.08, p=.004 and $F_{2,164}$=1.24, p=.002 respectively).

Table 3-70 Fecal Coliform Concentration (CFU/100mL) Wet Weather, Non-swimming Season (1 Oct. - 30 Apr.) (TTF CCR section 5.3.4.2 table 5.11 page 5-21)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std.Dev.
TF280	30	19959	4439	13150	20	70000	22417
TF500	9	14734	2439	3800	140	91000	29570
TF620	34	9038	3397	4000	110	35000	11028
TF760	9	4721	1311	3100	100	22000	6992
TF975	34	10361	3785	4750	100	49000	13111
TF1120	19	11272	3189	6200	50	47000	13559
TFJ110	3	60	51	40	30	110	44
TFM006	2	170	137	170	70	270	141

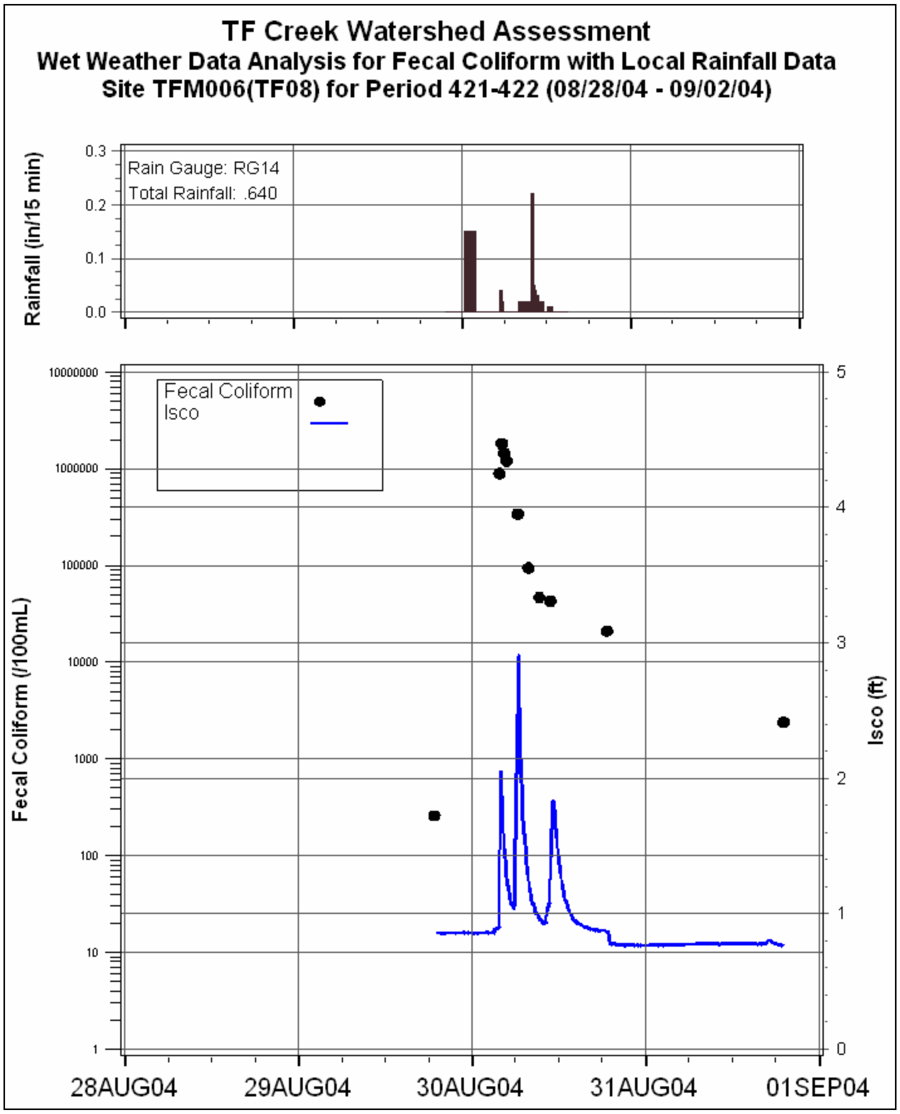


Figure 3-47 Fecal coliform analysis for wet weather event on August 30, 2004 at TFM006 (TTF CCR section 5.3.4.2 figure 5.5 page 5-20)

<u>Future Investigation of Bacteria Conditions in the Tacony and Frankford Creeks</u>
Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the lower Tacony Creek and the Frankford Creek. In the future, work efforts will be expanded to include the development of informational total maximum daily load assessments for bacteria in the watershed, both for loadings from the City as well as from dischargers to the Tookany Creek and other upstream tributaries. Progress and results of this work and any proposed remedial control actions will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature
Continuous water quality monitoring results suggest that temperatures in TTF sometimes exceed maximum WQ criteria and therefore is a parameter of potential concern. But increases of 2°F over a one hour period are common due to natural temperature fluctuations. Flow modifications have

probably reduced the influence of groundwater on baseflow water temperature. Dam construction and riparian buffer removal have also probably resulted in enhanced solar heating of stream water.

3.4.2.1.3 Biological Assessment of the TTF Watershed

Though TTF Watershed fish and benthic macroinvertebrate data suggest that many taxa have been extirpated or nearly extirpated in the past century, historical information to support these findings is generally lacking. There are simply no data to indicate what the biological communities of TTF Watershed looked like prior to changes wrought by man. While some measures of community structure (e.g., diversity indices) may provide meaningful information alone, conclusions of most analyses and metrics are enhanced by, or require, comparison to an unimpaired reference site. These unimpaired reference sites are often difficult to identify in southeast Pennsylvania due to extensive development and agricultural land uses. The most robust application of the reference site approach is a pair of sites located upstream and downstream of a suspected source of impairment. The downstream site in this scenario can be assumed to have a rather constant source of colonists, or "drift" from the upstream site, and all life stages of fish and macroinvertebrates are prone to displacement from the upstream site to the downstream site.

As applied to TTF Watershed, reference site-based biological indexing methods assume that all similar habitats within a given ecoregion will have similar communities (absent major stressors) and that recovery of biological communities, particularly benthic macroinvertebrate communities, will occur quickly once stressors are removed. However, in regions where impairments occur watershed-wide and most first order streams have been eliminated, one cannot assume that study sites have a constant upstream source of colonists. Therefore, the most likely means of colonization of TTF Watershed by rare or extirpated macroinvertebrate taxa is by winged adults, and the most likely means of re-colonization by rare or extirpated fish taxa is by passive dispersal (i.e., purposeful or incidental inter-basin transfer by man).

TTF Watershed is at the center of a region of widespread impairment due to urbanization. Some areas of the watershed may have water quality suitable for re-establishment of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT), but these taxa are generally much more abundant west of the Schuylkill River than in the Philadelphia region. Sites in TTF Watershed were compared to reference sites on French Creek and Rock Run in Chester County, PA (Figure 3-48 and Appendix F of the TTF CCR).

Reference sites were chosen to represent a range of stream drainage areas, yet extensive impervious cover in portions of TTF Watershed complicates these comparisons. Due to baseflow suppression, piping of tributaries, exaggerated storm flows and widespread erosion, sites in the urbanized TTF Watershed are difficult to categorize according to traditional frameworks (e.g., stream order, link magnitude, drainage area, geomorphological attributes). These details are addressed in greater detail in Section 7.1 Habitat Assessment of the TTF CCR. TTF Watershed is only linked to the tidal Delaware River and is considered a warm water stream, while the reference sites have better connectivity and are classified as trout stocking fisheries or high quality trout stocking fisheries.

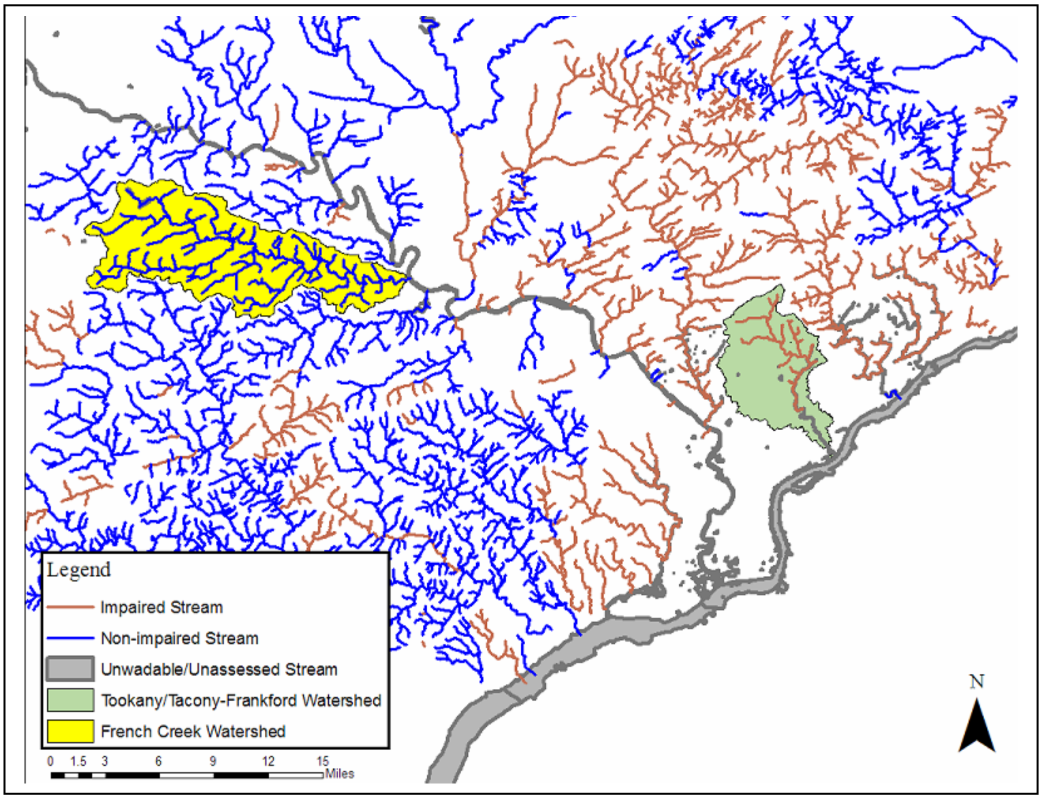


Figure 3-48 Southeastern PA stream segments in TTF Watershed, French Creek Watershed, and the surrounding region showing attainment status from PADEP 2004 List of Waters (formerly 303d list). (TTF CCR section 6.2 figure 6.1 page 6-3)

Benthic Macroinvertebrates Assessment

A total of 2,137 individuals from 19 taxa were identified during the 2004 benthic macroinvertebrate survey of TTF Watershed. The average taxa richness of the watershed was 7. Overall, moderately tolerant (91%) and generalist feeding taxa (96%) dominated the watershed. The average Hilsenhoff Biotic Index (HBI) of all assessment sites was 6.16. EPT taxa were absent throughout the watershed (Table 3-71). One site had one modified EPT taxon present. Modified EPT taxa are EPT taxa with Hilsenhoff Biotic Index score less than or equal to four. Seven of 12 sites included in the present study were sampled by PWD in November 2000 using the same protocols, allowing some rough comparisons to be made. Most sites had reduced taxa richness and metric scores compared to year 2000 samples.

Chironomidae (midges) dominated the benthic macroinvertebrate communities within the watershed (percent contribution ranged from 63% to 97%). Net-spinning caddisflies (Hydropsychidae), isopods, amphipods, tipulids, gastropods, and oligochaetes were also present throughout the watershed but in very low abundance. Benthic macroinvertebrate communities of TTF Watershed are thoroughly dominated by midges, suggesting stressors are affecting survival of more sensitive taxa.

Tolerance/intolerance measures are intended to be representative of relative sensitivity to perturbation and may include numbers of pollution tolerant and intolerant taxa or percent composition (Barbour *et al.* 1999). Moderately tolerant individuals (91%) dominated

Table 3-71 Summary of Benthic Macroinvertebrate Metric Scores from 12 sites in TTF Watershed and Reference Sites in French Creek Watershed, Spring 2004 (TTF CCR section 6.4 table 6.4 page 6-15)

Site	Taxa Richness	Modified EPT Taxa	Hilsenhoff Biotic Index (modified)	Percent Dominant Taxon	Percent Modified Mayflies	Biological Quality (%)	Biological Assessment	Habitat Quality (%)	Habitat Assessment
TF324	6	0	8.92	72.15 (*Tubificidae*)	0.00	0.00	Severely Impaired	31.84	Non-Supporting
TF396	13	0	5.79	63.31 (*Chironomidae*)	0.00	0.00	Severely Impaired	74.53	Supporting
TF500	4	0	5.98	96.99 (*Chironomidae*)	0.00	0.00	Severely Impaired	62.03	Partially Supporting
TF620	5	0	5.96	96.11 (*Chironomidae*)	0.00	0.00	Severely Impaired	72.41	Partially Supporting
TF827	6	0	5.94	95.22 (*Chironomidae*)	0.00	0.00	Severely Impaired	58.25	Non-Supporting
TF975	8	0	5.94	89.09 (*Chironomidae*)	0.00	0.00	Severely Impaired	54.95	Non-Supporting
TF1120	5	0	6.04	95.58 (*Chironomidae*)	0.00	0.00	Severely Impaired	58.02	Non-Supporting
TF1270	7	0	5.91	91.79 (*Chironomidae*)	0.00	0.00	Severely Impaired	48.03	Non-Supporting
TFU010	8	0	5.99	93.12 (*Chironomidae*)	0.00	0.00	Severely Impaired	48.46	Non-Supporting
TFM006	5	0	5.94	95.59 (*Chironomidae*)	0.00	0.00	Severely Impaired	38.60	Non-Supporting
TFR064	9	0	5.93	89.25 (*Chironomidae*)	0.00	0.00	Severely Impaired	64.69	Partially Supporting
TFJ013	11	1	5.57	63.24 (*Chironomidae*)	0.00	20.00	Moderately Impaired	60.53	Partially Supporting
FCR025	25	10	4.47	42.24 (*Chironomidae*)	27.44	Reference Sites			
FC1310	21	9	3.69	21.60 (*Hydropsyche*)	13.59				

macroinvertebrates communities of TTF Watershed. Sensitive taxa were poorly represented (2%), suggesting watershed-wide perturbation.

The Hilsenhoff Biotic Index (HBI) is a metric used to determine the overall pollution tolerance of a site's benthic macroinvertebrate community. The HBI is oriented toward the detection of organic pollution. The HBI can range from zero (very sensitive) to ten (very tolerant). Differences in HBI score between reference and assessment sites greater than 0.71 indicate impairment. Mean HBI score of sites within TTF Watershed was 6.16. Dominance by moderately tolerant individuals and general lack of pollution-sensitive taxa contributed to the elevated HBI. In comparison, the mean reference site HBI score was 4.08. When compared to reference conditions, TTF Watershed mean HBI exceeded reference site mean HBI by 2.08, indicating severe impairment overall.
While HBI is very effective in determining whether a site is impaired relative to a reference site, HBI scores are not very useful in comparing impaired urban sites to one another, as these systems typically have one to three dominant taxa with similar HBI scores. For example, 90% of benthic macroinvertebrate samples collected by PWD in urban streams had HBI scores between 5 and 6.

This lack of resolution is exacerbated when chironomids are not identified beyond the family level, as has been PWD practice.

Fish Assessment

During the 2004 Tacony-Frankford Watershed fish assessment, PWD collected a total of 9774 individuals representing 17 species in 7 families. Blacknose dace (*Rhinichthys atratulus)* and mummichog (*Fundulus heteroclitus),* two taxa extremely tolerant of poor stream conditions, were most abundant and comprised over half (56%) of all fish collected. Other common species included white sucker (*Catostomus commersoni*), satinfin shiner (*Cyprinella analostana*), banded killifish (*Fundulus diaphanus*), and swallowtail shiner (*Notropis procne*). Of 17 species collected in the watershed, four species comprised over 80% of the entire fish assemblage. Similarly, five species made up greater than 80% of the total fish biomass, with redbreast sunfish (*Lepomis auritus*) and American eel (*Anguilla rostrata*) contributing 42% of the biomass. American eel, blacknose dace, and satinfin shiner were found at all sites while bluegill sunfish (*Lepomis macrochirus*) and green sunfish (*L. cyanellus*) were each only found at one site and represented by a single individual. Two individual tessellated darters (*Etheostoma olmstedi*) were collected at two different sites (TF500, TF620) in the watershed; however, scientists from the Academy of Natural Sciences of Philadelphia likely stocked these fish as part of a reintroduction effort. The presence of only one tessellated darter at each site suggests that they have not become established and therefore were not included in the scoring criteria for the Index of Biotic Integrity. Overall, the non-tidal TTF Watershed displayed the lowest fish diversity (*i.e.*, species richness) of all the watersheds in Philadelphia.

Trophic composition evaluates quality of the energy base and foraging dynamics of a fish assemblage. This is a means to evaluate the shift towards more generalized foraging that typically occurs with increased degradation of the physicochemical habitat (Barbour, *et al.*, 1999). For example, the Tacony-Frankford fish assemblage was dominated by generalist feeders (69%) with insectivores composing 30% and top carnivores at less than 1% (Table 3-72). Generalists become dominant and top carnivores become rare when certain components of the food base become less reliable (Halliwell *et al.*, 1999). Relative abundance of insectivores decreases with degradation in response to availability of the insect supply, which reflects alterations of water quality and instream habitat (Daniels, *et al.* 2002). The near absence of insectivores in the two upstream-most sites illustrates this point. Trophic composition was poor compared to reference sites. Though community composition varied between sites, the fish assemblage in TTF Watershed was highly skewed towards a pollution tolerant, generalist feeding community.

Tolerance designations describe the susceptibility of a species to chemical and physical perturbations. Intolerant species are typically first to disappear following a disturbance (Barbour, *et al.*, 1999). For example, at least 70% of the fish collected at each monitoring station in TTF Watershed were classified as "tolerant", and no "intolerant" species were collected (Figure 3-49). Moderately tolerant individuals were absent from the lowermost (TF280) and uppermost (TF1120) stations, and represented less than one percent (TF396) to 29% (TF500) of the assemblage at the remaining five sites. Furthermore, with approximately 91% of the fish assemblage composed of tolerant individuals, this watershed had the greatest percentage of fishes tolerant of poor stream conditions in all of Philadelphia's watersheds.

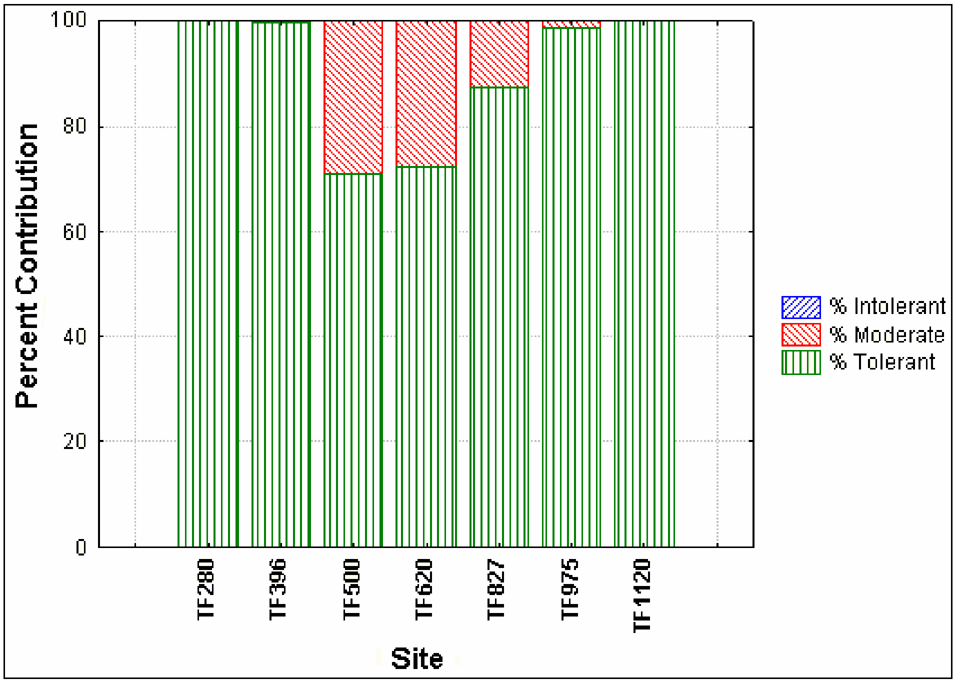


Figure 3-49 Fish Tolerance Composition of the TTF Watershed (TTF CCR section 6.3 figure 6.3 page 6-7)

The Index of Biotic Integrity (IBI) is useful in determining long-term effects and coarse-scale habitat conditions because fish are relatively long-lived and mobile. A site with high integrity (*i.e.* high score) is associated with communities of native species that interact under natural ecosystem processes and functions (Karr, 1986). Since biological integrity is closely related to environmental quality, assessments of integrity can serve as a surrogate measurement of health (Daniels, *et al.* 2002). The mean IBI score for TTF Watershed was 21 (out of 50), placing it in the “poor” category for biotic integrity. Low diversity, absence of benthic insectivorous species, absence of intolerant species, skewed trophic structure dominated by generalist feeders, high percentage of individuals with disease and anomalies, and high percentage of dominant species are characteristics of a fish community with "poor" biotic integrity. Spatial trends showed that only two sites received a "fair" IBI score, both centrally located within the watershed. Similar spatial trends were seen in Modified Index of Well-Being and Shannon Diversity Index values, which are measures of diversity and abundance. These indices were lowest in the lower and upper monitoring stations and highest in the middle of the watershed. This was to be expected because diversity is typically lower in upstream/smaller reaches of southeast Pennsylvania (Whiteside and McNatt, 1972; Platts, 1979). Overall, monitoring stations in the central portion of the watershed had higher biological integrity than downstream and upstream stations.

Table 3-72 Fish Community Attributes, Sampling Information, and Metric Scores for 7 Sites in TTF Watershed and 3 Reference Sites in French Creek Watershed (TTF CCR section 6.3 table 6.2 page 6-8)

Metric	FC472	FC1310	FCR025	TF324	TF396	TF500	TF620	TF827	TF975	TF1120	Avg(TF)
Total Number of Fish Species*	22	18	18	6	9	13	12	9	10	5	9
Number of Benthic Insectivorous Species**	5	4	3	0	0	0	0	0	0	0	0
Number of Water Column Species	3	5	2	2	4	6	5	3	3	1	3
Number of Intolerant/Sensitive Species	3	4	3	0	0	0	0	0	0	0	0
Percent White Sucker	7.50	11.39	2.90	0.12	0.00	0.74	4.00	12.35	16.23	0.80	5
Percent Generalists	34.58	53.42	57.56	98.65	92.59	26.08	36.00	66.20	97.90	99.08	74
Percent Insectivores	37.56	35.02	38.77	1.11	7.33	72.11	63.41	31.47	1.81	0.10	25
Percent Top Carnivores	27.86	11.56	3.67	0.25	0.08	1.81	0.59	2.33	0.29	0.82	1
Percent Individuals with Disease and Anomalies	6.97	2.83	14.54	2.34	4.36	3.57	4.49	5.71	8.78	8.98	5
Percentage of Dominant Species	14.40	14.98	29.70	98.40	90.62	37.81	37.22	41.00	79.33	86.50	67
IBI Score	Reference Streams			16	20	34	30	22	14	14	21
Integrity Class				POOR	POOR	FAIR	FAIR	POOR	POOR	POOR	POOR
Area (m^2)	1420.14	1192.50	400.00	1972.71	1123.52	1046.19	1208.14	1327.33	1163.05	630.81	1210
Density (# Individuals/m^2)	0.28	0.98	1.70	0.41	1.08	1.69	1.70	0.65	1.80	1.55	1
Number Of Individuals	402.00	1168.00	681	813.00	1215.00	1763.00	2050.00	858.00	2095.00	980.00	1396
Total Biomass (g)	17612.56	9413.91	5040	4917.13	1219.66	13267.95	16001.37	9939.68	11270.18	7183.74	9114
Biomass per m^2	12.40	7.89	12.60	2.49	1.09	12.68	13.24	7.49	9.69	11.39	8
Modified Index Of Well-Being (MIwb)	12.21	12.21	11.37	0.00	2.71	10.22	10.58	9.37	6.75	0.00	6
Shannon-Weiner Diversity Index (H')	2.84	2.51	2.10	0.10	0.44	1.29	1.41	1.45	0.70	0.46	1
Number of Cyprinid Species	9	10	8	2	4	7	7	5	5	3	5
Percent Resident Species	92.54	100.00	99.12	100.00	100.00	100.00	99.95	99.88	99.95	100.00	100
Percent Introduced/Exotic Species	7.46	0.00	0.88	0.00	0.00	0.00	0.05	0.12	0.05	0.00	0
Percent Tolerant Fish	35.32	29.45	45.23	100.00	99.67	71.09	72.34	87.53	98.57	100.00	90
Percent Moderately Tolerant Fish	48.76	61.30	24.82	0.00	0.33	28.91	27.66	12.47	1.43	0.00	10

Metric	FC472	FC1310	FCR025	TF324	TF396	TF500	TF620	TF827	TF975	TF1120	Avg(TF)
Percent Intolerant Fish	15.92	9.25	29.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total Electrofishing Time (min)	62.28		77.23	77.43	61.68	61.44	67.87	50.62	61.76	42.32	60
Catch per Unit Effort (# Individuals/min)	6.45		8.82	10.50	19.70	28.71	30.21	16.95	33.92	23.16	23
Stream Order	4	3	2	3	3	3	3	3	3	3	

*"Total # of fish species" metric excluded non-resident fish and tessellated darter (recently introduced)

**"Number of benthic insectivorous species" metric excluded tessellated darter (recently introduced)
excluded from MIwb were brown bullhead, American eel, white sucker, satinfin shiner, spotfin shiner, green sunfish, bluegill sunfish, blacknose dace, banded killifish, mummichog, and common shiner.

3.4.2.1.4 Habitat Assessment of the TTF Creek Watershed

Habitat features at twelve TTF Watershed sites were compared to those of the reference sites located in nearby Chester County. Mainstem and third order tributary sites were compared to French Creek reference sites, located in Coventry Township, Chester County, PA. Tributary sites, second order or less, were compared to Rock Run, a tributary to French Creek located in Coventry Township, Chester County, PA (Figure 3-48, also see Appendix F of the TTF CCR). In general, habitat was determined to be very poor, with seven of twelve sites designated "non-supporting" of the watershed's designated uses. Five sites, including three in Tacony Creek Park in the City of Philadelphia, had slightly better scores and were designated "partially supporting". Habitat degradation was considered to be the most important impairment in TTF Watershed, corroborating the results of biotic indexing. Figure 3-50 and Table 3-73 summarize the results of habitat assessment using USEPA habitat assessment protocols.

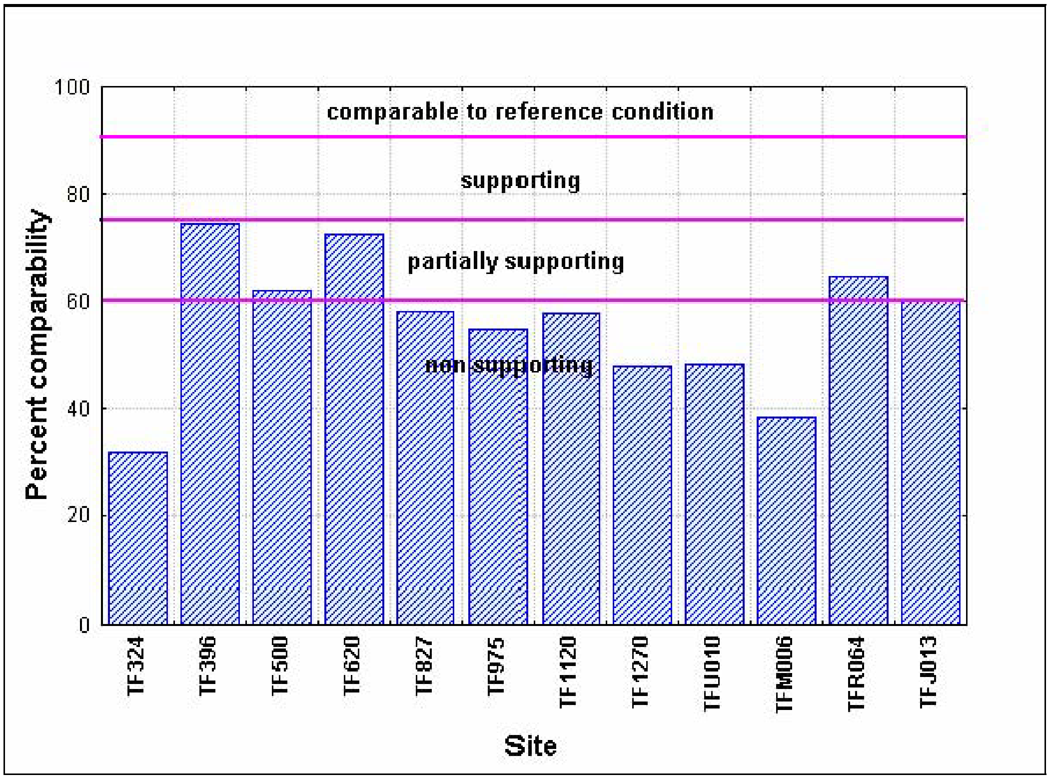


Figure 3-50 USEPA Habitat Assessment Percent Comparability to Reference Sites (TTF CCR section 7.2 figure 7.3 page 7.3)

Table 3-73 USEPA Physical Habitat Assessment Results for 12 Sites in TTF Watershed, Spring 2004 (TTF CCR section 7.2 table 7.1 page 7-4)

	Scores by Site											
Attribute	**TF324**	**TF396**	**TF500**	**TF620**	**TF827**	**TF975**	**TF1120**	**TF1270**	**TFJ013**	**TFM006**	**TFR064**	**TFU010**
Epifaunal Substrate/Available Cover	3	12.5	9.5	11	8.5	8	10	6.5	10.5	5	7.5	6
Pool Substrate	3	11	9.5	10.5	9	8.5	7	6.5	9	6	6	6
Pool Variability	4.5	11.5	9	9.5	8.5	6.5	10	5	12	2.5	4.5	2
Sediment Deposition	12	9	7	8	10	10	7.5	6.5	11	5.5	13.5	9
Channel Flow Status	8.5	11	7.5	12	9	9.5	7	8.5	11	7.5	8	7.5
Channel Alterations	1.5	16.5	12.5	16	10	9.5	8	11.5	6.5	6.5	14.5	12.5
Sinuosity	1	13	9	10.5	9.5	10.5	12	8.5	13.5	7.5	10	6.5
Bank Stability (Left Bank)	4	6	6.5	6	6	6.5	6	7.5	5	6	7.5	6.5
Bank Stability (Left Bank)	1.5	5	6	5.5	1	3.5	6	6	4	6.5	5	3.5
Vegetative Protection (Left Bank)	3.5	4.5	4.5	6	5	6	5	5	5.5	2	7.5	6.5
Vegetative Protection (Right Bank)	3	7	4	5.5	2	4	5	5	4	2	7.5	3.5
Riparian Zone Width (Left Bank)	1.5	5	5	7.5	3	3	4.5	4	4	2	8	5
Riparian Zone Width (Right Bank)	3.5	9	5	7.5	6	3.5	2	4.5	4	2	4.5	3.5
Embeddedness	3.5	11.5	9	14	9	10	8.5	8	12	8	15	9.5
Velocity/Depth Regime	8.5	13	16	14	14	8	13	8.5	13.5	8	12	8
Frequency of Riffles/Bends	5	12.5	11.5	10	13	9.5	11.5	8	12.5	11	16.5	15
Total	**67.5**	**158**	**131.5**	**153.5**	**123.5**	**116.5**	**123**	**109.5**	**138**	**88**	**147.5**	**110.5**

3.4.2.2 Darby-Cobbs Creek Watershed Characterization

Cobbs Creek is a receiving water body of combined sewer overflows. Cobbs Creek is located in Darby-Cobbs Creek Watershed (Figure 3-51). After a series of technical memos characterized Darby-Cobbs Creek Watershed (2000-2001), a Comprehensive Characterization Report (CCR) was completed for Darby-Cobbs Creek Watershed in 2002 and updated in 2004. These reports fully document the baseline conditions and lay the groundwork for future CSO planning and watershed management. Although the findings of the CCR are summarized in this section of the LTCPU, these reports extensively describe the land use, geology, soils, topography, demographics, meteorology, hydrology, water quality, ecology, fluvial geomorphology, and pollutant loads found in the watershed. The CCR provides the scientific basis for Cobbs Creek Integrated Watershed Management Plan (2004) (IWMP). The management plan guides the Philadelphia Water Department's efforts to restore and protect the designated uses described in Section 3.4.1. The IWMP and Comprehensive Characterization Report (CCR) can both be located at www.phillyriverinfo.org. Table 3-74 includes the titles and links to other reports that can be referenced for more detailed characterizations of the Darby-Cobbs Creek Watershed.

Table 3-74 Existing Documents Relevant to Characterization of Cobbs Creek Watershed

File Name	Year Published
Darby-Cobbs Creek Watershed Update (1st Annual Report)	2007
Southeast Regional Wetland Inventory and Water Quality Improvement Initiative: Cobbs Creek Watershed	2006
Darby-Cobbs Creek Comprehensive Characterization Report Update	2004
COBBS CREEK RESTORATION PROJECT: Baseline for Evaluating the Benefits of FGM-Based Stream Restoration in Cobbs Creek	2003
Geomorphologic Survey – Level II Guiding Principles for Fluvial Geomorphologic Restoration	2003
Darby-Cobbs Creek Watershed Comprehensive Characterization Report	2002
Inventory and Assessment of Existing Wetlands Within the Lower Cobbs Creek	2000

Darby-Cobbs Creek Watershed is defined as the land area that drains to the mouth of Darby Creek at the Delaware Estuary, encompassing approximately 80 square miles of southeast Pennsylvania (Figure 3-51). This area includes the drainage area of Cobbs Creek, Darby Creek, and Tinicum subwatersheds.

Cobbs Creek drains approximately 14,500 acres or 27% of the total Darby-Cobbs-Tinicum Watershed area. The upper portions and headwaters of Cobbs Creek, including East and West Branch Indian Creek, include portions of Philadelphia, Montgomery, and Delaware Counties. The lower portion of Cobbs Creek watershed, including the lower main stem and Naylors Run, drains parts of Philadelphia and Delaware Counties. Cobbs Creek discharges to Darby Creek. Within Cobbs Creek Watershed, combined sewers service over 20% of the drainage area. The City of Philadelphia has 38 CSOs and 3 major stormwater outfalls within Cobbs Creek Watershed.

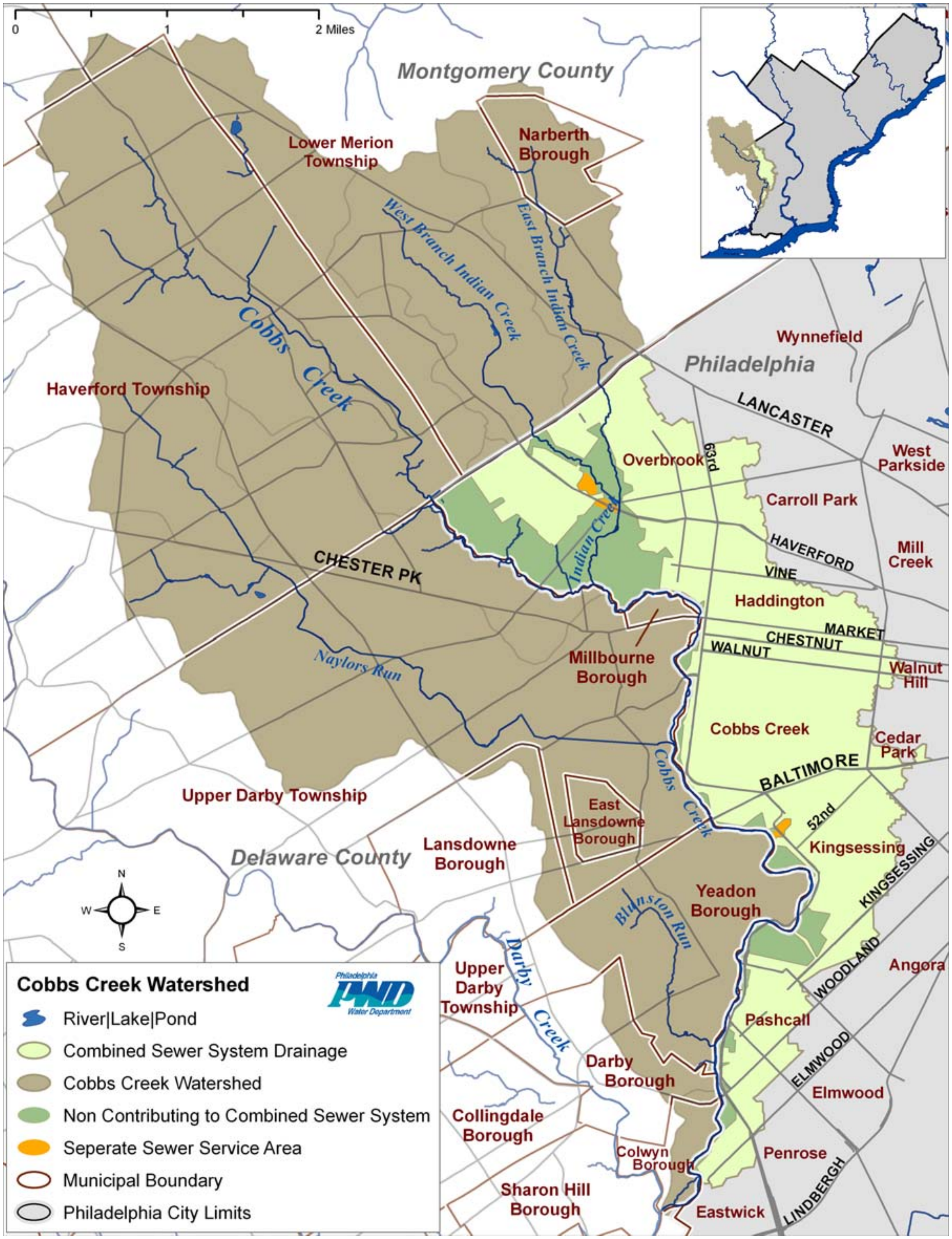


Figure 3-51: Cobbs Watershed

Darby Creek watershed drains approximately 29,000 acres or 55% of the total study area. The watershed is located primarily in Delaware County. The northwest corner of the watershed, including the headwaters of the main stem, is located in Chester County. Darby Creek has a number of small tributaries, including Little Darby Creek, Ithan Creek, and Foxes Run.

Darby-Cobbs Creek watershed discharges to Delaware River through the wetlands of Tinicum Refuge. Tinicum watershed includes portions of Philadelphia and Delaware Counties and totals 9800 acres or 18% of the total. Much of the area consists of low-lying wetlands, including the John Heinz National Wildlife Refuge. Named streams in the subwatershed include Hermesprota, Muckinipattis, and Stony Creeks.

Municipalities and Demographics

Darby-Cobbs Creek Watershed includes portions of Chester, Delaware, Montgomery, and Philadelphia Counties. The smaller Cobbs Creek Watershed does not include Chester County, but does include the other three counties. Figure 3-51 includes the watershed boundaries, hydrologic features, and municipal boundaries of Cobbs Creek Watershed.

Population density and other demographic information in the watershed are available from the results of the 2000 census. Approximately 104,000 people live within the drainage area of Cobbs Creek combined sewer area. Spatial trends in population correspond closely to land use, with multi-family row homes displaying the greatest population density of 20 people per acre or more, single-family homes displaying a lower density, and other land use types displaying the lowest density (Figure 3-52). The average population density is 23,436 people per square mile in the area that contributes to Cobbs Creek combined sewer service area.

Land Use

Figure 3-53 shows land use patterns in Cobbs Creek Watershed Combined Sewer Area. The area consists primarily of residential areas (73% of combined sewer area), almost all rowhouses (67% of combined sewer area). Parklands represent approximately 4%, and 5% of the combined sewer area is wooded. The area contributing to the combined sewer system is calculated to be 67% impervious.

Pollution Sources

In addition to CSO discharges to Cobbs Creek from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. These sources include Municipal and Industrial Process Water Discharges, Sanitary Sewer Overflows (SSOs), Stormwater and Urban Drainage, septic tank, and atmospheric deposition. More detail on these sources is included in the 2002 Comprehensive Characterization Report and the 2004 Update.

Additionally, more detailed information including watershed geology, hydrology, topography, wetlands, infrastructure features, history, cultural features, zoning, and ordinances can be found in Darby-Cobbs Creek Watershed CCR.

Receiving Waterbody Characterization

The Combined Sewer Area contains 11.7 miles of tributaries to Cobbs Creek and almost 6 miles of historic streams that are now encapsulated in pipes below the city's surface.

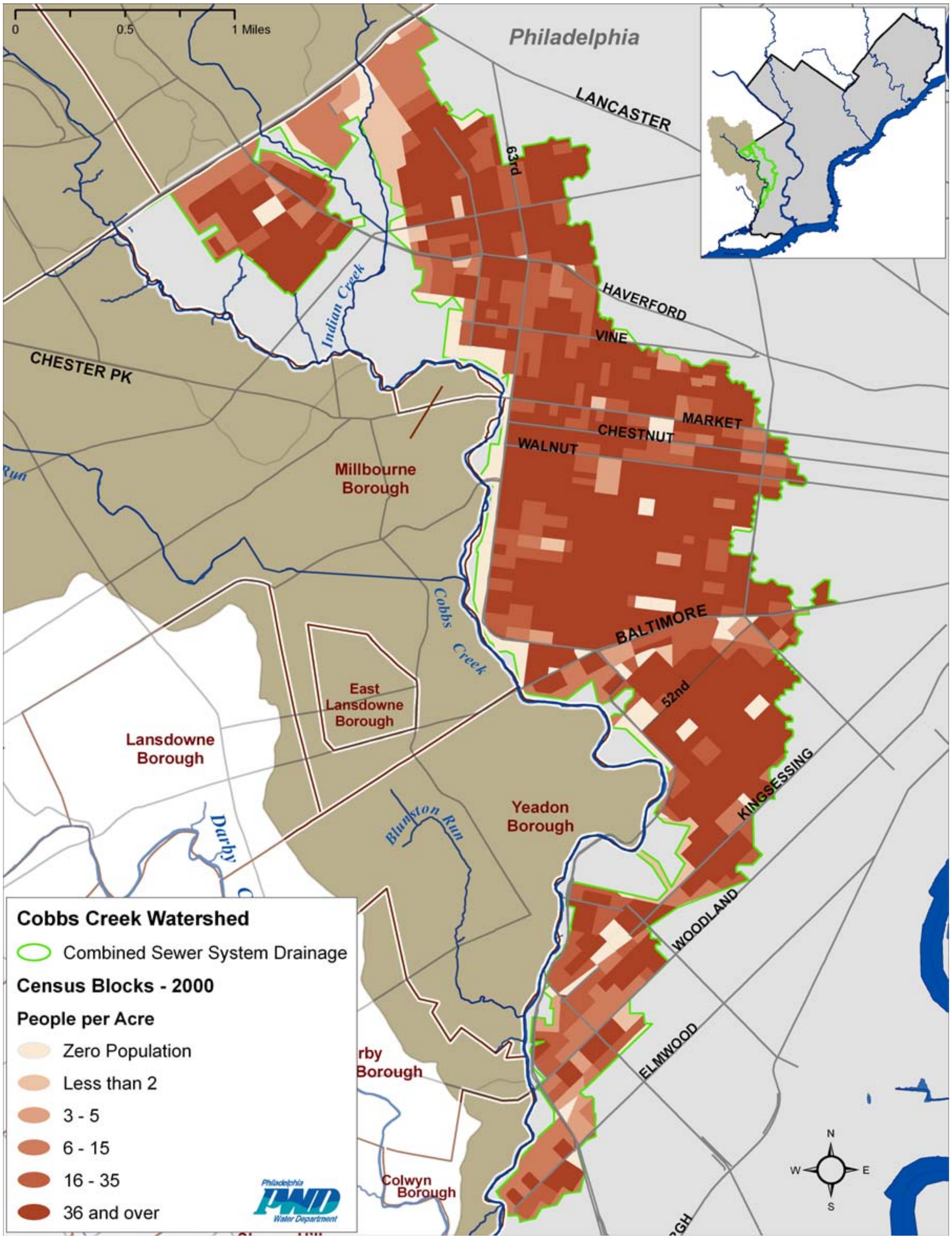


Figure 3-52: Population Density in Cobbs Combined Sewer Area

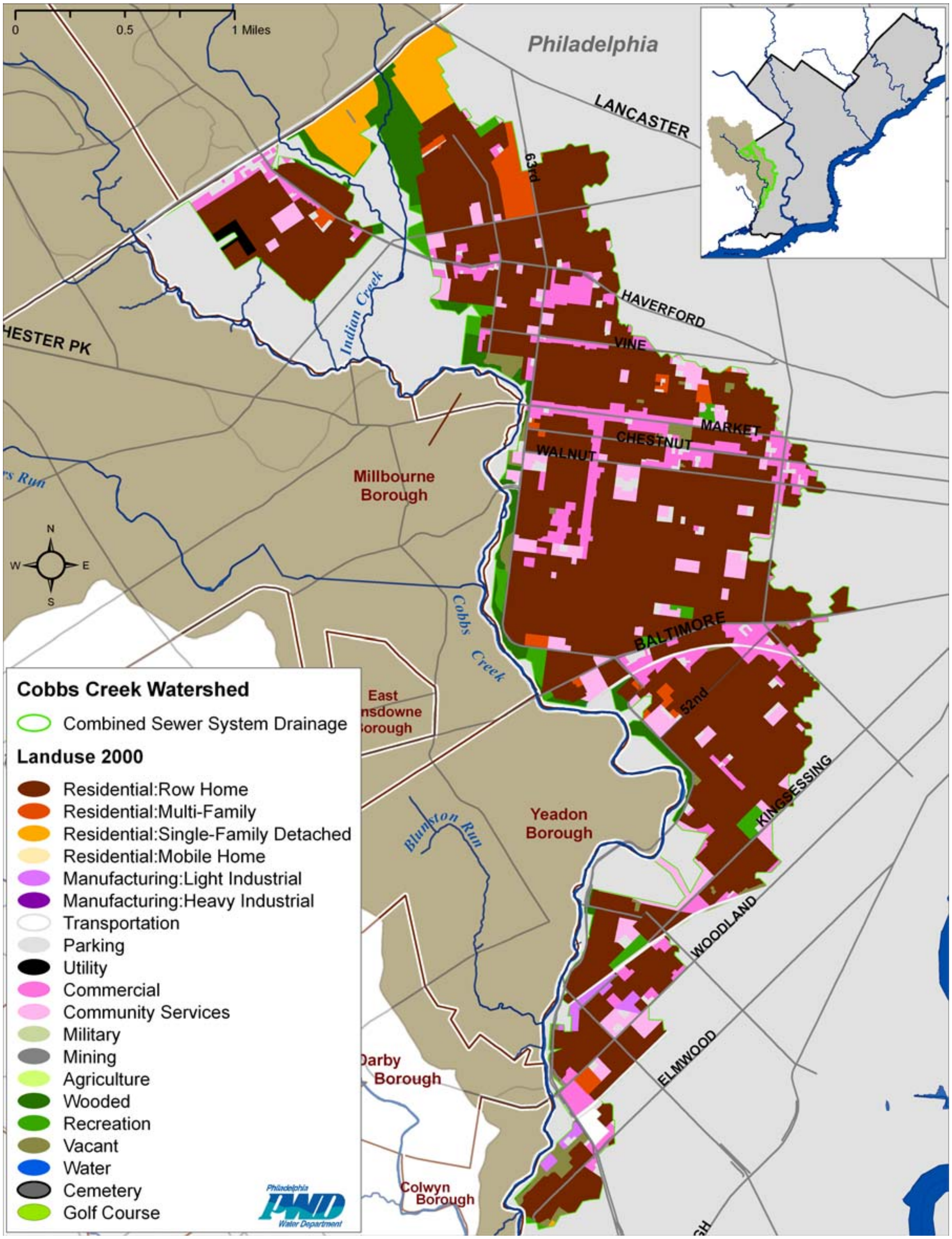


Figure 3-53: Land Use of the Combined Sewer Area in Cobbs Creek Watershed

3.4.2.2.1 Darby-Cobbs Creek Hydrologic Characterization

Components of the Urban Hydrologic Cycle

A water balance conducted for Darby-Cobbs Creek watershed is summarized in this section of the LTCPU and fully described in detail in Darby-Cobbs Creek Watershed CCR (2002).

Cobbs Creek Water Cycle Component Tables

The relevant components of the urban water cycle have been estimated for Darby-Cobbs watershed. Outside Potable Water is assumed to balance Outside Wastewater Discharges, with stormwater and CSO's considered as part of the Runoff component of the water cycle. Tables 3-75 and 3-76 show the results of the analysis, first in inches per year, then in million gallons per day. The inches per year figure simply takes all the flows over an average year, and divides by the area of the watershed. The million gallons per day table takes all the flows over an average year, and divides by 365 days to get an "average" day value.

Table 3-75: Water Budget Components (in/yr) (D-C CCR 2002 section 4.2 table 4-5 page 4-12)

		Inflow		Outflow		
	Period of Record	P	EDR	RO	BF	ET+Error
Cobbs Creek	1964 - 1990	42.1	0.05	10.6	8.1	23.4
Darby Creek	1964 - 1990	42.1	0.11	8.9	14.4	18.9

Table 3-76: Water Budget Components (MGD) (D-C CCR 2002 section 4.2 table 4-6 page 4-12)

	Period of Record	Inflow		Outflow		
		P	EDR	RO	BF	ET + Error
Cobbs Creek	1964-1990	44.4	0.06	11.2	8.6	24.7
Darby Creek	1964-1990	79.6	0.2	16.8	27.3	35.7

- ***ET*** is the evaporation and transpiration of water and is used to close the equation. It thus contains the sum of errors of the other terms as well as the estimated ET value.
- ***EDR*** is the estimated domestic recharge from private septic systems,
- ***RO*** is the surface water runoff component of precipitation,
- ***BF*** is the median baseflow of streams,
- ***P*** is the average precipitation at the Philadelphia gage

Hydrograph Decomposition Analysis

Areas and Gauges Studied

As discussed above, Cobbs Creek watershed and the lower portions of Darby Creek watershed are highly urbanized and contain a large proportion of impervious cover. The hydrologic impact of urbanization can be observed through analysis of streamflow data taken from USGS gauges on

Darby and Cobbs Creeks. In addition, data from French Creek in Chester County provide a picture of a nearby, less-developed watershed. Table 3-77 lists four gauges with available data, including their locations, periods of record, and drainage areas.

Table 3-77: Data Used for Baseflow Separation (D-C CCR 2002 section 4.3.2 table 4.8 page 4-19)

Gauge	Name	Period of Record (yrs)	Drainage Area	N	2N*
			(Sq. mi.)	(days)	(days)
01472157	French Creek near Phoenixville Pa.	33.0	59.1	2.26	5
01475550	Cobbs Creek at Darby Pa.	26.7	22.0	1.86	3
01475510	Darby Creek near Darby Pa.	26.7	37.4	2.06	5
01475300	Darby Creek at Waterloo Mills Pa.	25.4	5.15	1.39	3

The interval 2N* used for hydrograph separations is the odd integer between 3 and 11 nearest to 2N. N is calculated based on watershed area.

Summary Statistics

The results of the hydrograph decomposition exercise support the relationships between land use and hydrology discussed above. For convenience, the flows in Tables 3-78 and 3-79 are expressed as a mean depth (flow per unit area) over a one-year time period. Based on the French Creek gauge and the two Darby Creek gauges, the hydrologic behavior of these two systems is similar. Effective impervious cover allows sufficient groundwater recharge to give streamflow relatively natural characteristics; a mean of approximately 20% of annual rainfall contributes to the stormwater component of streamflow, and baseflow represents approximately 65% of total annual streamflow. This is fairly typical of streams in the Piedmont Province. Cobbs Creek exhibits behavior typical of a highly urbanized stream, with over 25% of rainfall contributing to stormwater runoff in a mean year and with mean baseflow comprising only 43% of mean annual streamflow.

Table 3-78: Summary of Hydrograph Separation Over the Period of Record (D-C CCR 2002 section 4.3.2 table 4-9 page 4-21)

Gauge	Mean Total Flow (in/yr)	Mean Baseflow (in/yr)	Mean Runoff (in/yr)	Baseflow (% of Total Flow)	Runoff (% of Rainfall)
French Creek 01475127	20.3	12.9	7.4	64	18
Cobbs Creek 01475550	18.8	8.1	10.7	43	26
Darby Creek D/S 01475510	23.3	14.5	8.9	62	21
Darby Creek U/S 01475300	23.7	15.6	8.1	66	20

Table 3-79: Annual Summary Statistics for Baseflow and Stormwater Runoff (D-C CCR 2002 section 4.3.2 table 4-10 page 4-21)

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	12.9	20.8	5.8	3.8	7.4	15.4	2.9	3.1
Cobbs Creek 01475550	8.1	16.1	1.8	3.6	10.7	15.6	5.2	2.7
Darby Creek D/S 01475510	14.5	21.4	7.6	4.0	8.9	15.6	3.6	2.9
Darby Creek U/S 01475300	15.6	26	8.0	4.3	8.1	16.7	3.8	2.9

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	31%	44%	15%	7%	17%	30%	7%	5%
Cobbs Creek 01475550	19%	31%	5%	7%	25%	33%	18%	3%
Darby Creek D/S 01475510	34%	44%	20%	8%	21%	31%	12%	4%
Darby Creek U/S 01475300	37%	51%	18%	9%	19%	32%	10%	5%

	Baseflow (% of Annual Total Flow				Runoff (% of Annual Total Flow)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	64%	75%	53%	5%	36%	47%	25%	5%
Cobbs Creek 01475550	42%	54%	16%	10%	58%	84%	46%	10%
Darby Creek D/S 01475510	62%	75%	54%	6%	38%	46%	25%	6%
Darby Creek U/S 01475300	66%	78%	50%	6%	34%	50%	22%	6%

As expected, the quantity of stormwater runoff on a unit-area basis follows patterns of impervious cover in the drainage area. The French Creek watershed, the least developed, has the smallest amount of stormwater runoff both as an annual mean quantity (7.4 in) and as an annual mean percent of rainfall (17%). As expected, the highly-developed Cobbs Creek watershed has the most runoff both as an annual mean quantity (10.7 in) and as an annual mean percent of rainfall (25%). Further highlighting the effects of development, mean runoff from Cobbs basin is almost 50% greater than mean runoff in the French Creek basin. The two Darby Creek gauges have an intermediate quantity of stormwater runoff; the downstream gauge, representing most of Darby basin, has slightly more runoff (8.9 in) on a unit-area basis than the gauge representing the less-developed headwaters (8.1 in).
The summary statistics for stormwater runoff in Table 3-79 present some interesting results. The standard deviation of annual stormwater flows for Cobbs Creek, both in inches (2.7 in) and as a percentage of rainfall (3%), is the lowest of the four gauges studied, indicating that these flows are less variable from year to year. A possible explanation for this pattern is that the capture of some stormwater as part of combined sewage reduces the variability of runoff reaching streams.

The magnitude of groundwater-derived stream baseflow also depends on impervious cover because pervious areas are necessary for groundwater to recharge. As expected, the unit-area Cobbs Creek baseflows (8.1 inches) shown in Table 3-79 are smaller than those in either Darby Creek (15.6 inches upstream, 14.5 inches downstream) or French Creek (12.9 inches). Baseflow is between 62% and 66% of mean annual streamflow in Darby and French Creeks and only 43% of mean baseflow in Cobbs Creek. Although Darby Creek watershed contains more impervious cover than the French Creek watershed, it has higher mean baseflows on a unit-area basis. The most likely explanation for this behavior is a difference in the groundwater yield of the geologic formations underlying each basin.

3.4.2.2.2 Darby-Cobbs Creek Water Quality Analysis

The Philadelphia Water Department carried out a comprehensive sampling and monitoring program in Darby-Cobbs Creek watershed between 1999-2000 and again in 2003 (see Section 3 of the Comprehensive Characterization Report). From 2007 through 2008 water quality data was monitored at two USGS stations in the Watershed. Tables 3-80 through 3-84 list parameters monitored, applicable state water quality standards, number of samples, and number of samples that exceed the standards.

Discrete (fixed interval) chemical sampling was conducted weekly under a variety of conditions (e.g., wet weather, ice) that may have influenced results of many chemical and water quality analyses. For example, instream measurements of dissolved oxygen and grab samples taken for fecal coliform analyses may exhibit great variability in response to environmental conditions. The former is dependent on time of day and sunlight intensity, while the latter may vary with rainfall. For this reason, results of discrete chemical sampling are most useful for characterizing dry weather water quality under Target A of the Watershed Management Plan. Target C and indicator 9 of the Watershed Management Plan were specifically targeted by PWD's Wet Weather Monitoring Program and Continuous Water Monitoring Program, respectively.

Wet weather is characterized using the five PWD operated rain gages in Darby-Cobbs Creek Watershed. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The rain gages and PWD water quality monitoring locations are depicted on Figure 3-49.

Much of Cobbs Creek Watershed in Philadelphia is served by a combined sewer system. Wet weather overflows at CSO structures periodically cause releases of combined sewage to streams. Effects of these releases may extend beyond the times when rain is falling or overflows are occurring. CSO discharges, even when infrequent, may be a significant factor in shaping a stream's water quality. Currently Philadelphia's streams do not meet water quality criteria during wet weather (Target C) because stormwater concentrations of bacteria are above the criteria and addressing only CSOs will not correct the problem.

PWD periodically monitors and continues to assess water quality of Cobbs Creek Watershed. The following results are largely based on the 2002 Darby-Cobbs Creek Watershed Comprehensive Characterization Report and the 2004 Update. Data collected since 2003 will continue to be published in future reports.

Discussion of Possible Problem Parameters

The following analysis of water quality data is focused on parameters that were listed in EPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow) in Darby-Cobbs Creek Watershed on Tables 3-80 to 3-84. The water quality criteria or target value is discussed in each parameter analysis.

pH

Water quality criteria established by PADEP regulate pH to a range of 6 to 9 in Pennsylvania's freshwater streams. pH is not considered a parameter of concern since the maximum standard of 9 was not exceeded during either the wet weather samples and dry weather samples (Tables 3-80 and 3-81). Acidity in Darby-Cobbs Creek watershed is chiefly determined by biochemical metabolic activity; the watershed is not heavily influenced by bedrock composition, groundwater sources or anthropogenic inputs, such as acid mine drainage.

Continuous monitoring through the use of sondes on the Darby-Cobbs Creeks recorded pH values at each of five sites. Continuous pH data was discretized to 15 min intervals and plotted against time and stream depth. Figures 3-54 through 3-85 depict pH trends at each of five continuously-monitored sites on the Darby-Cobbs Creek watershed, including the large diel pH fluctuations that accompany highly productive sites with abundant periphytic algae. Community metabolism regulates the extent of pH fluctuations. Environmental conditions, including ample sunlight, led to a dense autotrophic community at sites DCC208 and DCD765, which exhibited greater diel pH fluctuations than the other monitored sites; these sites also generally came closest to and occasionally violated water quality criteria by exceeding pH 9.0 (Figures 3-54 and 3-58, respectively). pH at shadier sites (i.e., DCC770, DCC455 and DCD1660) is probably less influenced by metabolic activity, and oscillations in pH appear noticeably damped as a result..

Two separate rain events occurred during the period of Sonde deployments in Darby-Cobbs Creek Watershed. Increased velocities and larger flows during wet weather swept away attached algae, macrophytes and suspended periphyton. Figures 3-54 through 3-58 demonstrate that without autotrophs to produce carbon dioxide through photosynthesis, pH levels remain steady. The autotrophic community recovers from this disturbance over subsequent weeks and pH gradually

Table 3-80: Dry Weather Water Quality Summary (1999-2000) – Parameters with Standards (D-C CCR 2002 section 5.2 table 5.5 page 35)

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles 0	25	50	75	100	No. Exceeding	% Exceeding
Alkalinity	Minimum	20	mg/L	59	58.0	66.0	74.0	79.0	98.0	0	0
Cd	Aquatic Life Acute Maximum	* 0.0043	mg/L	59	ND	ND	ND	ND	ND	0	0
Cd	Aquatic Life Chronic Maximum	* 0.0022	mg/L	59	ND	ND	ND	ND	ND	0	0
Cr	Aquatic Life Acute Maximum	0.0015	mg/L	59	ND	ND	ND	ND	0.00247	0	0
Cr	Aquatic Life Chronic Maximum	0.001	mg/L	59	ND	ND	ND	ND	0.00247	0	0
Cu	Aquatic Life Acute Maximum	* 0.013	mg/L	59	0.00107	0.00236	0.00330	0.00409	0.0101	0	0
Cu	Aquatic Life Chronic Maximum	* 0.0090	mg/L	59	0.00107	0.00236	0.00330	0.00409	0.0101	0	0
Diss Fe	Maximum	0.3	mg/L	59	0.0545	0.136	0.173	0.209	0.436	4	6.8
DO	Average Daily Minimum	5	mg/L	58	4.88	6.98	7.96	8.80	10.7	1	1.7
DO	Instantaneous Minimum	4	mg/L	58	4.88	6.98	7.96	8.80	10.7	0	0
F	Maximum	2	mg/L	59	ND	ND	ND	0.108	0.142	0	0
Fe	Maximum	1.5	mg/L	59	0.152	0.231	0.286	0.399	0.918	0	0
Fecal coliform	Maximum	Swimming Season Maximum 200 & Non-Swimming Season Maximum 2000	/100mL	60	90	290	410	620	23000	51	85.0
Nitrate + Nitrite	Maximum	10	mg/L	60	2.90	2.90	2.90	2.90	2.90	0	0

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Mn	Maximum	1	mg/L	59	0.0137	0.0251	0.0330	0.0460	0.0972	0	0
NH_3	Maximum	(pH dependent)	mg/L	58	ND	ND	ND	ND	0.186	0	0
Osmotic Pressure	Maximum	50	mOsm/kg	20	3.00	4.00	5.00	6.00	6.00	0	0
Pb	Aquatic Life Acute Maximum	* 0.065	mg/L	59	ND	ND	ND	0.0010	0.00433	0	0
Pb	Aquatic Life Chronic Maximum	* 0.025	mg/L	59	ND	ND	ND	0.0010	0.00433	0	0
pH	Maximum	9	--	58	7.09	7.39	7.57	7.73	8.18	0	0
TDS	Maximum	750	mg/L	59	148.0	210	234	289	420	0	0
Temp	Instantaneous Maximum	(varies)	^{o}C	58	13.7	15.7	18.9	20.3	24.1	7	12.1
Turbidity	Maximum	100	NTU	134	0.3	0.9	1.6	2.5	12.1	0	0
Zn	Aquatic Life Acute Maximum	* 0.120	mg/L	59	ND	0.00640	0.00947	0.0138	0.0582	0	0
Zn	Aquatic Life Chronic Maximum	* 0.120	mg/L	59	ND	0.00640	0.00947	0.0138	0.0582	0	0

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness.

Table 3-81: Wet Weather Water Quality Summary (1999-2000)– Parameters with Standards (D-C CCR 2002 section 5.2 table 5.5 page 35)

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Alkalinity	Minimum	20	mg/L	96	24.0	42.0	58.5	68.0	85.0	0	0
Cd	Aquatic Life Acute Maximum	* 0.0043	mg/L	93	ND	ND	ND	ND	ND	0	0
Cd	Aquatic Life Chronic Maximum	* 0.0022	mg/L	93	ND	ND	ND	ND	ND	0	0
Cr	Aquatic Life Acute Maximum	0.0015	mg/L	93	ND	ND	0.00151	0.00360	0.0140	0	0
Cr	Aquatic Life Chronic Maximum	0.001	mg/L	93	ND	ND	0.00151	0.00360	0.0140	6	6.5
Cu	Aquatic Life Acute Maximum	* 0.013	mg/L	93	0.00183	0.00428	0.00625	0.00960	0.0340	11	11.8
Cu	Aquatic Life Chronic Maximum	* 0.0090	mg/L	93	0.00183	0.00428	0.00625	0.00960	0.0340	23	24.7
Diss Fe	Maximum	0.3	mg/L	93	0.0739	0.129	0.155	0.214	0.392	5	5.4
DO	Average Daily Minimum	5	mg/L	94	1.73	5.27	6.52	8.07	10.3	22	23.4
DO	Instantaneous Minimum	4	mg/L	94	1.73	5.27	6.52	8.07	10.3	9	9.6
F	Maximum	2	mg/L	96	ND	ND	0.101	0.115	0.194	0	0
Fe	Maximum	1.5	mg/L	93	0.181	0.317	0.550	0.747	6.46	13	14.0
Fecal Coliform	Maximum	Swimming Season Maximum 200 & Non-Swimming Season Maximum 2000	/100mL	95	100	2100	7900	31000	200000	94	98.9

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Nitrate + Nitrite	Maximum	10	mg/L	102	2.90	2.90	2.90	2.90	2.90	0	0
Mn	Maximum	1	mg/L	93	0.0170	0.0385	0.0553	0.0744	0.212	0	0
NH_3	Maximum	(pH dependent)	mg/L	93	ND	ND	0.100	0.198	1.62	0	0
Osmotic Pressure	Maximum	50	mOsm/kg	10	2.00	2.00	3.00	3.00	4.00	0	0
Pb	Aquatic Life Acute Maximum	* 0.065	mg/L	93	ND	0.00144	0.00246	0.00577	0.0571	1	1.1
Pb	Aquatic Life Chronic Maximum	* 0.025	mg/L	93	ND	0.00144	0.00246	0.00577	0.0571	40	43.0
pH	Maximum	9	--	94	6.82	7.21	7.33	7.54	7.83	0	0
TDS	Maximum	750	mg/L	96	20.0	128	185	235	391	0	0
Temp	Instantaneous Maximum	(varies)	^{o}C	94	14.2	16.5	19.8	21.5	25.3	9	9.6
Turbidity	Maximum	100	NTU	278	0.5	3.0	5.9	13.0	155	2	1.1
Zn	Aquatic Life Acute Maximum	* 0.120	mg/L	93	ND	0.0110	0.0180	0.0295	0.111	3	3.2
Zn	Aquatic Life Chronic Maximum	* 0.120	mg/L	93	ND	0.0110	0.0180	0.0295	0.111	6	6.5

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness.

Table 3-82: Continuous Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	25307	0.0100	5.70	7.10	8.20	9.67	11.8	16.8	1678	6.6
DO	01475548	Instantaneous Minimum	4	mg/L	24158	0.0400	4.83	6.50	8.38	10.4	12.0	19.6	1547	6.4
DO	01475530	Daily Minimum	5	mg/L	533	0.0573	5.39	7.29	8.05	9.80	11.4	16.5	46	8.6
DO	01475548	Daily Minimum	5	mg/L	517	0.0513	5.28	6.83	8.41	10.4	11.7	14.5	46	8.9

Table 3-83: Continuous Wet Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	12477	0.0200	5.02	6.90	7.96	9.61	11.7	16.8	954	7.6
DO	01475548	Instantaneous Minimum	4	mg/L	11362	0.0400	4.29	5.82	7.63	9.87	11.4	19.4	911	8
DO	01475530	Daily Minimum	5	mg/L	335	0.0742	4.94	7.10	7.87	10.0	11.7	16.5	35	10.4
DO	01475548	Daily Minimum	5	mg/L	320	0.0533	4.81	6.17	7.78	10.0	11.8	14.5	37	11.6

Table 3-84: Continuous Dry Weather Water Quality Summary (2007-2008) – Parameter and Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	12830	0.0100	6.43	7.27	8.40	9.70	11.8	16.3	724	5.6
DO	01475548	Instantaneous Minimum	4	mg/L	12796	0.0400	5.64	7.13	8.96	10.7	12.4	19.6	636	5
DO	01475530	Daily Minimum	5	mg/L	198	0.0573	6.31	7.60	8.30	9.79	11.0	13.7	11	5.6
DO	01475548	Daily Minimum	5	mg/L	197	0.0513	6.78	8.04	8.94	10.5	11.5	14.2	9	4.6

Table 3-85: Sites with at least one Observed Exceedance of Water Quality Criteria (1999-2000) (D-C CCR 2002 section 5.2 table 5.7 page 39)

	Dry											
Parameter	**DCC110**	**DCC115**	**DCC455**	**DCC770**	**DCN010**	**DCI010**	**DCD765**	**DCD1170**	**DCD1570**	**DCD1660**	**DCM300**	**DCS170**
Cr												
Cu												
Diss Fe	X				X						X	X
DO		X										
Fe												
Fecal Coliform	X		X	X	X	X	X	X	X		X	X
Pb												
Temp							X		X	X		
Zinc												
	Wet											
Parameter	**DCC110**	**DCC115**	**DCC455**	**DCC770**	**DCN010**	**DCI010**	**DCD765**	**DCD1170**	**DCD1570**	**DCD1660**	**DCM300**	**DCS170**
Cr	X					X	X		X			
Cu	X		X			X	X					X
Diss Fe	X						X					X
DO	X	X					X			X		
Fe	X											
Fecal Coliform	X		X	X	X	X	X	X	X	X	X	X
Pb	X		X	X		X	X			X		X
Temp							X	X	X	X		
Zn	X						X					

Note: DCC115 was sampled for DO only on a continuous basis.

returns to normal fluctuations at each site. Decreased pH levels during and following wet weather events did not violate minimum pH standards.

Dissolved Oxygen
Based on the discrete sampling during 1999-2003, Dissolved Oxygen (DO) is not considered a parameter of concern during dry weather because state standards for daily average minimum of 5 mg/L and instantaneous minimum of 4 mg/L were never exceeded (Table 3-80). However, DO is considered a parameter of potential concern during wet weather for the instantaneous minimum because the standard was exceeded in 9.6% of samples (Table 3-81).

Samples analyzed from the continuous USGS monitoring from 2007-2008 show that DO concentrations are of potential concern in dry weather when compared to the instantaneous and daily minimum standards (Table 3-84). During wet weather, DO is considered a potential concern compared to the instantaneous standard, and a parameter of concern when compared to the daily average minimum standard at both USGS stations.

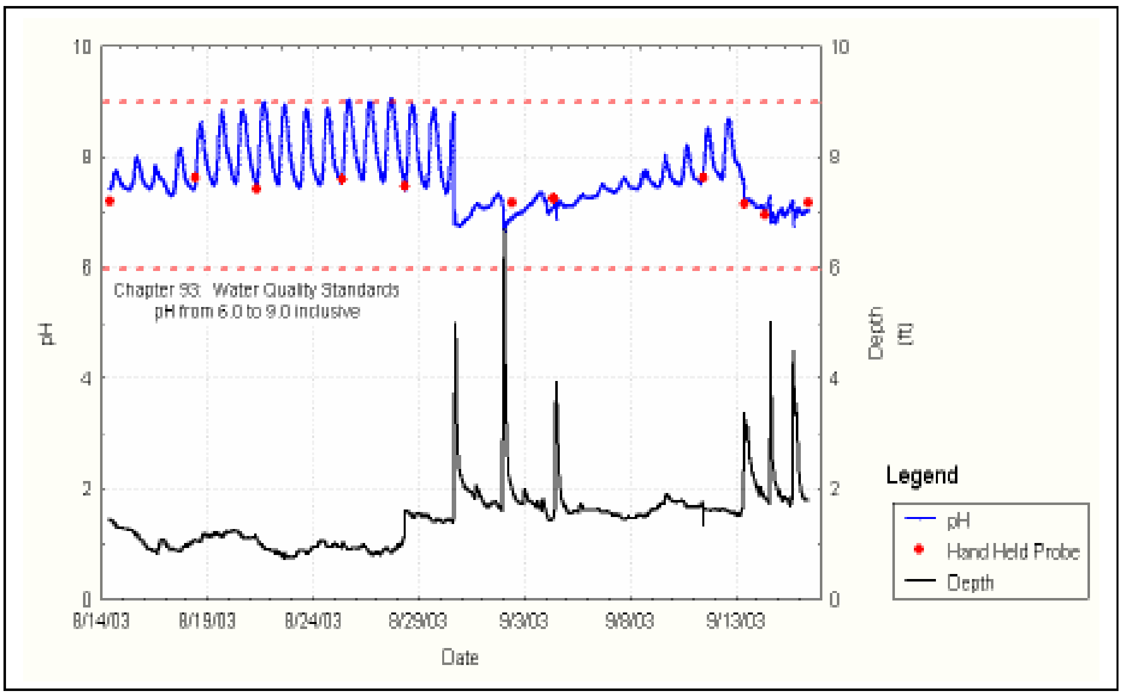


Figure 3-54: Continuous measurements of pH at DCC 208. (D-C CCR 2004 section 5.4.5 figure 6 page 98)

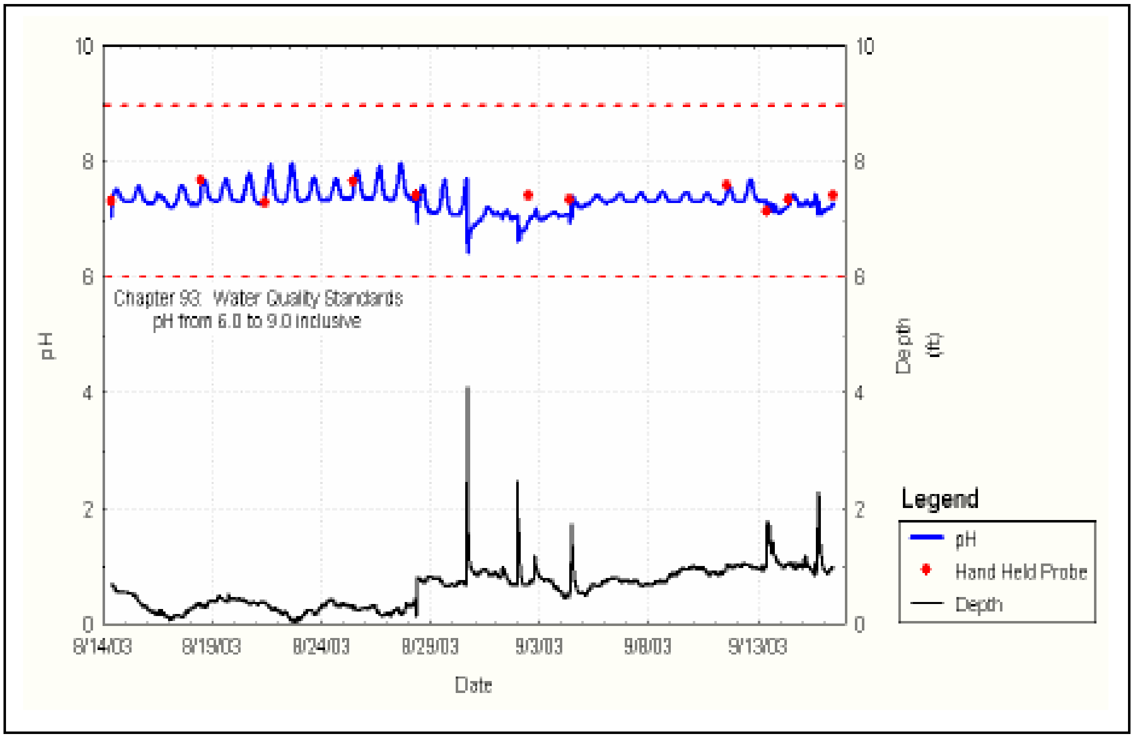


Figure 3-55: Continuous measurements of pH at DCC 455 (D-C CCR 2004 section 5.4.5 figure 7 page 99).

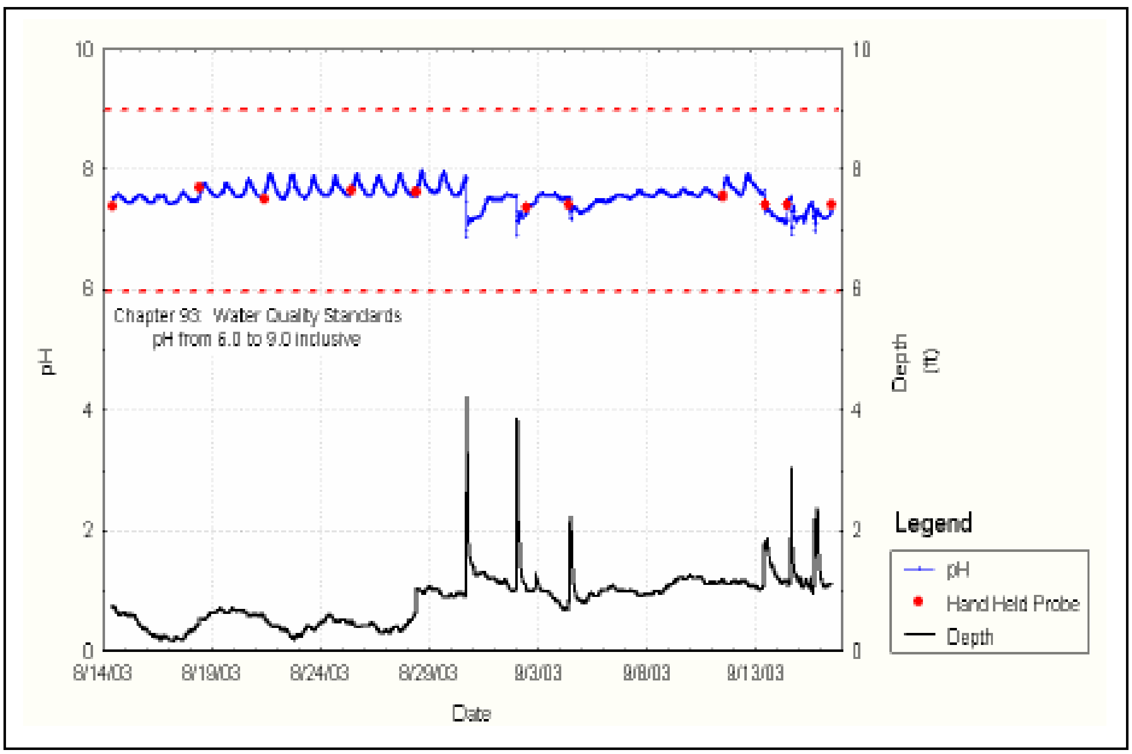


Figure 3-56: Continuous measurements of pH at DCC 770 (D-C CCR 2004 section 5.4.5 figure 8 page 99).

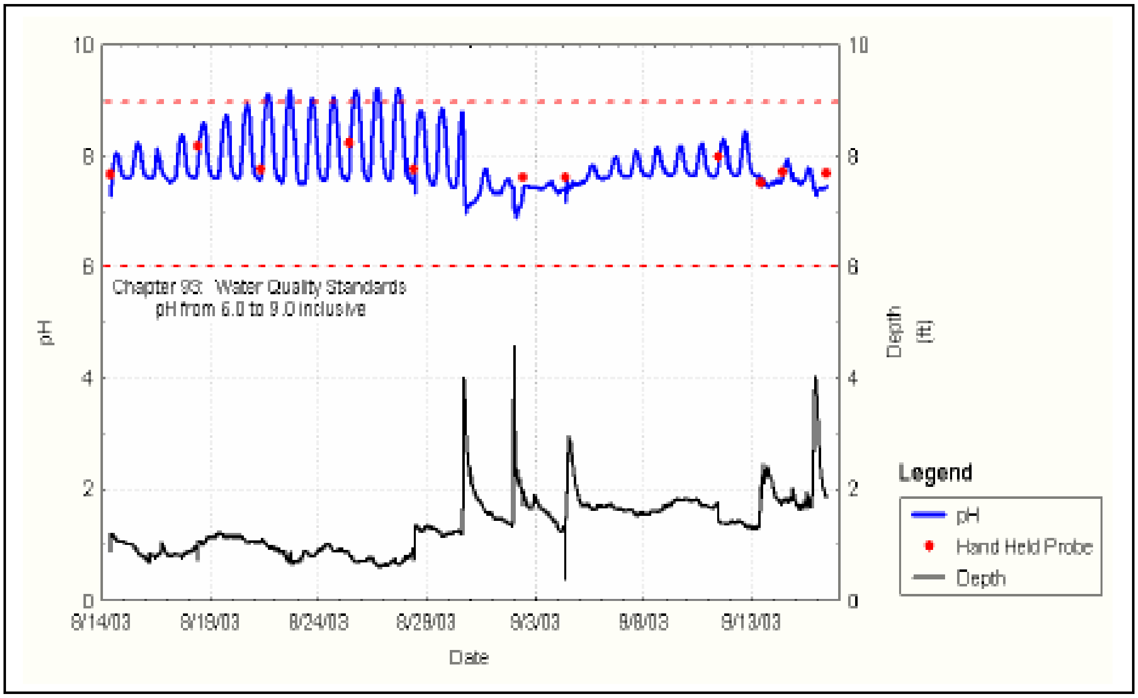


Figure 3-57: Continuous measurements of pH at DCD 765 (D-C CCR 2004 section 5.45 figure 9 page 100).

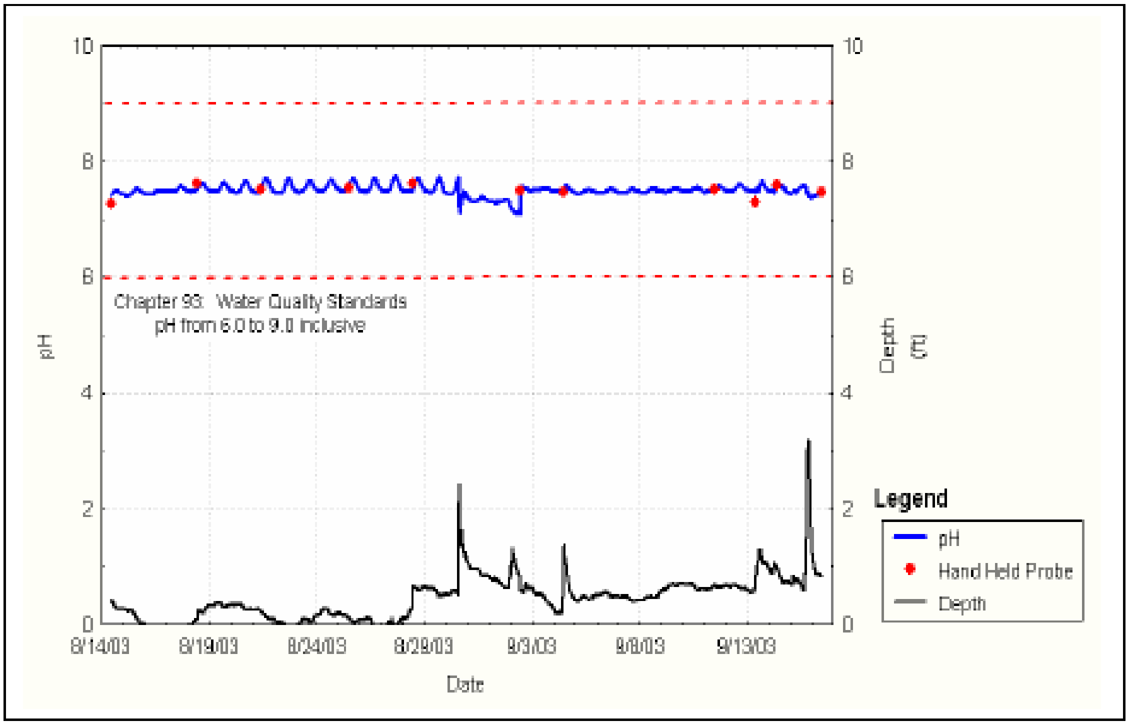
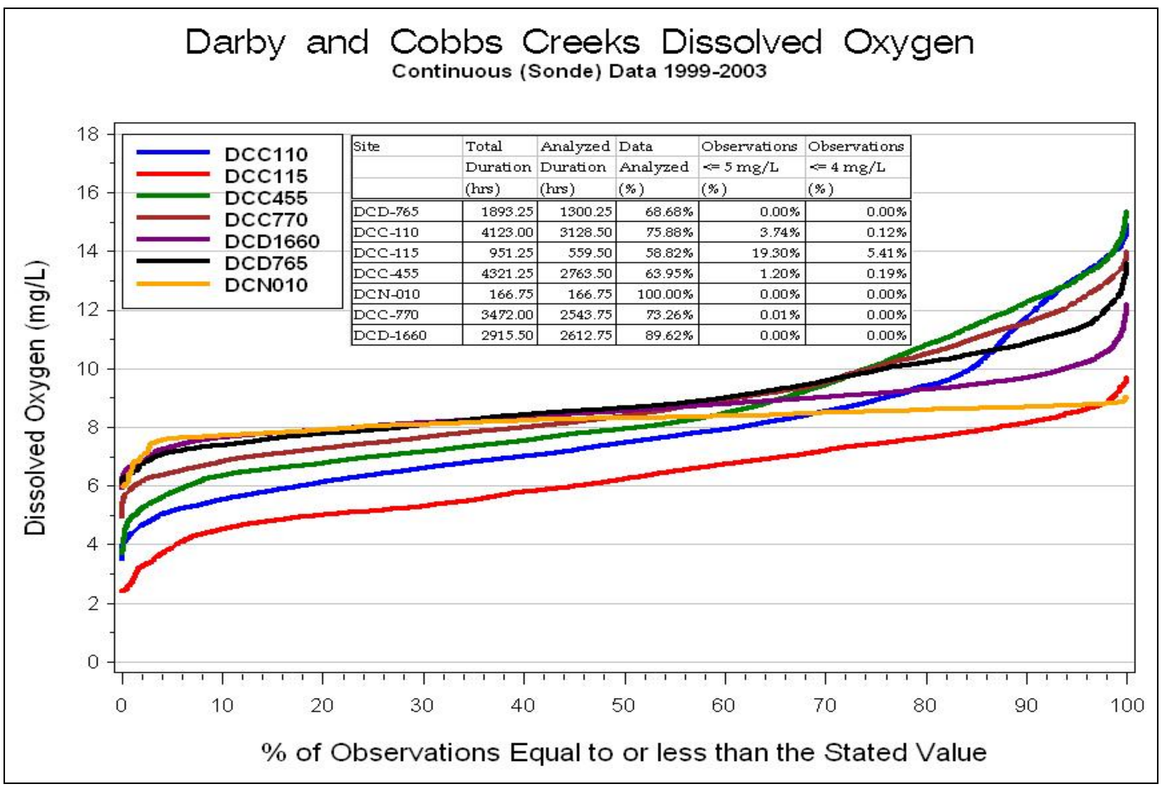


Figure 3-58: Continuous measurements of pH at DCD 1660 (D-C CCR 2004 section 5.4.5 figure 10 page 100).

PADEP also conducted continuous water quality monitoring from 1999-2003. All water chemistry monitoring sites within Darby-Cobbs Creek Watershed, with the exception of DCD1660, are designated as Warm Water Fisheries (WWF). Site DCD1660, and all segments of Darby Creek north of PA Rte. 3 (West Chester Pike) are designated a Trout Stocking Fishery (TSF). A TSF such as DCD1660 has more stringent DO standards to support more sensitive stocked salmonid fish species from February 15 to July 31 each year. During this period, a minimum daily DO average of 6.0 mg /L is required, and the allowable DO instantaneous minimum is 5.0 mg /L. For the remainder of the year, TSF criteria align with WWF standards. These regulations, along with corresponding temperature criteria, form the foundation of stream protection in general and allow for propagation and maintenance of healthy fish communities. Figure 3-59 shows that for data taken between 1999 and 2003, at sites DCC110 and DCC455, concentrations were occasionally (less than 5% of observations) below the average daily limit of 5 mg/L. The only site where concentrations were often below the average standard (20% of observations) and the instantaneous standard (5% of observations) is site DCC115. This site is just above the low dam at Woodland Ave.

Combinations of natural and anthropogenic environmental factors may affect DO concentration. Autotrophic and heterotrophic organisms are influenced by nutrient concentrations, solar radiation, temperature, and other environmental factors. Daily fluctuations of oxygen in surface waters are due primarily to the metabolic activity of these organisms. If temperature alone influenced DO concentration, saturation would increase at night, when water temperature drops, and decrease during the day as the water warms. Because the watershed is generally dominated by biological



Site	Total Duration (hrs)	Analyzed Duration (hrs)	Data Analyzed (%)	Observations <= 5 mg/L (%)	Observations <= 4 mg/L (%)
DCD-765	1893.25	1300.25	68.68%	0.00%	0.00%
DCC-110	4123.00	3128.50	75.88%	3.74%	0.12%
DCC-115	951.25	559.50	58.82%	19.30%	5.41%
DCC-455	4321.25	2763.50	63.95%	1.20%	0.19%
DCN-010	166.75	166.75	100.00%	0.00%	0.00%
DCC-770	3472.00	2543.75	73.26%	0.01%	0.00%
DCD-1660	2915.50	2612.75	89.62%	0.00%	0.00%

Figure 3-59: Continuous DO Monitoring Results (1999-2003) (D-C CCR 2002 section 5.3.5 figure 5.10 page 1-62)

activity, the reverse occurs: DO concentrations in Darby-Cobbs Creek Watershed rise during the day when autotrophic organisms are photosynthesizing and decrease at night when community respiration is the dominant influence. Another factor in the amount of oxygen dissolved in the water is re-aeration; the saturation deficit influences the amount of oxygen transferred to the stream from the atmosphere. Effects of re-aeration tend to augment or diminish (rather than shift or change) effects of stream metabolism.

DO fluctuations were more pronounced at some sites than at others, due in part to specific placement of the continuous monitoring instrument (Sonde) at each site. When interpreting this continuous DO data, one must keep in mind that the instrument can only measure dissolved oxygen concentration of water in direct contact with the DO probe membrane. Furthermore, to obtain the most accurate readings of DO, probes should be exposed to flowing water or probes themselves must be in motion. Local microclimate conditions surrounding the probe and biological growth on the probe itself may also contribute to errors in measurement. It is possible for Sondes situated in subtly different areas of the same stream site to exhibit marked differences in DO concentration due to flow, shading, and local microclimate differences. Sonde measurements of DO concentrations during the summer period (8/14/03-9/14/03) are depicted in Figures 3-60 thru 3-64.
The Sonde located at DCC208, for example, is located in a pool upstream of a dam. Additionally, the Sonde at DCC208 is not shaded. Deep pools, slower stream velocity, and ample sunlight provide excellent conditions for algal growth which are reflected in diel DO fluctuations (Figure 3-60). DCD765 is another site in which the Sonde is only partially shaded.
While not as large as DCC208, the amplitude of DO fluctuations exceeded 3 mg/L at this site. In contrast, the Sonde at DCD1660 is located under a bridge in shallow water. While not measured quantitatively, it is likely that algal periphyton density was smaller at this site; resulting diel fluctuations are damped in comparison to sites exposed to more sunlight (Figure 3-64). Sondes at sites DCC455 and DCC770 are in areas that are mostly shaded (Figures 3-61 and 3-62, respectively).

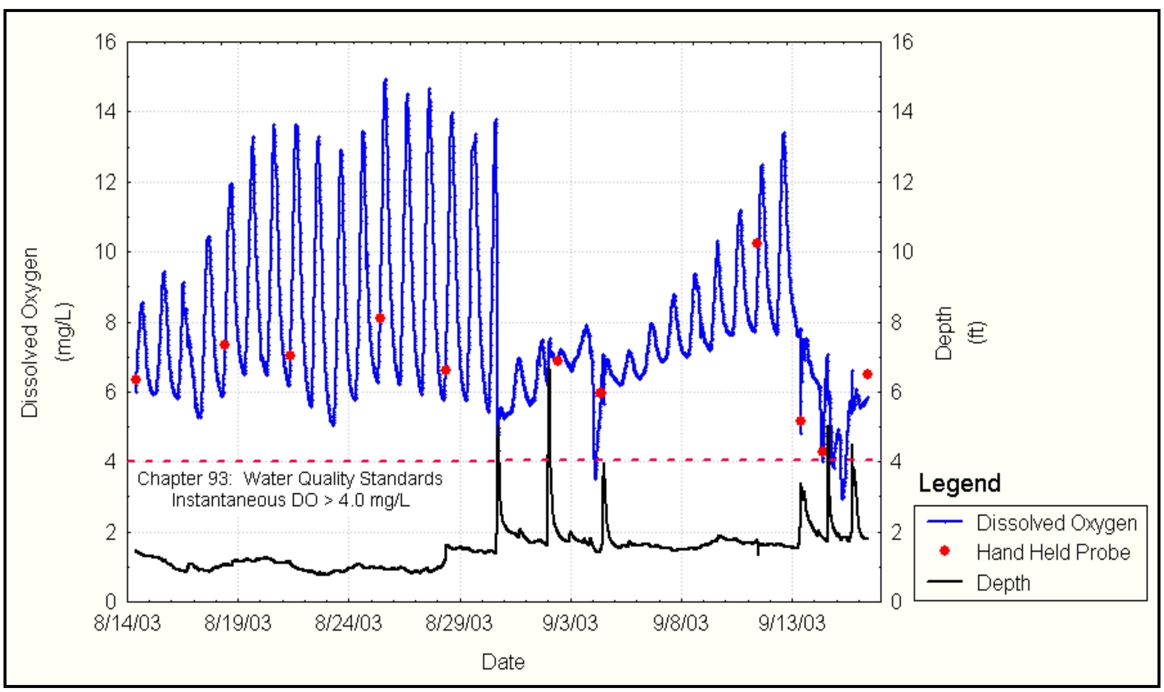


Figure 3-60: Continuous measurements of dissolved oxygen at DCC 208 (D-C CCR 2004 section 5.4.4 figure 1 page 94).

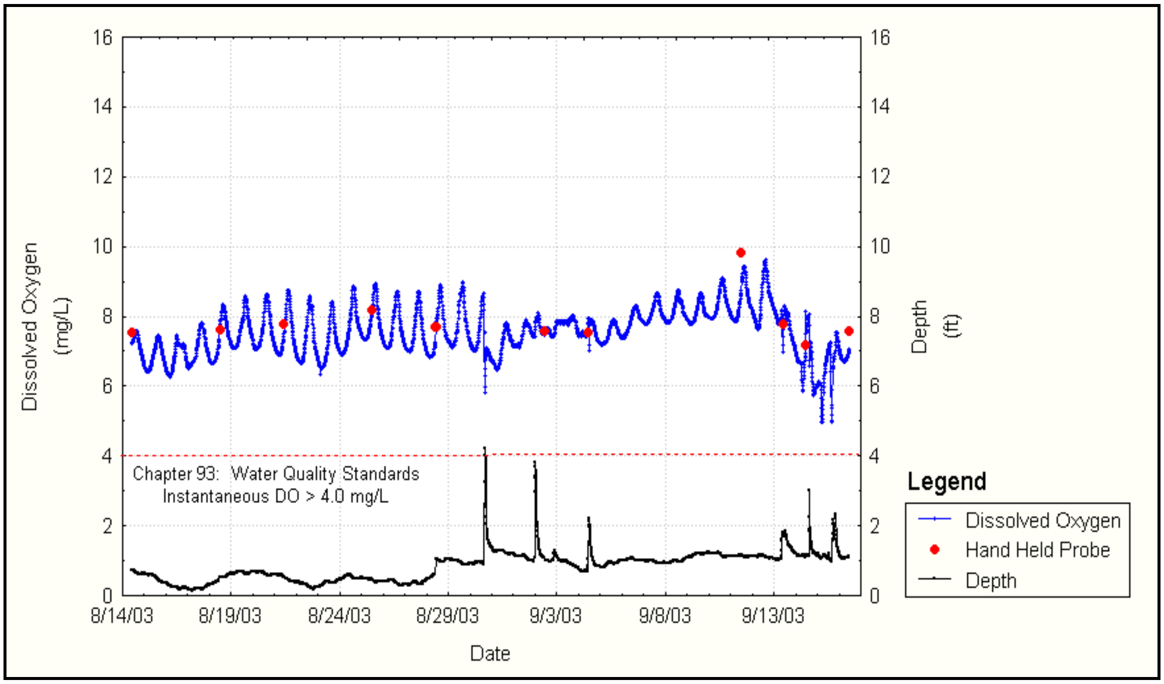


Figure 3-61: Continuous measurements of dissolved oxygen at DCC 455 (D-C CCR 2004 section 5.4.4 figure 2 page 95).

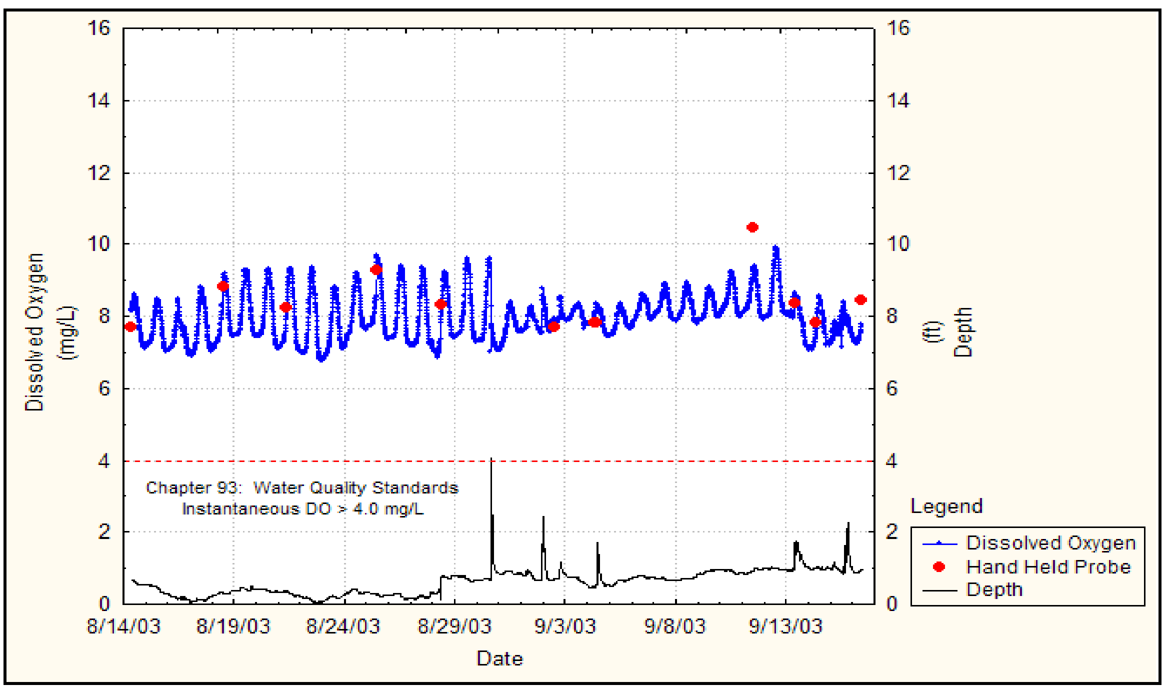


Figure 3-62: Continuous measurements of dissolved oxygen at DCC 770 (D-C CCR 2004 section 5.4.4 figure 3 page 95).

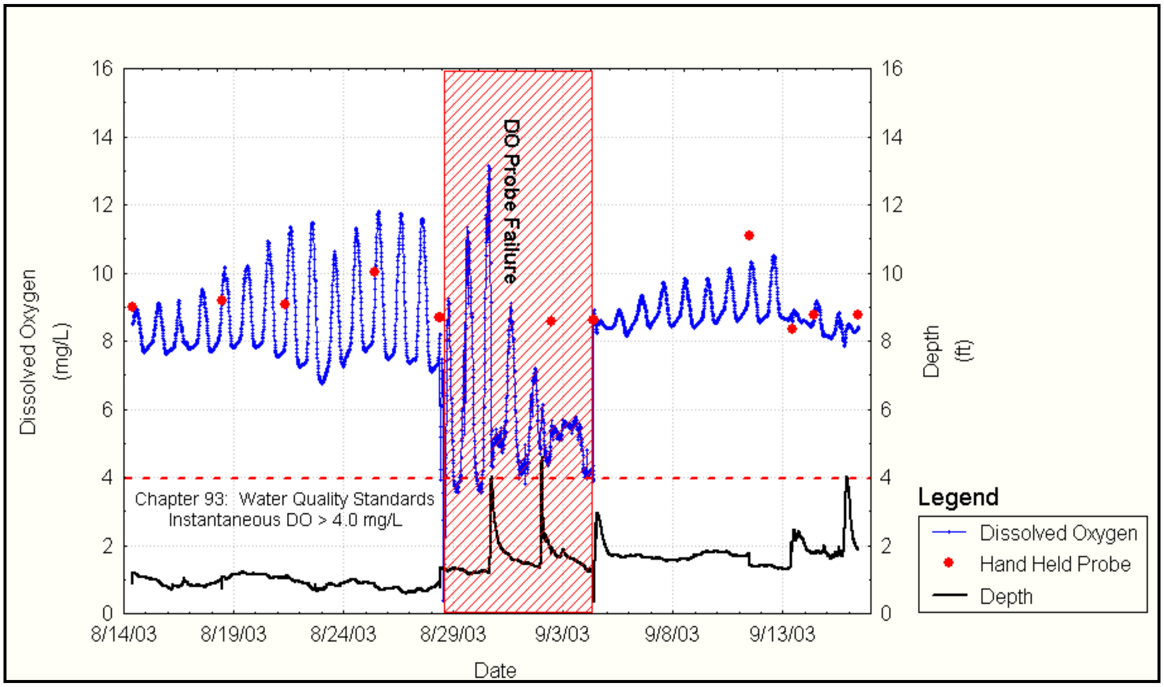


Figure 3-63: Continuous measurements of dissolved oxygen at DCD 765 (D-C CCR 2004 section 5.4.4 figure 4 page 96).

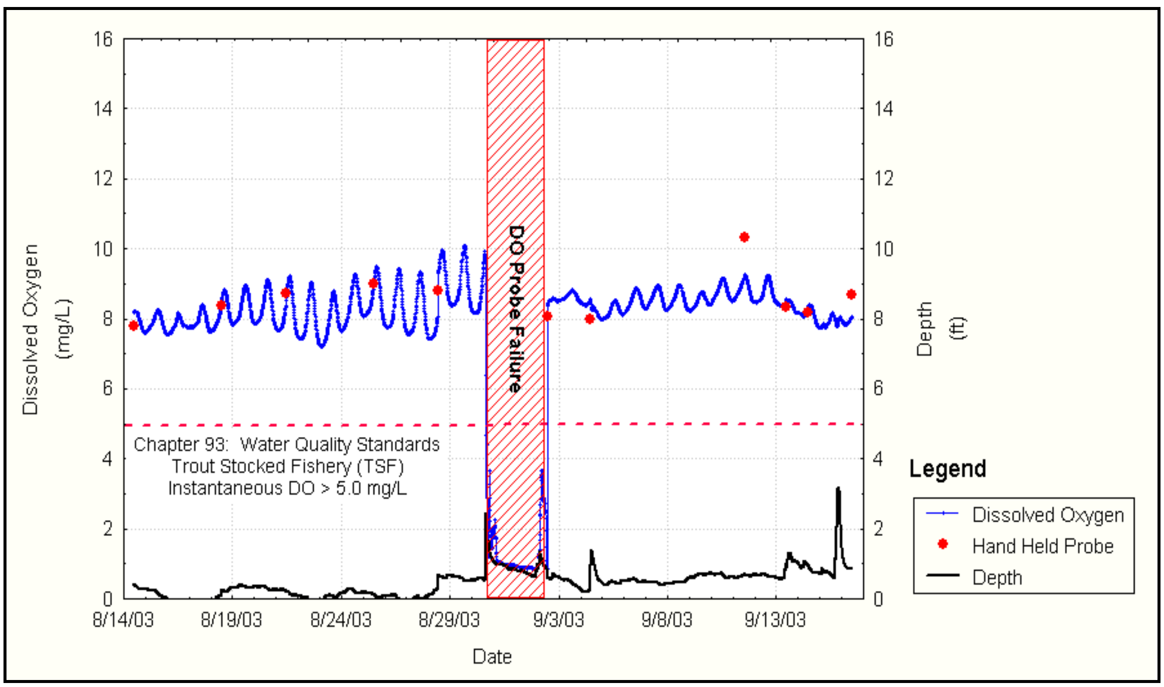


Figure 3-64: Continuous measurements of dissolved oxygen at DCD 1660 (D-C CCR 2004 section 5.4.4 figure 5 page 96).

Relation of Algal Activity to Dissolved Oxygen Concentration

Water quality monitoring sites on Cobbs Creek experience pronounced diurnal fluctuations in dissolved oxygen (DO) concentrations. When biological activity is high, DO concentrations may fall below the state-regulated limit of 4.0 mg/L. Dry weather dissolved oxygen suppression tends to occur at night and is likely caused by respiration of algae and microbial decomposition of algae and other organic constituents in the absence of additional photosynthetic oxygen production.

Following storm events, amplitude of daily DO fluctuations was reduced. DO concentrations may decrease sharply upon increase in stage, but it was difficult to determine how much of these instantaneous decreases were due to DO probe membrane fouling (Figures 3-63 and 3-64). It was hypothesized that anoxic effluent from storm sewers contributes to a sudden reduction in water column DO, but modeling of CSO discharge DO concentrations indicated that the discharge alone could not account for the observed DO reductions. BOD and SOD may have increased due to organic matter present in sewage. The scouring effect of high flows reduces algal biomass, and the oxygen produced through photosynthesis and consumed through respiration is reduced. As algal biomass accrues following scouring events, peak DO concentrations and range of diurnal fluctuations return to pre-flow conditions (Figures 3-61 and 3-62).

It is hypothesized that in dry weather the algae in combination with the residual effects of anoxic effluent, BOD and SOD accounts for the greater fluctuations in DO in stream segments heavily influenced by CSO discharge. Further confounding the interpretation of the data is the fact that microclimate conditions surrounding the DO probe membrane probably partially explain DO fluctuations observed.

Future Investigation of Dissolved Oxygen Conditions in Cobbs Creek

The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in Cobbs Creek are not well understood at this juncture. Efforts to better understand the dissolved oxygen situation in Philadelphia's streams continue including, in addition to ongoing continuous long-term monitoring, process studies conducted for PWD by the USGS. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from other dischargers to Cobbs Creek and its tributaries. If a relationship between loadings and the dissolved oxygen conditions is suspected, informational total maximum daily loads will be investigated for the watershed. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Total Dissolved Solids

Although it is has been monitored for the CSO program, Total Dissolved Solids (TDS) is not considered a parameter of concern in Darby-Cobbs Creek Watershed. The PADEP standard and target value of 750 mg/L was never exceeded during monitoring from 1999-2003. Often, average wet and dry weather TDS concentrations were well below the standard. Generally, average wet weather TDS concentrations were lower than average dry weather concentrations by about 10% when compared on a site by site basis. TDS appears to decrease slightly from the upstream to the downstream sampling stations. (PWD, 2000b)

Total Suspended Solids

There is no established state standard for Total Suspended Solids (TSS) but it is discussed in this section because it is listed in the EPA's 1995 Guidance for Long Term Control Plan. Data on TSS was not collected in Darby-Cobbs Creek Watershed.

Nutrients
With the exception of ammonia, PADEP does not currently have aquatic life-based nutrient criteria, only a limit on oxidized inorganic nitrogen (i.e., nitrate and nitrite) that is intended to protect public water supplies.

Nitrogen species
Though deep stagnant water is present in a few locations, particularly in pools behind dams and in "plunge pools", most of Darby-Cobbs Creek Watershed consists of shallow, well mixed and (at a minimum, partially) oxygenated stream segments. Inputs of organic matter and inorganic N, particularly concentrated inputs from SSOs and CSOs, may tax dissolved oxygen levels and result in violations of water quality standards. These effects are most severe in summer, when the rate of N-oxidizing reactions is fastest, dissolved oxygen capacity of stream water is reduced, instream biomass is high, and baseflow may be at or near yearly minimum.

Nitrite
As an intermediate product in the oxidation of organic matter and ammonia to nitrate, nitrite is seldom found in unimpaired natural waters in great concentrations provided that oxygen and denitrifying bacteria are present. Nitrite was never detected in any 2003 samples from Darby Creek or Naylors Run regardless of weather conditions, but was detected in 21 of 100 wet weather samples and 3 of 69 dry weather samples from Cobbs Creek. Observed wet-weather nitrite concentrations are likely due to CSO/SSO discharge and runoff. On 6/12/03, nitrite was detected during dry weather at sites DCI010, DCC455 and DCC208. The inability to detect nitrite at site DCC770 and observed pattern of longitudinally diminishing concentrations (from upstream to downstream) suggested a point source, later determined to be a leaking sewer. PADEP has established a maximum limit of 10 mg/L for total nitrate and nitrite N (Inorganic N) (note this limit is based on protection of drinking water and cannot reasonably be expected to prevent eutrophication of natural water bodies). Nitrite concentrations in Darby-Cobbs Creek watershed never exceeded nitrate concentrations, and were never responsible for water samples exceeding this criterion.

Nitrate
According to US EPA's nutrient criteria database, samples collected from unimpaired surface waters in the eastern coastal plain region of Pennsylvania had mean nitrate concentration of 1.9mg/l (n = 786). The 75th percentile seasonal median nitrate + nitrite concentration in EPA ecoregion IV, sub region 64 watersheds was 2.9mg/l. Close examination of nitrate data collected from southeastern PA streams by PWD and PADEP showed at least some nutrient impaired streams could be assigned to one of two broadly defined categories- streams in which nitrate concentrations increase due to runoff, and streams in which nitrate concentrations are elevated during baseflow conditions and diluted by stormwater. The former stream type is characteristic of agricultural regions, while the latter is characteristic of streams affected by wastewater effluent.

No sites in Darby-Cobbs Creek Watershed violated water quality criteria of 10 mg/L (see note above). The watershed is not affected by treated wastewater effluent, does not contain extensive areas of agricultural land use, and has not been listed as nutrient impaired by PADEP under section 303d of the Clean Water Act. However, all sites in Darby-Cobbs Creek have mean nitrate concentration >1.5 mg/L and would be considered "eutrophic" under the stream trophic classification system of Dobbs (1998).

During wet weather, nitrate concentrations were generally diluted; nitrate concentration was significantly higher (t-test, $p<0.05$) in dry weather at five of nine sites in Darby Cobbs Watershed (Figure 3-65). While nitrate concentrations were similar among Darby Creek sites, Cobbs Creek sites showed nitrate concentration decreasing in a downstream direction, suggesting uptake by producers, dilution as link magnitude increases, or denitrification by bacteria under anoxic conditions, where they exist. The Indian Creek Watershed had the highest mean nitrate concentration of all sites. Land use in the Indian Creeks' basins includes golf courses as well as areas where resident Canada geese congregate; topography is steep upstream of the sampling site.

Ammonia

Overall, Darby-Cobbs Creek Watershed sites had relatively low ammonia (NH_3) concentration and NH_3 is not considered a parameter of concern. 95 of 208 discrete grab samples (45%) taken in 2003 had NH_3 concentration below detection limits. Mean NH_3 concentration was highest at site DCI010, but this value was artificially high due to a sewage leak during dry weather on 6/12/03 (0.907mg/L). Wet weather impacts on NH_3concentration were most noticeable at Cobbs Creek sites DCC208 and DCC455 (Figure 3-66), which are likely affected by CSO discharge. NH_3 impacts from wet weather event 1 appeared more severe than from event 2.

PADEP has established maximum total NH_3 nitrogen standards for the waters of the Commonwealth, but each sample must be compared individually to a standard that integrates sample temperature and pH to account for dissociation of NH_3 in water. Higher temperatures and more alkaline pH allow more NH_3 to be present in the toxic, unionized form. Total NH_3 nitrogen concentration was above 1.0 mg/L in only 1 of 208 samples, a wet weather sample from site

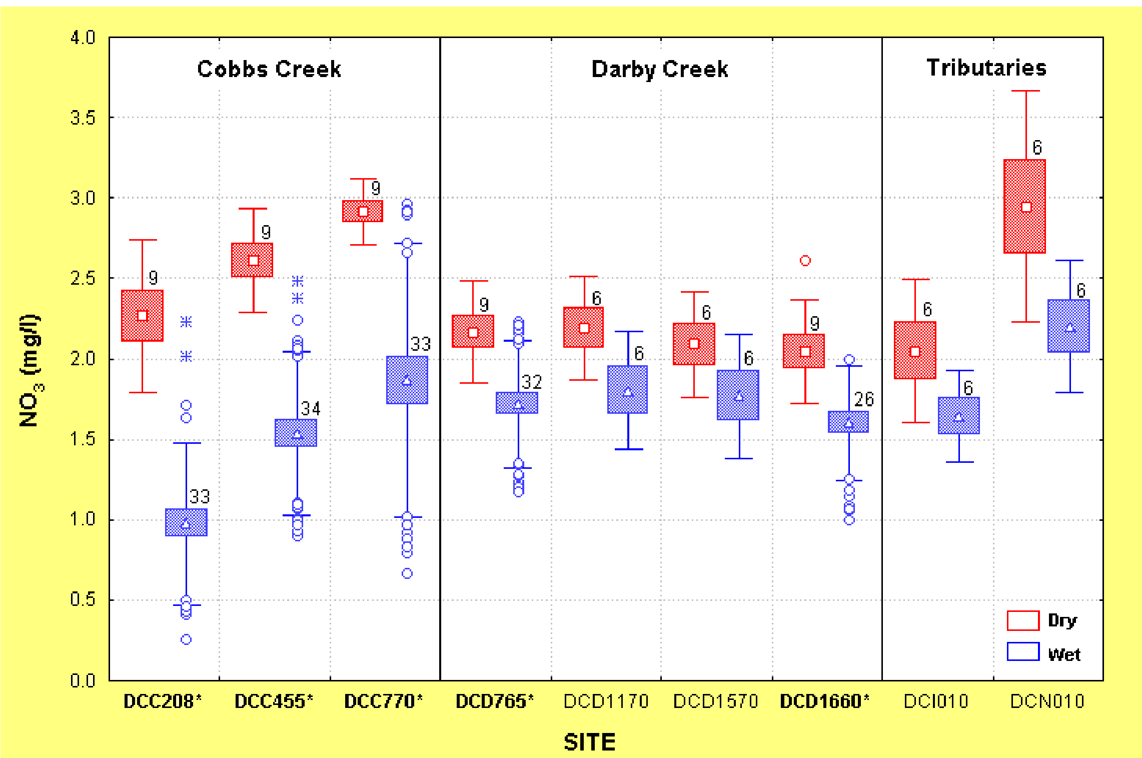


Figure 3-65: Dry and wet weather nitrate concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.5 figure 21 page 109).

DCC208. Despite pH values that occasionally exceeded 8.0, no violations of NH_3 water quality standards were observed. However, continuous water quality monitoring instruments recorded pronounced fluctuations in pH at sites DCD765 and DCC110 due to algal blooms. It is likely that if ammonia nitrogen were present during periods of upper-range pH violations (i.e., measurements greater than 9.0), its toxicity would be high.

Total Kjeldahl Nitrogen (TKN)

Although PADEP does not have an establish criteria for maximum Total Kjeldahl Nitrogen (TKN) concentration, the Environmental Protection Agency (EPA) requires that the TKN concentration not exceed 0.675 mg/L.

TKN provides an estimate of the concentration of organically-bound N, but the test actually measures all N present in the trinegative oxidation state. NH_3 must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters. Two outliers were excluded from the data analysis and graphics- these samples were collected from sites DCI010 and DCC455 during a sewer leak 6/12/03. TKN concentrations from these two sites were much greater than other dry weather samples and correspond with abnormally large concentrations of other parameters that serve as indicators of sewage contamination, (i.e., fecal coliform and *E. coli* bacteria, nitrate, ammonia, etc.) observed at these sites on this date.

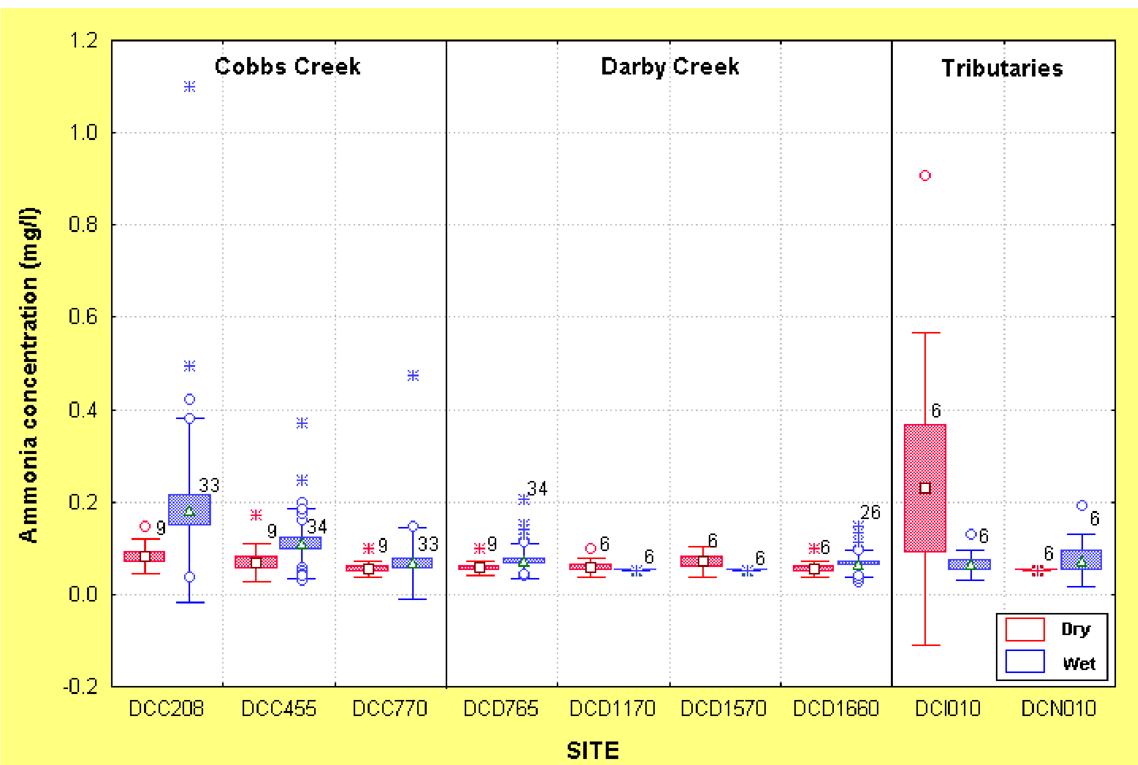


Figure 3-66: Dry and wet weather ammonia concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.4 figure 22 page 110).

Every site but DCC208 had TKN concentration less than the reporting limit of 0.3 mg/L on at least one occasion. All sites experienced increases in TKN concentration during wet weather, but this phenomenon was more pronounced at Darby Creek sites. Increases during wet weather can probably be attributed to organic compounds in stormwater runoff, breakdown products of accumulated streamside (allochthonous) plant material, re-suspended organic sediment particles, and displaced (sloughed) algae. Much of the TKN present during larger flows in Darby-Cobbs Creek Watershed may reach the Delaware estuary still in an organically-bound state.

Phosphorus

Phosphorus (P), like N, is a macronutrient (element required by plants in relatively large amounts); P concentrations are often correlated with algal density and are used as a primary indicator of cultural eutrophication of water bodies. P readily adsorbs to soil particles and is generally less mobile in soils than nitrogen compounds. Potential non-point sources of P are decomposing organic matter in or near the stream, runoff from industrial parks, agriculture and residential areas, and inorganic P adsorbed to soil particles that are washed into the stream by erosive forces. In fact, soil erosion may be the greatest source of P in some portions of Darby-Cobbs Creek watershed. Point sources of P include CSO and SSO discharges; though infrequent, they contribute large amounts of phosphorus where and when they occur.

Stream producers in Darby-Cobbs Creek Watershed are exposed to flow and a somewhat constant rate of nutrient delivery, albeit one that is punctuated with episodic inputs of greater P concentration due to runoff and erosion. These inputs, however, are coupled with physical disturbances (e.g., hydraulic shear stress, other abrasive forces, reduced light availability). These stressors respond to changes in flow in a non-linear fashion. Many taxa have the ability to store intercellular reserves of inorganic nutrients ("luxury consumption") when concentrations exceed immediate demands. It is thus very difficult to estimate the concentration of P available to stream producers and draw conclusions about stream trophic status from the (usually limited) data available.

Nevertheless, stream nutrient criteria have been proposed. For example, New Jersey's Department of Environmental Protection (NJDEP) has established a criterion of 0.10 mg/L total P for streams and rivers and 0.05 mg/L total P for lakes and their tributaries. USEPA has suggested the use of ecoregion-specific criteria based on the 75th percentile of total P concentration in unimpacted reference streams, or, in the case of insufficient reference stream data, the 25th percentile of TP for all streams in the ecoregion. For the ecoregion that includes Darby-Cobbs Creek Watershed, this criterion is (0.14) mg/l. Dobbs (1998) suggested that the mesotrophic/eutrophic boundary for TP is 0.07mg/l.

Total P concentration was used in analysis of Darby-Cobbs Creek Watershed because orthophosphate (PO4) concentrations were nearly always below reporting limits. Two data points from 6/12/03 at sites DCI010 and DCC455 were excluded from the analysis, because TP concentrations at these sites (0.22 and 0.130 mg/l, respectively) were likely influenced by a sewer leak in the immediate area. This sample from DCI010 was also the only dry weather sample in which PO4 was detected (0.149mg/l).

Phosphorus Concentration: Dry Weather

Darby Creek sites generally had less TP in dry weather than Cobbs Creek sites (Figure 3-67). Overall, 77% of Darby Creek dry weather samples had total P concentration below the reporting limit of 0.05 mg/l, while only 21% of Cobbs Creek sites had dry weather TP concentration below reporting limits. Though only two samples were above reporting limits, greatest mean total P concentration in dry weather (0.106 mg/l) was observed at site DCI010, which is located downstream of golf courses and areas where resident Canada geese congregate. Excluding samples below reporting limits, the watershed overall had mean dry weather TP concentration of 0.073mg/l, which is below NJDEP's criterion, approximately half the proposed EPA criterion, and slightly greater than the mesotrophic-eutrophic boundary concentration proposed by Dobbs (1998).

Phosphorus Concentration: Wet Weather

Total P concentrations were significantly higher in wet weather than in dry weather at sites DCC208, DCC455, DCC770, and DCD767 (student's t-tests, $p<0.05$) (Figure 3-67). Total P concentrations were also higher at all other sites, but statistical power was limited with too few samples exceeding reporting limits. Despite greater total P concentrations in wet weather, PO4 concentrations never exceeded reporting limits in wet weather, indicating that the majority of P within the watershed is adsorbed to sediment particles or organically-bound and is not immediately usable by stream producers. The degree to which wet weather P becomes bioavailable to stream producers depends on a variety of factors. Organically-bound macronutrients probably become transported out of the system (loading to the Delaware Estuary) during larger flows; P appears to be no exception.

Dry Weather N:P Ratios

Estimates of dry weather total N:P nutrient ratios were hindered by the number of samples with nitrite, total phosphorus, ammonia and/or TKN values below reporting limits. Only 3 of 69 samples could have nutrient ratios estimated directly. To generate a greater number of N:P ratio estimates, a value equal to half the reporting limit was substituted for all parameters with sample

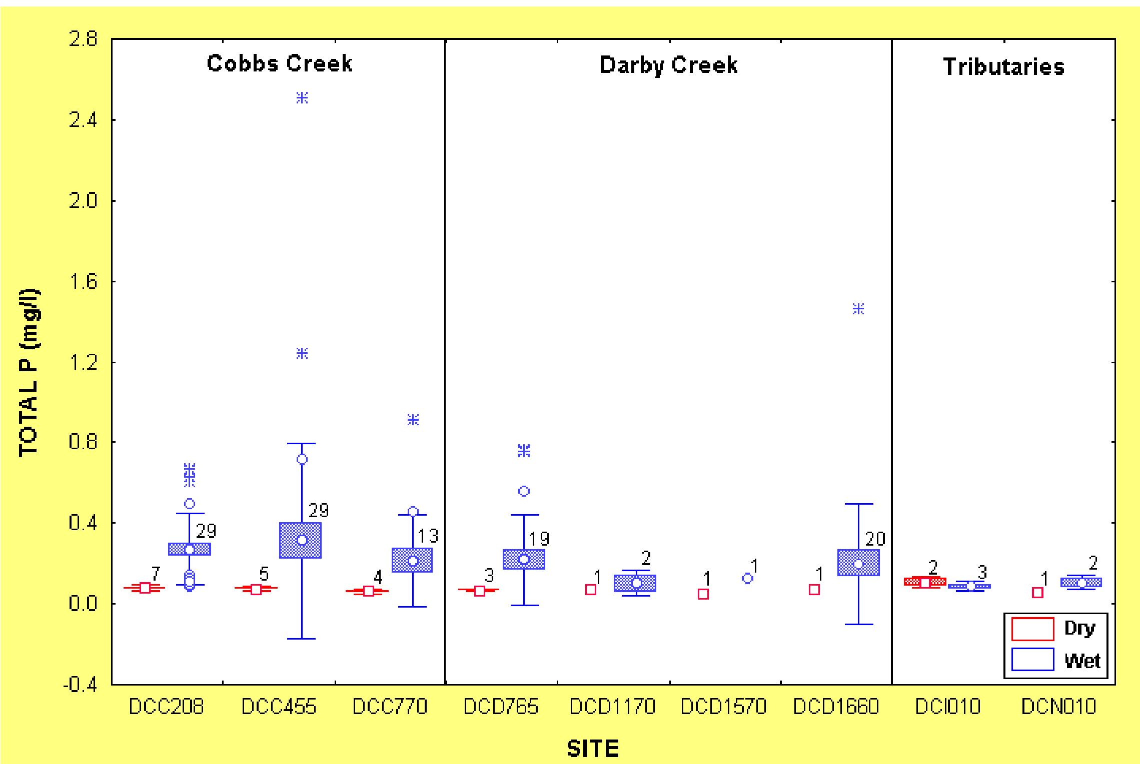


Figure 3-67: Dry and wet weather total phosphorus concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.8 figure 23 page 113).

concentration less than the reporting limit (Figure 3-68). However, because of the lower reporting limit for total P, these values probably greatly overestimated N:P ratio. A more unorthodox comparison of NO3 vs. actual TP observations was also used in an attempt to better estimate the relative proportions of these two nutrients (Figure 3-68). In any case, all sites within the watershed appear strongly P-limited.

Stream Nutrient Concentrations: Flow Implications
Stream nutrient concentrations in Darby-Cobbs Creek Watershed are dynamic, often increasing in wet weather due to CSO discharge, runoff, and erosion. But concomitant increases in physical stressors probably impose limits on the degree to which stream producers can take advantage of these increased concentrations. Particle size selection, traditionally related to flow by entrainment velocity curves, may determine the effective P loading for a given sediment load. Smaller particles, due to their greater relative surface area, can adsorb relatively more P than larger particles. Smaller particles are also generally more readily eroded and entrained in stormwater flow than larger particles.

Smaller storm events in Darby-Cobbs Creek Watershed probably contribute more to eutrophication than larger events. For example, if smaller sediment particles adsorb more P than larger particles as has been suggested, P loading becomes less efficient as larger particles are entrained in runoff. As shear stresses increase, streambank materials comprise a greater proportion of the sediment load. These particles are likely more similar to the soil parent material (i.e., lower in P concentration than more superficial soils layers that tend to incorporate more organic material). As flows increase, a greater proportion of the total load is transported out of the system, a greater proportion of the total

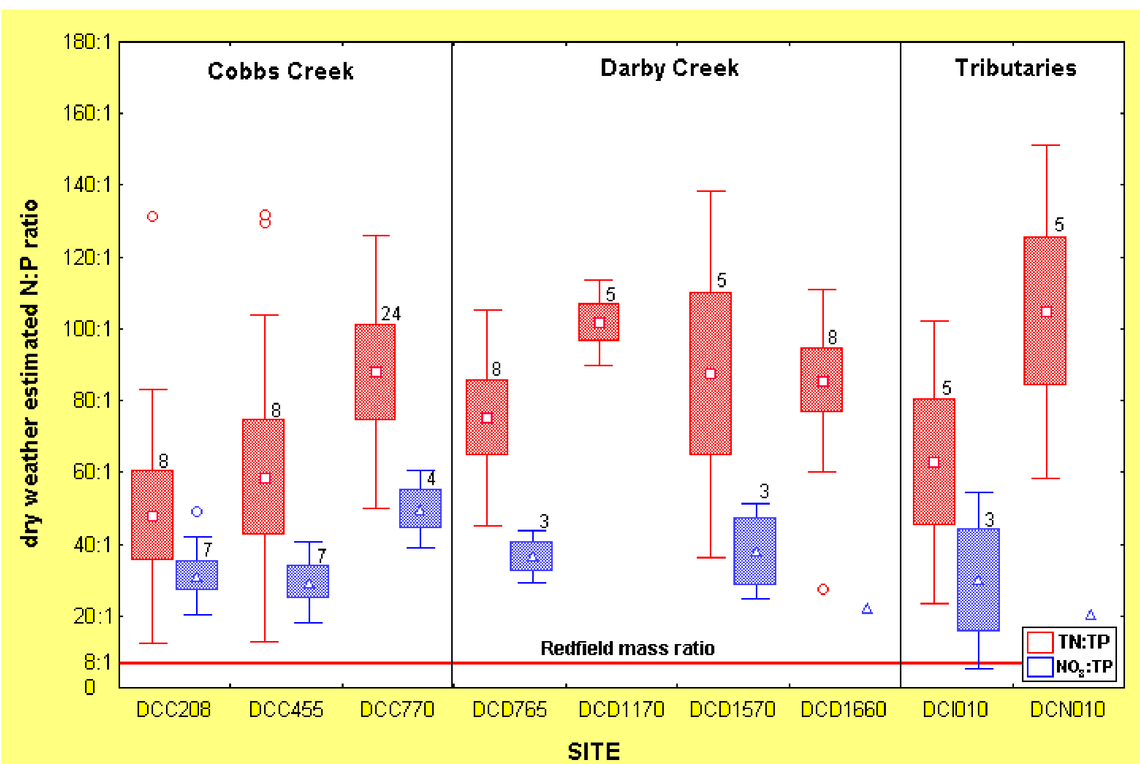


Figure 3-68: Estimated dry weather N:P ratios at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.9 figure 24 page 114).

nutrient load is inaccessible to producers, and much of the photosynthetic biomass (filamentous green algae and their associated epiphytes in particular) may be sloughed away and transported out of the system.

In areas served by combined sewers, the relative impact of small, intense storms is magnified. CSO discharge is minimally diluted by stormwater in the initial overflow phase, or "first flush". If nutrients present in these overflows can become deposited along with sediment or rapidly taken up by stream producers, discharges of short duration, particularly in which shear stresses do not result in major sloughing of algal communities, may have far-reaching consequences for stream nutrient dynamics and aquatic biota. A greater benefit may result from reducing frequency, number, and volume of small CSO discharges rather than attempting to capture releases from larger events.

Metals

Metals occur in all natural waters in varying concentrations due to runoff, erosion, atmospheric deposition, and interactions with streambed geological features. However, because certain metals may be toxic even in very small concentrations, toxic metals concentrations are included in the CCIWMP (indicator 8). Darby Creek Watershed (32.3 river miles including Darby Creek, Hermesprota Creek, Muckinipattis Creek, Stony Creek, Langford Run, and Whetstone Run) was listed by PADEP in 1996 as impaired due to metals in urban runoff/storm sewers, though individual segments were not identified. Cobbs Creek watershed (24.8 river miles, including Indian creek) was listed by PADEP in 2002 as impaired due to urban runoff/storm sewers and municipal point sources, but cause(s) of the impairment were not identified.

Metals of concern (e.g., lead, chromium, cadmium, copper, and zinc) were most often undetectable or present in minimal concentrations in water samples taken in 2003 from Darby-Cobbs Creek watershed. However, increases in concentration during rainfall were observed for copper, iron, and lead. Though water column toxic metal concentrations may be generally small, many metals readily adsorb to sediment particles, interact with organic molecules, or otherwise precipitate or become deposited or incorporated into stream sediments. Since most aquatic organisms either inhabit sediments or feed upon benthic invertebrates, possible toxic effects may not be reflected by water column concentrations alone.

Calcium and magnesium concentrations of Darby-Cobbs Creek watershed were not unusual, keeping with the predominant rock types in the watershed (schists and gneiss). As the major divalent cations in surface water, Calcium and Magnesium are used to compute hardness (expressed as mg/l $CaCO_3$). This is an important parameter, because toxicity of other metals generally has an inverse relationship with hardness. Most EPA and PADEP toxic metal water quality criteria are currently defined as linear regression equations that account for observed decreases in toxicity as hardness increases. Each sample metal concentration is evaluated against the criterion as calculated with sample hardness. Furthermore, two water quality criteria exist for each toxic metal, criteria continuous concentration (CCC) and criteria maximum concentration (CMC); these criteria address chronic and acute toxicity, respectively. Dry weather water samples were compared to CCC and wet weather samples were compared to CMC.

PADEP dissolved metal criteria are based on EPA toxic metals standards originally developed for total recoverable metals. Though these criteria have been modified to include a conversion factor for use with dissolved metals data, actual dissolved metal concentrations cannot be predictably determined as a proportion of total recoverable metals concentrations. Solubility of metals in natural waters varies with other environmental variables. Because of the degree to which metals may adsorb to sediment and form complexes with organic particles, it is likely that actual water column dissolved metal concentrations in the Darby-Cobbs Creek Watershed are smaller than those predicted using these conversion factors. To assess the effects of using these conversion factors, total recoverable metal concentrations were compared to both dissolved and total recoverable criteria.

Dry Weather Metals Concentrations

With the exception of copper, metals concentrations were relatively small in dry weather (Table 3-86). Cadmium and Chromium were not detected in any of 69 dry weather samples from Darby-Cobbs Creek Watershed. Lead was detected in only 3 samples, 2 from site DCC208 and one from site DCC455; only one of these three detections was a possible violation of the dry weather (continuous) criterion (CCC) for lead. Aluminum and zinc were detected in approximately two thirds of dry weather samples. Aluminum concentrations were consistently small, the maximum value was less than 50% of the CMC and the mean concentration was less than 10% of the CMC (no CCC has been established for aluminum). Zinc concentrations were typically 10% or less of the CCC. Copper was detected in all dry weather samples; three samples may have exceeded the CCC. While standards for each sample vary with hardness, many samples had copper concentration at 50% or more of the CCC. Based on ICP-MS performance on individual check standards, reporting limits for some metals were higher than 1μg/l on some occasions.

Table 3-86: Metal concentrations collected during dry weather in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.4.3.1 table 1 page 92).

Metal	non-detects	Max	Min	Arithmetic Mean	Std. Dev.	Geometric Mean	WQ Violations
Aluminum	16	0.363	0.015	0.067	0.053	0.055	N/A
Cadmium	69	N/A	N/A	N/A	N/A	N/A	0
Calcium	0	52.0	24.0	34.89	6.573	34.311	N/A
Chromium	69	N/A	N/A	N/A	N/A	N/A	0
Copper	0	0.020	0.002	0.006	0.004	0.006	3
Iron	4	0.785	0.052	0.196	0.113	0.171	0
Lead	66	0.007	0.002	0.004	0.003	0.003	1
Magnesium	0	19.320	11.700	14.945	1.510	14.781	N/A
Manganese	3	0.142	0.010	0.033	0.024	0.027	0
Zinc	19	0.084	0.002	0.017	0.017	0.012	0

Wet Weather Metals Concentrations

Wet weather metals concentrations were generally greater than concentrations in dry weather; the incidence of possible water quality violations was much higher overall in wet weather than in dry weather. For example, metals that may have violated water quality criteria only in wet weather included aluminum, cadmium, manganese, and zinc. Possible violations of copper and lead criteria were more frequent in wet weather as well. Hydrograph-matched scatterplots of toxic metal concentrations appear in (Appendix G of the Darby-Cobbs Creek Watershed Comprehensive Characterization Report 2004 Update).

While surface runoff undoubtedly contributes to increases in wet weather metals concentrations, it is likely that re-suspension of metals associated with sediments contributes to excursions from water quality criteria. Metal parameters considered to be a potential problem during wet weather were dissolved iron and Zn. Zn concentrations were found above both the aquatic life acute maximum and the aquatic life chronic maximum 3.2% and 6.5% of samples respectively. Metals considered parameters of concern in the CCR are Cu (aquatic life acute and chronic maximums exceeded), Fe (chronic maximum only), and Pb (chronic maximum only).

As seen in the list of parameters of concern and potential concern, most metal concentration were higher during wet weather samples. Concentrations of Fe and dissolved Fe do not always follow the trend of increasing in wet weather. This is especially true in the upper reaches of the watershed, where concentrations are higher. Mean dissolved iron is lower in wet weather at both sites in the Upper Cobbs (PWD 2002). In the Lower Cobbs, mean total iron increases in wet weather in the main stem of Cobbs Creek but decreases slightly at the Naylors Run site.

Public Health Effects (Metals and Fish Consumption)
Relatively small amounts of certain toxic compounds can kill aquatic life through acute poisoning, while chronic levels may be harmful to developmental stages of fish and macroinvertebrates. For example, bioaccumulation of toxins in fish may have a profound effect on fecundity and may also pose a threat to humans who regularly consume fish.

The established indicator measures the percent of cadmium, chromium, copper and zinc samples meeting state standards at various sites in Darby-Cobbs Creek Watershed. In 2003, PWD scientists collected 48 samples at each site for Cd, Cr, Cu and Zn during dry and wet weather. An additional 48 to 56 samples were collected at each site during two wet-weather targeted events. Results suggest standards intended to protect aquatic life were met at all locations during dry-weather in 2003 with the exception of copper in the upper reach of Darby Creek (Figure 3-69).

Conversely, wet-weather exceedances were omnipresent on both Darby Creek and Cobbs Creek (Figure 3-70). Of the metals, aluminum and copper generally exceeded standards more than 10 % of the time, while chromium and lead samples were greater than Pennsylvania's water quality criteria between 2% - 10% of the time.

Bacteria
Fecal coliform bacteria concentration is positively correlated with point and non-point contamination of water resources by human and animal waste and is used as an indicator of poor water quality (Indicator 7 of the Watershed Management Plan). PADEP has established a maximum limit of 200 colony forming units, or "CFUs," per 100 mL sample during the period 05/01-9/30, the "swimming season" and a less stringent limit of 2000 CFUs/100 ml for all other times. It should be noted that the state criterion is based on the geometric mean of five consecutive samples collected over a 30-day period. As bacterial concentrations can be significantly affected by rain events and otherwise may exhibit high variability, individual samples are not as reliable as replicate or multiple samples taken over a short period.

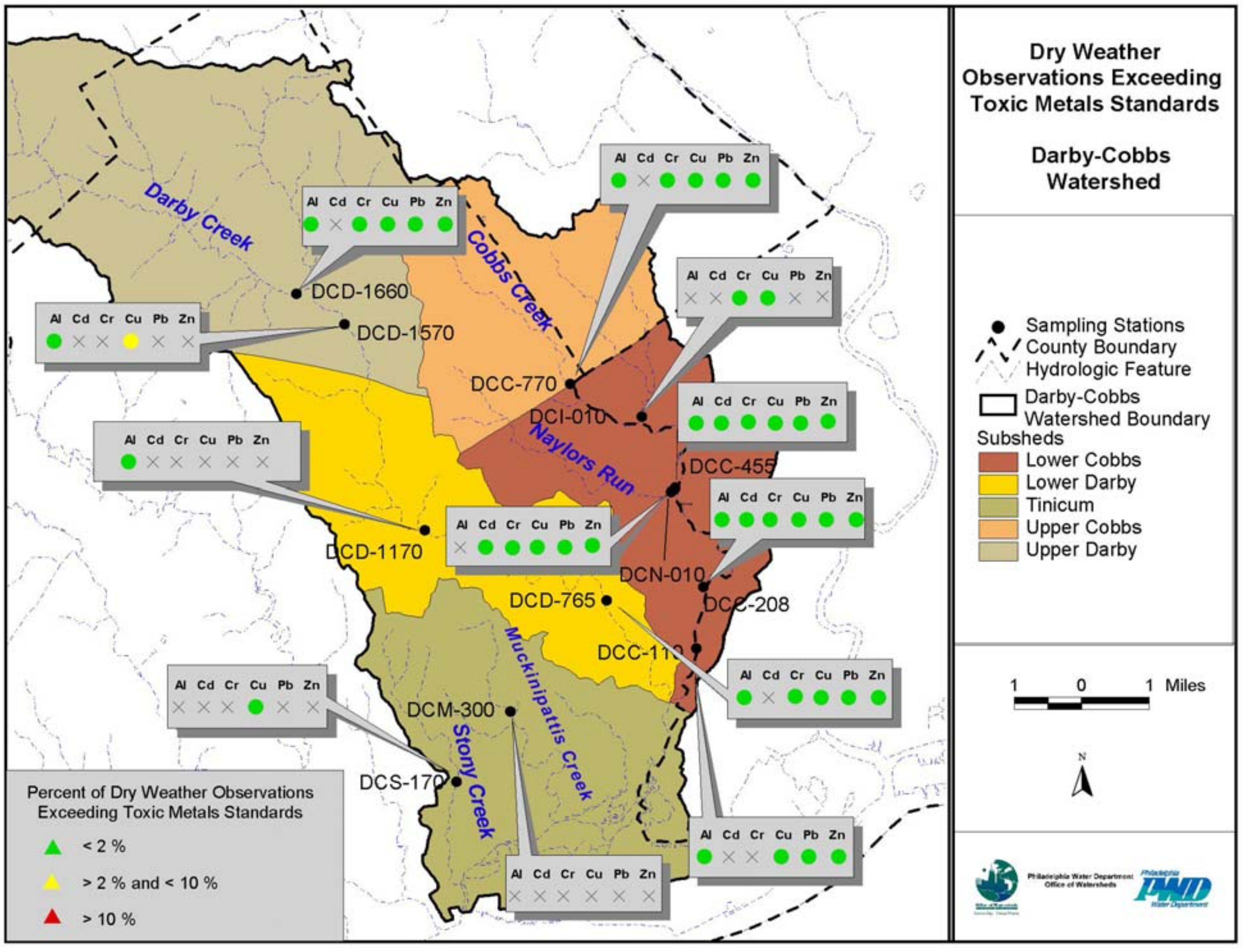


Figure 3-69: Dry weather metals indicator status update (D-C CCR 2004 section 6.7 figure 32 page 128).

Based on data from numerous sources (PADEP, EPA, USDA-NRCS, volunteer and non-profit organizations, etc.), it appears likely that many, if not most, southeastern PA streams would be found in violation of water quality criteria given sufficient sampling effort. PWD has expended considerable resources toward documenting concentrations of fecal coliform bacteria and *E. coli* in Philadelphia's watersheds. The sheer amount of data collected allows for more comprehensive analysis and a more complete picture of the impairment than does the minimum sampling effort needed to verify compliance with water quality criteria. In keeping with the organizational structure of the watershed management plan, fecal coliform bacteria analysis has been broken into dry (Target A) and wet weather (Target C) components, defined by a period with at least 48 hours without rain as measured at the nearest gauge in PWD's rain gauge network.

Dry Weather Fecal Coliform Bacteria (Target A)

Based on discrete sampling conducted during 1999-2003 (Table 3-80), fecal coliform is considered a dry weather parameter of concern because the standards for both swimming season and non-swimming season were exceeded in 85% of the samples.

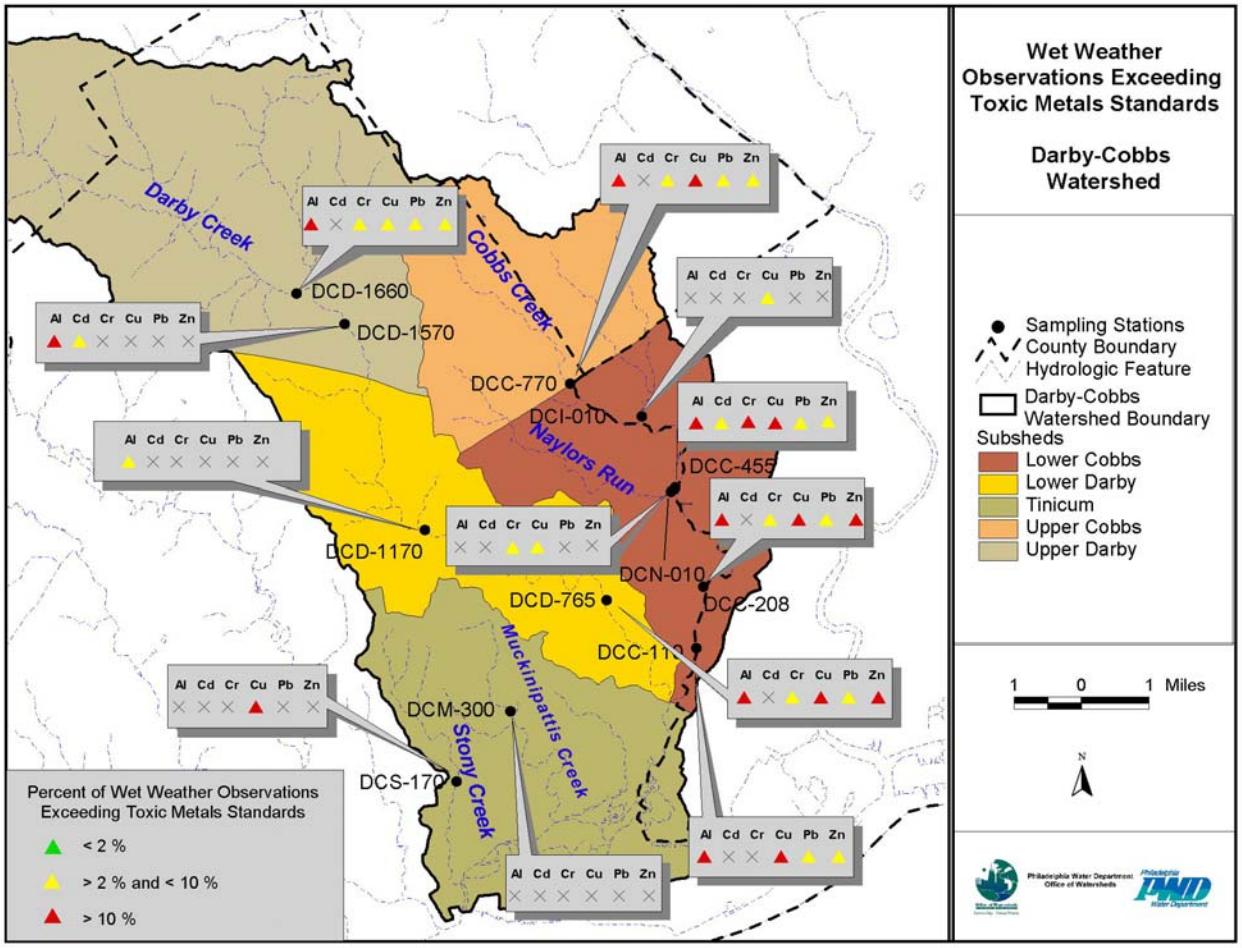


Figure 3-70: Wet weather metals indicator status update (D-C CCR 2004 section 6.7 figure 33 page 1289)

Data collected as part of PWD's 2003 fixed interval (weekly) discrete chemical sampling program also showed that the geometric mean of fecal coliform concentration at all sites exceeded water quality criteria during the swimming season (Table 3-87 and Figure 3-71). However, all individual dry weather samples collected from Darby-Cobbs Creek Watershed during the non-swimming season (n=18) showed fecal coliform bacteria concentration well below the water quality criterion of 2000 CFU/100mL. Samples from sites DCI010, DCC208, and DCC455 on 6/12/03 were likely affected by a leaking sewer. The sewer leak was subsequently detected by PWD biologists conducting a fish assessment downstream. Geometric means of fecal coliform from these sites would be 366, 324 and 696, respectively, with these samples omitted.

Overall, 33.3 % of all sites along Darby Creek mainstem met water quality standards during dry weather in 2003 (Figure 3-72). Geometric means calculated for Darby Creek sites revealed that values were generally between 2 to 4 times the season standards (i.e., 200 CFU/100 ml or 2000 CFU/100 ml) (Figure 3-73). In Cobbs Creek, sites DCI 010 and DCC 208 met water quality standards in 50.0 % and 33.3 % of the samples, respectively. Upstream and midstream sites (DCC 770 and DCC 455) had less desirable results, with standards being met only 22% of the time. No samples taken on Naylor's Run (DCN 010) met water quality standards during the swimming and non-swimming seasons.

With the exception of intense sampling upstream and downstream of a point source, surface water grab samples do not usually allow one to determine the source(s) of fecal contamination. Recent research has shown that fecal coliform bacteria may adsorb to sediment particles and persist for extended periods in sediments (VanDonsel, et al. 1967, Gerba 1976). Presence of bacterial indicators in dry weather may thus more strongly reflect past wet weather loadings than dry weather inputs (Dutka and Kwan, 1980). Clearly, there exist several possible sources of fecal coliform bacteria within the watershed, all or combinations of which may be acting within different spatial and temporal dimensions. PWD is piloting a Bacterial Source Tracking (BST) program that may eventually be useful in identifying the sources of fecal coliform bacteria collected in dry weather. Of particular interest is the relative proportion of the total bacterial load from human sources vs. domestic and wildlife animal sources.

Wet Weather Fecal Coliform Bacteria (Target C)

Based on discrete wet weather sampling conducted during 1999-2003 (Table 3-81), fecal coliform is considered a wet weather parameter of concern because the standards for both swimming season and non-swimming season were exceeded in 94% of the samples.

Table 3-87: Fecal coliform concentrations at the nine water quality monitoring sites (D-C CCR 2004 section 5.4.2.1 table 11 page 88).

Site	n	Max	Min	Median	Mean	Std. Dev.	Geometric Mean
DCC208	7	2600	140	410	674.29	859.03	437.06
DCC455	7	2900	390	540	1097.14	991.66	815.75
DCC770	7	1060	220	300	407.14	293.58	351.92
DCD765	7	530	160	310	311.43	118.80	292.60
DCD1170	4	700	120	400	412.50	32.02	411.61
DCD1570	4	320	210	240	252.50	49.92	249.00
DCD1660	7	380	160	240	257.14	68.97	249.36
DCI010	4	20000	150	600	5337.50	9778.40	995.67
DCN010	4	3000	770	1020	1227.50	598.02	1136.70

Surface water grab samples (n=54) were collected at nine sites throughout Darby- Cobbs Watershed during or within 48 hours of wet weather as part of PWD's 2003 fixed interval (weekly) discrete chemical sampling program. Results of weekly discrete fecal coliform bacteria concentration analysis appear in Table 3-88. An additional 130 automatic sampler composite samples were collected from 5 sites during two individual wet weather events as part of PWD's intensive wet weather monitoring program. Hydrograph-matched scatterplots of fecal coliform bacteria concentration at each site for each event appear in (Appendix F of the Darby-Cobbs Creek Watershed Comprehensive Characterization Report 2004 Update). The data from these events is summarized in Tables 3-89 and 3-90.

Not surprisingly, wet weather fecal coliform bacteria concentration is elevated significantly at each site compared to dry weather concentrations. Both Cobbs and Darby Creeks exhibited a typical pattern of fecal coliform bacteria concentration increasing at downstream locations. Wet weather sampling results showed concentrations of fecal coliform exceeding water quality standards at all sites in Darby-Cobbs Creek Watershed (Figure 3-70). Thirty-three percent of samples at Darby Creek sites met standards while only 16.7% of samples in Cobbs Creek were below water quality

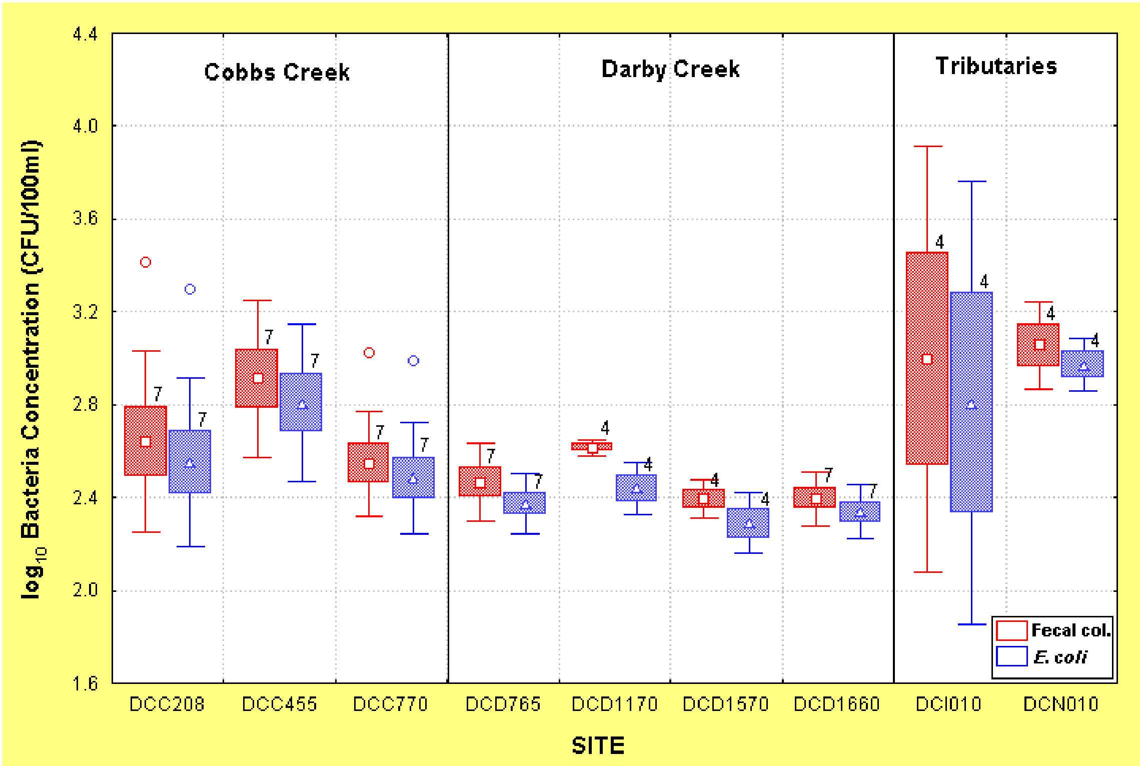


Figure 3-71: Dry weather fecal coliform and E. coli concentrations at the 9 monitoring sites, 2003 (D-C CCR 2004 section 5.4.2.1 figure 8 page 88).

standards. Moreover, fecal coliform concentrations were between 2 to 10 times greater than standard values in Darby Creek (i.e., 400-2000 CFU/100 ml during the swimming season). Similarly, mean concentrations of fecal coliform were greater than the water quality standard but varied spatially along the river continuum (Figure 3-71). For example, concentrations at the upstream location (DCC 770) were between 2 to 10 times the standard limit and increased steadily until values reached between 50 to 200 times (i.e., 10,000-40,000 CFU/100 ml) the water quality standards at Site DCC 208. Similarly, concentrations of fecal coliform at tributary locations (i.e., DCN 010 and DCI 010 ranged between 2,000 to 10,000 CFU/100 ml during wet conditions.

Table 3-88: Fixed interval fecal coliform samples collected in wet weather, 2003 (D-C CCR 2004 section 5.4.2.2 table 12 page 89).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	6	43,000	350	6,700	15,192	17,184	6,648
DCC455	6	36,000	310	2,550	8,162	13,838	2,629
DCC770	6	2,900	140	495	1,115	1,174	657
DCD765	6	4,000	440	710	1,452	1,402	1,040
DCD1170	6	3,000	320	675	1,288	1,274	802
DCD1570	6	4,000	160	325	1,133	1,537	532
DCD1660	6	5,300	30	275	1,772	2,474	449
DCI010	6	110,000	450	3,000	21,017	43,706	3,614
DCN010	6	4900	590	3,300	2,902	1,888	2,187

Table 3-89: Fecal coliform concentrations recorded at the 5 wet weather monitoring locations during storm event 1, 2003 (D-C CCR 2004 section 5.4.2.2 table 13 page 90).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	18	182,000	350	78,500	71,275	54,242	28,423
DCC455	19	200,000	1,400	43,000	63,168	63,202	28,615
DCC770	18	20,000	420	2,300	6,004	7,424	2,378
DCD765	11	41,000	1,000	9,400	12,100	11,731	7,199
DCD1660	19	161,000	1,800	6,600	26,763	39,534	11,101

Table 3-90: Fecal coliform concentrations recorded at the 5 wet weather monitoring locations during storm event 2, 2003 (D-C CCR 2004 section 5.4.2.2 table 14 page 90).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	9	82,000	25,000	29,000	41,000	21,529	36,891
DCC455	9	103,000	8,800	30,000	32,744	28,561	24,975
DCC770	9	46,000	2,200	6,600	14,167	16,827	8,387
DCD765	9	20,000	3,600	8,500	8,300	4,220	7,466
DCD1660	9	18,000	3,100	5,500	6,733	5,140	5,721

Future Investigation of Bacteria Conditions in Cobbs Creek

Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the lower Tacony Creek and the Frankford Creek. Future work efforts will include the development of informational total maximum daily load assessments for bacteria from all potential sources in the watershed. Progress and results of this work and any proposed remedial control actions will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

Based on discrete sampling, temperature is considered a parameter of concern because the state standard was exceeded in 12% of the samples collected during dry weather (Table 3-80). During wet weather, temperature is considered to be a parameter of potential concern because the standard was exceeded in 9.6% of the wet weather samples (Table 3-81). Although, discrete sampling indicated temperature was a concern, thermal maxima for sites in Darby Cobbs Watershed, as measured in 2003 with continuous water quality monitoring equipment, never exceeded state water quality standards. Changes in temperature of 2ºC or more were observed at most sites on a number of occasions; however, changes of this magnitude occurred in dry and in wet weather.

The role of temperature in shaping aquatic communities cannot be understated. With the exception of birds and mammals, all freshwater aquatic organisms are poikilotherms ("cold-blooded"). Unable to regulate body temperature through metabolism, these organisms must select suitable temperature conditions within their habitats. PADEP has established temperature criteria for the waters of the commonwealth, largely to delineate areas requiring more stringent thermal protection for naturally-reproducing populations of sensitive ("cold water") fish species, recreationally-sought salmonids, in particular. Temperature criteria also serve to protect aquatic life from increases in temperature from

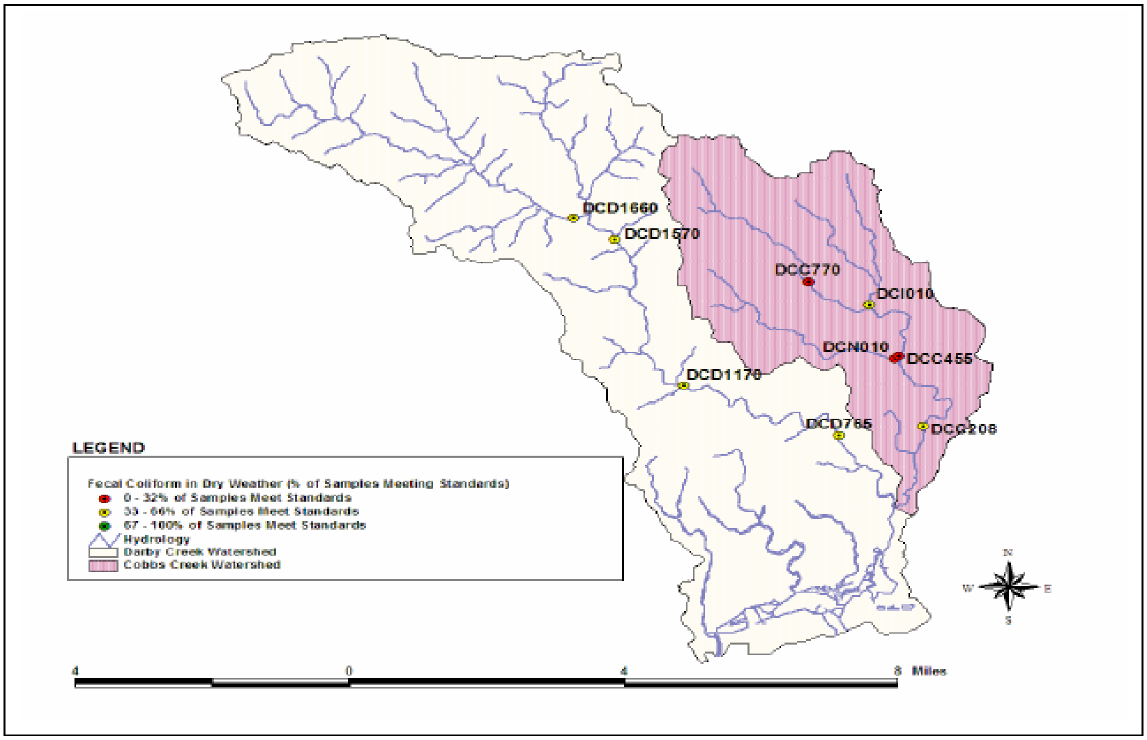


Figure 3-72: Dry weather fecal coliform indicator status update (D-C CCR 2004 section 6.5 figure 28 page 123).

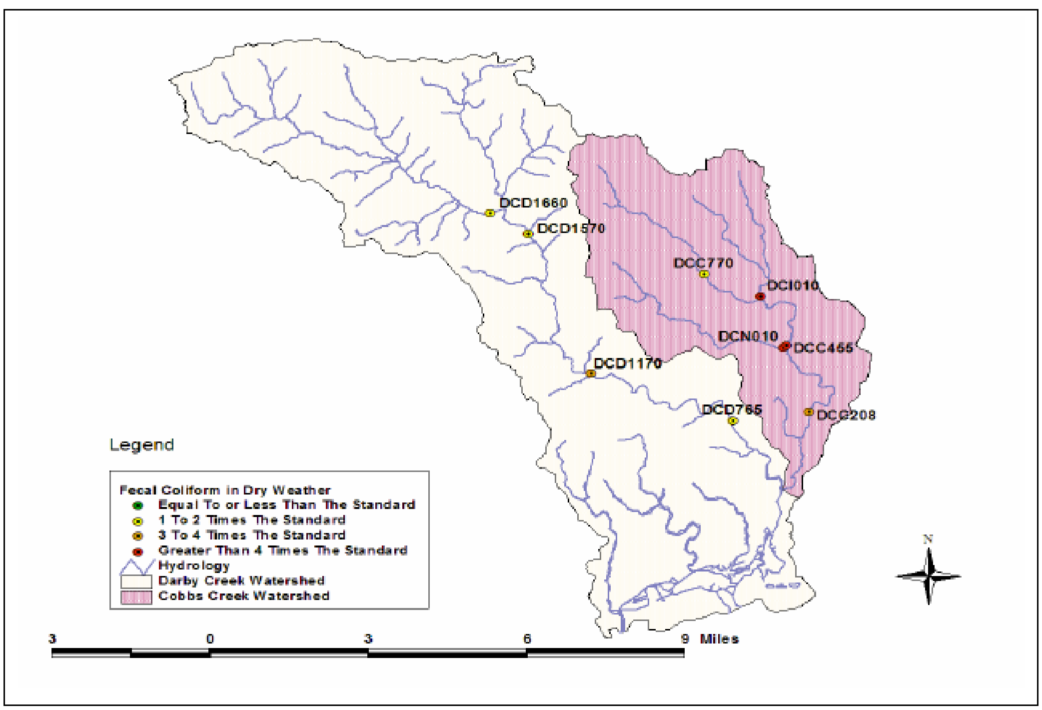


Figure 3-73: Geometric means of fecal coliform concentrations in dry weather (D-C CCR 2004 section 6.5 figure 29 page 124).

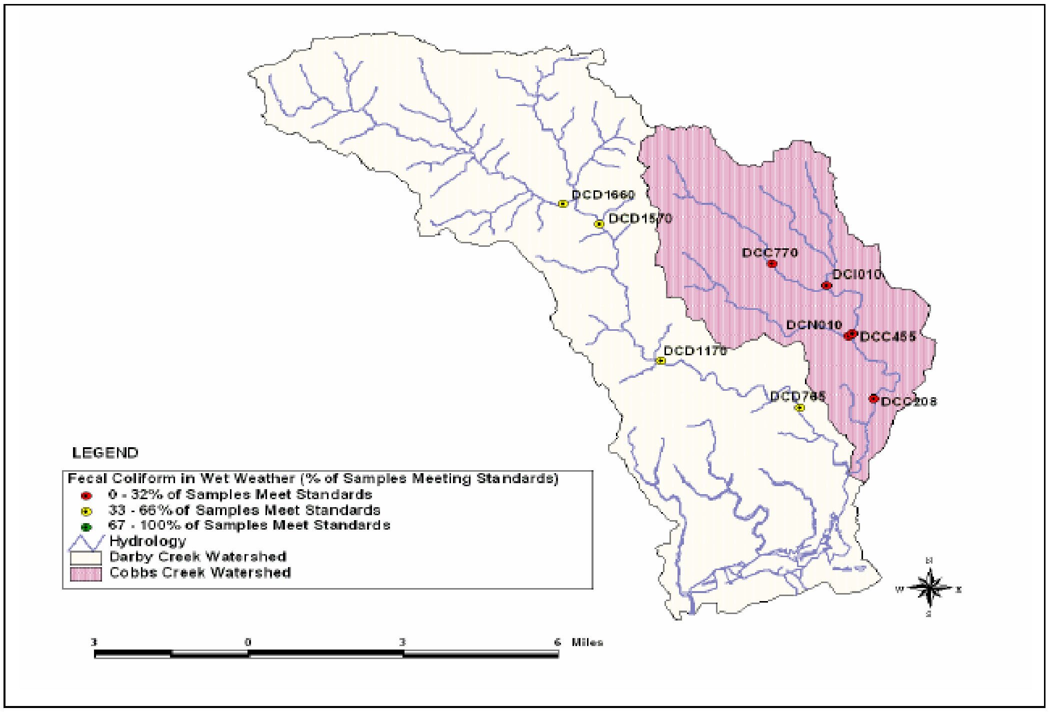


Figure 3-74: Wet weather fecal coliform indicator status update (D-C CCR 2004 section 6.5 figure 30 page 125).

.

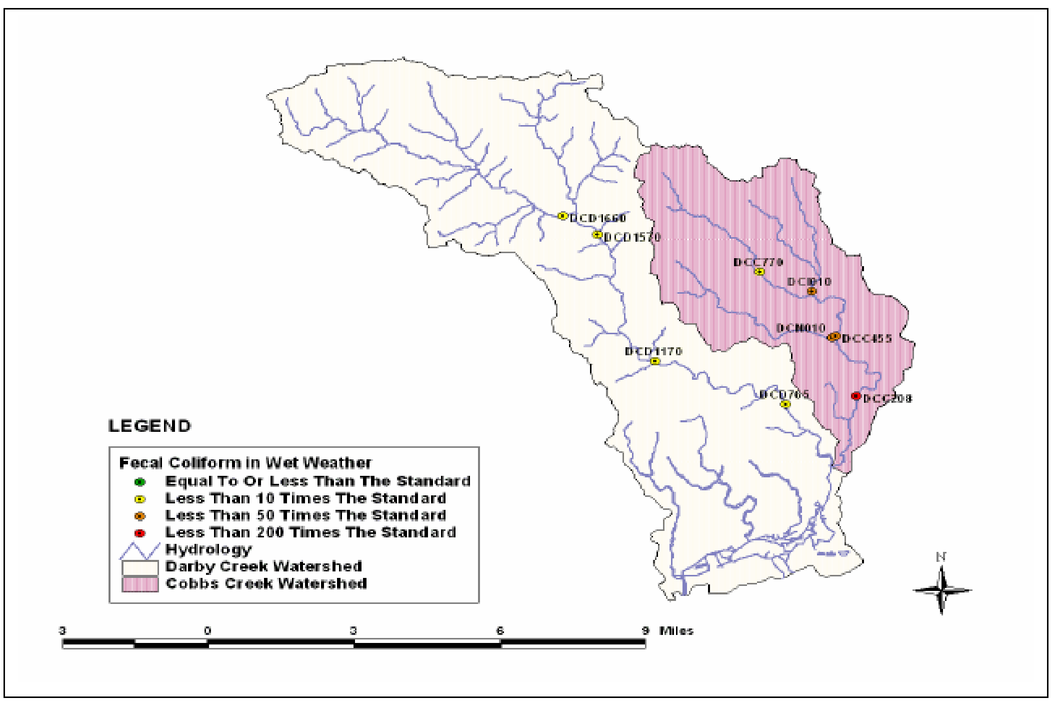


Figure 3-75: Geometric means of fecal coliform concentrations in wet weather (D-C CCR 2004 section 6.5 figure 31 page 126).

industrial activity (e.g., cooling water). Darby-Cobbs Creek Watershed does not support natural populations of coldwater fish, and is not known to be significantly affected by discharges of cooling waters.any water bodies that cannot support natural populations of cold water fish do have adequate thermal protection to maintain hatchery-raised adult trout. Segments of Darby Creek watershed north of PA Rte 3 (West Chester Pike) are so protected and are designated a trout stocking fishery (TSF); the remainder of Darby-Cobbs Creek Watershed is designated a warm water fishery (WWF).

In addition to limiting effects of lethal and sublethal temperatures on fish survival, temperature regime has myriad implications for aquatic communities. These effects are discussed in greater detail in Section 5.3.5, Habitat Suitability Indices of the 2004 Update to Darby-Cobbs Creek Watershed CCR.

3.4.2.2.3 Biological Assessment of Darby-Cobbs Creek Watershed

Biological monitoring is a useful means of detecting anthropogenic impacts to the aquatic community. Resident biota (e.g. benthic macroinvertebrates, fish, periphyton) in a water body are natural monitors of environmental quality and can reveal the effects of episodic and cumulative pollution and habitat alteration (Plafkin et. al.1989, Barbour et al. 1995). Biological surveys and assessments are the primary approaches to biomonitoring. During this period, macroinvertebrate, ichthyfauna and habitat assessments were conducted at specified locations within Cobbs Creek watershed. Geographical Information Systems (GIS) databases and watershed maps were also constructed to provide accurate locations of the sampling sites. The Office of Watersheds and the Bureau of Laboratory Services then analyzed compiled data to provide both a quantitative and qualitative assessment of the biological integrity of Cobbs Creek and to provide insight on the current problems associated with this urban stream system. Darby-Cobbs Creek Watershed Comprehensive Characterization Report and the 2004 Update address future assessments and potential solutions for the restoration of Darby-Cobbs Creek Watershed.
(PWD, 2004)

Sites in Darby-Cobbs Creek Watershed were compared to reference sites on French Creek and Rock Run, in Chester County, PA. Reference sites were chosen to reflect the range of stream drainage areas in Darby-Cobbs Creek Watershed, yet extensive impervious cover in portions of Darby-Cobbs Creek Watershed complicates this comparison. Due to exaggerated storm flows and concomitant erosion, many sites in the Darby-Cobbs Creek Watershed may be categorized as first or second order streams, yet exhibit geomorphological attributes (e.g., bankfull discharge area) similar to sites with much larger drainage areas. These details are addressed in greater detail in Section 5.3: Habitat Assessment of the Comprehensive Characterization Report 2004 Update.

Benthic Macroinvertebrate Assessment

Benthic macroinvertebrate monitoring occurred at 17 sites in Darby-Cobbs Creek Watershed during 2003. Similar to the 1999 sampling effort, Rapid Bioassessment Protocol III (RBP III) was chosen as the approved method for assessing the condition of the macroinvertebrate community in Darby-Cobbs Creek Watershed.

The assessment conducted in 2003 reconfirmed findings of the Pennsylvania Department of Environmental Protection (PADEP) and Philadelphia Water Department (PWD). Benthic impairment in Cobbs Creek was omnipresent; stream designations ranged from "moderately impaired” to “severely impaired” (Figure 3-76). Darby Creek monitoring sites received the same designations, with the exception of one upstream site which scored as “slightly impaired”.

A total of 2,114 individuals of 40 taxa were collected and identified during the 2003 benthic macroinvertebrate survey of Darby-Cobbs Creek Watershed. Mean taxa richness of all sites within the watershed was 14.3 (Table 3-91). Overall, moderately tolerant (89.74%) and generalist feeding taxa (75.72%) dominated the watershed. Mean Hilsenhoff Biotic Index (HBI) of all assessment sites was 5.63 (Figure 3-77). Overall, the watershed lacked pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. While present at four upstream Darby Creek sites, abundance of EPT taxa was very low (Figure 3-78). Midges (family Chironomidae) and net-spinning hydropsychid caddisflies (Hydropsyche and Cheumatopsyche) dominated the benthic assemblage of most sites within the watershed (percent contribution ranged from 23.14% to 74.07%). Annelids, riffle beetles, isopods, amphipods, tipulids, gastropods, and oligochaetes were also present throughout the watershed. Results of benthic macroinvertebrate studies are discussed in greater detail in the 2004 Comprehensive Characterization Report Update.

The severity of impairment throughout Darby-Cobbs Creek Watershed suggests that attaining healthy benthic communities in mainstem localities and associated tributaries is not a feasible option at this time without active habitat restoration. Habitat restoration, flow attenuation and active re-introduction (i.e., “invertebrate seeding”) may be the only solutions to ensure a viable benthic community within this watershed.

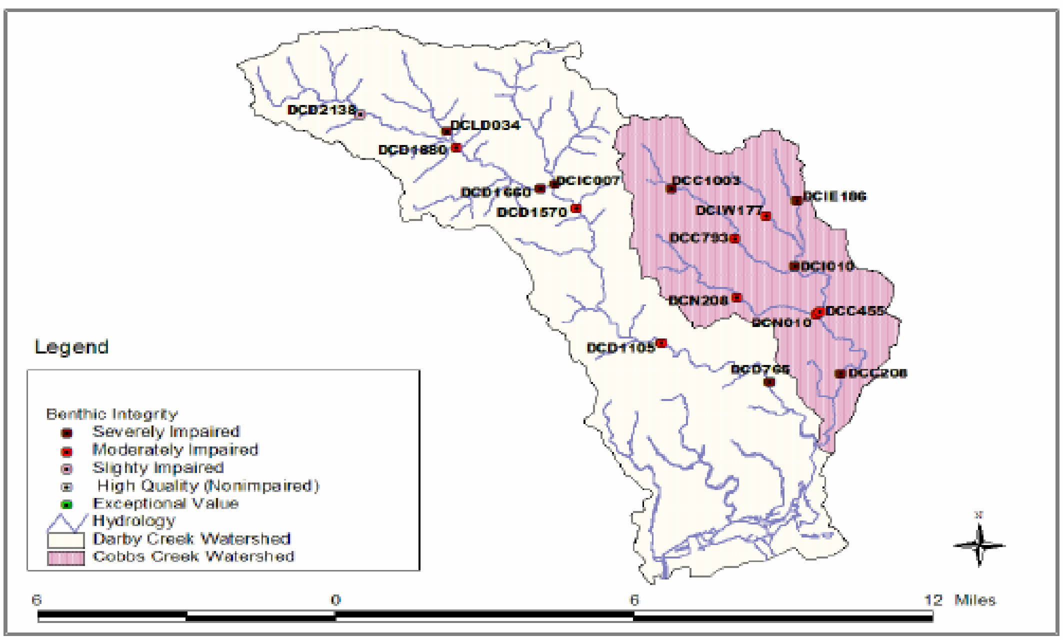


Figure 3-76: Benthic impairment in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 6.4 figure 27 page 121).

Table 3-91: Biological condition results for RBP III (D-C CCR 2004 section 5.1.1 table 1 page 46).

Watershed	Monitoring Site	Taxa Richness	Modified EPT Taxa	Hilsenhoff Biotic Index (modified)	Percent Dominant Taxon	% Modified Mayflies	Biological Quality (%)	Indicator Status
Cobbs	DCC208	12	0	7.06	42.42%	0.00	0.00	Severely Impaired
	DCC455	12	0	5.24	44.86%	0.00	26.67	Moderately Impaired
	DCC793	15	1	5.44	39.44%	0.00	40.00	Moderately Impaired
	DCC1003	13	0	5.88	57.80%	0.00	13.33	Severely Impaired
Darby	DCD765	11	1	5.69	68.70%	0.00	0.00	Severely Impaired
	DCD1105	17	1	5.38	32.08%	0.00	20.00	Moderately Impaired
	DCD1570	16	4	5.04	33.09%	100.00	46.67	Moderately Impaired
	DCD1660	14	1	5.45	61.42%	0.00	13.33	Severely Impaired
	DCD1880	17	3	4.81	23.14%	0.00	46.67	Moderately Impaired
	DCD2138	23	3	5.03	34.42%	100.00	73.33	Slightly Impaired
Tributaries	DCN010	16	1	6.13	15.04%	0.00	40.00	Moderately Impaired
	DCN208	13	0	6.02	23.97%	0.00	33.33	Moderately Impaired
	DCI010	12	0	5.97	60.29%	0.00	13.33	Severely Impaired
	DCIW177	12	1	5.83	37.82%	0.00	33.33	Moderately Impaired
	DCIE186	11	0	5.78	74.07%	0.00	6.67	Severely Impaired
	DCLD034	13	1	5.28	51.68%	0.00	13.33	Severely Impaired
	DCIC007	16	2	5.65	51.32%	0.00	6.67	Severely Impaired

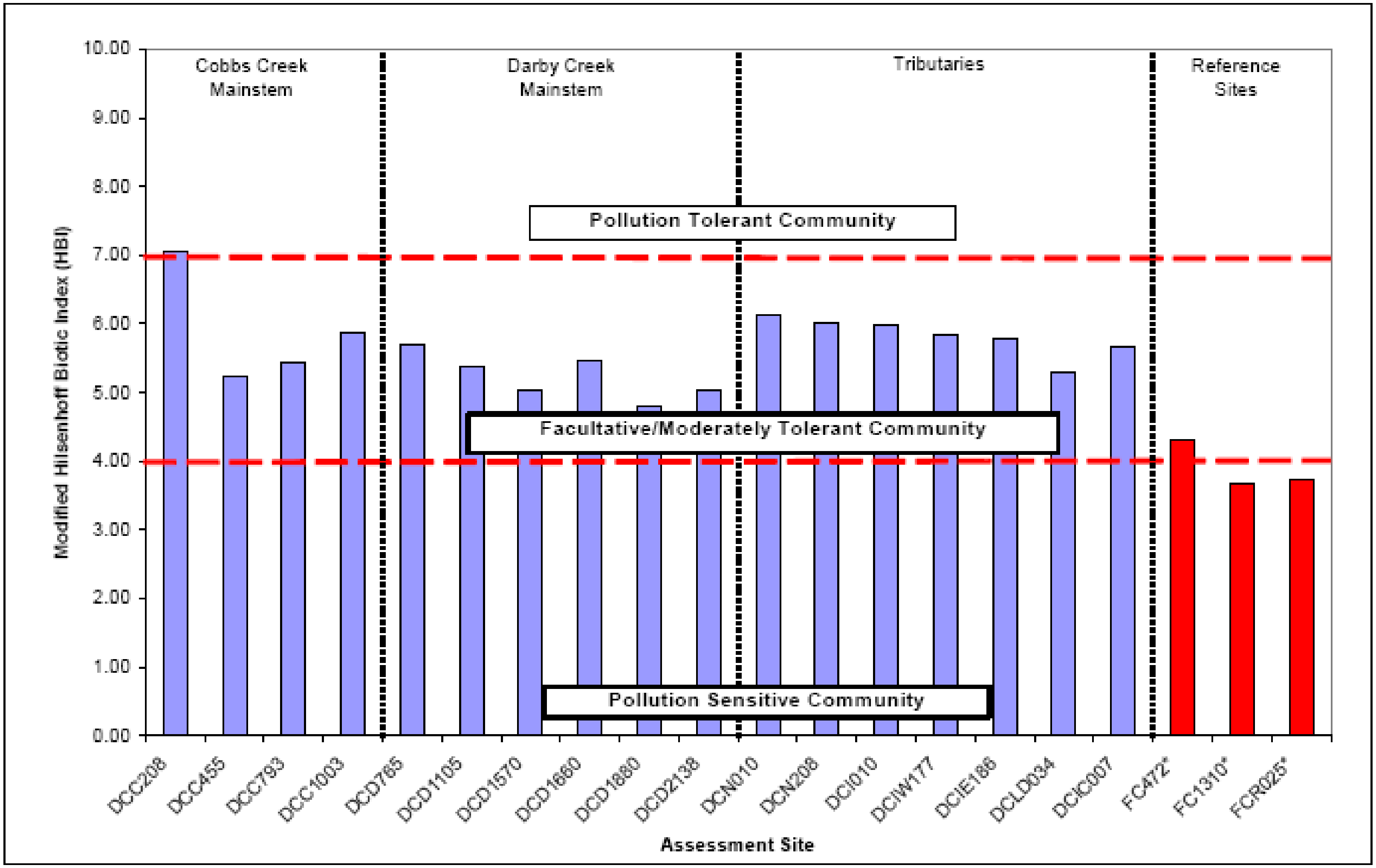


Figure 3-77: Modified Hilsenhoff Biotic Index (HBI) scores of assessment sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.1.1 figure 1 page 47).

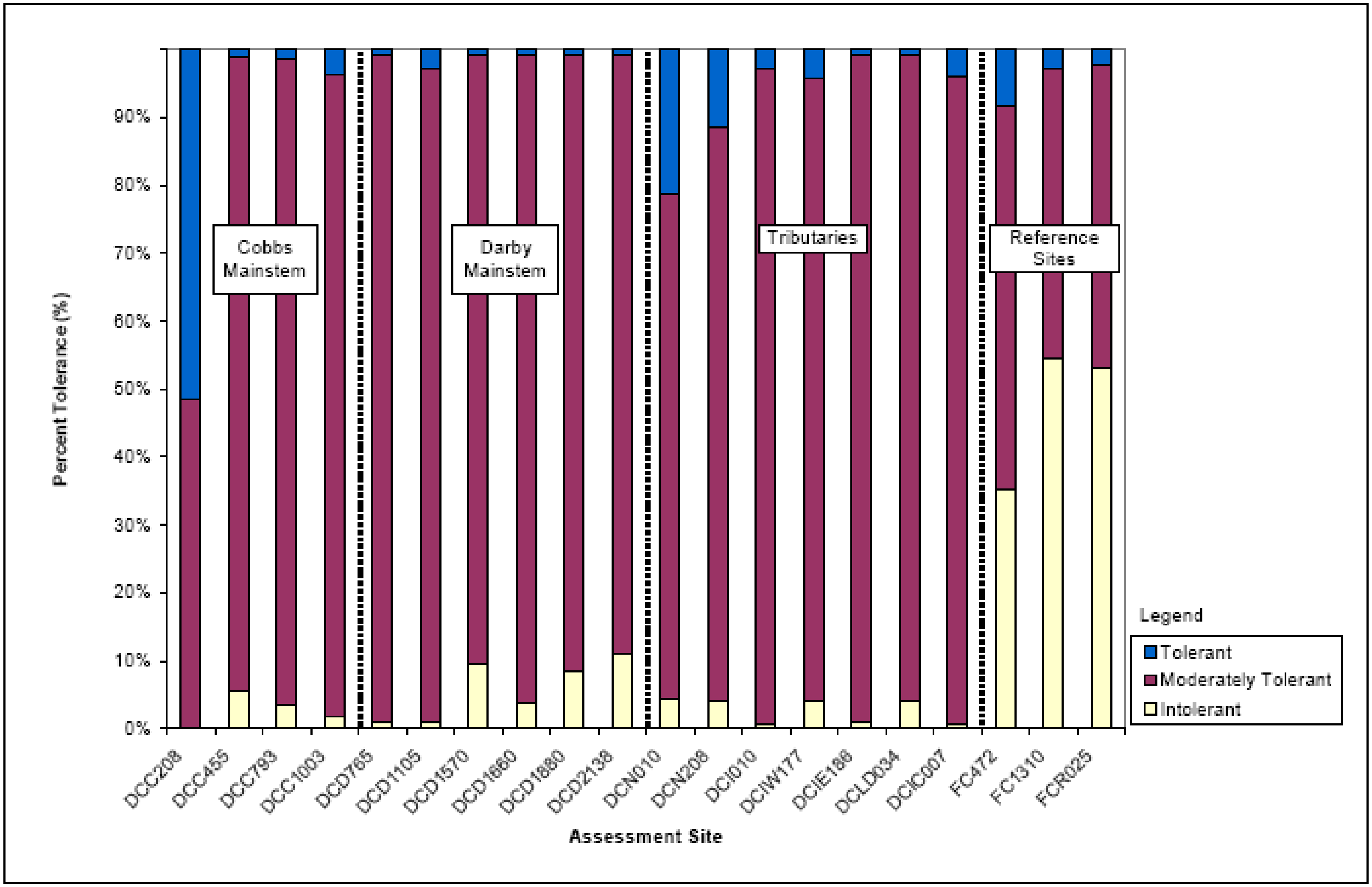


Figure 3-78: Pollution tolerance values (%) of macroinvertebrate assemblages at each assessment site in Darby-Cobbs Watershed (D-C CCR 2004 section 5.1.1 figure 2 page 49).

Fish Assessment

A total of 12,882 individuals of 44 species representing 13 families were collected throughout Darby-Cobbs Creek Watershed in the 2003 bioassessment (Table 3-92). Blacknose dace (Rhinichthys atratulus) and Banded killifish (Fundulus diaphanus), two taxa highly tolerant of poor stream conditions, were most abundant and comprised approximately 33% of all fish collected. Other common species were White sucker (Catostomus commersoni), Mummichog (Fundulus heteroclitus), Common shiner (Luxilus cornutus), and Swallowtail shiner (Notropis procne). Of 44 species collected, seven species comprised 78% of the entire fish assemblage. Similarly, four species made up nearly 70% of total biomass, with white sucker and American eel (Anguilla rostrata) contributing greater than 55%. In general, Darby Creek had greater species richness, but Cobbs Creek had higher abundance, density (individuals per unit area), and catch rates (catch per unit effort).

Trophic composition evaluates quality of the energy base and foraging dynamics of a fish assemblage. This is a means to evaluate the shift towards more generalized foraging that typically occurs with increased degradation of the physicochemical habitat (Barbour et al., 1999). Generalist feeders (54.7%) and insectivores (38.2%) dominated Darby-Cobbs Creek Watershed, with 6.1% top carnivores and approximately 1% herbivores and filter feeders. Trophic composition was fair compared to reference sites. In Cobbs Creek, top carnivore and insectivore taxa abundance decreased while abundance of generalist feeders increased in an upstream direction (Figure 3-79). Also, percentage of White suckers (C. commersoni) increased in an upstream direction, as White suckers typically increase in abundance in degraded streams. In Darby Creek, abundance of generalist feeders increased, whereas the percentage of insectivore taxa decreased in an upstream direction. Results of benthic macroinvertebrate studies are discussed in greater detail in the 2004 Comprehensive Characterization Report Update.

Tolerance designations describe the susceptibility of a species to chemical and physical perturbations. Intolerant species are typically first to disappear following a disturbance (Barbour et al., 1999). Tolerant and moderately tolerant species composed 95% of the fish fauna in Darby-Cobbs Creek Watershed (Figure 3-80). Cutlips minnow (Exoglossum maxillingua) and stocked trout (Oncorhynchus mykiss, Salmo trutta, Salvelinus fontinalis) were the only intolerant taxa found in the non-tidal sites. Eastern silvery minnow (Hybognathus regius) and Striped bass (Morone saxatilis) were additional intolerant species found in the tidal portions of the watershed. No more than one sensitive species was found at any given non-tidal site. Furthermore, all but two assessment sites were dominated by taxa tolerant of poor water quality. The non-tidal portion of Cobbs Creek was devoid of pollution-sensitive taxa. The relative low abundance of intolerant species implies a high level of disturbance that appears to increase upstream.

The Index of Biotic Integrity (IBI) is useful in determining long-term effects and coarse-scale habitat conditions because fish are relatively long-lived and mobile. A site with high integrity (i.e. high score) is associated with native communities that interact under natural community processes and functions (Karr 1981). Since biological integrity is closely related to environmental quality, assessments of integrity can serve as a surrogate measurement of health (Daniels et al., 2002). Mean IBI score for Darby-Cobbs Creek Watershed was 31 (out of 50), placing it in the “fair” category (Figure 3-81). Skewed trophic structure and rare intolerant species are characteristics of a fish community in the “fair” category. The Modified Index of Well-Being and Shannon Diversity Index values, which are measures of diversity and abundance, decreased in an upstream direction. Overall, the more downstream sites had higher biological integrity than upstream sites (Figure 3-82).

After a thorough review of historical and recent data compiled on Cobbs Creek (i.e., 1999 and 2003), it is evident that active restoration strategies must be implemented and monitored over time to measure the efficacy of planned habitat restoration projects, as defined in Darby-Cobbs Integrated Watershed Management Plan.

Table 3-92: Species list and relative abundance of fish taxa collected in the Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.1 table 2 page 55).

Scientific Name	Common Name	Number Of Individuals Identified
Alosa aestivalis	Blueback Herring	42
Alosa sapidissima	American Shad	1
Ameiurus catus	White Catfish	1
Ameiurus natalis	Yellow Bullhead Catfish	1
Ameiurus nebulosus	Brown Bullhead Catfish	60
Ambloplites rupestris	Rock Bass	76
Anguilla rostrata	American Eel	555
Carassius auratus	Goldfish	11
Catostomus commersoni	White Sucker	831
Cyprinella analostana	Satinfin Shiner	219
Cyprinus carpio	Common Carp	32
Cyprinella spiloptera	Spotfin Shiner	9
Dorosoma cepedianum	Gizzard Shad	3
Esox lucius x Esox masquinongy	Tiger Muskellunge	1
Etheostoma olmstedi	Tessellated Darter	237
Exoglossum maxillingua	Cutlips Minnow	442
Fundulus diaphanus	Banded Killifish	1917
Fundulus heteroclitus	Mummichog	1088
Gambusia affinis	Mosquitofish	3
Hybognathus regius	Eastern Silvery Minnow	117
Ictalurus punctatus	Channel Catfish	2
Lepomis auritus	Redbreast Sunfish	651
Lepomis cyanellus	Green Sunfish	8
Lepomis gibbosus	Pumpkinseed Sunfish	129
Lepomis auritus x Lepomis gibbosus	Sunfish Hybrid	1
Lepomis macrochirus	Bluegill Sunfish	52
Luxilus cornutus	Common Shiner	1018
Micropterus dolomieui	Smallmouth Bass	23
Micropterus salmoides	Largemouth Bass	6
Morone americana	White Perch	1
Morone saxatilis	Striped Bass	1
Notemigonus crysoleucas	Golden Shiner	11
Notropis hudsonius	Spottail Shiner	200
Notropis procne	Swallowtail Shiner	1465
Oncorhynchus mykiss	Rainbow Trout	26
Pimephales notatus	Bluntnose Minnow	65
Pimephales promelas	Fathead Minnow	148
Pomoxis nigromaculatus	Black Crappie	1
Rhinichthys atratulus	Blacknose Dace	2157
Salvelinus fontinalis	Brook Trout	1
Salmo trutta	Brown Trout	31
Semotilus atromaculatus	Creek Chub	143
Semotilus corporalis	Fallfish	24
Umbra pygmaea	Eastern Mudminnow	1

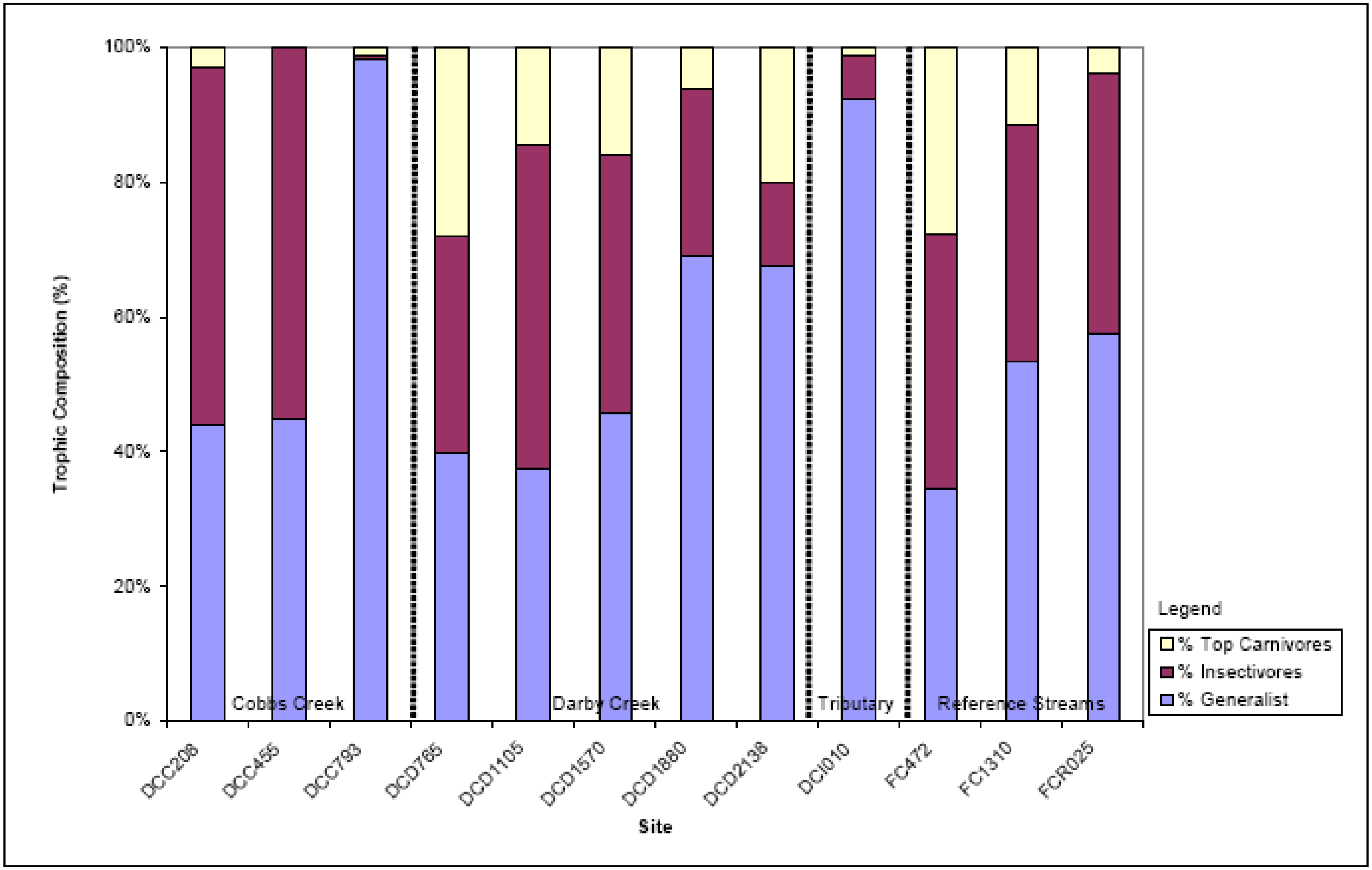


Figure 3-79: Trophic structure of fish assemblages in the Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.1 figure 3 page 56).

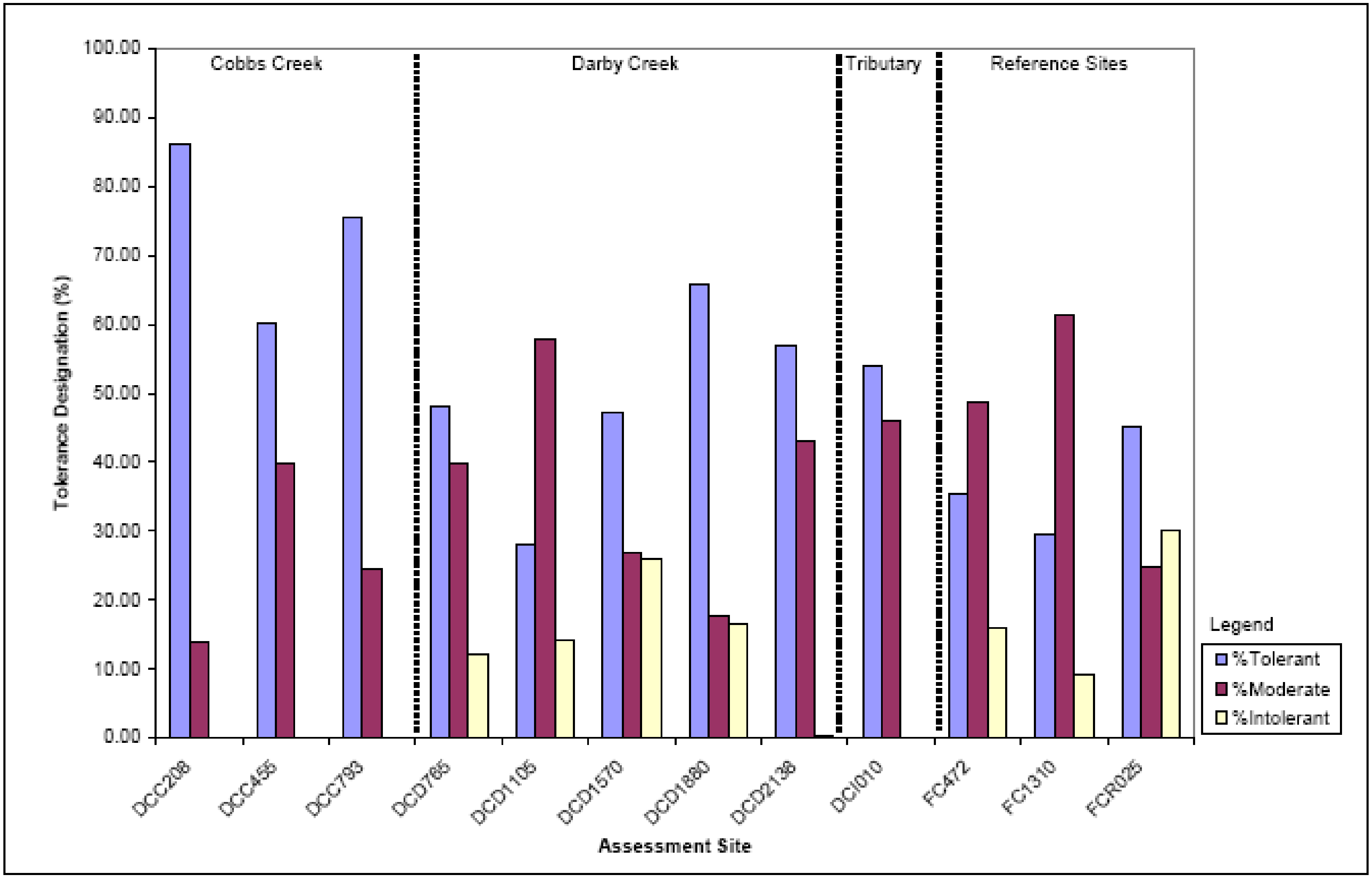


Figure 3-80: Pollution tolerance values at the monitoring sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.2.1 figure 4 page 58).

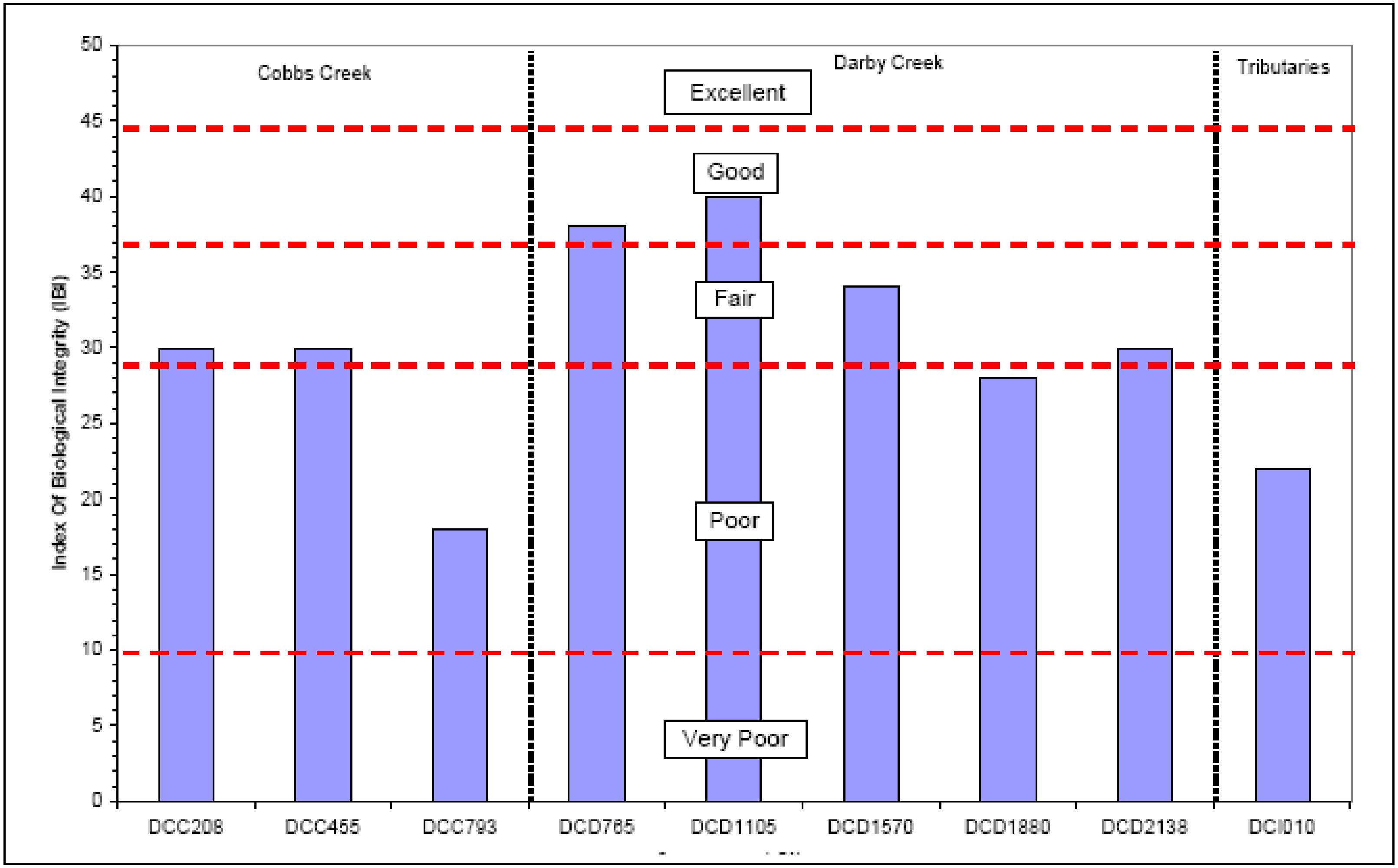


Figure 3-81: Index of Biological Integrity (IBI) scores at the nine assessment sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.2.1 figure 5 page 59).

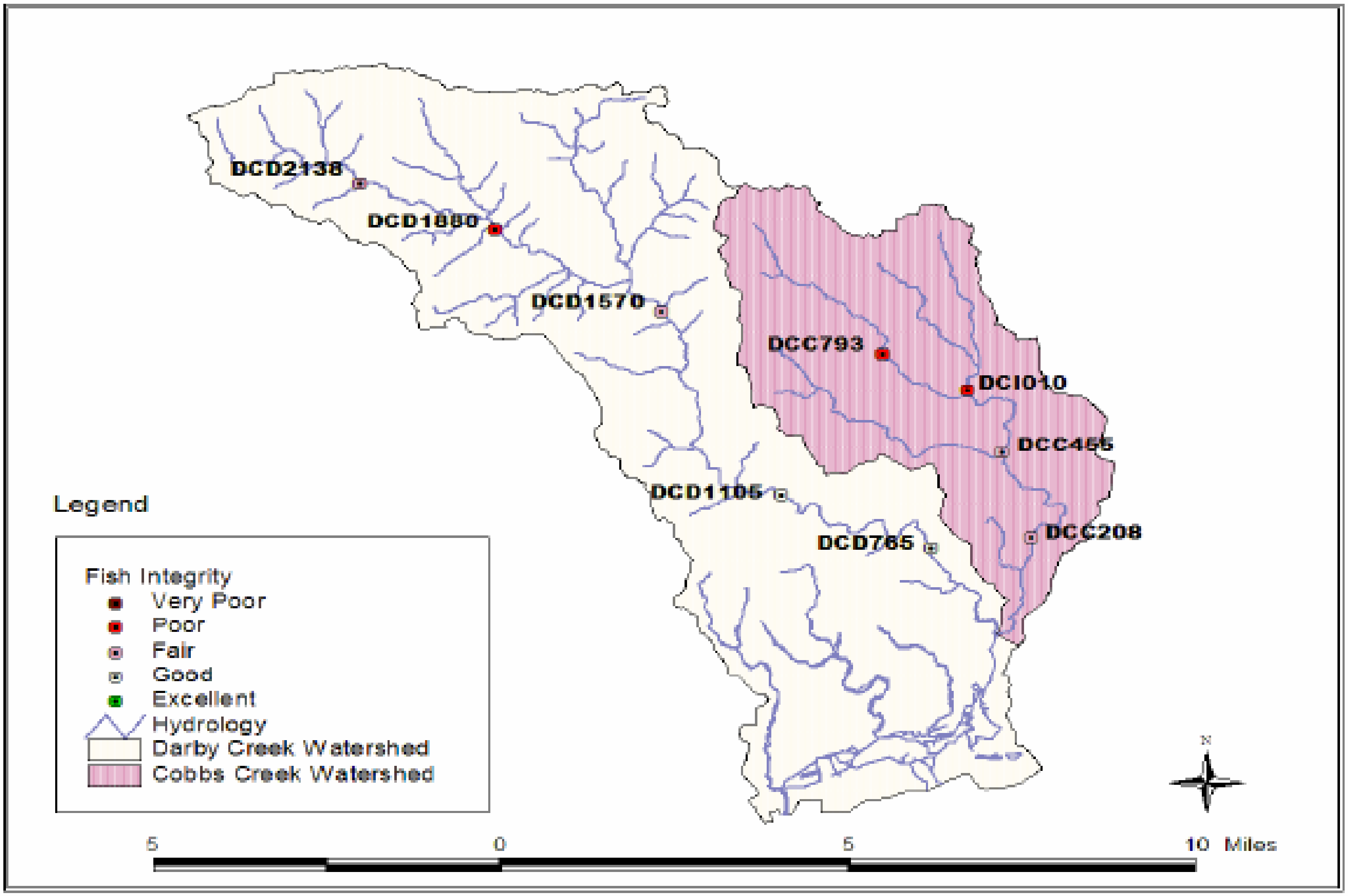


Figure 3-82: Fish assessment of the Darby-Cobbs Creek Watershed, 2003 (D-C CCR 2004 section 6.4 figure 26 page 120)

3.4.2.2.4 Habitat Assessment of Darby-Cobbs Creek Watershed

Habitat impairments in the Darby-Cobbs Creek Watershed are numerous, mirroring those of other urban stream systems assessed by PWD. First and foremost, stream habitats within the Darby-Cobbs Creek Watershed are impaired due to effects of stormwater. Preponderance of impervious surfaces, particularly within Cobbs Creek Watershed, has diminished baseflow and caused small streams to exhibit increasingly "flashy" hydrographs in response to rain events. According to a baseflow separation analysis based on 27 years of flow data at USGS gauge 01475550, baseflow currently accounts for only 42% of mean total yearly flow from Cobbs basin. In contrast, Darby Creek Watershed is less affected by impervious surfaces and has a yearly flow regime similar to the reference stream.

Exaggerated storm flows typical of urbanized watersheds result in erosion of banks and deposition of sediment in pools and on point bars. Many stream reaches in the watershed have been excessively over-widened and downcut; channels have been enlarged so severely that baseflow does not completely fill the channel or adequately cover riffle substrates. In many reaches, floodplain disconnection exists during almost all flow conditions. Due to ongoing erosion, nearly all stormwater forces are applied to a bare soil interface. Streambank erosion has also exposed sewer infrastructure (e.g., Manholes, interceptor sewers) increasing susceptibility of infrastructure to damage and leaks.

Fish and benthic macroinvertebrate sampling reinforced the view that stormwater flow is probably the most important factor shaping biological communities in most of the watershed. Stream organisms ill-adapted to extreme flows may be washed downstream and displaced from their optimum habitat. Erosion and sedimentation may decrease reproductive success of invertebrates and fish by washing away eggs, or alternately, covering eggs with sediment. Fish and benthic macroinvertebrate community responses to habitat modification were not consistent throughout the watershed. Serious effects were observed in Cobbs Creek and its tributaries, while upstream reaches of Darby Creek were similar in some aspects to reference conditions. Lower reaches of Darby Creek showed contrasting responses overall.

Common invertebrates of the most degraded portions of Cobbs and Lower Darby Creek have morphological or behavioral adaptations to increased stream velocities. Chironomid midges construct tubes made of silk that are firmly attached to stream substrates. The insect's body may be completely retracted within this protective tube. Similarly, hydropsychid caddisflies construct silk nets, which serve as refugia during exaggerated flow conditions. Free-living shredder taxa (e.g., case building caddisflies and tipulids) were not present at most degraded sites, and very few species with external gills were present.

Dominant fish in degraded reaches also exhibit morphological and behavioral adaptations to increased stream velocities. Blacknose dace and white suckers are generally more rounded in body cross-section (i.e., dorsoventrally flattened) than many other stream fish. This body shape may allow these fish to better hug the stream bottom or slope, thereby avoiding the highest velocities. American eels were dominant (in terms of biomass) at many sites. These fish have the ability to completely bury themselves in sediments, enter small crevices, and easily extract themselves from tight spaces by reversing their undulations and swimming backwards. American eels also have the advantage of reproducing at sea, only entering the watershed once they are able to swim freely. All other fish in the watershed are vulnerable to severe flows or smothering by silt during their embryo or larval stage.

Continuous DO and pH data suggest that periphyton biomass and community structure change fundamentally following severe storm events. Dense periphyton carpets are found in slower water throughout the watershed. While these algae have not been investigated taxonomically, filamentous greens (e.g., Cladophora sp.) appear to dominate the biomass of the periphyton climax community. Soil erosion and runoff, particularly during smaller storm events, may be a significant source of the phosphorus that drives these algal blooms.

Instream habitat was evaluated with EPA protocols at seventeen (n=17) sites targeted for benthic macroinvertebrate sampling. A much more detailed reach ranking survey, based in fluvial geomorphological principles, was conducted for Cobbs Creek, and West and East Indian Creeks in 2000. This document, entitled "Cobbs Creek Geomorphologic Survey-Level II: Guiding Principles for Fluvial Geomorphologic Restoration of Cobbs Creek" is available from PWD's Office of Watersheds.

Comparisons to Reference Site
Habitat features at Darby-Cobbs Creek Watershed sites were compared to those of the reference sites located in nearby Chester County. Mainstem and third order tributary sites were compared to French Creek reference sites, located in Coventry Township, Chester County, PA. Tributary sites, second order or less, were compared to Rock Run, a tributary to French Creek located in Coventry Township, Chester County, PA.

In 2003, habitat at 17 sites throughout Darby-Cobbs Creek Watershed was surveyed by PWD staff biologists. Monitoring locations along Darby Creek mainstem received consistent scores, ranging from the highest value, “Comparable to Reference Conditions”, to the next incremental level, “Supporting” (Figure 3-83). Five Darby Creek sites had greater habitat scores than the reference site, indicating good habitat conditions along mainstem reaches of Darby Creek. Similarly, two tributary sites, Little Darby Creek and Ithan Creek, received ratings of “Comparable to Reference Conditions” (Figure 3-84).

In contrast to Darby Creek, habitat values along Cobbs Creek and its tributaries were less desirable. Of the four main stem locations, two sites received “Supporting” while the remaining two locations were designated as “Partially Supporting” (i.e., marginal). Naylor’s Run, a 2nd order tributary to lower Cobbs Creek, received rankings of “Supporting” in the upper portion and “Non-Supporting” near the confluence with Cobbs Creek. Similarly, sites on the east and west branches of Indian Creek were determined to be only “Partially Supporting” of aquatic communities.

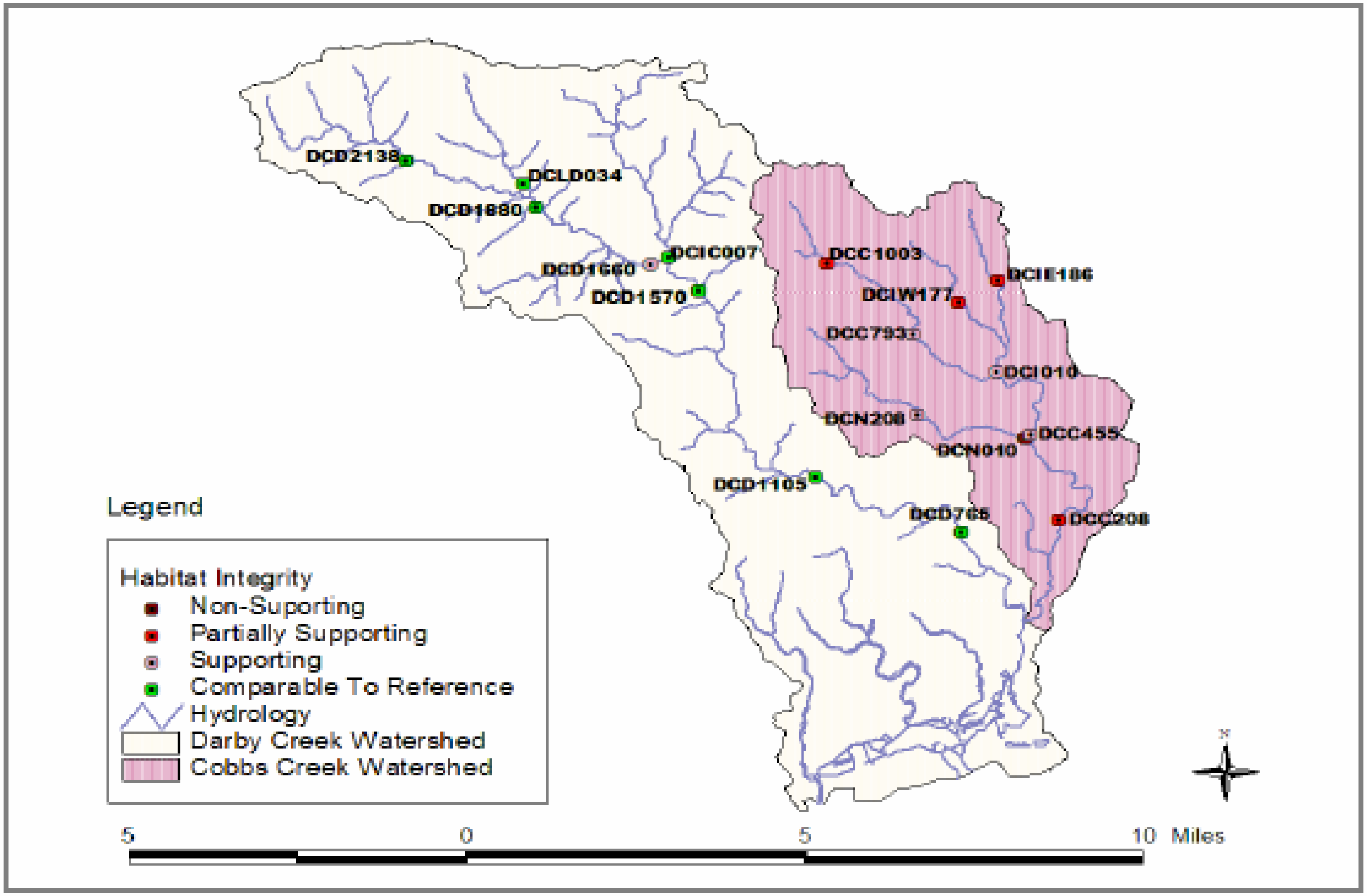


Figure 3-83: Stream channels and aquatic habitat assessment in the Darby-Cobbs Creek Watershed, 2003 (D-C CCR 2004 section 6.2 figure 25 page 118)

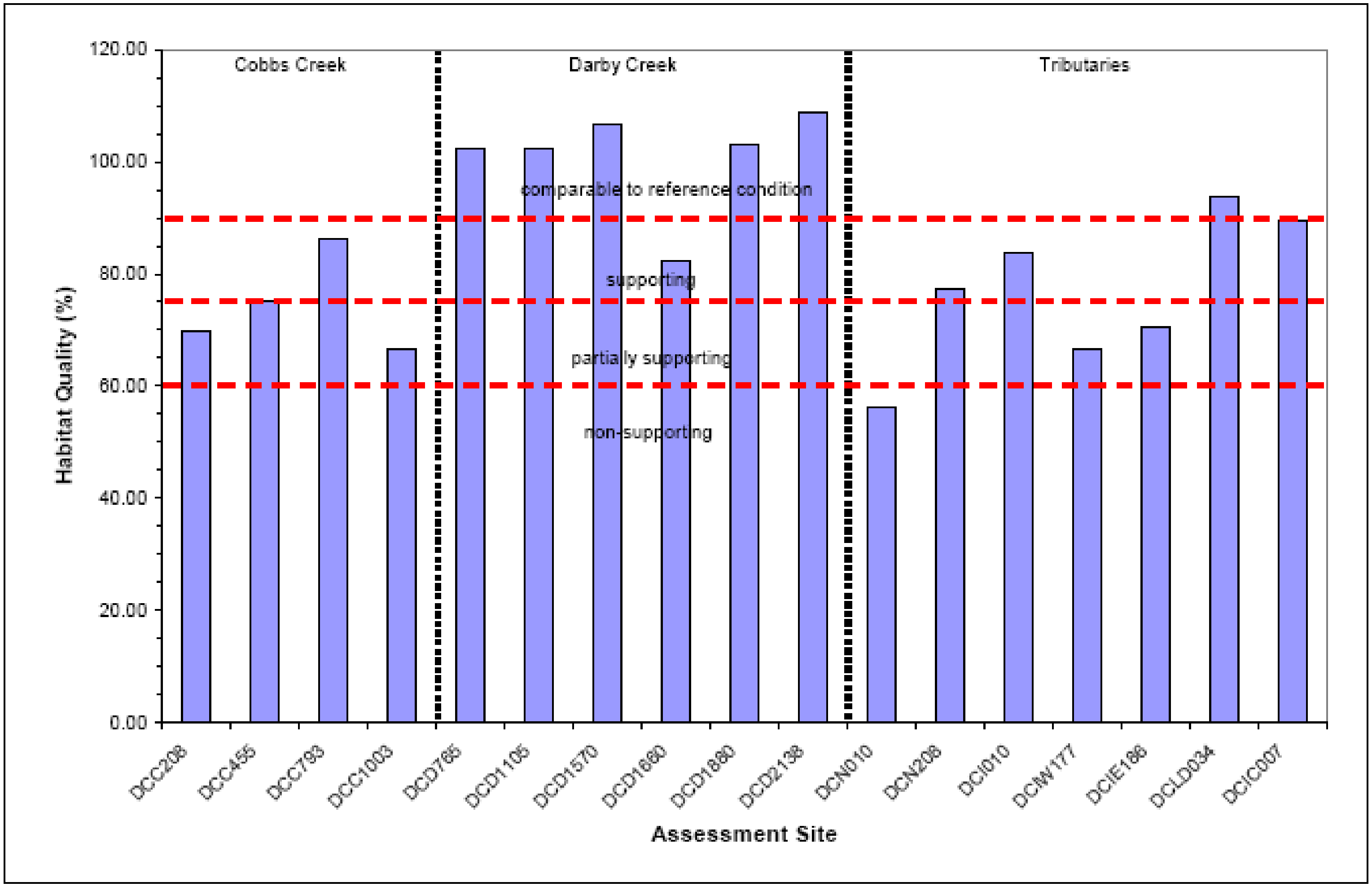


Figure 3-84: Habitat quality of 17 assessment sites in Darby-Cobbs Creek Watershed. Values are represented as percent comparability to reference conditions (D-C CCR 2004 section 5.3.4.1.3 figure 7 page 69).

Factor Analysis

Principal components analysis (PCA) in Statistica (Statsoft, 1998) was used to reduce the number of variables needed to explain the variation between scores for 13 different habitat attributes among Darby-Cobbs Creek sites. The first factor extracted accounted for 53% of the variance in the data matrix. Habitat attributes with high loading values for factor one included epifaunal substrate, velocity/depth regime, channel flow status, bank vegetative protection, and all pool attributes. The second factor extracted accounted for 19% of the variance, for a cumulative total of 72% variance explained. No habitat attributes showed high loading scores for factor two. An ordination plot of Darby-Cobbs Creek sites and three reference sites showed the sites distributed widely across PCA axis one, with five highest-rated upstream Darby Creek sites grouped closely between French Creek and Rock Run reference sites.

Overall, the placement of sites along axis 1 correlated closely with total habitat scores and relative comparability to the reference sites (Figure 3-85). PCA axis 2 was not particularly useful, except for weak negative associations with channel alteration and riparian zone width and positive associations with frequency of riffles, sedimentation, and embeddedness.

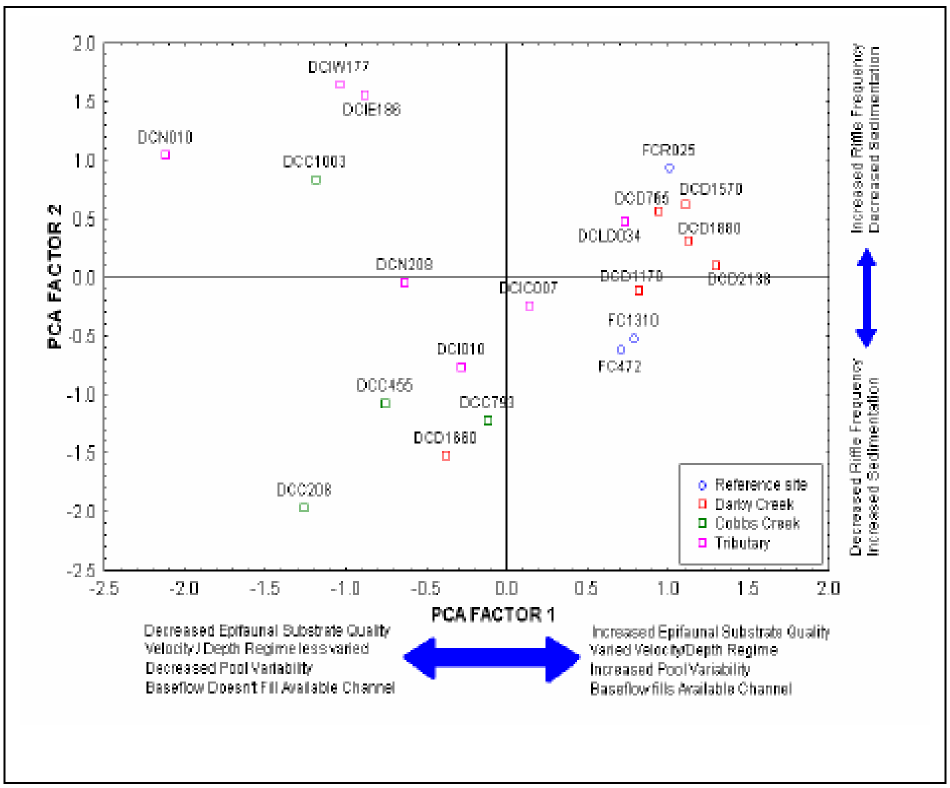


Figure 3-85 Principal Components Analysis ordination plot of 17 monitoring sites and 3 reference locations (D-C CCR 2004 section 5.3.3 figure 6 page 67).

Habitat Suitability Indices

Habitat Suitability Indices (HSI) developed by The U.S. Fish and Wildlife Service (USFWS) were applied to sites in Darby-Cobbs Creek Watershed targeted for fish sampling. These models integrate the expected effects of a variety of environmental, physicochemical, and hydrological variables on representative native species, as well as species of special environmental or economic concern. As stream restoration activities recommended under Target B of the Integrated Watershed Management Plan are implemented, these indices will allow for habitat improvements to be measured quantitatively. This work is discussed in more detail for each fish specie in the Section 5.3.5 of the Comprehensive Characterization Report Update (PWD, 2004).

3.4.2.3 Delaware River Basin and Delaware Direct Watershed Characterization

The Delaware Direct Watershed area was delineated as part of the approach being undertaken by the Philadelphia Water Department for watershed planning and CSO management (Figure 3-86). The Delaware Direct is the portion of the City of Philadelphia that drains directly to the Delaware River and is within the CSS. The 20.5 mile segment of the Delaware River that runs through Philadelphia is tidally influenced and water quality is regulated by standards set specifically for the Delaware Estuary. Additionally, the tidal portion of the Pennypack Creek is included in this plan under the Delaware Direct Watershed and is subject to the Delaware River Basin Commission's water quality standards for tidal Zone 2 as explained in Section 3.4.1. Only the tidal portion of the Pennypack Creek Watershed is within the CSS.

The Delaware Direct, at 28.5 square miles, includes the core of the City – the bulk of the Philadelphia Center City shopping district including Market Street East, the City Hall complex, the Pennsylvania Convention Center complex, Kimmel Center and Avenue of the Arts, Independence Mall and Independence National Historic Park and the related historic Society Hill surrounding neighborhood. Delaware Direct includes the rapidly redeveloping Delaware River Waterfront and the Temple University campus in North Philadelphia. Major transportation routes are included in the Delaware Direct Watershed, such as virtually the entire north/south Broad Street Corridor, the I-95 corridor from extreme North Philadelphia to South Philadelphia.

As of mid-2009, the PWD is developing a Rivers Conservation Plan (RCP) and an Integrated Watershed Management Plan (IWMP) for the Delaware Direct study area. The Rivers Conservation Plan will include a detailed description of the watershed and its history. The IWMP is being developed to guide the management of watershed protection and restoration. Both plans involved the development of goals and recommendations based on public participation in outreach activities. Both plans will be available at http://www.PhillyRiverInfo.org.

Due to local events and a growing national interest in urban riverfronts, the Delaware Waterfront is an area of high public attention for re-development. Both the North Delaware and the Central Delaware are the focus of large-scale planning initiatives. Other planning efforts have focused on specific neighborhoods or development sites. The Integrated Watershed Management Plan includes a comprehensive review of the plans related to watershed management and integrates the goals and recommendations of these and other PWD initiatives.

The Delaware Direct watershed is a small part (less than 1%) of the entire Delaware River Basin (Figure 3-87), which covers 13,539 square miles in New York, Pennsylvania, New Jersey, and Delaware (PWD, 2007). The Delaware River Basin is one of the most densely populated corridors in the northeastern United States, averaging 603 people/square mile (DRBC, 2008b). The Delaware River Basin Commission (DRBC) was created in 1961 as a regional body with legal enforcement capability to oversee the Delaware River Watershed. The DRBC is composed of five commissioners representing the federal government and the four states listed above. The DRBC provides watershed management, water resources stewardship, seeks public involvement in Delaware River issues, and coordinates interagency and state projects. Figure 3-88 depicts the entire Delaware River Basin.

Figure 3-86 The Delaware Direct Watershed in Philadelphia, PA

In 2004 the DRBC produced the Water Resources Plan for the Delaware River Basin, often called *The Basin Plan,* which incorporates watershed management policies, goals, and implementation strategies. The Basin Plan outlined key points of interest that will guide the actions of the DRBC for the next thirty years, including: sustainable use and supply, waterway corridor management, linking land and water resources management, institutional coordination and cooperation, and education and involvement for stewardship. The hydrology, water quality, living resources and landscape of the Delaware River Basin are characterized in the DRBC's 2008 Report, *The State of the Basin*. Both reports are available at http://www.drbc.net.

Land Use and Demographics of Delaware Direct Watershed

The Delaware Direct may be the most urbanized watershed in Pennsylvania (PWD 2009). It is almost entirely covered with impervious surface (72%). The population totals 499,750 at an average density of 17,530 people/square mile. Figure 3-88 illustrates the distribution of population density throughout the Combined Sewer Area. Almost half of the neighborhoods in Philadelphia are located at least partially in the Delaware Direct including some of the most affluent and some of the most impoverished. Although 48% of the combined sewer area is residential, the defining use is commercial (16%) and industrial (9%), since this land use is a higher percentage than any combined sewer area in Philadelphia due to a large number of abandoned industrial areas. The Delaware Riverfront is most likely to experience more redevelopment than other parts of Philadelphia. The current land use is shown in Figure 3-89. The Integrated Watershed Management Plan will take the current and future re-development into account and will include a detailed land use analysis based on the most up-to-date land use available.

The Delaware Direct Watershed includes approximately 20.5 miles of the Delaware River that flows through the City of Philadelphia, the tidal portion of the Pennypack Creek, and the "Old Frankford Creek," a small tidal tributary that was once connected to and the outlet of the Frankford Creek. Additionally, 63 miles of historic tributaries now encapsulated in pipes are part of the sewer system that flows into the Delaware River.

Pollution Sources

In addition to CSOs, other sources of pollution affect the water quality of the Delaware River. Numerous point and non-point sources exist in the drainage area upstream from the City of Philadelphia. Within the Delaware Direct Watershed, stormwater runoff from the highly impervious residential and industrial areas contributes to degraded water quality. Accidental sources of contamination are a greater concern in the Delaware Direct and include spills or leaks from cars, trains, shipping vessels, underground pipeline bursts, and industrial accidents (PWD, 2007).

3.4.2.3.1 Delaware River Basin Hydrologic Characterization

Annual average precipitation within the Delaware River Basin is about 45 inches of precipitation per year. The driest month is normally February, with precipitation totals ranging from 2.7 to 3 inches. In contrast, July and August are the months with the most precipitation, measuring from 4.5 to 4.7 inches of precipitation. The precipitation in the cold months results from the passage of fronts in the low-pressure systems of the westerly wind belt. During the warm months, much of the precipitation occurs as convectional storms, which are supplemented by the occasional passage of a front (Climate and Man, 1941 in Majumdar, Millar, and Sage, 1988).

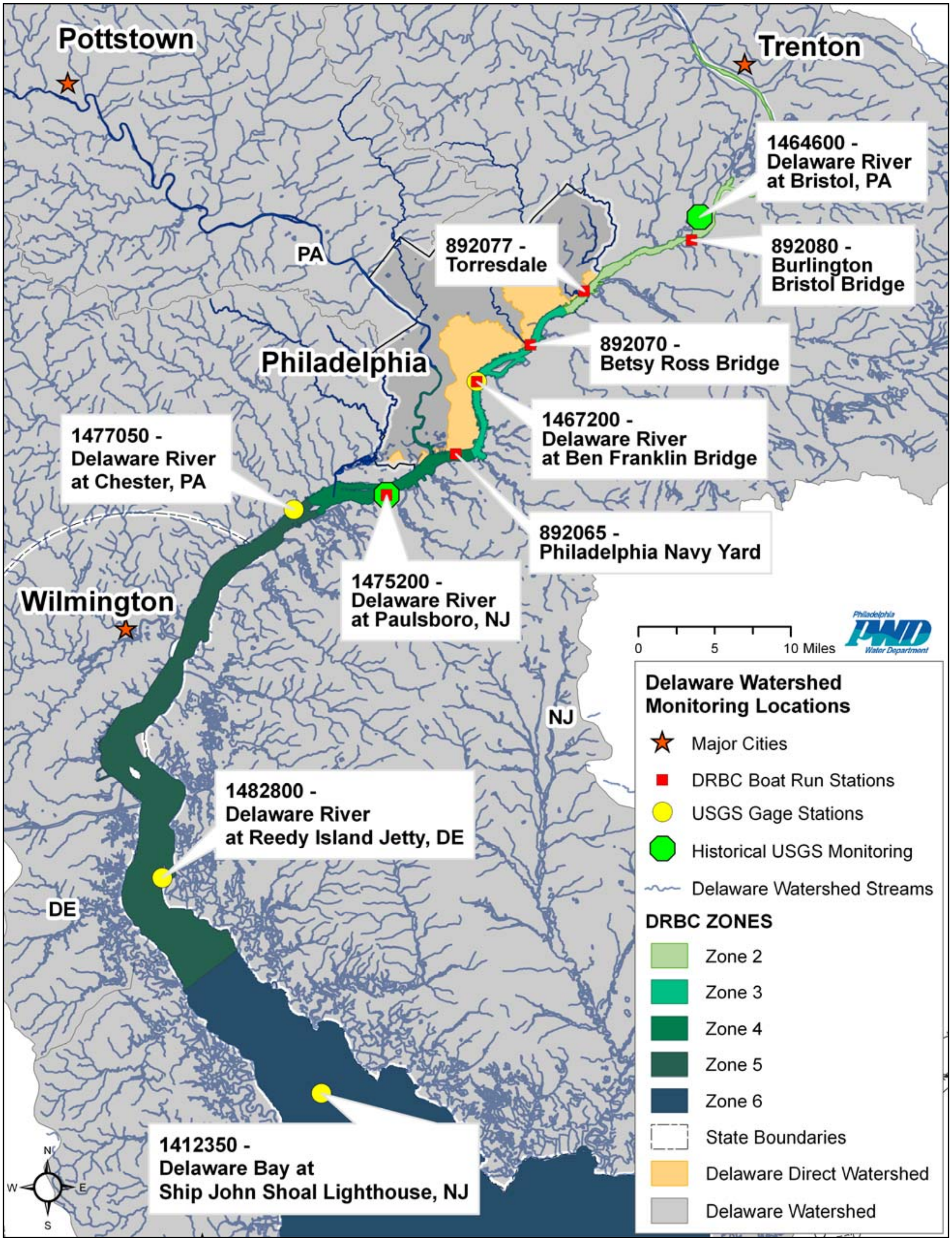


Figure 3-87 The Delaware River Basin (Source: DRBC)

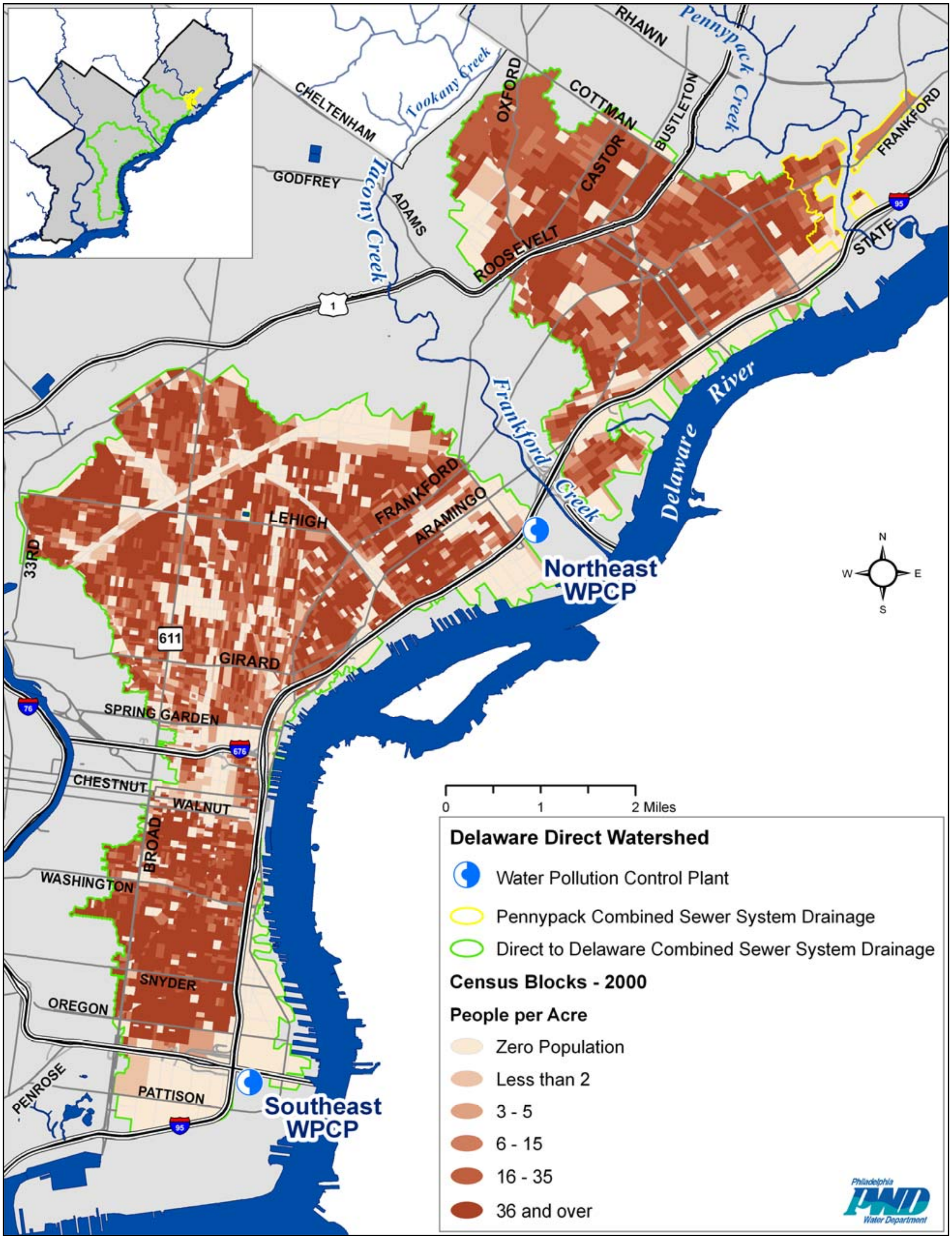


Figure 3-88 Population Density in the Delaware Direct Watershed in Philadelphia, PA Receiving Waters Characterization

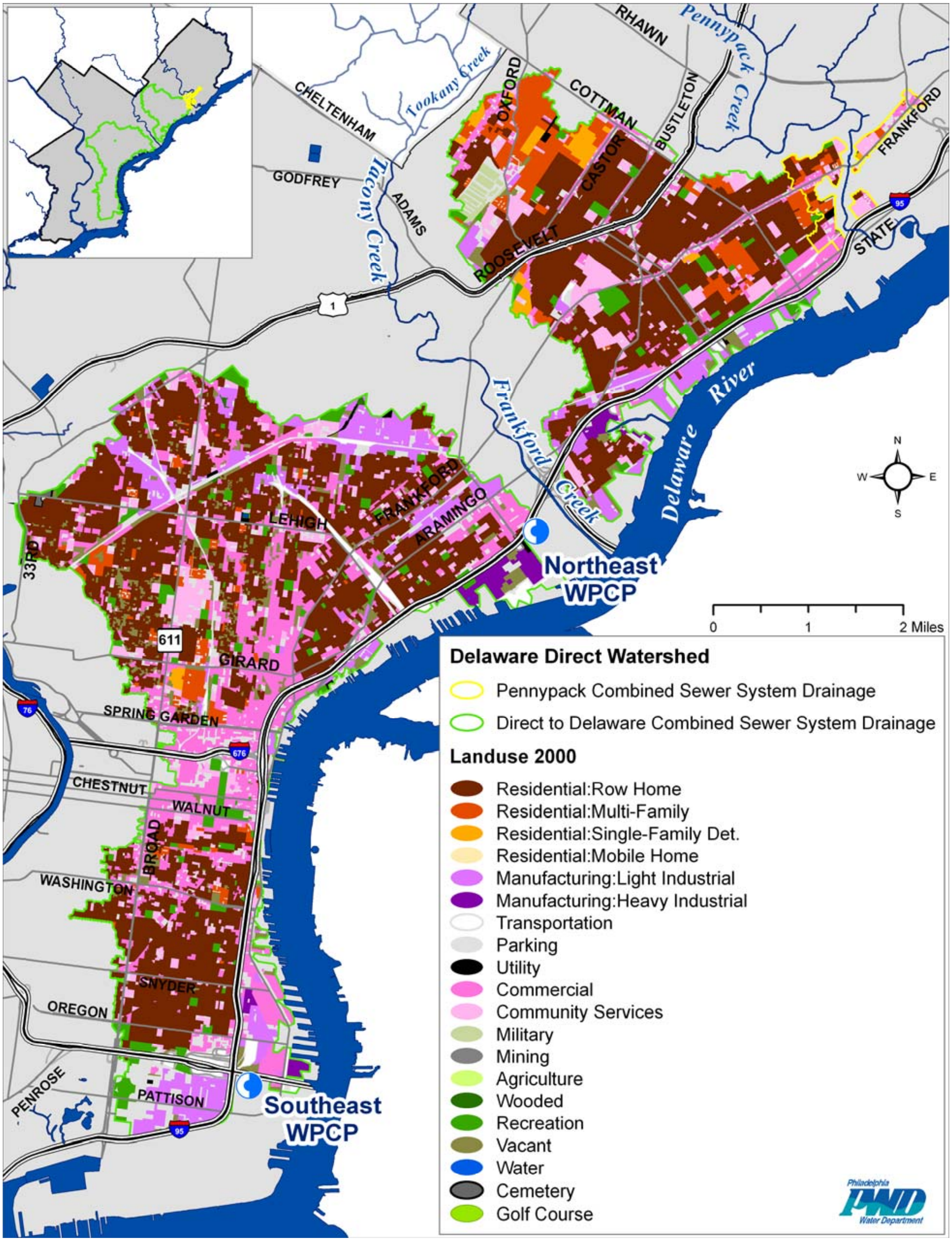


Figure 3-89 Land Use in the Delaware Direct Watershed

Table 3-93 gives a summary of the major tributaries in the Delaware River below Trenton New Jersey, their drainage areas, river mile location, and length. These tributaries are located within the tidal zone, and are therefore affected by water quantity and quality tidal cycles. The Neshaminy River and the Rancocas Creek are the two largest tributaries in this area. Both of these tributaries drain into the Delaware River above the Delaware Direct area in Philadelphia.

Table 3-93 Characteristics of Tributaries in the Lower Delaware River Watershed

Major tributary	Drainage Area (mi^2)	River Mile Location	Length (mi)
Assiscunk Creek	45.9	119	16.31
Big Timber Creek	55.2	96	16.00
Bustleton Creek	2.6	121	2.91
Byberry Creek	18.7	112	10.595
Cooper Creek	40.2	102	15.81
Crafts Creek	13.8	125	11.38
Crosswicks Creek	138.5	129	26.46
Martins Creek (Lower)	11.5	123	5.05
Mill Creek	19.8	119	39.96
Mill Run	37	105	14.81
Neshaminy Creek	232.4	116	51.37
Newton Creek	10.6	97	10.58
Pennsauken Creek	36.1	106	13.06
Pompeston Creek	7.7	109	5.37
Rancocas Creek	347.7	111	33.65
Rockledge Branch	55.1	110	15.57

The daily average streamflow of the Delaware River from 1910 to 2009 is presented in Figure 3-90. The measurements were recorded at USGS Gage 01463500 at Trenton, New Jersey, the nearest upstream USGS gauge to Philadelphia monitoring continuous flow. The historical daily average Delaware River streamflow at Trenton, NJ is 12,100 cubic feet per second (CFS).

3.4.2.3.2 Delaware River Water Quality Analysis

From 2003 through 2008, the Delaware River Basin Commission (DRBC) has collected water quality data from sampling locations within the Delaware River Watershed. Tables 3-94 thru 3-98 provide a basic, statistical profile of the data from the recent water quality monitoring program. Tables 3-94 thru 3-97 provide data from the discrete monitoring program and Table 3-98 provides data from the continuous monitoring program.

The Delaware River Basin was segmented into zones as defined by the above mentioned DRBC manual. This analysis will use water quality standards from zone 2 through zone 6. Zone 2 is defined as any location along the Delaware River between Rivermile (R.M.) 133.4 through R.M. 108.4 and any tidal portions of any tributaries. Zone 3 is defined as any location along the Delaware River between R.M. 108.4 through R.M. 95.0 and any tidal portions of any tributaries. Zone 4 is defined as any location along the Delaware River between R.M. 95.0 through R.M. 78.8 and any tidal portions of any tributaries. Zone 5 is defined as any location along the Delaware River between R.M. 78.8 through R.M. 48.2 and any tidal portions of any tributaries. Zone 6 is defined as any location along the Delaware River between R.M. 48.2 through R.M. 0.0 and any tidal portions of any tributary. The

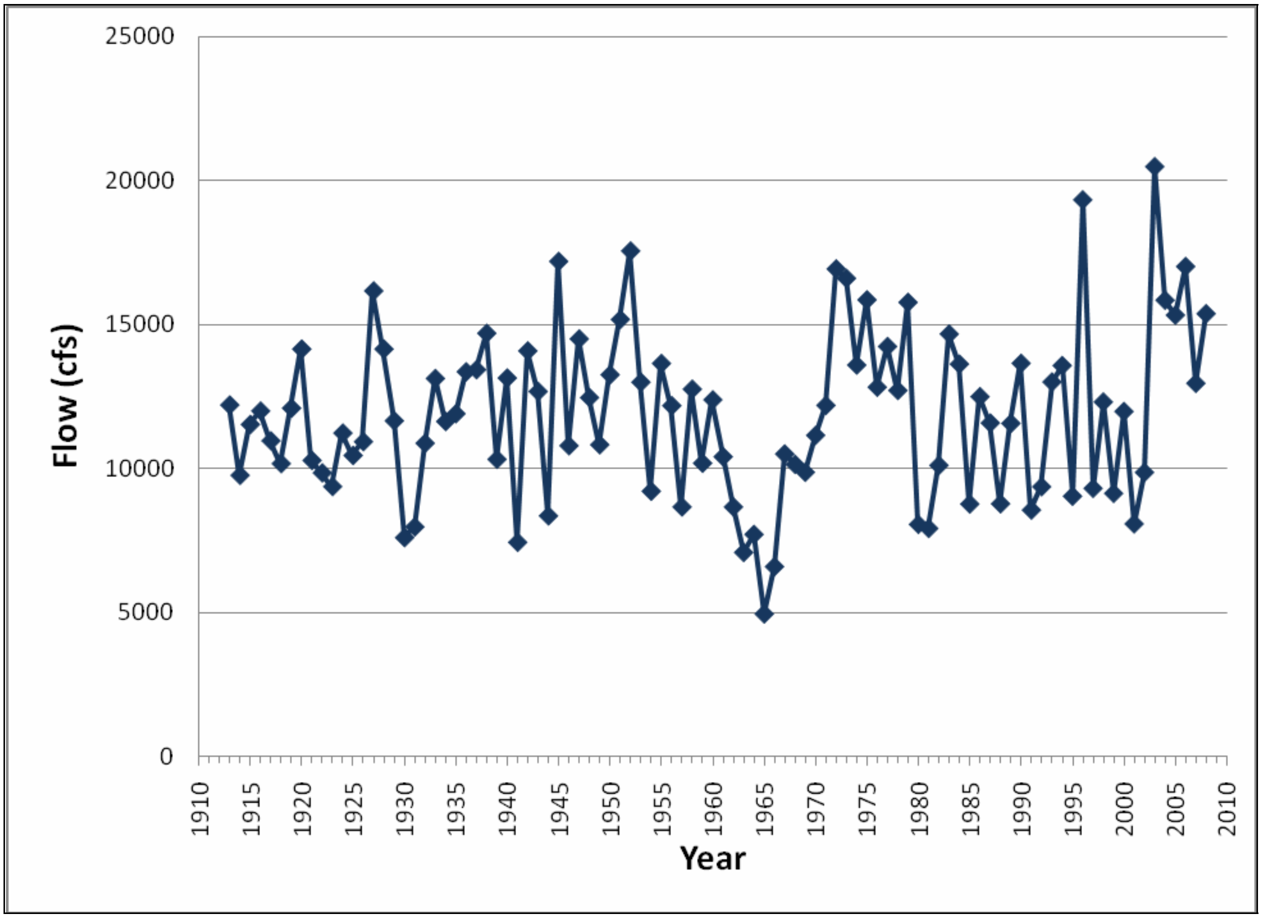


Figure 3-90 Daily Average Delaware River Flow at Trenton, NJ USGS gauge 01463500

Delaware Direct watershed includes part of Zone 2, Zone 3, and part of Zone 4 of the Delaware River between RM approximately 90 and 112.

Wet weather is characterized using the 11 PWD operated rain gages in the Delaware direct drainage district. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. Rain Gage locations, and PWD, DRBC, and USGS monitoring sites are depicted and discussed in Section 3.1.4.3.3.

The U.S. Geological Survey (USGS) recorded a baseline of existing water quality that can now be compared with the data collected by DRBC. Table 3-98 consists of USGS continuous monitoring data that was collected from 2003 through 2008. Tables 3-94 through 3-97 consist of DRBC discrete monitoring data that was collected from 2003 through 2008. This comparison allows for a more comprehensive analysis of water quality and the impacts of urbanization on the Delaware River Basin over the past 10 years. In some cases, historical data is provided for further analysis.

Table 3-94 Delaware River Dry Weather Water Quality Summary Statistics and Exceedances 2003 – 2008

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
Alkalinity	2	Maximum	100	mg/L	DRBC	33	27.5	39.2	42.8	50.3	55.4	57.5	0	0
Alkalinity	3	Maximum	120	mg/L	DRBC	32	27.0	38.5	43.7	50.9	53.4	56.5	0	0
Alkalinity	4	Maximum	120	mg/L	DRBC	35	34.3	38.6	45.6	52.9	54.9	57.4	0	0
Alkalinity	2	Minimum	20	mg/L	DRBC	33	27.5	39.2	42.8	50.3	55.4	57.5	0	0
Alkalinity	3	Minimum	20	mg/L	DRBC	32	27.0	38.5	43.7	50.9	53.4	56.5	0	0
Alkalinity	4	Minimum	20	mg/L	DRBC	35	34.3	38.6	45.6	52.9	54.9	57.4	0	0
Diss Cu	2	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	22	1.40	1.40	1.50	2.40	3.80	6.60	0	0
Diss Cu	3	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	24	1.40	1.40	1.60	2.25	4.30	5.60	0	0
Diss Cu	4	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	31	1.10	1.50	2.10	2.60	5.30	8.50	0	0
Diss Cu	2	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	22	1.40	1.40	1.50	2.40	3.80	6.60	0	0
Diss Cu	3	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.40	1.40	1.60	2.25	4.30	5.60	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Cu	4	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	31	1.10	1.50	2.10	2.60	5.30	8.50	0	0
Diss Zn	2	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	38	0.40	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Toxicants FIO Maximum	68700	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Toxicants FIO Maximum	68700	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
Diss Zn	4	Toxicants FIO Maximum	68700	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Toxicants FWI Maximum	9110	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Toxicants FWI Maximum	9110	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Toxicants FWI Maximum	9110	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
DO	2			mg/L		67	5.39	7.02	8.23	9.94	11.0	12.2	--	--
DO	3			mg/L		62	4.88	5.89	7.29	9.35	10.1	11.8	--	--
DO	4			mg/L		75	4.65	5.81	6.59	8.75	10.0	12.0	--	--
Enterococcus	2	Maximum	33	#/100mL	DRBC	77	1.00	6.00	13.0	24.0	34.0	160	8	10.4
Enterococcus	3	Maximum	88	#/100mL	DRBC	68	1.00	6.00	9.00	18.5	73.0	240	6	8.8
Enterococcus	4	Maximum	(2)	#/100mL	DRBC	80	1.00	5.00	10.0	15.0	28.5	117	2	2.5
Fecal Coliform	2	Maximum	200	#/100mL	DRBC	70	9.00	22.0	42.5	90.0	130	270	4	5.7
Fecal Coliform	3	Maximum	770	#/100mL	DRBC	65	13.0	38.0	68.0	150	240	520	0	0
Fecal Coliform	4	Maximum	(3)	#/100mL	DRBC	77	6.00	23.0	46.0	77.0	140	430	0	0
Inorganic N	2	No Standard	--	mg/L		24	0.601	0.841	0.969	1.09	1.29	1.53	--	--
Inorganic N	3	No Standard	--	mg/L		24	0.756	0.929	1.03	1.32	1.67	1.91	--	--
Inorganic N	4	No Standard	--	mg/L		31	0.890	1.29	1.53	1.90	2.46	2.77	--	--
NH_3	2	No Standard	--	mg/L		24	0.0200	0.0685	0.0825	0.123	0.143	0.164	--	--
NH_3	3	No Standard	--	mg/L		24	0.0210	0.0620	0.101	0.174	0.290	0.357	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
NH_3	4	No Standard	--	mg/L		31	0.0210	0.0290	0.126	0.265	0.316	0.389	--	--
pH	2	Maximum	8.5		DRBC	67	6.01	6.98	7.21	7.40	7.66	8.86	1	1.5
pH	3	Maximum	8.5		DRBC	62	5.87	6.88	7.10	7.24	7.38	7.76	0	0
pH	4	Maximum	8.5		DRBC	75	6.08	6.91	7.12	7.24	7.46	7.94	0	0
pH	2	Minimum	6.5		DRBC	67	6.01	6.98	7.21	7.40	7.66	8.86	7	10.5
pH	3	Minimum	6.5		DRBC	62	5.87	6.88	7.10	7.24	7.38	7.76	6	9.7
pH	4	Minimum	6.5		DRBC	75	6.08	6.91	7.12	7.24	7.46	7.94	6	8.0
Temp	2	Maximum	(1)	°C	DRBC	67	7.07	15.5	19.5	25.3	27.1	30.2	19	28.4
Temp	3	Maximum	(1)	°C	DRBC	62	8.00	15.2	20.0	25.0	25.9	29.0	12	19.4
Temp	4	Maximum	(1)	°C	DRBC	75	8.70	15.4	20.0	24.5	26.0	29.1	11	14.7
TKN	2	No Standard	--	mg/L		6	0.374	0.392	0.427	0.481	0.500	0.500	--	--
TKN	3	No Standard	--	mg/L		6	0.390	0.451	0.530	0.617	0.681	0.681	--	--
TKN	4	No Standard	--	mg/L		9	0.469	0.505	0.605	0.650	0.696	0.696	--	--
TN	2	No Standard	--	mg/L		6	1.19	1.21	1.43	1.51	2.01	2.01	--	--
TN	3	No Standard	--	mg/L		6	1.41	1.42	1.56	1.71	1.92	1.92	--	--
TN	4	No Standard	--	mg/L		9	1.75	1.94	2.02	2.05	2.28	2.28	--	--
TP	2	No Standard	--	mg/L		20	0.0240	0.0375	0.0615	0.0785	0.0840	0.0890	--	--
TP	3	No Standard	--	mg/L		16	0.0390	0.0670	0.0790	0.0980	0.113	0.113	--	--
TP	4	No Standard	--	mg/L		19	0.0440	0.0700	0.0990	0.121	0.148	0.165	--	--
TSS	2	No Standard	--	mg/L		66	3.00	5.00	7.00	10.0	15.0	25.0	--	--
TSS	3	No Standard	--	mg/L		61	2.00	7.00	12.0	17.0	22.0	38.0	--	--
TSS	4	No Standard	--	mg/L		74	4.00	10.0	14.0	21.0	29.0	73.0	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Turbidity	2	Maximum	150	NTU	DRBC	76	1.00	4.00	5.00	9.00	150	150	0	0
Turbidity	3	Maximum	150	NTU	DRBC	62	2.00	4.00	6.00	10.0	15.0	19.0	0	0
Turbidity	4	Maximum	150	NTU	DRBC	75	2.00	6.00	10.0	13.0	18.0	55.0	0	0

(1) Water Temperature Standards Change by Zone and Month
(2) Enterococcus (Above R.M. 81.8 Maximum 88, Below R.M. 81.8 Maximum 33)
(3) Fecal Coliform (Above R.M. 81.8 Maximum 770, Below R.M. 81.8 Maximum 200)
(4) Water Quality Standard Requires Hardness Correction; Value listed is water quality standard calculated at 100 ug/L $CaCO_3$ hardness

Table 3-95 Delaware River Dry Weather Water Quality Problem Parameters 2003 – 2008

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
Enterococcus	2	117.8	Maximum	33	#/100mL	DRBC	36	1.00	7.00	16.0	25.5	37.0	113	6	16.7
Enterococcus	2	110.7	Maximum	33	#/100mL	DRBC	37	1.00	5.00	10.0	18.0	28.0	160	2	5.4
Enterococcus	3	104.75	Maximum	88	#/100mL	DRBC	34	2.00	6.00	8.50	21.0	57.0	240	3	8.8
Enterococcus	3	100.2	Maximum	88	#/100mL	DRBC	34	1.00	4.50	9.00	16.0	73.0	220	3	8.8
Enterococcus	4	93.2	Maximum	88	#/100mL	DRBC	41	2.00	6.00	11.0	16.0	25.0	117	1	2.4
Enterococcus	4	87.9	Maximum	88	#/100mL	DRBC	34	1.00	4.00	8.00	13.0	32.0	100	1	2.9
Fecal Coliform	2	117.8	Maximum	200	#/100mL	DRBC	32	9.00	21.0	37.0	88.0	130	230	1	3.1
Fecal Coliform	2	110.7	Maximum	200	#/100mL	DRBC	34	14.0	22.0	55.5	77.0	180	270	3	8.8
pH	2	131.04	Minimum	6.5		DRBC	2	6.28					8.86	1	50.0
pH	2	122.4	Minimum	6.5		DRBC	2	6.12					8.21	1	50.0
pH	2	117.8	Minimum	6.5		DRBC	31	6.03	7.04	7.21	7.43	7.66	7.80	2	6.5
pH	2	110.7	Minimum	6.5		DRBC	32	6.01	6.99	7.23	7.38	7.47	7.79	3	9.4
pH	3	104.75	Minimum	6.5		DRBC	31	5.87	6.88	7.13	7.25	7.40	7.75	2	6.5
pH	3	100.2	Minimum	6.5		DRBC	31	5.88	6.87	7.10	7.20	7.34	7.76	4	12.9
pH	4	93.2	Minimum	6.5		DRBC	37	6.08	6.96	7.08	7.20	7.40	7.71	2	5.4
pH	4	87.9	Minimum	6.5		DRBC	32	6.11	6.90	7.15	7.27	7.46	7.94	3	9.4

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
pH	4	84	Minimum	6.5		DRBC	6	6.10	7.04	7.32	7.46	7.84	7.84	1	16.7
Temp	2	131.04	Maximum	*	°C	DRBC	2	11.4					16.2	1	50.0
Temp	2	122.4	Maximum	*	°C	DRBC	2	11.3					15.8	1	50.0
Temp	2	117.8	Maximum	*	°C	DRBC	31	7.07	15.8	20.2	25.3	27.3	30.2	10	32.3
Temp	2	110.7	Maximum	*	°C	DRBC	32	7.84	15.3	20.1	25.4	26.7	29.5	7	21.9
Temp	3	104.75	Maximum	*	°C	DRBC	31	8.00	15.2	20.0	25.1	25.9	29.0	7	22.6
Temp	3	100.2	Maximum	*	°C	DRBC	31	8.61	15.1	20.0	24.6	25.9	28.8	5	16.1
Temp	4	93.2	Maximum	*	°C	DRBC	37	8.70	15.8	20.3	24.6	25.8	28.9	4	10.8
Temp	4	87.9	Maximum	*	°C	DRBC	32	8.97	15.7	21.1	24.5	26.0	29.1	6	18.8
Temp	4	84	Maximum	*	°C	DRBC	6	8.87	9.07	16.6	19.4	24.9	24.9	1	16.7

* Water Temperature Standard Change by Month and Zone

Table 3-96 Delaware River Wet Weather Water Quality Summary Statistics and Exceedances 2003 - 2008

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Alkalinity	2	Maximum	100	mg/L	DRBC	14	10.7	30.1	46.0	53.4	57.9	64.5	0	0
Alkalinity	3	Maximum	120	mg/L	DRBC	14	12.0	23.7	45.1	51.1	55.8	57.6	0	0
Alkalinity	4	Maximum	120	mg/L	DRBC	14	13.4	31.8	46.3	57.3	58.9	60.0	0	0
Alkalinity	2	Minimum	20	mg/L	DRBC	14	10.7	30.1	46.0	53.4	57.9	64.5	2	14.3
Alkalinity	3	Minimum	20	mg/L	DRBC	14	12.0	23.7	45.1	51.1	55.8	57.6	2	14.3
Alkalinity	4	Minimum	20	mg/L	DRBC	14	13.4	31.8	46.3	57.3	58.9	60.0	2	14.3
Diss Cu	2	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	24	1.40	1.40	1.45	2.35	3.85	7.90	0	0
Diss Cu	3	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	24	1.00	1.40	1.80	4.00	6.10	12.2	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Cu	4	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	31	1.20	1.40	2.40	4.30	6.20	11.8	0	0
Diss Cu	2	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.40	1.40	1.45	2.35	3.85	7.90	0	0
Diss Cu	3	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.00	1.40	1.80	4.00	6.10	12.2	0	0
Diss Cu	4	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	31	1.20	1.40	2.40	4.30	6.20	11.8	0	0
Diss Zn	2	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Zn	3	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Toxicants FIO Maximum	68700	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Toxicants FIO Maximum	68700	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Toxicants FIO Maximum	68700	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Toxicants FWI Maximum	9110	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Toxicants FWI Maximum	9110	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Toxicants FWI Maximum	9110	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
DO	2			mg/L		66	4.69	7.15	8.23	10.4	12.0	13.9	--	--
DO	3			mg/L		59	4.96	6.19	8.05	9.80	11.7	13.3	--	--
DO	4			mg/L		76	4.94	6.14	7.45	9.39	11.8	12.9	--	--
Enterococcus	2	Maximum	33	#/100mL	DRBC	68	1.00	9.00	16.0	78.5	160	600	22	32.4
Enterococcus	3	Maximum	88	#/100mL	DRBC	60	3.00	10.0	23.0	78.5	225	370	11	18.3

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Enterococcus	4	Maximum	(2)	#/100mL	DRBC	75	1.00	7.00	12.0	25.0	42.0	330	5	6.7
Fecal Coliform	2	Maximum	200	#/100mL	DRBC	68	8.00	30.3	55.0	133	320	770	9	13.2
Fecal Coliform	3	Maximum	770	#/100mL	DRBC	59	17.0	73.0	130	430	600	600	0	0
Fecal Coliform	4	Maximum	(3)	#/100mL	DRBC	78	1.00	27.0	56.5	210	310	600	0	0
Inorganic N	2	No Standard	--	mg/L		24	0.621	0.788	0.886	1.12	1.29	1.43	--	--
Inorganic N	3	No Standard	--	mg/L		25	0.587	0.837	0.960	1.25	1.58	1.77	--	--
Inorganic N	4	No Standard	--	mg/L		36	0.804	1.14	1.46	1.99	2.42	4.25	--	--
NH_3	2	No Standard	--	mg/L		24	0.0220	0.0575	0.0730	0.0965	0.110	0.202	--	--
NH_3	3	No Standard	--	mg/L		25	0.0150	0.0530	0.0840	0.156	0.259	0.399	--	--
NH_3	4	No Standard	--	mg/L		36	0.00800	0.0590	0.107	0.216	0.292	0.459	--	--
pH	2	Maximum	8.5		DRBC	66	6.31	7.13	7.30	7.52	7.90	8.34	0	0
pH	3	Maximum	8.5		DRBC	59	6.31	7.03	7.20	7.40	7.65	7.80	0	0
pH	4	Maximum	8.5		DRBC	76	6.34	7.00	7.18	7.40	7.70	7.85	0	0
pH	2	Minimum	6.5		DRBC	66	6.31	7.13	7.30	7.52	7.90	8.34	2	3.0
pH	3	Minimum	6.5		DRBC	59	6.31	7.03	7.20	7.40	7.65	7.80	1	1.7
pH	4	Minimum	6.5		DRBC	76	6.34	7.00	7.18	7.40	7.70	7.85	1	1.3
Temp	2	Maximum	(1)	°C	DRBC	66	2.81	10.9	17.3	24.1	26.0	27.3	22	33.3
Temp	3	Maximum	(1)	°C	DRBC	59	2.80	13.3	17.4	23.7	26.1	26.9	13	22.0
Temp	4	Maximum	(1)	°C	DRBC	76	3.64	13.3	17.8	23.6	26.1	27.5	15	19.7
TKN	2	No Standard	--	mg/L		12	0.126	0.335	0.426	0.464	0.479	0.540	--	--
TKN	3	No Standard	--	mg/L		13	0.346	0.384	0.417	0.550	0.727	0.743	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
TKN	4	No Standard	--	mg/L		21	0.391	0.453	0.487	0.547	0.759	0.851	--	--
TN	2	No Standard	--	mg/L		12	0.908	1.12	1.27	1.47	1.55	1.57	--	--
TN	3	No Standard	--	mg/L		13	1.14	1.34	1.48	1.62	1.691	1.70	--	--
TN	4	No Standard	--	mg/L		21	1.29	1.62	1.85	2.04	2.171	2.45	--	--
TP	2	No Standard	--	mg/L		28	0.0260	0.0500	0.0765	0.0935	0.105	0.110	--	--
TP	3	No Standard	--	mg/L		20	0.0350	0.0780	0.0900	0.109	0.158	0.161	--	--
TP	4	No Standard	--	mg/L		23	0.0510	0.0970	0.120	0.132	0.152	0.164	--	--
TSS	2	No Standard	--	mg/L		64	2.00	5.00	7.50	11.5	18.0	144	--	--
TSS	3	No Standard	--	mg/L		59	4.00	8.00	11.0	16.0	23.0	206	--	--
TSS	4	No Standard	--	mg/L		76	5.00	10.0	14.0	20.0	29.0	178	--	--
Turbidity	2	Maximum	150	Units	DRBC	74	1.00	3.00	6.00	12.0	150	150	0	0
Turbidity	3	Maximum	150	Units	DRBC	59	1.00	4.00	6.00	11.0	16.0	200	2	3.4
Turbidity	4	Maximum	150	Units	DRBC	76	3.00	6.00	9.00	13.0	18.0	170	2	2.6

(1) Water Temperature Standards Change by Zone and Month
(2) Enterococcus (Above R.M. 81.8 Maximum 88, Below R.M. 81.8 Maximum 33)
(3) Fecal Coliform (Above R.M. 81.8 Maximum 770, Below R.M. 81.8 Maximum 200)
(4) Water Quality Standard Requires Hardness Correction; Value listed is water quality standard calculated at 100 ug/L CaCO3 hardness

Table 3-97 Delaware River Wet Weather Water Quality Problem Parameters 2003 – 2008

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
Alkalinity	2	117.8	Minimum	20	mg/L	DRBC	7	15.0	30.1	48.8	57.9	64.5	64.5	1	14.3
Alkalinity	2	110.7	Minimum	20	mg/L	DRBC	7	10.7	28.0	43.4	49.7	54.7	54.7	1	14.3
Alkalinity	3	104.75	Minimum	20	mg/L	DRBC	7	14.2	23.7	46.1	51.1	57.6	57.6	1	14.3
Alkalinity	3	100.2	Minimum	20	mg/L	DRBC	7	12.0	22.7	44.1	54.0	55.8	55.8	1	14.3
Alkalinity	4	93.2	Minimum	20	mg/L	DRBC	7	13.4	26.1	45.8	58.1	58.9	58.9	1	14.3
Alkalinity	4	87.9	Minimum	20	mg/L	DRBC	7	13.7	31.8	46.9	57.3	60.0	60.0	1	14.3
Enterococcus	2	117.8	Maximum	33	#/100mL	DRBC	30	4.00	9.0	21.0	113	173	335	12	40.0
Enterococcus	2	110.7	Maximum	33	#/100mL	DRBC	30	2.00	10.0	16.0	57.0	157	600	10	33.3
Enterococcus	3	104.75	Maximum	88	#/100mL	DRBC	30	3.00	10.0	23.0	55.0	147	370	3	10.0
Enterococcus	3	100.2	Maximum	88	#/100mL	DRBC	30	4.00	11.0	22.5	107	280	340	8	26.7
Enterococcus	4	87.9	Maximum	88	#/100mL	DRBC	29	1.00	6.00	10.0	22.0	42.0	220	3	10.3
Enterococcus	4	84	Maximum	88	#/100mL	DRBC	10	1.00	5.00	7.00	10.0	17.0	19.0	2	20.0
Fecal Coliform	2	117.8	Maximum	200	#/100mL	DRBC	30	10.0	29.5	58.0	160	350	590	5	16.7
Fecal Coliform	2	110.7	Maximum	200	#/100mL	DRBC	30	8.00	35.0	71.5	140	310	770	4	13.3
pH	2	117.8	Minimum	6.5	--	DRBC	29	6.31	7.10	7.30	7.50	8.12	8.30	1	3.4
pH	2	110.7	Minimum	6.5	--	DRBC	29	6.32	7.14	7.27	7.40	7.71	7.90	1	3.4
Turbidity	3	104.75	Maximum	150	NTU	DRBC	29	2.00	4.00	6.00	10.0	14.0	170	1	3.4
Turbidity	3	100.2	Maximum	150	NTU	DRBC	30	1.00	4.00	6.00	11.0	16.0	200	1	3.3
Turbidity	4	93.2	Maximum	150	NTU	DRBC	37	3.00	6.00	8.00	12.0	17.0	170	1	2.7
Turbidity	4	87.9	Maximum	150	NTU	DRBC	29	3.00	6.00	9.00	13.0	28.0	170	1	3.4
Temp	2	131.04	Maximum	*	°C	DRBC	4	5.08	7.98	17.8	25.1	25.4	25.4	3	75.0
Temp	2	122.4	Maximum	*	°C	DRBC	4	3.88	5.97	16.0	24.2	24.5	24.5	1	20.0
Temp	2	117.8	Maximum	*	°C	DRBC	29	2.86	13.8	17.1	23.9	26.9	27.3	9	31.0
Temp	2	110.7	Maximum	*	°C	DRBC	29	2.81	13.6	17.5	23.4	26.2	27.0	9	31.0
Temp	3	104.75	Maximum	*	°C	DRBC	29	2.80	13.6	17.4	23.5	26.1	26.9	7	24.1
Temp	3	100.2	Maximum	*	°C	DRBC	30	3.14	13.3	17.3	23.7	26.0	26.7	6	20.0
Temp	4	93.2	Maximum	*	°C	DRBC	37	3.64	13.5	17.8	23.8	26.1	27.1	7	18.9
Temp	4	87.9	Maximum	*	°C	DRBC	29	3.87	13.3	17.8	23.5	26.3	27.4	6	20.7
Temp	4	84	Maximum	*	°C	DRBC	10	3.95	9.34	18.8	23.2	27.2	27.5	2	20.0

* Water Temperature Standards Change by Zone and Month

Table 3-98 Delaware River Continuous Water Quality Summary Statistics and Exceedances 2003 – 2008

Parameter	USGS Gauge	RM	Standard	Target Value	Units	No. Obs.	Percentiles						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
DO	1482800	37	Daily Minimum	5	mg/L	1838	4.10	6.70	8.40	11.1	12.3	14.0	182	9.9
DO	1477050	82	Daily Minimum	3.5	mg/L	1377	3.70	5.30	6.60	8.30	10.0	13.2	0	0
DO	1467200	100.2	Daily Minimum	3.5	mg/L	1396	3.20	4.90	6.80	9.00	10.5	13.7	6	0.4
pH	1482800	37	Maximum	8.5		2201	6.90	7.40	7.50	7.70	7.80	8.40	0	0
pH	1477050	82	Maximum	8.5		1415	6.80	7.10	7.20	7.30	7.50	8.10	0	0
pH	1467200	100.2	Maximum	8.5		1460	6.40	7.00	7.20	7.30	7.40	7.80	0	0
pH	1482800	37	Minimum	6.5		2201	6.70	7.20	7.40	7.50	7.60	8.00	0	0
pH	1477050	82	Minimum	6.5		1415	6.70	7.00	7.10	7.20	7.30	7.60	0	0
pH	1467200	100.2	Minimum	6.5		1460	6.20	6.90	7.10	7.20	7.30	7.60	40	2.7
Temp	1482800	37	Maximum	*	°C	2174	-0.300	5.40	14.5	24.3	27.2	30.7	38	1.7
Temp	1477050	82	Maximum	*	°C	1415	4.30	14.9	21.3	26.1	27.7	30.8	342	24.2
Temp	1467200	100.2	Maximum	*	°C	1459	3.40	13.5	19.6	25.2	26.8	29.4	277	19.0

*Water Temperature Standard Changes by Zone and Month

Discussion of Possible Problem Parameters
The following analysis of water quality data is focused on parameters that were listed in US EPA's 1995 Guidance for Long Term Control Plan. All sample results were compared to relevant DRBC water quality criteria as defined in Administrative Manual Part III Water Quality Regulations 18 CFR Part 410. Tables 3-94 through 3-98 were compared to stream quality objectives set forth in section 3.30 of the above mentioned DRBC manual. Water quality parameters were classified as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow). The water quality criteria or target value is discussed in each parameter analysis.

pH
Both the continuous and discrete monitoring tracked pH at several sites within the monitored watershed. DRBC WQ criteria set minimum and maximum pH limits of 6.5 and 8.5, respectively, for Zones 2, 3, and 4. The continuous data (Table 3-98) shows the minimum DRBC pH standards were rarely exceeded, except for within Zone 3 (exceeded 2.7% of the time). Overall, pH is considered to be of little concern. During the DRBC discrete monitoring the minimum pH standard was exceeded both during dry and wet weather. The minimum standard was exceeded during dry weather (Table 3-94) within Zones 2, 3, and 4 and accounted for 10.5%, 9.7%, and 8.0% of the samples respectfully. During dry weather pH was considered a problem parameter in Zone 2 and a potential problem parameter in Zones 3 and 4. The minimum standard was also exceeded during wet weather (Table 3-96) within Zone 2. The minimum standard was exceeded in Zone 2 within 3.0% of the samples. During wet weather pH was considered to be a potential problem parameter.*Dissolved Oxygen*
The DRBC has set minimum DO daily averages as well as minimum seasonal averages for the mainstem of the Delaware River. The minimum DO daily average values change by zone throughout the monitored area while the minimum seasonal averages are constant within Zones 1 through 5. Seasonal averages are effective between April 1st thru June 15th and September 16th thru December 31st and require a minimum average seasonal DO level of 6.5 mg/L. DRBC water quality criteria require a minimum daily average DO concentration within Zone 2 of 5 mg/L. Both zones 3 and 4 require a minimum daily average DO concentration of 3.5 mg/L. The continuous data (Table 3-98) shows that the most serious exceedances occurred at USGS gage 01482800. DO is therefore considered a potential concern in Zone 2.

Historical data show an improving trend over time. Figure 3-91 illustrates that historically, DO has dropped below standards downstream of the Delaware Direct Watershed, however, the DO in the Delaware River has generally improved since 1980. Figure 3-92 indicates that DO has improved over time since 1984 at the Navy Yard, the most downstream point in the Delaware River in the Delaware Direct Watershed. DRBC sampling has found the DO standard was met continuously since 1980.

According to the "Development of a Hydrodynamic and Water Quality Model for the Delaware River" (DRBC, 1998) "the elimination of the CSO loading," … "shows almost no impact on dissolved oxygen concentrations."

Future Investigation of Dissolved Oxygen Conditions in the Tidal Delaware River
The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the tidal Delaware River are not well understood at this juncture. Efforts to better understand the dissolved oxygen conditions will continue through evaluation of ongoing continuous long-term

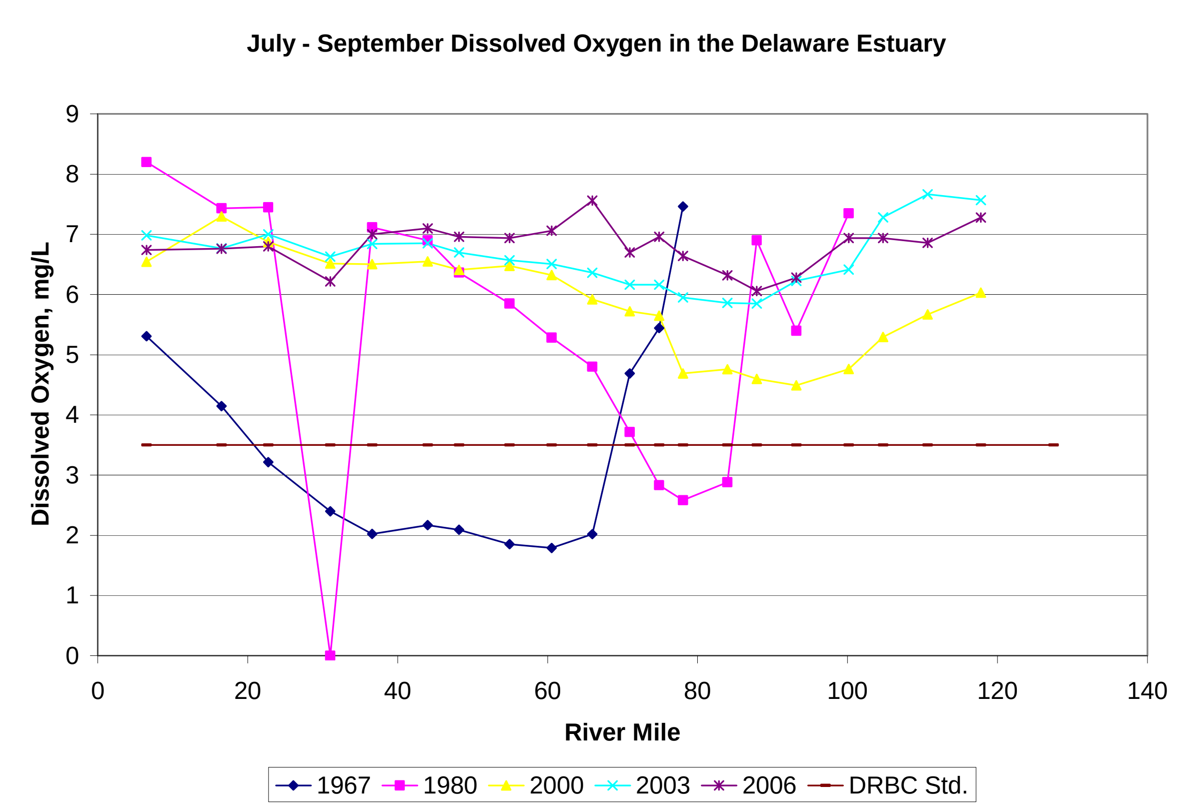


Figure 3-91 Historical Dissolved Oxygen in the Delaware River Estuary by river mile, 1967 – 2006

monitoring. PWD continues to work with the Delaware River Basin Commission and its partners on issues related to the dissolved oxygen conditions in the estuary. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from other dischargers to the tributaries that run through the City. If a relationship between loadings and the dissolved oxygen conditions in the River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all potential sources of the identified water quality constituents to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Total Dissolved Solids

Total Dissolved Solids (TDS) were not included in the wet weather and dry weather sampling in the Schuylkill River because the DRBC has no standard for TDS in Zone 2 through 4. TDS are not considered a parameter of concern in the Philadelphia portion of the Delaware River.

Total Suspended Solids

Total Suspended Solids (TSS) is a measure of the concentration of solids suspended in the water column. TSS ranged from 2.0 mg/L in Zone 2 to 206 mg/L in Zone 3 during wet weather sampling (Table 3-96). Dry weather samples (Table 3-94) ranged from 2 mg/L to 73 mg/L in Zone 4. The DRBC does not have water quality standards for TSS and TSS is not considered to be a concern in the Philadelphia portion of the Delaware River.

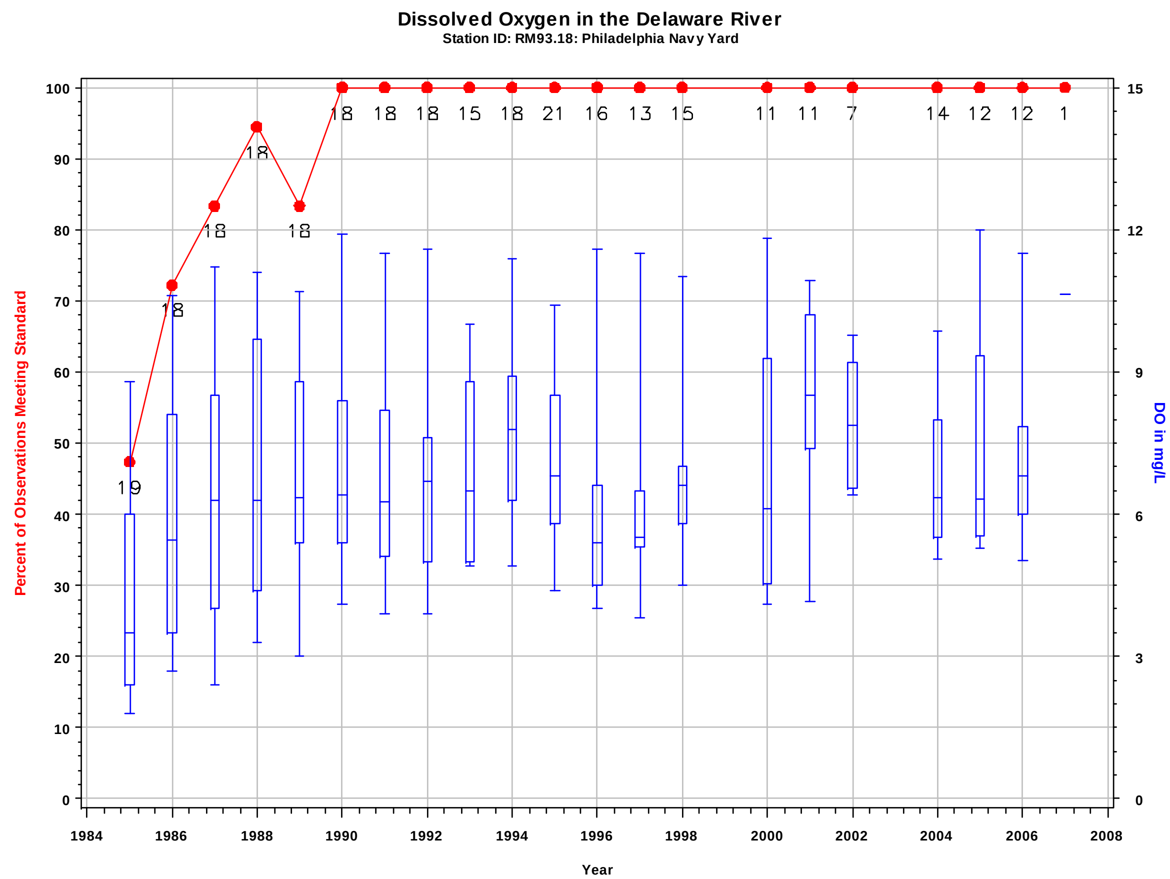


Figure 3-92 Delaware River Dissolved Oxygen at the Philadelphia Navy Yard 1984 - 2007

Turbidity

Turbidity is a measure of the light scattering properties of particles suspended in water. In streams, turbidity can come from many sources, but the chief cause of increased turbidity is suspended sediment. While a correlation between turbidity and TSS certainly exists, the relationship between turbidity and TSS may differ between water bodies and even among different flow stages/seasons in the same water body due to sediment characteristics. Consistently turbid waters often show impairment in aquatic communities. Light penetration is reduced, which may result in decreased algal production; suspended particles can clog gills and feeding apparatus of fish, benthic invertebrates, and microorganisms. Feeding efficiency of visual predators may also be reduced. Turbidity is measured in Turbidity Units, and the DRBC has set a water quality standard of 150 units maximum.

In the Delaware River Zones 2 through 4, turbidity ranged from 1 NTU in Zone 2 to 150 NTU in Zone 3 during dry weather (Table 3-94). Wet weathers samples (Table 3-96) ranged from 1 NTU in Zone 2 to 200 NTU in Zone 3. The DRBC standard was exceeded twice in both Zones 2 (3.4% of observations) and 4 (2.6 % of observations. Turbidity is not considered to be a concern during dry weather, as no samples exceeded the standard, and is considered a potential concern during wet weather.

Nutrients
Nutrient samples were collected by the DRBC from 2005-2008. The DRBC has not set water quality standards for nutrients in Zones 2-4, which includes the tidal portions of the Delaware River. Therefore, collected data could not be compared to a target value.

Total Phosphorous
The DRBC reported sampling of Total Phosphorous (TP) in the Delaware River from 2003 to 2008. TP dry weather samples (Table 3-94) ranged from 0.0450 mg/L in Zone 2 to 0.165 mg/L at the Zone 4 sampling site. During wet weather events (Table 3-96), samples ranged from 0.0240 mg/L in Zone 2 to 0.165 mg/L in Zone 4. DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. Total Phosphorous is not considered a problem parameter in the Philadelphia portion of the Delaware River.

Ammonia
Ammonia, present in surface waters as un-ionized ammonia gas (NH3), or as ammonium ion (NH4+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH3, although at the expense of increased NO3 concentration.

During dry weather (Table 3-94), ammonia concentrations ranged from 0.02 mg/L (Zone 2) to 0.389 mg/L (Zone 4). During wet weather events (Table 3-96), samples ranged from 0.008 mg/L (Zones 4) to 0.459 mg/L (Zone 4). DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin, and ammonia is not considered to a parameter of concern in the Philadelphia portion of the Delaware River.

Total Nitrogen
TN dry weather samples (Table 3-94) ranged from 1.41 mg/L in Zone 3 to 2.28 mg/L in Zone 4. During wet weather events (Table 3-96), samples ranged from 0.908 mg/L in Zone 2 to 2.45 mg/L in Zone 4. DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. TN is not considered to be a concern in the Philadelphia portion of the Delaware River.

Total Kjeldahl Nitrogen
The Total Kjeldahl Nitrogen (TKN) test provides an estimate of the concentration of organically-bound N, but actually measures all N present in the trinegative oxidation state. Ammonia must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters.

TKN dry weather samples (Table 3-94) ranged from 0.374 mg/L in Zone 2 to 0.696 mg/L in Zone 4. During wet weather events (Table 3-96), samples in the Philadelphia Zones of the Delaware ranged from 0.126 mg/L (Zone 2) to 0.851 mg/L (Zone 4). DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. TKN is not considered to be a concern in the Philadelphia portion of the Delaware River.

Toxic Metals
With the exception of Aluminum (Al) and hexavalent Chromium (Cr), PA WQ criteria are based on hardness (as CaCO3), to reflect inverse relationships between hardness and toxicity that exist for

most metals (Figure 3-36). While these criteria are much improved over simple numeric criteria, they fail to describe the complex interactions between dissolved metals and other water constituents and physicochemical properties (e.g., Dissolved Organic Carbon, pH, temperature, and ions other than Ca and Mg,). Hardness-based criteria may represent an intermediate step between simple numeric criteria and criteria based on more complex water quality models (i.e., Biotic Ligand Model), drafts of which have been recently been presented by US EPA.

Dissolved Zinc

Zinc (Zn) is a common element present in many rocks and in small concentrations in soil. Zn is a micronutrient needed by plants and animals, but when present in greater concentrations in surface water, it is moderately toxic to fish and other aquatic life. Toxicity is most severe during certain sensitive (usually early) life stages. Zn is a component of common alloys such as brass and bronze and is used industrially for solders, galvanized coatings, and in roofing materials.

Since the water quality criteria for dissolved Zn requires a hardness correction, the standard was calculated at 100 µg/L $CaCO_3$ hardness. With the correction, the Aquatic Life Acute Maximum for Dissolved Zn is 117 µg/L and the Aquatic Life Chronic Maximum is 106 µg/L . The toxicity limit for Fish Ingestion Only (FIO) Maximum is 68700 µg/L and the toxicity limit for Fish and Water Ingestion (FWI) Maximum is 9110 µg/L.

Dissolved Zn samples in the Philadelphia segment of the Delaware River ranged from 0.400 µg/L in Zone 3 to 32.4 µg/L in Zone 3 during dry weather (Table 3-94). Wet weather samples (Table 3-96) ranged from 0.400 µg/L in Zone 3 to 36.0 µg/L in Zone 4. The water quality standards were never exceeded during sampling, therefore, Dissolved Zn is not considered to be a parameter of concern in the Philadelphia portion of the Delaware River.

Dissolved Copper

Copper (Cu) occurs naturally in numerous forms and is present to some degree in most soils and natural waters. Cu is also used industrially for electric wires and coils, as well as in building materials such as roofing and pressure-treated lumber. Cupric Ion (Cu2+) is the bioavailable form of Cu in aquatic systems and its mode of toxicity involves ligand bonding with the gill surface of fish or similar structures of invertebrates. As such, WQ criteria are based on dissolved Cu concentration, which is a better predictor of Cu toxicity than total recoverable metal concentration. Dissolved concentrations are usually much smaller than total recoverable concentrations in natural waters, as Cu forms complexes and ligand bonds with other water column constituents (Morel & Hering, 1993).

Since the water quality criteria for dissolved copper requires a hardness correction, PWD calculated the standard at 100 µg/L $CaCO_3$ hardness. With the correction, the Aquatic Life Acute Maximum for Dissolved Cu is 18 µg/L and the Aquatic Life Chronic Maximum is 12 µg/L. In the Delaware River Zones 2-4, Dissolved Cu ranged from 1.10 µg/L in Zone 4 to 8.50 µg/L in Zone 4 during dry weather (Table 3-94). Wet weather samples (Table 3-96) ranged from 1.00 µg/L in Zone 3 to 12.2 µg/L in Zone 3. The standards were never exceeded during sampling, and therefore Dissolved Cu is not considered a concern in the Philadelphia portion of the Delaware River.

Indicator Bacteria

Fecal Coliform

The fecal coliform criteria change by Zone within the monitoring area. DRBC water quality criteria limit fecal coliform levels within Zone 2, Zone5, and Zone 6 to 200 per 100 mL. The DRBC water quality standard within Zone 3 for fecal coliform is set at 770 per 100 mL. Within Zone 4 the fecal coliform limit is broken down by R.M. such that, below R.M. 81.8 the limit is set at 200 per 100 mL and above R.M. 81.8 the limit is set at 770 per 100 mL. No areas of the Delaware Direct Watershed are located below R.M. 81.8.

Dry Weather Fecal Coliform Bacteria Concentration
The discrete sampling program conducted by DRBC from 2003-2008 broke down sampling into both dry weather (Tables 3-94 and 3-95) and wet weather (Tables 3-96 and 3-97). During dry weather only Zone 2 showed exceedance of fecal coliform criteria (5.7 % of observations) and is considered to be a potential concern. Sampling within Zone 2 consisted of two locations along the Delaware River. The first location was at R.M. 110.7, which had fecal coliform levels above the standard 8.8% of the time. The second location was at R.M. 117.8, which had fecal coliform levels above the standard 3.1% of the time.

Wet Weather Fecal Coliform Bacteria Concentration
During wet weather (Tables 3-96 and 3-97) the only zone to exceed the criteria for fecal coliform was Zone 2. Roughly 13.2% of all wet weather samples within Zone 2 exceeded the standard for fecal coliform concentration. At R.M 110.7, the standard was exceeded 13.3% of the time. At R.M. 117.8, and it was exceeded 16.7% of the time.

A review of historical data collected by DRBC (1984-2007) shows Zone 2, Zone 3 and Zone 4 in Philadelphia had the lowest percent of observations meeting standards (Figure 3-93). However, since 1997, fecal coliform has remained below the standard at the Navy Yard, the most downstream monitoring station in Philadelphia which includes all drainage from the Delaware Direct Watershed (Figure 3-94).

Enterococcus
Enterococcus is a bacteria genus used to indicate human pathogens. DRBC has set maximum enterococcus concentrations for this watershed. The maximum enterococcus concentration changes by zone throughout the monitoring area. The water quality limit for enterococcus concentration levels in Zone 2 is 33 per 100mL. Within Zone 3, the limit is increased to 88 per 100mL. Within Zone 4 the enterococcus limit is broken down by R.M. such that, below R.M. 81.8 the limit is 33 per 100mL and above R.M. 81.8 the limit is 88 per 100mL.

Within each zone a significant increase in exceedances can be seen between the dry and wet weather. During periods of dry weather (Tables 3-94 and 3-95) Zone 2 had the largest percentage of data that exceeded the standard set forth by DRBC with 10.4% of all data samples. During periods of wet weather (Table 3-95 and 3-96), the standard was exceeded in 32.4% of observations. The two monitoring sites within Zone 2 were located at R.M. 110.7 and 117.8. At R.M 110.7, the standard was exceeded in 5.4% of observations in dry weather and in 33.3% of observations in wet weather. Similarly, at R.M. 117.8, the number of samples exceeding the standard increased from 16.7% in dry weather to 40% in wet weather.

Zone 3 contained the second largest percentage of data that exceeded the standard in dry weather (8.8% exceedance) and wet weather (18.3% exceedance). Monitoring sites within Zone 3 were located at R.M. 100.2 and 104.75. 8.8% of all samples at both stations exceeded the standard in dry weather. In wet weather, 26.7% and 10% of their total samples exceeded the standards, respectively.

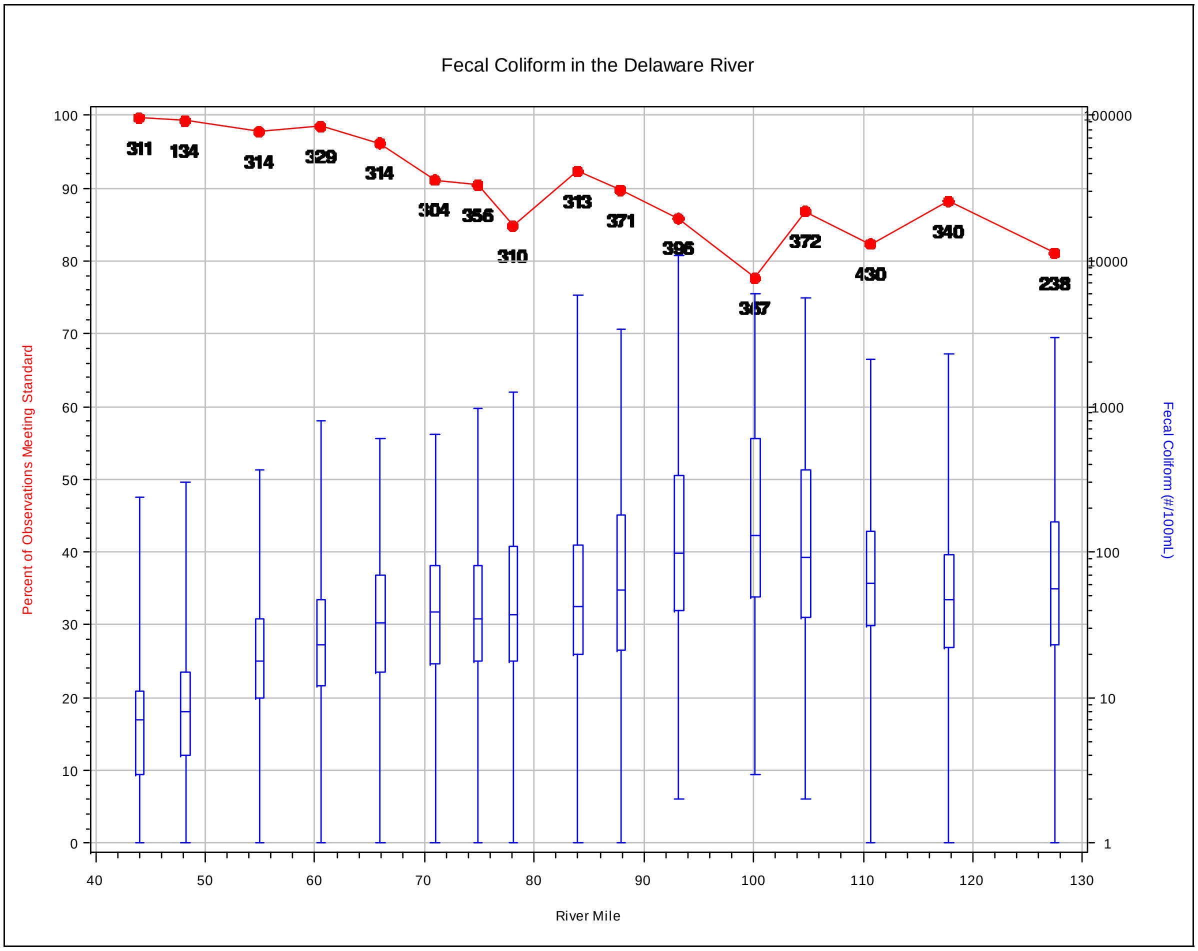


Figure 3-93 DRBC Boat Run Fecal Coliform in the Delaware River Estuary by river mile 1984 - 2007

Lastly, Zone 4 had the smallest increase in exceedances between dry and wet weather observations. At the station at R.M. 87.9, 2.4% of all samples exceeding the set limit during dry weather and 10.3% of samples exceeded the limit during wet weather.

Overall, enterococcus is parameter of concern in Zones 2 through 4 during both dry and wet weather, and especially in Zone 2 where the maximum limits are more stringent.

Future Investigation of Bacteria Conditions in the Tidal Delaware River

The nature, causes, severity and opportunities for control of the bacteria conditions in the tidal Delaware River are not well understood at this juncture. Efforts to better understand the bacteria conditions will continue through evaluation of ongoing monitoring efforts, and the establishment of additional monitoring efforts if necessary to better define potential problems. PWD will work with the Delaware River Basin Commission and its partners on issues related to the bacteria conditions in the estuary if such efforts are initiated by DRBC. Estimates will be refined and analyses performed on the loading of bacteria, both from the City as well as from other dischargers to the tributaries that run through the City. If a relationship between loadings and the bacteria conditions in the River adjacent to the City is suspected, informational total maximum daily loads will be investigated for the City's watersheds. Progress and results of this work, and any proposed remedial control actions,

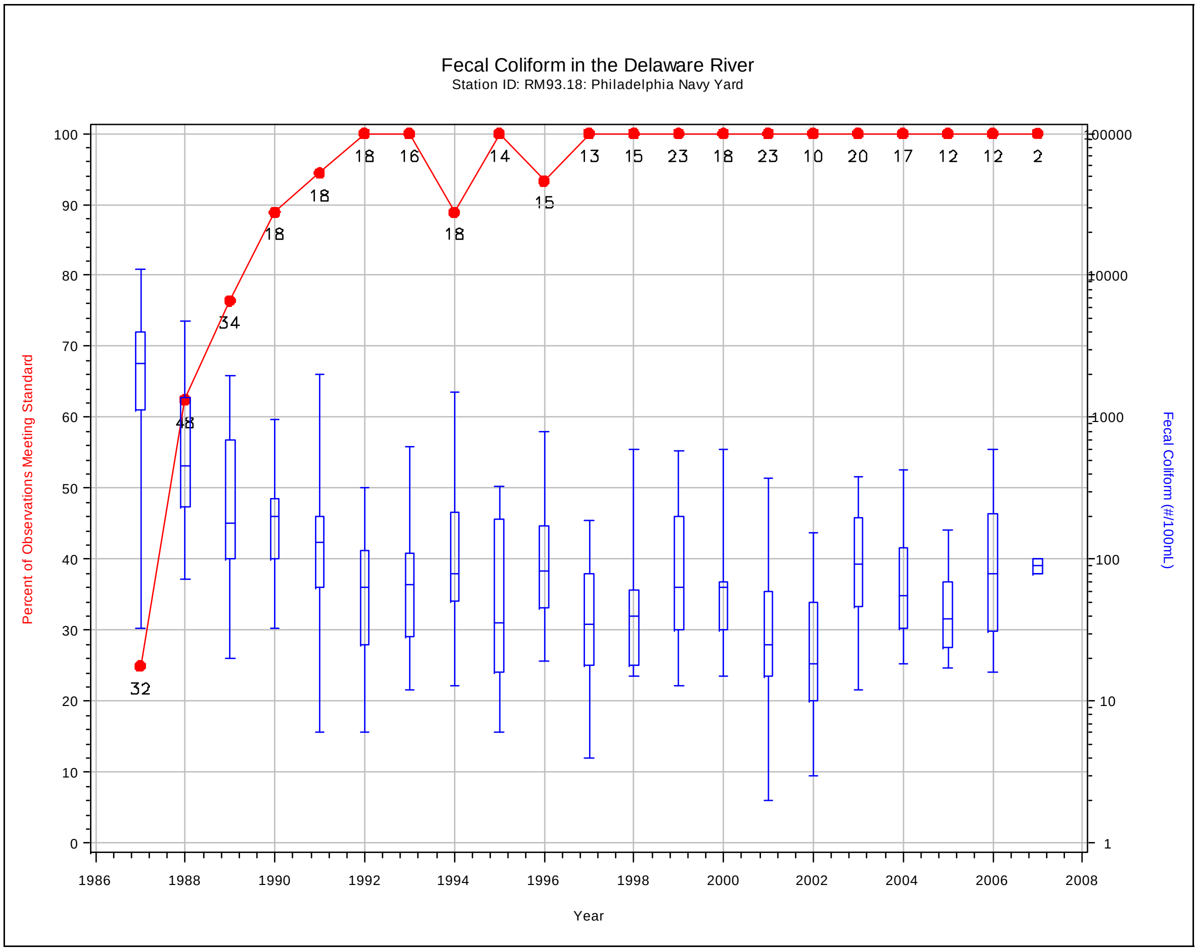


Figure 3-94 Delaware River Fecal Coliform at the Philadelphia Navy Yard 1984 - 2007

will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

The DRBC has set water quality criteria for temperature based on month and zone. Exceedances of temperature standards within the Delaware River were recorded by both discrete and continuous sampling in Zones 2 through 4. Temperature is therefore considered a parameter of concern in all three zones. The continuous data (Table 3-98) shows that the largest percentage of exceedance occurred at USGS gauge 01477050 in Zone 4. However, the discrete monitoring data (Table 3-94 and 3-96) shows that the largest exceedance occurred within Zone 2. During dry weather the standard was exceeded 28.4% of the time and during wet weather the standard was exceeded 33.3% of the time.

Total Alkalinity

The maximum and minimum total alkalinity standards set by DRBC change by zone throughout the monitoring area. DRBC water quality criteria limit the maximum value to 100 mg/L and a minimum value to 20 mg/L for any location within Zone 2. Zones 3 through 6 have a maximum value of 120 mg/L and a minimum value of 20 mg/L throughout their areas.

The standard for minimum alkalinity was often exceeded during discrete wet weather monitoring (Table 3-96). These exceedances occurred in Zone 2, 3, and 4, and occurred 14.3%, 14.3%, and 14.3% of the time.

3.4.2.3.3 Biological Assessment of the Delaware Direct Watershed

Benthic Assessment

The Partnership for the Delaware Estuary (PDE) is currently leading the Delaware Estuary Benthic Inventory Program (DEBI) due to an expressed need in "*White Paper on the Status and Needs of Science in the Delaware Estuary*" (Kreeger, et al 2006). The Benthos community is expected to differ in the Delaware River than in other non-tidal stream. Previously, no reference site was available to study benthos in the tidal streams in Philadelphia. The Delaware Direct IWMP will summarize the findings of DEBI in the Delaware Direct Watershed to help guide watershed management and restoration.

The Philadelphia Water Department has performed Biological Monitoring in the Delaware Direct Watershed, focusing on the tidal portion of the Pennypack Creek. Site PP180 was studied in the 2002-2003 Baseline Assessment of the Pennypack Creek and is located in the Delaware Direct Watershed (Figure 3-95). Reference sites used for Pennypack Creek Watershed were located on French Creek and Pine Creek in Chester County, PA (Figure 3-45). French Creek had high taxa richness (n = 27) and low HBI score (4.470). Seven EPT taxa were found, and all trophic levels were represented. Biological assessment scores of this site may be biased due to poor reference site scores. This comparison resulted in better scores and "moderately impaired" designations, which do not accurately portray the benthic population at these sites. The Pennypack Creek Watershed Comprehensive Characterization Report provides additional detail on the tidal Pennypack Creek and will be released in the Summer 2009.

Site PP180 received a total metric score of zero out of a possible 30 (Figure 3-96). When compared to the French Creek reference location, it was designated as "severely impaired." Impairment is based on low taxa richness (n = 7) and an elevated Hilsenhoff Biotic Index (HBI). This site had the highest HBI score of all Pennypack Creek sites (6.087), and midge larvae (Chironomidae) dominated benthic assemblage (74.02% of all individuals). Because of the abundance of chironomids, feeding structure was skewed toward generalist gatherer/collectors. This portion of Pennypack Creek is tidal; its "impairment" is largely due to water level fluctuations (i.e., the riffle ceases to be a functional riffle at high tide).

Fish Assessment in the Pennypack Creek

Site PP180 at High Tide

Site PP180 is located near the head of tide (Figure 3-95) and was sampled at both high and low tide to determine if the fish community and biological integrity changed. A total of 705 individuals representing 20 species were collected at PP180 at high tide. Three species comprised 83% of all fish collected, with banded killifish (F. diaphanus) most abundant. As in all sites, tolerant and moderately tolerant species dominated the fish community (99%). However, this site had the largest percentage of intolerant fish (0.85%) in the watershed, with striped bass (Morone saxatilis) as the only intolerant species. Intolerant species are usually the first to disappear following a disturbance.

Despite the high diversity (n=20), this site had low number of individuals, density (fish per unit effort), and biomass. PP180, at high tide, received an Index of Biotic Integrity (IBI) score of 32 (out of 50), placing this site in the "fair" category.

One reason for the “fair” IBI score is that PP180 displayed a well-balanced trophic structure, with the highest percentage of insectivores and lowest percentage of generalist feeders. This trophic structure is similar to that of the reference site. The main factor that kept the IBI score down was that the percentage of individuals with disease, lesions, tumors, and anomalies were highest in the Pennypack Watershed (26.8%).

Site PP180 at Low Tide

At low tide, PP180 had greater abundance but less diversity than at high tide. The five-fold increase in top carnivores shifted the trophic structure, but insectivores still dominated. At low tide, this site had no intolerant species. Conversely, the percentage of individuals with disease, lesions, tumors, and anomalies was greatly reduced from the high-tide assemblage. This site received an IBI score of 34 (out of 50), placing it in the “fair” category similar to the high-tide conditions. Overall, the biological integrity of this site did not change significantly with tidal fluctuation.

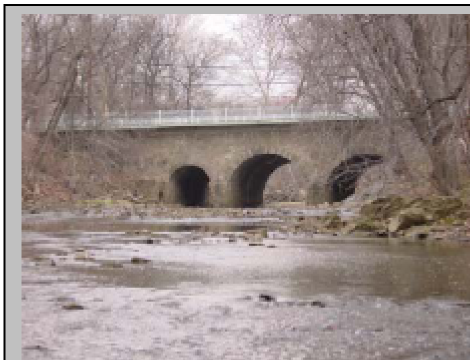
3.4.2.3.4 Habitat Assessment of the Delaware Direct Watershed

The Philadelphia Water Department has performed habitat assessment in the Delaware Direct Watershed, focusing on the tidal portion of the Pennypack Creek.

Habitat Assessment of the Tidal Pennypack Creek

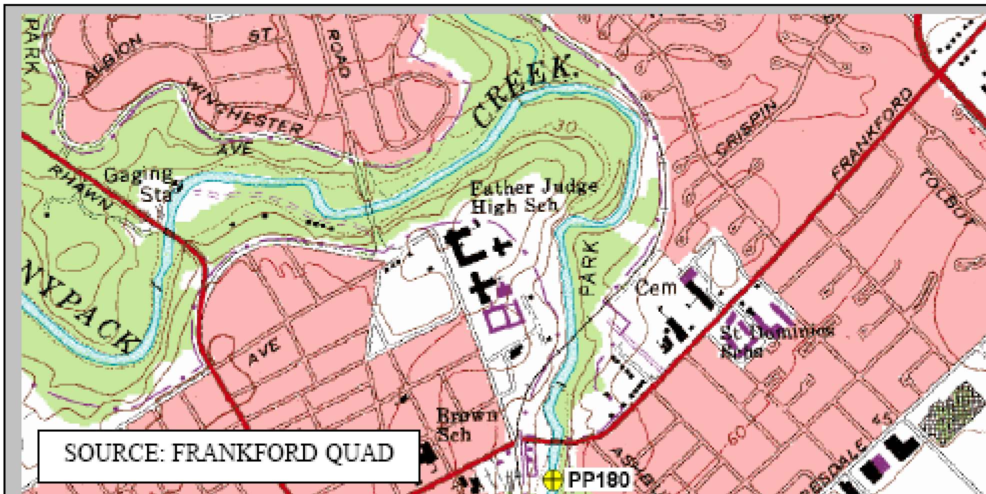
Site PP180 (Figure 3-95) received a habitat assessment score of 175.34, or 85% comparability to the reference site ("supporting" designation). This tidally-influenced site had a desirable combination of bedrock and smaller gravel/sand substrates, as well as a variety of depth/velocity regimes. As with many sites located within parklands, this site had high scores for measures of bank stability and vegetative protection. Streambanks were quite steep in places and evidence of moderate sedimentation and embeddedness were observed. Pennypack Creek lacks sinuosity in a majority of the tidal area. Sediment deposition in tidal areas appears to be increasing, possibly due to headcutting of the stream channel upstream of breached dam(s).

PP180: Pennypack Creek Study Area Philadelphia County



Upstream view of PP180

Downstream view of PP180



SOURCE: FRANKFORD QUAD

Location and Description:

Location:

Access gained at unmarked paved trail at Frankford Avenue Bridge (Latitude: 40.04278, Longitude: -75.02103).

Description:

Site PP180 is the most downstream monitoring location in the Pennypack Watershed, located approximately 100m downstream from Frankford Avenue Bridge. Land use is varied and includes multi-family residential properties, forested parkland (Pennypack Park), and community services.

Assessment Type(s):

Chemical, Benthic (RBP III), Fish (RBP V), Habitat

Figure 3-95: Site PP180 in the 2002-2003 Baseline Assessment of the Pennypack Creek

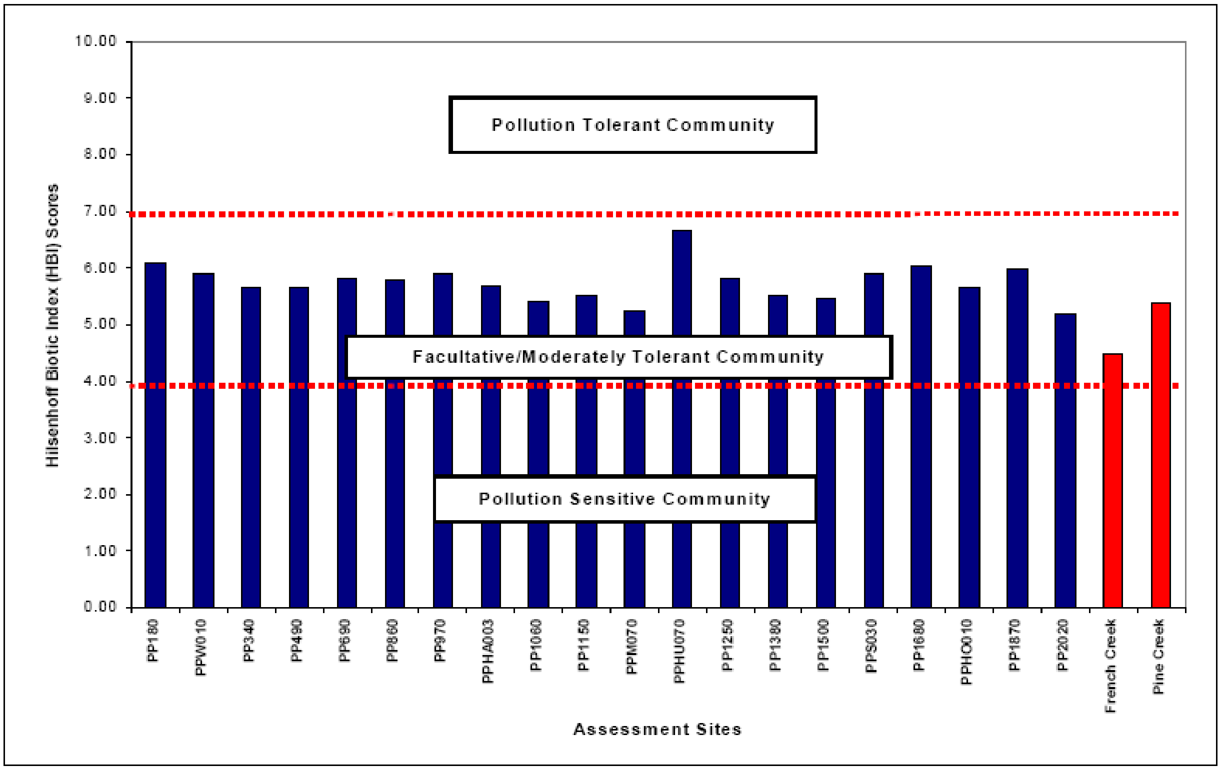


Figure 3-96: Site PP180 in the 2002-2003 Baseline Assessment of the Pennypack Creek

3.4.2.4 Combined Sewer Area of Schuylkill River Watershed Characterization

Approximately 15 square miles contribute to the combined sewers directed to the tidal Schuylkill River. This area is called the Combined Sewer Area of the Schuylkill River and is 40% of the Schuylkill River Watershed in Philadelphia (Figure 3-97).

The Tidal Schuylkill River Master Plan conducted by the Schuylkill River Development Corporation in 2003 provides additional characterization of the tidal Schuylkill River. The Master Plan can be found online at www.schuylkillbanks.org/admin/controls/doc/2_20051213123301.pdf. As of mid-2009, PWD is developing an Integrated Watershed Management Plan (IWMP) to guide restoration and management of the Schuylkill River Watershed within the city boundaries of Philadelphia.

The entire Schuylkill River Watershed is over 130 miles long, includes over 180 tributaries, and drains an area of 2,000 square miles. The watershed is located in southeastern Pennsylvania and is comprised of eleven counties and over three million residents (Figure 3-98). The headwaters of the Schuylkill River drain approximately 270 square miles of Schuylkill County and flow in a southeasterly direction into the tidal waters at the river's confluence with the Delaware Estuary. The basin includes large parts of Schuylkill, Berks, Montgomery, Chester, and Philadelphia counties and smaller parts of Carbon, Lehigh, Lebanon, Lancaster, Bucks, and Delaware counties. The major towns and cities along the river are Pottsville, Reading, Pottstown, Phoenixville, Norristown, Conshohocken, and Philadelphia.

Land Use and Demographics

As shown in Figure 3-99, the Combined Sewer Area in Schuylkill River Watershed is dominated by residential (50%) and commercial (13%) land uses. Consequently, the area is covered by 66% impervious surface. The population of the Combined Sewer Area of the Schuylkill River is 290,251, averaging 19,013 people per square mile. Figure 3-100 shows the distribution of population density throughout the Combined Sewer Area in the Schuylkill River Watershed.

Receiving Waters Characterization

The Combined Sewer Area in Schuylkill River Watershed includes the Schuylkill River and almost 7 miles of tributaries plus 33 miles of historic streams that are now encapsulated in pipes.

Pollution Sources

In addition to CSO discharges to the Schuylkill River from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. The main sources of pollution in the Schuylkill River are acid mine drainage in the headwaters, agricultural and suburban runoff in the middle reaches, and suburban and urban stormwater runoff in the lower reaches. Minor sources of pollution are likely to include atmospheric deposition, overland runoff from urban and suburban areas, and individual on-lot domestic sewage systems discharging through shallow groundwater. A complete list of industrial and municipal dischargers can be found in the Schuylkill River Source Water Protection Plan located online at http://www.phillyriverinfo.org. The urban and industrial nature of the combined sewer area is likely to contribute pollutants to the stormwater and combined sewer flows.

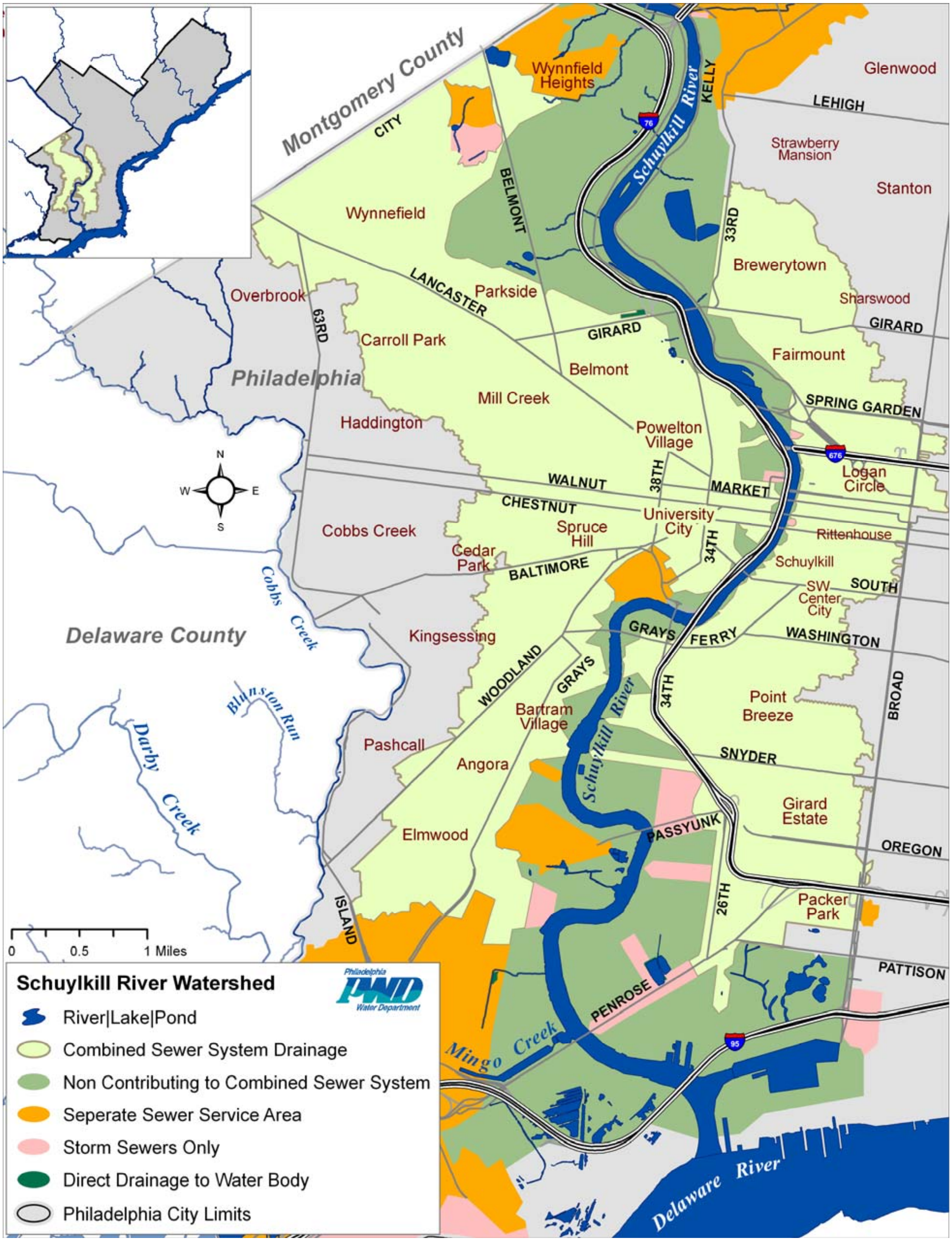


Figure 3-97: The Combined Sewer Area in the Schuylkill River Watershed.

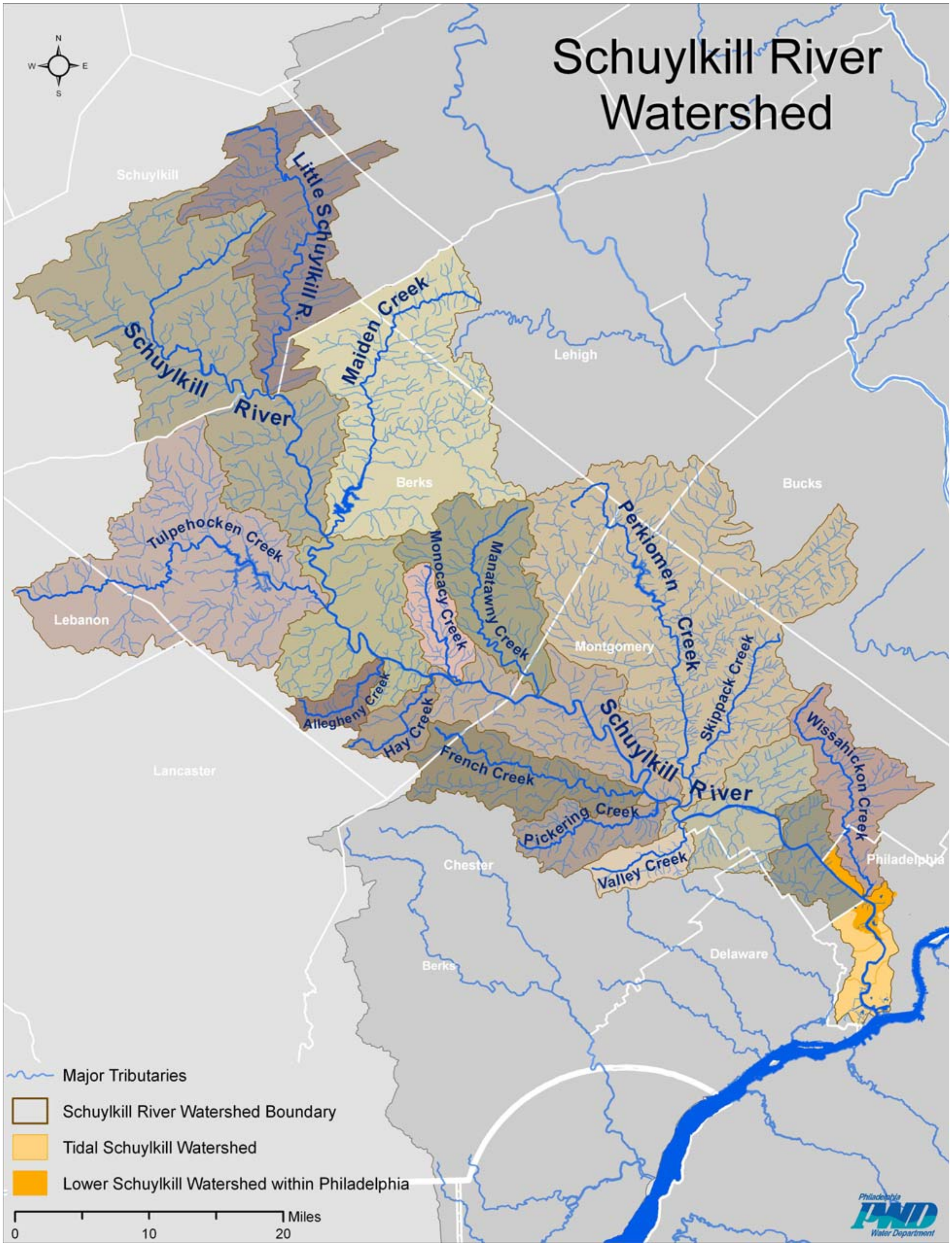


Figure 3-98 Schuylkill River Watershed

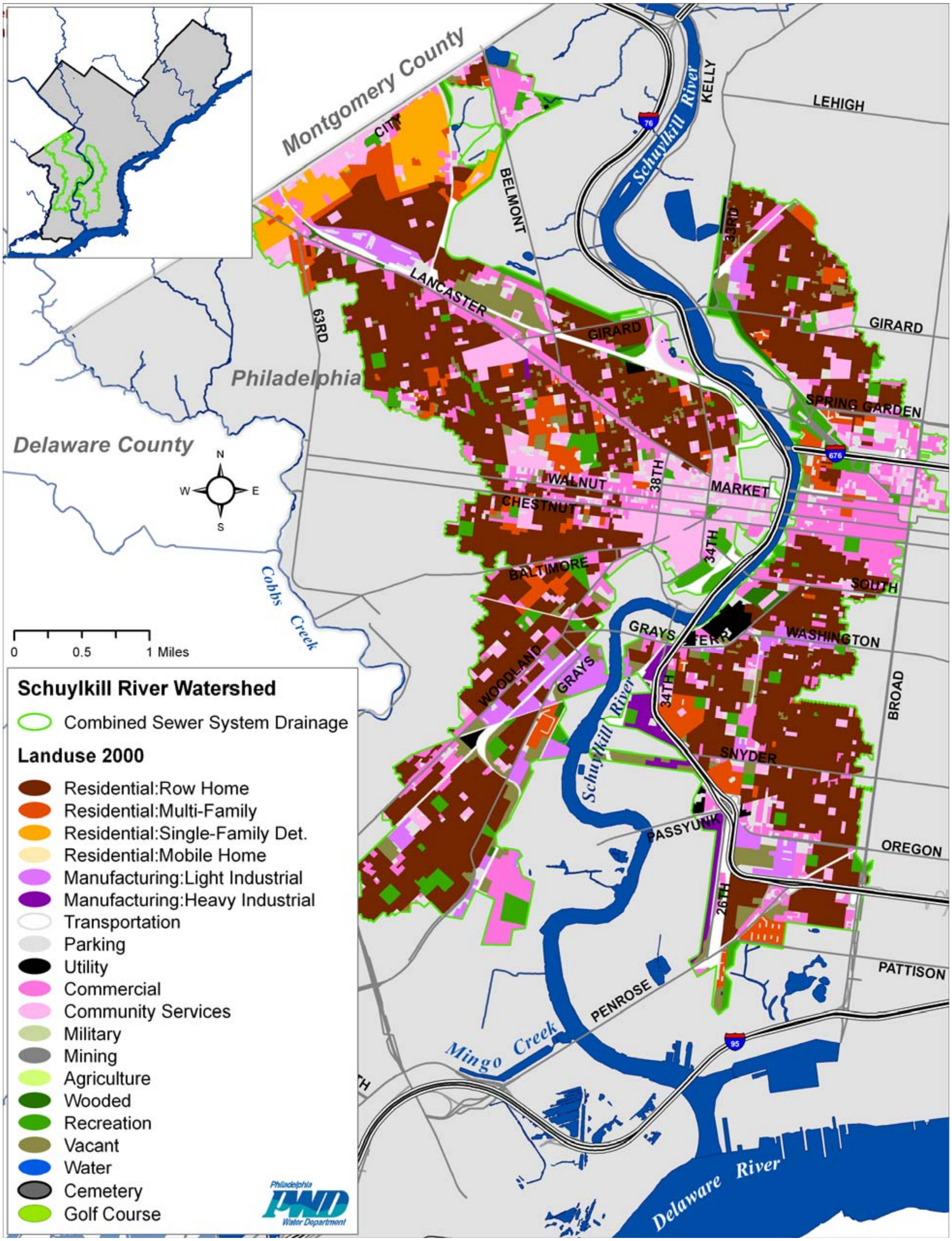


Figure 3-99 Land Use in the Combined Sewer Areas in the Schuylkill River Watershed

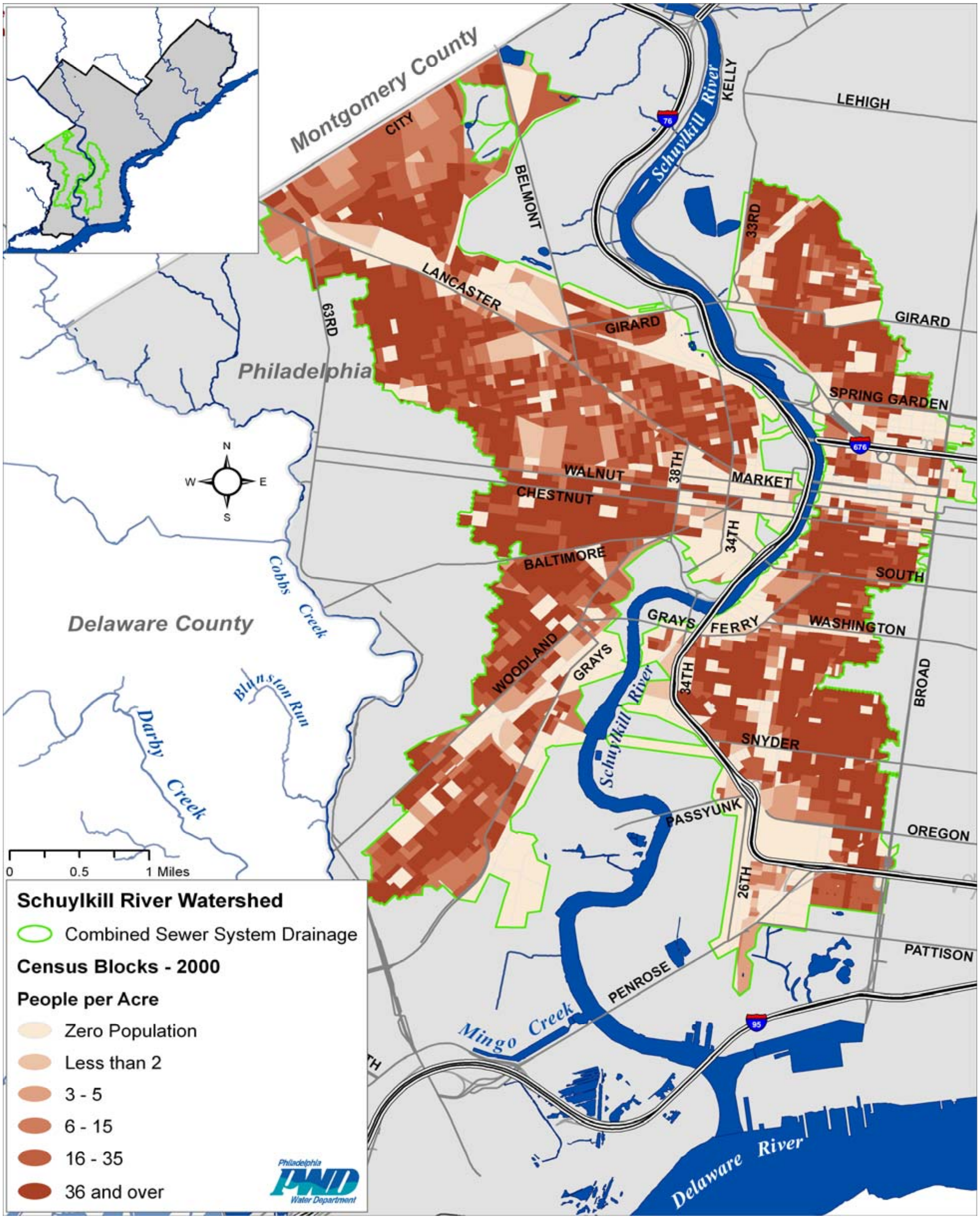


Figure 3-100 Population Density of the Combined Sewer Area in the Schuylkill River Watershed

3.4.2.4.1 Schuylkill River Watershed Hydrologic Characterization

Average annual Schuylkill River flow at Philadelphia is 2,721 cfs. Daily average Schuylkill River flow at Fairmount Dam through the 1990s is summarized in Figure 3-101 and indicates extremely high flow conditions in January 1996, with less pronounced high flow conditions occurring in 1994 and 1995. Lowest flows through the decade were not always associated with extended low levels of summer precipitation, suggesting that evaporation, groundwater storage, and surface water removal are important components in the water budget of the region. Based on monthly averages, no long-term temporal trends in flow were evident through this period (n = 120, Rho = -0.013, P = 0.884 for non-parametric rank order regression).

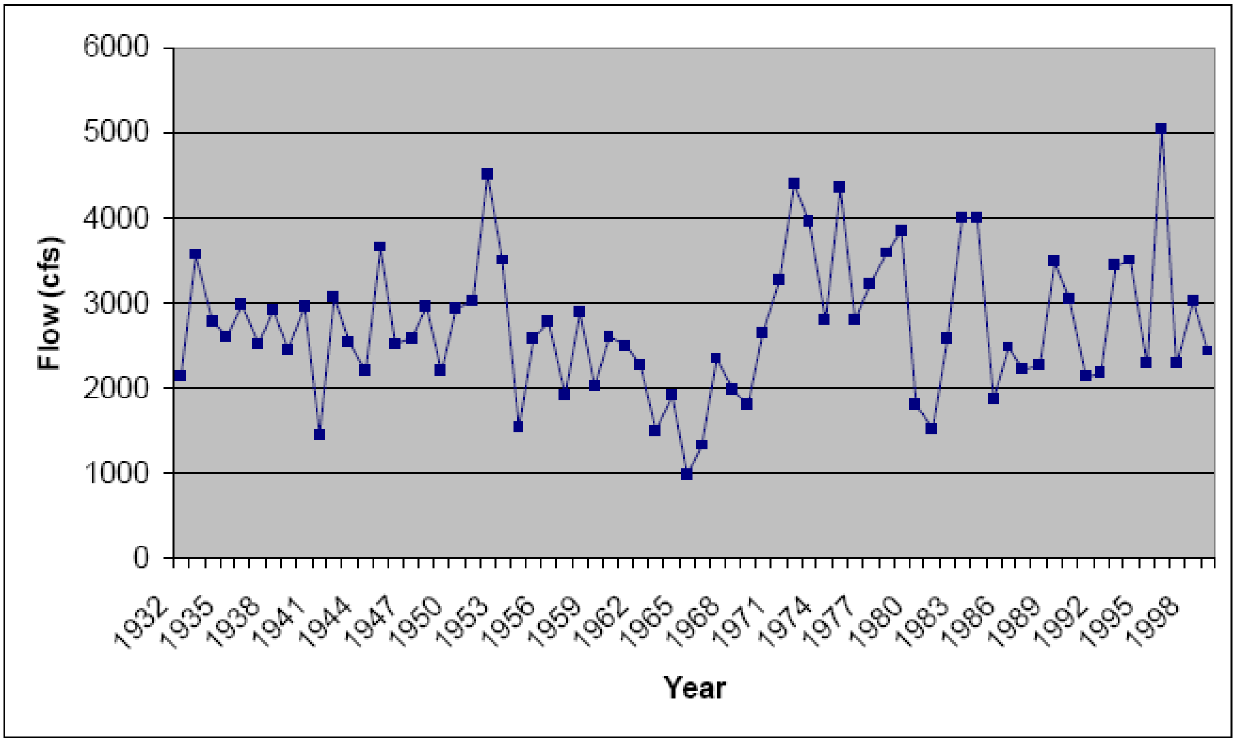


Figure 3-101 Daily Average Schuylkill River Flow at Fairmount Dam through the 1990's

Seasonal variation is driven primarily by precipitation, which is highest in spring, and evaporation, which is highest in summer months. Lowest flows occurred in 1993 and 1999. Minimum flows were higher through the 1990s than earlier in the century.

Surface Water

Runoff generated as overland flow just after a storm in the Schuylkill River Basin has a distinct seasonal variation. The most runoff occurs during winter or early spring, and the lowest amount of runoff occurs during the late summer or early fall. Runoff is chiefly dependent on the amount of rainfall that a specific area receives; after the winter months, the accumulated snow melts in the early spring create additional runoff. During the late summer months, there is very little runoff. The northern area of the basin, specifically in the area surrounding Tamaqua, receives the most precipitation and runoff, and runoff decreases with the amount of precipitation from north to south. As a result of loss of precipitation by evaporation, transpiration, and consumptive use, only about half of the precipitation falling within the watershed ever reaches surface waters. Table 3-99 summarizes the locations, drainage areas, annual mean flows, and annual runoff at 21 gauging stations along the Schuylkill River. The first gauging station listed is the northernmost one located along the Little Schuylkill River. The last gauging station on the chart is located along the lower portion of the Schuylkill River. As shown, Perkiomen, Tulpehocken and Maiden Creeks are by far the largest tributaries discharging to the Schuylkill River and can have significant impacts on Schuylkill water quality. First order streams comprise approximately 57% of the total stream miles within the Schuylkill River Watershed.

Table 3-99 Stream Gauging Data in the Schuylkill River Basin

Station ID	Location	Drainage Area (mi^2)	Period of Record	Annual Mean Flow (cfs)	Annual Runoff (Inches)	10% Exceeds (cfs)	50% Exceeds (cfs)	90% Exceeds (cfs)
01468500	Schuylkill at Landingville	133	1947-1953 1963-1965 1973-1999	278	28.43	560	195	75
01469500	Little Schuylkill at Tamaqua	43	1933-1999	84.2	N/A	177	51	13
01470500	Schuylkill at Berne	355	1947-1999	716	27.41	1480	450	158
01470779	Tulpehocken Creek Near Bernville	67	1975-1999	108	22.13	183	85	43
01470853	[(1)]Furnace Creek at Robesonia	4	1983-1999	6.87	22.33	14	4.7	1.4
01470960	Tulpehocken Creek at Blue Marsh Dam	175	1979-1999	273	N/A	539	174	65
01471000	Tulpehocken Creek Near Reading	211	1980-1999	320	N/A	625	213	83
01471510	Schuylkill River at Reading	880	1977-1999	1630	N/A	3330	1070	400
01471875	Manatawny Creek Near Spangsville	57	1993-1999	91	21.73	171	58	22
01471980	Manatawny Creek Near Pottstown	86	1974-1999	131	20.86	243	85	34
01472000	Schuylkill River at Pottstown	1147	1928-1999	1909	N/A	3860	1300	473
01472157	French Creek Near Phoenixville	59	1969-1999	89	20.47	170	56	20
01472198	Perkiomen Creek at East Greenville	38	1982-1999	60.4	21.59	115	37	15
01472199	West Branch Perkiomen at Hillegrass	23	1982-1999	38.1	22.43	74	23	7.9
01472620	East Branch Perkiomen Near Dublin	4	1990-1999	41.2	N/A	62	42	13
01472810	East Branch Perkiomen Near	59	1991-1999	126	N/A	191	72	48

Station ID	Location	Drainage Area (mi^2)	Period of Record	Annual Mean Flow (cfs)	Annual Runoff (Inches)	10% Exceeds (cfs)	50% Exceeds (cfs)	90% Exceeds (cfs)
	Schwenksville							
01473000	Perkiomen Creek at Graterford	279	1957-1999	411	N/A	831	180	60
01473169	Valley Creek Near Valley Forge	21	1983-1999	32.3	21.09	52	23	15
01473900	Wissahickon Creek at Fort Washington	21	N/A	N/A	N/A	N/A	N/A	N/A
01474000	Wissahickon Creek Mouth at Philadelphia	64	1966-1999	104	22.02	177	60	28
01474500	Schuylkill River at Philadelphia	1893	1932-1999	2721	N/A	5850	1670	430

3.4.2.4.2 Schuylkill River Water Quality Analysis

From 2005 through 2007, PWD collected water quality data from sampling locations along the Schuylkill River. PWD conducted continuous monitoring and discrete monitoring along the river. The continuous monitoring (Tables 3-100 through 3-103) was located at the Fairmount Fish Ladder (SC823), Tidal Schuylkill Buoy (SC048) and Bartram Garden (SC482). The discrete monitoring (Tables 3-101 and 3-102) was located at the BRC Pier (SC136), Gray's Ferry Ave. (SC587), and West River Drive (SC791). Tables 3-100 through 3-102 provide a basic, statistical profile of the data from the recent water quality monitoring program.

The Delaware River Basin tidal areas are segmented into zones as defined above in Section 3.4.2.3.2 The Schuylkill River falls within Zone 4 because it flows into the Delaware River between river mile (R.M.) 95.0 and R.M. 78.8.

Wet weather is characterized using the 7 PWD operated rain gages in the Schuylkill River direct drainage area. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The rain gages are depicted on Figure 3-1.

USGS collected water quality data at the Fairmount Dam (USGS 01474500) historically through 2004. Data collected in 2003 and 2004 were used in this analysis and are summarized in Table 3-103. These data combined with the PWD data from 2005 through 2007 provide the status of the water quality in the Schuylkill River.

All monitoring locations are depicted on Figure 3-13 in Section 3.1.4.3.4.

Table 3-100 Schuylkill River Continuous Water Quality Summary Statistics and Exceedances 2007 - 2008

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
DO	Daily Average Minimum	SC823	3.5	mg/L	153	6.81	8.60	9.63	11.2	12.0	14.0	0	0.0
DO	Daily Average Minimum	SC048	3.5	mg/L	297	3.54	4.73	5.19	7.99	8.85	13.0	0	0.0
DO	Daily Average Minimum	SC482	3.5	mg/L	184	3.19	6.48	7.86	10.0	11.0	14.8	4	2.2
pH	Maximum	SC823	8.5		14390	7.21	7.65	7.74	7.90	8.07	8.65	66	0.5
pH	Maximum	SC048	8.5		29720	4.28	7.07	7.16	7.32	7.44	8.99	12	0.0
pH	Maximum	SC482	8.5		17599	3.98	7.37	7.57	7.69	7.80	9.45	556	3.2
pH	Minimum	SC823	6.5		14390	7.21	7.65	7.74	7.90	8.07	8.65	0	0.0
pH	Minimum	SC048	6.5		29720	4.28	7.07	7.16	7.32	7.44	8.99	19	0.1
pH	Minimum	SC482	6.5		17599	3.98	7.37	7.57	7.69	7.80	9.45	28	0.2
Turbidity	Maximum	SC823	150	NTU	14388	0.00	3.10	5.90	15.9	47.6	1508	577	4.0
Turbidity	Maximum	SC048	150	NTU	29718	0.70	4.50	6.00	7.90	10.0	1185	7	0.0
Turbidity	Maximum	SC482	150	NTU	17596	0.30	4.70	5.80	7.50	10.2	1452	49	0.3
Temp	Maximum	SC823	*	°C	14390	5.89	16.5	23.5	26.2	27.8	30.5	6592	45.8
Temp	Maximum	SC048	*	°C	29720	4.28	18.2	23.7	26.0	27.6	29.9	2704	9.1
Temp	Maximum	SC482	*	°C	17599	5.44	18.3	24.5	26.9	27.8	30.5	3183	18.1

* Water Temperature Standards Change by Month

Table 3-101 Schuylkill River Dry Weather Summary Statistics and Exceedances 2005 – 2007

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Cu	Aquatic Life Acute Maximum	SC587	18**	µg/L	6	3.00	3.00	3.00	4.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC791	18**	µg/L	8	3.00	3.00	4.00	4.50	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC791	12**	µg/L	8	3.00	3.00	4.00	4.50	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC136	12**	µg/L	6	2.00	3.00	3.50	5.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC587	12**	µg/L	6	3.00	3.00	3.00	4.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC136	18**	µg/L	6	2.00	3.00	3.50	5.00	7.00	7.00	0	0
Diss Zn	Aquatic Life Acute Maximum	SC136	117**	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC587	117**	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
Diss Zn	Aquatic Life Acute Maximum	SC791	117**	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC136	106**	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC587	106**	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC791	106**	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Toxicants FIO Maximum	SC136	68700	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Toxicants FIO Maximum	SC587	68700	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Toxicants FIO Maximum	SC791	68700	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Toxicants FWI Maximum	SC136	9110	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Toxicants FWI Maximum	SC587	9110	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Toxicants FWI Maximum	SC791	9110	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
DO	Daily Average Min	SC136	3.5	mg/L	5	3.57	10.2	12.0	12.4	12.6	12.6	0	0
DO	Daily Average Min	SC587	3.5	mg/L	5	6.34	10.0	11.9	12.5	12.9	12.9	0	0
DO	Daily Average Min	SC791	3.5	mg/L	7	7.34	8.57	10.7	12.7	12.8	12.8	0	0
Fecal Coliform	Maximum	SC136	770	#/100mL	6	18.0	30.0	65.0	90.0	260	260	0	0
Fecal Coliform	Maximum	SC587	770	#/100mL	6	10.0	10.0	71.0	109	160	160	0	0
Fecal Coliform	Maximum	SC791	770	#/100mL	8	9.00	10.0	15.0	45.0	100	100	0	0
Inorganic N	No Standard	SC136	--	mg/L	6	2.46	2.47	2.77	2.91	3.27	3.27	--	--
Inorganic N	No Standard	SC587	--	mg/L	6	2.46	2.47	2.77	2.91	3.27	3.27	--	--
Inorganic N	No Standard	SC791	--	mg/L	8	2.46	2.60	2.82	3.22	3.41	3.41	--	--
NH_3	No Standard	SC136	--	mg/L	4	0.134	0.136	0.175	0.281	0.350	0.350	--	--
NH_3	No Standard	SC587	--	mg/L	4	0.134	0.136	0.175	0.281	0.350	0.350	--	--
NH_3	No Standard	SC791	--	mg/L	5	0.101	0.104	0.106	0.133	0.173	0.173	--	--
pH	Maximum	SC136	8.5	--	5	7.23	7.69	7.70	7.94	8.01	8.01	0	0
pH	Maximum	SC587	8.5	--	5	7.59	7.64	7.74	7.80	8.11	8.11	0	0
pH	Maximum	SC791	8.5	--	7	7.42	7.45	7.79	7.84	7.98	7.98	0	0
pH	Minimum	SC136	6.5	--	5	7.23	7.69	7.70	7.94	8.01	8.01	0	0
pH	Minimum	SC587	6.5	--	5	7.59	7.64	7.74	7.80	8.11	8.11	0	0
pH	Minimum	SC791	6.5	--	7	7.42	7.45	7.79	7.84	7.98	7.98	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
Temp	Maximum	SC136	*	°C	5	5.90	6.40	9.80	18.7	28.1	28.1	2	40.0
Temp	Maximum	SC587	*	°C	5	6.00	6.70	9.80	18.1	27.6	27.6	2	40.0
Temp	Maximum	SC791	*	°C	7	6.00	6.30	17.5	20.9	26.0	26.0	4	57.1
TKN	No Standard	SC136	--	mg/L	6	0.486	0.507	0.599	0.820	1.01	1.01	--	--
TKN	No Standard	SC587	--	mg/L	6	0.486	0.507	0.599	0.820	1.01	1.01	--	--
TKN	No Standard	SC791	--	mg/L	6	0.441	0.510	0.627	0.870	1.14	1.14	--	--
TN	No Standard	SC136	--	mg/L	6	3.07	3.27	3.39	3.76	3.77	3.77	--	--
TN	No Standard	SC587	--	mg/L	6	3.07	3.27	3.39	3.76	3.77	3.77	--	--
TN	No Standard	SC791	--	mg/L	6	3.20	3.33	3.60	4.06	4.37	4.37	--	--

* Water Temperature Standards Change by Month
** Water quality standard requires hardness correction; values listed is water quality standard calculated at 100 μg/L $CaCO_3$ hardness

Table 3-102 Schuylkill River Discrete Wet Weather Summary Statistics and Exceedances 2005 – 2007

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Cu	Aquatic Life Acute Maximum	SC136	18*	µg/L	4	3.00	3.50	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC587	18*	µg/L	4	4.00	4.00	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC791	18*	µg/L	9	3.00	4.00	5.00	6.00	10.0	10.0	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC136	12*	µg/L	4	3.00	3.50	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC587	12*	µg/L	4	4.00	4.00	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC791	12*	µg/L	9	3.00	4.00	5.00	6.00	10.0	10.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC136	117*	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC587	117*	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Zn	Aquatic Life Acute Maximum	SC791	117*	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC136	106*	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC587	106*	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC791	106*	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Toxicants FIO Maximum	SC136	68700	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Toxicants FIO Maximum	SC587	68700	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0
Diss Zn	Toxicants FIO Maximum	SC791	68700	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Toxicants FWI Maximum	SC136	9110	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Toxicants FWI Maximum	SC587	9110	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Zn	Toxicants FWI Maximum	SC791	9110	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
DO	Daily Average Minimum	SC136	3.5	mg/L	4	8.07	8.73	10.7	13.0	14.0	14.0	0	0
DO	Daily Average Minimum	SC587	3.5	mg/L	4	9.25	9.66	11.1	12.8	13.4	13.4	0	0
DO	Daily Average Minimum	SC791	3.5	mg/L	9	7.81	9.14	10.2	11.1	13.8	13.8	0	0
Fecal Coliform	Maximum	SC136	770	#/100mL	4	144	202	425	640	690	690	0	0
Fecal Coliform	Maximum	SC587	770	#/100mL	4	10.0	30.0	140	285	340	340	0	0
Fecal Coliform	Maximum	SC791	770	#/100mL	9	10.0	30.0	300	370	510	510	0	0
Inorganic N	No Standard	SC136	--	mg/L	3	1.575	1.58	2.47	3.35	3.35	3.35	--	--
Inorganic N	No Standard	SC587	--	mg/L	3	1.865	1.87	2.67	3.03	3.03	3.03	--	--
Inorganic N	No Standard	SC791	--	mg/L	8	1.90	2.62	2.68	3.01	3.57	3.57	--	--
NH_3	No Standard	SC136	--	mg/L	3	0.158	0.158	0.184	0.246	0.246	0.246	--	--
NH_3	No Standard	SC587	--	mg/L	2	0.125					0.139	--	--
NH_3	No Standard	SC791	--	mg/L	7	0.105	0.122	0.132	0.168	0.170	0.170	--	--
pH	Maximum	SC136	8.5	--	4	7.66	7.67	7.67	7.77	7.87	7.87	0	0
pH	Maximum	SC587	8.5	--	4	7.60	7.66	7.78	7.87	7.89	7.89	0	0
pH	Maximum	SC791	8.5	--	9	7.35	7.44	7.50	7.71	7.90	7.90	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
pH	Minimum	SC136	6.5	--	4	7.66	7.67	7.67	7.77	7.87	7.87	0	0
pH	Minimum	SC587	6.5	--	4	7.60	7.66	7.78	7.87	7.89	7.89	0	0
pH	Minimum	SC791	6.5	--	9	7.35	7.44	7.50	7.71	7.90	7.90	0	0
Temp	Maximum	SC136	*	°C	4	5.30	5.85	8.70	16.4	21.8	21.8	1	25.0
Temp	Maximum	SC587	*	°C	4	5.40	5.95	8.55	16.2	21.7	21.7	1	25.0
Temp	Maximum	SC791	*	°C	9	4.90	9.30	14.7	21.3	24.5	24.5	1	11.1
TKN	No Standard	SC136	--	mg/L	3	0.562	0.562	0.971	1.01	1.01	1.01	--	--
TKN	No Standard	SC587	--	mg/L	3	0.526	0.526	0.758	0.963	0.963	0.963	--	--
TKN	No Standard	SC791	--	mg/L	8	0.558	0.569	0.591	0.677	0.799	0.799	--	--
TN	No Standard	SC136	--	mg/L	2	2.546					3.91	--	--
TN	No Standard	SC587	--	mg/L	2	2.828					3.55	--	--
TN	No Standard	SC791	--	mg/L	7	2.70	3.18	3.28	3.70	4.19	4.19	--	--

* Water Temperature Standards Change by Month
** Water quality standard requires hardness correction; values listed is water quality standard calculated at 100 µg/L $CaCO_3$ hardness

Table 3-103 Schuylkill River at USGS 014745000 Fairmount Dam Summary Statistics and Exceedances 2003 - 2004

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles						No. Exceeding	% Exceeding
					0	25	50	75	90	100		
Alkalinity	Maximum	120	mg/L	16	42.0	59.5	65.0	74.5	78.0	80.0	0	0
Alkalinity	Minimum	20	mg/L	16	42.0	59.5	65.0	74.5	78.0	80.0	0	0
DO	Daily Average Minimum	3.5	mg/L	16	7.90	9.00	10.2	13.5	14.6	15.6	0	0
pH	Maximum	8.5	--	19	7.20	7.50	7.70	7.80	8.10	8.60	1	5.3
pH	Minimum	6.5	--	19	7.20	7.50	7.70	7.80	8.10	8.60	0	0
Temp	Maximum	*	°C	16	1.40	4.95	13.7	21.5	24.4	27.0	0	0

* Water Temperature Standards Change by Month

Discussion of Possible Problem Parameters

The following analysis of water quality data is focused on parameters that were listed in EPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow) in the Schuylkill River on Tables 3-102 through 3-105. The water quality criteria or target value is discussed in each parameter analysis. The data were compared to stream quality objectives (DRBC 2008A). This analysis was completed in order to provide an initial impression of which parameters might need further investigation.

pH

The pH standards within the Schuylkill River Watershed set by DRBC are constant throughout the monitoring area and are set at a maximum of 8.5 and a minimum of 6.5.

Exceedances of the maximum pH limit were observed during USGS (Table 3-103) and continuous PWD monitoring (Table 3-100). During continuous monitoring at the SC482, the maximum standard was exceeded less than 3.2% of the time. At all other sites, pH rarely exceeds the maximum limit. During the USGS monitoring the maximum standard for pH was exceeded 5.3% of the time. pH is considered a parameter of potential concern in the Schuylkill River.

Dissolved Oxygen

The DRBC has set minimum DO daily averages as well as minimum seasonal averages for this watershed. DRBC water quality criteria require a daily average minimum DO concentration of 3.5 mg/L. The DRBC seasonal standard requires a minimum seasonal average of 6.5 mg/L between April 1 thru June 15 and September 16 thru December 31.

The daily minimum DO standard was exceeded during continuous monitoring (Table 3-100) at SC482 (2.2% of observations). At other sites, no violations were observed. Therefore, DO is not a concern in the Schuylkill River.

Future Investigation of Dissolved Oxygen Conditions in the Tidal Schuylkill River

Investigations continue into the nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the tidal Schuylkill River. The nature, causes and severity are not well understood at this juncture. Efforts to better understand the dissolved oxygen conditions will continue through evaluation of ongoing continuous long-term monitoring. PWD continues to work with the Delaware River Basin Commission and its partners on issues related to the dissolved oxygen conditions in the Delaware estuary and its tidal tributaries. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City, from other dischargers to the tributaries that run through the City, and at the fall-line of the River. If a relationship between loadings and the dissolved oxygen conditions in the tidal River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all potential sources of the identified water quality constituents to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to thePADEP.

Total Dissolved Solids
Total Dissolved Solids (TDS) were not included in the wet weather and dry weather sampling in the Schuylkill River. DRBC standards state that TDS should not exceed 133% of background levels or 500 mg/L (whichever is less) in Zone 2 and 3; and 133% of background levels in Zone 4.

Total Suspended Solids
Like TDS, Total Suspended Solids (TSS) were not included in the wet weather and dry weather sampling in the Schuylkill River. DRBC requires that wastewater treatment projects maintain minimum levels of treatment using "Best Demonstrable Technology" that includes 30-day average TSS levels at or below 10 mg/L.

Nutrients
Discrete samples of nutrients were collected and analyzed by PWD from 2005-2007. Tables 3-101 and 3-102 document concentrations found in both wet and dry weather conditions. DRBC has not set water quality standards for Zone 4, which includes the tidal portions of the Schuylkill River. Therefore, collected data could not be compared to a target value.

Ammonia
Ammonia, present in surface waters as un-ionized ammonia gas (NH3), or as ammonium ion (NH4+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH3, although at the expense of increased NO3 concentration

NH3 concentrations observed during dry weather (Table 3-101) ranged from 0.101 mg/L at SC791 to 0.350 mg/L at stations SC136 and SC587. During wet weather events (Table 3-102), samples ranged from 0.105 mg/L at SC791 to 0.246 mg/L at SC136.

Total Nitrogen
PWD sampled for Total Nitrogen (TN) in the Schuylkill River from 2005 to 2007. TN dry weather samples (Table 3-101) ranged from 3.07 mg/L at SC136 to 4.37 mg/L at SC791. During wet weather events (Table 3-102), samples ranged from 2.55 mg/L at SC136 to 4.19 mg/L at SC791.

Total Kjeldahl Nitrogen
TKN dry weather samples (Table 3-101) ranged from 0.441 mg/L at SC791 to 1.14 mg/L at SC791. During wet weather events (Table 3-102), samples ranged from 0.562 mg/L at SC136 to 1.01 mg/L at SC136.

Toxic Metals
It is now widely accepted that dissolved metals best reflect the potential for toxicity to organisms in the water column, and many states, including PA, have adopted dissolved metals criteria (40 CFR 22227-22236). As many metals occur naturally in various rocks, minerals, and soils, storm events can expose and entrain soil and sediment particles that naturally contain metals. These inert particles are removed when samples are filtered for dissolved metals analysis (Greenberg *et al.* 1992).

Dissolved Zinc

Since the water quality criteria for dissolved zinc requires a hardness correction the standard was calculated at 100 µg/L $CaCO_3$ hardness. With hardness correction, the Aquatic Life Acute Maximum for Dissolved Zn is 117 µg/L and the Aquatic Life Chronic Maximum is 106 µg/L. Toxicity limits for Fish Ingestion Only (FIO) are a maximum of 68700 µg/L; and for Fish and Water Ingestion (FWI) a maximum of 9110. µg/L.

Dissolved Zn ranged from 5.00 µg/L at SC136 to 14.0 µg/L at SC791 during dry weather (Table 3-101). Wet weather samples (Table 3-102) were slightly elevated, ranging from 7.00 µg/L at SC587 to 27.0 µg/L at SC136, although PA water quality standards were never exceeded during sampling. Dissolved Zn is not considered a parameter of concern in the Schuylkill River. Wet weather sampling and flow are shown in Figures 3-101 through 3-111.

Dissolved Copper

Since the water quality criteria for dissolved Cu requires a hardness correction, the standard was calculated at 100 µg/L $CaCO_3$ hardness. With hardness correction, the Aquatic Life Acute Maximum for dissolved Cu is 18 µg/L and the Aquatic Life Chronic Maximum is 12 µg/L. Dissolved Cu ranged from 2.00 at SC136 to 7.00 at all sites during dry weather (Table 3-101). Wet weather samples (Table 3-102) ranged from 3.00 µg/L at sites SC136 and SC791 to 10.0 µg/L at SC791 (Figures 3-101 through 3-111). The standards were never exceeded during sampling and therefore dissolved Cu is not considered a parameter of concern in the Schuylkill River.

Fecal Coliform

DRBC has set maximum fecal coliform concentrations for this watershed. Within Zone 4, the fecal coliform limit is broken down by R.M., such that, below R.M. 81.8 the limit is 200 per 100mL and above R.M. 81.8 the limit is 770 per 100 mL. All monitoring sites in the tidal Schuylkill are subjected to a maximum fecal coliform limit of 770 per 100 mL. Water quality sampling from the USGS station upstream of the Fairmount Dam was also analyzed due to the lack of samples in the tidal portion. Water quality sampling performed by PWD in the tidal areas from 2005 through 2007 captured 10 quality samples. This monitoring in the tidal portion of the Schuylkill River does not show any exceedance of the DRBC criteria. Additional monitoring data at the USGS monitoring station at the Fairmount Dam is subjected to the PADEP water quality criteria but was compared against the DRBC criteria for this study in order to characterize the quality of the water entering the tidal area. River conditions and access on the tidal portion of the river make it difficult to obtain water quality samples during wet weather and can account for the lack of fecal coliform samples not exceeding the standard.

Figure 3-100 is a summary of fecal coliform in the Schuylkill River following rainfall events from a study performed in the 1990's. The figure suggests that after approximately 2 days, fecal coliform measurements fall below the DRBC standard of 770 per 100 mL. Figures 3-101 through 3-111 show fecal coliform concentrations in response to rainfall during wet weather events at all sampling locations, and show that concentrations are below the DRBC standard 2 to 3 days following rainfall.

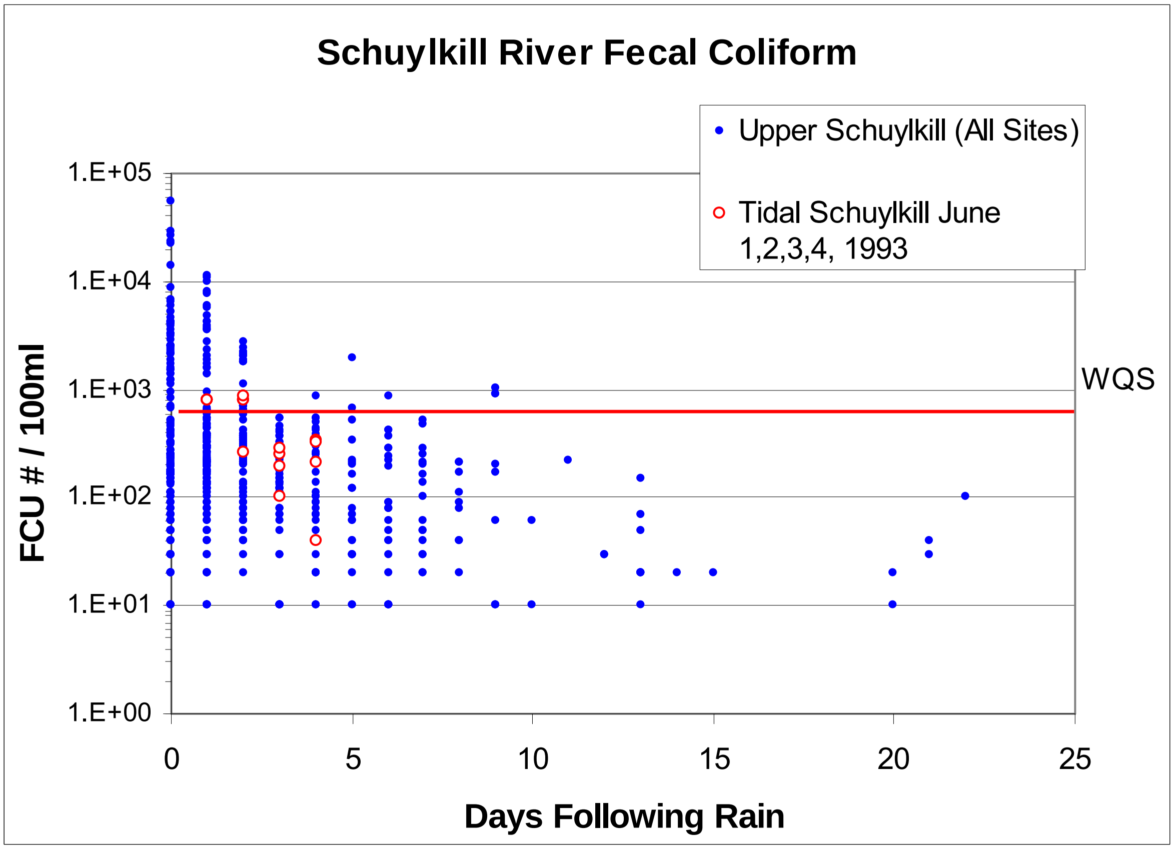


Figure 3-102 Fecal Coliform in Schuylkill River following rainfall events.

Future Investigation of Bacteria Conditions in the Tidal Schuylkill River

Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the tidal Schuylkill River. Efforts to better understand the bacteria conditions will continue through evaluation of ongoing monitoring efforts, and the establishment of additional monitoring efforts if necessary to better define potential problems. PWD will work with the Delaware River Basin Commission and its partners on issues related to the bacteria conditions in the estuary if such efforts are initiated by DRBC. Estimates will be refined and analyses performed on the loading of bacteria, both from the City as well as from other dischargers to the tributaries to the Schuylkill River that run through the City. If a relationship between loadings and the bacteria conditions in the tidal River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all identified sources that discharge to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

The DRBC has a maximum value which changes by month within the monitoring area. The temperature standard was exceeded at all continuously monitored sites (Table 3-100). At site SC823, maximum limits were exceeded in 46% of all observations and at site SC482, limits were exceeds in 18% of observation. At all discrete sampling sites, greater than 10% of observations violated temperature limits during both dry and wet weather. Temperature is therefore considered to be a parameter of concern for the Schuylkill River.

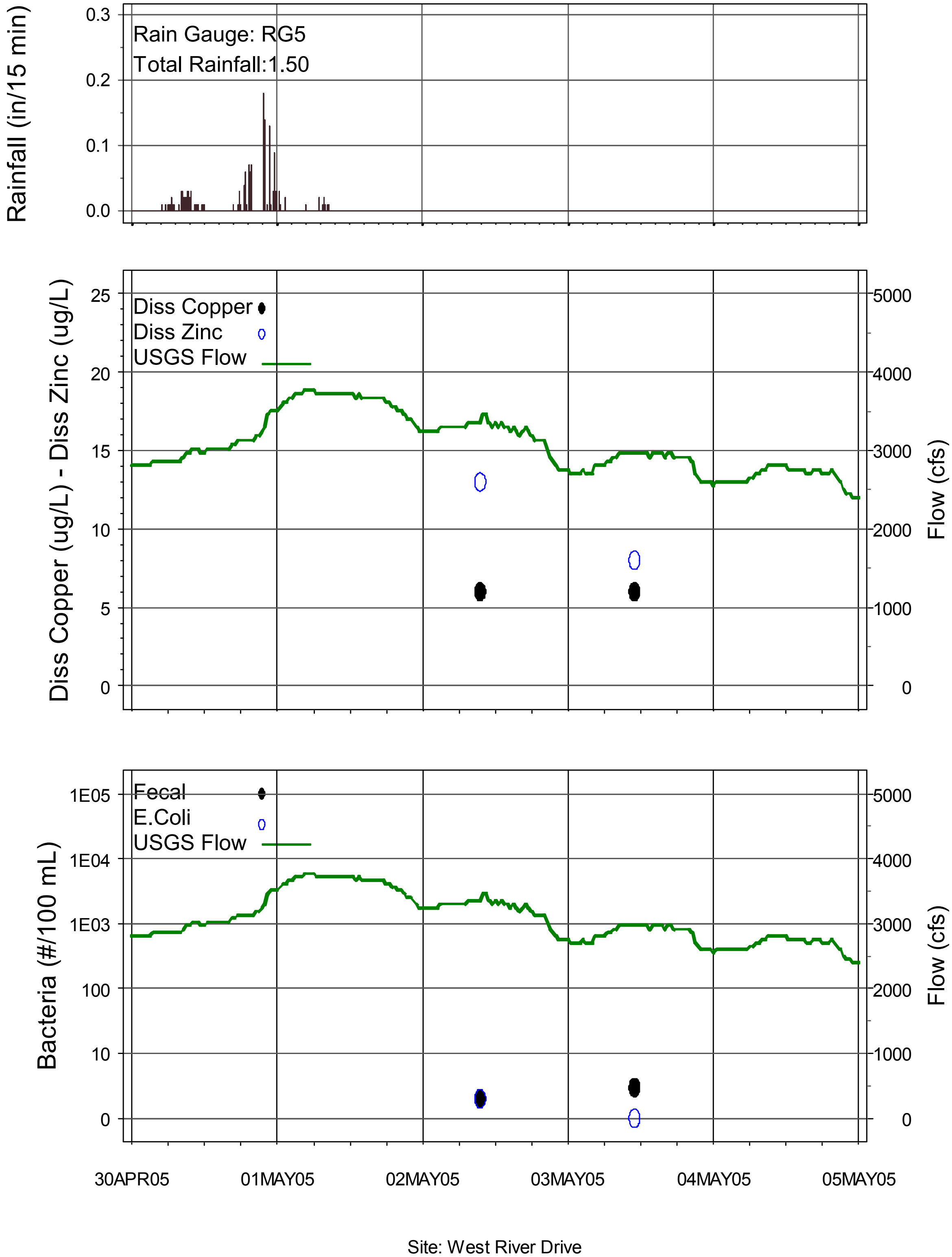


Figure 3-103 Bacteria and Dissolved Metals wet weather event on April 30, 2005 at SC791

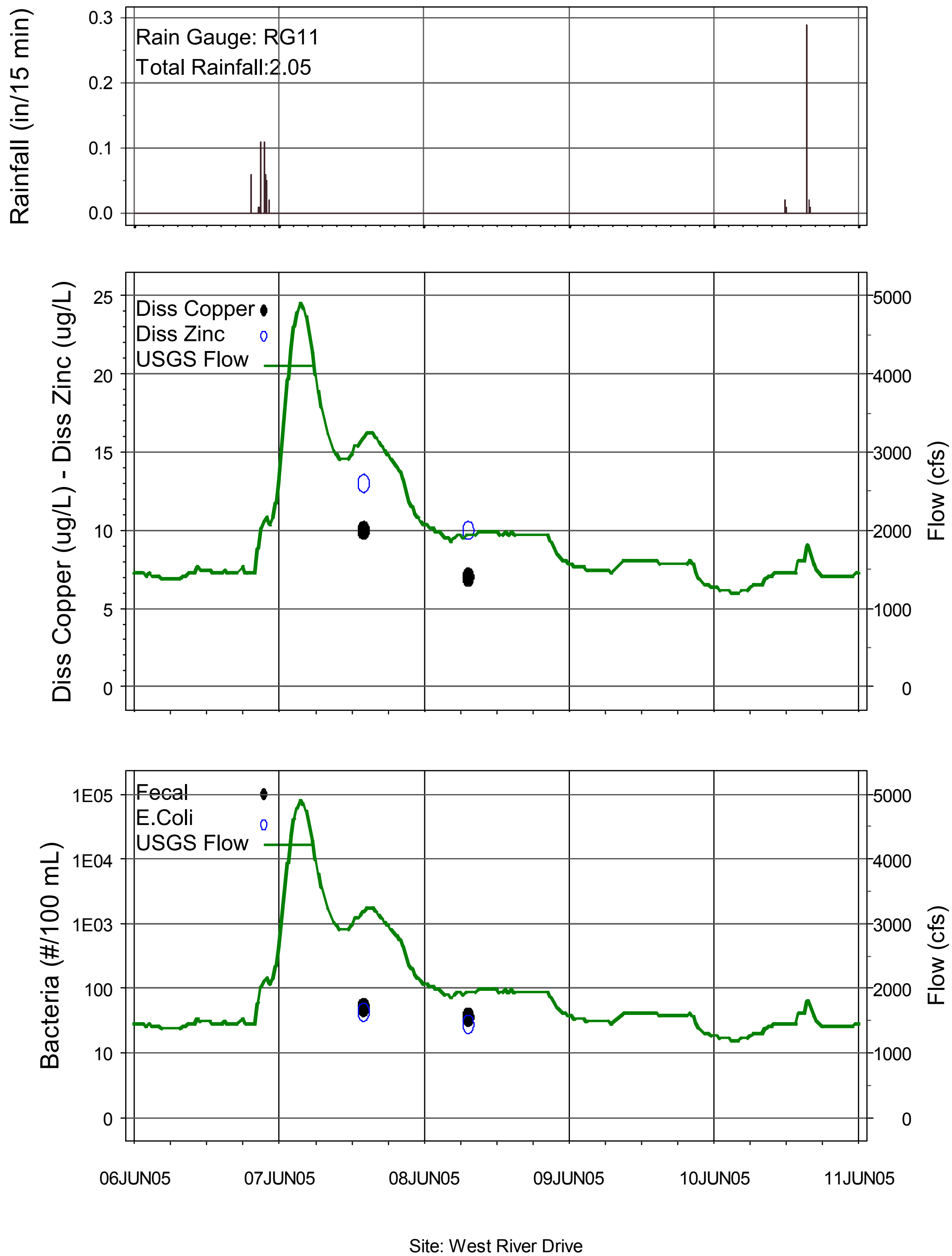


Figure 3-104 Bacteria and Dissolved Metals wet weather event on June 6, 2005 at SC791

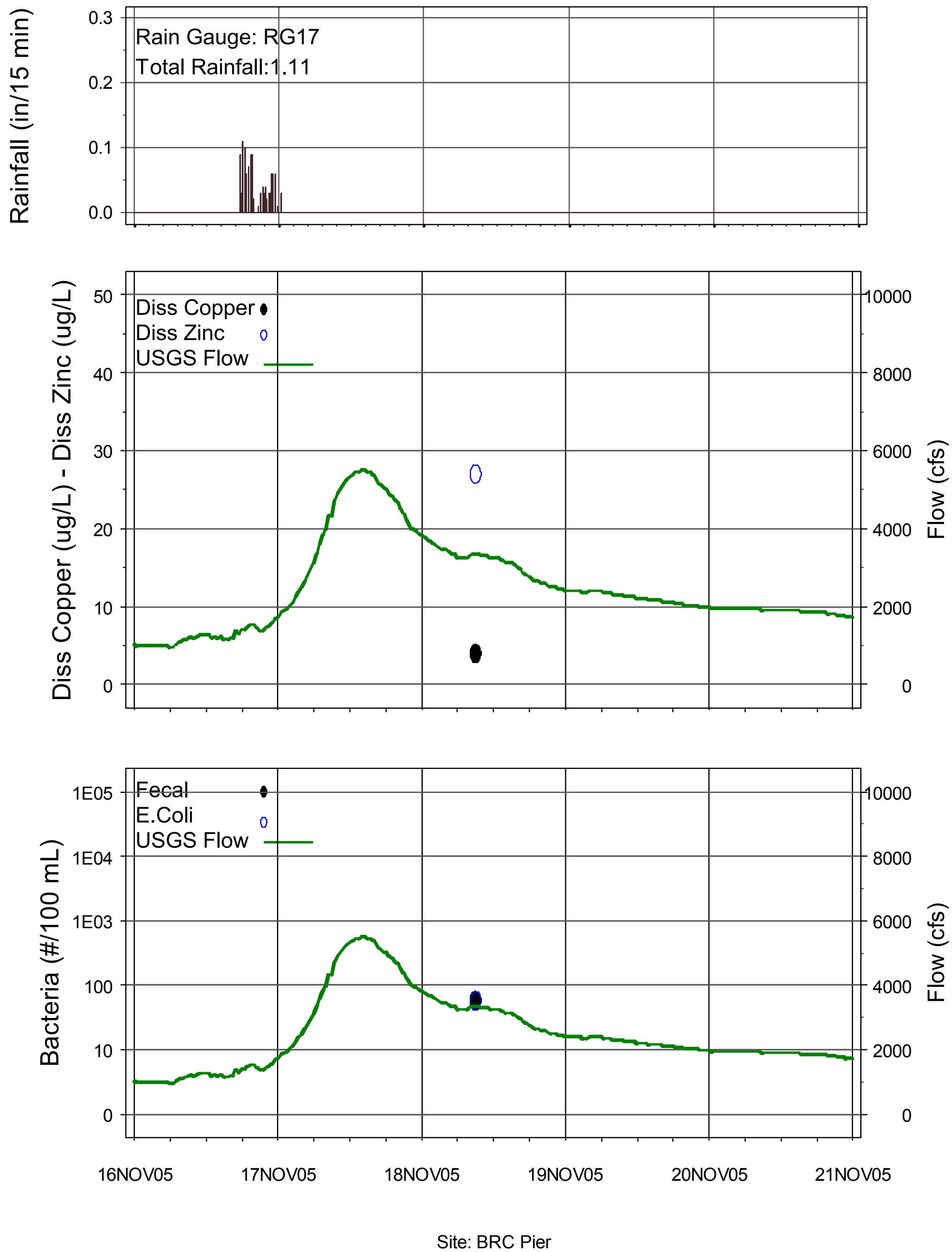


Figure 3-105 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC136

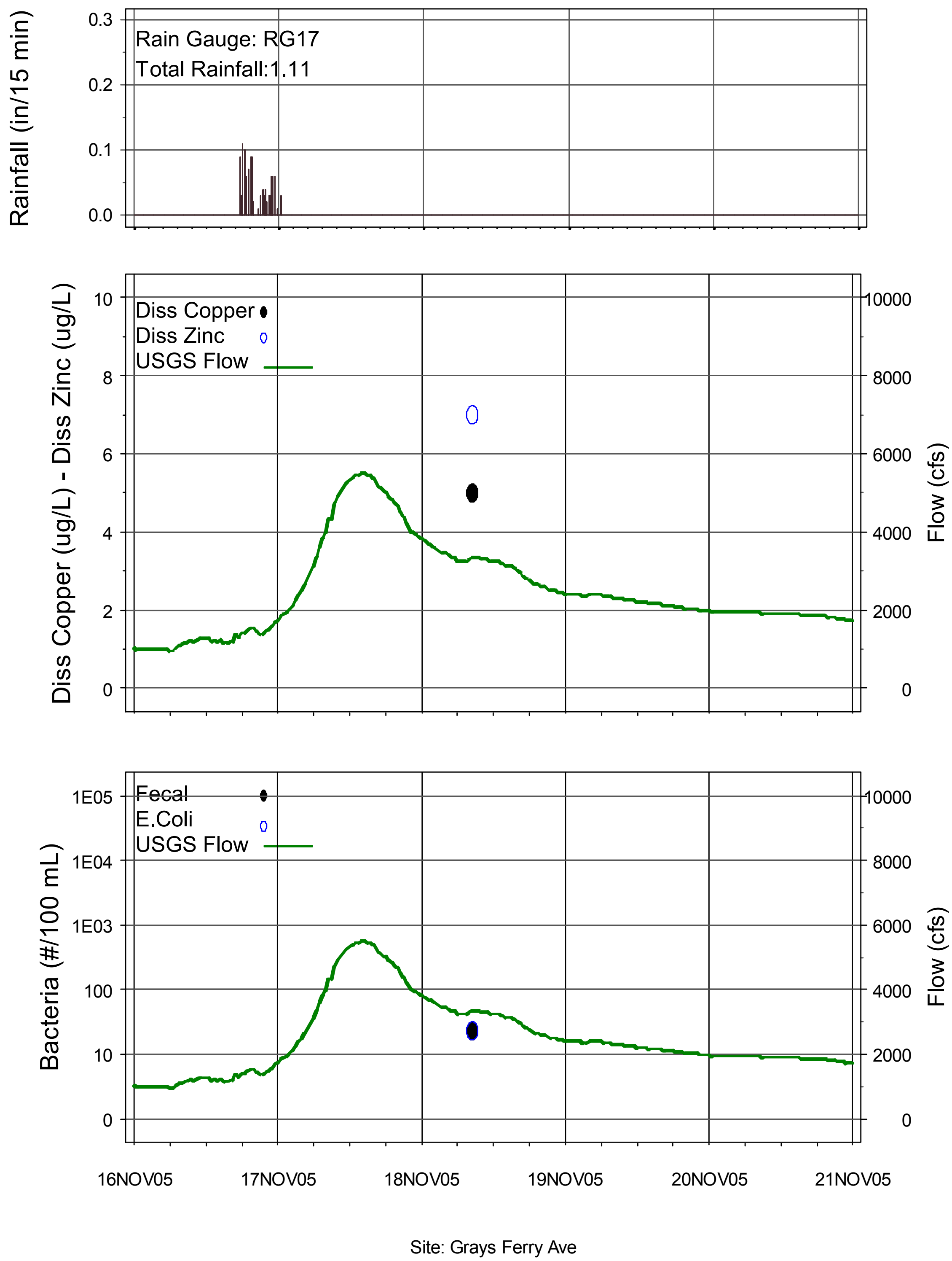


Figure 3-106 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC587

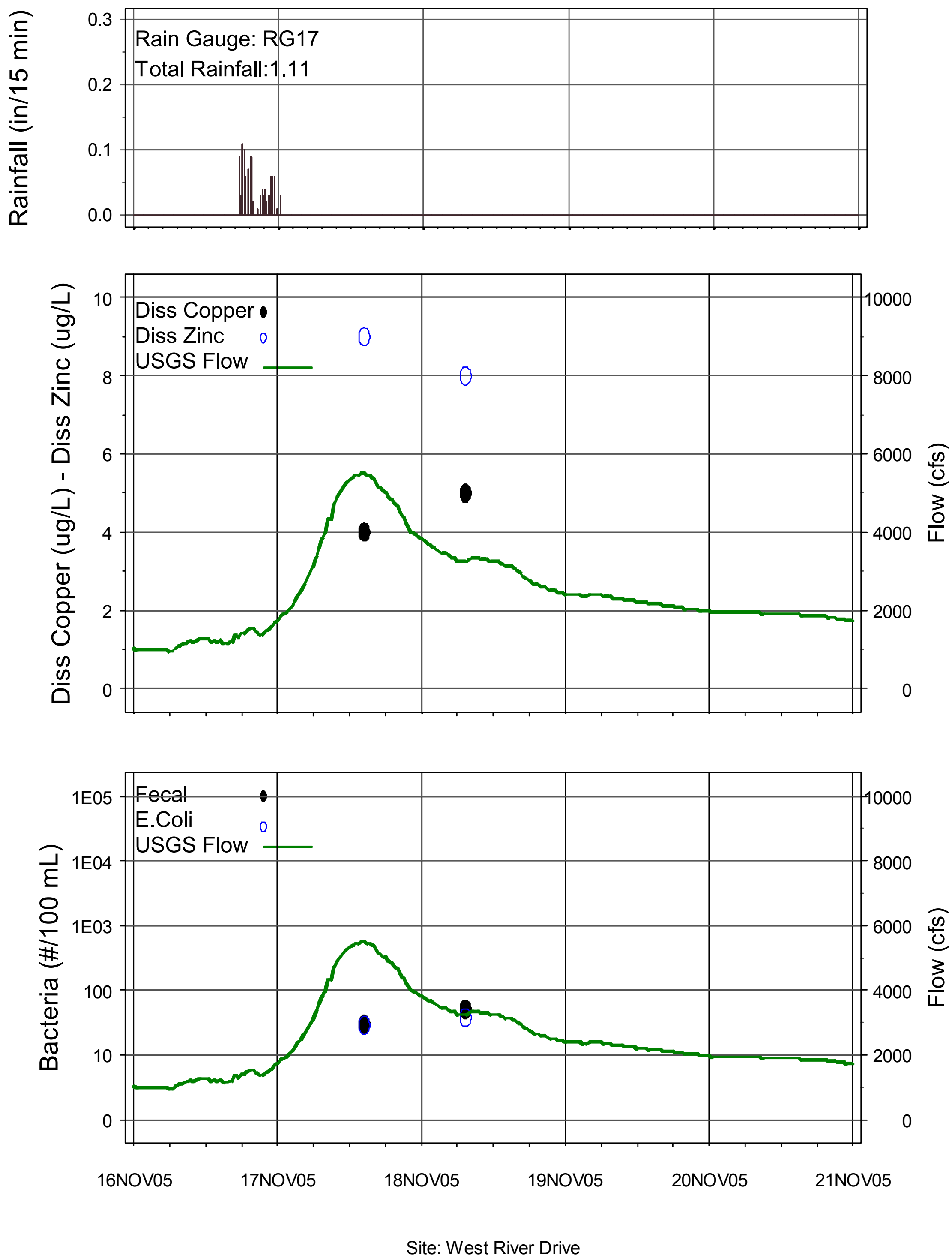


Figure 3-107 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC791

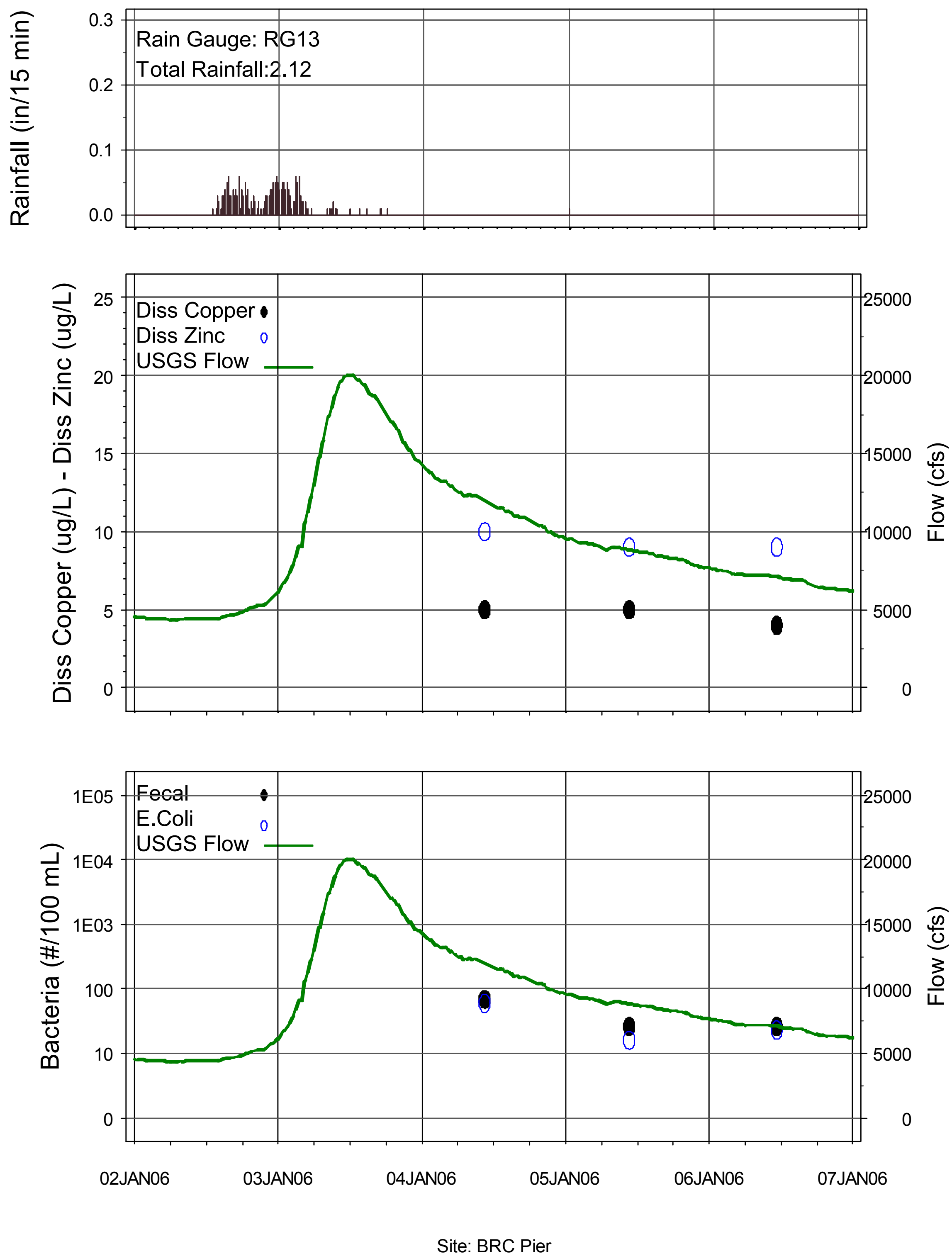


Figure 3-108 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC136

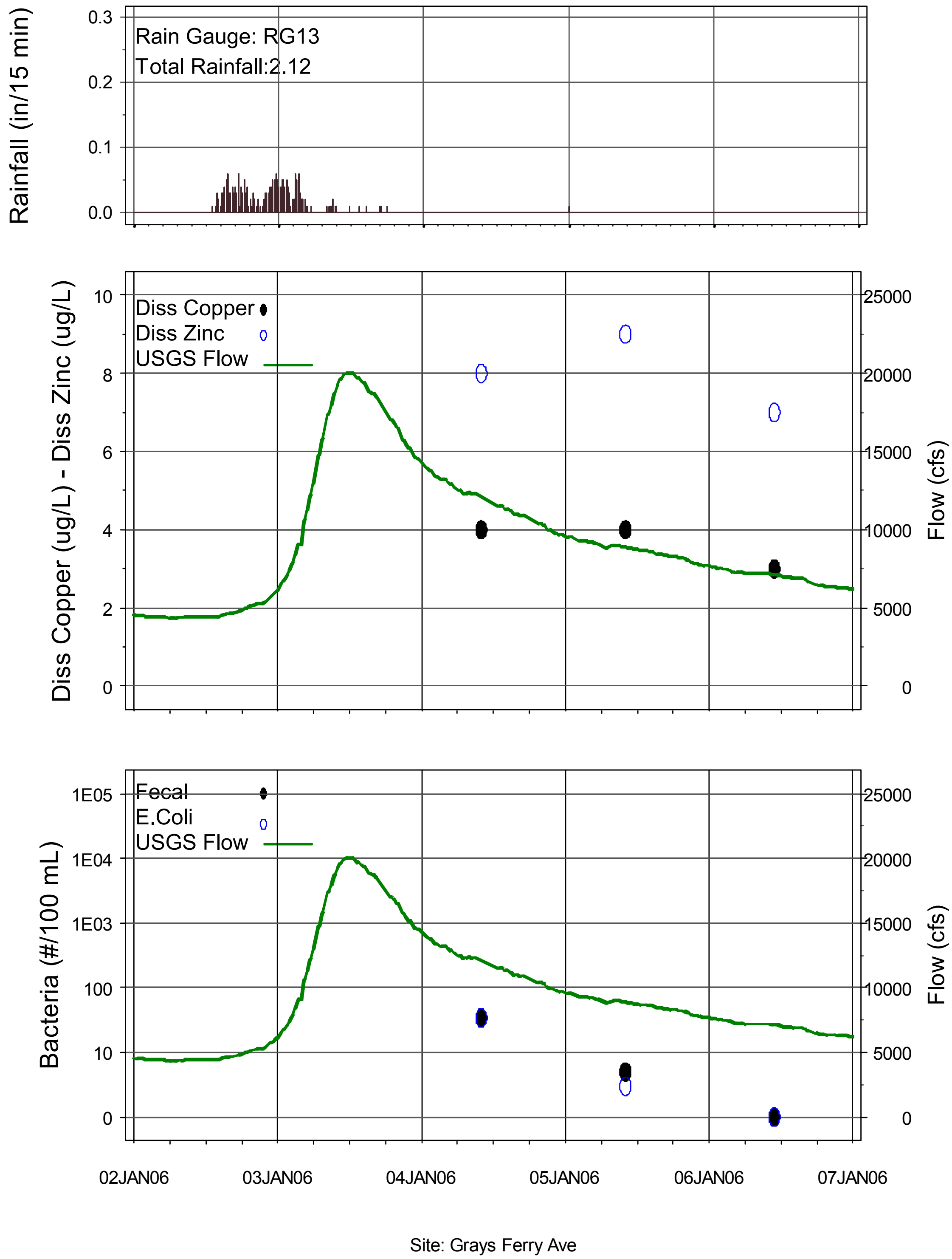


Figure 3-109 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC587

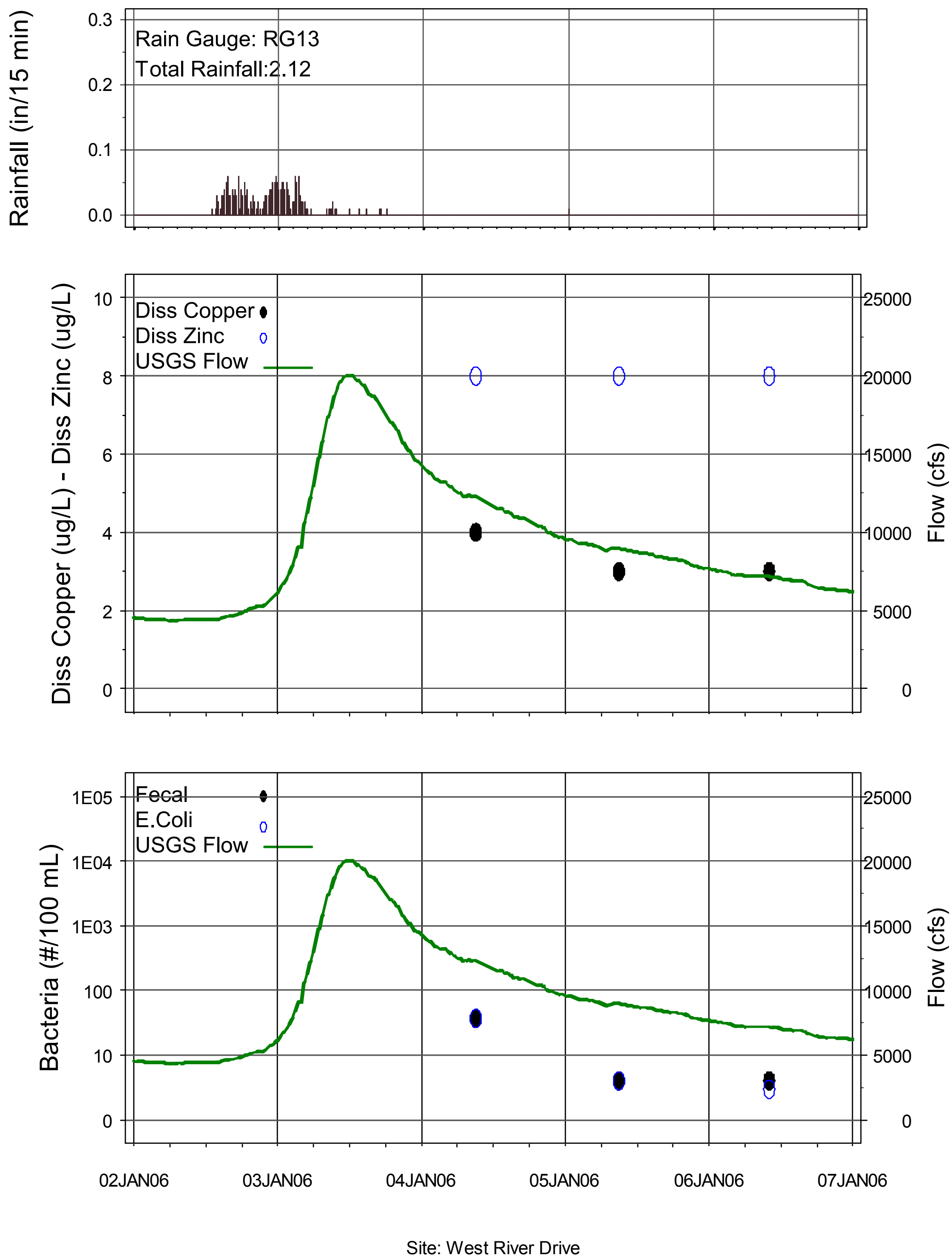


Figure 3-110 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC791

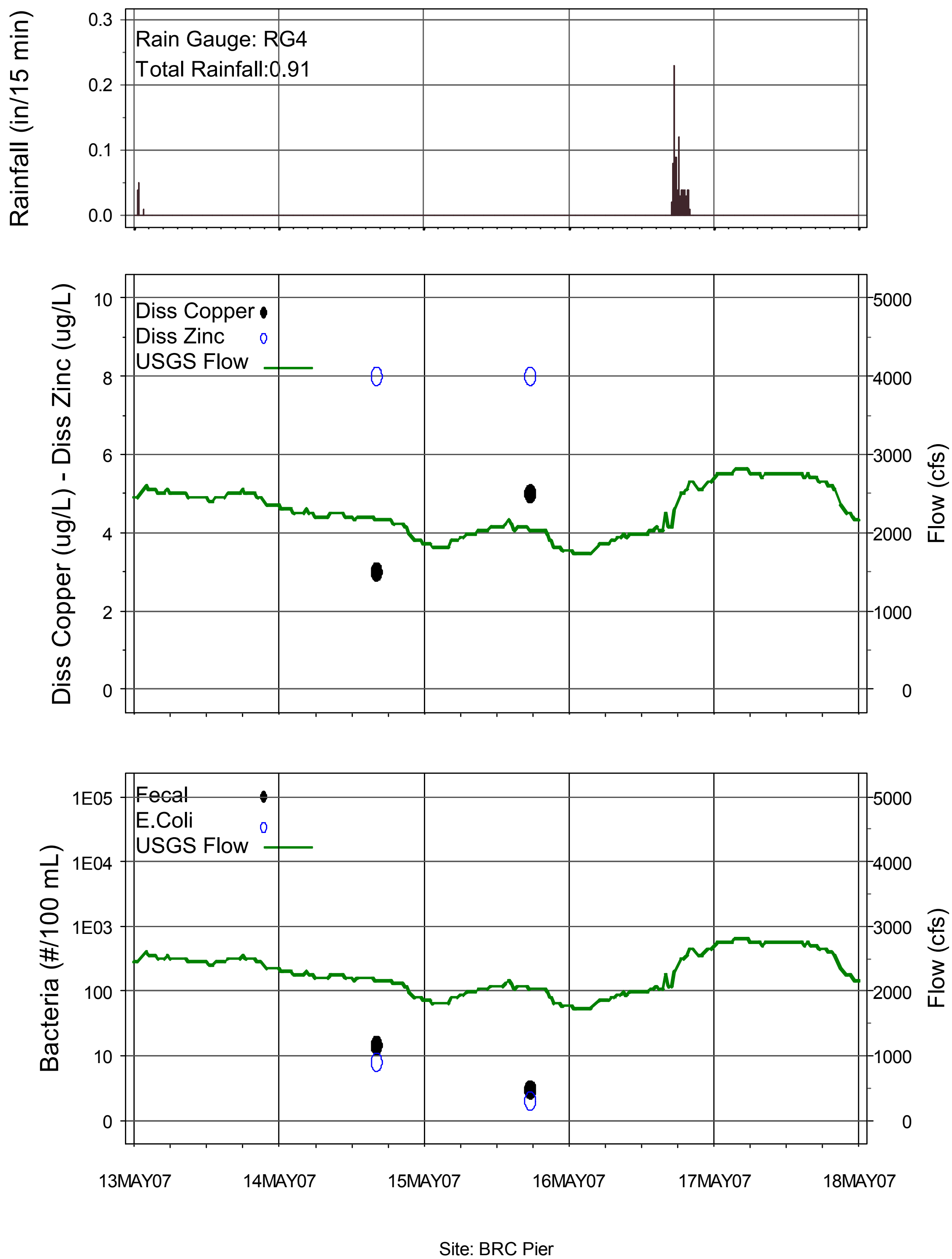


Figure 3-111 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC136

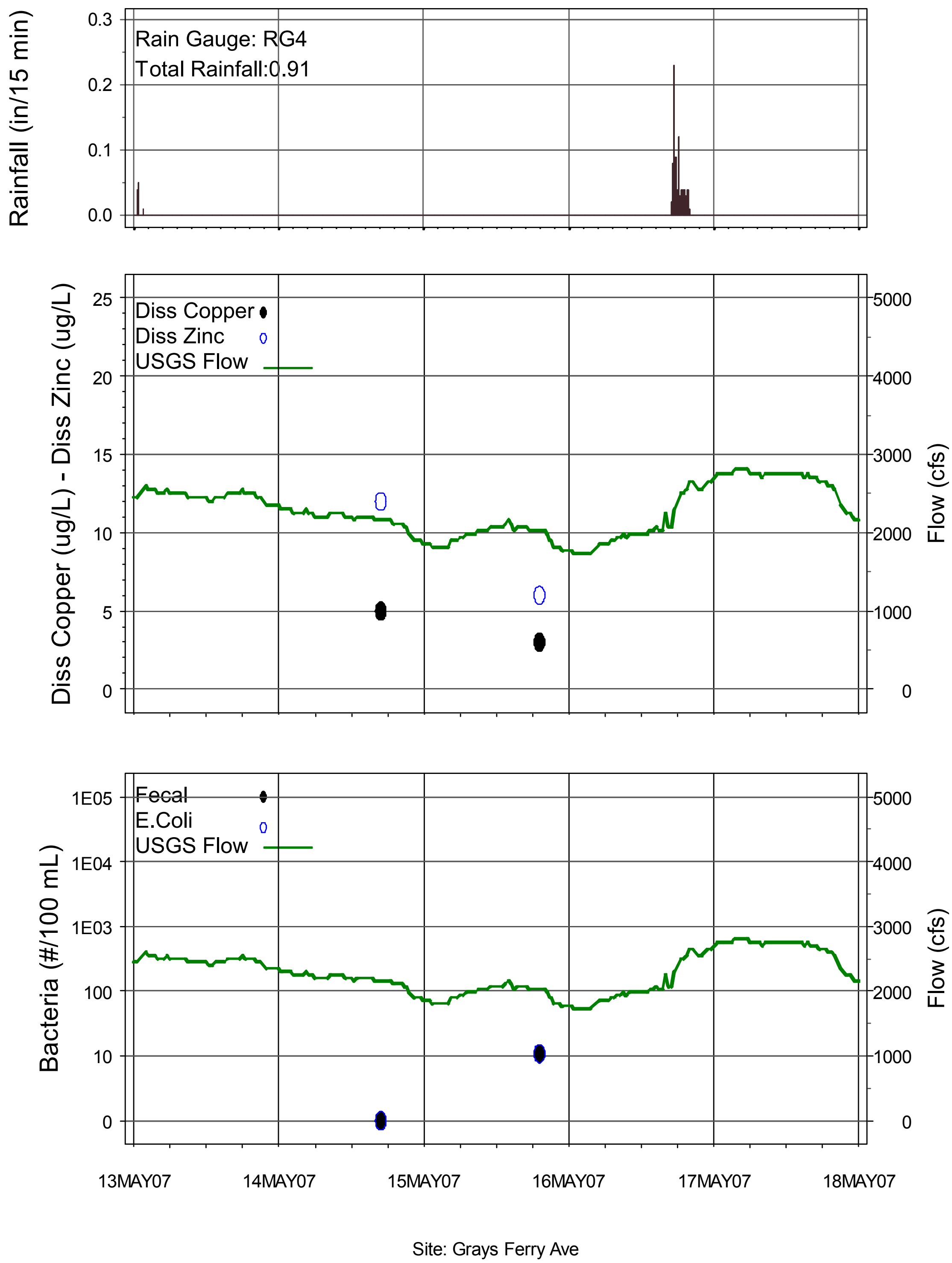


Figure 3-112 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC587

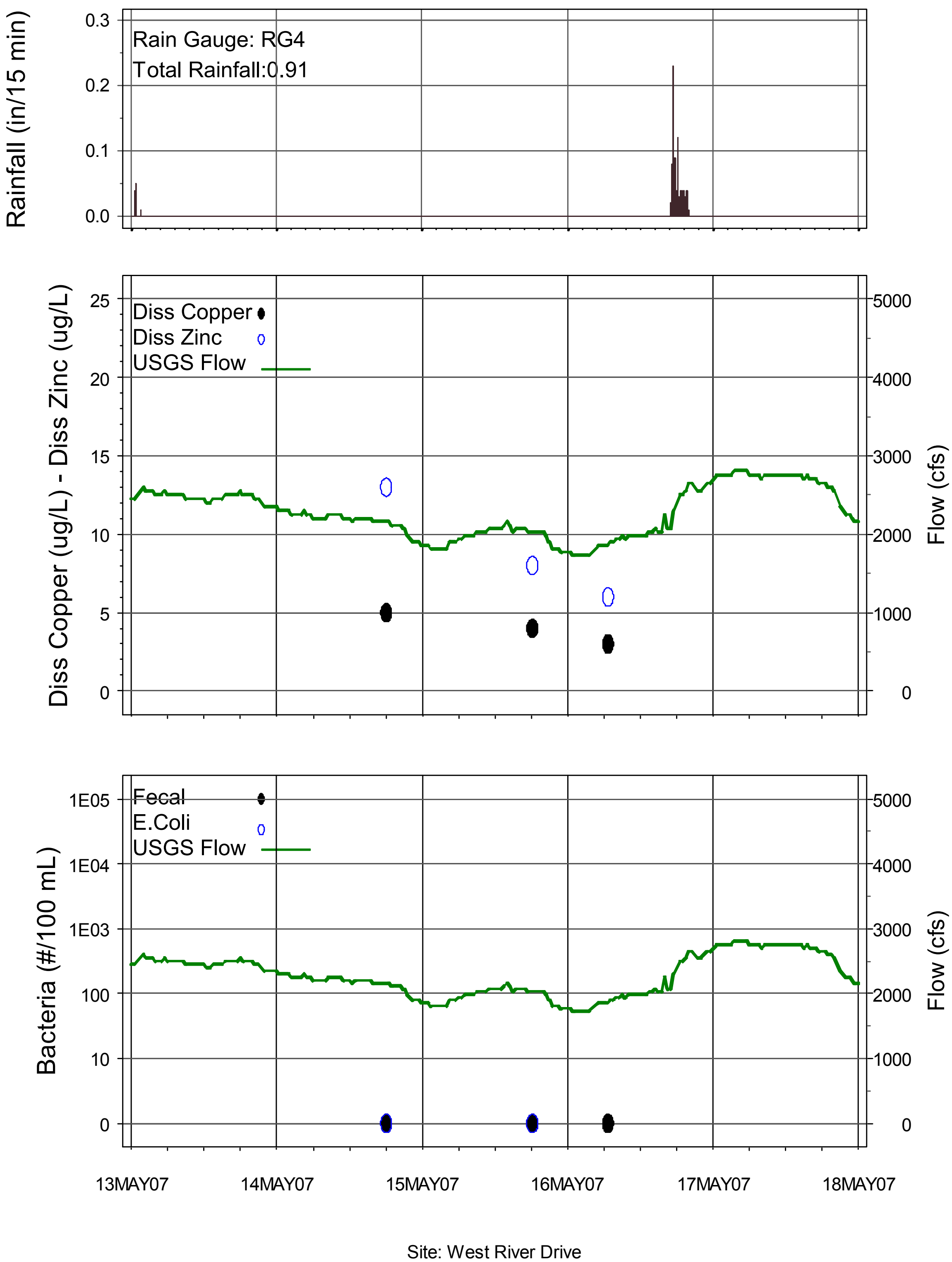


Figure 3-113 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC791

3.4.2.4.3 Biological Assessment of the Schuylkill River

Benthic Assessment

The Partnership for the Delaware Estuary (PDE) is currently leading the Delaware Estuary Benthic Inventory Program (DEBI) due to an expressed need in "*White Paper on the Status and Needs of Science in the Delaware Estuary*" (Kreeger, et al 2006). The Benthos community is expected to differ in the Delaware and Schuylkill Rivers from other non-tidal streams. Previously, no reference site was available to study benthos in the tidal streams in Philadelphia. The Delaware Direct IWMP will summarize the findings of DEBI in the Delaware Direct Watershed to help guide watershed management and restoration for both the Schuylkill and Delaware Rivers.

Fish Assessment

Between 2002 and 2006, PWD directed its monitoring efforts above and below the Fairmount Dam fishway (Perillo and Butler, 2009). Electrofishing surveys were conducted three to four times per month from April 1st to July 1st, between 2002 and 2006. A video monitoring program was established in 2003 to assess fish passage at the Fairmount Dam fishway and determine temporal variability of fish assemblages inhabiting the lower Schuylkill River. All fish captured on video were identified to species, time stamped (*i.e.*, h:m:s) and dispersal direction (*i.e.*, upstream vs. downstream) was recorded.

Table 3-104 summarizes fish collection results during electrofishing surveys from 2002 to 2006. In 2002, a total of 1728 fish representing 23 species were collected during spring sampling events (Table 3-105). Species diversity was greatest in 2002 (*H'=2.38*) and a more evenly distributed fish assemblage (E=0.68) was represented when compared to all of the sampling years (*i.e.*, 2003-2006). Table 3-106 summarizes the fish passage observed through video monitoring from 2004 to 2006. During this three-year study, a total of twenty-six species of fish, as well as several hybrid species, were documented using the fishway during spring migrations. Anadromous fishes such as American shad, hickory shad, striped bass, and river herring frequently utilized the fishway for passage above the dam, and the presence of juvenile alewife upstream of the fishway in 2005-2006 suggests that quality spawning and nursery habitats still exist above Fairmount Dam. Moreover, fish passage counts for adult American shad show a discernable increase during the three-year period and although the numbers are significantly lower than historical records, fish surveys below Fairmount Dam indicate increasing trends in fish density during spring migrations.

Repairs and improvements to the Fairmount Dam fishway were completed in 2009. The slots between the chambers of the fishway have been widened, the flow through the chambers has been modified, and the entrance and exit channels have been redesigned. The improvements were made to increase the variety of species and the numbers of fish using the fishway. PWD will continue to monitor fish in the tidal Schuylkill River and passage through the Fairmount Dam fishway. The results will be incorporated into long-term CSO program planning and the Schuylkill River IWMP.

Table 3-104 Fish collection counts by species below the Fairmount Dam, Schuylkill River, during spring monitoring, 2002-2006

Species		2002		2003		2004		2005		2006	
Scientifc Name	Common Name	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)
Alosa mediocris	Hickory shad	0	0.0	0	0.0	4	0.2	120	4.2	51	1.0
Alosa sapidissima	American shad	63	3.6	535	32.0	470	26.6	1047	36.2	1950	38.0
*Alosa. sp**	Herring*	97	5.6	173	10.3	261	14.8	12	0.4	1215	23.7
Ambloplites rupestris	Rock bass	0	0.0	1	0.1	0	0.0	1	0.0	0	0.0
Anchoa mitchilli	bay anchovy	3	0.2	0	0.0	0	0.0	0	0.0	1	0.0
Anguilla rostrata	American eel	35	2.0	26	1.6	39	2.2	65	2.2	40	0.8
Catostomus commersoni	White sucker	107	6.2	44	2.6	56	3.2	193	6.7	67	1.3
Carassius auratus	goldfish	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Carpiodes cyprinus	Quillback	204	11.8	226	13.5	145	8.2	310	10.7	337	6.6
Cyprinella spiloptera	Spotfin shiner	0	0.0	0	0.0	0	0.0	0	0.0	5	0.1
Cyprinus carpio	Common carp	189	10.9	26	1.6	221	12.5	237	8.2	306	6.0
Dorosoma cepedianum	Gizzard shad	425	24.6	485	29.0	387	21.9	275	9.5	592	11.5
Esox lucius x Esox masquinongy	Tiger muskellunge	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Hybognathus regius	Eastern silvery minn	13	0.8	0	0.0	0	0.0	0	0.0	0	0.0
Ictalurus punctatus	Channel catfish	146	8.4	48	2.9	37	2.1	134	4.6	178	3.5
Lepomis auritus	Redbreast sunfish	3	0.2	3	0.2	6	0.3	1	0.0	3	0.1
Lepomis gibbosus	Pumpkinseed sunfis	4	0.2	5	0.3	7	0.4	4	0.1	1	0.0
Lepomis macrochirus	Bluegill sunfish	6	0.3	3	0.2	3	0.2	4	0.1	11	0.2
*Lepomis sp***	Lepomis sp**	144	8.3	0	0.0	1	0.1	5	0.2	13	0.3
Menidia beryllina	inland silverside	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Micropterus dolomieui	Smallmouth bass	74	4.3	19	1.1	7	0.4	15	0.5	67	1.3
Micropterus salmoides	Largemouth bass	21	1.2	28	1.7	5	0.3	16	0.6	37	0.7
Morone americana	White perch	8	0.5	2	0.1	0	0.0	197	6.8	42	0.8
Morone saxatilis	Striped bass	166	9.6	40	2.4	102	5.8	153	5.3	127	2.5
Morone saxatilis x Morone chryso	Hybrid striped bass	0	0.0	0	0.0	1	0.1	14	0.5	4	0.1
Notropis amoenus	Comely shiner	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
Notropis hudsonius	Spottail shiner	0	0.0	0	0.0	0	0.0	2	0.1	1	0.0
Oncorhynchus mykiss	Rainbow trout	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0
Perca flavesins	Yellow perch	7	0.4	3	0.2	3	0.2	14	0.5	22	0.4
Pomoxis nigromaculatus	Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pylodictis olivaris	Flathead catfish	0	0.0	0	0.0	0	0.0	0	0.0	3	0.1
Salmo trutta	Brown trout	3	0.2	1	0.1	1	0.1	1	0.0	0	0.0
Sander vitreus	Walleye	8	0.5	6	0.4	7	0.4	69	2.4	58	1.1

**Alosa sp.* include both *A. aestivalis* and *A. pseudoharengus*.
***Lepomis sp.* include all sunfish that were not identified to species.

Table 3-105 Fish community metrics for electrofishing surveys below Fairmount Dam, Schuylkill River, during spring migration (2002-2006)

Metrics	Year				
	2002	2003	2004	2005	2006
Total (N)	1728	1674	1764	2890	5133
Species Richness	23	19	21	24	26
Shannon Index (H')	2.39	1.85	2.03	2.18	1.92
Evenness (E)	0.68	0.53	0.58	0.62	0.55

Table 3-106 Fish passage counts by species at the Fairmount Dam Fishway, Schuylkill River, Pennsylvania, during spring monitoring. Species status codes are as follows: NA = native anadromous; NC = native catadromous; NR = native resident; IR = introduced resident; and I = introduced.

Scientific Name	Common Name	Status	2004[a] Number Passed	2005[b] Number Passed	2006[c] Number Passed
Alosa mediocris	hickory shad	NA	0	0	9
Alosa sapidissima	American shad	NA	91	41	345
Ameiurus catus	white catfish	NR	6	1	6
Ameiurus spp.	bullhead catfish	NR	0	0	2
Ambloplites rupestris	rock bass	IR	0	1	0
Anguilla rostrata	American eel	NC	32	70	34
Catostomus commersoni	white sucker	NR	731	1767	2887
Carpiodes cyprinus	quillback	NR	1807	2042	2631
Ctenopharyngodon idella	grass carp	I	2	0	1
Cyprinella analostana	satinfin shiner	NR	0	2	0
Cyprinus carpio	common carp	IR	401	1197	2215
Dorosoma cepedianum	gizzard shad	NR	691	553	2899
Ictalurus punctatus	channel catfish	IR	1816	1663	3421
Lepomis auritus	redbreast sunfish	NR	13	3	4
Lepomis gibbosus	pumpkinseed sunfish	NR	0	7	1
Lepomis macrochirus	bluegill sunfish	IR	22	147	276
Lepomis species	unknown sunfish		72	10	2
Micropterus dolomieui	smallmouth bass	IR	143	124	1225
Micropterus salmoides	largemouth bass	IR	11	10	42
Morone americana	white perch	NR	55	105	112
Morone saxatilis	striped bass	NA	161	127	61
Morone saxatilis x Morone chrysops	hybrid striped bass	IR	20	16	48
Oncorhynchus mykiss	rainbow trout	I	7	13	16
Pylodictis olivaris	flathead catfish	IR	68	43	466
Alosa aestivalis or pseudoharengus	River Herring	NA	2	5	7
hybrid trout	hybrid trout	I	0	8	40
Salmo trutta	brown trout	I	4	7	5
Sander vitreus	walleye	IR	57	33	84
	unknown		172	14	11
	unknown catfish		12	0	0
	unknown minnow		3	7	0
	unknown shad		32	0	0
	unknown trout		7	1	0
TOTAL			6438	8017	16850

3.4.3 Sensitive Areas

In accordance with the National CSO Control Policy, PWD is required to give highest priority to controlling overflows to receiving waters considered sensitive areas. As part of developing the LTCPU, PWD performed an analysis to identify any sensitive water bodies and the CSO outfalls that discharge to them. This analysis has not identified any portions of CSO receiving waters that meet the definition of sensitive areas. According to the National CSO Control Policy, sensitive areas include:

- Outstanding National Resource Waters
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contact recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas
- Shellfish beds.

Outstanding National Resource Waters
No Outstanding National Resource Waters have been identified in areas impacted by Philadelphia's CSO outfalls.

National Marine Sanctuaries
No National Marine Sanctuaries have been identified in areas impacted by Philadelphia's CSO outfalls.

Waters with threatened or endangered species or their designated critical habitat
In Pennsylvania, four different agencies have the primary responsibility for administering the program for protection and management of threatened and endangered species and other species of special concern. The federal U.S. Fish and Wildlife Service is responsible for federally listed, proposed and candidate species under the Federal Endangered Species Act. The Pennsylvania Fish and Boat Commission are responsible for fish, reptiles, amphibians, and aquatic organisms. The Pennsylvania Game Commission is responsible for wild birds and mammals. The Department of Conservation and Natural Resources is responsible for preserving the Commonwealth's native wild plants, terrestrial invertebrates, significant natural communities and geologic features.

Two endangered species and two threatened species known to occur in the Delaware River basin (Pennsylvania or New Jersey) are listed under the Federal Endangered Species Act.

Shortnose Sturgeon, Acipenser brevirostrum (endangered)
The shortnose sturgeon is found on the Atlantic Coast of North America where its range extends from the Saint John River, New Brunswick, to the St. Johns River, Florida. The federal recovery plan (NMFS 1998) for the species identifies 19 distinct population segments, each defined as a river/estuarine system in which shortnose sturgeons have been captured in the generation time of the species (30 years). Although originally listed as endangered rangewide, the NMFS recognizes 19 distinct population segments occurring in New Brunswick, Canada (1), Maine (2), Massachusetts (1), Connecticut (1), New York (1), New Jersey/Delaware (1), Maryland/Virginia (1), North Carolina (1), South Carolina (4), Georgia (4) and Florida (2). The population in the Delaware River in the early 1980s was estimated to be somewhere between 6,000 and 14,000 (NMFS, 1998).

Dwarf Wedgemussel, Alasmidonta heterodon (endangered)
This freshwater mussel has declined precipitously over the last hundred years. Once known from at least 70 locations in 15 major Atlantic slope drainages from New Brunswick to North Carolina, it is now known from only 20 localities in eight drainages. These localities are in New Hampshire, Vermont, Connecticut, New York, Maryland, Virginia, and North Carolina. The dwarf wedge mussel was listed as an endangered species in March of 1990 (U.S. Fish and Wildlife Service, 1993). Pennsylvania has proposed to change the status of the dwarf wedgemussel to extirpated.

Bald Eagle, Haliaeetus leucocephalus (threatened)
Federal status is categorized by state/region, rather than by subspecies. The bald eagle is listed as threatened in the coterminous U.S. It is not federally classified as endangered anywhere as of mid-1995 (USFWS, Federal Register, 12 July 1995). It was proposed for delisting July 6, 1999 (USFWS 1999). (Source: NatureServe, 2006) This species has been observed in the Philadelphia Naval Yard and in the John Heinz National Wildlife Refuge at Tinicum. The recovery of the species in recent decades, along with associated improvements in water quality in the Delaware River, suggests that this species will continue to recover as CSO controls are implemented.

Bog Turtle, Clemmys muhlenbergii (threatened)
The northern population of the bog turtle was listed as a threatened species on November 4, 1997. This population is currently known to occur in Connecticut (5 sites), Delaware (4), Maryland (71), Massachusetts (3), New Jersey (165), New York (37), and Pennsylvania (75). The bog turtle has experienced at least a 50 percent reduction in range and numbers over the past 20 years. The greatest threats to its survival include the loss, degradation, and fragmentation of its habitat, compounded by the take of long-lived adult animals from wild populations for illegal wildlife trade. Bog turtles usually occur in small, discrete populations, generally occupying open-canopy, herbaceous sedge meadows and fens bordered by wooded areas. The bog turtle is listed as extirpated in Philadelphia in the USFWS recovery plan (USFWS, 2001).

Additional information on threatened and endangered species that may be present in CSO receiving waters was collected from the Pennsylvania Natural Heritage Program (PNHP). PNHP is a partnership between the Department of Conservation and Natural Resources, the Nature Conservancy, Western Pennsylvania Conservancy, Pennsylvania Game Commission, Pennsylvania Fish and Boat Commission and the U.S. Fish and Wildlife Service. PNHP conducts inventories and collects data regarding the Commonwealth's native biological diversity. PNHP lists a number of species present in Philadelphia County that are considered endangered or threatened under the Pennsylvania Code, but not listed under the federal Endangered Species Act.

- American Bittern, Botaurus lentiginosus (endangered)
- Great Egret, Casmerodius albus (endangered)
- Banded Sunfish, Enneacanthus obesus (endangered)
- Threespine Stickleback, Gasterosteus aculeatus (endangered)*
- Peregrine Falcon, Falco peregrinus (endangered)**
- Least Bittern, Ixobrychus exilis (endangered)
- Tadpole Madtom, Noturus gyrinus (endangered)
- Black-crowned Night-heron, Nycticorax nycticorax (endangered)
- Coastal Plain Leopard Frog, Rana sphenocephala (endangered)
- Brook Floater, Alasmidonta varicosa (endangered)

- King Rail, Rallus elegans (endangered)
- Osprey, Pandion haliaetus (threatened)

* A subspecies of the threespine stickleback is listed as endangered under the federal Endangered Species Act in California.

** Eurasian subspecies PEREGRINUS is listed by USFWS as Endangered. Subspecies TUNDRIUS was delisted by USFWS in 1994. USFWS proposed removing all Endangered Species Act protections from all subspecies (including removing designation of endangered due to similarity of appearance for falcons with the 48 conterminous U.S.) (Federal Register 63:45446-45463, 26 August 1998). Subspecies ANATUM was formally removed from the U. S. federal list of endangered and threatened wildlife, along with the 'similarity of appearance' provision for free flying Peregrine Falcons in the conterminous U. S. (Federal Register, 25 August 1999)(NatureSource, 2006).

The literature reviews performed as part of this analysis have yielded no basis to infer that these species or their habitat are directly impacted or excluded by the discharge of stormwater runoff in the Philadelphia area. Absent any such direct evidence specific to Philadelphia's CSO receiving waters, it was not possible to identify any geographic subset of the receiving waters that can be specifically identified as meeting this definition of sensitive areas. Without a basis to prioritize one area over another, it is not possible to prioritize control scenarios geographically based on this definition of sensitive areas. However, the selection of CSO control alternatives that will evolve from the implementation of this Plan will reduce overflows of combined sewage to all receiving waters.

Primary contact recreation waters, such as bathing beaches
An annual triathlon, including a swimming component, is held in the nontidal portion of the Schuylkill River above Fairmount Dam. This area is upstream of PWD's CSO outfalls on the Schuylkill River. Occasional primary contact recreation occurs in Cobbs Creek and Tacony-Frankford Creek. These activities are physically unsafe in addition to exposing recreators to potentially unsafe levels of pathogens in wet weather. The City of Philadelphia is addressing these concerns through education, signage, and enforcement.

Public drinking water intakes or their designated protection areas
The Philadelphia Water Department operates two drinking water intakes on the Schuylkill River and one on the Delaware River. On both rivers, all CSOs are downstream of intakes. On the Schuylkill River, the Fairmount Dam prevents any movement of water and pollutants upstream to the water intakes. The closest CSO that discharges to the Delaware River is CSO D02, which is located approximately 2 miles downstream of the Baxter Intake. There are also 5 CSOs on the Pennypack Creek. The Pennypack Creek flows into the Delaware River approximately 0.7 miles downstream of the Baxter intake.

Shellfish beds
No shellfish beds have been identified in areas impacted by Philadelphia's CSO outfalls.

3.4.4 Pollutant Loads

3.4.4.1 Background and Methods

Estimating pollutant loads is a key step of a watershed approach to urban water resources planning and management. The analysis identifies sources of pollutants and their relative importance for a number of constituents that affect water quality. Pollutant loads contributed by CSOs are compared to upstream loads and to loads from separate storm sewer systems, for example. Loads of key constituents will be compared to observed water quality conditions to draw conclusions about the extent to which CSOs cause or contribute to observed impairments. Finally, this section defines baseline pollutant loads that future reductions can be measured against.

For the TTF and Cobbs Creek Watersheds, watershed-wide estimates of pollutant loads and their sources are presented in detail in the Comprehensive Characterization Report for each watershed. These results are summarized below. Estimated loads contributed by combined sewer overflows have been updated to reflect the representative year precipitation record and results of hydrologic/hydraulic computer modeling used in LTCPU planning. Pollutant concentrations in combined sewer overflow have been estimated based on a flow-weighted average of their sanitary sewage and stormwater components.

In the tributaries, baseflow loads were estimated based on observed dry weather flows and concentrations in the streams. Dry weather flows were derived from long-term USGS daily flow monitoring data, while concentrations were derived from PWD dry weather instream monitoring data. Stormwater flows were estimated from hydrologic modeling and from streamflow records where available. Stormwater event mean concentrations used for this study for urban land uses are from Smullen, Shallcross, and Cave (1999). These values represent a compilation of stormwater monitoring data from NURP, the USGS, and NPDES Phase I Municipal Stormwater Monitoring Requirements.

In the tidal estuary, estimates of pollutant loads for the entire contributing area were impractical due to the size of the Delaware and Schuylkill Watersheds. An alternative approach was taken focusing on just the system of interest, the portions of the Schuylkill and Delaware Rivers impacted by Philadelphia's combined sewer outfalls. Estimated loads contributed by combined sewer overflows have been updated to reflect the representative year precipitation record and results of hydrologic/hydraulic computer modeling used in LTCPU planning. Pollutant concentrations in CSOs have been estimated based on a flow-weighted average of the sanitary sewage and stormwater components.

Loads entering the boundary of the CSO-impacted area were estimated using USGS flow monitoring and water quality data. Flow monitoring and water quality data collected at the USGS station at Trenton was used for the Delaware River and from the USGS station at the Fairmount Dam for the Schuylkill River. Streamflow volumes were estimated from the average daily flow measurements. Water quality parameter concentrations were estimated from data collected at the monitoring locations. The water quality data collected at Trenton was summarized into an average concentration for the period of 1999-2008. The water quality sampled at the Fairmount Dam was less comprehensive and average concentrations were used for the period of record that was available for each parameter.

3.4.4.2 Tookany/Tacony-Frankford Pollutant Loads

Table 3-107 presents the approximate load each source contributes to the TTF Creek. Runoff from areas with separate sanitary and storm sewer systems is a significant (over 10%) source of most pollutant types except fecal coliform. Discharges of untreated sanitary sewage may be a significant source of pollutants, but information concerning these sources was insufficient to include in the current analysis. Baseflow contributes a significant amount of total nitrogen. Results indicate that over 90% of the fecal coliform introduced to the system is the result of CSOs, excluding any sources of sanitary sewage such as SSOs and illicit connections, which have not been explicitly accounted for.

Table 3-107 TTF Estimated Annual Pollutant Loads (lb except as noted)

Parameter	Stormwater Runoff	Baseflow	CSO	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	2.54E+05	5.26E+04	9.91E+05	1.30E+06	76%
TSS	1.44E+06	1.43E+05	2.09E+06	3.68E+06	57%
Fecal Coliform (#/yr)	2.49E+15	2.06E+14	3.65E+16	3.92E+16	93%
Total Nitrogen	4.42E+04	1.24E+05	1.66E+05	3.34E+05	50%
Total Phosphorus	5.67E+03	7.16E+03	2.39E+04	3.67E+04	65%
Copper	2.27E+02	3.16E+02	7.16E+02	1.26E+03	57%
Lead	1.36E+03	4.21E+01	1.49E+03	2.89E+03	51%
Zinc	3.06E+03	8.63E+02	4.88E+03	8.80E+03	55%

3.4.4.3 Cobbs Creek Pollutant Loads

Lower Cobbs includes the combined-sewered portions of the watershed inside Philadelphia. Table 3-108 presents the approximate load each source contributes to the Cobbs Creek watershed. Runoff from areas with separate sanitary and storm sewer systems is a significant source of most pollutant types, except fecal coliform. Discharges of untreated sanitary sewage may be a significant source of pollutants, but information concerning these sources was insufficient to include in the current analysis. Baseflow contributes a significant amount of total nitrogen. The results indicate that CSOs represent more than 10% of the total load for every parameter except total nitrogen and lead. The model indicates that over 50% of the fecal coliform introduced to the system is the result of CSOs, excluding any sources of sanitary sewage such as SSOs and illicit connections, which have not been explicitly accounted for.

Table 3-108 Cobbs Estimated Annual Pollutant Loads (lb except as noted)

Parameter	Stormwater Runoff	Baseflow	CSO	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	5.34E+05	1.70E+05	1.88E+05	8.92E+05	21%
TSS	2.99E+06	4.05E+05	4.28E+05	3.82E+06	11%
Fecal Coliform (#/yr)	5.06E+15	3.20E+14	6.53E+15	1.19E+16	55%
Total Nitrogen	9.06E+04	3.07E+05	3.16E+04	4.29E+05	7%
Total Phosphorus	1.19E+04	5.72E+03	4.52E+03	2.21E+04	20%
Copper	5.41E+02	3.81E+02	1.39E+02	1.06E+03	13%
Lead	2.97E+03	1.06E+02	3.16E+02	3.39E+03	9%
Zinc	6.28E+03	1.25E+03	1.00E+03	8.53E+03	12%

3.4.4.4 Tidal Delaware Pollutant Loads

Table 3-109 presents the average loads contributed by runoff from boundary and combined sewer areas.

Table 3-109 Tidal Delaware Estimated Annual Pollutant Loads

Parameter	Boundary load	CSO load	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	5.84E+07	1.15E+06	5.95E+07	1.9%
TSS	7.64E+08	2.75E+06	7.66E+08	0.4%
Fecal Coliform (#/yr)*		3.80E+16		
Total Nitrogen	3.60E+07	1.93E+05	3.62E+07	0.5%
Total Phosphorus	2.23E+06	2.75E+04	2.26E+06	1.2%
Copper	6.22E+07	8.59E+02	6.22E+07	0.001%
Lead	4.22E+07	2.08E+03	4.22E+07	0.005%
Zinc	4.88E+08	6.42E+03	4.88E+08	0.001%

* Insufficient data to estimate boundary load.

2.4.4.5 Tidal Schuylkill Pollutant Loads

Table 3-110 presents the average loads contributed by runoff from boundary and combined sewer areas.

Table 3-110 Tidal Schuylkill Estimated Annual Pollutant Loads

Parameter	Boundary load	CSO load	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD*		5.12E+05		
TSS	2.48E+08	1.52E+06	2.49E+08	0.6%
Fecal Coliform (#/yr)*		1.31E+16		
Total Nitrogen	2.48E+07	8.68E+04	2.48E+07	0.3%
Total Phosphorus	1.86E+06	1.21E+04	1.88E+06	0.6%
Copper	6.89E+04	4.10E+02	6.93E+04	0.6%
Lead*		1.25E+03		
Zinc	7.10E+05	3.56E+03	7.13E+05	0.5%

* Insufficient data to estimate boundary load.

3.5 Meteorologic Characterization

3.5.1 Background

The EPA CSO Control Policy (1994) requires the characterization of the combined sewer system (CSS) area and evaluation of control measure performance in terms of system-wide average annual hydrologic conditions. The identification of an average annual precipitation record, therefore, is critical for the evaluation of CSS performance.

3.5.2 Long-Term Meteorologic Conditions

The hydrologic conditions over the Philadelphia CSS area are characterized using the long-term historic hourly precipitation record, 59-year period (1948-2006), for the National Weather Service Cooperative Station located at the Philadelphia International Airport (WBAN#13739). Statistical analyses of the long-term record are performed to determine the average frequency, volume, and peak intensity of rainfall events. A selection of these analyses generally characterizing average precipitation volume and frequency are presented below. Results of further analyses are found in the Supplemental Documentation Volume 5.

Average Precipitation Volumes

Average annual and monthly precipitation volumes are determined from the long-term record at the PIA. Comparisons are made between the individual annual precipitation volumes and the long-term average to identify relatively 'wet' and 'dry' years.

Figure 3-112 shows the total annual precipitation volume at the PIA for the years 1948-2006 along with one standard deviation from the mean. By this measure, 1983 and 1965 are shown to be the wettest and driest years on record, respectively.

Average monthly total precipitation volumes are used to characterize relatively 'wet' and 'dry' months. Figure 3-113 shows the average monthly precipitation volumes relative to a range of plus and minus one standard deviation from the mean based upon the PIA historical record. Table 3-111 presents accompanying historical monthly precipitation volume statistics. Long term seasonal variation in monthly precipitation volumes can readily be seen between summer and winter, with summer months having marginally more rainfall than winter months.

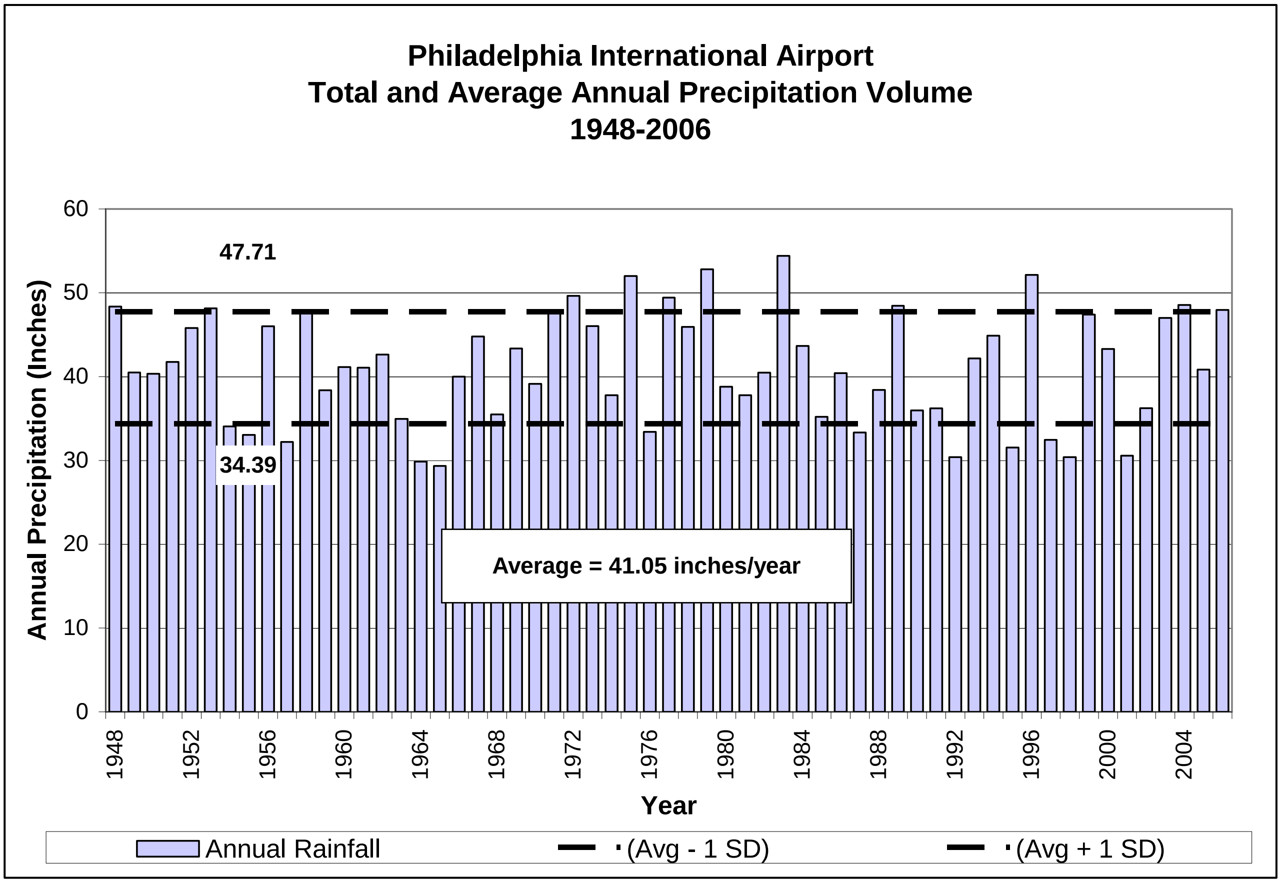


Figure 3-114 PIA total annual precipitation volume (1948-2006)

Figure 3-115 PIA average monthly precipitation volume (1948-2006)

Table 3-111 Monthly Precipitation Inches Statistics for PIA Historical Record (1948-2006)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.18	2.69	3.79	3.41	3.51	3.59	4.07	3.82	3.60	2.86	3.21	3.33	41.05
Avg + 1SD	4.83	3.89	5.32	4.95	5.13	5.67	6.40	5.83	5.92	4.46	5.11	5.14	47.71
Avg - 1SD	1.54	1.49	2.26	1.87	1.89	1.51	1.73	1.80	1.28	1.27	1.31	1.53	34.39
Std. Dev.	1.65	1.20	1.53	1.54	1.62	2.08	2.34	2.01	2.32	1.59	1.90	1.80	6.66
Maximum	8.86	6.44	6.89	8.12	7.03	8.08	10.42	9.70	13.07	8.68	9.05	8.09	54.41
Minimum	0.45	0.46	0.69	0.61	0.48	0.11	0.37	0.49	0.21	0.09	0.32	0.25	29.34

Event Based Precipitation Analyses

Event based analysis of the long-term precipitation record is used to best represent average annual CSO frequency and volume statistics needed for measurement of collection system performance. These event statistics are specific for a given minimum inter-event time (MIT) used for event definition.

A minimum inter-event time (MIT) is chosen for event definition so that the coefficient of variation (the ratio of the standard deviation to the mean) of inter-event times most closely approximates unity. A six-hour minimum inter-event time is selected on this basis for the PIA using hourly precipitation data for the period 1948-2006 as seen in Table 3-112.

Table 3-112 Inter-event Time (IET) statistics determined for a range of minimum inter-event times (MIT) using PIA hourly precipitation (1948-2006)

MIT (Hours)	Mean IET (Hours)	Std. Dev.IET (Hours)	CV IET
2	48.2	70.7	146.5
4	66.2	76.2	115.1
6	75.5	77.5	102.7
8	81.4	78.0	95.8
10	85.6	78.2	91.3
12	89.5	78.2	87.4
14	92.7	78.2	84.4
16	95.2	78.2	82.1
18	97.5	78.1	80.1
20	99.5	78.1	78.4
22	101.8	78.0	76.6
24	104.0	77.9	74.9

A minimum total event volume of 0.05 inches is selected as the minimum storm depth needed for precipitation events to significantly increase wastewater flows potentially contributing to CSO discharges. Table 3-113 presents event-based summary statistics for the PIA long-term precipitation record.

Table 3-113 Philadelphia International Airport Average Annual Wet Weather Event Statistics (1948-2006)

Month	Event Size Class	Average Number of Events	Average Total Rainfall (Inches)	Average Event Peak Hourly Intensity (In / hour)	Average Event Duration (hours)	Average Inter-Event Time (hours)
1	>= 0.05 in	6.4	3.04	0.11	11.2	83.2
2	>= 0.05 in	5.9	2.66	0.11	11.1	82.0
3	>= 0.05 in	7.1	3.81	0.14	10.9	83.6
4	>= 0.05 in	7.1	3.27	0.15	9.4	66.5
5	>= 0.05 in	7.6	3.46	0.18	7.9	73.5
6	>= 0.05 in	7.3	3.51	0.25	5.8	79.5
7	>= 0.05 in	7.2	4.02	0.29	5.6	83.7
8	>= 0.05 in	6.7	3.77	0.32	6.0	90.3
9	>= 0.05 in	5.7	3.58	0.26	8.1	95.7
10	>= 0.05 in	4.9	2.82	0.19	9.3	115.1
11	>= 0.05 in	5.7	3.16	0.16	9.9	100.1
12	>= 0.05 in	6.0	3.31	0.13	11.9	89.4
All	>= 0.05 in	77.6	40.39	0.19	8.7	77.1
All	< 0.05 in	30.3	0.62	0.02	1.7	74.6
All	All	107.9	41.05	0.14	6.7	76.4
* Events defined based on 6 hour Minimum Interevent Time (MIT)						

3.5.3 Local Meteorologic Conditions

The average spatial distribution of precipitation over the CSS areas is characterized using the 17-year rainfall record for the PWD 24-raingage network collected over the period 1990-2006, along with fifteen months of gage calibrated radar rainfall data. Extensive analyses of non-climatic gage biases based on inter-gage comparison and radar rainfall data are performed leading to the creation of a bias adjusted rainfall dataset for the PWD 24-raingage network over the period of record (1990-2006). The detailed analyses are presented in Supplemental Documentation Volume 5.

Increasing the level of detail of the rainfall input spatially increases the accuracy and precision of the model results. The method selected to estimate rainfall values in areas between rain gages is an inverse distance-squared weighting procedure to populate a 1-km square grid followed by area weighting for each modeled sewershed. The details of this procedure are presented in Supplemental Documentation Volume 5.

3.5.4 Average Annual Precipitation Record

The characterization of long-term system-wide average hydrologic conditions across the CSS is necessary in order to identify a continuous short–term period contained within the PWD 24-gage fifteen-minute rainfall record (1990-present) that simulates long-term average annual CSO statistics needed for the evaluation of CSO control measure performance. After initial identification of the continuous 12-month period in the short-term PWD 24-gage record that most closely represents long-term conditions, adjustment of selected events is performed to further match long-term statistics.

CSO occurrence is considered to be a complex function of storm-event characteristics such as total volume, duration, peak intensity, and length of antecedent dry period or inter-event time (IET). In order to identify short-term continuous periods likely to generate CSO statistics representative of the long-term record, continuous 12-month periods selected from the recent PWD 24-raingage record (1990-2006) are evaluated against the long-term record based on the following storm-event characteristics:

- Annual number of storm events
- Total annual rainfall volume
- Best fit CDF plot of event peak hourly rainfall intensity

The calendar year 2005 is selected to represent long-term average hydrologic conditions for CSO LTCP project evaluations, based on the annual number of storm events, the total annual rainfall volume, and the best fit CDF plot of event peak hourly rainfall intensity, with preference given to more recent calendar years to better represent current conditions. Details of the selection process are presented in Supplemental Documentation Volume 5.

The calendar year 2005, however, contains the extreme event of October 8, 2005 which recorded an average rainfall volume across the PWD 24-gage network of 5.40 inches between October 7 12:15 PM and October 9 8:45 AM. This rainfall event has the third largest annual peak rainfall volume recorded at the Philadelphia International Airport (PIA) station over the long-term period of 1948-2006. Furthermore, this rainfall event accounts for nearly thirty percent of the total annual estimated combined sewer overflow volume for the year 2005 based on SEDD baseline model simulations. Because the extreme rainfall event of October 8, 2005 accounts for a disproportionately large fraction of the total annual overflow volume, the results of CSO LTCPU project evaluations may be unintentionally skewed to minimize the long-term effectiveness of certain alternatives in favor of others.

In response to these concerns, a decision was made to adjust the rainfall record for the calendar year 2005 to better represent long-term average hydrologic conditions by scaling down the October 8th rainfall event so that the average rainfall volume across the PWD 24-gage network for this event is equal to the median peak annual rainfall volume estimated for the network over the long-term period of 1948-2006. The details of the time-series modification procedures are presented in Supplemental Documentation Volume 5.

3.5.5 Temperature Data

Temperature statistics are shown below in Table 3-114 and were obtained from the National Oceanic and Atmospheric Administration. The air temperature statistics that are shown below come from a period of record from 1947 to 2008. The dry-bulb temperature which is commonly referred to as the ambient air temperature is the temperature of the air that is measured by a thermometer that is freely exposed to the air but is shielded from radiation and moisture. Table 3-114 shows that the highest mean dry-bulb air temperature occurs during the month of July and is 77.3OF while the lowest mean dry-bulb air temperature occurs during the month of January and is 32.3OF.

Table 3-114 Temperature Statistics

Element	Period of Record (years)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean Daily Maximum Air Temperature (°F)	61	39.7	42.5	51.5	63.4	73.3	82.0	86.6	84.8	77.7	66.7	55.3	44.0
Mean Dry Bulb Air Temperature (°F)	61	32.3	34.5	42.5	53.3	63.2	72.4	77.3	75.8	68.5	57.1	46.7	36.6
Mean Daily Minimum Air Temperature (°F)	61	24.9	26.4	33.6	43.1	53.1	62.3	68.0	66.8	59.3	47.6	38.1	29.1

3.5.6 Snowfall Data

Snowfall statics are shown below in Table 3-115 and were obtained from the National Oceanic and Atmospheric Administration. The snowfall statistics shown below come from a period of record from 1978 to 2008. The table shows that the average yearly snowfall for the period of record was 19.3 inches with the highest monthly average snowfall occurring during the month of February and accounted for 6.6 inches. The table also shows that for the period of record the average total days with a snowfall amount greater than or equal to 1 inch is only 5.1 days. The table shows that Philadelphia does not normally receive large snow events.

Table 3-115 Snowfall Statistics

Element	Average Monthly Snowfall (in)	No. of Days with Snowfall >= 1.0 in
Period of Record (years)	30	30
JAN	6.4	1.9
FEB	6.6	1.5
MAR	3.2	0.8
APR	0.6	0.2
MAY	0	0
JUN	0	0
JUL	0	0
AUG	0	0
SEP	0	0
OCT	0.1	0
NOV	0.4	0.2
DEC	2	0.5
Total Annual	19.3	5.1

3.5.7 Evaporation Data

Limited long-term daily evaporation data exists for the Philadelphia area. Neither the Philadelphia Airport nor the Wilmington Airport records evaporation data. One site in New Castle County, Delaware was located with recorded daily evaporation data from 1956 through 1994. Average evaporation rates (inches per day) determined from this site is given in Table 3-116.

Table 3-116 Evaporation Statistics

Month	Average Evaporation Rate (in/day)
Jan	0.07
Feb	0.07
Mar	0.07
Apr	0.15
May	0.18
Jun	0.21
Jul	0.22
Aug	0.19
Sep	0.14
Oct	0.09
Nov	0.07
Dec	0.07

4 PROBLEM ANALYSIS AND GOAL SETTING

4.1 OVERVIEW

This section summarizes the concerns identified in each watershed by the characterization presented in Section 3, draws conclusions about the extent to which CSOs cause or contribute to these problems, discusses the regulatory framework, and presents a set of goals to solve the problems based on requirements of the Clean Water Act and goals of PWD's Integrated Watershed Management Plans.

The goals of PWD's *Green City, Clean Waters* program are developed in the context of an Integrated Watershed Management approach to achieve not only Water Quality Standards compliance, but to achieve the true end goal of the Clean Water Act and provide maximum benefit to the public. The watershed approach addresses all the issues confronting urban streams and allows PWD to consider all of the environmental, social, and economic benefits of alternatives. PWD views its LTCP and NPDES permits as elements within the context of this far broader approach. The Integrated Watershed Management Plans (IWMPs) were crafted after extensive input from the community and numerous stakeholders. In each watershed, stakeholders provided input on goals and weighted the relative importance of each goal to the community.

Goals of PWD's *Green City, Clean Waters* Program

Target A: Dry Weather Water Quality, Aesthetics, and Recreation

- A.1 Eliminate dry weather discharges from combined sewer systems to the maximum extent possible. Continue to correct any short-term issues such as blockages as soon as they are identified. Following implementation, CSOs will not cause or contribute to exceedance of water quality criteria for bacteria in dry weather.
- A.2 Control discharges of solids, floatables, and trash to receiving waters.
- A.3 Improve opportunities for water-based recreation under safe physical conditions.
- A.4 Support regional efforts to create safer, more accessible, more enjoyable waterfronts and stream corridors.

Target B: Healthy Living Resources in Streams/Rivers and Along Riparian Corridors

- B.1 Protect and restore stream corridors, buffers, floodplains, and natural habitats including wetlands. Following implementation of stream channel and habitat restoration measures, CSOs will not cause or contribute to erosion and habitat degradation in the tributaries.
- B.2 Restore tidal wetlands and wetland habitats.

Target C: Wet Weather Water Quality and Quantity

- C.1 Restore a more natural water balance between surface runoff, infiltration, and evaporation. In the tributaries, reduce the magnitude and duration of peak flows to protect investments in channel and habitat restoration.
- C.2 Reduce CSO volume, frequency, and length of discharge.
- C.3 Implement a phased approach to meeting appropriate wet weather bacteria criteria.

Stewardship and Community

- SC.1 Foster community stewardship and improve inter-municipal, inter-county, state-local, and stakeholder cooperation and coordination on a watershed basis.
- SC.2 Support regional efforts to create greener, more inviting urban communities.

4.2 CSO Contribution to Water Quality Conditions

Problems and their sources have been analyzed on a watershed basis, including areas inside and outside the combined sewersheds and areas inside and outside the City of Philadelphia. For many cities like Philadelphia located at the confluence or terminus of streams or river systems with large upstream drainage areas (such as the Delaware and Schuylkill Rivers), boundary load is a significant source of many pollutants. The area served by combined sewers within the City of Philadelphia covers about 20% of the total Cobbs Creek Watershed area, 1% of the total Pennypack Creek Watershed area, 1% of the Schuylkill River Watershed, about 46% of the Tacony-Frankford Creek Watershed area, and less than 1% of the Delaware River Watershed area. As presented in the characterization of pollutant loads, CSO flows typically consist of roughly 90% or more urban stormwater runoff, and except for bacteria and sanitary floatables, have pollutant characteristics similar to other wet weather point and nonpoint sources. Upstream point and non-point sources can be the dominant sources of biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, phosphorus, and metals for watersheds.

As in most watersheds, causes of non-attainment are related not only to CSOs, but are proportional to the drainage area for elements such as land use category, the loading per unit area of pollutant from each category of land use, and the hydrologic, hydraulic and water quality processes that govern mixing, transport, sedimentation, die-off and other factors. Another source of bacteria may be contributed through illicit connections to the city's storm drains. Physical factors also play a role in affecting the ability to utilize a water body, including channelization or culverts. Low flow during summer months can contribute to diminished recreational use by hindering activities such as boating or swimming.

4.2.1 Tookany/Tacony-Frankford Creek Watershed Problem Summary

The City of Philadelphia occupies 58% of the Tookany/Tacony-Frankford Creek Watershed, and of that, the CSO drainage area within the City makes up 46% of the Tookany/Tacony-Frankford Creek Watershed. An important aspect of the Tookany/Tacony-Frankford Creek Integrated Watershed Management Plan (TTFIWMP) is a basic description of existing conditions within the watershed and streams. Through the extensive field studies, modeling, and data analysis, the highest priority problems in the Tookany/Tacony-Frankford Creek were identified, and the means for addressing the problems were developed. Section 3 of this LTCPU incorporates many of the relevant findings of the TTFIWMP and related studies. Given that the Tookany/Tacony-Frankford Creek Watershed is a highly urbanized watershed with both CSOs and significant stormwater flows, some of the highest priority problems included:

Dry Weather Water Quality, Aesthetics and Recreation

- Water quality concerns including high fecal coliform and temperature during dry weather
- Potential dry weather sewage flows in separate sewered areas
- Litter and unsightly streams that discourage residential use
- Safety concerns along streams and stream corridors

Watershed Stewardship

- Recreational opportunities and public access below potential
- Limited public awareness and sense of stewardship for TTF Creek

Healthy Living Resources

- Degraded aquatic and riparian habitats
- Loss of wetlands
- Channelized stream sections
- Limited diversity of fish and other aquatic life
- Periodic, localized occurrences of reduced dissolved oxygen concentrations in downstream areas
- Wide diurnal swings in dissolved oxygen
- Utility infrastructure threatened by bank and streambed erosion

Wet Weather Water Quality and Quantity

- Water quality concerns including high fecal coliform, temperature, and metals during wet weather flows
- CSO and stormwater impacts on water quality and stream channels
- Little volume control and treatment of stormwater flows in separate sewered areas

Dry Weather Water Quality, Aesthetics and Recreation

Problem: Water quality concerns including high fecal coliform during dry weather

- Similar concentrations and frequencies of exceedance in combined-sewered and separate-sewered areas, inside and outside Philadelphia
- Suspected dry weather sewage inputs from separate-sewered areas
- Sewage odors noticed by public and sampling teams

<u>What pollutants or physical conditions are causing this problem, and what are their sources?</u>

- Pathogen loads from combined sewers and sanitary sewers caused by dry weather discharges due to choked sewers and illicit cross connections
- Nonpoint sources of pathogens, including animal sources, are an active area of research
- Heated stormwater runoff

<u>Are CSOs causing or contributing to this problem?</u>
No, except for occasional, short-term issues such as blocked sewers. These situations are quickly corrected as soon as they are identified. PWD believes the combined sewer system is being properly operated and maintained in accordance with NMC 5 and other applicable regulations. However, continuing to properly operate and maintain the system is an important component of the LTCPU.

Problem: Potential dry weather sewage flows in separate sewered areas

<u>What pollutants or physical conditions are causing this problem, and what are their sources?</u>

- Defective laterals
- Illicit cross connections

<u>Are CSOs causing or contributing to this problem?</u>
No. CSOs are not directly contributing to this problem.

Problem: Litter and unsightly streams that discourage residential use

What pollutants or physical conditions are causing this problem, and what are their sources?

- Illegal littering and dumping
- Solids loads from CSO and stormwater discharges

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to this problem through loads of solids and floatables to streams. PWD has an effective solids and floatables control program in accordance with NMC 7 and other applicable regulations. Maintaining and increasing this level of control is an important component of the LTCPU.

Problem: Safety concerns along streams and stream corridors

What pollutants or physical conditions are causing this problem, and what are their sources?

- Lack of patrols and enough recreational users to create a safe environment
- Prohibited swimming during poor water quality conditions that may pose a risk to human health (note that swimming in streams and rivers is prohibited throughout the City of Philadelphia)
- Prohibited swimming in areas with unsafe physical conditions or where drowning is a hazard

Are CSOs causing or contributing to this problem?
Yes, CSOs do contribute to the problem

Watershed Stewardship

Problem: Limited public awareness and sense of stewardship for TTF Creek

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public participation and stewardship are an important component of the LTCPU and larger integrated watershed management approach.

Problem: Recreational opportunities and public access below potential

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public recreation and riverfront access are an important component of the LTCPU and larger integrated watershed management approach. CSO outfalls may add to the public's sense that waterfronts are not attractive places to be.

Healthy Living Resources in Streams and along Stream Corridors

Problem: Degraded aquatic and riparian habitats and channelized stream sections

- Bed and bank erosion
- Deposition of sediment in pools and on point bars
- Overwidening and downcutting of stream channels
- Exposure of potential riffle habitats during low flows
- Floodplain disconnection

- Invasive vegetation on stream banks
- Impediments to fish passage

What pollutants or physical conditions are causing this problem, and what are their sources?

- High instream wet weather flows and velocities
- Alteration of the natural hydrologic cycle in wet weather, uncontrolled runoff from impervious surfaces leading to discharges from combined sewer and stormwater outfalls
- Alteration of the natural hydrologic cycle in dry weather, reduced soil infiltration and groundwater recharge

Are CSOs causing or contributing to this problem?

Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Problem: Loss of wetlands

- Nearly all wetlands in the watershed exhibit impaired functions that indicate extensive disturbance and deterioration

What pollutants or physical conditions are causing this problem, and what are their sources?

- Urban and suburban development has resulted in the piping of historic streams, destruction of wetlands, and deforestation and modification of historic floodplains
- Stormwater is piped directly to waterways rather than flowing overland through vegetation, wetlands, and woodlands
- Flow and volume of runoff is intensified
- There is no longer a source of water to maintain many of the wetlands that once existed

Are CSOs causing or contributing to this problem?

Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Problem: Channelized stream sections

What pollutants or physical conditions are causing this problem, and what are their sources?

- Urban and suburban development has resulted in the straightening and channelizing of historic streams

Are CSOs causing or contributing to this problem?

Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Problem: Limited diversity of fish and benthic life

- Nonattainment of designated aquatic life use (warm water fishery, migratory fishes)
- Abundance of pollution-tolerant and disturbance-tolerant species relative to reference sites and scarcity of sensitive species
- Species present exhibit morphological and behavioral adaptations to high velocities

What pollutants or physical conditions are causing this problem, and what are their sources?

- Physical alteration of habitat, erosion and deposition of substrates
- Dry weather flow insufficient to cover key habitats

- Wet weather flows and sediment loads capable of burying or washing away invertebrates, fish, and fish eggs
- Occasional exceedance of water quality criteria designed to protect aquatic life

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts. CSOs may be slightly less destructive because a portion of stormwater is treated.

Problem: Periodic, localized occurrences of reduced dissolved oxygen primarily associated with low flow conditions and plunge pools and stagnant water behind dams; and wide diurnal swings in dissolved oxygen

What pollutants or physical conditions are causing this problem, and what are their sources?
- Structures such as dams and outfalls creating poorly mixed, low velocity pools
- Intensity and duration of sunlight, lack of shade
- Loads of oxygen-demanding material and nutrients introduced by CSOs, stormwater, nonpoint sources, and groundwater
- Localized growth of nuisance algae leading to large diurnal variation in DO
- Naturally occurring low flow conditions

Are CSOs causing or contributing to this problem?
Yes, CSOs and stormwater outfalls contribute to this problem by introducing loads of oxygen-demanding materials and nutrients.

Problem: Utility infrastructure threatened by bank and streambed erosion

What pollutants or physical conditions are causing this problem, and what are their sources?
- High instream wet weather flows and velocities leading to erosion of beds and banks intended to protect the infrastructure

Are CSOs causing or contributing to this problem?
Yes, CSOs and stormwater outfalls are a cause of these problems. CSO and stormwater outfalls cause similar impacts.

Wet Weather Water Quality and Quantity

Problem: Water quality concerns including fecal coliform, temperature, and metals during wet weather

What pollutants or physical conditions are causing this problem, and what are their sources?
- Loads of pathogens introduced by CSOs, stormwater, and nonpoint sources in wet weather. Because the concentrations of pathogens are much higher in CSOs than in other discharges, loading analyses estimate that CSOs contribute approximately 90% of the fecal coliform load to TTF Creek on an average annual basis
- Heated stormwater runoff
- Loads of metals introduced by CSOs and stormwater in wet weather. Possible exceedance of metals criteria was identified only as a potential problem in the Integrated Watershed Management Plan due to uncertainty in estimation of concentrations of dissolved metals. Please see discussion in the characterization section
- Sediments may store oxygen demanding organisms, which may become re-suspended during storms, moving the area of DO deficit further downstream

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to these problems by introducing significant loads to surface waters. In all cases, loads from other sources in the watershed are also significant and need to be addressed on a watershed basis to solve the problems.

Problem: CSO and stormwater impacts on water quality and stream channels

What pollutants or physical conditions are causing this problem, and what are their sources?

- Uncontrolled discharges from both CSO and stormwater outfalls causing damaging flows and velocities in wet weather

Are CSOs causing or contributing to this problem?
Yes, both CSOs and uncontrolled stormwater runoff contribute to these problems. Both sources need to be addressed concurrently on a watershed basis to solve the problems.

Problem: Little volume control and treatment of stormwater flows in separate sewered areas

What pollutants or physical conditions are causing this problem, and what are their sources?

- Alteration of the natural hydrologic cycle in wet weather, uncontrolled runoff from impervious surfaces leading to discharges from combined sewer and stormwater outfalls

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem.

4.2.2 Cobbs Creek Watershed Problem Summary

The City of Philadelphia occupies 25% of the Cobbs Creek Watershed, and of that, the CSO drainage area within the City makes up only 20% of the Cobbs Creek Watershed. An important aspect of the Cobbs Creek Integrated Watershed Management Plan (CCIWMP) is a basic description of existing conditions within the watershed and streams. Through the extensive field studies, modeling, and data analysis, the highest priority problems in the Cobbs Creek were identified, and the means for addressing the problems were developed. Section 3 of this LTCPU incorporates many of the relevant findings of the CCIWMP and related studies. Given that the Cobbs Creek Watershed is a highly urbanized watershed with both CSOs and significant stormwater flows, some of the highest priority problems included:

Dry Weather Water Quality, Aesthetics and Recreation

- Water quality concerns including high fecal coliform and temperature during dry weather
- Potential dry weather sewage flows in separate sewered areas
- Litter and unsightly streams that discourage residential use
- Safety concerns along streams and stream corridors

Watershed Stewardship

- Recreational opportunities and public access below potential
- Limited public awareness and sense of stewardship for Cobbs Creek

Healthy Living Resources

- Degraded aquatic and riparian habitats
- Limited diversity of fish and benthic life

- Periodic, localized occurrences of reduced dissolved oxygen primarily associated with plunge pools and areas of stagnant water behind dams
- Utility infrastructure threatened by bank and streambed erosion
- Loss of wetlands

Wet Weather Water Quality and Quantity

- Water quality concerns including fecal coliform, temperature, and metals during wet weather
- CSO and stormwater impacts on water quality and stream channels
- Little volume control and treatment of stormwater flows in separate sewered areas

Dry Weather Water Quality, Aesthetics and Recreation

Problem: Water quality concerns including high fecal coliform and temperature during dry weather

- Similar concentrations and frequencies of exceedance in combined-sewered and separate-sewered areas, inside and outside Philadelphia
- Suspected dry weather sewage inputs from separate-sewered areas
- Sewage odors noticed by public and sampling teams

<u>What pollutants or physical conditions are causing this problem, and what are their sources?</u>

- Pathogen loads from combined sewers and sanitary sewers caused by dry weather discharges due to choked sewers and illicit cross connections
- Nonpoint sources of pathogens, including animal sources, are an active area of research
- Heated stormwater runoff

<u>Are CSOs causing or contributing to this problem?</u>
No. PWD believes the combined sewer system is being properly operated and maintained in accordance with NMC 5 and other applicable regulations. However, continuing to properly operate and maintain the system is an important component of the LTCPU.

Problem: Potential dry weather sewage flows in separate sewered areas

<u>What pollutants or physical conditions are causing this problem, and what are their sources?</u>

- Defective laterals
- Illicit cross connections

<u>Are CSOs causing or contributing to this problem?</u>
No. CSOs are not directly contributing to this problem.

Problem: Litter and unsightly streams that discourage residential use

<u>What pollutants or physical conditions are causing this problem, and what are their sources?</u>

- Illegal littering and dumping
- Solids loads from CSO and stormwater discharges

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to this problem through loads of solids and floatables to streams. PWD has an effective solids and floatables control program in accordance with NMC 7 and other applicable regulations. Maintaining and increasing this level of control is an important component of the LTCPU.

Problem: Safety concerns along streams and stream corridors

What pollutants or physical conditions are causing this problem, and what are their sources?

- Lack of patrols and enough recreational users to create a safe environment
- Swimming during water quality conditions that may pose a risk to human health
- Swimming under unsafe physical conditions

Are CSOs causing or contributing to this problem?
Yes, CSOs do contribute to the problem.

Watershed Stewardship

Problem: Limited public awareness and sense of stewardship for Cobbs Creek

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public participation and stewardship are an important component of the LTCPU and larger integrated watershed management approach.

Problem: Recreational opportunities and public access below potential

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public recreation and riverfront access are an important component of the LTCPU and larger integrated watershed management approach. CSO outfalls may add to the public's sense that waterfronts are not attractive places to be.

Healthy Living Resources in Streams and along Stream Corridors

Problem: Degraded aquatic and riparian habitats

- Bed and bank erosion
- Deposition of sediment in pools and on point bars
- Overwidening and downcutting of stream channels
- Exposure of potential riffle habitats during low flows
- Floodplain disconnection
- Invasive vegetation on stream banks
- Impediments to fish passage

What pollutants or physical conditions are causing this problem, and what are their sources?

- High instream wet weather flows and velocities
- Alteration of the natural hydrologic cycle in wet weather, uncontrolled runoff from impervious surfaces leading to discharges from combined sewer and stormwater outfalls

- Alteration of the natural hydrologic cycle in dry weather, reduced soil infiltration and groundwater recharge

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Problem: Limited diversity of fish and benthic life

- Nonattainment of designated aquatic life use (warm water fishery, migratory fishes)
- Abundance of pollution- and disturbance-tolerant species relative to reference sites; scarcity of sensitive species
- Species present exhibit morphological and behavioral adaptations to high velocities

What pollutants or physical conditions are causing this problem, and what are their sources?

- Physical alteration of habitat, erosion and deposition of substrates
- Dry weather flow insufficient to cover key habitats
- Wet weather flows and sediment loads capable of burying or washing away invertebrates, fish, and fish eggs
- Occasional exceedance of water quality criteria designed to protect aquatic life

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts. CSOs may be slightly less destructive because a portion of stormwater is treated.

Problem: Periodic, localized occurrences of reduced dissolved oxygen primarily associated with low flow conditions and areas of plunge pools and areas of stagnant water behind dams

What pollutants or physical conditions are causing this problem, and what are their sources?

- Structures such as dams and outfalls creating poorly mixed, low velocity pools
- Intensity and duration of sunlight, lack of shade
- Loads of oxygen-demanding material and nutrients introduced by CSOs, stormwater, nonpoint sources, and groundwater
- Localized growth of nuisance algae leading to large diurnal variation in DO
- Naturally occurring low flow conditions

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to this problem by introducing loads of oxygen-demanding materials and nutrients.

Problem: Utility infrastructure threatened by bank and streambed erosion

What pollutants or physical conditions are causing this problem, and what are their sources?

- High instream wet weather flows and velocities leading to erosion of beds and banks intended to protect the infrastructure

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSO and stormwater outfalls cause similar impacts.

Problem: Loss of wetlands

- Nearly all wetlands in the watershed exhibit impaired functions that indicate extensive disturbance and deterioration

What pollutants or physical conditions are causing this problem, and what are their sources?

- Urban and suburban development has resulted in the piping of historic streams, destruction of wetlands, and deforestation and modification of historic floodplains
- Stormwater is piped directly to waterways rather than flowing overland through vegetation, wetlands, and woodlands
- Flow and volume of runoff is intensified
- There is no longer a source of water to maintain many of the wetlands that once existed

Are CSOs causing or contributing to this problem?

Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Wet Weather Water Quality and Quantity

Problem: Water quality concerns including fecal coliform, temperature, and metals during wet weather

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of pathogens introduced by CSOs, stormwater, and nonpoint sources in wet weather. Because the concentrations of pathogens are much higher in CSO than in other discharges, loading analyses estimate that CSOs contribute approximately 90% of the fecal coliform load to Cobbs Creek on an average annual basis
- Loads of metals introduced by CSOs and stormwater in wet weather. Possible exceedance of metals criteria was identified only as a potential problem in the Integrated Watershed Management Plan due to uncertainty in estimation of concentrations of dissolved metals. Please see discussion in the characterization section.
- Heated stormwater runoff

Are CSOs causing or contributing to this problem?

Yes, CSOs contribute to these problems by introducing significant loads to surface waters. In all cases, loads from other sources in the watershed are also significant and need to be addressed on a watershed basis to solve the problems.

Problem: CSO and stormwater impacts on water quality and stream channels

What pollutants or physical conditions are causing this problem, and what are their sources?

- Uncontrolled discharges from both CSO and stormwater outfalls causing damaging flows and velocities in wet weather

Are CSOs causing or contributing to this problem?

Yes, both CSOs and uncontrolled stormwater runoff contribute to these problems. Both sources need to be addressed concurrently on a watershed basis to solve the problems.

Problem: Little volume control and treatment of stormwater flows in separate sewered areas

What pollutants or physical conditions are causing this problem, and what are their sources?

- Alteration of the natural hydrologic cycle in wet weather, uncontrolled runoff from impervious surfaces leading to discharges from combined sewer and stormwater outfalls

Are CSOs causing or contributing to this problem?

No, CSOs are not directly contributing to this problem.

4.2.3 The Delaware River Watershed Problem Summary

The entire City of Philadelphia occupies less than 1% of the Delaware River Watershed, and of that, the CSO drainage area within the City makes up even less of the drainage area. An important aspect of the characterization of the Philadelphia part of the Delaware River watershed is a basic description of existing conditions within the watershed and streams. Through the extensive field studies, modeling, and data analysis, the highest priority problems in the Philadelphia part of the Delaware River Watershed were identified, and the means for addressing the problems were developed. Given that the Delaware River watershed in Philadelphia is a highly urbanized watershed with both CSOs and significant stormwater flows, some of the highest priority problems included:

Dry Weather Water Quality, Aesthetics and Recreation

- Water quality concerns including bacteria and temperature during dry weather
- Exceedance of bacteria criteria
- Delaware estuary listed as impaired by metals and priority organics
- Potential dry weather sewage flows in separate sewered areas

Watershed Stewardship

- Limited public awareness and sense of stewardship for the Delaware River
- recreational opportunities and public access below potential

Healthy Living Resources

- Loss of wetlands

Wet Weather Water Quality and Quantity

- Water quality concerns including bacteria, temperature, and turbidity during wet weather
- Exceedance of DO criteria
- Total Maximum Daily Load and fish advisories established for PCBs

Dry Weather Water Quality, Aesthetics and Recreation

Problem: Water quality concerns including bacteria and temperature during dry weather

- Fecal coliform and enterococcus, and temperature criteria are exceeded in dry weather samples

What pollutants or physical conditions are causing this problem, and what are their sources?

- Possible pathogen loads from upstream combined sewers and sanitary sewers caused by dry weather discharges due to choked sewers and illicit cross connections.
- Nonpoint sources of pathogens, including animal sources, are an active area of research

- Heated stormwater runoff

Are CSOs causing or contributing to this problem?
No. PWD believes the combined sewer system is being properly operated and maintained in accordance with NMC 5 and other applicable regulations. However, continuing to properly operate and maintain the system is an important component of the LTCPU.

Problem: Litter and unsightly streams that discourage residential use

What pollutants or physical conditions are causing this problem, and what are their sources?
- Illegal littering and dumping
- Solids loads from CSO and stormwater discharges

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to this problem through loads of solids and floatables to streams. PWD has an effective solids and floatables control program in accordance with NMC 7 and other applicable regulations, including use of skimmer vessels. Maintaining and increasing this level of control is an important component of the LTCPU.

Problem: Delaware estuary listed as impaired by metals and priority organics

What pollutants or physical conditions are causing this problem, and what are their sources?
- The scientific basis for these listings is unknown, and recent water quality monitoring data do not indicate a problem

Are CSOs causing or contributing to this problem?
No. There is no evidence of a current problem with metals or priority organics caused by CSOs.

Problem: Potential dry weather sewage flows in separate sewered areas

What pollutants or physical conditions are causing this problem, and what are their sources?
- Defective laterals
- Illicit cross connections

Are CSOs causing or contributing to this problem?
No. CSOs are not directly contributing to this problem.

Watershed Stewardship

Problem: Limited public awareness and sense of stewardship for the Delaware River

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public participation and stewardship are an important component of the LTCPU and larger integrated watershed management approach.

Problem: Recreational opportunities and public access below potential

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public recreation and riverfront access are an important component of the LTCPU and larger integrated watershed management approach. CSO outfalls may add to the public's sense that waterfronts are not attractive places to be.

Healthy Living Resources in Streams and along Stream Corridors

Problem: Loss of wetlands

- Nearly all wetlands in the watershed exhibit impaired functions that indicate extensive disturbance and deterioration

What pollutants or physical conditions are causing this problem, and what are their sources?

- Urban and suburban development has resulted in the piping of historic streams, destruction of wetlands, and deforestation and modification of historic floodplains
- Stormwater is piped directly to waterways rather than flowing overland through vegetation, wetlands, and woodlands
- Flow and volume of runoff is intensified
- There is no longer a source of water to maintain many of the wetlands that once existed

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Wet Weather Water Quality and Quantity

Problem: Water quality concerns including bacteria, temperature, and turbidity during wet weather

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of pathogens introduced by CSOs, stormwater, and nonpoint sources in wet weather
- Heated stormwater runoff

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to these problems by introducing significant loads to surface waters. In all cases, loads from other sources in the watershed are also significant and need to be addressed on a watershed basis to solve the problems.

Problem: Exceedance of DO criteria

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of oxygen-demanding material and nutrients introduced by CSOs, stormwater, and nonpoint sources

Are CSOs causing or contributing to this problem?
Yes, CSOs may contribute to this problem by introducing loads of oxygen-demanding materials and nutrients. However, DRBC indicated that CBOD loads introduced by Philadelphia CSOs cause a maximum DO reduction of 0.5 mg/L in the lower estuary.

Problem: Total Maximum Daily Load and fish advisories established for PCBs

What pollutants or physical conditions are causing this problem, and what are their sources?

- Historical sources
- Sediments
- Loads of PCBs introduced by CSOs, municipal separate sewer systems, continuous point sources, contaminated sites, stormwater discharges, tributaries and the atmosphere in wet weather

Are CSOs causing or contributing to this problem?
Yes, the contribution of CSOs was estimated for the TMDL study and a pollutant minimization plan is in place.

4.2.4 The Schuylkill River Watershed Problem Summary

The entire City of Philadelphia occupies only 2% of the Schuylkill River Watershed, and of that, the CSO drainage area within the City makes up less than 1% of the Schuylkill River Watershed. An important aspect of the characterization of Philadelphia's part of the Schuylkill River Watershed is a basic description of existing conditions within the watershed and streams. Through the extensive field studies, modeling, and data analysis, the highest priority problems in the Schuylkill River Watershed within Philadelphia were identified, and the means for addressing the problems were developed. Given that the Schuylkill River Watershed in Philadelphia is a highly urbanized watershed with both CSOs and significant stormwater flows, some of the highest priority problems included:

Dry Weather Water Quality, Aesthetics and Recreation

- Exceedance of temperature criteria
- Exceedance of DO criteria

Watershed Stewardship

- Limited public awareness and sense of stewardship for the Schuylkill River
- Recreational opportunities and public access below potential

Healthy Living Resources

- Loss of wetlands

Wet Weather Water Quality and Quantity

- Water quality concerns including bacteria and temperature during wet weather
- Exceedance of DO criteria
- Total Maximum Daily Load and fish advisories established for PCBs

Dry Weather Water Quality, Aesthetics and Recreation

Problem: Exceedance of temperature criteria

What pollutants or physical conditions are causing this problem, and what are their sources?

- Heated stormwater runoff

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to these problems by introducing stormwater with elevated temperatures.

Problem: Exceedance of DO criteria

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of oxygen-demanding material and nutrients introduced by CSOs, stormwater, and nonpoint sources

Are CSOs causing or contributing to this problem?
Yes, CSOs may contribute to this problem by introducing loads of oxygen-demanding materials and nutrients. However, DRBC modeling results indicated that CBOD loads introduced by Philadelphia CSOs cause a maximum DO reduction of 0.5 mg/L in the lower estuary below the city boundary.

Problem: Potential dry weather sewage flows in separate sewered areas

What pollutants or physical conditions are causing this problem, and what are their sources?

- Defective laterals
- Illicit cross connections

Are CSOs causing or contributing to this problem?
No. CSOs are not directly contributing to this problem.

Watershed Stewardship

Problem: Limited public awareness and sense of stewardship for the Schuylkill River

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public participation and stewardship are an important component of the LTCPU and larger integrated watershed management approach.

Problem: Recreational opportunities and public access below potential

Are CSOs causing or contributing to this problem?
No, CSOs are not directly contributing to this problem. However, public recreational and riverfront access are an important component of the LTCPU and larger integrated watershed management approach.

Healthy Living Resources in Streams and along Stream Corridors

Problem: Loss of wetlands

- Nearly all wetlands in the watershed exhibit impaired functions that indicate extensive disturbance and deterioration

What pollutants or physical conditions are causing this problem, and what are their sources?

- Urban and suburban development has resulted in the piping of historic streams, destruction of wetlands, and deforestation and modification of historic floodplains
- Stormwater is piped directly to waterways rather than flowing overland through vegetation, wetlands, and woodlands
- Flow and volume of runoff is intensified
- There is no longer a source of water to maintain many of the wetlands that once existed

Are CSOs causing or contributing to this problem?
Yes, CSOs are a cause of these problems. CSOs and stormwater outfalls cause similar impacts.

Wet Weather Water Quality and Quantity

Problem: Water quality concerns including bacteria and temperature during wet weather

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of pathogens introduced by CSOs, stormwater, and nonpoint sources in wet weather
- Stormwater runoff from warm surfaces

Are CSOs causing or contributing to this problem?
Yes, CSOs contribute to these problems by introducing significant loads to surface waters. In all cases, loads from other sources in the watershed are also significant and need to be addressed on a watershed basis to solve the problems.

Problem: Exceedance of DO criteria

What pollutants or physical conditions are causing this problem, and what are their sources?

- Loads of oxygen-demanding material and nutrients introduced by CSOs, stormwater, and nonpoint sources

Are CSOs causing or contributing to this problem?
Yes, CSOs may contribute to this problem by introducing loads of oxygen-demanding materials and nutrients. However, DRBC modeling results indicated that CBOD loads introduced by Philadelphia CSOs cause a maximum DO reduction of 0.5 mg/L in the lower estuary below the City boundary.

Problem: Total Maximum Daily Load and fish advisories established for PCBs

What pollutants or physical conditions are causing this problem, and what are their sources?

- Historical sources
- Sediments
- Loads of PCBs introduced by CSOs, stormwater, and nonpoint sources in wet weather

Are CSOs causing or contributing to this problem?
Yes, the contribution of CSOs was estimated for the TMDL study and a pollutant minimization plan is in place.

4.3 REGULATORY COMPLIANCE FRAMEWORK

4.3.1 NPDES Permits, National CSO Control Policy, and Consent Order

As required by its NPDES Permits, PWD submitted a Long Term Control Plan to PADEP in 1997. This document laid out a three-part program: continuing implementation of the Nine Minimum Controls, implementation of a series of traditional stormwater and combined sewer overflow controls, and a commitment to watershed-based assessment and planning. This program led to creation and implementation of Integrated Watershed Management Plans for each of the combined-sewered watersheds. The plans identify goals of PWD, watershed stakeholders, and the public, while also making sure these goals are consistent with regulatory requirements.

To provide an appropriate enforcement mechanism as required by the National CSO Control Policy, PWD entered into a Consent Order and Agreement (CO&A) with the Pennsylvania Department of Environmental Protection on August 4, 2008. As stated in the CO&A, the goal of PWD's Combined Sewer Overflow control program is to meet the water quality requirements of the Clean Water Act and Pennsylvania Clean Streams Law no later than September 1, 2029. This CO&A is intended to be consistent with the requirements of the National CSO Control Policy and PWD's Integrated Watershed Management Plans.

4.3.2 Planning Approach

The goal of PWD's "Green City-Clean Waters" program is not just to achieve Water Quality Standards compliance, but to achieve the true end goal of the Clean Water Act: to have healthy streams where aquatic life can prosper; to make these streams pleasant, accessible and safe when people are recreating in and around them; to protect, preserve and maintain these streams against the challenges of sedimentation, erosion and the careless disposal of trash; to improve the riparian habitat and to make stream corridors a great asset for everyone to enjoy.

The watershed approach, recommended by the National CSO Control Policy, addresses all these issues confronting urban streams - in dry and wet weather - whether they fall within or outside the direct control of the Clean Water Act. The approach allows PWD to consider all of the societal and environmental benefits and impacts. In Combined Sewer Overflows: Guidance for Long Term Control Plan, EPA encourages permittees "to consider innovative and alternate approaches and technologies that achieve the objectives of the Policy and the Act." PWD's watershed-based, green infrastructure-focused approach to address CSOs accomplishes exactly that.

Therefore, PWD has viewed its CSO LTCP, as it has all of its NPDES permits and other obligations, as elements within the context of a far broader Integrated Watershed Management approach. The Integrated Watershed Management Plans (IWMPs) were crafted after extensive input from the community and numerous stakeholders. The goals, and the strategies employed to achieve them, go well beyond nominal compliance with Water Quality Standards and look to achieve a broad array of environmental and societal goals that the community values and respects. The IWMPs set forth three targets - A, B and C, - to be achieved in all watersheds. Target A relates to improvements in dry weather conditions when use of our waterways is greatest. Target B restores ecosystems and natural habitats. Finally, Target C addresses wet weather concerns.

The National CSO Control Policy recognizes the site specific nature of CSOs and their impacts and provides the necessary flexibility to tailor controls to local situations. PWD believes it will be able to demonstrate that after the LTCPU has been implemented it will have achieved not only the broader endpoints of the ambitious goals contained in the IWMPs but also the more narrowly focused compliance with Water Quality Standards. PWD believes that after implementation of the LTCPU it will be able to demonstrate that the level of protection provided by the Water Quality Standards has been achieved.

PWD has begun a preliminary study to document recreation occurring along waterways and potential health implications of that recreation. PWD would like to develop this data in a more comprehensive fashion and looks forward to working with EPA, DEP and local Health Department authorities in planning and conducting further studies.

While PWD believes that the protective goal of the Water Quality Standards can be achieved, it recognizes that there is a possibility that achieving this goal may take longer than 20 years. Should additional time be needed to achieve wet weather water quality goals, PWD will work with PADEP in reviewing and possibly revising the Water Quality Standards as permitted under the Clean Water ACT regulations. PWD's decentralized green infrastructure-based approach will continue to make improvements year after year beyond the 20-year window of the LTCPU. Revamping the way development is practiced over time will change the very fabric of the City. Updating the infrastructure will continue forever to make constant improvements not only to the water environment but to air and to the quality of life in neighborhoods as well.

4.3.3 Policy and Guidance on the Watershed Approach

Approaching CSO control on a watershed basis is clearly supported in recent Federal policy and guidance. One example is provided in the encouragement to NPDES permit writers "... to evaluate water pollution control needs on a watershed management basis and coordinate CSO control efforts with other point and nonpoint source control activities" (1.B). The watershed approach is also discussed in the section of the CSO Control Policy addressing the demonstration approach to CSO control (II.B.4.b; and Chapter 3 of the USEPA *Combined Sewer Overflows: Guidance For Long-Term Control Plan*), which, in recommending that NPDES permitting authorities allow a demonstration of attainment of WQS, provides for consideration of natural background conditions and pollution sources other than CSOs.

Combined Sewer Overflows: Guidance For Long-Term Control Plan ("the Guidance") suggests that EPA is committed to supporting the implementation of a comprehensive watershed management approach. According to the Guidance, EPA has convened a Watershed Management Policy Committee, consisting of senior managers, to oversee the reorientation of all EPA water programs to support watershed approaches. Of particular importance to CSO control planning and management is the NPDES Watershed Strategy. This strategy outlines national objectives and implementation activities to integrate the NPDES program into the broader watershed protection approach. The NPDES Watershed Strategy also supports the development of basin management as part of an overall watershed management approach

The Guidance suggests that the sources of watershed pollution and impairment, in addition to CSOs, are varied and include other point source discharges; discharges from storm drains; overland runoff; habitat destruction; land use activities, such as agriculture and construction; erosion; and septic systems and landfills. The benefits to implementing a watershed approach are significant and include:

- Consideration of all important sources of pollution or impairment
- Clearer definition of water quality benefits resulting from a given level of CSO reduction
- Greater flexibility to reflect the site-specific nature of CSO discharges
- Greater cost effectiveness (through coordination of monitoring programs, for example)

- Fostering of prevention as well as control
- Fairer allocation of resources and responsibilities.

The Guidance notes that the major advantage in using a watershed-based approach to develop a LTCP is that it allows the site-specific determination of the relative impacts of CSOs and non-CSO sources of pollution on water quality. For some receiving water reaches within a watershed, CSOs could well be less significant contributors to non-attainment than stormwater or upstream sources. In such cases, a large expenditure on CSO control could result in negligible improvement in water quality.

The Guidance outlines a conceptual framework for conducting CSO planning in a watershed context (Figure 4-1). The approach is intended to identify CSO controls for each receiving water segment based on the concepts of watershed management and use attainability.

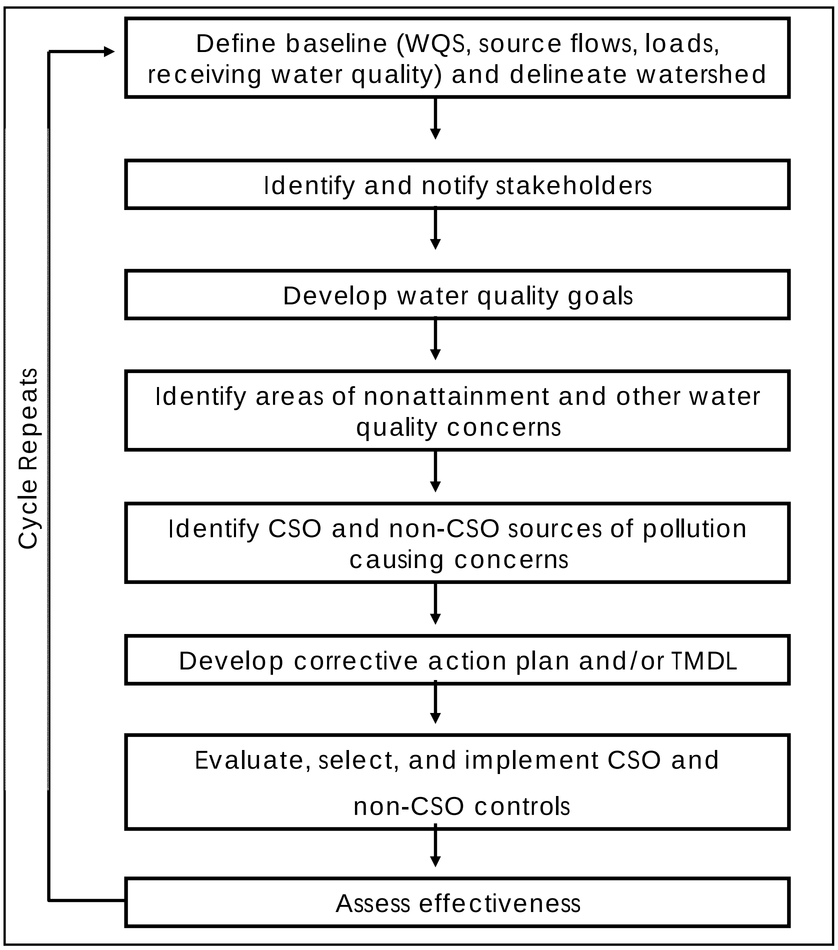


Figure 4-1 Watershed-Based CSO Control Planning Approach for a Receiving Water Segment (adapted from LTCP Guidance, Exhibit 1-5)

4.3.4 Policy and Guidance on Green Infrastructure

The City of Philadelphia's LTCPU also has been devised in light of the recent Green Infrastructure guidance and policy documents developed by the United States Environmental Protection Agency (US EPA). The US EPA signed the "Green Infrastructure Statement of Intent" in April 2007 and issued a "Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint

Source and other Water Programs" memo in March 2007. This memo was intended to highlight opportunities for increasing the development and use of Green Infrastructure. Former Assistant Administrator to the US EPA Benjamin Grumbles states in this memo that he strongly supports the use of green infrastructure approaches and suggests to the EPA Regional offices that they promote green infrastructure approaches to the states. Also, in a memo titled "Use of Green Infrastructure in Permits and Enforcement" from the Directors of the Water Permits Division and the Water Enforcement Division, it is stated that "in developing permit requirements permitting authorities may structure their permits, as well as guidance or criteria for stormwater plans and CSO Long-term control plans, to encourage permittees to utilize green infrastructure approaches, where appropriate, in lieu of or in addition to more traditional controls." This memo also states that EPA will consider the feasibility of the use of green infrastructure as a pollution control technology in its enforcement activities, and encourages state authorities to do so as well.

4.4 WATER QUALITY GOALS

4.4.1 Introduction: LTCPU and the Integrated Watershed Management Framework

PWD's Integrated Watershed Management Planning (IWMP) process is designed to address both stakeholder goals and regulatory obligations in one coordinated implementation approach for each of the watersheds that drain to the City. The City of Philadelphia's Long Term CSO Control Plan Update seeks to meet the regulatory requirements of the National CSO Control Policy through this comprehensive watershed-based approach.

Implementation of IWMPs shall create and maintain safe, inviting stream corridors and riverfronts as well as improve recreational opportunities for residents of the city. The approach is part of the City's larger vision of creating greener and more attractive urban communities. PWD's IWMP commitment involves restoration of historical amenities through creation of physical habitat to support healthy aquatic communities. PWD's LTCPU has a complimentary commitment to mitigating physical and water quality conditions that prevent establishment of healthy aquatic communities and safe enjoyment of streams and rivers by reducing runoff and increasing baseflow to the creeks through infiltration practices.

PWD has defined three distinct "targets" to meet the plan objectives and priorities identified by stakeholders, which will be addressed simultaneously. Two of the targets were defined so that they could be fully met through implementation of a limited set of options, while the third target would best be addressed through an adaptive management approach.

The US EPA, through their watershed academy, defines adaptive management as follows: Adaptive management is the process by which new information about the health of the watershed is incorporated into the watershed management plan. Adaptive management is a challenging blend of scientific research, monitoring, and practical management that allows for experimentation and provides the opportunity to "learn by doing." It is a necessary and useful tool because of the uncertainty about how ecosystems function and how management affects ecosystems.

PWD's watershed management approach is separated into three targets, or parallel tracks:

Target A: Dry Weather Water Quality, Aesthetics, and Recreation
The first target is to meet water quality standards in streams and rivers during dry weather flows. Target A was defined for the tributaries with a focus on trash removal and litter prevention, and the elimination of sources of sewage discharge during dry weather. Target A is also associated with improving the aesthetic quality of streams and stream corridors so that it can be viewed and treasured as a resource. Access and interaction with the stream during dry weather has the highest priority, because dry weather flows occur about 60-65% of the time during the course of a year. These are also the times when the public is most likely to be near or in contact with the stream.

The LTCPU includes implementation of Minimum Control Measure 5, which prohibits dry weather discharge from combined sewer systems. The LTCPU supports efforts to create more enjoyable, safer streams by ensuring the physical and water quality conditions needed for safe recreation.

Target B: Healthy Living Resources
Improvements to the number, health, and diversity of benthic macroinvertebrate and fish species in the tributaries will require investment in habitat improvement and measures to provide the opportunity for organisms to avoid high velocities during storms. Improving the ability of an urban stream to support viable habitat and fish populations must focus primarily on the elimination or remediation of the more obvious impacts of urbanization. These include loss of riparian habitat, eroding and undercut banks, scoured streambed or excessive silt deposits, channelized and armored sections, trash buildup, and invasive species. In the tidal rivers, impairment of living resources has not been identified as a problem.

The LTCPU complements Target B measures by protecting investments in restored stream channels and habitat, which in turn support healthy living resources.

Target C: Wet Weather Water Quality and Quantity
The third target of the integrated approach is to restore water quality to meet fishable and swimmable criteria during wet weather and to address flooding issues. Improving water quality and flow conditions during and immediately following storms is the most difficult target to meet in the urban environment. The integrated approach seeks to restore a more natural water balance to help recharge groundwater, reduce the burden on sewer systems, and reduce the quantity and pollutant loads of discharges to receiving waters. The approach also seeks to identify appropriate wet weather water quality criteria that do not pose a health risk to people engaging in recreation.

The LTCPU will make specific commitments to improving wet weather water quality and reducing the impacts of combined sewer overflows.

4.4.2 Review of Integrated Watershed Management Plan Goals

PWD's Integrated Watershed Management Plans (IWMPs), developed in cooperation with stakeholder partnerships, are based on a carefully developed approach to meeting the challenges of watershed management in an urban setting. A critical step in the IWMP Process is the establishment of stakeholder goals – deemed representative of the multitude of watershed perspectives. PWD's interest is in seeing that the final set of goals that drive the planning process are designed to meet the goals and objectives of the numerous water resource related regulations and programs that PWD and our upstream municipal partners must address. They also draw from the similarities contained in many watershed-based planning approaches authored by PADEP and US EPA. As such, PWD has developed a set of consolidated watershed goals with a focus on attaining priority environmental goals in a phased approach, by making use of the numerous existing programs that directly or indirectly require watershed planning. These consolidated goals were presented to each stakeholder partnership as a "master set" of goals, which they are invited to evaluate for applicability and completeness.

PWD's IWMP goal setting process is based on the use of the following definitions for the terms "goal", "objective", and "indicator":

> **Goal:** Goal statements are intentionally general and not specifically measurable (however a goal must be able to be "translated" into a measurable objective). Goals should represent a series of "wishes" for the watershed.
>
> **Objective:** For each goal statement – one or more objectives will be defined. An objective *translates* the broad language of a goal statement into a measurable quantity. The objective should lead toward the establishment of a target value, and could help to establish a trend over time.
>
> **Indicator:** Indicators are directly related to the measurable objectives; for each watershed objective – an indicator has been developed to measure whether progress is made. Indicators are often defined by actual numeric quantity that the objective is measured against. They are intended to broadly characterize condition and vulnerability.

The goals and objectives represent the collective idea of the stakeholders on what the watershed management plan should achieve. Not all goals, however, are of equal importance. It is important to elicit from the stakeholders a collective opinion on the relative importance of each goal for the watershed. Because the achievement of goals is an important yardstick for measuring the effectiveness of the management plan, some numerical representation of the importance of each goal is useful.

Results from the Darby-Cobbs Watershed Partnership are presented here as an example of the relative importance one stakeholder group assigned to each goal. To develop a set of numerical weights that represent the importance of each goal relative to the other goals, a workshop was held on October 29, 2002, with members of the partnership participating. The goal of the workshop was to work towards a consensus on a numerical set of weights that best represent the collective opinion on the importance of each goal. Each participant filled in a worksheet that described, as a percent, the individual contribution of each goal to the overall goal of watershed management. These sheets provided a variety of opinions on how the goals should be weighted, and served as a guide to a discussion on the relative importance of each goal. Through the group discussion, a consensus set of goal weights was developed that best represents the importance of each goal as defined by the stakeholders. Table 4-1 shows the weights assigned to each goal. The weights represent a percentage of the overall importance of each goal relative to all goals.

Table 4-1 Weights Assigned to Individual Goals by the Darby-Cobbs Watershed Partnership

Streamflow and Living Resources. Reduce the impact of urbanized flow on the living resources (increase baseflow and recharge, reduce impervious area and runoff peaks, improve stormwater ordinances).	**12**
Stream Habitat and Aquatic Life. Improve stream habitat and indices of aquatic integrity (improve physical habitat, benthic, fish, algae).	**9**
Stream Channels and Banks. Reduce streambank and stream channel deposition and scour to protect and restore the natural functions of aquatic habitat and ecosystems, streambanks, and stream channels (increase stabilized areas, reduce frequency of bankfull flow).	**7**
Flooding. Decrease flooding (improve stormwater management, trouble spots, inlet cleaning, floodplain management and structures).	**11**
Water Quality. Improve dry and wet weather stream quality (meet designated uses, prevent fish advisories).	**9**
Pollutant Loads. Decrease pollutant loads to surface waters (decrease runoff, SSO, septic tank, CSO, and debris loads).	**10**
Stream Corridors. Protect and restore stream corridors, buffers, floodplains, and natural habitats including wetlands.	**11**
Quality of Life. Enhance community environmental quality of life (protect open space, access and recreation, security, aesthetics, historical/cultural resources).	**12**
Stewardship. Foster community stewardship (increase awareness and responsibility, volunteer programs, education).	**11**
Coordination. Improve inter-municipal, inter-county, state-local, and stakeholder cooperation and coordination on a watershed basis.	**8**

For each watershed, after a series of broad-based goals was adopted by the stakeholder partnership, PWD developed a number of specifically measurable objectives and associated indicators for each goal so that progress toward achievement of these goals can be assessed as implementation takes place. These were also presented to watershed stakeholders for approval and adoption.

Prior to presenting the master set of goals to watershed stakeholders, PWD evaluated a number of existing plans for each watershed planning area in order to assemble a comprehensive list of "existing" stakeholder goal statements, which were then compared with PWD's master list. What has emerged in each watershed planning area is that PWD's goals, which are purposely broadly worded, are able to encompass the intent of each of the goals of the numerous plans as a subset because they are often of the same intent – but more geographically or project specifically focused, and can be fit neatly under the broad goal set.

PWD's "master goal set" has successfully been applied and accepted by stakeholders in five watershed planning processes city-wide thus far, and are the existing draft set for two ongoing planning initiatives. PWD has evaluated this goal set against the intent of their LTCPU commitment to see which goals will be complimented and/or addressed by the LTCPU (Table 4-2).

Table 4-2 Integrated Watershed Management Plan Goals

IWMP Goal	Is This Goal Addressed?		Notes
	Guidance for LTCP	*Green City, Clean Waters*	
Goal 1 – Streamflow and Living Resources. Improve stream habitat and integrity of aquatic life.		X	Restoration of a more natural water balance protects investments in restored stream channels and habitat, which in turn support healthy living resources.
Goal 2 – Instream Flow Conditions. Reduce the impact of urbanized flow on living resources.		X	Measures to control stormwater at the source restore a more natural water balance with minimal negative impact on water resources.
Goal 3 – Water Quality and Pollutant Loads. Improve dry weather stream quality to reduce the effects on public health and aquatic life.		X	Both the traditional LTCP approach and PWD's approach address pollutant loads and water quality standards in wet weather.
Goal 4- Water Quality and Pollutant Loads. Improve wet weather stream quality to reduce the effects on public health and aquatic life.	X	X	*Green City, Clean Waters* targets dry weather water quality.
Goal 5 – Stream Corridors. Protect and restore stream corridors, buffers, floodplains, and natural habitats including wetlands.		X	Restoration of stream channels, riparian areas, and wetlands restores habitat features necessary for healthy ecosystems.
Goal 6 – Flooding. Identify flood prone areas and decrease flooding by similar measures intended to support Goals 1, 2, and 4.			*Green City, Clean Waters* does not directly address flooding. Although out-of-bank flooding is uncommon in Philadelphia, basement flooding is a concern. These concerns are addressed separately by PWD's Storm Flood Relief program.
Goal 7 – Quality of Life. Enhance community environmental quality of life.		X	PWD's approach complements efforts to make urban communities greener and more inviting.
Goal 8 – Stewardship, Communication, and Coordination. Foster community stewardship and improve inter-municipal, inter-county, state-local, and stakeholder cooperation and coordination on a watershed basis.	X	X	PWD's public participation program directly involves the public and municipal officials in decisions and helps all stakeholders to understand the amenities that healthy urban water resources systems can provide. LTCP guidance also requires public participation.

4.4.3 LTCPU Goals

Goals of the LTCPU have been generated based on both the assessment of problems identified in the receiving waters (Section 4.1) and from the goals utilized by the IWMPs, as well as through alignment with the City's vision "Green City – Clean Waters." This vision seeks to unite the City with its water environment, creating a green legacy for future generations while incorporating a balance between ecology, economics and equity. Each goal is intended to improve the water resources system and help the community to recover a historical resource or amenity that has been impaired through urbanization.

Outlined below are the goals of the LTCPU aligned with the target that each will help to achieve:

Target A: Dry Weather Water Quality, Aesthetics, and Recreation

- A.1 Eliminate dry weather discharges from combined sewer systems to the maximum extent possible. Continue to correct any short-term issues such as blockages as soon as they are identified. Following implementation, CSOs will not cause or contribute to exceedance of water quality criteria for bacteria in dry weather.
- A.2 Control discharges of solids, floatables, and trash to receiving waters.
- A.3 Improve opportunities for water-based recreation under safe physical conditions.
- A.4 Support regional efforts to create safer, more accessible, more enjoyable waterfronts and stream corridors.

Target B: Healthy Living Resources in Streams/Rivers and Along Riparian Corridors

- B.1 Protect and restore stream corridors, buffers, floodplains, and natural habitats including wetlands. Following implementation of stream channel and habitat restoration measures, CSOs will not cause or contribute to erosion and habitat degradation in the tributaries.
- B.2 Restore tidal wetlands and wetland habitats.

Target C: Wet Weather Water Quality and Quantity

- C.1 Restore a more natural water balance between surface runoff, infiltration, and evaporation. In the tributaries, reduce the magnitude and duration of peak flows to protect investments in channel and habitat restoration.
- C.2 Reduce CSO volume, frequency, and length of discharge.
- C.3 Implement a phased approach to meeting appropriate wet weather bacteria criteria.

Stewardship and Community

- SC.1 Foster community stewardship and improve inter-municipal, inter-county, state-local, and stakeholder cooperation and coordination on a watershed basis.
- SC.2 Support regional efforts to create greener, more inviting urban communities.

5 Overview of the Long Term Control Plan Update (LTCPU)

5.1 Model Development Process and Tools

This section presents the tools, methods and development processes used in conducting numerical analyses of the LTCPU alternatives and options. Computer modeling and data processing provided the necessary means to evaluate and estimate the current CSO conditions throughout each watershed as well as to estimate the impact on CSO reduction from incorporating green stormwater infrastructure practices, implementing a variety of storage elements and sizing storage tunnels and conveyance pipes. Additional details on modeling tools employed can be found in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

Tools and methods were developed to conduct quality assurance checks on input data to the computer models and to the computer model parameters themselves. Supplemental hydrologic analyses and programs to aide in the quality assurance tasks and to bring parameter data current were created and used. These include calculations of Rainfall Dependent Inflow and Infiltration (RDI/I) and Directly Connected Impervious Area (DCIA) estimates based on collected flow monitor and updated GIS data, which were discussed in previous sections.

Inherited models from previous LTCP analyses were updated to ensure proper representation of the City's infrastructure after implementation of system modifications due to constructed projects since the previous LTCP model development (*e.g.*, Nine Minimum Controls, Capital Projects, etc). Calibration and validation of the updated baseline models were completed to verify model results were accurately simulating the observed data. From the baseline models, hydrologic features and hydraulic infrastructure were modified and/or added to represent various alternatives intended to mitigate CSOs within each watershed for evaluation within this LTCPU. To more accurately simulate concepts such as tree canopy interception or benefits produced from implementing green infrastructure throughout the City, other supplemental tools were created and subsequent analyses performed.

After model Quality Assurance/Quality Control (QA/QC), calibration and validation were completed and development of alternative model representations were created, it was necessary to organize and analyze the resulting data from these models in an efficient and consistent manner. All alternative and baseline model results were summarized with the same SAS post-processing tool in order to maintain consistency for result comparison purposes. Spreadsheet analyses were applied to a number of alternatives, such as the parallel interceptor and satellite treatment facility alternatives, to facilitate efficiency in determining the feasibility of these controls. All alternative results had the estimated costs associated with design layouts, design element dimensions, lengths, volumes and other parameters calculated with the use of a costing spreadsheet tool. The results produced from these analyses are presented in further detail in subsequent sections.

The following section describes the methods and programs used during the course of the LTCPU model development process. Baseline and alternatives model development details follow, which presents specific tasks and information required to build these models. The last section summarizes the alternatives analysis process.

5.2 Overview of Analysis Tools and Methods

This section briefly outlines the programs and other tools used in the development and assessment of current and potential alternatives for the LTCPU. The tools and analysis methods for the LTCPU may be categorized into the following sections:

- Precipitation analysis
- Monitored flow analysis
- Special analyses
- Hydrologic and hydraulic analysis
- GIS analysis
- Alternatives costing
- Economic impact model

5.2.1 Precipitation Analysis

PWD maintains a large collection of historical precipitation data and continues to collect current data through its 24 rain gage network, as well as the National Weather Service Cooperative Station located at the Philadelphia International Airport. The PWD rain gauge data are analyzed through extensive QA/QC procedures to identify bad or missing data and fill with nearby gauge data, and perform bias adjustment using a combination of Microsoft Excel and Access, and SAS software tools developed by PWD for these purposes.

The development of a typical year precipitation record to represent average annual hydrologic conditions over the Philadelphia area is critical for the evaluation of combined sewer system (CSS) performance for the LTCPU. Statistical analyses of the long-term record are performed using the Philadelphia International Airport data to determine the average frequency, volume, duration, and peak intensity of rainfall events. Similar analyses are performed on the bias adjusted PWD rain gauge data in order to identify periods requiring minor adjustment to represent long-term average conditions. Performing these analyses and adjustments required the use of NetSTORM in addition to data processing and analysis tools developed by PWD using Excel, Access and SAS software. More details on precipitation analysis can be found in Supplemental Documentation Volume 5: Precipitation Analysis.

NetSTORM is discussed in the following subsection.

5.2.1.1 NetSTORM

NetSTORM is CDM's computer program for rainfall and planning-level rainfall-runoff storage-treatment analysis. NetSTORM adapts selected algorithms originally included in the HEC-STORM (USACE, 1977) program into a modern interface, extends the HEC-STORM methodology to simulation of linked structures in a complex collection system, performs intensity – duration – frequency analysis (IDF) of precipitation data and disaggregates daily and hourly precipitation data to higher resolutions for use in rainfall – runoff modeling. While these functions and others included in the program have been explored and improved upon by other researchers, NetSTORM possesses a unique collection of tools for rapid assessment of precipitation data and urban runoff assessment. NetSTORM has been used in the development of the LTCPU for both evaluation of long-term rainfall IDF analyses and for screening level evaluation of CSS performance.

5.2.2 Monitored Flow Analysis

Efficiently analyzing collected flow data is equally as important as the precipitation data with regard to shaping the LTCPU. Applying quality control measures to the data and disaggregating the hydrograph into specific components to more accurately define how and when rainfall and runoff enter the CSS are an integral part of the development process. The tools used to create a set of flow data to calibrate and build the LTCPU baseline and alternative models included quality assurance spreadsheets and CDM SHAPE software. RTK analysis spreadsheets were also created – RTK parameters being three values used to define a unit hydrograph. Specifically, they are the ratio of rainfall entering the sewer system (R), the time elapsed to reach the peak of the unit hydrograph (T) and the ratio of the length of the recession limb of the unit hydrograph to the time to peak (K). These three tools are discussed in further detail below.

5.2.2.1 QA/QC Spreadsheets

Flowmeter data collected at a variety of strategically placed locations throughout the City were imported into template QA/QC spreadsheets where missing, errant or otherwise unusable data could be identified, flagged and either removed or filled using averaging techniques. The spreadsheet is a facilitating source for organizing, documenting and fixing monthly flow data into a more useful form. The spreadsheet allows the flow data to be plotted and qualitatively assessed (alongside quantitative analyses) for anomalies that may have otherwise gone unnoticed.

The spreadsheets also allow for easy recognition of flowmeters requiring maintenance. For situations where a meter produced unusable data for extended periods of time, the data was flagged within the spreadsheet and data from that particular time period was not used in calibration assessments.

5.2.2.2 SHAPE Software

SHAPE is designed to manipulate a complete series of flow monitoring data. The program uses a Microsoft Access database to contain all the data used in RDI/I analyses. Data preparation features allow flow and rainfall monitoring data to be imported from several sources into the database. Once flow and rainfall data are imported into the database, the program offers the ability to manipulate the raw data. For instance, missing flow data can be filled in by interpolation. Once these data have been imported and altered, it is not necessary to further manipulate the raw flow and rain data again.

After flow and rain data are present in the database, dry weather evaluations allow dry weather weekend and weekdays to be identified from the period of record. The weekend and weekday dry weather flow patterns are different and require individual evaluation. The selected days with normal dry weather flows are used to determine the average, maximum and minimum dry weather flows for a monitoring location. The dry weather flows include groundwater infiltration (GWI) and base wastewater flows (BWF). Average weekday and weekend day dry weather flow hydrographs are computed, which are then subtracted from observed flows to determine the RDI/I flows during rainfall events.

Wet weather flow evaluations allow the determination of RDI/I flow volumes and peak flows for individual events. SHAPE computes the percentage of rainfall over the sewered area that enters the sewer system, or the total R-value. SHAPE also allows the fitting of triangular unit hydrograph parameters to simulate RDI/I flows from observed rainfall using the SHAPE methodology. For the purposes of this LTCPU, a more specialized set of spreadsheet tools (described below) were employed to develop the RTK values incorporating the use of a unit hydrograph methodology through an iterative process. Figure 5-1 is a flowchart of the processing steps used within the SHAPE software.

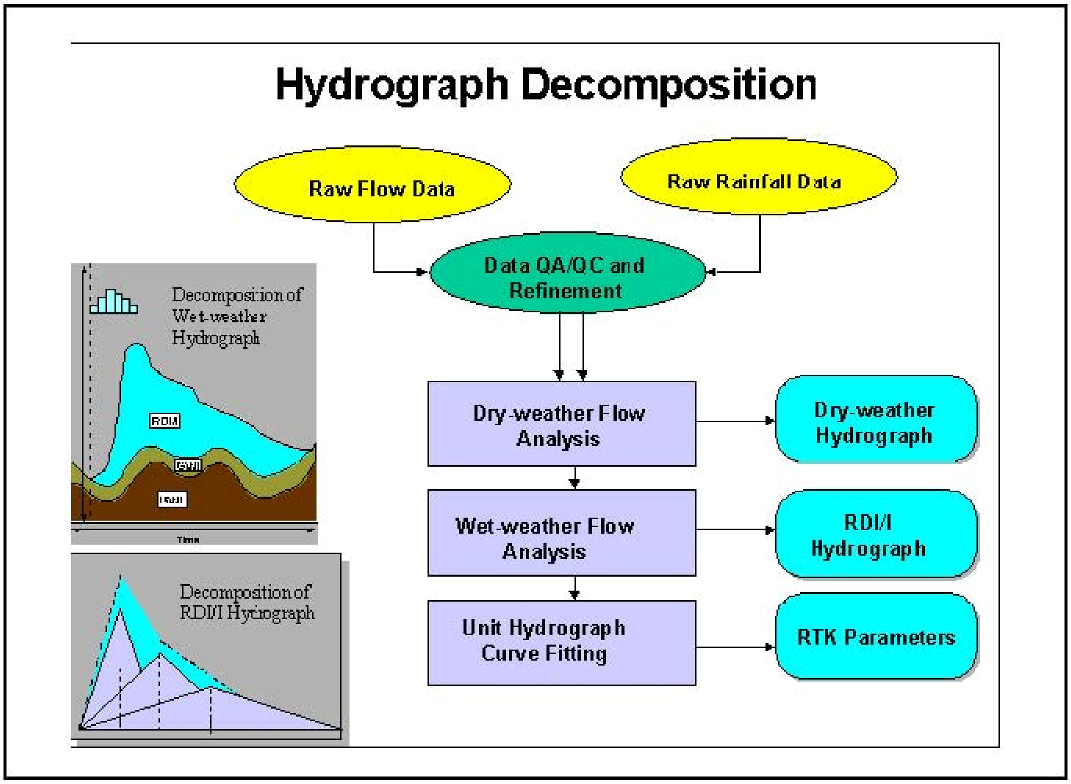


Figure 5-1 Processing Steps and Outputs from the SHAPE Software

5.2.2.3 RTK Analysis Spreadsheets

The RTK method is similar to the unit hydrograph methods commonly used to simulate flows in stormwater runoff analyses. This method is based on fitting three triangular unit hydrographs to an actual RDI/I hydrograph derived from flow meter data. A unit hydrograph is defined as the flow response that results from one unit of rainfall during one unit of time. Figure 5-2 presents a visualization of the RTK hydrograph and its components.

The development of the R, T and K elements to characterize RDI/I for sanitary sheds (discussed in greater detail in Section 5.3) was a multi-stage analysis process requiring the creation and use of two spreadsheet tools to analyze the output produced from the SHAPE software described above. The first analysis tool compares the observed temporary flowmeter data with simulated RTK responses to determine a first cut estimation of the RTK parameters at each site having sufficient data to analyze. The purpose of this analysis was to determine which flow monitoring sites provided the most consistent and fewest errors in the data for use as templates to distribute to the remaining flow monitoring sites. These sites were used as the templates and foundations for the second phase of the RTK processing within the second spreadsheet tool. The template data were used to adjust the remaining flow monitoring sites to more closely follow seasonal and monthly RDI/I variations. Following is a summary of the spreadsheets, the data used in them and the processing steps. Further details can be found in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

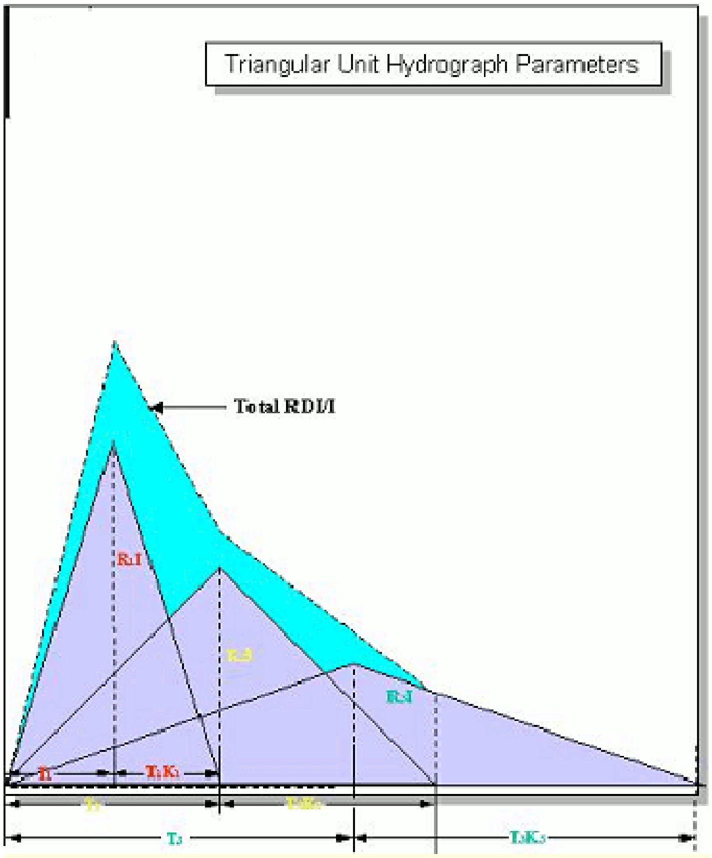


Figure 5-2 Decomposition of RDI/I Hydrograph into Three Unit Hydrographs with SHAPE Software

5.2.2.4 RTK Template Analysis Spreadsheet

The output from the SHAPE analysis – described previously in Section 5.2.2.2 – serves as input to the RTK Template Analysis Spreadsheet. The total R-value for defined event boundaries, which is the total fraction of RDI/I volume for the event, is divided into three parts representing the fast, medium and slow hydrograph response of the time series. T- and K-values are also defined for each response. The simulated RTK values are plotted and compared against observed flow data for each individual event. A best-fit volume line and scatter plot of the total event volume are created within the spreadsheet to show the tightness of fit of the individual events to the best-fit line between the observed and simulated RDI/I responses.

Based on the time-series comparison and the best-fit plot, the RTK values are adjusted and the data re-plotted. When a match has been achieved for one event, a new event for the same flowmeter site is plotted to compare the hydrographs and best-fit scatter plot volume with the new RTK values. If the simulated data does not satisfactorily match with observed data, adjustments to the RTK values continue. This process is iterative and continues until the best possible matches can be achieved among all the observed event data.

5.2.2.5 RTK Seasonal and Monthly Variation Spreadsheet

The output data from the previously described spreadsheet was used as input into the seasonal and monthly adjustment spreadsheet tool. Each month's RTK values were imported into the spreadsheet. The unit hydrograph is plotted for the imported data and adjusted to remove any anomalies that may produce a complex hydrograph or, in other words, more than one peak. For the template sites a month is chosen that has the most reliable data available to use as a datum to determine the seasonal variation. The spreadsheet calculates the ratios for the monthly values first and then uses those values to apply the seasonal ratios to calculate the final set of R-values.

Table 5-1 shows the ratio information for Site 44. The monthly ratios are determined by dividing the total R value for that month by the individual R1 (fast response value), R2 (medium response value) and the R3 (slow response value). To determine the seasonal ratio, the month with the most data and best correlation results as compared to the observed data was chosen for each template site. For Table 5-1, March was the chosen month. The R-values for every other month were divided by the March R-values.

Table 5-1 Ratio Information for Site 44

Month	R1	R2	R3	Total R (R1+R2+R3)	Monthly Ratios			Seasonal Ratios		
					R1/ Total R	R2/ Total R	R3/ Total R	R1/ March R1	R2/ March R2	R3/ March R3
January	0.0081	0.0074	0.0070	0.0225	0.3593	0.3292	0.3114	1.0096	1.0571	1.0769
February	0.0081	0.0074	0.0070	0.0225	0.3593	0.3292	0.3114	1.0096	1.0571	1.0769
March	0.0080	0.0070	0.0065	0.0215	0.3721	0.3256	0.3023	*	*	*
April	0.0080	0.0070	0.0065	0.0215	0.3721	0.3256	0.3023	1	1	1
May	0.0075	0.0065	0.0060	0.0200	0.3750	0.3250	0.3000	0.9375	0.9286	0.9231
June	0.0075	0.0051	0.0055	0.0181	0.4142	0.2812	0.3046	0.9375	0.7273	0.8485
July	0.0075	0.0051	0.0055	0.0181	0.4142	0.2812	0.3046	0.9375	0.7273	0.8485
August	0.0075	0.0051	0.0055	0.0181	0.4142	0.2812	0.3046	0.9375	0.7273	0.8485
September	0.0078	0.0057	0.0061	0.0196	0.3973	0.2917	0.3110	0.9750	0.8182	0.9394
October	0.0078	0.0064	0.0061	0.0203	0.3848	0.3139	0.3012	0.9750	0.9091	0.9394
November	0.0080	0.0070	0.0065	0.0215	0.3721	0.3256	0.3023	1	1	1
December	0.0081	0.0070	0.0065	0.0216	0.3743	0.3244	0.3012	1.0096	1	1

5.2.3 Special Analyses

A number of concept specific analyses were done for this LTCPU requiring creation of a set of tools to be built in order to interpret the preliminary results prior to fully implementing the conceptual model within SWMM4. These tools were meant to reduce model development time, while at the same time facilitate development of a sufficient "first-cut" estimation for a number of control alternatives that incorporate green infrastructure at varying levels of implementation.

5.2.3.1 Capture Program

The capture program was written within the FORTRAN environment and is used to calculate the volume captured and sent to the water pollution control plants (WPCPs) as well as the volume that overflows into the receiving body from a regulator. The capture program uses an input file to identify the dry weather capture and the wet weather overflow pipes associated with each regulator for which the capture calculations are performed. An inter-event time is also specified for event generation. For the LTCPU the inter-event time is set to six hours.

The output from the capture program is the capture volume, overflow volume, the respective storm and sanitary portion of the captured volume, overflow volumes and percent capture for each regulator for each of the respective wet weather events. Percent capture is determined by summing the total "captured" flow during a wet weather event, which is the volume of flow directed to the interceptor and ultimately to the WPCP. If all flow entering the regulating chamber is diverted to the interceptor, it is considered 100% capture. For events where a portion of the total flow entering the regulating chamber is overflowed, the captured volume is divided by the total volume entering the regulator to determine the percent capture. The results from the capture program may be further summarized to annual numbers using an external program written in the SAS environment.

5.2.3.2 SAS End-of-Pipe (EOP) Processing Tool

A SAS program was written to analyze the treatment rates required at each of the outfalls in the CSS so that a targeted overflow frequency can be achieved. For example, if an outfall overflows fifty (50) times a year and the treatment capacity exists to treat the third largest overflow among the fifty (50), then there will be only two storm events that will cause an overflow and the rest of the 48 events can be treated.

The specific steps followed to identify the treatment rate requirements are available in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling. Essentially, the overflow volume produced for every outfall and the output from the capture program described in Section 5.2.3.1 are used as input to the SAS program. These data are summarized into annual overflow numbers for a respective overflow goal (1 to 25 overflows/year) to be used in preliminary estimates of required satellite treatment and parallel interceptor alternatives analysis.

5.2.3.3 Parallel Interceptor Transmission Spreadsheet

The purpose of this tool is to determine parallel pipe segment dimensions using the existing interceptor as a guide prior to building a conceptual model for specific alternatives having a certain green-infrastructure implementation level. The tool is spreadsheet based and does not simulate flow through pipes, rather, it serves as a first cut estimation of pipe sizing for all possible parallel interceptor alternatives at every overflow goal between the values of 1 and 25 overflows per year for each potential level of green-infrastructure implementation. The parallel conveyance pipes use the slope of the respective existing interceptor segment and the cumulative overflow at that regulator (output produced from the SAS EOP tool discussed in the previous section) within the Manning's flow equation to calculate a pipe dimension. The spreadsheet tool also sums the total peak flow and resulting CSO (untreated overflow) volume for each system for every overflow goal. Details of this spreadsheet tool are available in the Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

5.2.3.4 Parallel Interceptor with Satellite Treatment Spreadsheet

Similar to the Parallel Interceptor Transmission spreadsheet described in Section 5.2.3.3 above, the Parallel Interceptor with Satellite Treatment is a spreadsheet-based tool that does not simulate flow through pipes; instead, it sizes pipes based on peak flow values and existing interceptor slope values for overflow goals of 1, 4, 10 and 25 overflows per year. To determine the pipe sizes, the spreadsheet uses the Manning's equation in the same manner as outlined above. Where the two spreadsheets diverge is in the calculations to determine satellite treatment locations. Generally, the Parallel Interceptor with Satellite Treatment spreadsheet sums the total peak overflow value for a particular interceptor system and places the satellite treatment unit at the regulator where half the cumulative total peak flow for the system is reached or exceeded.

There are locations predetermined to be suitable for placing and constructing satellite treatment facilities specific to each drainage district. For these situations, the automated process of locating the satellite treatment location within the spreadsheet is manually overridden. The same procedures for calculating pipe dimensions are applied in this situation. More details of this spreadsheet tool are available in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

5.2.4 Hydrologic and Hydraulic Analysis Tools

5.2.4.1 Storm Water Management Model Version 4 (SWMM4)

The US EPA SWMM4 was used to develop the watershed-scale model for the LTCPU. The components of the SWMM4 model used in the development of the Philadelphia watershed and wastewater conveyance model were the RUNOFF and EXtended TRANsport (EXTRAN) (Huber and Dickinson, 1998) modules. The physical parameters and their initial estimations for each module are discussed individually in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

5.2.4.2 RUNOFF Module

The RUNOFF module was developed to simulate the quantity and quality of runoff in a drainage basin and the routing of flows and contaminants to sewers or receiving waters. The program uses a precipitation (rainfall or snowfall) hyetograph to perform a step by step accounting of infiltration losses in pervious areas, surface detention, overland flow, channel flow and water quality constituents leading to the calculation of one or more hydrographs and/or pollutagraphs at a certain geographic point such as a sewer inlet. The driving force of the RUNOFF module is precipitation, which may be a continuous record, single measured event, or artificial design event. The RUNOFF module also simulates RDI/I in separate sanitary areas using three sets of unit hydrographs defined by R, T and K – described in Section 5.2.2 above – values to represent the shape of the RDI/I hydrograph response to the input precipitation hyetograph.

The RUNOFF module requires the input of several physical parameters to determine the rainfall-runoff response from modeled combined-sewer subcatchments. These include:

- Subcatchment area
- Subcatchment width (used to determine overland flow length)
- Percent DCIA (effective impervious area)
- Subcatchment ground slope
- Manning's roughness coefficient for pervious and impervious areas
- Depression storage for pervious and impervious areas
- Soil infiltration parameters
- RDI/I parameters or user input hydrographs for sanitary sheds
- Baseflow data
- Precipitation data
- Evaporation data

5.2.4.3 EXTRAN Module

The EXTRAN module was developed to simulate hydraulic flow routing for open channel and/or closed conduit systems. The EXTRAN module receives hydrograph inputs at specific nodal locations by interface file transfer from an upstream module (*e.g.*, the RUNOFF module) and/or by direct user input (*e.g.*, user defined hydrographs for sanitary sheds). The module performs dynamic routing of stormwater and wastewater flows through drainage systems and receiving streams. To calculate the flow in the sewers SWMM4 uses values for the following variables:

- Pipe data including shape, cross-sectional area, length, width, depth, hydraulic radius and slope
- Junction data including ground and invert elevations, storage volume (if necessary) and baseflow
- Orifice data (if necessary) including type, cross-sectional area, discharge coefficient, invert elevation, depth and width
- Weirs including length, width and a weir coefficient
- Pump data including type and pumping rate
- Outfalls

5.2.5 GIS Analysis Tools (ArcTools)

ArcGIS Hydro is a collection of tools that analyzes various GIS layers for hydrologic modeling. It provides a consistent method for developing watershed and stream networks by analyzing digital elevation models (DEMs). Terrain pre-processing is performed on the DEMs. For example, one function performed during the terrain processing is sink pre-processing where unnatural depressions are filled. Flow direction, flow accumulation, stream definition, drainage line delineation and catchment polygon processing result in a stream and watershed network. With the network created watersheds can be generated from any point on the network.

ArcGIS and its components were used in nearly every aspect of LTCPU data processing. It was used extensively in analyses involving impervious cover definitions, highway and waterfront disconnection analyses and all subcatchment area delineation adjustments involved in the model development for both the baseline and generic green-infrastructure models.

5.2.6 Alternatives Costing Tool (PWD Capital Projects Cost Estimating Tool)

The Alternatives Costing Tool (ACT) provides planning-level cost estimates to facilitate the evaluation and comparison of preliminary alternatives and the preparation of feasibility reports. The ACT is an EXCEL spreadsheet based program. It calculates capital and operation and maintenance (O&M) costs of wet weather conveyance, storage and treatment facilities in one of two ways. It scales complete treatment facility costs based on costing algorithms developed from evolving and expanding national data sets and other regional capital and O&M cost data. Otherwise, it assembles construction and O&M costs from smaller components (*e.g.*, material cost of a particular type and size of pipe, energy cost for pumping at a specific total dynamic head, flow rate, duration and electrical rate, etc). Further details can be found in Supplemental Documentation Volume 3: Basis of Cost Opinions. Key outputs from the ACT include:

- Current year capital cost
- Current year O&M costs
- Present worth based on capital costs and projected O&M costs

A user of the ACT develops control alternatives, including conceptual level determinations of facility size, type and configuration. This information is then entered into the costing tool through standardized templates. All assumptions and calculations are viewable by the user. The ACT has a number of input parameters that use fixed values (*e.g.*, the discount rate for present worth calculations). The user is able to override these fixed values.

The following control technologies were included in the ACT and were used to develop opinions of cost:

Source Controls

- Land-based stormwater management
  - Green roofs
  - Porous pavement
  - Bioretention and similar surface vegetated practices
  - Subsurface infiltration

Transmission

- Pump stations
- Open cut pipe
  - Gravity sewer
  - Force main
- Short-bore tunnel (trenchless)
  - Microtunneling
  - Pipe jacking

Storage

- Conventional tunnels (storage/conveyance)
- Tank storage

Treatment

- Retention treatment basins

The following control technologies were included in the ACT, but were not used to develop opinions of cost:

Not Used

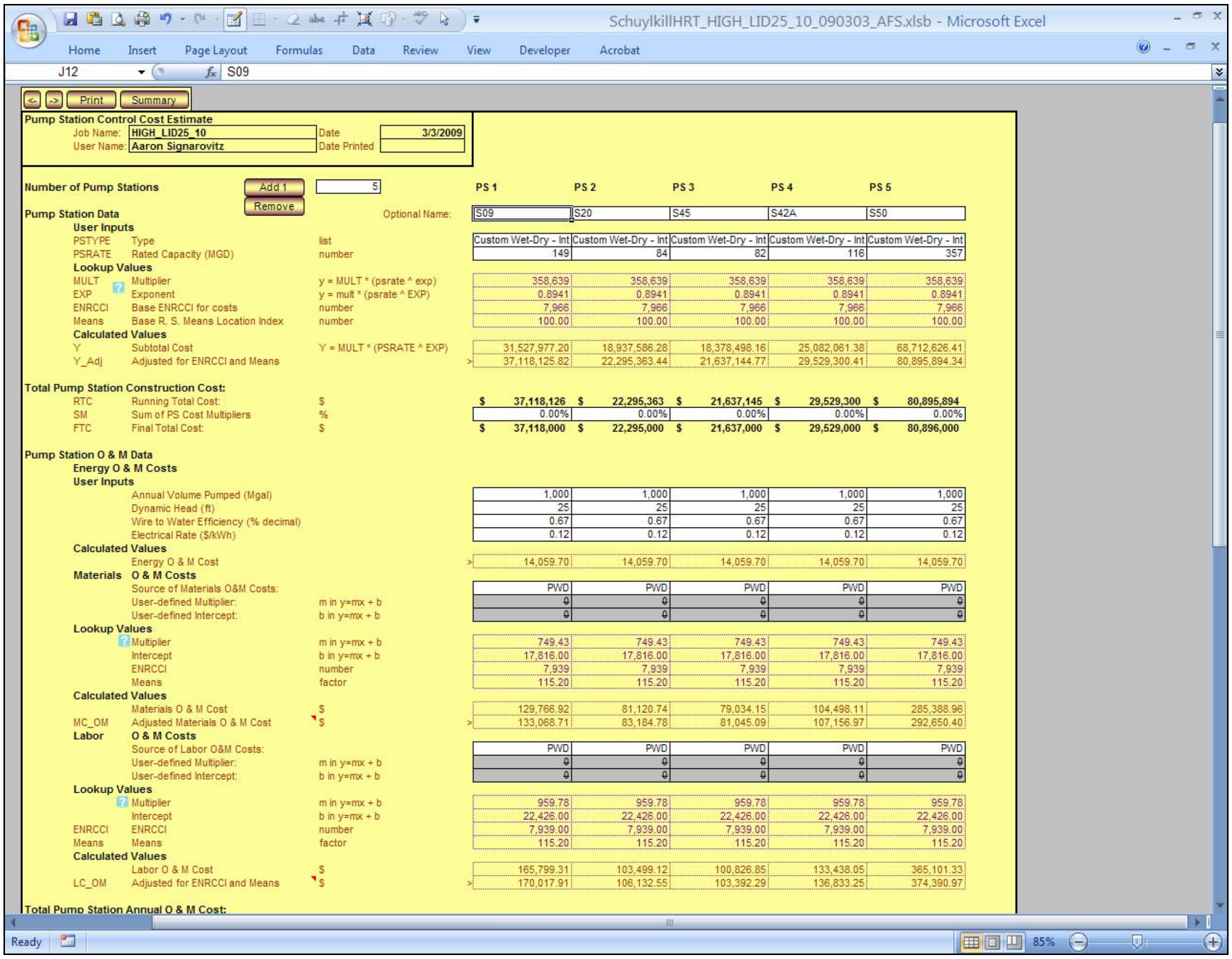
- Private and municipal I/I reduction
- Sewer separation
- Vortex separation
- High rate clarification
- Screening
- Disinfection

Other opinions of cost were developed outside of the ACT including sewer separation and satellite treatment. Further details on costing methods for all controls can be found in Supplemental Documentation Volume 3: Basis of Cost Opinions.

5.2.6.1 Input Formats and Organization

The ACT is organized into groups by control technology; these groups within the ACT are called modules. Modules can contain large numbers of individual items (*e.g.*, multiple pump station facilities, multiple pipeline segments, etc.). Figure 5-3 shows an example of multiple items in the

Pump Station Module. Figure 5-4 shows an example of multiple control technology costs that make up an alternative cost.


SchuylkillHRT_HIGH_LID25_10_090303_AFS.xlsb - Microsoft Excel

Pump Station Control Cost Estimate

Job Name: HIGH_LID25_10 | Date: 3/3/2009

User Name: Aaron Signarovitz | Date Printed:

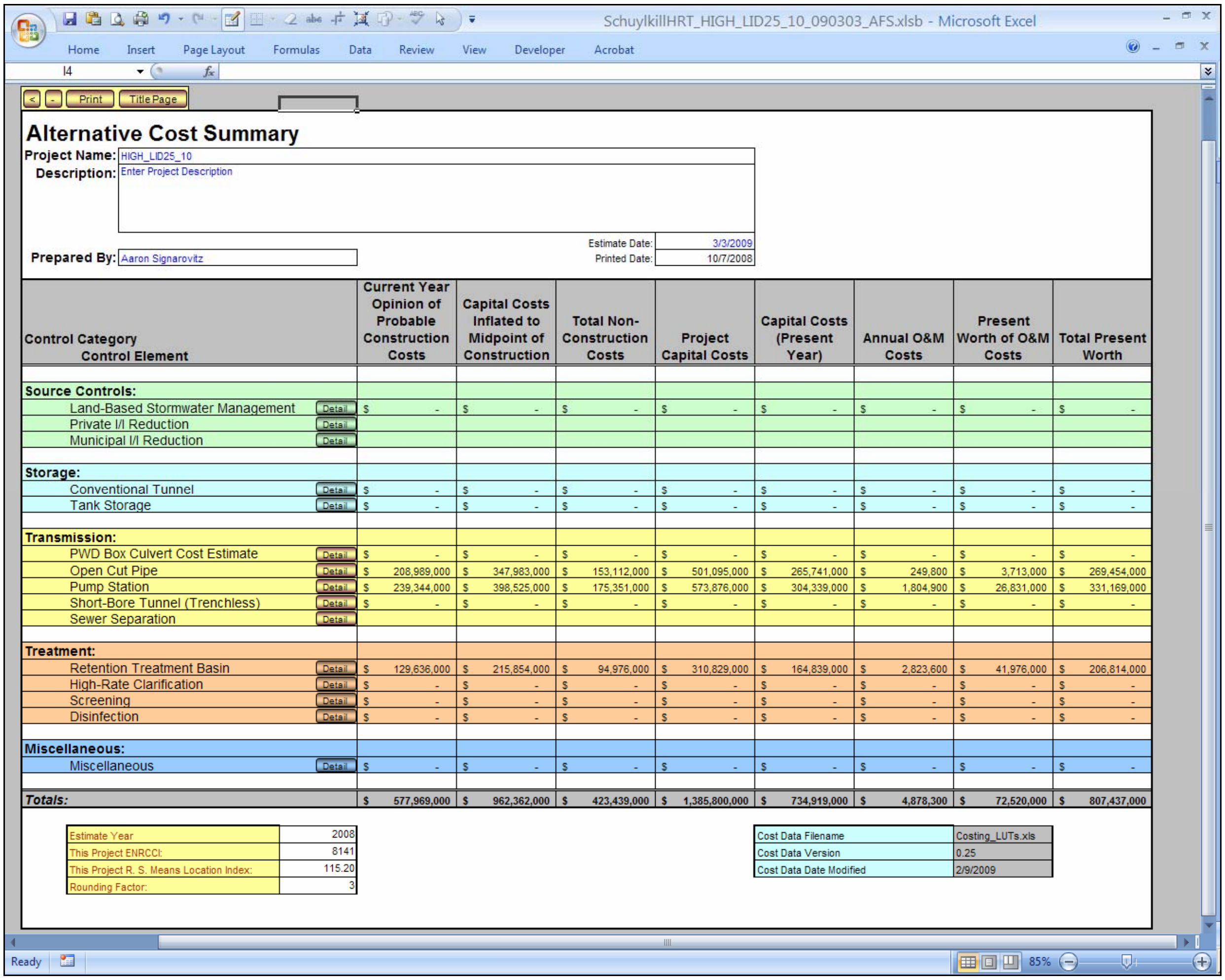
Number of Pump Stations: 5

			PS 1	PS 2	PS 3	PS 4	PS 5
Pump Station Data		Optional Name:	S09	S20	S45	S42A	S50
User Inputs							
PSTYPE	Type	list	Custom Wet-Dry - Int	Custom Wet-Dry - Int	Custom Wet-Dry - Int	Custom Wet-Dry - Int	Custom Wet-Dry - Int
PSRATE	Rated Capacity (MGD)	number	149	84	82	116	357
Lookup Values							
MULT	Multiplier	y = MULT * (psrate ^ exp)	358,639	358,639	358,639	358,639	358,639
EXP	Exponent	y = mult * (psrate ^ EXP)	0.8941	0.8941	0.8941	0.8941	0.8941
ENRCCI	Base ENRCCI for costs	number	7,966	7,966	7,966	7,966	7,966
Means	Base R. S. Means Location Index	number	100.00	100.00	100.00	100.00	100.00
Calculated Values							
Y	Subtotal Cost	Y = MULT * (PSRATE ^ EXP)	31,527,977.20	18,937,586.28	18,378,498.16	25,082,061.38	68,712,626.41
Y_Adj	Adjusted for ENRCCI and Means		37,118,125.82	22,295,363.44	21,637,144.77	29,529,300.41	80,895,894.34
Total Pump Station Construction Cost:							
RTC	Running Total Cost:	$	$ 37,118,126	$ 22,295,363	$ 21,637,145	$ 29,529,300	$ 80,895,894
SM	Sum of PS Cost Multipliers	%	0.00%	0.00%	0.00%	0.00%	0.00%
FTC	Final Total Cost:	$	$ 37,118,000	$ 22,295,000	$ 21,637,000	$ 29,529,000	$ 80,896,000
Pump Station O & M Data							
Energy O & M Costs							
User Inputs							
	Annual Volume Pumped (Mgal)		1,000	1,000	1,000	1,000	1,000
	Dynamic Head (ft)		25	25	25	25	25
	Wire to Water Efficiency (% decimal)		0.67	0.67	0.67	0.67	0.67
	Electrical Rate ($/kWh)		0.12	0.12	0.12	0.12	0.12
Calculated Values							
	Energy O & M Cost		14,059.70	14,059.70	14,059.70	14,059.70	14,059.70
Materials	**O & M Costs**						
	Source of Materials O&M Costs:		PWD	PWD	PWD	PWD	PWD
	User-defined Multiplier:	m in y=mx + b	0	0	0	0	0
	User-defined Intercept:	b in y=mx + b	0	0	0	0	0
Lookup Values							
	Multiplier	m in y=mx + b	749.43	749.43	749.43	749.43	749.43
	Intercept	b in y=mx + b	17,816.00	17,816.00	17,816.00	17,816.00	17,816.00
	ENRCCI	number	7,939	7,939	7,939	7,939	7,939
	Means	factor	115.20	115.20	115.20	115.20	115.20
Calculated Values							
	Materials O & M Cost	$	129,766.92	81,120.74	79,034.15	104,498.11	285,388.96
MC_OM	Adjusted Materials O & M Cost	$	133,068.71	83,184.78	81,045.09	107,156.97	292,650.40
Labor	**O & M Costs**						
	Source of Labor O&M Costs:		PWD	PWD	PWD	PWD	PWD
	User-defined Multiplier:	m in y=mx + b	0	0	0	0	0
	User-defined Intercept:	b in y=mx + b	0	0	0	0	0
Lookup Values							
	Multiplier	m in y=mx + b	959.78	959.78	959.78	959.78	959.78
	Intercept	b in y=mx + b	22,426.00	22,426.00	22,426.00	22,426.00	22,426.00
ENRCCI	ENRCCI	number	7,939.00	7,939.00	7,939.00	7,939.00	7,939.00
Means	Means	factor	115.20	115.20	115.20	115.20	115.20
Calculated Values							
	Labor O & M Cost	$	165,799.31	103,499.12	100,826.85	133,438.05	365,101.33
LC_OM	Adjusted for ENRCCI and Means	$	170,017.91	106,132.55	103,392.29	136,833.25	374,390.97
Total Pump Station Annual O & M Cost:							

Figure 5-3 Example ACT Pump Station Module with Multiple Items

5.2.6.2 Land-Based Stormwater Management Module Overview

There are four different land-based stormwater management control types that are listed as follows: green roofs, porous pavement, bioretention and subsurface infiltration. The construction costs for each control type are divided into two different construction types: retrofit and redevelopment. Retrofit costs include the full cost of installing a control technology at an existing location, whereas redevelopment costs represent a cost savings that can occur when installation is conducted concurrently with traditional building activities (*e.g.*, sidewalk restoration). Construction and O&M costs are based on materials and labor required to construct controls. For large-scale, long-term planning purposes, engineering cost opinions are normalized on a per-acre basis.



SchuylkillHRT_HIGH_LID25_10_090303_AFS.xlsb - Microsoft Excel

Alternative Cost Summary

Project Name: HIGH_LID25_10

Description: Enter Project Description

Prepared By: Aaron Signarovitz

Estimate Date: 3/3/2009

Printed Date: 10/7/2008

Control Category / Control Element	Current Year Opinion of Probable Construction Costs	Capital Costs Inflated to Midpoint of Construction	Total Non-Construction Costs	Project Capital Costs	Capital Costs (Present Year)	Annual O&M Costs	Present Worth of O&M Costs	Total Present Worth
Source Controls:								
Land-Based Stormwater Management	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Private I/I Reduction								
Municipal I/I Reduction								
Storage:								
Conventional Tunnel	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Tank Storage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Transmission:								
PWD Box Culvert Cost Estimate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Open Cut Pipe	$ 208,989,000	$ 347,983,000	$ 153,112,000	$ 501,095,000	$ 265,741,000	$ 249,800	$ 3,713,000	$ 269,454,000
Pump Station	$ 239,344,000	$ 398,525,000	$ 175,351,000	$ 573,876,000	$ 304,339,000	$ 1,804,900	$ 26,831,000	$ 331,169,000
Short-Bore Tunnel (Trenchless)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Sewer Separation								
Treatment:								
Retention Treatment Basin	$ 129,636,000	$ 215,854,000	$ 94,976,000	$ 310,829,000	$ 164,839,000	$ 2,823,600	$ 41,976,000	$ 206,814,000
High-Rate Clarification	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Screening	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Disinfection	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Miscellaneous:								
Miscellaneous	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Totals:	$ 577,969,000	$ 962,362,000	$ 423,439,000	$ 1,385,800,000	$ 734,919,000	$ 4,878,300	$ 72,520,000	$ 807,437,000

Estimate Year	2008
This Project ENRCCI:	8141
This Project R. S. Means Location Index:	115.20
Rounding Factor:	3

Cost Data Filename	Costing_LUTs.xls
Cost Data Version	0.25
Cost Data Date Modified	2/9/2009

Figure 5-4 Example ACT Alternative Cost

5.2.6.3 Pump Station Facility Module Overview

The pump station module represents pump station facility construction and O&M costs. The construction costs are comprised of two different wastewater pump types: submersible and custom built wet-dry well. A range of cost curves are presented for each pump type based on the total dynamic head and use of standby power. The key input used to calculate construction cost is pump station flow rate capacity. The key inputs used to calculate O&M include: annual volume pumped, total dynamic head, wire to water pump station efficiency and electrical rate.

5.2.6.4 Open Cut Pipe Module Overview

The open cut pipe module estimates the complete construction and O&M cost for pipes installed through the open cut method. The total construction costs are assembled through many smaller component costs. It can estimate construction costs for a range of pipe features and additional cost factors, which are listed as follows:

- Pipe features
    - Size
    - Material

  - Depth to invert
  - Circular, or box shape
  - Length in street or through open land
  - Length in soil or rock
- Additional cost items
  - Manholes
  - Service laterals
  - Utility crossing
  - Curb and sidewalk restoration
  - Traffic control
  - Dewatering
  - Flow maintenance
- Additional cost placeholders (calculated outside of ACT or in another module)
  - Railroad crossing costs
  - Stream crossing costs
  - Additional force main costs
  - Miscellaneous

The key inputs used to calculate construction cost include: pipe shape, pipe material, length (in street/out of street), average depth to pipe invert, percent rock excavated, number of manholes, manhole diameter and others. The key inputs used to calculate O&M costs include length of pipe and number of manholes.

5.2.6.5 Short-Bore Tunnel (Trenchless) Module Overview

The short-bore tunnel (trenchless) module estimates construction and O&M cost for pipes installed through trenchless methods. The construction costs were comprised of two trenchless methods: microtunneling and pipe jacking. The key inputs used to calculate construction costs include: pipe size, pipe material, laying conditions (*i.e.*, soil, rock, mixed), pipe length between pits, pit type (*i.e.*, jacking or receiving), pit depth in soil, and pit depth in rock. The key inputs used to calculate O&M costs include length of pipe and number of manholes.

5.2.6.6 Conventional Tunnels (Storage/Conveyance) Module Overview

The conventional tunnel module is used to list complete construction and O&M costs for large diameter conventional tunnels, dewatering pump stations and secondary tunnel structures. The cost estimation for conventional tunnels is performed with supplementary spreadsheets outside of the ACT; the results are copied or linked into the conventional tunnel module. Cost estimation of conventional tunnels requires significant geotechnical data and expertise.

5.2.6.7 Tank Storage Module Overview

The tank storage module represents complete tank storage facility construction and O&M costs. The key input used to calculate construction cost is storage tank volume. The key inputs used to calculate O&M include storage tank volume and labor rates.

5.2.6.8 Retention Treatment Basins Module Overview

The retention treatment basin module represents complete retention treatment facility construction and O&M costs. The key inputs used to calculate construction cost include peak treatment flow rate and design detention time. The key inputs used to calculate O&M include: peak treatment flow rate, design detention time, labor rates, annual non-event hours and annual event hours.

5.2.7 Economic Impact Model

The US EPA suggests that a financial capability assessment should be included in the CSO LTCPU in order to establish the burden of compliance on both ratepayers and the permittee. The purpose of the financial capability assessment is twofold.

First, US EPA allows flexibility in scheduling completion of CSO compliance measures, based on the financial capability of the area served. The results of the capability assessment serve as documentation for negotiating enforcement orders and scheduling implementation of CSO-related projects with US EPA. Second, a financial capability assessment is the basis for determining funding needs by agencies providing loan and grant monies for capital projects

US EPA suggests a two-phase approach to a financial capability assessment. The first phase is the calculation of a residential indicator and the second phase is the analysis of the permittee's financial capability indicator.

The residential indicator is the percentage of median household income expended on wastewater and stormwater treatment. The financial capability indicator is an assessment of the permittee's debt burden, socioeconomic conditions and financial operations. These two measures are subsequently entered into a financial capability matrix, suggested by US EPA, to determine the level of financial burden that wastewater/stormwater treatment and CSO compliance measures will place on residential customers and the permittee.

In addition to following guidelines for these two measures, US EPA encourages inclusion of any information that would have a financial impact on CSO compliance by the permittee in the capability report. This assessment, therefore, includes extensive discussion of socioeconomic trends in the Philadelphia area because of the financial challenges that the region faces.

5.3 Baseline Model Development

Development of the baseline model for the LTCPU was important as it is the foundation from which all alternatives were built and results compared. Accurately simulating the current hydrologic conditions and hydraulic infrastructure was essential to producing valuable and reliable results. The methods and input data utilized in order to create the baseline model with respect to the hydrology, hydraulics and the calibration and validation, are discussed in the subsections following.
More details on the baseline model development subsections can be found in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

5.3.1 Hydrologic Model Development

The baseline model was developed using the US EPA SWMM4 software discussed in previous sections. The RUNOFF module in SWMM4 requires the input of several physical parameters to determine the rainfall-runoff response from modeled combined-sewer and separate sanitary sewer subcatchments. To reiterate from the previous section, these include:

- Subcatchment area
- Subcatchment width (used to determine overland flow length)
- Percent DCIA (effective impervious area)
- Subcatchment ground slope
- Manning's roughness coefficient for both pervious and impervious areas
- Depression storage for both pervious and impervious areas (initial abstraction)
- Soil infiltration parameters
- RDI/I parameters
- Baseflow ranges
- Precipitation input data
- Evaporation input data
- Temperature input data and snowmelt

A brief description of each parameter and the source data follow in the subsections below.

5.3.1.1 Subcatchment Area

Natural stormwater drainage subcatchment area can be determined by constructing drainage divides on topographic maps and is dependent upon the detail of the topographic information. Combined sewer subcatchment area is determined based on detailed sewer plats within the City and the topographic maps needed to determine surface drainage to sewer inlet locations. The delineation of sanitary sewer subcatchment area both inside and outside of the City is based solely on detailed sewer plans. The complete hydrologic model consists of 2098 subcatchments representing the entire PWD service area.

5.3.1.2 Subcatchment Width

The width of the subcatchment is the physical width of overland flow. Since real subcatchments are not rectangular with properties of symmetry and uniformity, it is necessary to adopt other procedures to obtain the width for more general cases. This is important because if the slope and roughness are fixed, the width can be used to alter the hydrograph shape. For the PWD LTCPU CSS models, width was initially taken to be double the square root of the subcatchment's area and later treated as a calibration parameter.

5.3.1.3 Percent DCIA

The percent imperviousness of a subcatchment is a parameter that can be reasonably estimated from aerial photos or land use maps. However, not all of the impervious area is directly connected to the drainage system, or is "effective" when simulating a hydrologic response from these areas. For example, if a rooftop drains onto pervious area, this should not be included as directly connected. The total percent impervious area was used as the initial effective impervious area and then reduced during the calibration process to best simulate the observed hydrologic response over a range of precipitation events.

For all areas within the City of Philadelphia, GIS coverage of impervious areas delineated from 2004 orthodigital photographs was used. This coverage delineated all land use in the City into pervious or "natural surfaces," comprised of lawns, parks, marshes, golf courses, wooded areas and cemeteries, as well as several different classifications of impervious areas. Impervious land uses were broken down into the following types:

- Alleys
- Buildings
- Building centers
- Concrete/asphalt slabs/patios
- Ditches (asphalt or concrete)
- Driveways
- Institutions
- Lakes
- Medians
- Parking
- Pedestrian bridges
- Parking islands
- Pond
- Pools
- Railroad ballast
- Railroad bridges
- Reservoirs
- Rivers
- Sidewalks
- Shoulders
- Streams
- Tanks
- Travel bridges
- Travelways

For each RUNOFF subcatchment, the area of these land uses was summed to generate a total impervious area. Impervious areas in each subcatchment were summed and divided by the total area in order to get the first estimate of subcatchment "effective" impervious area.

5.3.1.4 Slope

The subcatchment slope should reflect the average slope along the pathway of overland flow to inlet locations. For a simple geometry, the calculation is simply the elevation difference divided by the length of flow. Subcatchments containing highway ramps underwent a more technical slope procurement procedure in order to prevent distortion of the slopes due to the grade of the ramp. ArcGIS was utilized in order to calculate the slopes for these subcatchments. Two different procedures were documented and applied for scenarios inside the City and those existing outside the City. Generally, the topographic lines representing the ramps were removed and new raster layers were created. From the new raster layers, slopes were calculated using the remaining topographic lines.

5.3.1.5 Manning's Roughness Coefficient

Manning's roughness values must be estimated for both pervious and impervious overland flow. Roughness is an empirical value and was treated as a calibration parameter when necessary.

5.3.1.6 Depression Storage

Depression (retention) storage is the rainfall abstraction volume that must be filled prior to the occurrence of runoff on both pervious and impervious areas. By default, the model assumes 25% of the impervious area has zero depression storage. This default value was not altered in the LTCPU model setup. In the model, water stored as depression storage on pervious areas is subject to infiltration and evaporation. Water stored in depression storage on impervious areas is depleted only by evaporation. Depression storage is an empirical value and was treated as a calibration parameter when necessary. Following calibration, impervious depression storage was set to values selected based on literature review and past modeling experience with the City's existing hydrologic models of combined sewer areas.

5.3.1.7 Pervious Area Infiltration Parameters

The rate of infiltration is a function of soil properties in the drainage area, ground slopes and ground cover. For the LTCPU hydrologic model, the Green-Ampt method is used to simulate infiltration rates within the RUNOFF module. The Green-Ampt equation for infiltration has physically based parameters that can be estimated based on soil characteristics. Soil information for the Philadelphia watersheds was obtained at the beginning of the PWD CSO program in the early 1990s from the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service, which is responsible for collecting, storing, maintaining and distributing soil survey information for privately owned lands in the United States. Initial infiltration parameters were assigned to each subcatchment based on soil texture classification. The saturated hydraulic conductivity parameter was treated as a calibration parameter within reasonable bounds.

5.3.1.8 RDI/I

RDI/I – shown in Figure 5-5 – into sanitary sewer systems has long been recognized as a major source of operating problems, causing poor performance of many sewer systems. RDI/I analyses are done to more accurately account for excess rain water entering the sanitary sewers through a combination of inflows from illicit connections of downspout pipes, sump pumps and foundation drains. Contributions may also come from manhole openings and large pipe defects along streams as well as infiltration through saturated soils and elevated groundwater levels into small cracks in degraded sewer pipes and joints. RDI/I decreases the available sewer capacity available to convey stormwater runoff through the trunks and into the interceptor during wet weather events.

To define the City of Philadelphia's Sanitary Sewer RDI/I response for the LTCPU, the RTK hydrograph generation method was used. RDI/I analysis was applied to subcatchments with separate sanitary sewers contributing to the CSS. The RUNOFF module uses three sets of unit hydrographs defined by R, T and K values – detailed descriptions of these parameters are available in Section 5.2.2 of this report - to represent the shape of the RDI/I hydrograph.

To define the RTK values for the City, a selection of flowmeter sites was made from 39 sites. Selection of the flowmeter sites was based on the quantity and quality of data existing at each site. Out of the 39 sites, 13 provided a satisfactory amount of observed flow data. The selected flowmeter site ID, contributing area and the location (district) are shown below in Table 5-2.

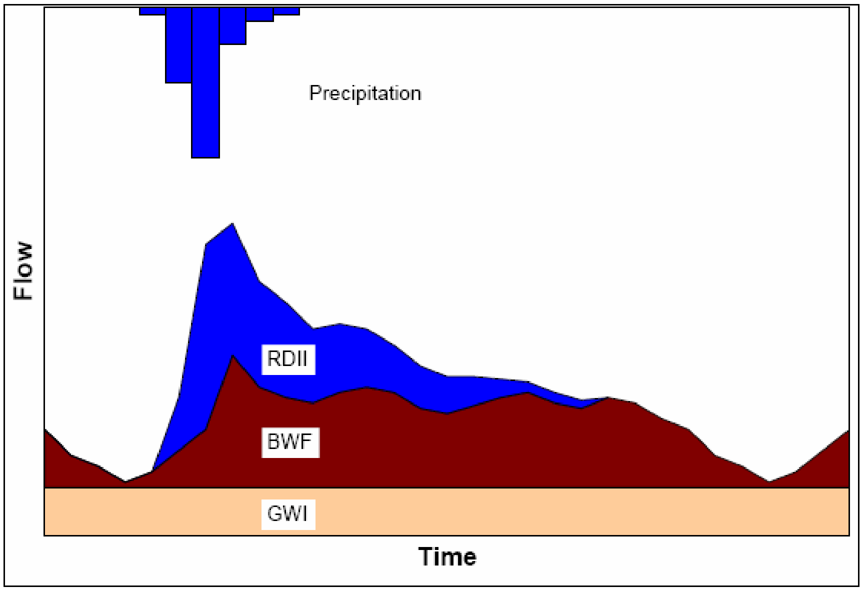


Figure 5-5 The Three Major Components of Wet Weather Wastewater Flow into a Sanitary System - BWF, GWI and RDI/I (US EPA, 2007)

QA was carried out on the data from the above sites. The flow data was checked for date/time inconsistencies, unusable data due to flowmeter malfunctions or missing data. Flags were used to help calculate statistical information on the data and to facilitate identification of anomalies in subsequent data processing steps (*e.g.*, subsequent SHAPE analysis). Data having previous QA checks were re-evaluated and brought up to current quality standards.

Following QA of the flow data, CDM SHAPE software was used to determine the estimated ratio of rainfall entering the sewers from each dataset. More details of the SHAPE software and processes involved are available in Section 5.2.2.

Results of the SHAPE analysis were further refined using Excel spreadsheets to compare monitored or observed data with the generated hydrographs using the estimated R, T and K parameters produced from the SHAPE analysis. An example of an acceptable matching hydrograph and corresponding best-fit volume scatter plot are shown in Figures 5-6(a) and (b).

The results from the spreadsheet analysis (Table 5-2) were further refined to have seasonal and monthly variability by processing through the Seasonal and Monthly Variation Spreadsheet (Section 5.2.2.5).

Figures 5-6(a) and (b) provide examples of an acceptable observed to simulated data hydrograph and best-fit volume scatter plot match from the RTK template analysis spreadsheet tool. The red line represents the ideal best-fit line, green representing the calculated actual fit line computed with a y-intercept value set to 0 (slope = 0.9952) and the black line representing the actual fit line with a computed y-intercept value (slope = 0.9035).

Four sites were chosen as templates for the remaining 26 flowmeter sites and all remaining un-metered sanitary sewershed loading points. Selection of the four sites to use as templates was based on flowmeter data consistency, accuracy and precision of observed hydrographs compared to estimated hydrographs. The size of the contributing area to the flowmeter was used as the criteria for distributing the templates to the un-metered sheds. Table 5-3 outlines the four sites selected as templates.

Table 5-2 Sites chosen for full RTK analysis

Site ID	Contributing Area (ac)	District	Date Range
5	9361	NE	6/2000 to 9/2001
27	674	NE	8/1999 to 4/2000
29	656	NE	9/1999 to 10/1999
40	4557	SW	8/1999 to 9/2001
44	1986	NE	11/1999 to 4/2000
49	1784	SE	5/2000 to 8/2002
57	164	SW	6/2000 to 9/2001
70	276	NE	6/2000 to 9/2001
72	301	NE	3/2001 to 5/2005
75	179	NE	6/2001 to 7/2004
77	162	NE	9/2000 to 7/2002
95	3540	NE	6/2004 to 5/2006
96	12594	NE	6/2004 to 5/2006

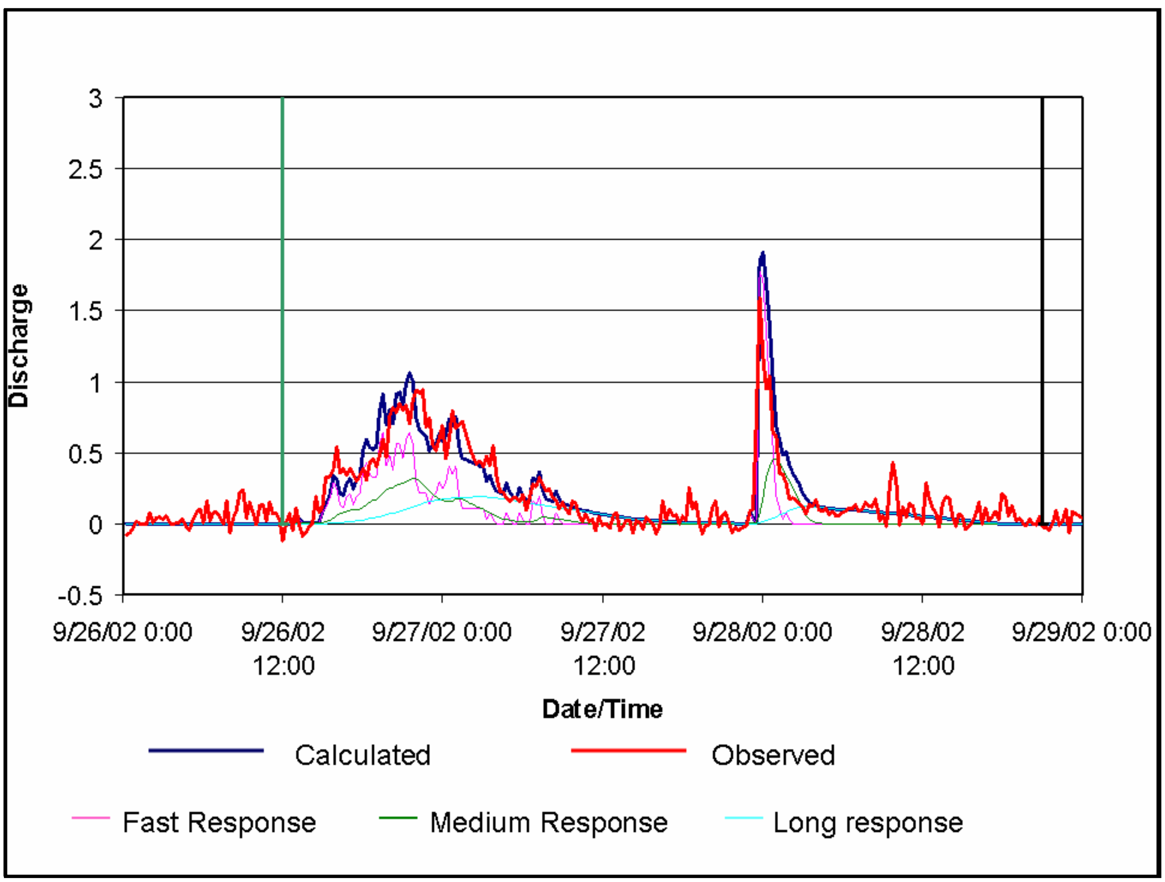


Figure 5-6(a) Hydrograph Used to Fit RTK Values

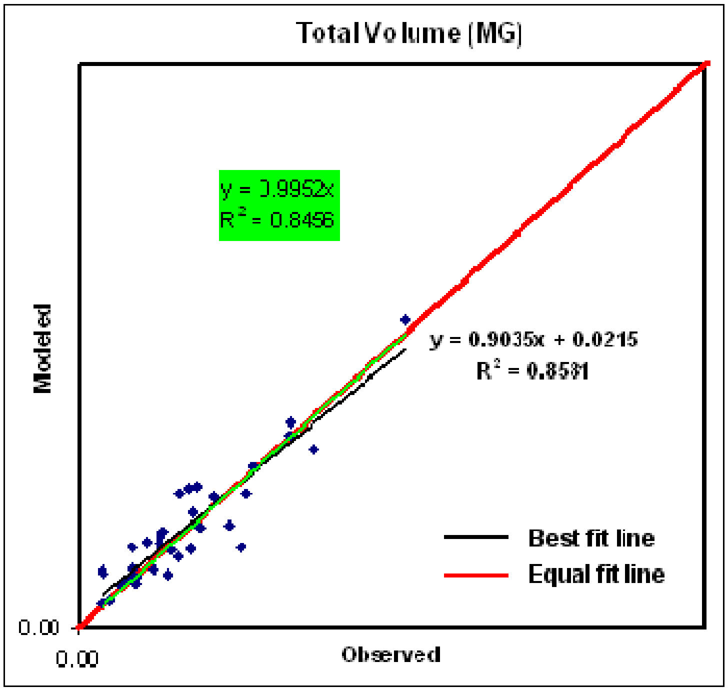


Figure 5-6(b) Best-Fit Line from a Volume Scatter Plot Used to Fit RTK Values

Table 5-3 Listing of the Sites Chosen as Templates and the Corresponding Ranges of Application

Site ID	Contributing Area (ac)	Area Range to Apply
75	179	area < 300 ac
70	276	300 ac ≤ area ≤ 1000 ac
40	4557	1000 ac ≤ area ≤ 5000 ac
5	9361	area > 5000 ac

5.3.1.9 Outlying Community User Input Hydrographs

The amount and quality of data from the outlying community flowmeters was insufficient to appropriately define the RTK values and analyze with SHAPE software, therefore an alternative method of representing the sanitary sewer flow was adopted for these sheds. For outlying community separate sanitary sewered areas, time-series data was loaded to the SWMM4 model through the user input hydrograph option line. A representative annual time series was created from available monitoring data. The time-series data underwent a QA process where missing or suspicious data was filled with hourly averaged values.

5.3.2.10 Baseflow Ranges

High and low average annual dry weather flow rates are used to establish upper and lower estimates of available wet weather treatment capacity (worst and best case scenarios) for LTCPU alternatives evaluations. The baseflow values representing the 80th, 50th and 20th percentiles for each WPCP were selected for determining high, median and low baseflow estimates, respectively. These low, median and high baseflow estimates are expressed as a fraction of current SWMM4 EXTRAN model dry weather WPCP influent flow. These baseflow multiplication factors are presented in Table 5-4 for each drainage district model.

Table 5-4 Baseflow Modifier Values Used Within the SWMM4 Model to Adjust the Baseflow to Represent Upper and Lower Limit Baseflow Estimates

WPCP	SWMM EXTRAN Baseflow Multiplier Factors		
	Low	Median	High
SE	0.938	1.003	1.073
NE	0.911	0.980	1.088
SW	0.892	0.979	1.049

5.3.1.11 Precipitation Input Data

Precipitation hyetographs are the fundamental input data of the RUNOFF module for the duration of the simulation. Precipitation data usually is obtained from gages maintained by government agencies such as the National Weather Service. Synthetic "design" events frequently used in planning or design studies also may be used as input to the model.

Identification of long-term average hydrologic conditions is often based primarily upon average annual and monthly precipitation volumes determined from the long-term precipitation record. Comparisons are made between the annual precipitation volumes and the long-term average to identify relatively 'wet' and 'dry' years. CSO occurrence, however, is a complex function of storm-event characteristics such as total volume, duration, peak intensity and length of antecedent dry period or inter-event time. In addition to annual precipitation volumes, event based analysis of the long-term precipitation record is used to identify short-term periods that best represent average annual CSO frequency and volume statistics for evaluation of collection system performance. In order to identify short-term continuous periods likely to generate CSO statistics representative of the long-term record, continuous 12-month periods selected from the recent PWD 24 rain gage record (1990-2006) were evaluated against the period of record based on the total annual precipitation volume, the annual number of precipitation events and the distribution frequency of event peak hourly precipitation intensity. Details of the event based analysis and procedure may be found in the Supplemental Documentation Volume 5: Precipitation Analysis.

5.3.1.12 Evaporation Input Data

Evaporation data is required by the model in the form of average monthly evaporation rates, although finer time increments may be input as negative flows by creating an evaporation time series. Average monthly evaporation (inches per day) are used for all SWMM4 models determined from New Castle County, Delaware recorded daily evaporation data from 1956 through 1994.

5.3.1.13 Temperature Input Data and Snowmelt

Temperature time series input data can be used to run a snowmelt routine in SWMM44. The average snowfall volume and frequency for Philadelphia, however, does not account for a significant portion of the average annual precipitation. Therefore, the snowmelt routine was not employed. Instead several snowfall events that occurred during the year 2005, which was selected as the basis for the typical year, were modified to represent snowmelt time series based on PWD non-heated raingage observations, Philadelphia International Airport observed hourly snowfall, daily snow cover, and daily maximum temperatures.

5.3.2 Hydraulic Model Development

This section describes the process by which the hydraulic model of PWD's combined and separate sanitary sewer system has been developed. The hydraulic model was developed using EXTRAN. Section 3 describes the sources of the data and the inventory used to develop the Tier 2 hydraulic models. The Tier 2 models were developed by refining and adding hydraulic elements to the Tier 1 EXTRAN models. The Tier 1 EXTRAN models in combination with the U.S. Army Corps of Engineers' Storage, Treatment, Overflow, Runoff Model (STORM; Hydrologic Engineering Center, 1977) were used to represent the hydraulic elements and evaluate alternatives for the 1997 LTCP.

The EXTRAN module of SWMM4 is used to analyze and simulate flow through the CSS. EXTRAN uses a link-node description of sewer and open channel systems facilitating the physical prototype and the mathematical solution of the gradually-varied unsteady flow (St. Venant) equations, which forms the mathematical basis of the model. The links transmit the flow from node to node. To reiterate the list of elements required by SWMM4, which was initially presented in Section 5.2.4, to calculate the flow in the sewers, values for the following variables are necessary:

- Pipes
- Junctions
- Orifices
- Weirs
- Pumps
- Outfalls

The information required to accurately represent these elements within the model were obtained from the return plans (as-built), contract drawings and drainage plats available through the Engineering Records Viewer developed by the City of Philadelphia. Values which did not match the drawings were modified to bring them current with plan drawings. Individual descriptions of these elements follow below.

5.3.2.1 Pipes

Pipes are the conveyance element in the EXTRAN models. For the EXTRAN model the following pipe information is required.

- Pipe name
- Pipe’s upstream and downstream nodes
- Initial flow in the pipe
- Shape of the pipe
- Pipe dimensions
- Offsets of pipes
- Manning’s roughness coefficient – used to characterize the pipe material and conditions
- Minor losses
- Sediment depth in the pipe

Generally, the pipes within the LTCPU EXTRAN module representing the wastewater collector systems of the City can be separated in to four categories; trunk sewers, dry weather flow pipes, interceptors and the wet weather overflow pipes. Trunk sewers collect sanitary and wet weather flow from elements such as house lateral branches and street inlets and convey that flow to the regulators. The dry weather flow pipes take all of the dry weather sanitary and a percentage of the wet weather flow to the interceptor. Interceptors collect the flows from the dry weather flow pipes and deliver the flows to another downstream interceptor system or to the WPCPs. The wet weather overflow pipes convey flow to receiving waters that cannot be accommodated in either the dry weather pipes or interceptor.

5.3.2.2 Junctions (Nodes)

Nodes are the connection points for the pipes. Flow and volume continuity are calculated at nodes in the EXTRAN model. The nodes in the model can be actual manholes or places where there is pipe size, slope or material change or there is a hydraulic control structure in the pipe network. The following information is required to model a node in EXTRAN:

- Junction name
- Ground elevation/top of the node
- Invert elevation (bottom of the junction)
- Constant inflow, if any, into the junction
- Initial water depth in the junction above invert
- Junction location data (x,y) for spatial location
- Junction volume calculation parameters

Data to define a node in the LTCPU hydraulic model was reviewed and verified using sewer return plans managed by the City of Philadelphia Electronic Records Viewer system.

5.3.2.3 Orifices

Two types of orifices are used within the LTCPU model – static and variable. Static orifice opening sizes remain constant over the length of a simulation. The opening of variable orifices is controlled by either a set of time closure rules or head level in a control node. EXTRAN internally converts the orifices to equivalent pipes of 200 ft and a Manning's coefficient representing the same head loss as the orifice.

Following are the parameters necessary to define an orifice in EXTRAN:

- Upstream and downstream nodes
- Type of orifice
- Orifice coefficient
- Orifice offset from the bottom of the junction invert
- Orifice dimensions
- Orifice control information

5.3.2.4 Weirs

For EXTRAN models used in LTCPU analyses, all weirs were modeled as equivalent pipes with the head loss and flow characteristics simulating those that would be produced from a weir. The information required to model a weir is:

- Upstream and downstream junctions for the weir
- Type of weir
- Weir length and height to the crest of the weir
- Weir coefficient

5.3.2.5 Pumps

Pumps in EXTRAN are modeled to lift the flows to a higher head at a pre-specified rate. Pump station and WPCP data, wet well depths and corresponding pumping rates were studied to determine the type of pump and curves used for the EXTRAN model for LTCPU analyses. All pumps simulated in the models used for LTCPU analyses were represented as variable speed inline pumps. To model a pump the following information was required:

- Pump type
- Pumped junction name
- Pump discharge junction name
- Pairs of pumped junction depth and corresponding pump rates
- Pump on and off water levels in the pumped junction

5.3.2.6 Outfalls

Outfalls represent the discharge points in the EXTRAN models. The outfalls can either have a boundary condition the head has to overcome for outflow to occur or the outfalls can be free outfalls without any boundary conditions. For most of the sections in the EXTRAN model where the outfalls are in the tidal sections of the rivers – for instance, the Schuylkill and Delaware watersheds – the outfalls have boundary conditions equal to the mean tide. For the non-tidal sections in the model the outfalls do not usually have outfall boundary conditions. For special conditions – like the gravity flow into the WPCPs, where the plant boundary had to be overcome to reach the plant or computer controlled outflows – the appropriate boundary conditions were applied.

To model an outfall in EXTRAN the following information was needed:

- Name of the outfall
- Boundary condition to be applied

5.3.2.7 Regulators

A regulator's function is to divert all the dry weather and part of the wet weather flow (*e.g.*, storm flow) into a dry weather pipe (DWO) that feeds the interceptor pipes, delivering the flows to the WPCPs. Any excess wet weather flow that cannot be accommodated in the DWO goes into the storm overflow pipe (SWO) and overflows to the receiving water by way of an outfall. Significant differences in design approaches and philosophies can be observed from system to system. The various types of regulators include weir diversions into side or bottom orifices, float-controlled gates, tipping-plate gates, vortex drop shafts, leaping weirs, motor-operated sluice gates and a number of other configurations. Detailed descriptions of the various regulator devices are beyond the scope of this report and are presented in the literature (*e.g.*, American Public Works Association, 1970 and Water Pollution Control Federation, 1989). The characterization section – Section 2.2 – describes the various regulator types throughout the City.

There are five types of common regulators simulated in the EXTRAN models:

- Slot
- Sluice gate
- Water hydraulic
- Computer controlled
- Brown and Brown (B&B)

Three types of additional structures are used for storm relief and control:

- Dams
- Side overflow weirs
- Tide gates

5.3.2.8 Model Simplification

Once all the information is compiled into the model, test simulations and error checks are performed to find mathematical and implementation problems. The models were put through a thorough QA procedure. The EXTRAN model gets inflow information from the preceding hydrologic and or hydraulic model runs. This model was then simplified by reducing the number of nodes and pipes within the network. The goal of the simplification process was to increase the efficiency by decreasing run-time, while keeping the integrity of the model results. The simplification process followed the steps outlined below:

- Increase the minimum length of the pipes for all feasible situations to 1000 ft
- Most non-critical branches shorter than 1000 ft were identified and eliminated
- All pipes in a branch with the same shape and slope were combined
- Branches having pipes of varying capacities or shapes and not having a series of equivalent pipe sizes to combine to a length of 1000 ft were combined regardless and the hydraulic characteristics of the combined section was made so as the represent the original
- If slopes were changed to meet the 1000 ft pipe length requirement, the Manning's coefficient was adjusted accordingly
- If baseflow existed at a node to be eliminated, the baseflow was transferred to the downstream node if less than 500 ft from the eliminated node, otherwise it was loaded to the upstream node
- Equivalent pipes were avoided, where possible, to conserve volumes

The resulting simplified model allowed for a larger time step to be used without violating the Courant conditions and, thus, decreasing the computational burden of the model. Continuous simulations were performed using the RUNOFF and EXTRAN models and the results from the simulations were directly or indirectly used to evaluate effects of various alternatives for the LTCPU.

5.3.3 Model Calibration / Validation

Development of the SWMM4 model for the LTCPU was followed by calibration and optimization of the parameters for both the RUNOFF and EXTRAN modules. During the calibration of any model, it should not be expected that simulated results will match perfectly the measured data, since the measured data is subjected to some degree of error, while the model is an approximation of the system hydrology and hydraulics. Therefore, the measured data must be thoroughly reviewed and any limitations must be identified before adjusting calibration parameters. Note that the model calibration is accomplished by finding the best comparison between simulated and measured runoff characteristics over a range of storm events.

Model calibration was accomplished by adjusting initial estimates of the selected variables, within a specified range, to obtain a satisfactory correlation between simulated and measured flow and volume. The variables selected to adjust or calibrate were parameters that typically cannot be measured accurately - percent impervious, soil infiltration parameters, etc. - and which have the greatest effect on the accuracy of the results. The calibration parameters were prioritized according to their influence on the model results, which can vary from one drainage system to another and on several model simulations (sensitivity analyses) on the PWD LTCPU.

For the hydrologic calibration, the following data were assessed:

- Precipitation data
- CSS Trunk Monitor data
- DCIA calibration
- RTK distribution

For the hydraulic validation, the following elements were considered:

- WPCP inflow and pumping data
- Measures of "goodness-of-fit"
- Validation results

5.3.3.1 Hydrologic Model Calibration

Calibration of the hydrologic model was an iterative process by which RUNOFF module parameters were changed, within acceptable ranges based on available data, from initial estimated values to ones that quantitatively provide the best match between modeled results and observed data.

5.3.3.2 Precipitation data

The main goal in acquiring precipitation data is to get the most detailed and consistent - temporally and spatially – data available for the periods in which hydraulic data were available for the Philadelphia CSS service area. It was determined after extensive review and QA assessment that the PWD 24-raingage network data required bias adjustment and normalization to provide the spatial and temporal consistency necessary for the calibration process. Further details can be found in Supplemental Documentation Volume 5: Precipitation Analysis.

The SWMM4 RUNOFF module requires assignment of an input rainfall time series for each stormwater runoff or sanitary sewer RDI/I basin in the model. Inverse distance-squared weighting was used to estimate rainfall in areas between rain gages. A 1 km^2 grid was imposed over the PWD service area. Next, a rainfall value for every time step was assigned to each grid element by inverse distance-squared weighting of the rainfall values from three nearby surrounding gages. Finally, the gridded precipitation values were area-weighted to provide average rainfall values for each individual sewershed in the model. In this manner, the bias adjusted 15 minute accumulated rainfall data for the PWD 24 rain gage network is distributed to RUNOFF model basin areas using the Inverse Distance Weighted (IDW) method.

Specific rainfall event boundaries were defined using SHAPE software – previously described in Section 5.2.2 – with rain gage data as input for each flowmeter site as listed in Table 5-5. The initial selection criterion included a minimum rainfall depth of 0.1 in. QA of the events was done after event boundary delineation to remove events affected by errant data, snow or malfunctioning rain gages. These selected rainfall event boundaries were used along with the IDW basin average rainfall time-series throughout the model calibration process.

5.3.3.3 CSS Trunk Monitor Data

Flow data taken from flow monitors located in trunk sewers throughout the combined sewer area were analyzed and then used to adjust calibration parameters for the hydrologic models. There were six combined trunk sewer monitors having sufficiently usable data to perform calibration analyses. These six flow monitors are presented below in Table 5-5. Included in the table are the model pipe names of the monitor location, the area draining to the monitor, the calibration period and corresponding drainage districts.

Hydrograph decomposition was performed on the data from the above flow monitors to extract the wet weather portion. This flow was used to compare to the simulated model flow. To assess the goodness-of-fit of the model output to observed data, a series of plots were created including scatter plots of event volumes, time to peak and peak flows, Cumulative Frequency Distributions (CFDs), cumulative mass regression plots and time-series plots for each event. A selection of result plots for monitor 83 is presented collectively as Figure 5-7 (a) and (b) below. The R-squared value, slope, intercept and the equal fit line from the scatter plots and the qualitative assessment of the time-series plots were used to determine the level of fit for model output as compared to observed data.

The results for each model run were organized into a performance spreadsheet and the best-fit calibration scenario was chosen. The criteria from the best-fit calibration scenario were applied to the entire combined sewer district for all sheds without monitors. For sheds draining to the six selected trunk monitors, the site specific calibrated data were used.

Table 5-5 Trunk Monitor Calibration Information

Monitor	District	Pipe Name	Data Range	Drainage Area (ac)
79	SW	TS27-3308	1/1/2002-9/2/2002	4.33
83	SW	TS16-104	1/1/2004-12/31/2004	19.65
84	SW	TS13-108	1/13/2004-5/2/2006	25.11
85	SW	TC06-112	10/25/2002-7/28/2004	98.56
S42-130	SW	TR25-104	4/26/2006-9/19/06	73.05
D54-15	SE	TD54-604	5/26/2006-9/15/2006	167.19

5.3.3.4 Directly Connected Impervious Area (DCIA)

For all sewersheds with monitored trunk sewers, DCIA in the best-fit model was lower than gross impervious cover derived from aerial photography. The ratio of DCIA to total gross impervious area ranged from 50% to 100%. Because the majority of sewersheds are unmonitored and the measurements themselves have uncertainty associated with them, it is reasonable to present this value as a range. Presented below are ranges associated with specific areas in the drainage district.

- 5 monitors in trunk sewers: Adjustments in the best-fit model range from 50% to 95% of gross impervious cover (*i.e.*, effective impervious cover was estimated to be 50% to 95% of total impervious cover)
- Cobbs Creek Watershed model: Adjustments were made watershed-wide based on USGS streamflow records. Adjustments were made in combined and separate areas and in areas inside and outside the City. This calibration process had a higher level of uncertainty than the trunk monitors. Adjustments ranged from 50% to 100% of total impervious cover
- Tookany/Tacony-Frankford Creek Watershed model: Adjustments were made watershed-wide based on USGS streamflow records. Adjustments were made in combined and separate areas and in areas inside and outside the City. This calibration process had a higher level of uncertainty than the trunk monitors. Adjustments ranged from 50% to 75% of total impervious cover

Based on the histogram shown below (Figure 5-8), the mean and most common adjustment is 70% of DCIA. This value is used in the best-fit model, with the exception of monitored sheds.

5.3.3.5 RTK Distribution

The purpose of this task was to determine an acceptable average R-value range within the simplified SWMM4 model to represent RDI/I volumes across all un-monitored separate sanitary sewer areas. The existing RDI/I values from the 39 flow monitoring sites discussed previously were used in this process. The full range of R-values showed no apparent correlation to population density, geographic location or size of monitored shed, therefore, the analysis included:

- Ranking of the 39 sites based on R-value
- Creation of a histogram and cumulative frequency distribution plot
- Upper (80^{th} percentile) and lower (20^{th} percentile) limit determination based on the central tendency about the median

The resulting histogram is presented as Figure 5-9 below. The final median R-value to represent the watershed area is 0.0401.

5.3.3.6 Hydraulic Model Validation

Once the hydrologic models for all districts were calibrated based on combined trunk and sanitary sewer monitoring data, the system hydraulic models were validated against observed WPCP influent flow and level data for the calendar year 2005. PWD monitors level and inflow at its three WPCPs. These flows were compared to simulated flows for a range of storm events during the calendar year 2005. WPCP influent flow and pump wet-well level data are stored in average hourly time intervals. A QA process was performed on the flow data, during which errant or missing data were removed. The observed flow time increments were interpolated to a 15-minute time interval before being imported into the SHAPE program along with the rainfall data for analysis. The data underwent hydrograph decomposition and the wet weather portion of the flow coming to the plant was extracted.

The model parameters adjusted to best match the monitored WPCP influent flow and level data included plant head boundaries, pump curves, metering head losses and QA of regulator gate settings.

5.3.3.7 Measures of "Goodness-of-Fit"

Simulations were performed using different model settings and compared using a combination of quantitative and qualitative measures. The measures were applied to the following event characteristics:

- Event volume
- Event peak flow
- Time to peak

5.3.3.8 Validation Results

The calibration and validation results for each drainage district are discussed below using the quantitative and qualitative best-fit measures outlined above as a guide for model result accuracy.

5.3.3.8.1 Southeast Drainage District

The results of final Southeast drainage district (SEDD) hydraulic model validation, performed using SE WPCP influent hydrograph separated wet weather flow data, are presented in Figures 5-10 through 5-12. Linear regression analysis is performed comparing model estimated SE WPCP influent wet weather flow volumes (y-axis) to monitored event volume (x-axis) using IDW rainfall data for the calendar year 2005. The events that have been excluded from the regression analysis based on the protocols described previously are presented in the scatter plots with different symbols and shading so they can be distinguished from those events included in the regression. Ideally the plots would reveal a one to one relationship, meaning that the model estimated volumes equal to the exact monitored runoff volume for each event.

Figure 5-10 is a scatter plot with the linear regression analysis results used to determine quantitatively how well the model simulated total event volumes treated at the SE WPCP. The red line is the 45-degree line that would indicate a perfect fit with an R-squared value of 1. Figure 5-11 is an overlay of model and monitored SE WPCP influent wet weather event volume cumulative frequency distribution (CFD) plots. Figure 5-12 is an overlay of model and monitored hydrograph time-series plots for the October 22, 2005 storm event. The plots display a good correlation between

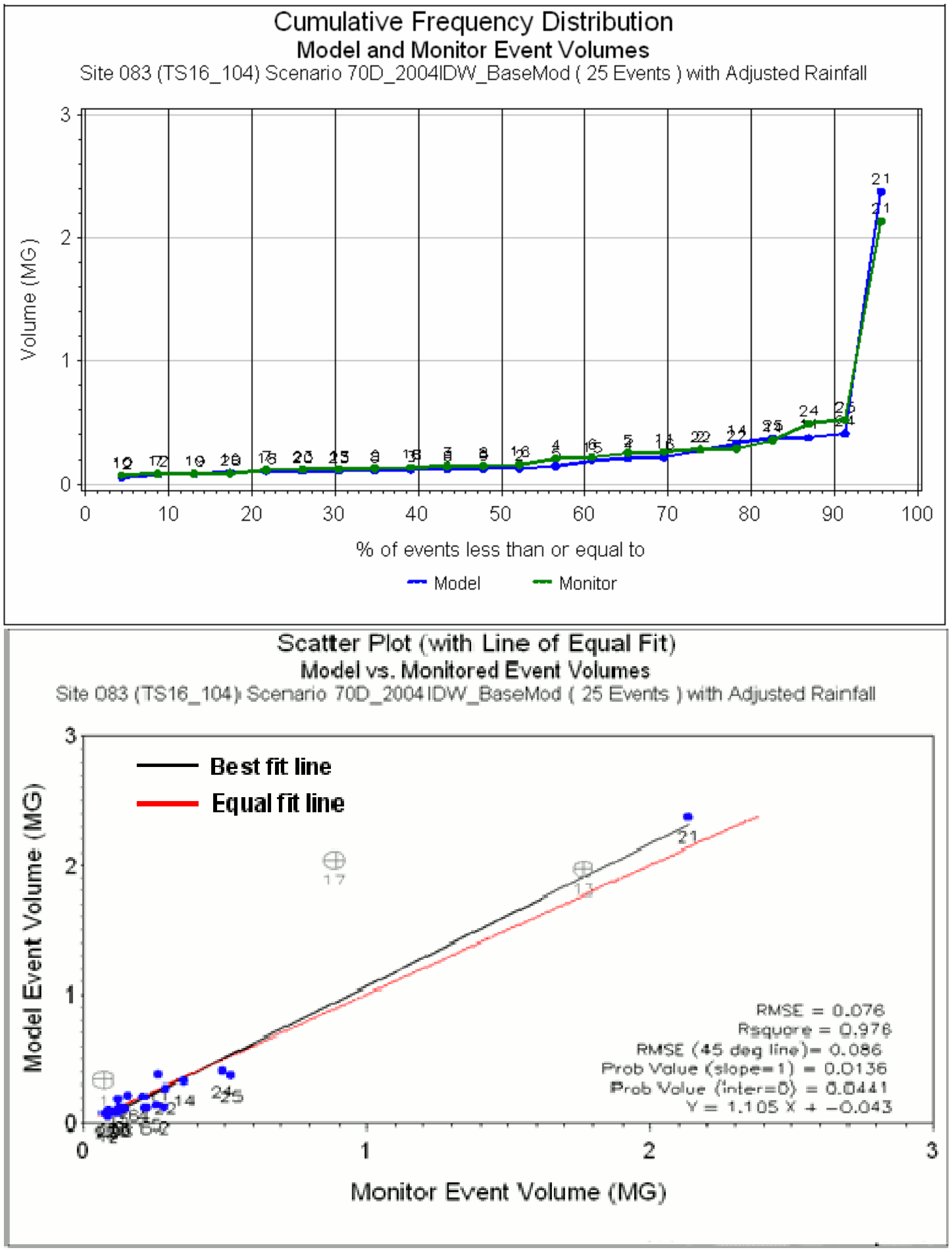


Figure 5-7(a) Result Plots for Site 83 Including the CFD, Event Volume Scatter Plot

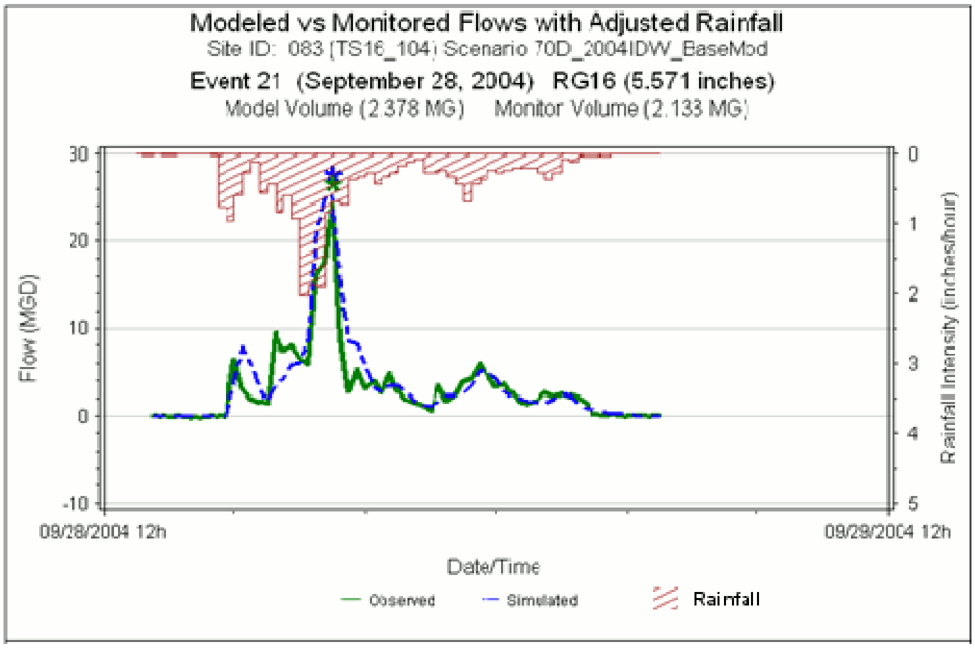


Figure 5-7(b) Result Plots for Site 83 Including the CFD, 2004 Event Time-Series Plot

observed and simulated event volumes over the full range of events analyzed. Any significant systematic deviation between simulated and observed data would indicate events of a certain volume range were not being adequately simulated by the model.

5.3.3.8.2 Southwest Drainage District

Final validation plots for the Southwest drainage district (SWDD) hydraulic model are presented in Figures 5-13 through 5-16. The plots are presented separately for the two interceptor systems that feed the Southwest Water Pollution Control Plant, the Southwest Low Level (SWLL) and the Southwest High Level (SWHL). The events that have been excluded from the calibration analyses, using the set of protocols described previously are presented in the scatter plots with different symbols and shading so they can be distinguished from those included in the regression analyses.

Figure 5-13 shows the linear regression analysis used to determine quantitatively how well the SWLL simulated the wet weather event volumes. The monitored wet weather event volumes are on the horizontal axis and the modeled event volumes are on the vertical axis. (The red-dashed line is the 45-degree line that would indicate a perfect fit with an r-squared value of 1.0). Figure 5-14 shows the cumulative frequency distribution (CFD) plots of the monitored and the modeled wet weather volume from the SWLL, this plot is used to check if the wet weather volumes being simulated are different from the observed in various sized storms. Similarly Figures 5-15 and 5-16 show the linear regression analysis and the cumulative frequency distribution plots for the SWHL interceptor system.

The curves at the SW interceptors match each other reasonably well without significant deviation for each plot.

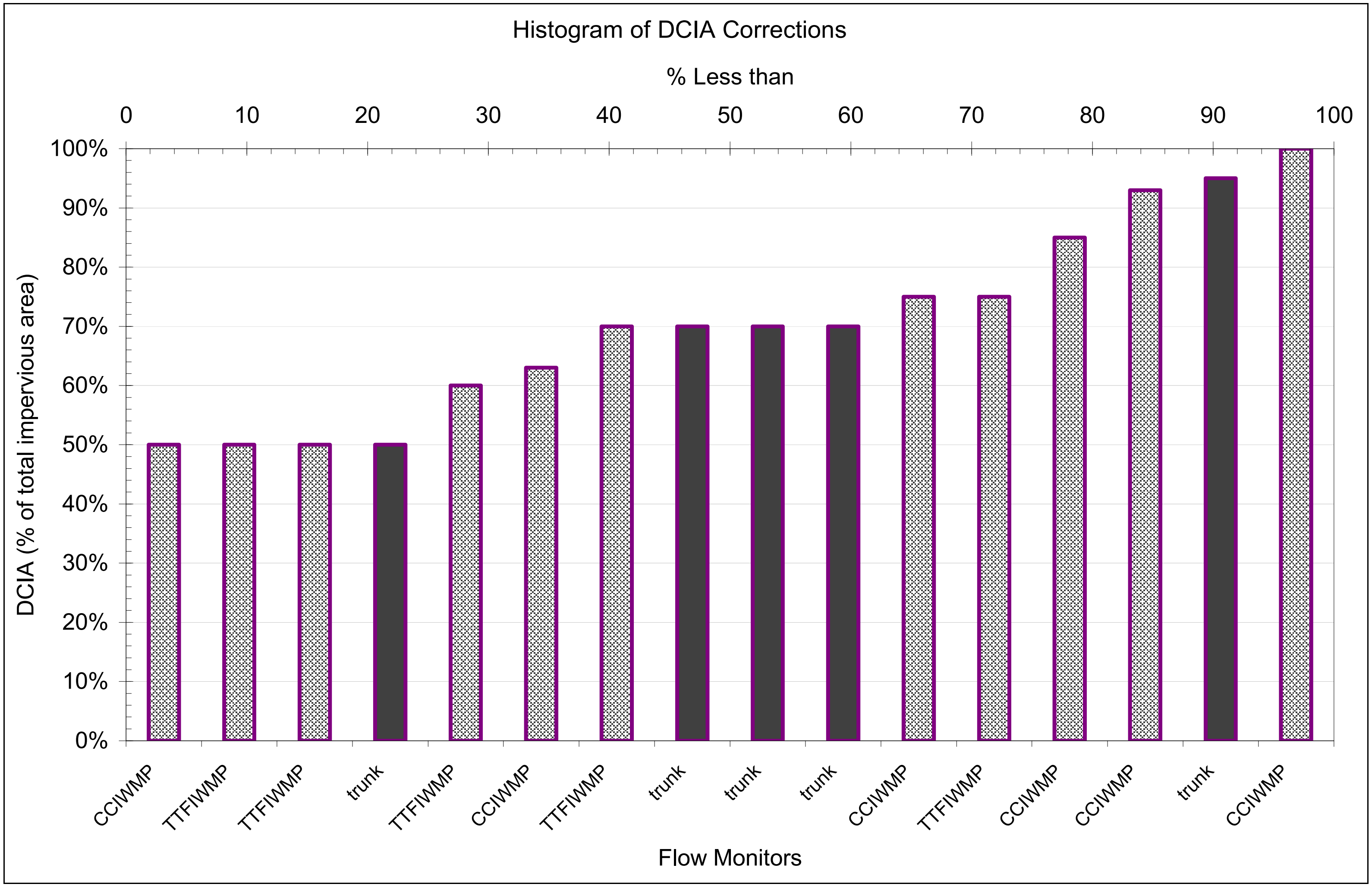


Figure 5-8 Histogram of Resulting Calibrated DCIA Percentages of Gross Impervious Area for Available Monitors Within the Drainage District

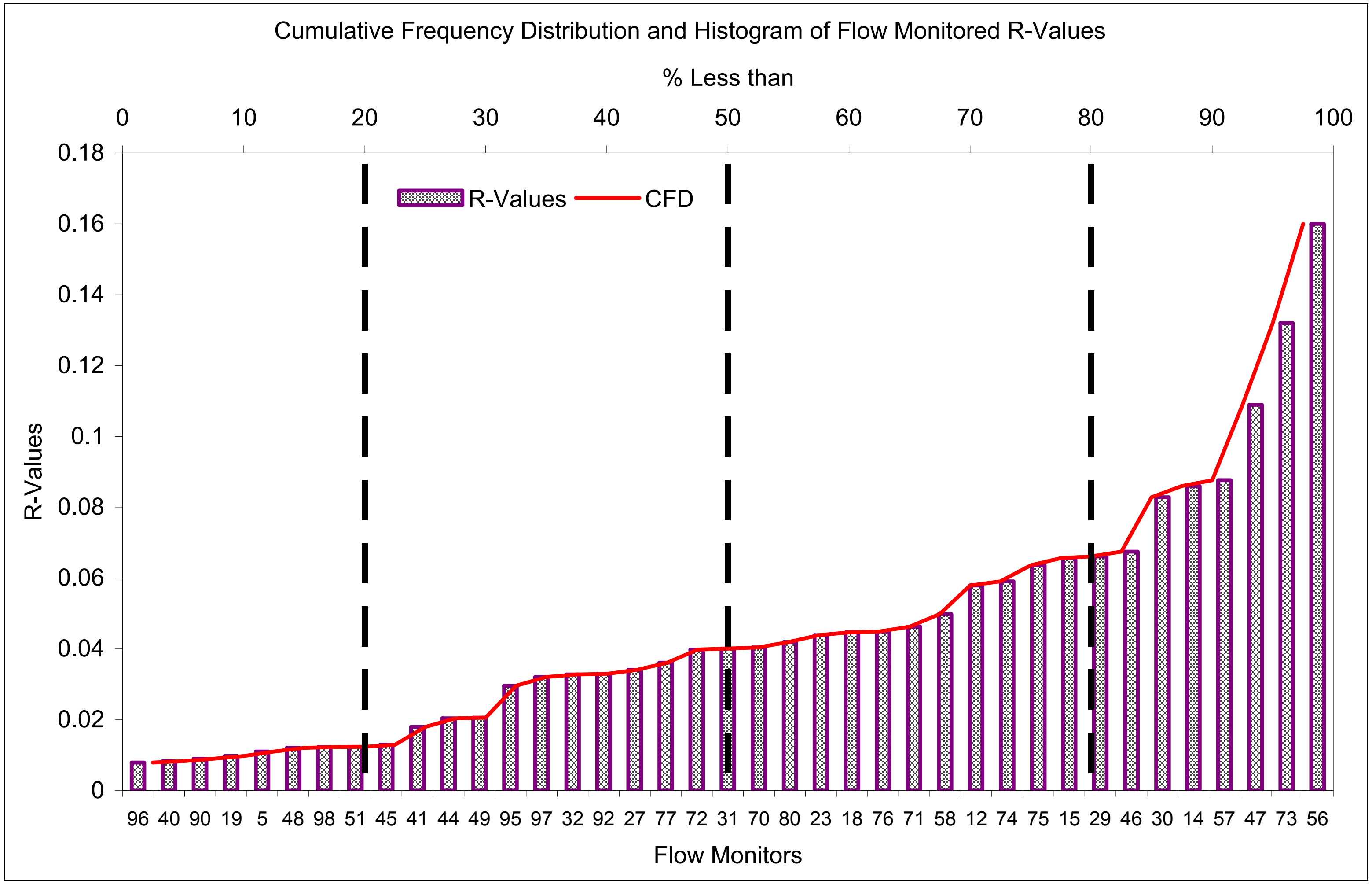


Figure 5-9 Histogram of Resulting Calibrated R-Values for Selected Monitors Within the Drainage District

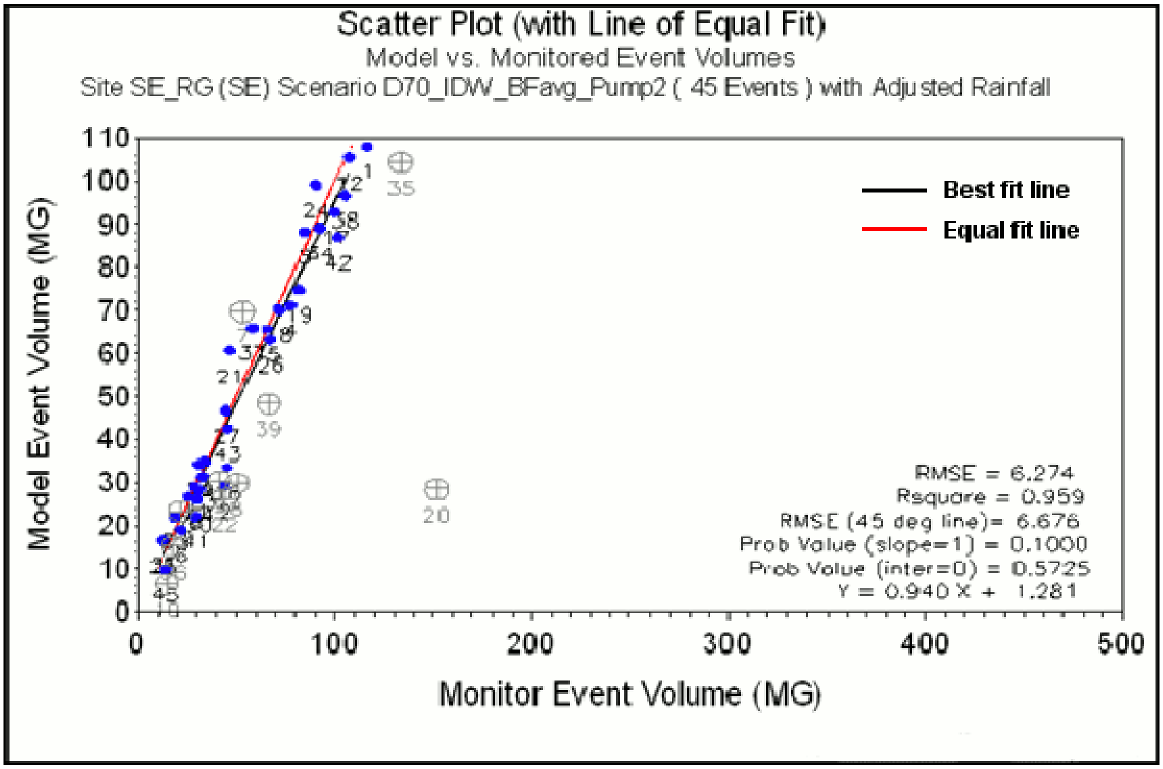


Figure 5-10 SE WPCP Linear Regression of Modeled Versus Monitored Event Volumes

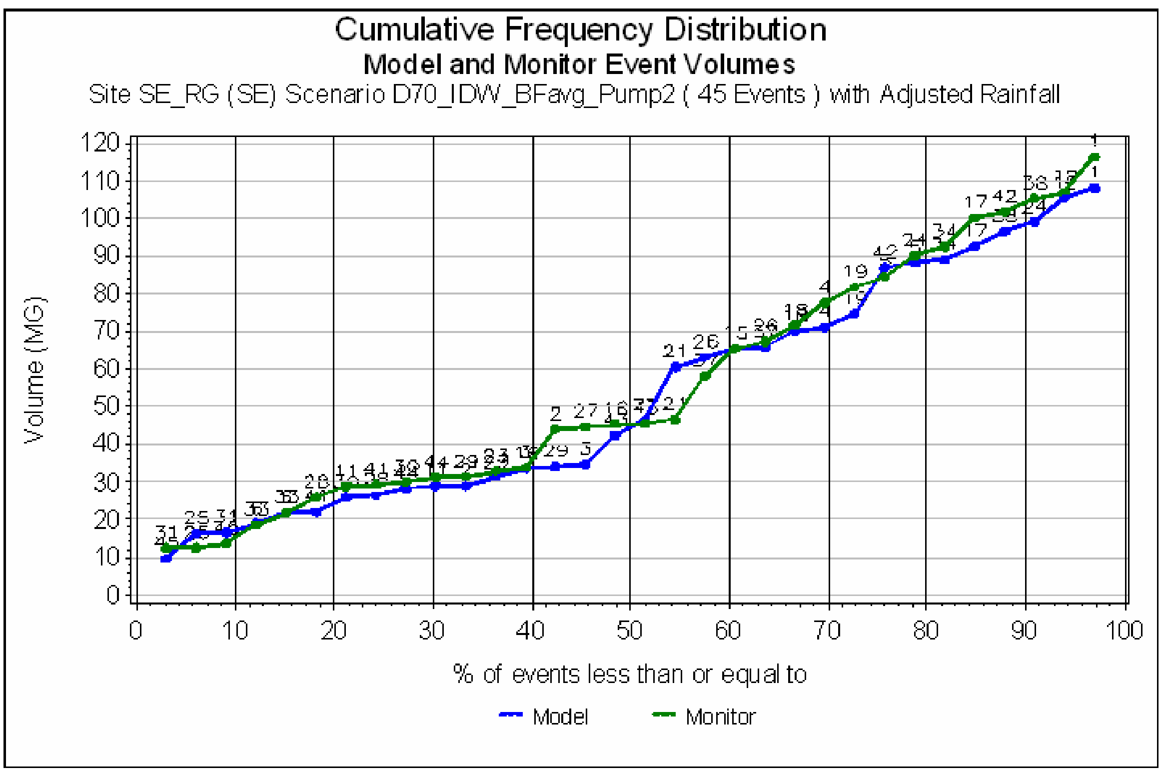


Figure 5-11 SE WPCP CFD Plots of Monitored and Modeled Event Volumes

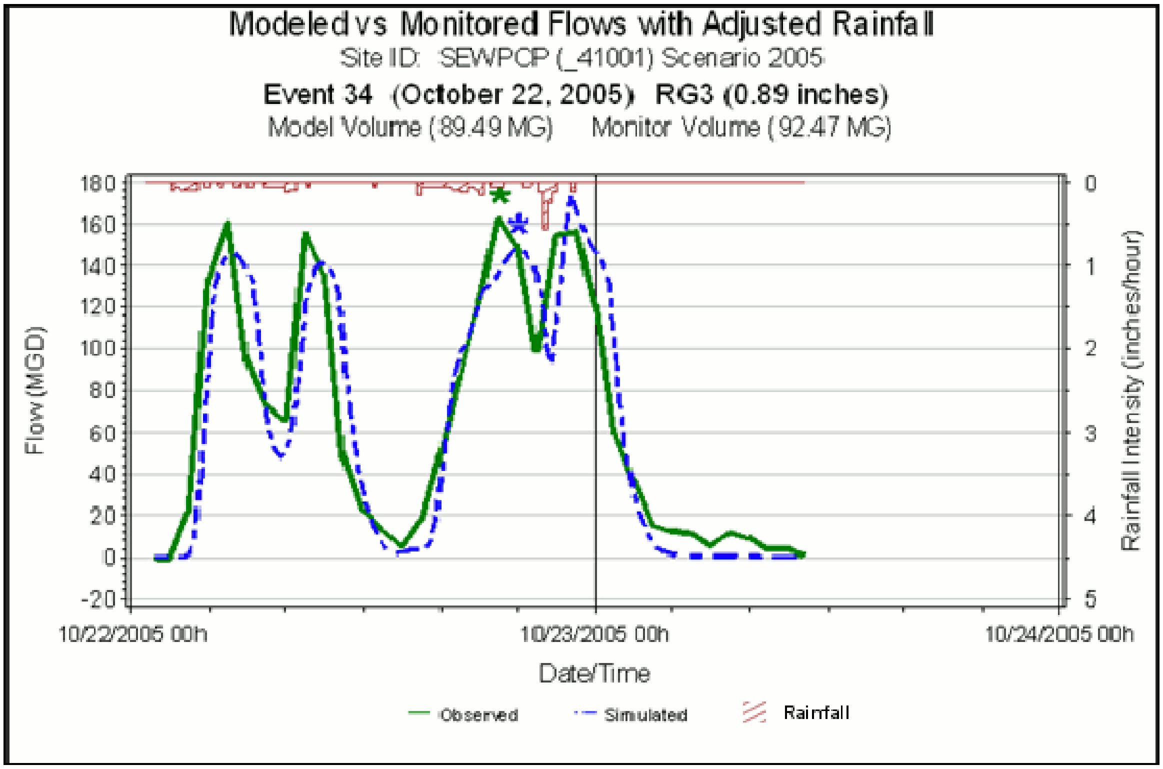


Figure 5-12 SE WPCP Model and Monitored Wet Weather Flow Time-Series Plot for the October 22, 2005 Event

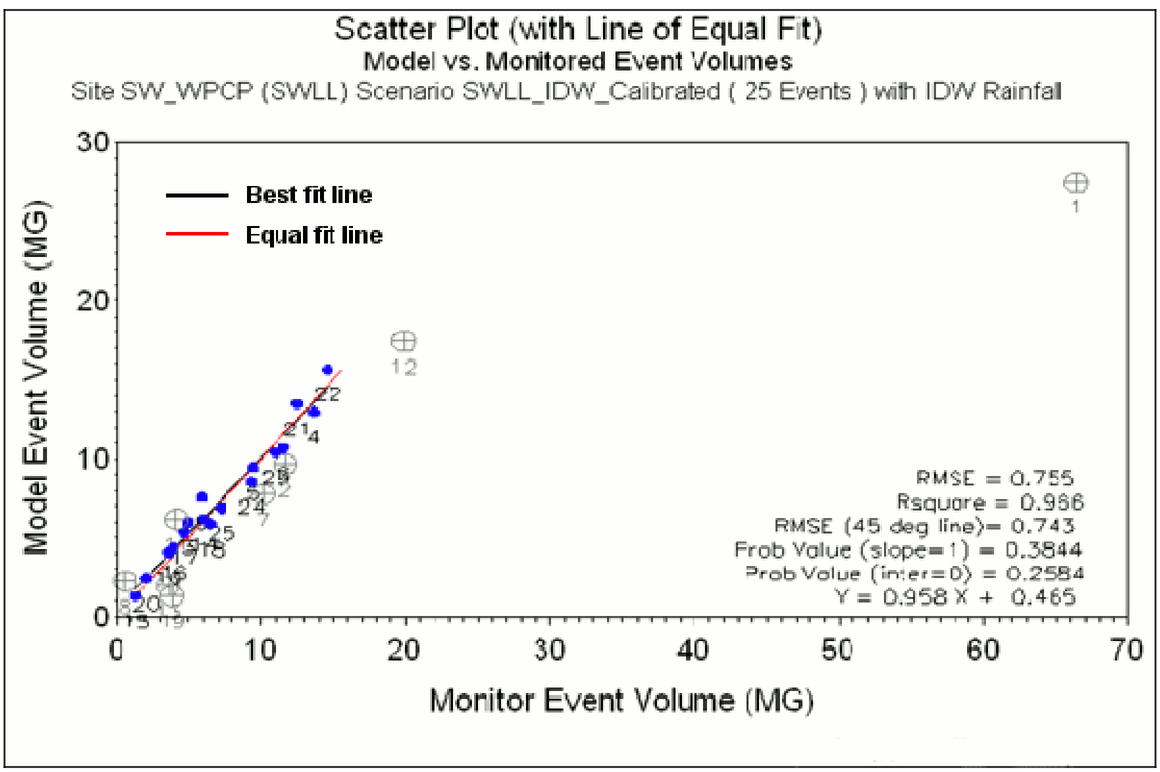


Figure 5-13 SWLL Linear Regression of Modeled versus Monitored Event Volumes

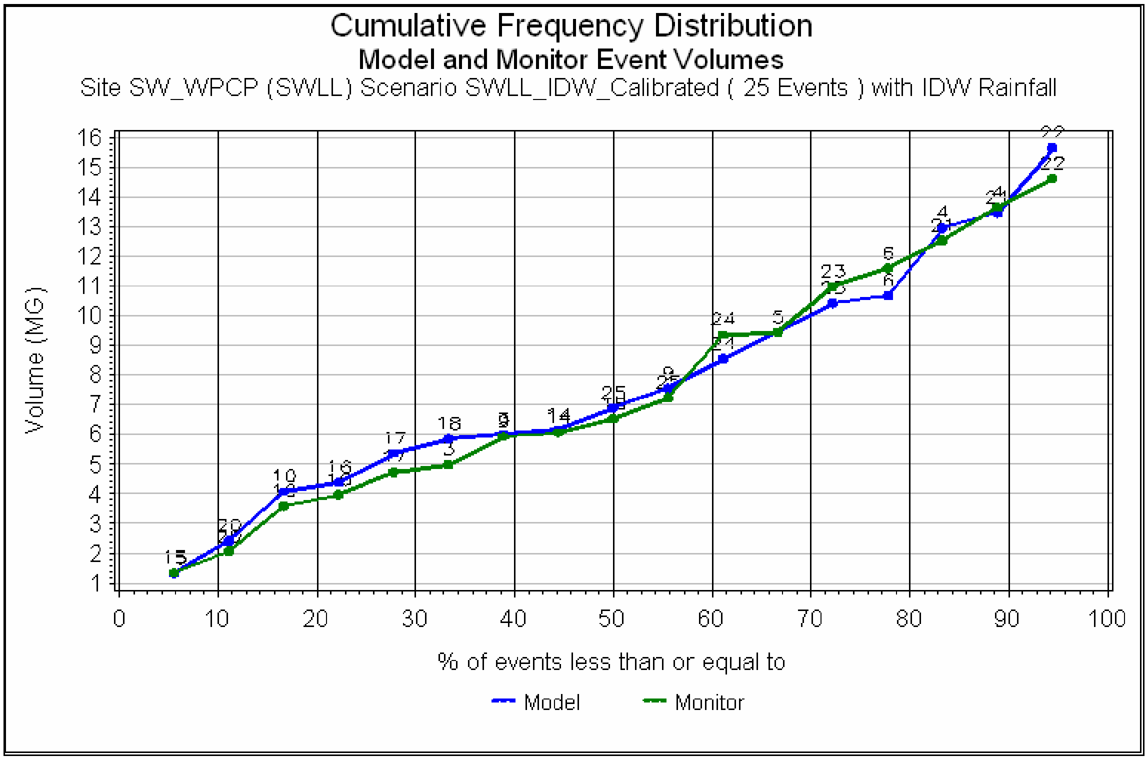


Figure 5-14 CFD Monitored and Modeled Event Volumes SWLL

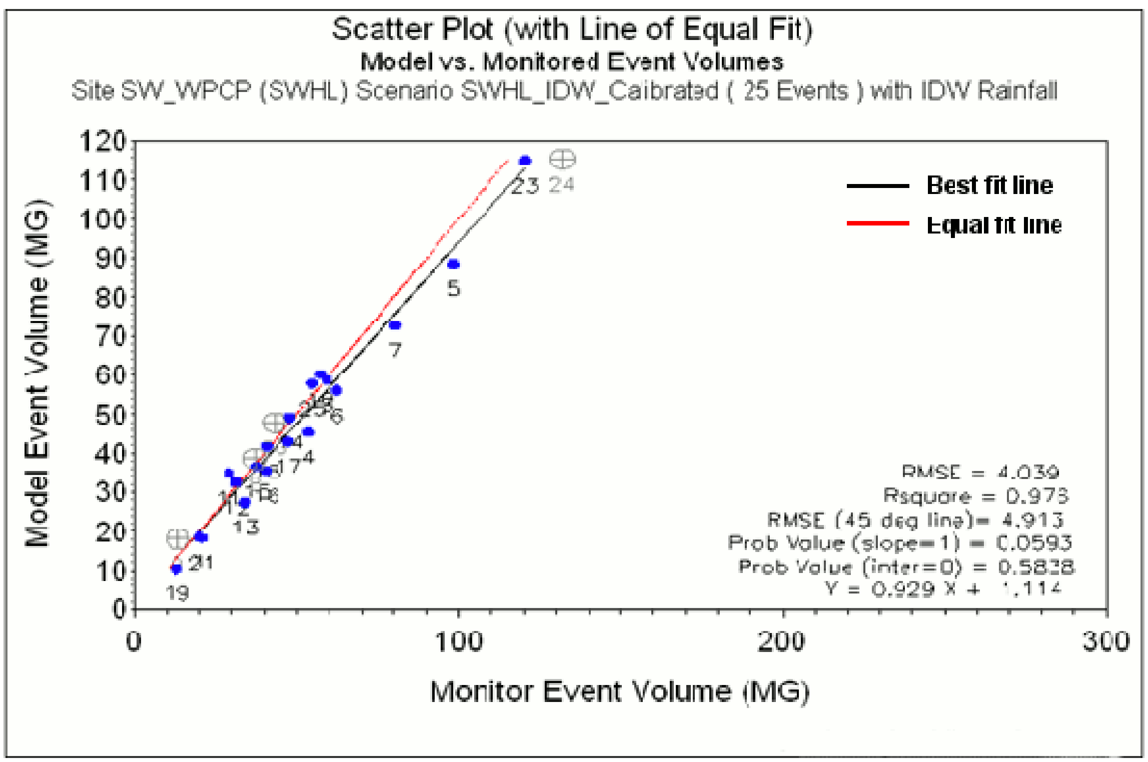


Figure 5-15 SWHL Linear Regression of Modeled Versus Monitored Event Volumes

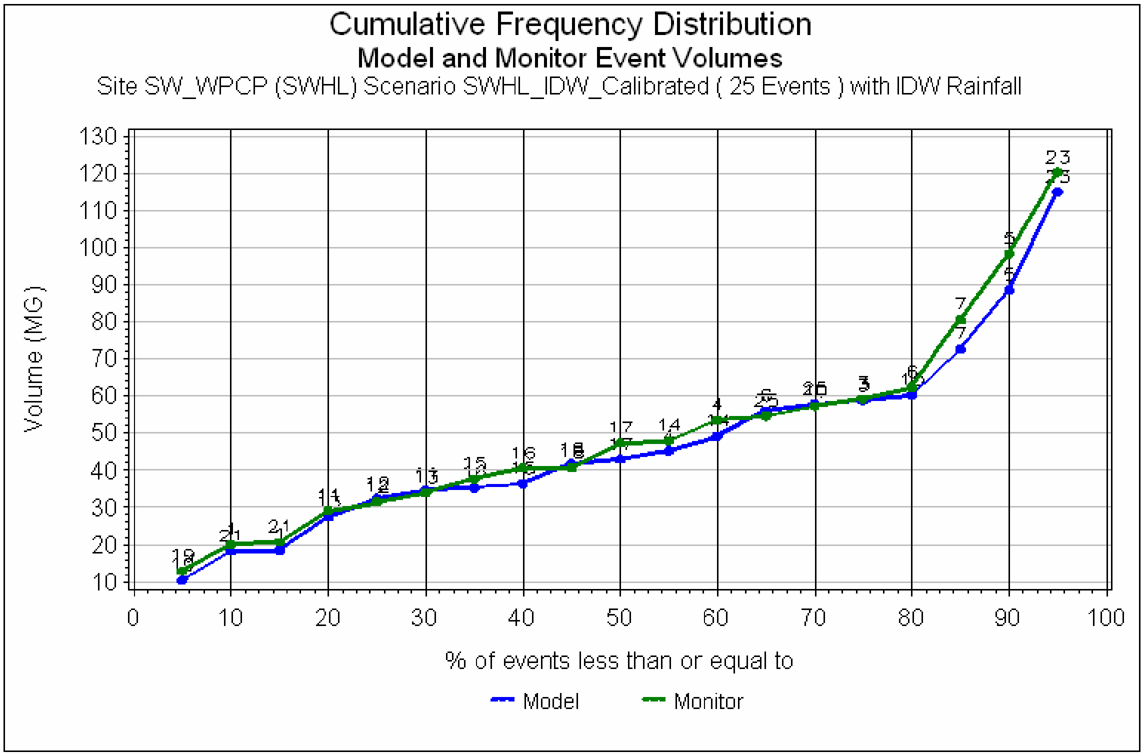


Figure 5-16 CFD Monitored and Modeled Event Volumes SWHL

5.3.3.8.3 Northeast Drainage District

The Northeast Water Pollution Control Plant (NE WPCP) receives combined sewer flows by gravity from the Northeast High-Level system (NEHL) and through pumping from the Northeast Low-Level system (NELL). These two drainage systems connect at the NE WPCP and can be modeled separately or as a single combined model. The NEHL is comprised of two interceptor systems: the Frankford High Level (FHL) and the Tacony (T). The NELL is comprised of five interceptor systems: the Somerset Low-Level (SOM), the Upper-Frankford Low-Level (UFLL), the Lower Frankford Low-Level (LFLL), the Upper Delaware Low-Level (UDLL) and the Pennypack (P).

Final validation plots for the Northeast drainage district (NEDD) model are presented in Figures 5-17 through 5-30. These plots include scatter plots of model versus monitored WPCP influent wet weather event volumes showing linear regression analysis results, cumulative frequency distribution plots of model and monitored WPCP influent wet weather event volumes and selected model and monitored influent wet weather flow hygrographs. Plots are first presented for the total NE WPCP and the combined NELL. Calibration plots are also presented for each of the following three metered plant influent lines: FHL, the combined Somerset and Upper Frankford Low-Level (Som-Frk) and UDLL, which also includes flow from LFLL. The same event list is used for all analyses. Events are excluded from the calibration analyses based on the set of protocols described previously and are distinguished from those included in the regression plots by use of different symbols and shading.

The plots generally display a good correlation between observed and simulated event volumes over the full range of events analyzed. Any significant systematic deviation between simulated and observed data would indicate events of a certain volume range were not being adequately simulated by the model.

Significant systematic under-estimation of Som-Frk influent wet weather event volumes is indicated by the CFD and linear regression presented in Figure 5-17 and Figure 5-18. However, inspection of individual influent wet weather flow hydrographs for the January 7 and July 1, 2005 rainfall events presented in Figure 5-19 and Figure 5-20, respectively, reveal a very close overall correlation between modeled and monitored hydrographs. In fact, the correlation between modeled and monitored hydrographs for the Som-Frk appears to be much better than that for the UDLL, as illustrated in Figure 5-21 and Figure 5-22, which shows a higher correlation in the linear regression and CFD plots than the Som-Frk.

5.4 LTCPU Alternatives Model Development

Development of the alternatives model was initiated using the previously discussed baseline model as its foundation. The alternatives model analysis process was separated into two categories: land-based and infrastructure-based controls. Projects for green stormwater infrastructure implementation and those utilizing BMPs were modeled with the land-based control methodology, while designs involving elements such as tunnels and parallel interceptor systems were considered infrastructure-based controls. Descriptions of the model development for each category are presented below. More details on the LTCPU alternatives model development subsections can be found in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

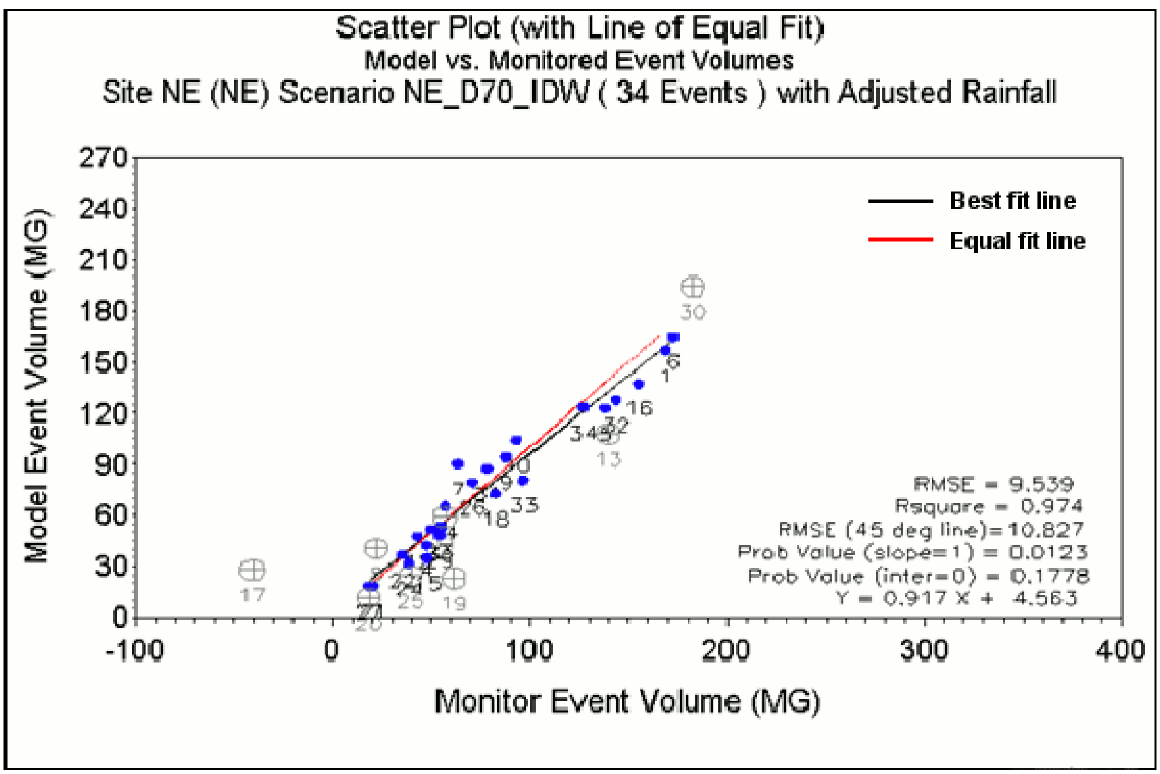


Figure 5-17 NE WPCP Linear Regression of Modeled Versus Monitored Event Volumes

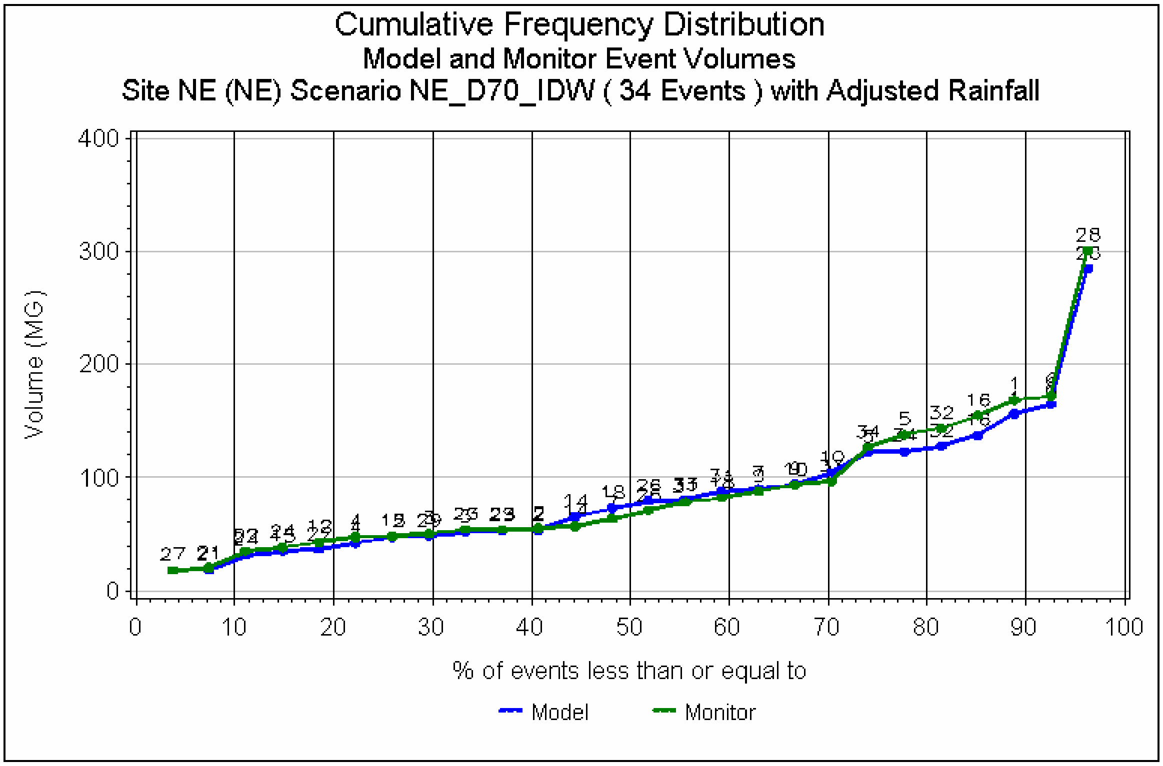


Figure 5-18 NE WPCP CFD of Modeled and Monitored Event Volumes

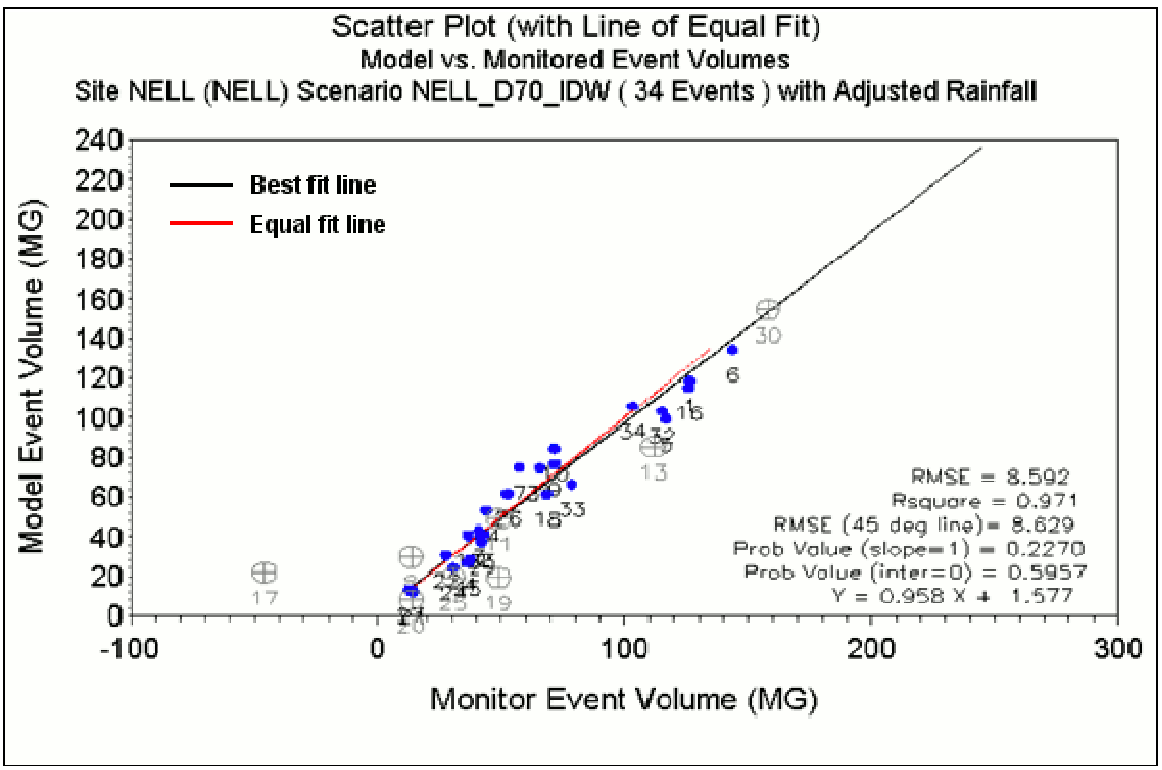


Figure 5-19 NELL Linear Regression of Modeled Versus Monitored Event Volumes

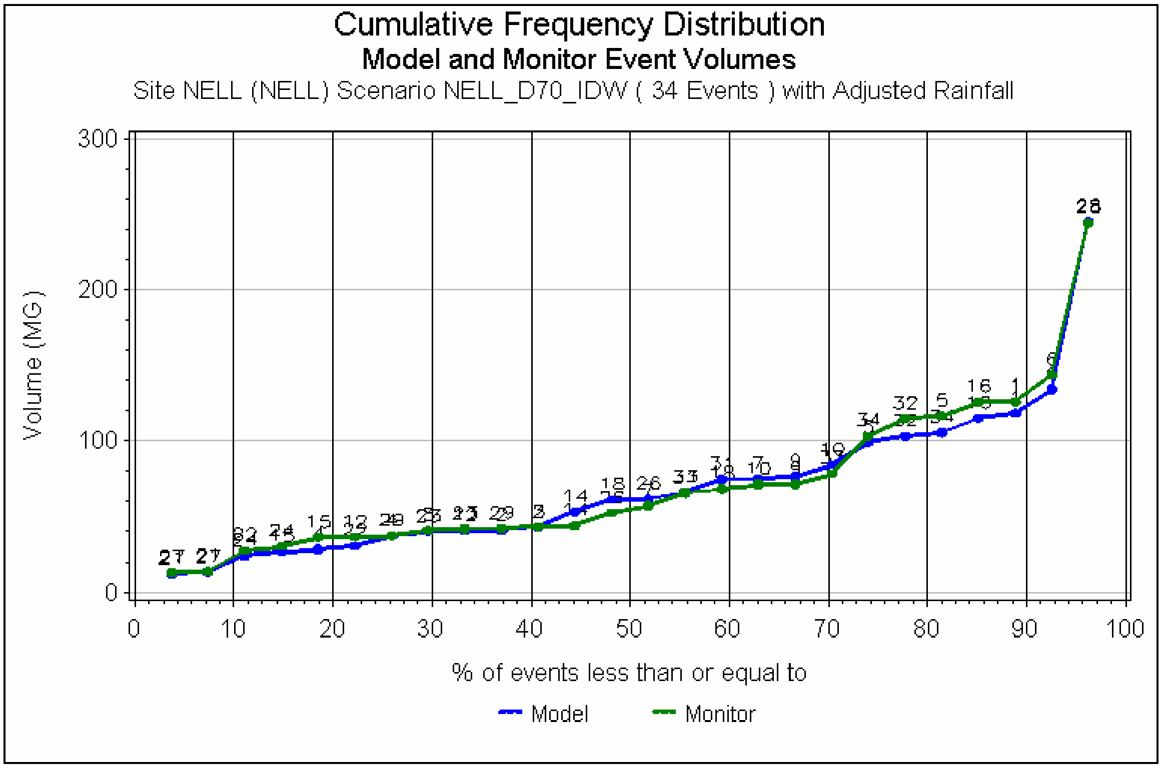


Figure 5-20 NELL CFD of Modeled Versus Monitored Event Volumes

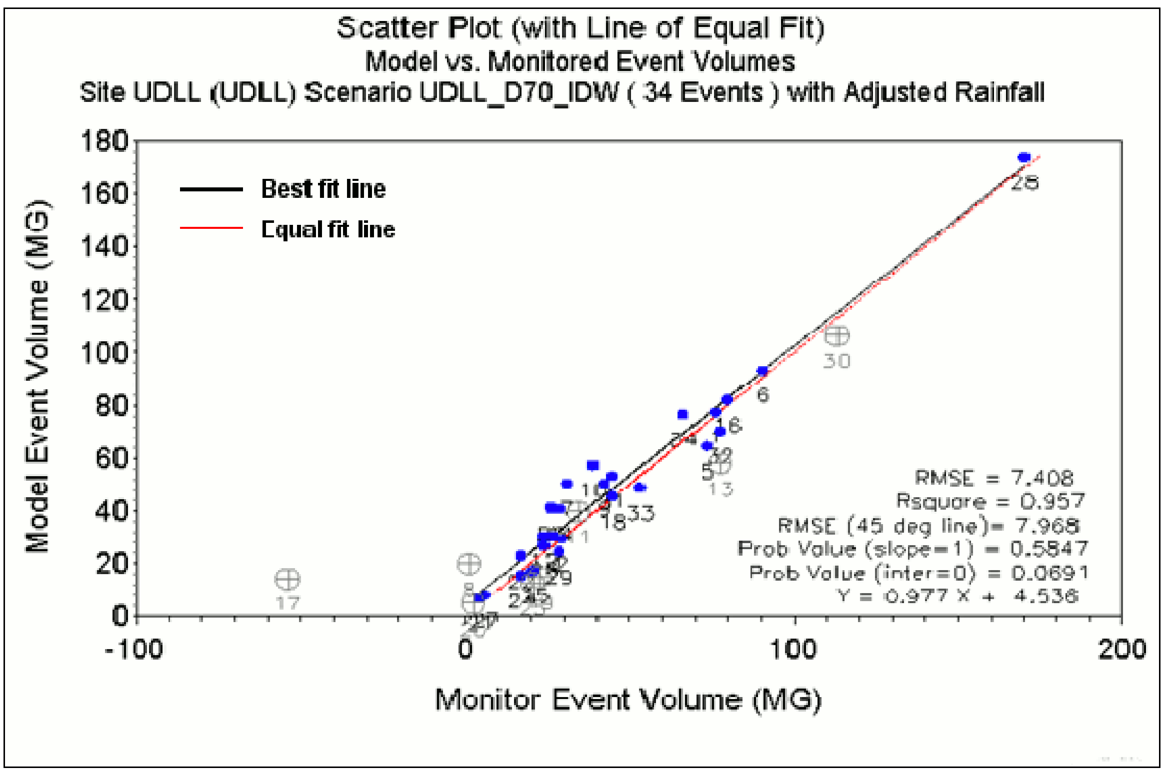


Figure 5-21 UDLL Linear Regression of Modeled Versus Monitored Event Volumes

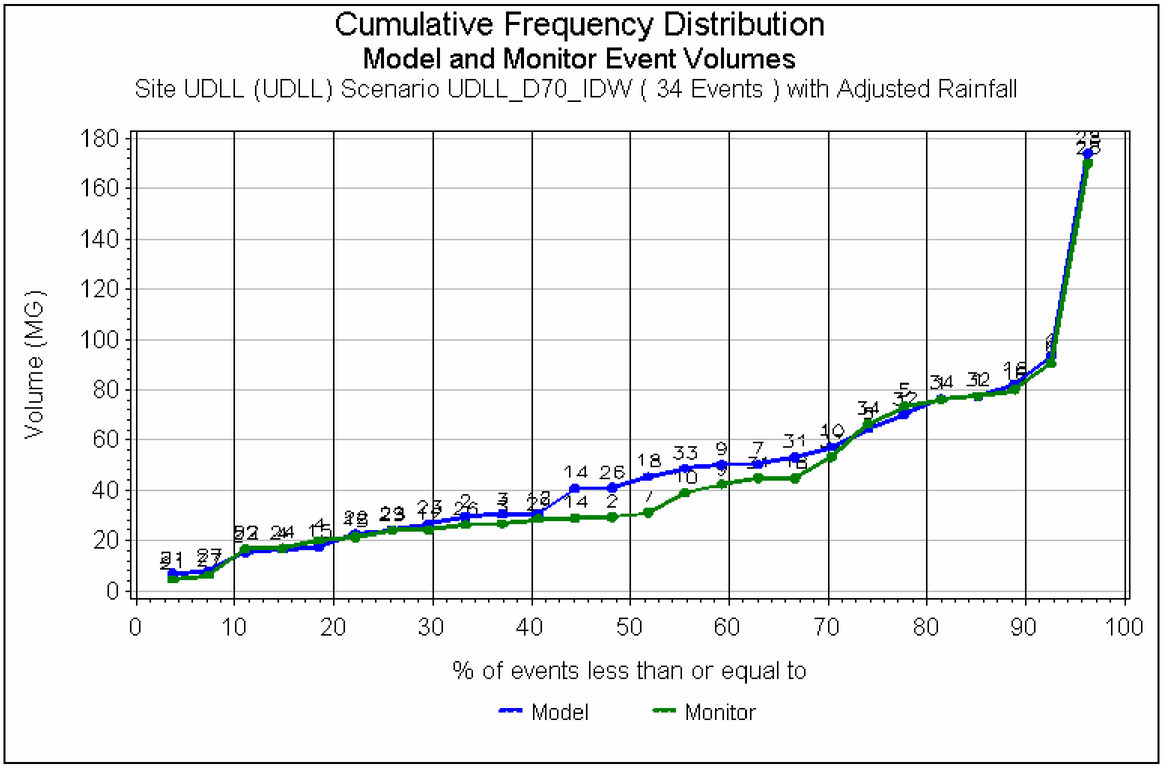


Figure 5-22 UDLL CFD of Modeled Versus Monitored Event Volumes

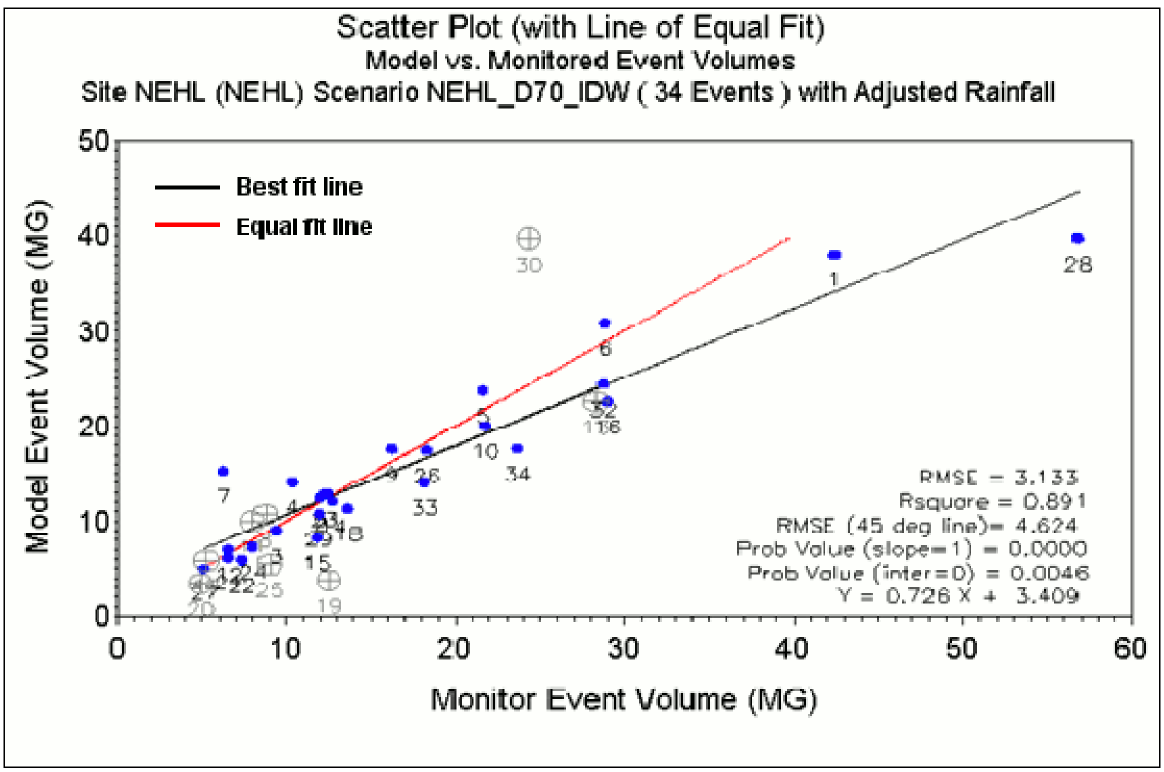


Figure 5-23 NEHL Linear Regression of Modeled versus Monitored Event Volumes

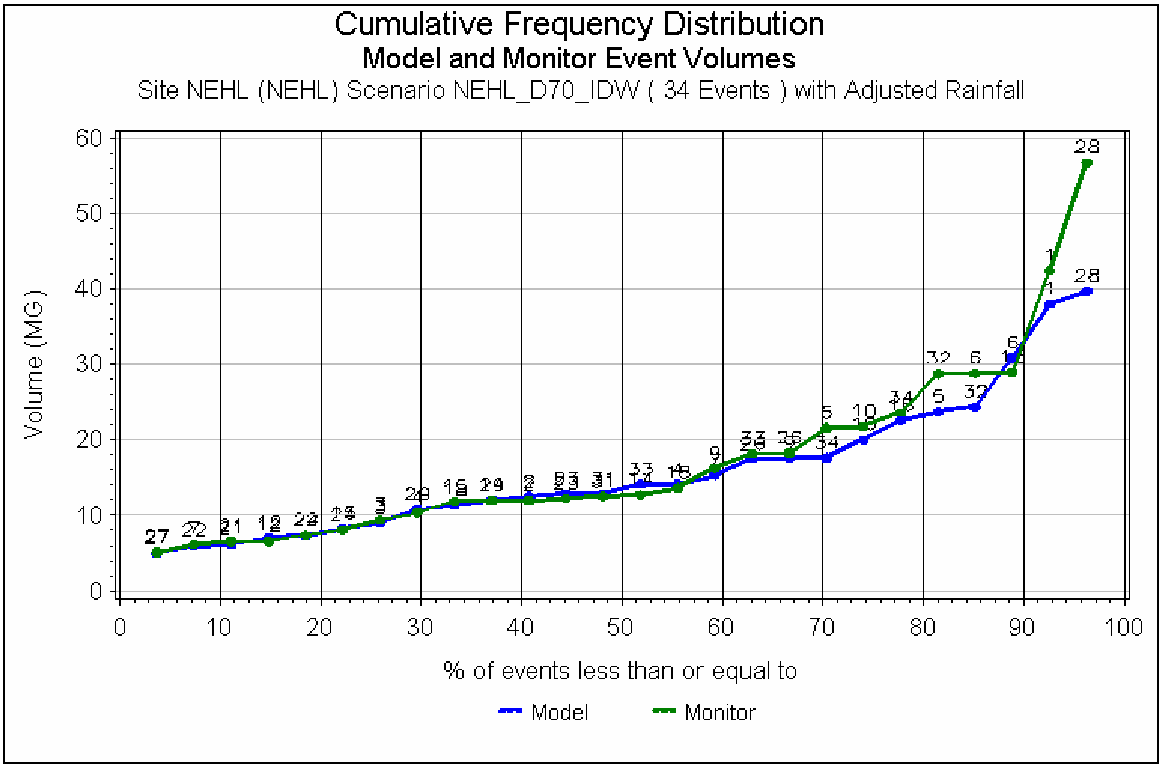


Figure 5-24 NEHL CFD of Modeled Versus Monitored Event Volumes

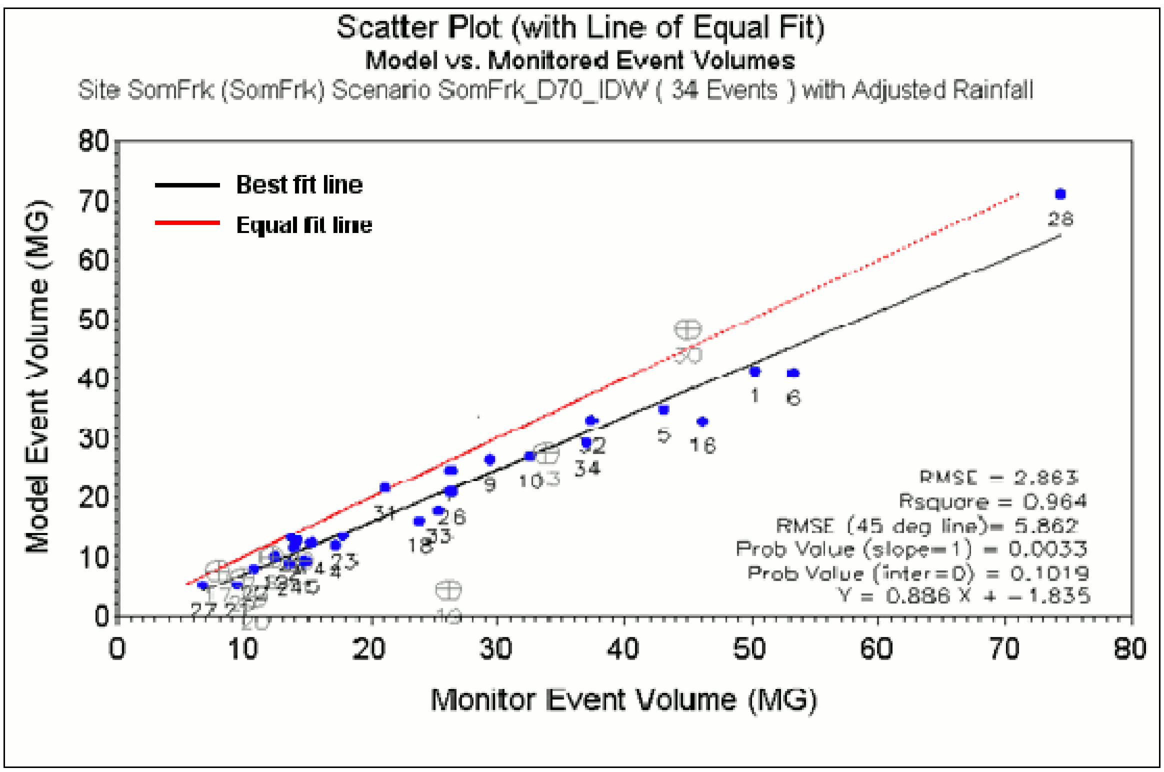


Figure 5-25 Som-Frk Linear Regression of Modeled versus Monitored Event Volumes

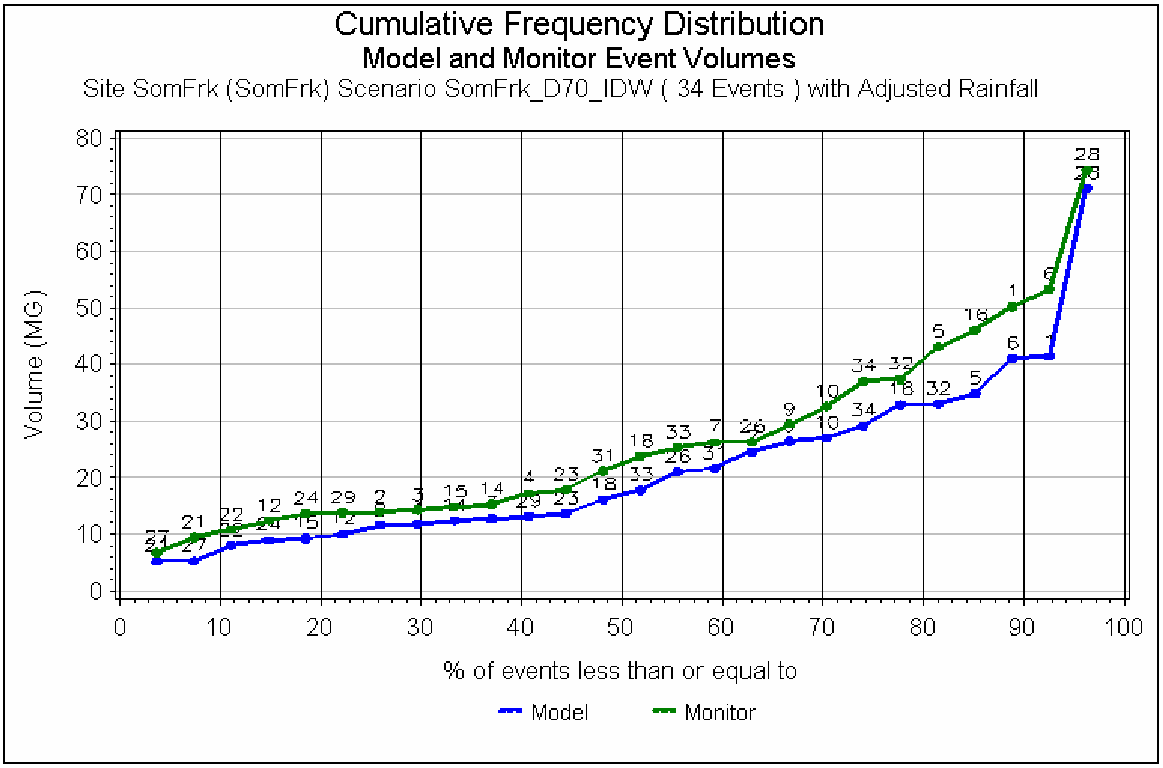


Figure 5-26 Som-Frk CFD of Modeled Versus Monitored Event Volumes

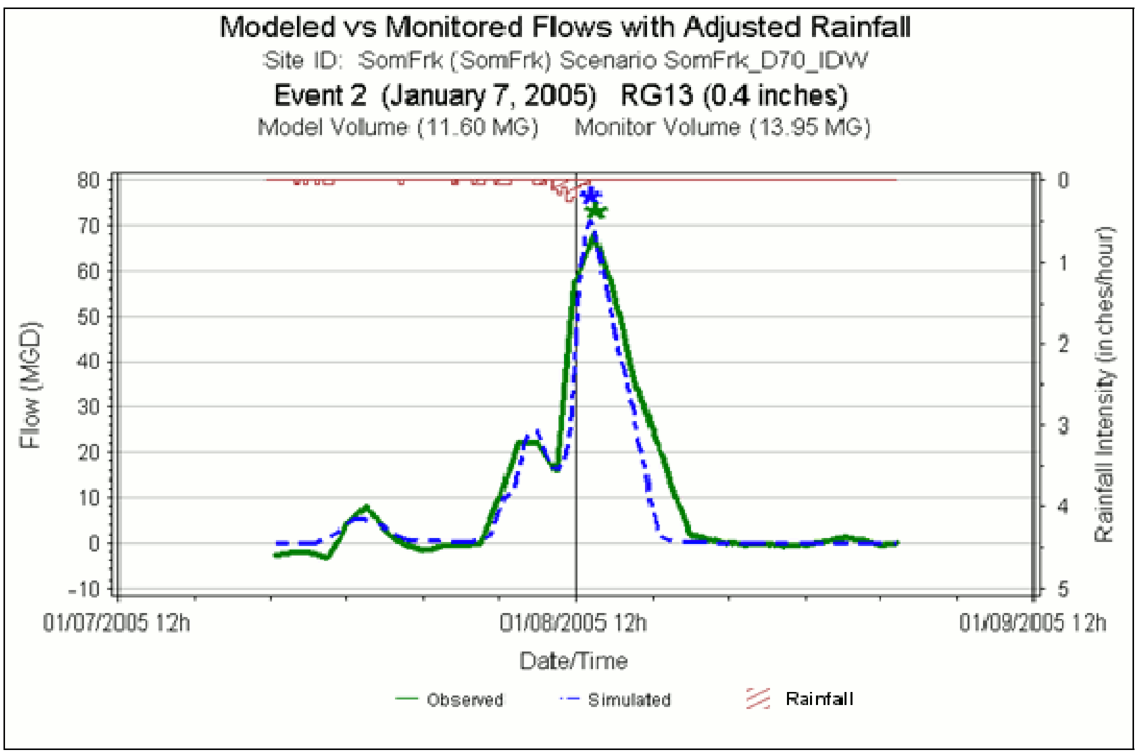


Figure 5-27 Som-Frk Model and Monitored Wet Weather Flow Time-Series Plot for the January 7, 2005 Event

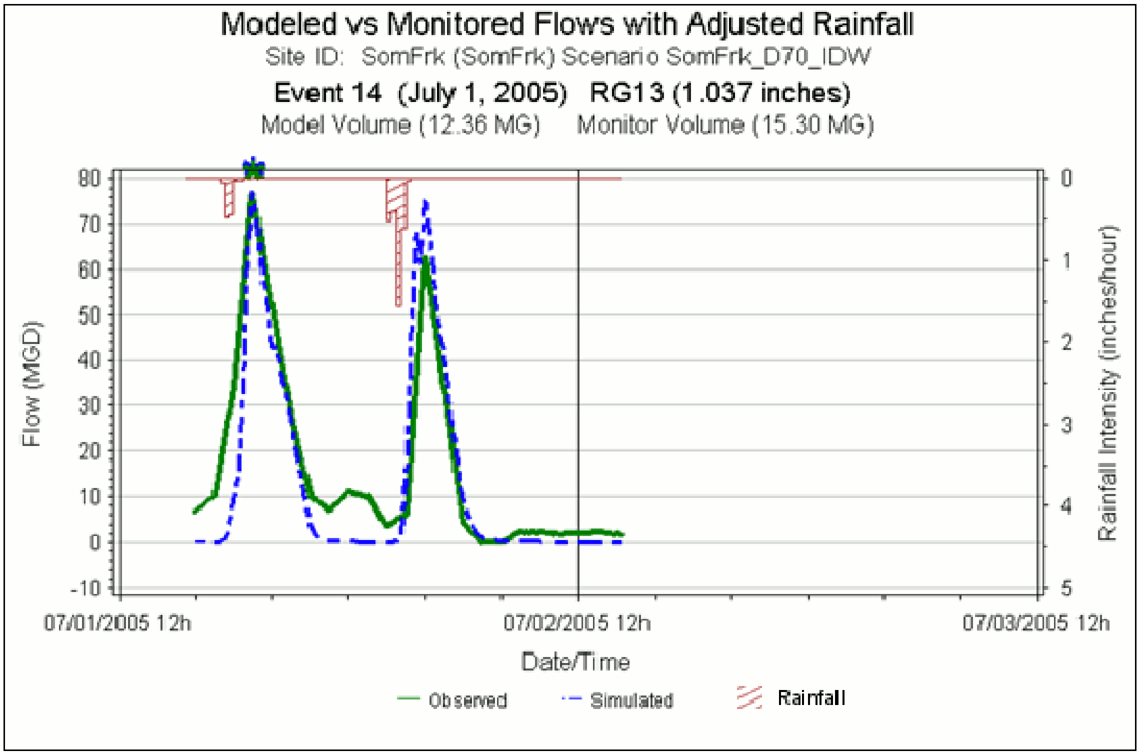


Figure 5-28 Som-Frk Model and Monitored Wet Weather Flow Time-Series Plot for the July 1, 2005 event

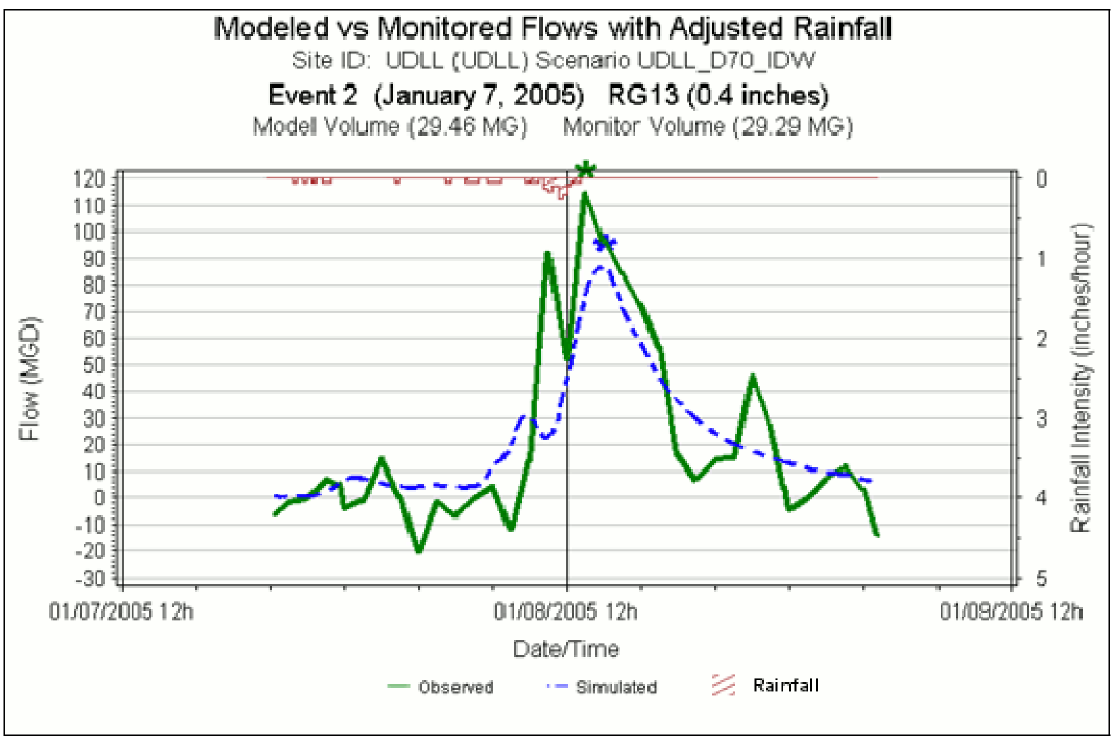


Figure 5-29 UDLL Model and Monitored Wet Weather Flow Time-Series Plot for the January 7, 2005 Event

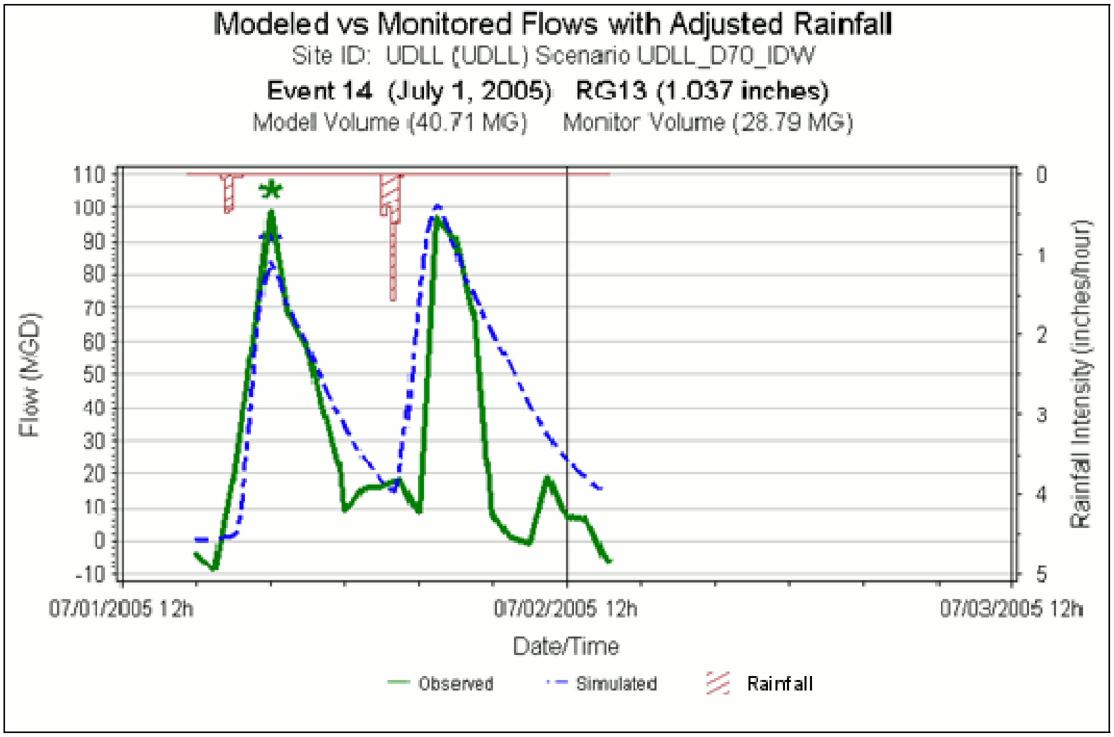


Figure 5-30 UDLL Model and Monitored Wet Weather Flow Time-Series Plot for the July 1, 2005 event

5.4.1 Land-Based Controls

Philadelphia's stormwater regulations require a minimum level of performance from post-construction stormwater management structures. To efficiently analyze this level of performance within each watershed a generalized approach was adopted in representing green infrastructure within the models. A green infrastructure tool was built to model green infrastructure and to thoroughly quantify the benefits of the stormwater ordinance, demonstration programs and incentive programs in the same terms used to evaluate capital projects on a watershed by watershed basis. In order to do so, detailed analyses of the City's impervious cover were conducted to correctly define targeted areas.

5.4.1.1 General Low Impact Development Model Approach

The City's stormwater ordinances, demonstration programs and incentive programs promote implementation of a variety of stormwater control types and require a certain level of performance. The first task in analyzing how the City's sewer systems will respond to implementing more of the green stormwater infrastructure was building a general model to represent a mix of the various types of stormwater control structures which are designed to meet or exceed the required level of performance. A general model that represents the hydraulic and hydrologic processes like storage, slow release and infiltration was adapted to represent a variety of physical structures. Standardizing the model setup allows analysis of green infrastructure option alongside other traditional infrastructure options.

To more accurately assess the potential benefit of green infrastructure a thorough analysis and assessment of Philadelphia's impervious surfaces available for green stormwater infrastructure implementation was conducted. Through the use of GIS tools and aerial photography, a comprehensive and highly detailed account of the City's impervious land cover was created. The impervious surfaces were broken down into the following categories:

- Total impervious area
- Highways
- Streets
- Private land
  - Land targeted for incentives
  - Other private land
- Public land
  - PWD property
  - Recreation department
  - Fairmount Park
  - School district
  - Vacant/abandoned land
  - Other public land (non-PWD, Recreation Dept, Fairmount Park)

Within the private and public land categories, the impervious area attributed to streets, sidewalks, parking and buildings was determined. The model manipulated these impervious area values to represent various levels of green infrastructure implementation. A more detailed account of the impervious analysis will be described subsequently in Section 6.

The model setup followed a series of model shed processing setup steps, which were carried out within an Excel spreadsheet. First, an area (or range of areas) of impervious surface was determined to be affected by the stormwater ordinance over the planning horizon – labeled in Figure 5-31 as I_o. This area may be adjusted as practices are implemented that provide a lower level of performance than the ordinance. Second, additional areas are determined to be affected by incentives for private land not subject to the ordinance and public land to be targeted for stormwater management. These areas are updated within the model and produce a range of performance results for varying levels of implementation based on the desired amount of impervious surface managed by land-based controls. Flow produced from the controlled impervious surface – identified as I_c in Figure 5-31 – is routed onto a pervious surface, labeled as P_c, to allow infiltration to be simulated. Any runoff from the pervious shed is loaded to a storage node large enough to meet required capture volume. An overflow weir simulates the overflow volume from this storage node once the storage volume has been exceeded. The storage volume is slow released into the CSS at a designated rate set by the City's regulations. The slow release flow is combined with the uncontrolled portion of flow entering the CSS. The total runoff volume from the shed, slow release structure, overflow weir and combined flow into the CSS is recorded and subsequently used to determine control structure volumes necessary to fulfill the stormwater ordinances and regulations. The hydrologic surface flow routing is shown in the Figure 5-31.

I_O is equal to the impervious area controlled (I_C + P_C). The remaining impervious area is labeled as I_{NC}. The existing pervious area not associated with a green-stormwater infrastructure control structure is identified as P_{NC}.

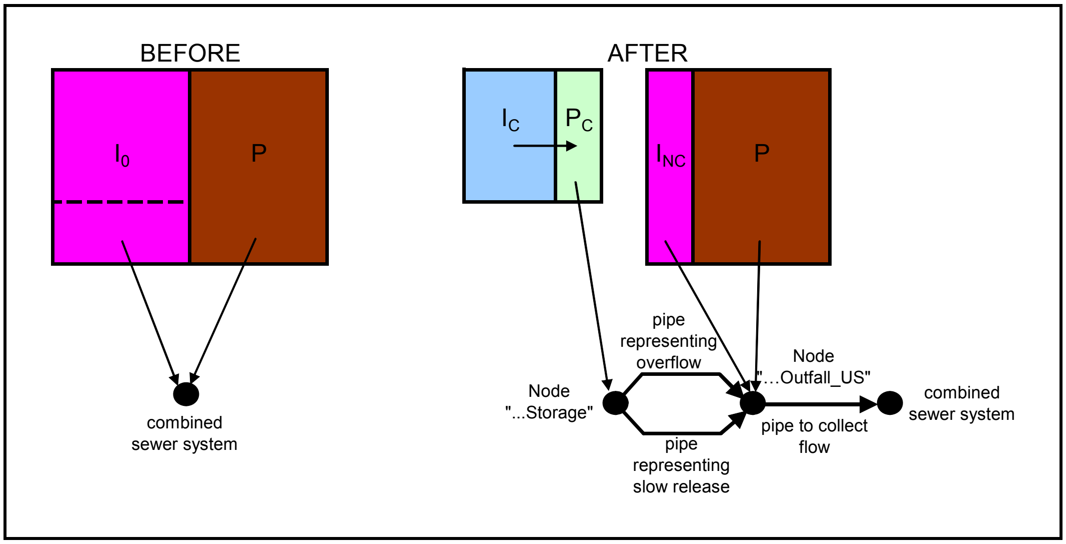


Figure 5-31 Visual Representation of How a Portion of a Subcatchment is Controlled and Routed Through Green Infrastructure Within the Model

Other urban communities have incorporated street trees in an effort to quickly and inexpensively incorporate rainfall interception mechanisms into the urban environment. Street trees by themselves provide a level of control lower than that defined by the PWD Stormwater Regulations and what may be simulated by the general model approach. Due to the complexity of street tree analysis a literature review, followed by a detailed analysis specific to Philadelphia, was conducted to define an appropriate equivalency ratio to supplement the general model for land-based control analyses.

Simulation of a single tree canopy and comparison to a previously uncontrolled area retrofitted to meet the PWD Stormwater Regulations requirements was done to derive a runoff reduction ratio. This defined the relative difference in benefit between the two scenarios. Results produced a ratio of 0.875, meaning the tree canopy specific model total runoff reduction was 87.5 percent of the total runoff reduction produced by the model meeting the stormwater regulations requirements.

The area of implementation of street trees is limited, therefore it was necessary to adjust this ratio to represent the city-wide benefit of street tree implementation. The process to determine the available street area for tree implementation involved a literature review of other cities' street tree ordinances and regulations and an available sidewalk/street impervious area analysis from the information produced from the impervious analysis mentioned previously.

A significant reduction in the equivalency ratio was expected at the end of this analysis due to the limitations for planting street trees. The adjustments applied to the preliminary equivalency ratio of 0.875 produced a reduced runoff reduction equivalency ratio of approximately 0.287 or 28.7 %. Ultimately, the ratio states that 1 ac of impervious surface covered by tree canopy results in the same total runoff volume reduction as approximately 0.287 ac of impervious surface draining to an infiltration bed meeting the stormwater regulations requirements.

5.4.2 Infrastructure Based Controls

5.4.2.1 Sewer Separation – Highway and Waterfront Disconnection

PWD is considering a long-term policy to require disconnection of waterfront property from the CSS where appropriate. Runoff from these properties will be discharged directly to the Delaware River after water quality pre-treatment. Some properties may be allowed to connect to PWD's outfall pipe downstream of the combined sewer regulator structure, while other properties may be required to construct and permit a new outfall.

Through the use of GIS, sewersheds intersecting I-95 were identified and the total area of highway and impervious area between the highway and the Delaware River were calculated for each shed. The affected shed area was then removed from consideration and the total impervious percentage was recalculated for the sewershed. Table 5-6 provides the total shed areas for each drainage district and Figure 5-32 highlights the areas affected by the waterfront disconnection for the SEDD and NEDD. Areas in the SWDD affected by I-676 and I-76 eligible for sewer separation were removed from the model and simulations were performed to determine the magnitude of change in runoff volume. The effects were negligible and, therefore, further analysis of waterfront disconnection within the SWDD was not done.

Table 5-6 Sewershed Areas and Percent Impervious Area Removed Due to Waterfront Sewer Separation Analysis

Land Location	Combined-Sewered Impervious Area (ac)				Combined-Sewered Impervious Area (% of total)		
	City-Wide	SEDD	NEDD	SWDD	City-Wide	SEDD	NEDD
Non-Waterfront	43,414	8,700	20,060	14,654	95.8	91.5	98.4
Between Major Highways and Rivers	1,507	578	234	695	3.5	6.6	1.2
Highway	315	165	94	56	1.1	1.9	0.5
Waterfront + Highway	1,822	743	327	752	4.2	8.5	1.6

5.4.2.2 Deep Tunnels

For a tunnel storage alternative, CSO flows in excess of the interceptor capacity are diverted via a modified or new diversion structure to a series of secondary tunnel structures that convey flow into the storage tunnel. The approach to model the tunnels for all three districts was to simulate the tunnels as storage nodes. To model the tunnels as a storage node, the length of the tunnel to be modeled is obtained by doing a preliminary tunnel alignment. Once the length is determined models are set up for varying tunnel diameters. The tunnel is assumed to be circular. The diameters range from 15 to 35 ft and are increased by an interval of 2.5 ft for each simulation. Using the tunnel length and the diameter a volume is calculated. Using eighty percent (80%) of the calculated volume, a storage node 20 ft deep with constant surface area is simulated. The storage section representing the tunnel volume itself has a plan surface area that will satisfy the tunnel volume requirements. The maximum tunnel drain down rate was set so that the tunnel would drain down in 24 hours when the capacity of the WPCP is available. All the outfalls that will contribute to the tunnel are connected to the storage node. Figure 5-33 shows a visual representation of the tunnel in the models. The sub-sections that follow describe the model details specific to each drainage district.

The planning level alignments were based on proximity to the existing CSO diversions and Water Pollution Control Plants (WPCP), available geotechnical boring data, avoidance of significant underground property easements and the tunnel boring machine's turning radius. Conceptually, the tunnel alignments can be represented as broad cross sectional corridors.

The secondary structures of the tunnel include a near surface drop shaft, vertical drop shaft, de-aeration chamber and connecting tunnel. The process of combining and conveying flow from multiple diversion structures is called flow consolidation. The flow consolidation strategy for a particular storage tunnel alternative was primarily selected through a least cost comparison of flow consolidation versus conveying the flow to the tunnel. This cost comparison was made at each regulator and the cheaper option selected. The cost to consolidate flow was based on the lengths, sizes and depths of the consolidation piping. The length of the consolidation piping was based on the distance between adjacent diversion structures, existing rights of way, the existing street and property layout and the selection of alignments that balances longer pipeline lengths with shallower pipeline depths. The lengths were measured with ArcGIS utilities and the consolidation alignments largely followed the existing interceptor's path. The sizes of the consolidation piping were based on SWMM4 model predictions of the peak design flow rates and various assumed design slopes and velocities. The depths of the consolidation piping were calculated as the differences between the diversions' overflow elevation and the average ground surface elevation along the pipeline alignment.

The cost to convey flow to the tunnel was based on the depths, sizes and lengths of the secondary structures. The depths of the near surface drop structures were based on the differences between the diversions' overflow elevation or the consolidation piping invert elevations and the ground surface elevation at the near surface drop structure locations. The sizes and specific designs of the near surface drop structures, vertical drop shaft structures, de-aeration chambers and adits – which may be described as access points to the tunnel –were based on the same design flow rates used to size the consolidation piping. The lengths of the adits were based on the distances between the drop shaft locations and the planning level tunnel alignments.

The volume captured by the tunnel over the course of a one-year simulation was calculated as the difference between the overflow produced from the simulated tunnel scenario and the corresponding baseline scenario. There are two baseline scenarios, each representing the upper and lower boundary of an uncertainty range for DCIA, baseflow and RDI/I watershed characteristics. Each baseline scenario has the interceptors draining to the plant with pumping boundary conditions limiting the high level interceptors' inflow into the WPCP. The baseline plant capacities for the SEDD, NEDD and SWDD are 280, 435 and 480 MGD, respectively.

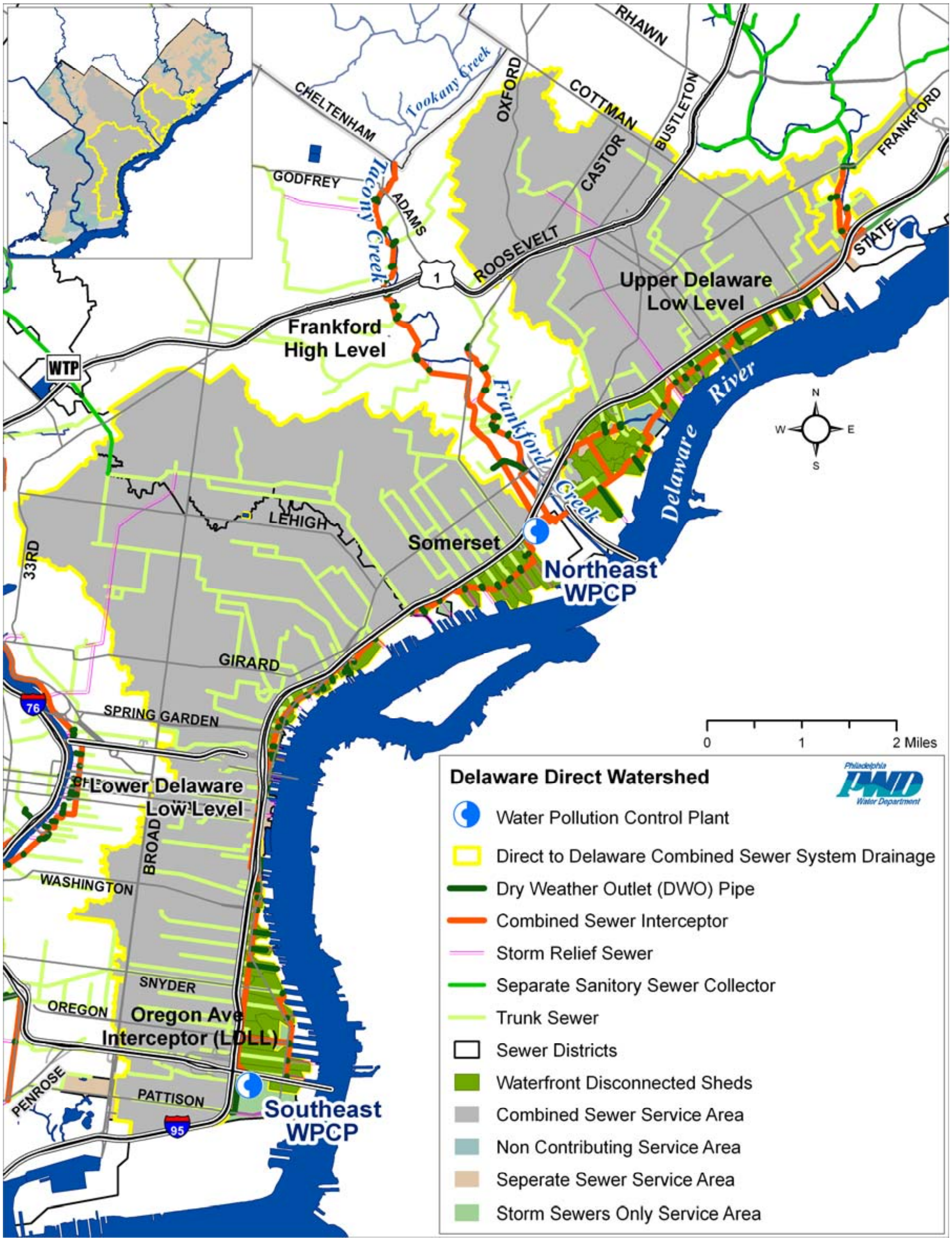


Figure 5-32 CSO Areas Affected by the Waterfront Sewer Separation (Green Highlighting)

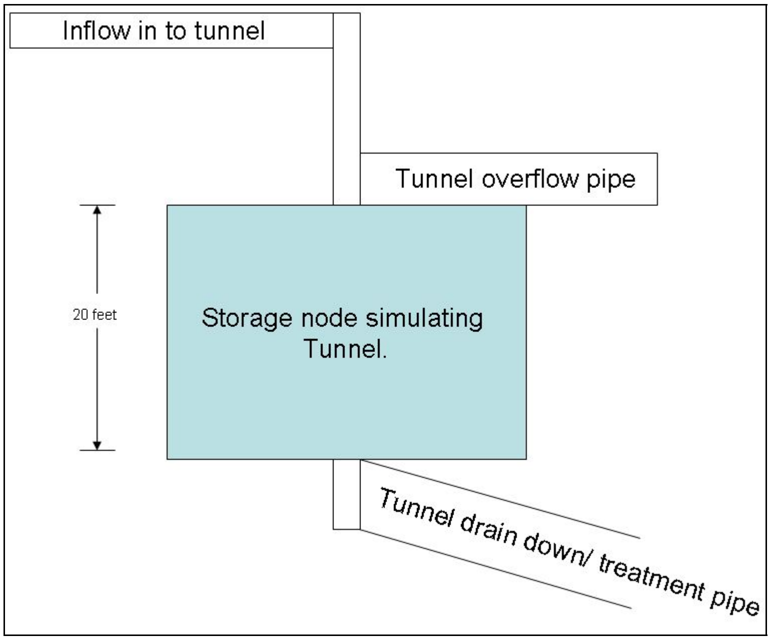


Figure 5-33 Storage Depicting the Tunnel

5.4.2.2.1 SEDD Tunnel

The SEWPCP was assumed to be expanded to treat 330 MGD. The total length of the tunnel, excluding the drain down section, was 5.9 mi. The inflow into the tunnel model is the total flow produced from each regulator's outfall. Table 5-7 presents the tunnel length and corresponding volume of the storage node for the SEDD tunnel. The volumes shown in the first row represent the total tunnel volume and the second row shows the 80% tunnel volume that was used for the simulations.

Table 5-7 Length and Volume Data for the SEDD Tunnel Model

			Tunnel Diameter (ft)								
			15	17.5	20	22.5	25	27.5	30	32.5	35
	Length (ft)	Length (mi)	Tunnel Volume (MG)								
SEDD	31340.0	5.9	41.4	56.4	73.7	93.2	115.1	139.3	165.8	194.6	225.6
Volume used For simulation	**31340.0**	**5.9**	**33.2**	**45.1**	**58.9**	**74.6**	**92.1**	**111.4**	**132.6**	**155.6**	**180.5**

5.4.2.2.2 NEDD tunnel

It was assumed the NEWPCP will be expanded to treat 650 MGD. The total NEDD tunnel length is estimated to be 10 mi. The tunnel length along the Delaware was estimated as 5.3 mi and along Tacony as 4.7 mi. It is also assumed all tunnels will be interconnected. Table 5-8 presents the tunnel length and corresponding volume of the storage node. The volumes shown in the first row are the total volumes of the tunnel and the 80% volume used for simulations is presented in the second row.

Table 5-8 Length and Volume Data for the NEDD Tunnel Model

			Tunnel Diameter (ft)								
			15	17.5	20	22.5	25	27.5	30	32.5	35
	Length (ft)	Length (mi)	Tunnel Volume (MG)								
NEDD	53000.0	10.0	70.1	95.4	124.6	157.7	194.7	235.6	280.3	329.0	381.6
Volume used for simulation	**53000.0**	**10.0**	**56.1**	**76.3**	**99.7**	**126.2**	**155.7**	**188.5**	**224.3**	**263.2**	**305.3**

The NEDD also includes all regulators draining to the Upper Frankford Low Level (UFLL), Lower Frankford Low Level (LFLL) and the Pennypack (PP) interceptor systems in addition to the regulators draining to the UDLL, SOM and TAC interceptor systems. The flow was directed to the tunnel for these interceptor systems using the same methodology as described previously.

5.4.2.2.3 SWDD Tunnel

It was assumed the SWWPCP will be expanded to treat 540 MGD. The total SWDD tunnel length is estimated to be 13.7 mi. The tunnel length along the Schuylkill was estimated as 6.4 mi and along Cobbs Creek as 7.3 mi. It is also assumed all tunnels will be interconnected. Table 5-9 presents the tunnel length and corresponding volume of the storage node. The volumes shown in the first row are the total volumes of the tunnel and the 80% volume used for simulations is presented in the second row.

Table 5-9 Summary of SWDD Tunnel Volume and Length Data

			Tunnel Diameter (ft)								
			15	17.5	20	22.5	25	27.5	30	32.5	35
	Length (ft)	Length (mi)	Tunnel Volume (MG)								
SWDD	72491	13.7	95.9	130.5	170.4	215.7	266.3	322.2	383.4	450.0	521.9
Volume used for simulation	**72491**	**13.7**	**76.7**	**104.4**	**136.3**	**172.5**	**213.0**	**257.8**	**306.7**	**360.0**	**417.5**

5.4.2.3 Parallel Interceptors – Transmission Systems

Prior to modeling, a preliminary spreadsheet was created to align a parallel conveyance system to capture and convey flow to the respective WPCP of the existing interceptor system being paralleled. Output from the SAS EOP processing tool served as input to the spreadsheet. The SAS tool identifies a peak flow value and overflow volume for each overflow goal at every regulator in the system having an outfall. The spreadsheet analyzes each regulator producing an overflow for each green-stormwater infrastructure implementation scenario for all overflow goals 1 through 25 – which were previously discussed in Section 5.2.3.

The spreadsheet sizes the conveyance pipe segments based on the cumulative flow as it is captured at the regulator outfall and is moved downstream to the plant. Once the cumulative flow requires a pipe larger than a 12 ft x 12 ft box sewer, a second parallel interceptor must be considered to convey

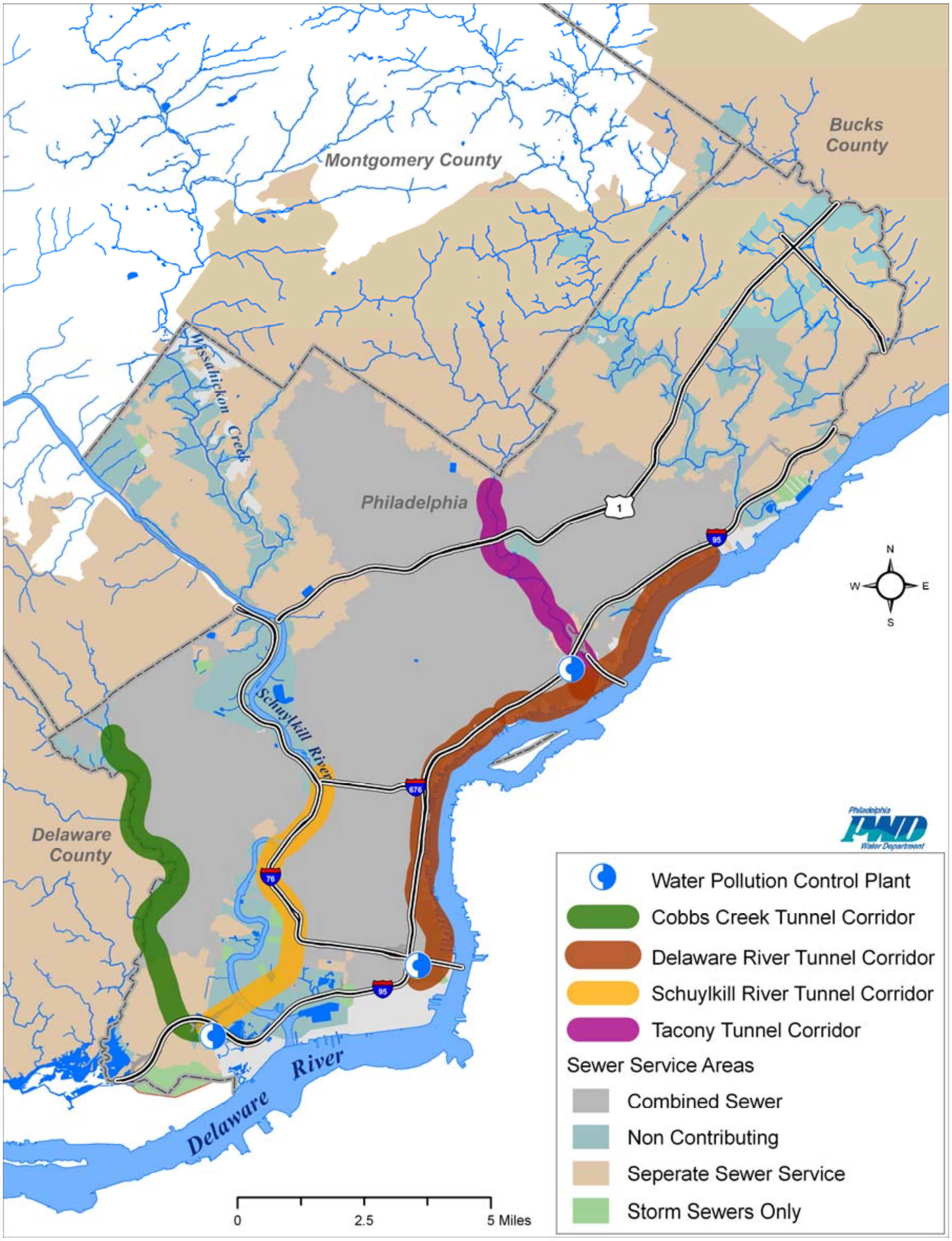


Figure 5-34 Potential Tunnel Alignment

the excess flow to the plant in order to reach the target overflow goal for the respective target overflow goal. Figure 5-35 presents a potential transmission parallel interceptor conveyance layout for the Cobbs Creek Watershed.

5.4.2.4 Satellite High Rate Treatment

Prior to implementing the conceptual modeling design of conveyance pipes routed to a satellite treatment plant into SWMM4, a preliminary spreadsheet analysis was performed to determine the feasibility of this family of alternatives. At each implementation level of land-based controls, the required end-of-pipe treatment rates were determined using the SAS EOP program, which was described in Section 5.2.3. The SAS program uses capture regulator data, land-based control general green infrastructure model simulation output and an outfall list as input. Depending on the desired performance level, the program determines the corresponding event peak treatment rate that satisfies the target performance overflow rate. The peak treatment rate is used to size the parallel interceptor for transmission to the plant, with the maximum pipe diameter limited by constructability, taken to be a 12 ft x 12 ft concrete box sewer.

For the purposes of the spreadsheet analysis, at a minimum, the plant receives the maximum flow that may be delivered by the existing interceptors and the base wastewater flow (BWWF) as defined by the results of the stress test updated in the attached plant capacity report completed in March 2009, which is attached in Supplemental Documentation Volumes 6, 7 and 8 (Stress Testing of the Northeast WPCP, Stress Testing of the Southeast WPCP and Stress Testing of the Southwest WPCP). The peak flow from the outfalls of the existing interceptor systems are collected and conveyed through a parallel interceptor system to satellite treatment facilities until the size of pipe equals the constructability limit. The total flow delivered to the satellite treatment facility determines the required size of the plant and consolidation sewers for each level of land-based control. The spreadsheet determines the most appropriate regulator outfall to place at the satellite treatment plant, based on the volume of overflow, and then routes the remaining overflow collected from the other regulator overflows to that chosen location.

In some cases, satellite treatment locations are manually overridden to place facilities at locations where PWD has known space availability for such construction. In this situation, the conveyance pipes are routed to the user designated treatment location and sized according to cumulative flow.

Figure 5-36 shows a visual representation of a potential parallel conveyance system routed to various locations of satellite treatment facilities for the Delaware Watershed located with the spreadsheet analysis.

Areas available for satellite treatment construction are:

- Frankford Arsenal (Delaware Direct Watershed) near Regulator D12
- Near Eagle Creek (Schuylkill Watershed) at Regulator S45
- Oregon Avenue (Delaware Direct Watershed) at Regulator D70

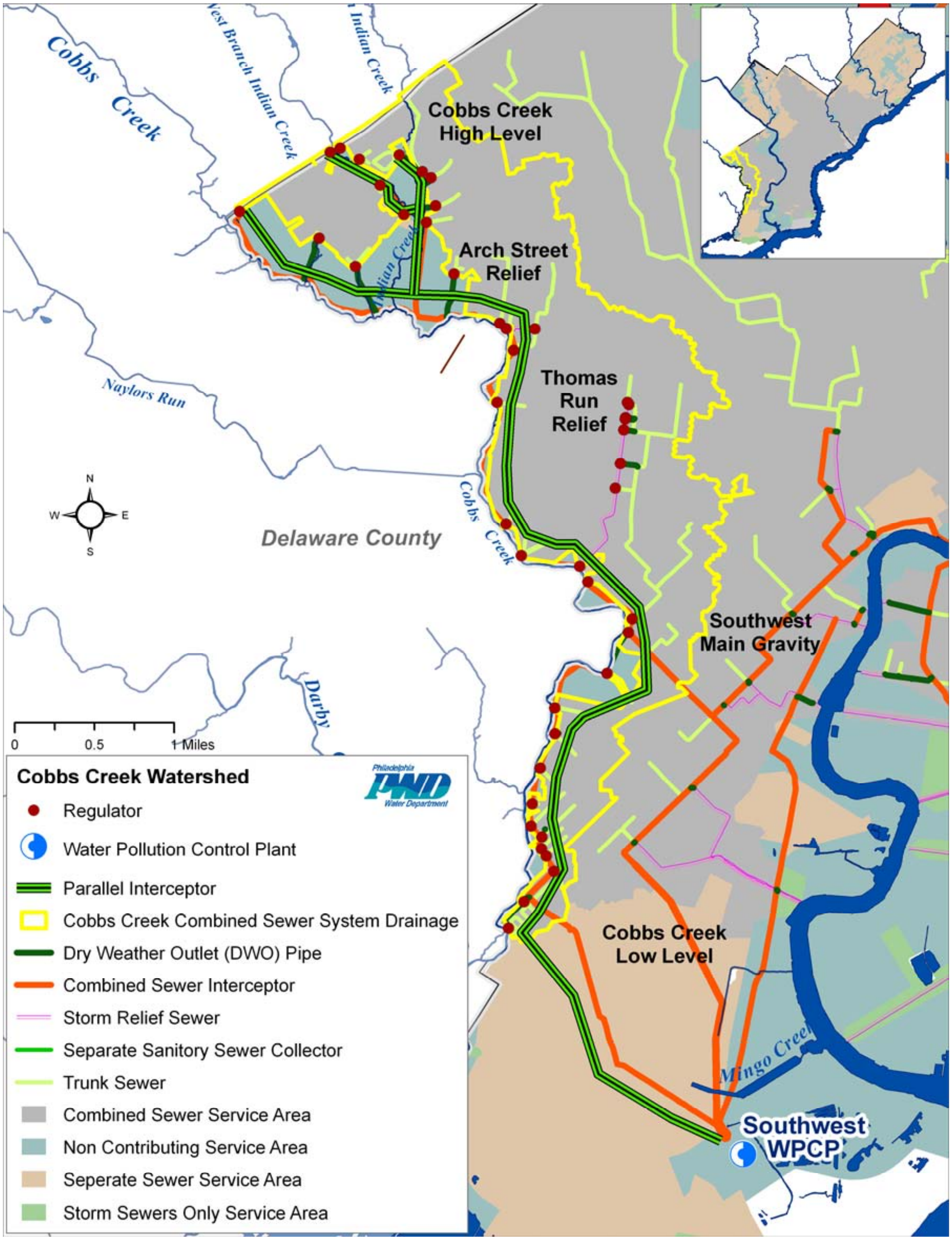


Figure 5-35 Potential Layout for an All Transmission Parallel Interceptor System to Capture Overflow from the Cobbs Creek Watershed CSO Regulators

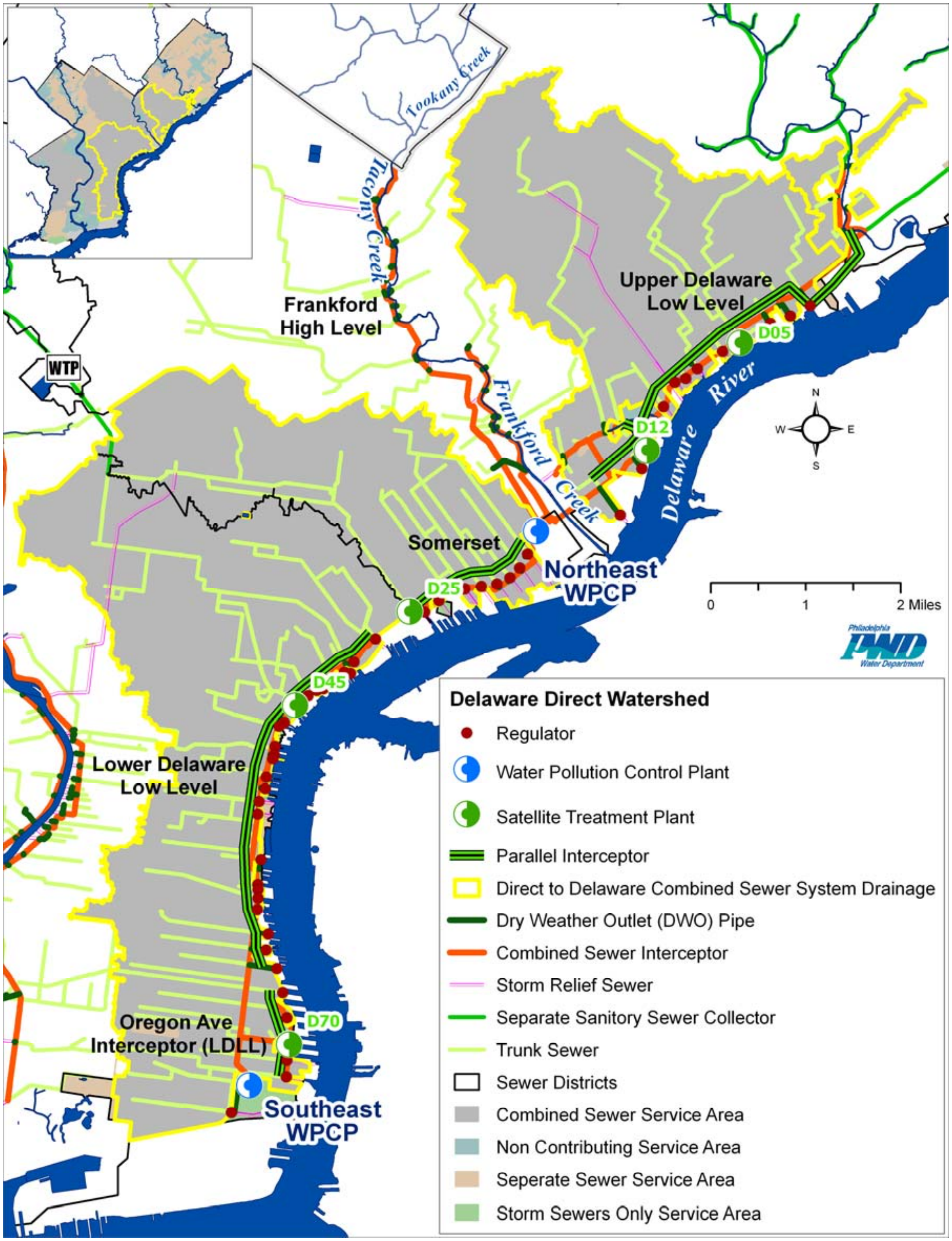


Figure 5-36 Example of a Parallel Interceptor System with Strategically Placed Satellite Treatment Facilities for the Delaware Watershed

5.4.2.5 Retention Treatment Basins (RTBs)

RTBs are satellite high rate treatment facilities designed to provide screening, settling, skimming (with a fixed baffle) and disinfection of combined sewer flows before discharge to a receiving water. Since RTBs are empty between wet weather events, they also provide storage, which can completely capture combined sewer flows from small wet weather events for later dewatering and conveyance to the WWTP for treatment. RTBs can be designed with a variety of screen types, disinfection methods and basin geometries. The surface loading rates can also vary but are typically higher than rates used for design of primary clarifiers. RTBs can be constructed above or below grade but typically require at least an above grade process/control building. If pumping of the combined sewer flow is required, the pump station may be integral to the RTB facility or constructed as a separate structure.

The RTB facilities are assumed to include:

- Coarse, mechanically cleaned bar screens located at the headworks of the facility
- Disinfection via chlorine using sodium hypochlorite- disinfectant contact time is achieved in the basin, which is sized to achieve the design contact time at the design flow rate
- A basin divided into two parallel compartments just below grade, with an effluent weir and geometry based on a design surface overflow rate of 6,000 gal per day/ft^2. If pumping is required, it will be provided in a separate structure

A preliminary method of analysis is employed for evaluation of the effectiveness of RTB facilities in the reduction of CSO volume and frequency. This method is based on the development of peak flow reduction factors that can be used with existing high-rate treatment tools used for sizing high-rate treatment facilities designed without a significant storage component.

For this study, a simplified representation of an RTB was created in NetSTORM (see Figure 5-37 below). The system operates as follows:

- During small storms that do not exceed the treatment rate of the RTB, flow in the model continues through the RTB uninterrupted and is considered treated. In the real system, flow is detained in the storage element for settling and disinfection. When the storage element reaches capacity, treated effluent is discharged to a receiving water. When interceptor capacity is again available after the storm, the storage element is slowly drained back to the interceptor
- During large storms that exceed the treatment rate of the RTB, excess flow is discharged untreated to a receiving water
- Storage in the RTB is assumed to be 0.20 in over the drainage area
- Simulations were run with hourly rainfall records from the representative year used in LTCPU simulations
- Simulations were run for three regulator structures and their drainage areas: D65, C19 and S02. These were chosen because they represent a range of treatment rate to drainage area ratio
- Effects of low-impact development were approximated by reducing runoff coefficients by 25%, 50% and 75%

Compared to the treatment systems without storage, systems represented in the satellite treatment spreadsheet reduce design flows by the following amounts:

The recommendations after evaluating the conclusions above are as follows:

- Compared to the treatment systems without storage represented in the satellite treatment spreadsheet, reduce design flows by the following amounts:
    - 10 overflows per year: 55%
    - 4 overflows per year: 50%
    - 1 overflow per year: 30%

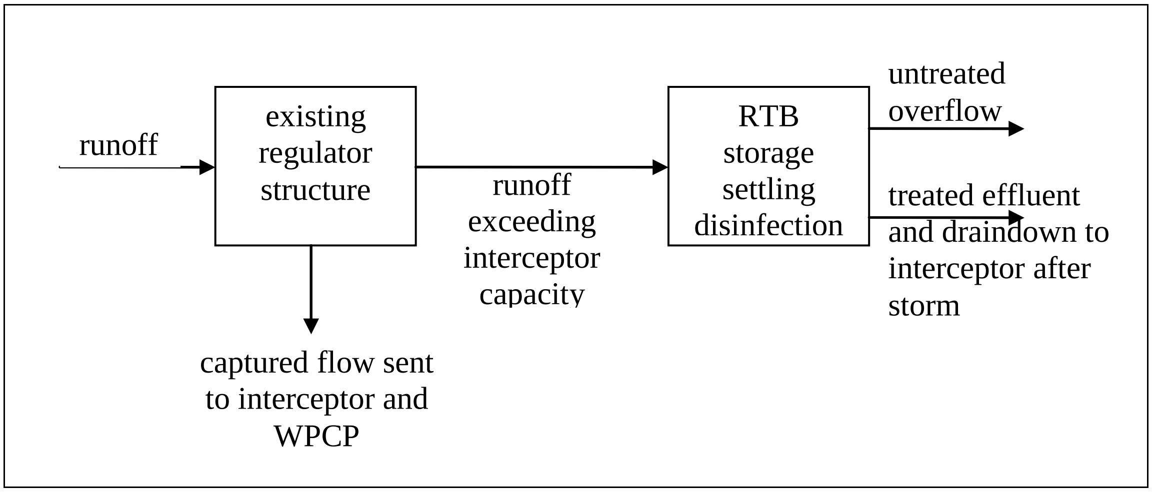


Figure 5-37 Schematic Diagram of RTB Model

Table 5-10 Results

	Regulator Treatment Rate (cfs/ac)	Treatment Rate Percentile (percentile)	Reduction in Design Flow Compared to a No-Storage System		
			≤ 10 overflows per year	≤ 4 overflows per year	≤ 1 overflow per year
D65	0.017	17th	50 - 66%	43 - 60%	25 - 33%
S02	0.065	51st	N/A	N/A	22 - 77% (median 40%)
C19	0.173	76th	N/A	N/A	22 - 36%

N/A: This regulator generated less than this number of overflows during the typical year.
Ranges given are for a range of reduction in runoff coefficient.

5.4.2.6 Off-Line Storage

Off-line storage facilities are designed, whenever possible, to be fed by gravity during wet weather surcharge conditions through overflow weirs in the trunk sewer and drained by gravity to a downstream location using a head dependant sluice gate orifice. Off-line storage projects that have been modeled for evaluation of CSO performance benefit as part of the LTCPU include:

- State Road Relief Sewer (Delaware Direct Watershed)

Off-line storage projects that are planned or have been completed as part of the 1997 LTCP have been incorporated into all baseline models for LTCPU evaluations. These include:

- Venice Island Storage Tank (Schuylkill River Watershed)

5.4.2.7 In-Line Storage

In-line storage facilities are modeled as either conduits or storage nodes with both downstream dry weather outlets modeled as wet weather overflow weirs and orifices with either head dependant or static orifices. The wet weather overflow weirs can be either static structures or head dependant dynamically controlled structures such as inflatable dams or crest gates. These structures allow for the maximum use of in-line storage capacity while providing maximum flood protection.

In-line storage projects that have been modeled for evaluation of CSO performance benefit as part of the LTCPU include:

- T14 Crest Gate (Tacony Creek Watershed)
- Rock Run Relief Inflatable Dam (Tacony Creek Watershed)
- Indian Creek Day lighting (Cobbs Creek Watershed)

In-line storage projects that are planned or have been completed as part of the 1997 LTCP have been incorporated into all baseline models for LTCPU evaluations. These include:

- Main Relief Inflatable Dam (Schuylkill River Watershed)

5.5 OVERVIEW OF THE ALTERNATIVES ANALYSIS PROCESS

In order to appropriately determine and select an alternative, it is necessary to develop a thorough and comprehensive analysis procedure. For the PWD LTCPU, this process followed the following outline:

- Problem identification and goal setting
- Development and screening of management options
- Development and initial screening of alternatives
- Detailed evaluation of alternatives
- Selection of a recommended alternative
- Refinement of the recommended alternative

These tasks are briefly discussed in the following sections.

5.5.1 Overview

The LTCPU alternatives analysis process follows the following steps:

- Watershed-specific characterization and problem identification
- Watershed-specific goal setting
- Development and screening of management options
- Development and initial screening of alternatives by watershed

- Detailed evaluation of alternatives by watershed
- Selection of a recommended alternative by watershed
- Refinement of the selected alternative, integration of watershed-specific alternatives into a single plan and implementation planning

5.5.2 Problem Identification and Goal Setting

The characterization, problem statement and goal setting process, presented in Sections 3 and 4, form the foundation for the alternatives development and evaluation process. Through the extensive field studies, modeling and data analysis, the highest priority problems in each watershed are identified and goals are set to address each of these problems. Goals set by the Integrated Watershed Management Plans (IWMP) incorporate the needs expressed by stakeholders in each watershed. The goals also include applicable regulatory requirements.

5.5.3 Development and Screening of Management Options

The IWMP process defines a management option as an individual project, technology, or practice intended to address some aspect of watershed management. Bioretention basins, street sweeping and public notification are examples of options. An individual option is not intended to address all watershed management or combined sewer overflow control goals. Watershed management and combined sewer overflow control options to be considered are compiled from many sources including the following:

- Options recommended for implementation in IWMPs
- Continuing implementation of the Nine Minimum Controls
- Continuing options from PWD's 1997 Long Term CSO Control Plan
- Options required by an NPDES permit or consent order agreement
- A wide range of additional combined sewer overflow controls from the National CSO Policy and EPA guidance documents, professional literature, other cities' experiences and best professional judgment, including:
    - Green infrastructure and other stormwater source controls
    - Modification and optimization of existing infrastructure
    - Storage
    - Increased collection system capacity
    - Satellite treatment facilities
    - Bypass of secondary treatment at existing WPCPs
    - Expansion of wet weather treatment capacity at WPCPs

A screening process is applied to these potential options to identify those that should be incorporated into all alternatives, those that should be considered for incorporation into some alternatives and those that should be dropped from further consideration. This process results in one of the following outcomes for each option:

1. An option is recommended for inclusion in all alternatives if the option is a regulatory requirement or if its implementation has already been ensured by a related planning process, such as an IWMP. Many non-structural options fall into this category.

2. An option is dropped from further consideration if it does not address at least one goal and is not a regulatory requirement.

3. Options that do not fall into categories 1 or 2 are recommended for consideration in the alternatives development process. Most green infrastructure and traditional infrastructure controls fall into this category.

Options from category 3 above are subjected to an initial, qualitative cost-effectiveness screen. Options are dismissed at this point if their cost is expected to be approximately an order of magnitude or more greater per unit of combined sewer overflow eliminated. In this initial step, care is taken to eliminate only those options that are clearly much less cost-effective than the body of options as a whole.

5.5.4 Development and Initial Screening of Alternatives

Alternatives are formulated as packages of options that meet the following criteria:

- An alternative must include options to address all goals of the LTCPU over the course of the planning period
- An alternative must meet these goals in a cost-effective manner relative to other alternatives. Options are dismissed at this point if their cost is expected to be approximately an order of magnitude or more greater per unit of combined sewer overflow eliminated relative to the body of alternatives as a whole. This determination is made graphically

5.5.5 Detailed Evaluation of Alternatives

Alternatives are evaluated using several measures, ranging from cost and performance to ancillary benefits and qualitative criteria.

5.5.5.1 Performance (CSO Control Level)

Performance of the urban hydrologic system is quantified in terms of stormwater runoff generated and loaded to the CSS.

5.5.5.2 Cost

Cost opinions include capital cost, operation and maintenance cost and, where appropriate, replacement and residual costs. Cost opinions were developed using ACT described previously. To allow direct comparison of multiple alternatives, costs are expressed as present value over the course of the planning period. However, present value can be misleading or inappropriate when trying to predict cash flows and staffing needs at specific points in the future. For this reason, annual cost and current dollar cost projections are also given where appropriate.

5.5.5.3 Affordability and Financial Capability

For initial alternatives analysis, quantitative measures of affordability include percent of median household income spent on wastewater and stormwater management and average annual increase in wastewater and stormwater bills for residential households.

5.5.5.4 Triple Bottom Line: Quantifiable Benefits and External Costs

The methods in determining the costs and benefits associated with the sustainability and environmental, social and economic benefits produced from implementing green infrastructure versus the traditional grey technologies are discussed below. Please refer to Supplemental Documentation Volume 2: Triple Bottom Line Analysis for more details.

Water Quality and Ecosystem Improvement
Green infrastructure improves ecosystems in two ways. First, by restoring a water cycle more similar to a natural watershed, green infrastructure allows rain to soak into the ground and return to streams slowly. Second, PWD's green infrastructure approach includes physical restoration of stream channels and streamside lands, including wetlands, to restore habitat needed for healthy ecosystems. Water quality and ecosystem health are difficult to value economically. However, human beings clearly value clean water and healthy ecosystems both for themselves and for future generations. Environmental economists refer to this as a "non-use" or "non-market" value and have a number of tools for estimating these values in monetary terms. For this study, these values were monetized based on a large body of academic literature where households were surveyed to determine how much they would be willing to pay to improve water quality or habitat by a defined amount. Values also were derived from a large body of literature on the economic value of wetlands.

Selected References: Van Houtven *et al*., 2007; Woodward and Wui, 2001; Borisova-Kidder, 2006

Recreation Benefits
Improved access, appearance, and opportunities in these areas will make them more desirable destinations for the public. Recreation also will be more desirable along newly greened neighborhood streets and public places. The team established a baseline for the number of visitors to Philadelphia's parks today, based on reports prepared for the Philadelphia Parks Alliance and the Fairmount Park Commission, and input from park staff. With improvements to underused areas along stream corridors and riverfronts, the team estimated that these areas could be brought up to a level of use more similar to the park system as a whole. Recreation along newly greened streets and public places was linked to the area greened in each watershed. Environmental economists are able to estimate monetary values for recreation activities using "direct use" values from the academic literature and government agencies. These values estimate what a typical user pays or would be willing to pay to take part in that activity. For this study, the team was able to draw upon Philadelphia-specific direct-use values for different recreational activities, as published in a report prepared by the Trust for Public Lands (2008): *How Much Value Does the City of Philadelphia Receive from its Park and Recreation System?*.

Selected References: Trust for Public Lands, 2008; Tidal Schuykill River Master Plan, 2003

Reduction in Heat Stress Mortality
Green infrastructure (for example, trees, green roofs, and bioretention sidewalks) reduces the severity of extreme heat events in three ways - by creating shade, by reducing the amount of heat absorbing pavement and rooftops, and by emitting water vapor – all of which cool hot air. This cooling effect will be sufficient to actually reduce heat stress-related fatalities in the City during extreme heat wave events. Extreme heat events in Philadelphia have been studied extensively by the Philadelphia Health Department, the federal Centers for Disease Control, the US EPA and others. The study team used results of several of these studies that quantified the reduction in temperature that results from significant increases in urban vegetated acreage. The study team incorporated these results into the City's existing methodology for quantifying excess heat mortality to evaluate human deaths avoided under the different green CSO options. The value of avoided heat-related deaths was then monetized based on standard methods routinely used by US EPA in regulatory impact assessments.

Selected References: CDC, 1994; Hudischewskyj *et al.*, 2001; Kalkstein and Sheridan, 2003

Air Quality Improvement from Trees

Like many major cities in the United States, US EPA currently classifies the Philadelphia metropolitan area as exceeding federal air quality standards for both ozone (smog) and fine particles (soot). Once in the air, some ozone and particles are taken into the leaves of trees as they "breathe." Leaves also trap additional fine particulates, which then wash off in the rain or fall with the autumn leaf drop. The U.S. Forest Service estimated air concentration removal rates associated with the urban forest in Philadelphia. The study team combined these pollutant removal rates with the projected number of new trees under the various green infrastructure scenarios. The study team then used BenMAP, US EPA's air quality benefits model, to estimate corresponding health impacts using current and projected Philadelphia air quality levels. US EPA also provides the standard methods used to value the economic impact of these avoided health effects. Additional air pollution related impacts associated with changes in emissions from energy production and vehicles are discussed in more detail in the energy and carbon section.

Selected References: USDA, 2007; US EPA, 2008a; US EPA, 2008b

Green Infrastructure Jobs Reduce the Social Cost of Poverty

Green infrastructure creates jobs which require no prior experience and are therefore suitable for individuals who might be otherwise unemployed and living in poverty. Green infrastructure is not by itself the solution to poverty, but it is a valuable tool in the toolbox of poverty reduction. Based on a number of local and national studies, economists have estimated that the cost of poverty related outlays in Philadelphia divided by the number of adults living in poverty ranges from about $15,000 to $45,000 per year. These studies are based on estimates of spending by all levels of government on assistance programs and avoidable crime and health impacts (*e.g.*, it costs $30,000 per year to keep a person in jail in Philadelphia). Many of the study estimates include documented increased costs of seemingly unrelated City services due to poverty. Some of the lower estimates of total social cost are missing a number of these cost elements, thus, the higher estimates seem more plausible.

Based on these various studies, this study assumes an avoided social cost of $10,000 per new green infrastructure job created. This study also assumes that three-quarters of these new jobs would require no experience and thus provide the benefits of hiring unemployed adults living in poverty, and reducing poverty expenditures.

Selected References: Schwartz, 1993; Summers and Jakubowski 1996; Pack, 1998; Oppenheim and MacGregor, 2006; Holzer *et al.*, 2007; Glaster *et al.*, 2007; Laurie *et al.*, 2008

Energy Savings

Green infrastructure reduces energy use, fuel use, and carbon emissions in two ways. First, the cooling effects of trees and plants shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Second, rain is managed where it falls in systems of soil and plants, reducing the energy needed for traditional systems to store, pipe, and treat it. The team estimated energy savings, pollutant emission reductions, and carbon emission reductions from trees and plants using a study published by the U.S. Forest Service. Emissions related to energy production in Pennsylvania are published by the Energy Information Administration. The cost of carbon emissions to society is an area of active debate, but in the study the team used an estimate provided by the Intergovernmental Panel on Climate Change (IPCC).

Estimates of carbon emissions and sinks also considered construction, traffic delays caused by construction, and the manufacturing and transport of concrete.

Selected References: EIA, 2007; IPCC, 2007; USDA, 2007

Improved Property Values
One way to estimate a value is to study property values in areas that are close to parks and greenery. There is a rich body of academic literature showing that property values are higher when trees and other vegetation are present in urban neighborhoods, including some Philadelphia-specific studies. The study team combined estimates from this literature, data on current Philadelphia home values, and proposed increases in "greened area" to estimate these benefits under the greened area CSO options. It is important to note that the study team evaluated increases in the value of residential properties only. However, commercial, industrial and institutional property values would also likely increase.

Selected References: Braden and Johnston, 2003; Shultz and Schmitz, 2008; Wachter and Wong, 2006

5.5.5.5 Qualitative Factors
The following are the qualitative factors that are used to screen the alternatives:

Public Support
- High: The majority of public feedback received has been positive
- Medium: About half of public feedback received has been positive and half negative
- Low: Less than half of public feedback received has been positive

Construction Feasibility
- High: Construction is seen as routine and low-risk. Many local contractors will have experience with the technology
- Medium: Construction is moderately difficult or risky
- Low: The technology is new or perceived as high risk. A limited number of specialty contractors have experience with the technology

Operation Feasibility
- High: The technology is familiar. Either skill required is low or skilled labor is readily available
- Medium: The technology is familiar but significant new staff and training are required
- Low: The technology is unfamiliar. New staff, skills and training are required

Reliability and Past Performance of Technology
- This measure is derived from a matrix comparing the risk of failure to the consequences of a particular alternative failing to perform as expected

Complexity and Difficulty of Solution
- High: The alternative requires difficult coordination of many phases, technologies, sites, or contracts

- Low: The alternative requires one or a small number of phases, technologies, sites, or contractors

Coordination and Consistency with other PWD and City Programs

- High: The alternative supports and benefits from other programs taking place in PWD and the City. Examples include basement flooding abatement and waterfront revitalization
- Low: The alternative solves only CSO-related problems and does not support or benefit from other programs

Table 5-11 Risk of Failure Matrix

Likelihood of Failure	Consequences of Failure		
	Low	Medium	High
Low	High	High	Medium
Medium	High	Medium	Low
High	Medium	Low	Low

5.5.6 Selection of a Recommended Alternative

For each watershed, a recommended alternative is selected for implementation that achieves the best balance between the criteria listed in the previous section:

- The alternative meets all goals of the IWMP, including improved dry weather water quality, aesthetics and recreational opportunities; restoration of living resources; improved wet weather water quality and minimal adverse impact on people who choose to engage in wet weather recreation
- The alternative achieves a level of stormwater management and CSO control acceptable to PWD, regulatory agencies and the public
- The alternative is cost-effective relative to the body of alternatives studied
- The cost is within the financial capability of the PWD and its ratepayers
- The alternative is sustainable, adaptable and resilient under uncertain long-term conditions. The alternative achieves a net benefit to the public, considered both quantitatively and qualitatively. Net benefit is the difference between the total cost of an alternative to the public and private sectors and the total value to society. Considering net benefit may give a different picture than considering cost to the utility alone
- The public expresses support for the alternative relative to other alternatives
- Controls chosen are constructible, operable, reliable and not overly complex
- The alternative is reasonable in a larger context of other water resources and urban planning-related programs taking place in Philadelphia

5.5.7 Refinement of the Recommended Alternative

The alternative selected in each watershed will be further refined and optimized. Interactions and dependencies between alternatives selected in the different watersheds will be evaluated. Sensitivity analyses were performed to evaluate the response of the system under a range of economic and climatic conditions. Institutional, programmatic and legal changes needed to operationalize the program will be identified. Steps will be taken to reduce uncertainty in site constraints and cost, which will be further refined during a subsequent facilities planning stage. Affordability and financial capability analysis are further refined for the selected alternative at this stage and a detailed financing plan is developed.

5.6 IMPLEMENTATION

5.6.1 Adaptive Management

Adaptive management is a management approach that assumes management policies and actions, once implemented, are not static but must be adjusted based on the combination of practical experience, new scientific and technical advances, and socio-economic changes. This adaptability is needed to improve management of uncertain systems by learning from the system being affected. Given the inherent environmental, technical, financial, and social uncertainty in LTCP implementation, adaptive management recognizes that it is not possible, a priori, to identify the "best" management alternative. Therefore, an incremental approach is warranted, and learning about the system becomes an integral part of achieving the economic, social, and environmental goals.

Adaptive management includes:

- Taking near term actions to improve water quality
- Experimenting with a variety of approaches toward implementing the program
- Data collection and analysis on initial projects
- Reassessment of appropriate actions and adaptation of the program to improve effectiveness

5.6.2 Adaptive Management Strategy Requirements

An adaptive management strategy as part of the LTCPU should include a number of elements to provide sufficient and timely feedback to adjust the program during the implementation phase. In general, these elements include:

- Rationale for choosing the adaptive management approach
- Interim milestones - related to the targets over a specific time frame, *i.e.*, the expected outcome of the above actions
- Monitoring plan - to gather sufficient information to assess progress towards expected milestones

6 LAND-BASED CONTROL MEASURES (SOURCE CONTROLS)

6.1 IDENTIFICATION AND DESCRIPTION OF CONTROL MEASURES

PWD is committed to a balanced "land-water-infrastructure" approach to achieve its watershed management and CSO control goals. This method includes infrastructure-based approaches where appropriate, but relies on a range of land-based stormwater management techniques and physical reconstruction of aquatic habitats where appropriate. The ultimate goal of PWD's approach is to achieve full regulatory compliance in a cost-effective manner while regaining the resources in and around streams that have been lost due to urbanization, both within the City of Philadelphia and in the surrounding counties. Land-based measures are a key part of this approach because they provide benefits to the community beyond water quality improvement. These benefits include recreational opportunities, improved aesthetics, and increased home values.

Philadelphia is making a substantial commitment to reducing the burden on combined sewer infrastructure by controlling stormwater at the source. Development and redevelopment projects are taking place throughout the City under the stormwater requirements enacted in 2006. A number of demonstration projects are complete, in design, or in construction on public lands, including PWD properties, parks and recreation facilities, and schools. PWD will be revising its stormwater rate structure based on impervious cover.

Land-based management measures provide a number of additional long-term benefits. They help to protect the City's investment in stream channel and habitat restoration. They will help reduce sediment loads from runoff and streambank erosion. They help protect infrastructure along stream corridors that can be damaged by high stream flows and velocities. They provide source water protection benefits. By reducing the burden on combined sewers, they help reduce the frequency and severity of basement flooding in some locations. Outside the combined sewered areas, land-based stormwater management is helping Philadelphia to meet requirements of total maximum daily loads (TMDLs) and its Non-Point Discharge Elimination System (NPDES) Phase 1 MS4 permit. The measures also help Philadelphia and the region meeting requirements of Pennsylvania's Act 167 Stormwater Management Program, which requires stormwater management on a watershed basis in developing areas.

Table 6.1 lists the land-based options (source controls) that are being considered for implementation in the initial screening stage and identifies the goals that each option is designed to meet. Descriptions of these options are described in this section. Details on Table 6.1's headers are:

- Required: required under CSO permits
- IWMP: commented to in an Integrated Watershed Management Plan (IWMP)
- Dry Weather WQ: addresses dry weather water quality (WQ)
- Solids / Floatables: addresses solids and floatables
- Recreation: addresses recreation
- Tributary Habitat: addresses tributary habitat
- Water Balance: addresses water balance

Table 6.1 Land-Based Options (Source Controls)

			Goals Addressed									
Number	Category	Option	Required	IWMP	Dry Weather WQ	Solids/ Floatables	Recreation	Tributary Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
L.1	Flow reduction	Catch basin modifications				X					X	
L.2	Flow reduction	Sump pump disconnect									X	
L.3	Flow reduction	Catch basin and storm inlet maintenance	X	X		X					X	
L.4	Flow reduction	Illicit connection control	X	X	X						X	
L.5	Flow reduction	Roof leader disconnect program		X							X	
L.6	Flow reduction	Street storage (catch basin inlet control)									X	
L.7	Flow reduction	Offload groundwater pumpage									X	
L.8	Flow reduction	Stream diversion		X							X	
L.9	Flow reduction	Groundwater infiltration reduction		X							X	
L.10	Flow reduction	Reduction of contractual flow									X	
L.11	Low impact development/ re-development/retrofit	Require existing resources inventory, sketch plan, initial meeting		X						X	X	
L.12	Low impact development/ re-development/retrofit	Require integrated site design		X						X	X	
L.13	Low impact development/ re-development/retrofit	Require post-construction stormwater management	X	X						X	X	
L.14	Low impact development/ re-development/retrofit	Post-construction inspection and enforcement		X						X	X	

			Goals Addressed									
Number	Category	Option	Required	IWMP	Dry Weather WQ	Solids/ Floatables	Recreation	Tributary Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
L.15	Low impact development/ re-development/retrofit	Demonstration Projects on Public Lands		X						X	X	X
L.16	Low impact development/ re-development/retrofit	Large-Scale Implementation on Public Lands		X						X	X	X
L.17	Low impact development/ re-development/retrofit	Street Trees and Street Greening		X						X	X	X
L.18	Low impact development/ re-development/retrofit	Revise Stormwater Rate Structure		X						X	X	
L.19	Low impact development/ re-development/retrofit	Stormwater Management Incentives for Retrofit		X						X	X	
L.20	Public education	Water Efficiency									X	
L.21	Public education	Catch Basin Stenciling		X							X	X
L.22	Public education	Community Cleanup and Volunteer Programs		X	X	X						X
L.23	Public education	Pet Waste Education		X							X	X
L.24	Public education	Public Notification and Signage	X	X	X		X				X	X
L.25	Public education	Litter and Dumping Education		X	X	X					X	X
L.26	Public education	School-Based Education		X	X	X	X				X	X
L.27	Good housekeeping	Loading, Unloading, and Storage of Materials	X	X							X	
L.28	Good housekeeping	Spill Prevention and Response	X	X	X						X	
L.29	Good housekeeping	Street Sweeping Programs		X		X					X	
L.30	Good housekeeping	Vehicle & Equipment Management	X	X							X	
L.31	Good housekeeping	Private Scrapyard Inspection and Enforcement		X							X	

			Goals Addressed									
Number	Category	Option	Required	IWMP	Dry Weather QQ	Solids/Floatables	Recreation	Tributary/Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
L.32	Good housekeeping	Employee training	X	X							X	
L.33	Good housekeeping	Record keeping and reporting	X	X							X	
L.34	Good housekeeping	Flow diversion and exposure minimization structures		X							X	
L.35	Good housekeeping	Responsible landscaping practices on public lands		X		X					X	
L.36	Good housekeeping	Responsible bridge and roadway maintenance		X							X	
L.37	Pollution prevention	Require industrial pretreatment	X	X							X	
L.38	Pollution prevention	On-lot disposal (septic system) management		X	X						X	
L.39	Pollution prevention	Household hazardous waste collection			X						X	
L.40	Pollution prevention	Oil/water separator/WQ inlets									X	
L.41	Pollution prevention	Industrial stormwater pollution prevention	X	X							X	
L.42	Pollution prevention	Litter and illegal dumping enforcement		X	X	X						
L.43	Pollution prevention	Require construction-phase stormwater/E&S controls	X	X		X					X	

- Wet Weather WQ: addresses wet weather water quality
- Stewardship: addresses stewardship

L.1 Flow Reduction: Catch Basin Modifications

Philadelphia's catch basins are surface-level inlets to the sewer system that allow runoff from streets and lawns to enter the CSS. These basins include features to prevent floatables from entering the system. Inlet grates installed at the top of many catch basins reduce the amount of street litter and debris that enters the catch basin. Catch basins also contain hoods and traps to capture floatables and a portion of solids from street runoff. These inlets are periodically cleaned.

Additional modifications are possible, including trash buckets installed in the basin beneath the grate and vortex valves. A vortex valve is a conical shaped discharge throttling device installed within catch basins that are able to reduce the frequency and the volume of CSO events by restricting flow through the outlet. Vortex valves have also proven capable of controlling floatables.

L.2 Flow Reduction: Sump Pump Disconnect

Many buildings have sump pumps to pump floodwater from basements. Often this water is discharged directly into combined and sanitary sewers, adding to wet weather inflow and infiltration and reducing combined sewer capacity. Redirecting this flow away from sewer systems and onto lawns or dry wells or drainfields reduces the volume of stormwater entering the CSS. Discharge of sump pumps to combined and sanitary sewers is not permitted in the City of Philadelphia. Increased enforcement of these rules in Philadelphia and in surrounding municipalities serviced by PWD is recommended as part of a larger wet weather inflow and infiltration control program and may be considered as part of the Green Homes program discussed in Section 10.

L.3 Flow Reduction: Catch Basin and Storm Inlet Maintenance

Catch basins and storm inlets that are part of the stormwater collection and conveyance system should be cleaned on a regular basis. Sediments, leaves, grass clippings, pet wastes, litter and other materials commonly accumulate in catch basins. These materials can contain significant concentrations of nutrients, organics, bacteria, metals, hydrocarbons, and other pollutants. When a storm occurs, runoff entering the basin may dislodge and suspend some of this material. This debris can be conveyed along the storm sewer system and released to a surface water body.

The City of Philadelphia has in place a catch basin/inlet cleaning program through which approximately 79,000 inlets are cleaned annually.

L.4 Flow Reduction: Illicit Connection Control

This option refers to illicit or accidental connection of storm drains to sanitary sewer systems and sanitary sewers to storm drains. These connections may impact receiving waters outside the combined sewer areas by causing sanitary sewer overflows. Eliminating these connections is part of a comprehensive watershed approach to water quality improvement. PWD has had a Defective Lateral Abatement Program in place since the early 1990's. This program involves the track-down of cross connected lateral pipes.

Where sanitary sewer systems ultimately drain to a combined sewer interceptor, the increase in flow caused by direct stormwater inflow decreases capacity available for combined sewage and will increase overflows. A program to detect and mitigate these connections can help reduce CSO. A program to reduce direct inflows in Philadelphia and in surrounding municipalities serviced by PWD is recommended as part of a larger wet weather inflow and infiltration control program.

L.5 Flow Reduction: Roof Leader Disconnect Program

In the combined sewer systems in Philadelphia, roof drains are required to convey rainfall directly from residential and commercial roofs into the CSS. In some cases, flow into the CSS can be safely reduced by redirecting roof drains onto lawns or into dry wells or drainfields where flows can infiltrate into the soil. To reduce direct inflows, changes to municipal codes are first required to allow roof leader disconnection where practical without causing property damage or a safety hazard. Following those legal changes, a program can be designed to encourage or require disconnection through public education and technical assistance programs. Many of these tools will be discussed as part of a Green Homes program in Section 10.

L.6 Flow Reduction: Street Storage (Catch Basin Inlet Control)

Flow restriction and flow slipping methods utilize roadways and overland flow routes to temporarily store stormwater on the surface, or to convey stormwater away from the CSS. Flow restriction is accomplished by installing static flow or "braking" devices in catch basins to limit the rate at which surface runoff can enter the CSS. Excess storm flow is retained on the surface and enters the system at a controlled rate, eliminating or reducing the chance that the system will be hydraulically overloaded and overflow. The volume of on-street storage is governed by the capacity of the static flow device, or orifice, used for restriction, as well as surface drainage patterns. In Philadelphia, widespread implementation of this option may not be practical due to street configurations and curb heights. However, this option should be retained as one tool to be considered in a larger green streets program. These tools will be considered as part of a Green Streets program.

L.7 Flow Reduction: Offload Ground Water Pumpage

Groundwater is continuously pumped in some industrial and commercial areas and discharged directly to a combined sewer system. Where possible, this flow should be discharged directly to a receiving water (with appropriate permitting) rather than discharged to the CSS. This situation does occur in some parts of Philadelphia. A program to reduce these inflows is recommended as part of a larger wet weather inflow and infiltration control program and may be considered as part of the Green Industry and Commerce tool.

L.8 Flow Reduction: Stream Diversion

As cities grew during the nineteenth and early twentieth centuries, many small streams were routed into pipes to facilitate development. In communities where streams have been routed into CSSs, the surface runoff once conveyed in these streams reduces capacity in the CSS and contributes to overflows. Rerouting natural streams and surface runoff away from the CSS and back to their original watercourse or to other receiving waters can have a significant impact on CSS capacity. Urban stream diversion is one of the more expensive inflow reduction options since it typically requires design and construction of new storm drain lines. Stream diversion resembles CSO separation in that new alternative flow routes are required for surface runoff. It is typically employed in situations where less expensive and less disruptive options for inflow reduction are not feasible, or do not provide sufficient inflow reduction. The potential amount of inflow to be diverted from the CSS needs to be well documented in order to assess its cost-effectiveness.

L.9 Flow Reduction: Groundwater Infiltration Reduction

Groundwater infiltration into combined sewers, and into sanitary sewers that ultimately discharge into combined sewer interceptors, represents a significant portion of the average daily dry weather flow in the collection and treatment system. This infiltration of groundwater into the CSS takes up wet weather capacity that would otherwise be available to stormwater flows. The primary measure to reduce these inflows is through a long-term program of combined sewer rehabilitation. PWD and municipal sewer authorities have these programs in place. Expansion of the rate at which sewers are repaired and rehabilitated should be considered. A program to reduce these inflows is recommended as part of a larger wet weather inflow and infiltration control program.

L.10 Flow Reduction: Reduction of Contractual Flow

PWD contracts with ten other municipalities to discharge a specific flow of sanitary sewage to Philadelphia's combined sewer system. Contracted flows are discussed in detail in Section 3. As explained in Section 3.3, allowable flow is typically expressed as peak, daily, and annual average flow. Reducing these contractual flows is one option to increase capacity in the CSS for flows within the City of Philadelphia. Working with other municipalities to reduce wet weather inflows over the long-term is recommended as part of a larger wet weather inflow and infiltration control program.

L.11 Low Impact Development/Redevelopment/Retrofit: Require Existing Resources Inventory, Sketch Plan, Initial Meeting

The developer's first task is to assess features and conditions at the site before design begins. It is during this initial step that the developer is required to complete the Existing Resources and Site Analysis (ERSA) Worksheet.

Philadelphia requires a PWD Development Review meeting early in the development process, before developers have invested extensive time and money in design and engineering. The goal is to decrease the plan approval time by addressing issues early in the process while helping to ensure compliance with the stormwater regulations. The developer is required to prepare a conceptual plan, an ERSA map and submit photographs from each face of the parcel being developed.

PWD representatives review the ERSA, ERSA map, site photographs, and concept plan and, if needed, meet with the developer and their engineers to discuss the conceptual development plan in terms of water, sewer, and stormwater utilities.

Based on the recommendations from PWD, the Philadelphia City Planning Commission, and the Streets Department, the developer prepares a final site plan.

L.12 Low Impact Development/Redevelopment/Retrofit: Require Integrated Site Design

The City's Stormwater Management Manual provides a recommended site design procedure for comprehensive stormwater management. It is based on the procedure recommended by the Pennsylvania Department of Environmental Protection (PADEP), with minor modifications to adapt it to conditions in Philadelphia. This procedure includes non-structural controls that reduce the quantity of stormwater that needs to be managed and structural controls that meet the water quality, channel protection, and flood control requirements of the regulations. The integrated site design procedure can be summarized in three steps:

1. Protect and utilize existing site features
2. Reduce impervious cover to be managed
3. Manage remaining stormwater using a systems approach to stormwater management facility design

L.13 Low Impact Development/Redevelopment/Retrofit: Require Post-Construction Stormwater Management

Land-based stormwater management approaches include Philadelphia's stormwater management regulations for new development and redevelopment, enacted in 2006. These regulations focus on restoring a more natural balance between stormwater runoff and infiltration, reducing pollutant loads, and controlling runoff rates at levels that minimize stream bank erosion. When a given site is developed in accordance with the requirements, the regulations ensure that the site will not contribute to impairment of a surface water body in Philadelphia. Site designers can provide the level of performance required using a variety of controls such as disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, and tree canopy.

L.14 Low Impact Development/Redevelopment/Retrofit: Post-Construction Inspection and Enforcement

With post-construction stormwater control requirements in place, an inspection and enforcement program is necessary to ensure that controls are properly constructed and maintained on private land. PWD inspectors verify that facilities are constructed in accordance with post-construction stormwater management plans approved by PWD. Inspectors also make periodic inspection to check that facilities are maintained in accordance with operation and maintenance agreements required under Philadelphia's stormwater regulations.

L.15 Low Impact Development/Redevelopment/Retrofit: Demonstration Projects on Public Lands

Retrofit of public lands with innovative stormwater management measures provide a benefit and also serve as an example to developers and others in the region. This demonstration program will allow PWD to implement various types of projects on a small scale in order to assess effectiveness of various technologies.

L.16 Low Impact Development/Redevelopment/Retrofit: Large-Scale Implementation on Public Lands

In addition to stormwater management required in redevelopment projects, the City of Philadelphia plans to lead by example. Retrofit of public lands with innovative stormwater management measures provide a benefit and also serve as an example to developers and others in the region.

L.17 Low Impact Development/Redevelopment/Retrofit: Street Trees and Street Greening

Increased tree cover over streets reduces runoff while providing a range of additional benefits including aesthetics. When possible, additional street greening measures can further improve the appearance and stormwater management performance of a street. These include surface vegetated practices, tree trenches that receive street and sidewalk runoff, and infiltration inlets.

L.18 Low Impact Development/Redevelopment/Retrofit: Revise Stormwater Rate Structure

PWD has conducted an extensive study of the possibility of stormwater management fees based on impervious cover. As the owner and operator of combined and separate storm sewers, PWD is considered a stormwater utility and has the authority to collect a stormwater service fee. Currently, that fee is tied to the size of a customer's meter. The new stormwater rates will tie the fee to the area of impervious cover on the customer's site, creating an incentive to reduce impervious cover. If a residential property is four units or less, they will not be charged based on the individual property characteristics.

L.19 Low Impact Development/Redevelopment/Retrofit: Stormwater Management Incentives for Retrofit

Incentives and outreach form the third part of Philadelphia's long-term plan for widespread implementation of stormwater management. PWD is studying a number of potential programs to encourage stormwater controls beyond those required by ordinance.

L.20 Public Education: Water Efficiency

Water efficiency can be defined as practices, techniques, and technologies that improve the efficiency of water use. An effective water efficiency program helps to reduce CSOs by reducing sanitary flow. This reduction provides an increase in CSS collection and treatment capacity during storm events. A water efficiency program can improve both CSO control and the long-term sustainability of the urban water system.

L.21 Public Education: Catch Basin Stenciling

Storm drain marking involves labeling storm drain inlets with plaques, tiles, painted or pre-cast messages warning citizens not to dump pollutants into the drain. The messages are generally a simple phrase or graphic to remind those passing by that the storm drains connect to local waterbodies and that dumping will pollute those waters. Some storm drain markers specify which waterbody the inlet drains to or name the particular river, lake, or bay. Common messages include: "No Dumping. Drains to Water Source," "Drains to River," and "You Dump It, You Drink It. No Waste Here." In addition, storm drain markers often have pictures to convey the message, including common aquatic fauna or a graphic depiction of the path from drain to waterbody. Communities with a large population which speak other languages might wish to develop markers in both English and that other language, or use a graphic alone.

In the City of Philadelphia, on an annual basis, community and watershed volunteers participate in PWD and Water Quality Council sponsored Earth Day service project by installing storm drain curb markers throughout the City. Roughly 10,000 stencils are decaled annually.

L.22 Public Education: Community Cleanup and Volunteer Programs

Hosting a stream cleanup is an effective way to promote stormwater awareness. A stream cleanup allows concerned citizens to become directly involved in water pollution prevention and to see the effects of pollution. Participants volunteer to walk (or paddle) the length of the stream or river, collecting trash and recording information about the quantity and types of garbage that has been removed. Stream cleanups also educate members of the community about the importance of stream water quality through media coverage and publicity efforts. Many programs have experts on hand at the event to discuss the stream's ecology and history. As a result, the stream is cleaner, volunteers feel a sense of accomplishment, and the community is better informed. The watershed partnerships initiated by PWD coordinate stream cleanups throughout the year. The PWD Waterways Restoration Team have been able to assisted these efforts by removing large debris that volunteers would not be able to remove by hand. Continuation of these practices is recommended.

L.23 Public Education: Pet Waste Education

Pet waste is a major contributor of bacteria loading in urban stormwater. The City of Philadelphia actively enforces code which covers the regulation of animal waste. The Philadelphia Code and Charter Chapter 10.100 – Animals and Chapter 10.700 – Refuse and Littering address the proper clean-up of pet waste and applicable fines and penalties. In addition, signs advertising the said penalties are displayed city-wide in any effort to prevent residents from violating this statute. The

City of Philadelphia also provides the text of this code online at http://municipalcodes.lexisnexis.com/codes/philadelphia/.

L.24 Public Education: Public Notification and Signage

PWD has developed and will continue to develop a series of informational brochures and other materials about its CSO discharges and the potential effect on the receiving waters. Brochures and other educational materials discuss the detrimental effects of these overflows and request that the public report these incidences to the department.

CSO Outfall Signage

The CSO Signage project was initiated to inform the public of the potential hazards of contact with the stream during combined sewer overflow events. The signs, placed at outfalls that are accessible by the public, let people know that during wet weather, it is possible for polluted water to flow from the outfall and that it would be hazardous to their health to contact the water during such events. It also requests that PWD be informed of any overflows during dry weather and provides an emergency number to call.

The CSO Signage Project was a pilot project aimed at determining if outfall signage was a feasible way to accomplish public notification of combined sewer overflows. PWD, in conjunction with the Philadelphia Department of Parks and Recreation, installed 13 signs at CSO outfalls in the City. Survey of the sites determined that several of the signs were removed or vandalized. Of the thirteen signs that were installed, five of them were vandalized or removed during the short amount of time between installation and the survey.

Although signage is seen as a simple, low-cost, visual way to raise awareness of combined sewer outfalls, this pilot project has highlighted the difficulties in using signs as a public notification system in Philadelphia due to the high rate of vandalism or loss of the signs in the field.

CSO Identification Signage

Signage was installed at each of Philadelphia's CSO outfalls, with the exception of eight difficult to reach sites. The CSO outfalls now have identification signs displaying their outfall ID number. These signs are very useful if the public needs to report a problem at an outfall, they are able to accurately identify the outfall. This helps to alleviate communication problems between the public and the PWD responders.

L.25 Public Education: Litter and Dumping Education

Because stormwater runoff is generated from dispersed land surfaces—pavements, yards, driveways, and roofs—efforts to control stormwater pollution must consider individual, household, and public behavior and activities that can generate pollution from these surfaces.

It takes individual behavior change and proper practices to control such pollution. Therefore it is important to make the public sufficiently aware and concerned about the significance of their behavior for stormwater pollution, through information and education.

CSS permittees are required to educate their community on the pollution potential of common activities, and increase awareness of the direct links between land activities, rainfall-runoff, storm drains, and their local water resources. Most importantly the requirement is to give the public clear guidance on steps and specific actions that they can take to reduce their stormwater pollution potential.

The intent of the NMC 8, public notification, is to inform the public of the location of CSO outfalls, the actual occurrences of CSOs, the possible health and environmental effects of CSOs, and the recreational or commercial activities (*e.g.*, swimming and shellfish harvesting) curtailed as a result of CSOs. Public notification is of particular concern recreation areas directly or indirectly affected by CSOs. Potential risk is generally indicated by the exceedance of relevant water quality criteria.

The City of Philadelphia promotes, develops, and implements litter reduction programs, in an effort to increase public awareness of litter as a source of stormwater pollution. To supplement the Streets Department street cleaning program and to create awareness, the Philadelphia More Beautiful Committee organizes neighborhood cleaning events city-wide.

L.26 Public Education: School-Based Education

School-based watershed education takes many forms, from lesson plans within the classroom, to hands-on activities outside of the classroom such as field trips to the Cobbs and Darby Creeks and nearby nature centers, as well as conducting actual restoration projects. Teacher training programs, developed to assist teachers in bringing watershed concepts to their students. Being engaged in actual restoration projects, whether through service learning, after school clubs, or as part of lesson plans, translates lessons into action. The Fairmount Waterworks Interpretive Center utilizes innovative technology and provides an engaging field trip to teach school groups about their impact on Philadelphia's watersheds..

L.27 Good Housekeeping: Loading, Unloading, and Storage of Materials

Responsible management of common chemicals, such as fertilizers, solvents, paints, cleaners, and automotive products, can significantly reduce polluted runoff. Such products must be handled properly in all stages of development, use, and disposal. Materials management entails the selection of the individual product, the correct use and storage of the product, and the responsible disposal of associated waste(s).

Failure to properly store hazardous materials dramatically increases the probability that they will end up in local waterways. Many people have hazardous materials stored throughout their homes, especially in garages and storage sheds. Practices such as covering hazardous materials or storing them properly can have dramatic impacts. The Philadelphia Streets Department advertises locations and times of household hazardous waste can be dropped off at http://www.phila.gov/streets/HHW.html. The website also describes the types of waste that can be collected and other online resources.

L.28 Good Housekeeping: Spill Prevention and Response

Spill prevention is prudent both economically and environmentally, because spills increase operating costs and lower productivity. The City's response plan to contain harmful spills that may discharge to the municipal sewer system is managed by the Philadelphia Local Emergency Planning Committee. PWD is represented by the Industrial Waste Unit (IWU), whose personnel are charged with response to such events.

In order to protect the PWD's structures and treatment processes, IWU personnel respond to oil and chemical spills and other incidents that have the potential to threaten the water supply or impact the combined sewer system, twenty-four hours per day, seven days per week. IWU supervises cleanup activities and assesses environmental impact. The inspectors also investigate various other types of complaints.

L.29 Good Housekeeping: Street Sweeping Programs

Street and parking lot cleaning performed on a regular basis in urban and dense residential areas can be an effective measure for minimizing stormwater pollutant, sediment, and floatables loading to receiving waters.

Street sweeping programs had largely fallen out of favor as a pollutant removal practice following the U.S Environmental Protection Agency's (US EPA's) 1983 Nationwide Urban Runoff Program (NURP) report. Recent improvements in street sweeper technology, however, have enhanced the ability of modern machines to pick up the fine grained sediment particles that carry a substantial portion of the stormwater pollutant load, and have led to a recent reevaluation of their effectiveness. New studies show that conventional mechanical broom and vacuum-assisted wet sweepers reduce non-point pollution by 5 to 30% and nutrient content by 0 to 15%. However, newer dry vacuum sweepers can reduce non-point pollution by 35 to 80% and nutrients by 15 to 40% for those areas that can be swept (Runoff Report, 1998). A benefit of high-efficiency street sweeping is that by capturing pollutants before they are made soluble by rainwater, the need for structural stormwater control measures might be reduced. Structural controls often require costly added measures, such as adding filters to remove some of these pollutants and requiring regular maintenance to change-out filters. Street sweepers that can show a significant level of sediment removal efficiency may prove to be more cost-effective than certain structural controls, especially in more urbanized areas with greater areas of pavement.

L.30 Good Housekeeping: Vehicle & Equipment Management

Common activities at municipal maintenance shops include parts cleaning, vehicle fluid replacement, and equipment replacement and repair. Automotive maintenance facilities are considered to be stormwater "hot spots." Hot spots are areas that generate significant loads of hydrocarbons, trace metals, and other pollutants that can affect the quality of stormwater.

Fluid spills and improper disposal of materials result in pollutants, heavy metals, and toxic materials entering ground and surface water supplies, which can create public health and environmental risks. Municipal facilities that properly store automotive fluids and thoroughly clean up spills can help reduce the effects of automotive maintenance practices on stormwater runoff and, consequently, local water supplies.

L.31 Good Housekeeping: Private Scrapyard Inspection and Enforcement

Automobile recycling facilities can release stormwater polluted with oil, antifreeze, pesticides, animal waste, and a range of other materials. Increased enforcement can be an effective pollution prevention measure when owners fail to follow required best management practices.

L.32 Good Housekeeping: Employee Training

In-house employee training programs are established to teach employees about stormwater management, potential sources of contaminants, and Best Management Practices (BMPs). Employee training programs should instill all personnel with a thorough understanding of their Storm Water Pollution Prevention Plan (SWPPP), including BMPs, processes and materials they are working with, safety hazards, practices for preventing discharges, and procedures for responding quickly and properly to toxic and hazardous material incidents.

L.33 Good Housekeeping: Record Keeping and Reporting

Keeping records of spills, leaks, and other discharges can help a facility run more efficiently and cleanly. Records of past spills contain useful information for improving BMPs to prevent future spills. Typical items that should be recorded include the results of routine inspections, and reported spills, leaks, or other discharges.

L.34 Good Housekeeping: Flow Diversion and Exposure Minimization Structures

Flow diversion structures (such as gutters, drains, sewers, dikes, berms, swales, and graded pavement) are used to collect and divert runoff to prevent the contamination of stormwater and receiving water. Flow diversion structures can be used in two ways. First, flow diversion structures may be used to channel stormwater away from industrial areas so that it does not mix with on-site pollutants. Second, flow diversion may be used to carry contaminated runoff to a treatment facility.

L.35 Good Housekeeping: Responsible Bridge and Roadway Maintenance

Sediment and pollutants are generated during daily roadway and bridge use and scheduled repair operations, and these pollutants can impact local water quality by contributing heavy metals, hydrocarbons, sediment and debris to stormwater runoff. The use of road salt and de-icing material is a public safety as well as a water quality issue. Aside from contaminating surface and groundwater, high levels of sodium chloride from road salt can kill roadside vegetation, impair aquatic ecosystems, and corrode infrastructure such as bridges, roads, and stormwater management devices. Responsible maintenance includes proper storage and application of materials to the roadways. There are six municipal salt storage areas in the City, all of which have been covered to prevent precipitation from coming in contact with the salt.

L.36 Pollution Prevention: Require Industrial Pretreatment

Under the NMC 3, the municipality should determine whether nondomestic sources are contributing to CSO impacts and, if so, investigate ways to control them. The objective of this control is to minimize the impacts of discharges into CSSs from nondomestic sources (*i.e.*, industrial and commercial sources, such as restaurants and gas stations) during wet weather events, and to minimize CSO occurrences by modifying inspection, reporting, and oversight procedures within the approved pretreatment program. Once implemented, this minimum control should not require additional effort unless CSS characterization and modeling indicate that a pollutant from a nondomestic source is causing a specific health, water quality, or environmental problem.

L.37 Pollution Prevention: On-Lot Disposal (Septic System) Management

Septic tank management programs are presently required of all Pennsylvania municipalities as part of their Official Act 537 Sewage Facilities Plans. Keeping these plans up to date, including provisions related to operation and maintenance of on-lot sewage disposal systems is an important means of controlling the release of pathogens and nutrients within the watershed.

L.38 Pollution Prevention: Household Hazardous Waste Collection

Leftover household products that contain corrosive, toxic, ignitable, or reactive ingredients are considered to be "household hazardous waste." Products, such as paints, cleaners, oils, batteries, and pesticides that contain potentially hazardous ingredients require special care when disposed of.

Improper disposal of household hazardous wastes can include pouring them down the drain, on the ground, into storm sewers, or in some cases putting them out with the trash. The dangers of such disposal methods might not be immediately obvious, but improper disposal of these wastes can pollute the environment and pose a threat to human health.

L.39 Pollution Prevention: Oil/Water Separator/WQ Inlets

Water quality inlets (WQIs), also commonly called oil/grit separators or oil/water separators, consist of a series of chambers that promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater. Most WQIs also contain screens to help retain larger or floating debris, and many of the newer designs also include a coalescing unit that helps to promote oil/water separation. WQIs typically capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other BMPs.

L.40 Pollution Prevention: Industrial Stormwater Pollution Prevention

These measures include monitoring and enforcing existing industrial stormwater permit requirements under Phase I of the NPDES program, as well as, Official Industrial Pollution Prevention Plans and Spill Response Actions required by the state. Full implementation of these measures should be monitored and enforced throughout the watershed.

L.41 Pollution Prevention: Litter and Illegal Dumping Enforcement

This option involves increased enforcement of Philadelphia's litter and dumping ordinance.

L.42 Pollution Prevention: Require Construction-Phase Stormwater/E&S Controls

PWD enforces construction-phase erosion and sediment (E&S) control within the City in accordance with PADEP requirements. These measures reduce the load of solids to the combined sewer system and receiving waters. PWD staff review and approve E&S plans submitted by developers. During construction, site inspections are conducted and fines are levied if necessary to ensure compliance.

6.2 Detailed Evaluation of Green Infrastructure Feasibility

For the reasons discussed in Section 6.1, there is no question that measures to control stormwater at the source will be part of the City's CSO LTPCU. The questions to be answered by the screening and analysis tools discussed in this section are the following:

- How much land-based stormwater management is possible over the long-term planning horizon? In other words, at the conclusion of the period covered by the CSO LTCPU, what land area can be served by measures to manage stormwater at the source?

- What is the benefit of these land-based measures in terms of the water quality and CSO control goals set forth earlier in this LTCPU?

6.2.1 Performance Criteria

Philadelphia's stormwater ordinance, contained in Chapter 14-1600 of the City's Code and Charter, lays out a broad framework for required post-construction stormwater controls. Chapter 14 1603.1.6.c.1 of the ordinance allows the PWD to develop additional regulations that clarify requirements of the ordinance and specify types of controls that can be used to meet the requirements.

Requirements of the Stormwater Management Regulations define a minimum level of performance for all stormwater controls in the City. There are three major elements to the Philadelphia Stormwater Regulations: a water quality requirement, a channel protection and CSO reduction requirement, and a flood control requirement.

Water Quality Requirement

The Water Quality Requirement is equivalent to 1.0 in of precipitation over the directly connected impervious area (DCIA) on a site. This requirement is established to: 1) recharge the groundwater table and increase stream baseflow; and 2) reduce stormwater runoff and combined sewer overflow. The requirement is similar to water quality requirements in surrounding states and in other major cities.

1. The management technique required is infiltration unless infiltration is determined to be physically impossible (due to contamination, high groundwater table, shallow bed rock, impermeable soil) or where it can be shown that doing so would cause property or environmental damage. Infiltration efficiently reduces overflow volume, frequency, and duration by preventing water from reaching the combined sewer system

2. Where infiltration is not feasible for the entire volume, any remaining portion that cannot be infiltrated must be detained and released at a specified rate. This slow release rate reduces overflow volume and frequency by diverting more flow to wastewater treatment plants. However, detention and slow release are less efficient at reducing CSOs than infiltration, as demonstrated by results presented later in this section

In addition to efficiency in preventing overflow, infiltration is desirable for a number of reasons:

- Nearly all portions of streams in Philadelphia are listed as impaired by quantity-related issues (high flows and velocities caused by urban runoff), while only a few are listed for quality-related issues. Infiltration restores a more natural water balance, reducing both the quantity and duration of runoff and overflow
- The easiest way to manage the 1.0 in water quality volume is to infiltrate it. Designing a control structure to store and release runoff at a slow rate is more difficult technically and requires more maintenance
- Approximately 0.3 to 0.5 in of recharge is sufficient to restore the natural (historical) water balance on a watershed basis. However, redevelopment takes place very slowly and it makes sense to infiltrate more than this amount on sites where it is feasible. Most development taking place in the City will be redevelopment
- The water table is deep in most parts of the City, and there is little concern that increased infiltration on redevelopment sites will lead to a regional water table rise that will cause problems. The water table can be assessed on a site-by-site basis
- Many peer cities require a portion of the water quality volume to be infiltrated based on natural soil type. Philadelphia has mostly urban soils and limited information is available for them. It makes sense to determine infiltration capacity on a site-by-site basis rather than prescribe it
- Design alternatives exist to address many common objections to infiltration, such as wet basements and groundwater contamination due to small amounts of pollutants in parking lot runoff

Channel Protection Requirement

The channel protection requirement results in release of runoff from a 1 -yr, 24-hr event at a specified rate. The channel protection requirement is established to: 1) protect quality of stream channels and banks, fish habitat, and man-made infrastructure from the influences of high stream velocity erosive forces and 2) further reduce the quantity, frequency and duration of CSOs. Philadelphia's channel protection requirement is modeled after those adopted in many other cities and states, including Atlanta, Baltimore, Boston, Detroit, Minneapolis, Portland, Seattle, Washington D.C., Maryland, New Jersey, and New York.

Some development sites receive an exemption from the requirement because they provide a sufficient level of control without it. The channel protection requirement does not apply to sites directly discharging to the larger rivers or tidal waters. As an incentive for innovative design, sites are exempt if they can demonstrate a minimum 20% reduction in DCIA between the pre-construction and post-construction conditions. Finally, sites with less than one ac of earth disturbance receive an exemption because it is believed the requirement may be a disincentive for redevelopment on smaller sites.

Numerically, the channel protection requirement states that the design must detain and release runoff from a 1-yr, 24-hour event at an average rate of 0.12 cfs per ac and a maximum rate of 0.24 cfs per ac in no less than 24 hours and no more than 72 hours. This release rate protects streambanks by approximating streamflow in an undeveloped watershed. Modeling results, presented later in this section, demonstrate that it is sufficient to reduce, but not eliminate, combined sewer overflows. The specified release rate in combined sewered areas was not further reduced because it is believed that design and maintenance of a control structure to provide an even smaller release rate may be infeasible on smaller sites. Design alternatives exist to prevent clogging of small orifices, but practical limits exist to these technologies.

Flood Control Requirement

The flood control requirement is established to reduce or prevent the occurrence of flooding in areas downstream of the development site caused by inadequate sewer capacity or overtopping of stream banks. In general, a development project is required to limit peak runoff in the post-development condition to peak runoff in the pre-development condition. The flood control requirement is not intended to provide a significant CSO or water quality benefit but is a necessary part of a comprehensive stormwater management program.

Systems Approach to Design of Stormwater Management Practices

The design process is intended to meet the level of control required. Site designers can provide the level of performance required using a variety of controls such as disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, and tree canopy.

A structural stormwater management facility is a system that uses physical, chemical, and biological processes to provide the level of stormwater control required. These requirements are met through the five principle hydraulic functions of stormwater control structures: storage, infiltration, evapotranspiration, controlled release, and overflow or bypass flow. Figure 6.1 illustrates a variety of design elements available to provide these functions. Depending on the configuration, physical, chemical, and biological processes lead to removal of pollutants during these processes.

By combining design components in a variety of ways, the designer can identify alternative systems that achieve a given function. Figure 6.2 illustrates several different designs that are capable of storing the runoff from a 1-yr storm over a parking lot, infiltrating the first inch of runoff, and releasing the remainder at a slow rate.

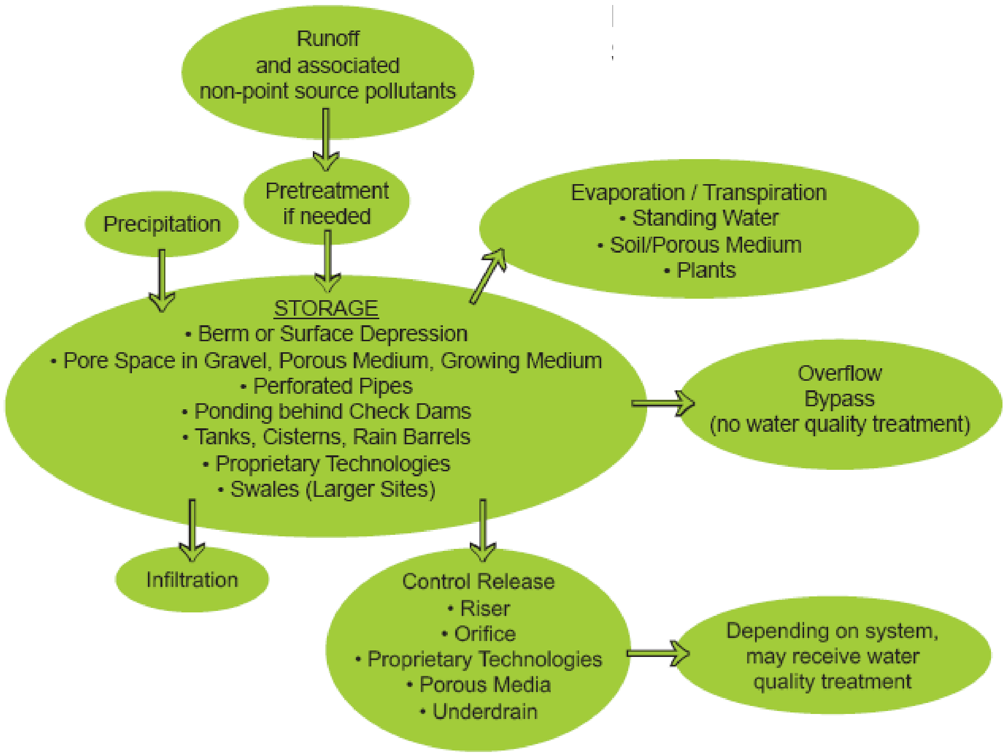


Figure 6.1 Systems Approach to SMP Design

6.2.2 Study Methods

The US EPA's Storm Water Management Model (SWMM) was chosen to evaluate the operational characteristics and benefits of structural measures because it is suitable to the hydrologic and hydraulic complexity of the system and provides the capability to simulate the operation of most structural options under consideration. In addition, a SWMM-based model of land-based measures can easily interface with PWD's SWMM combined sewer model.

Modeling was conducted according to the same systems principles applied to facility design. Philadelphia's stormwater regulations require a minimum level of performance from post-construction stormwater management structures (hereafter referred to as Stormwater Regulations Level of Control, SRLC). Rather than focusing on differences in structure between different land-based practices, the modeling team assumed that an appropriate practice or mix of practices can be designed to meet this level of performance. The team modeled a general structure that meets management goals through some combination of storage, infiltration, and slow release. Details of the modeling approach are discussed in Section 5.

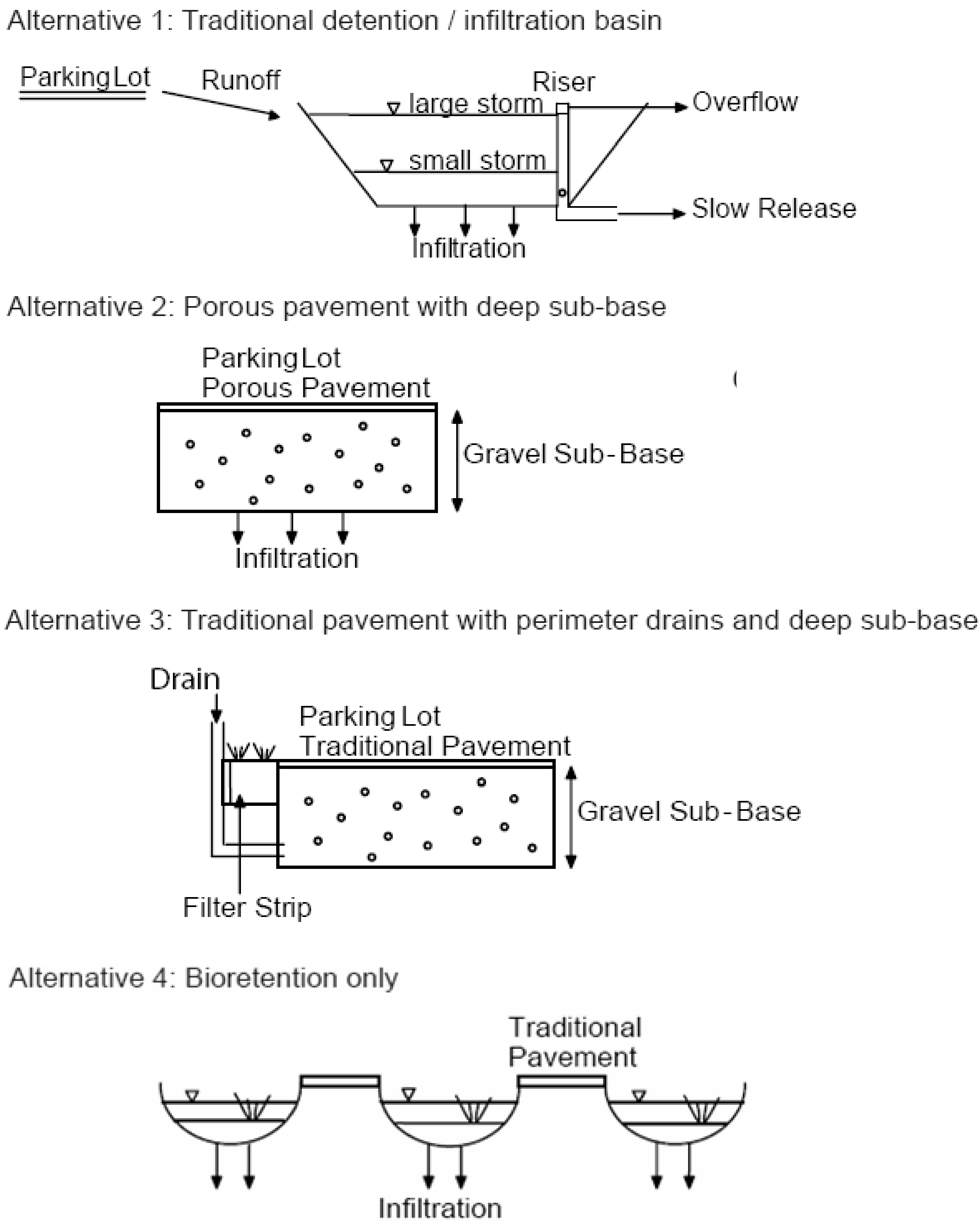
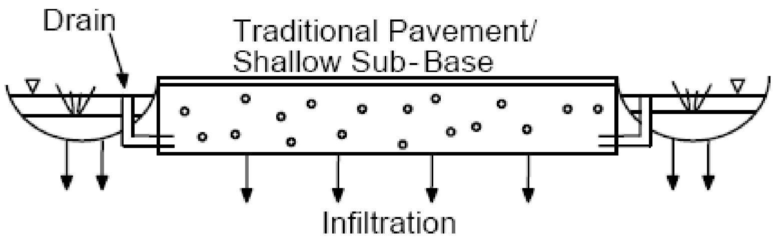


Figure 6.2 Different Designs for Storing Runoffs

Alternative 5: Bioretention and subsurface storage



Alternative 6: Swale (large site option)

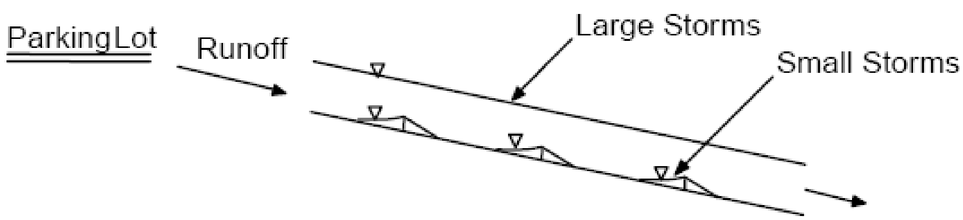


Figure 6.2 Different Designs for Storing Runoffs (Continued)

6.2.3 Results

Green Infrastructure Performance Simulation Results

The primary purpose of green infrastructure is to restore a water balance more similar to natural, pre-development conditions. The water budgets for SRLC simulations with varying levels of implementation for each drainage district are shown in Table 6.2. Figures 6.3 through 6.5 show a visual representation of results for the SE, NE and SW districts, respectively. These show changes in soil infiltration volume, detained and released volume, overflow from management facilities, surface evaporation and uncontrolled runoff volume as the percentage of land area managed increases. As the level of implementation increases, the total runoff is reduced. The runoff instead either infiltrates the soil or is detained and released prior to entering the combined sewer system.

Table 6.2 Component Volumes of the Water Budget Comparing Results of Baseline Model Simulations to SRLC Simulations Representing Varying Levels of Impervious Area Served by Land-Based Controls for Each Drainage District

SE Drainage District						
Model	Percent of Area Served by LID	LID Overflow (MG)	Detained and Released (MG)	Soil Infiltration (MG)	Surface Evaporation (MG)	Uncontrolled Runoff (MG)
Upper Limit of Uncertainty Range						
Baseline	Existing	-	-	4,350	534	6,375
SRLC	25%	134	202	5,554	541	4,976
SRLC	50%	265	406	6,754	548	3,564
SRLC	75%	394	611	7,957	559	2,144
SRLC	100%	523	818	9,164	582	704

Model	Percent of Area Served by LID	LID Overflow (MG)	Detained and Released (MG)	Soil Infiltration (MG)	Surface Evaporation (MG)	Uncontrolled Runoff (MG)
SE Drainage District						
Lower Limit of Uncertainty Range						
SRLC	25%	101	151	6,850	397	3,872
SRLC	50%	200	304	7,754	405	2,805
SRLC	75%	298	458	8,660	417	1,731
SRLC	100%	395	613	9,567	439	643

Model	Percent of Area Served by LID	LID Overflow (MG)	Detained and Released (MG)	Soil Infiltration (MG)	Surface Evaporation (MG)	Uncontrolled Runoff (MG)
NE Drainage District						
Upper Limit of Uncertainty Range						
Baseline	Existing	0	0	10,879	1,262	12,218
SRLC	25%	267	591	13,098	1,254	9,508
SRLC	50%	518	1,186	15,137	1,266	6,893
SRLC	75%	770	1,785	17,181	1,285	4,267
SRLC	100%	1,040	2,387	19,230	1,325	1,628
Lower Limit of Uncertainty Range						
Baseline	Existing	0	0	13,936	927	9,499
SRLC	25%	200	443	15,615	933	7,443
SRLC	50%	396	889	17,148	947	5,480
SRLC	75%	590	1,336	18,683	968	3,505
SRLC	100%	770	1,785	20,221	1,003	1,495

Model	Percent of Area Served by LID	LID Overflow (MG)	Detained and Released (MG)	Soil Infiltration (MG)	Surface Evaporation (MG)	Uncontrolled Runoff (MG)
SW Drainage District						
Upper Limit of Uncertainty Range						
Baseline	Existing	0	0	8,702	727	9,031
SRLC	25%	181	404	10,271	736	6,973
SRLC	50%	360	810	11,832	750	5,018
SRLC	75%	536	1,218	13,397	769	3,050
SRLC	100%	710	1,628	14,995	807	1,057
Lower Limit of Uncertainty Range						
Baseline	Existing	0	0	10,939	534	6,998
SRLC	25%	136	304	12,137	545	3,811
SRLC	50%	271	608	13,315	560	2,686
SRLC	75%	405	914	14,494	580	1,554
SRLC	100%	537	1,223	15,717	611	407

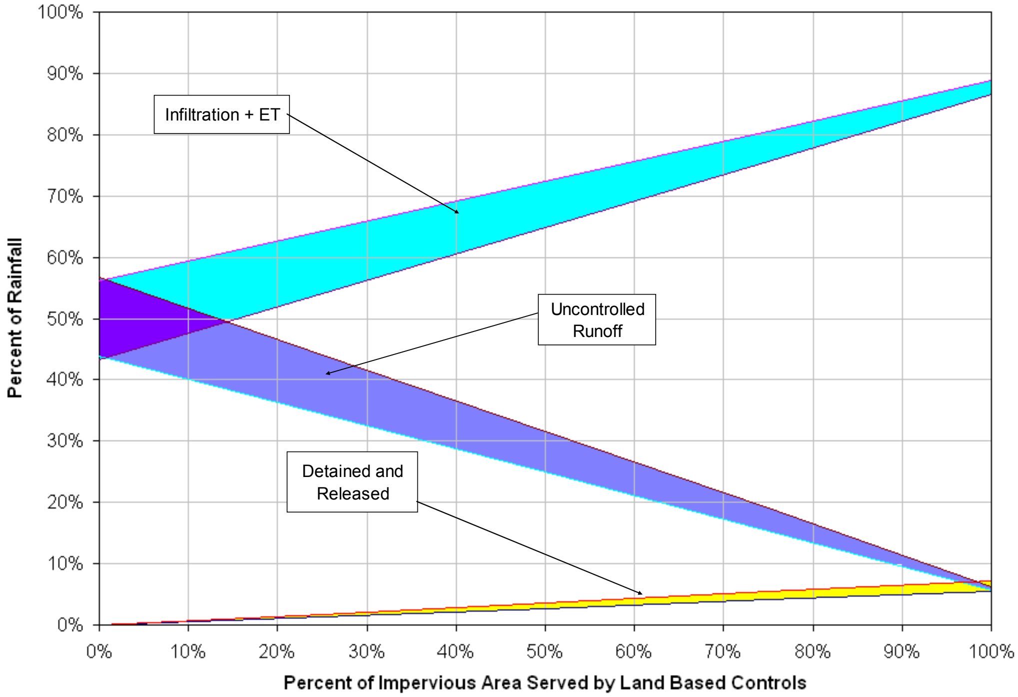


Figure 6.3 SE Drainage District Water Budget Estimated From Simulating Stormwater Regulations for Varying Levels of Implementation. The Shaded Region Represents a Range of Uncertainty for the Quantity of Runoff Occurring

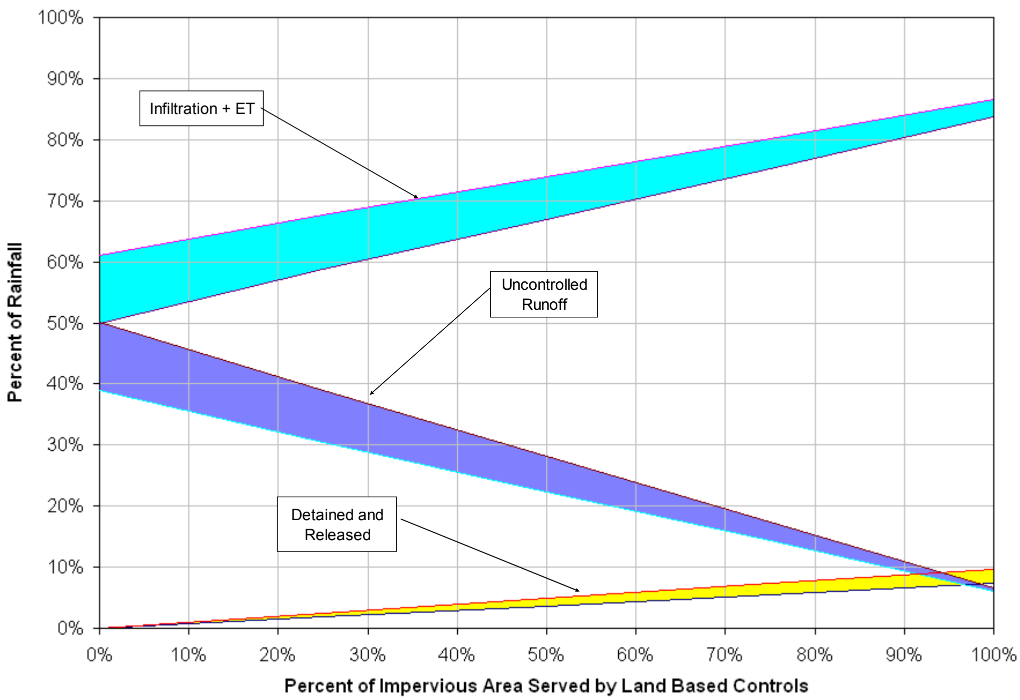


Figure 6.4 NE Drainage District Water Budget Estimated From Simulating Stormwater Regulations for Varying Levels of Implementation. The Shaded Region Represents a Range of Uncertainty for the Quantity of Runoff Occurring

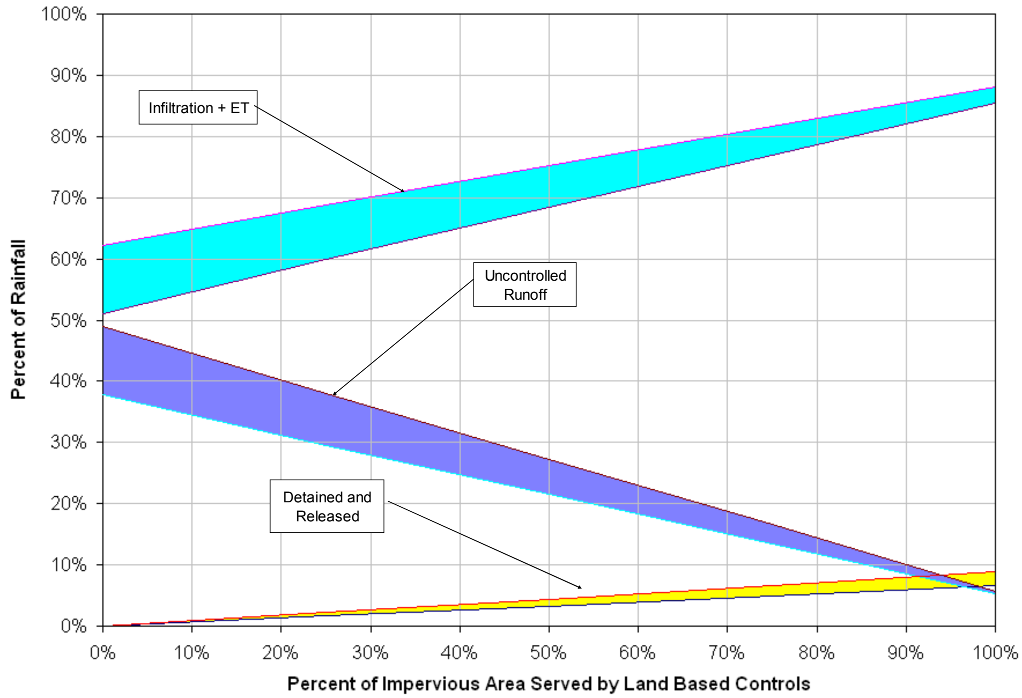


Figure 6.5 SW Drainage District Water Budget Estimated From Simulating Stormwater Regulations for Varying Levels of Implementation. The Shaded Region Represents a Range of Uncertainty for the Quantity of Runoff Occurring

Percent capture is a measure of the CSS performance and is defined as the percent of total combined sewage collected that is conveyed to the water pollution control plant (WPCP) during wet weather. Green Infrastructure implementation, however, reduces the volume of stormwater entering the CSS and thereby reduces the volume requiring treatment at the WPCP. In order to account for this performance benefit, an effective capture volume is determined as the total baseline combined sewage volume (sum of captured and overflow volumes) minus the SRLC simulation combined sewer overflow volume.

6.2.4 Feasible Implementation Range

Analysis of Impervious Surfaces in Combined-Sewered Areas

Distribution of Impervious Surfaces by Type

The type of impervious structure influences options available for management of stormwater. The distribution of buildings, parking, streets, and sidewalks is relatively constant in the three drainage districts, although highways are more significant in the southeast due to the smaller drainage area relative to Interstate 95 (Table 6.3).

Surfaces intended for parking (parking lots and driveways) represent approximately 20% of total impervious surfaces. Parking presents some of the most technically feasible stormwater management options. A portion of a parking lot can be converted to a surface vegetated management facility where space is available. Subsurface pretreatment, storage, and infiltration facilities, below traditional or porous pavement, can be installed where space is limited. Strategies on public and private land are similar.

Building roofs represent approximately 40% of impervious surfaces in the combined-sewered areas of Philadelphia. In the space-limited urban environment, managing stormwater from roofs can be

Table 6.3 Distribution of Impervious Surfaces by Type

Impervious Surface Type	Combined-Sewered Impervious Area (ac)				Combined-Sewered Impervious Area (% of total)			
	City-Wide	SEDD	NEDD	SWDD	City-Wide	SEDD	NEDD	SWDD
Building	11,385	2,538	5,026	3,821	40	39.9	39.1	41.4
Parking	5,959	1,229	2,896	1,834	21	19.3	22.5	19.9
Street+Sidewalk	10,774	2,426	4,828	3,519	37.9	38.2	37.6	38.1
Highway	315	165	94	56	1.1	2.6	0.7	0.6

more challenging than managing parking lot runoff. Where space is available, runoff can be directed to the ground or subsurface level and managed using the same types of structures used to manage parking runoff. Where space is limited, green roofs are an option. Strategies on public and private land are similar.

Surfaces related to transportation (streets, sidewalks, and highways) represent approximately 40% of the total, including approximately 1% covered by interstate highways. This finding is significant because it suggests management of street runoff is critical to a program of widespread impervious cover mitigation. Management options include increased street tree cover with or without additional subsurface storage, surface vegetated approaches, porous pavement, and inlets designed for pretreatment and infiltration. These approaches may be more technically and programmatically challenging than management of building and parking lot runoff.

Distribution of Impervious Surfaces by Ownership/Management

Ownership of impervious surfaces has implications for management strategies. Although technical approaches on public and private land may be similar, approaches to implementation may be different. Approaches on private land include regulation and incentive programs. Approaches on public land require a commitment and coordinated implementation strategy across multiple agencies. Section 10 includes a description of the many tools available.

Approximately 55% of land in the combined-sewered areas is privately owned. Public land is dominated by streets and sidewalks, managed in Philadelphia by the Philadelphia Streets Department. PWD, Department of Parks and Recreation, School District, and other City agencies manage a relatively small portion (approximately 3%) of impervious area but have an opportunity to demonstrate and lead an effective city-wide implementation program. Approximately 2-3% of impervious surfaces are found on vacant or abandoned lands. In the long-term, these lands can either be left as open space or redeveloped in a way that does not impact water resources.

Distribution of Impervious Surfaces by Size

The distribution of parking lot sizes suggests that to achieve widespread implementation, both smaller and larger lots must be targeted. Small lots and driveways up to 1 ac in area make up approximately 55% of the total impervious area related to parking. Lots between 1 ac and 5 ac make up approximately 25% of the total. The largest lots greater than 5 ac make up approximately 20% of the total (Table 6.5).

Table 6.4 Distribution of Impervious Surfaces by Ownership/Management

Impervious Surface Owner/Manager	Combined-Sewered Impervious Area (ac)				Combined-Sewered Impervious Area (% of total)			
	City-Wide	SEDD	NEDD	SWDD	City-Wide	SEDD	NEDD	SWDD
Private Owner	15,734	3,291	7,261	5,182	55.3	51.8	56.5	56.1
PWD	22	6	5	12	0.1	0.1	0.04	0.1
Streets Department	10,774	2,426	4,828	3,519	37.9	38.2	37.6	38.1
Interstate Highway	315	165	94	56	1.1	2.6	0.7	0.6
Recreation Department	115	26	65	25	0.4	0.4	0.5	0.3
Fairmount Park Commission	157	63	50	44	0.6	1	0.4	0.5
School District of Philadelphia	404	91	198	116	1.4	1.4	1.5	1.3
Other Public Property	213	83	68	62	0.7	1.3	0.5	0.7
Vacant/Abandoned Property	699	208	277	215	2.5	3.3	2.2	2.3

Table 6.5 Distribution of Parking Area (City-Wide Combined Sewered Area)

Parking Area	Percent of Total	Cum. Percent of Total Parking Area
≤ 10,000 ft^2	30.8	30.8
≤ 20,000 ft^2	3.9	41.9
≤ 30,000 ft^2	6.3	48.2
≤ 1 ac	6.4	54.6
≤ 2 ac	12..7	67.3
≤ 3 ac	6.7	74.0
≤ 5 ac	7.4	81.4
≤ 10 ac	6.9	88.3

Table 6.6 Distribution of Building Area (City-Wide Combined Sewered Area)

Percentile	Size (ft^2)	Percent of Total	Cum. Percent of Total Building Area
10	404	0.40%	0.40%
20	933	1.20%	1.60%
30	1,421	2.20%	3.80%
40	1,812	2.90%	6.70%
50	2,205	3.70%	10.40%
60	2,837	4.50%	14.90%
70	4,549	6.50%	21.40%
80	7,645	10.90%	32.30%
90	13,568	18.60%	50.90%
95	19,277	14.70%	65.60%
99	42,608	18.80%	84.40%
100	1,102,144	15.50%	100.00%

The distribution of roof sizes suggests that it may be efficient to focus on larger buildings. The smallest half of buildings represents only 10% of total roof area, while the largest 10% represents nearly 50% of total roof area (Table 6.6).

Interstate Highways and Waterfront Land

Properties located close to the Delaware and Schuylkill waterfronts present opportunities for sewer separation, appropriate pretreatment of stormwater, and direction of stormwater to public or private permitted outfalls. It is important to note that the same land-based stormwater management techniques being considered for the combined sewer system can function as pretreatment for runoff entering a separate storm sewer system. This runoff would no longer be included in PWD's CSO management program but would continue to be managed through PWD's larger stormwater and watershed management programs.

Table 6.7 lists the "waterfront" drainage area currently draining to combined sewers. Waterfront can be defined in one of two ways. Defined as all land between interstate highways and rivers, it comprises approximately 4% of combined drainage area. This percentage is highest in the southeast drainage district at 7%. Defined more narrowly as the area between combined sewer regulator structures and the river, the waterfront area comprises approximately 2% of drainage area. There is also a long-term potential to disconnect the interstate highways themselves from the combined sewer system.

Table 6.7 Distribution of Waterfront Land

Land Location	Combined-Sewered Impervious Area (ac)				Combined-Sewered Impervious Area (% of total)			
	City-Wide	SEDD	NEDD	SWDD	City-Wide	SEDD	NEDD	SWDD
Non-waterfront	43,414	8,700	20,060	14,654	95.8	91.5	98.4	94.9
Between regulator structures and rivers	681	157	245	279	1.6	1.8	1.2	1.9
Between major highways and rivers	1,507	578	234	695	3.5	6.6	1.2	4.7
Highway	315	165	94	56	1.1	1.9	0.5	0.4
Waterfront + hghway	1,822	743	327	752	4.2	8.5	1.6	5.1

6.3 SCREENING RESULTS

The following criteria are proposed for initial screening of options:

1. Options that are required by NPDES permit or other regulation are recommended for inclusion in all management alternatives.
2. Options recommended for implementation in one of PWD's Integrated Watershed Management Plans are recommended for inclusion in all management alternatives.
3. Other options must meet at least one stated goal of the LTCPU to be considered for inclusion in management alternatives. Options also must be technically feasible to implement and maintain.

Table 6.8 Recommendations for Land-Based Options

Number	Category	Option	Include in All Alternatives	Consider Including in Alternatives	Do Not Include in Alternatives
L.1	Flow reduction	Catch basin modifications	X		
L.2	Flow reduction	Sump pump disconnect	X		
L.3	Flow reduction	Catch basin and storm inlet maintenance	X		
L.4	Flow reduction	Illicit connection control	X		
L.5	Flow reduction	Roof leader disconnect program	X		
L.6	Flow reduction	Street storage (catch basin inlet control)		X	
L.7	Flow reduction	Offload groundwater pumpage	X		
L.8	Flow reduction	Stream diversion	X		
L.9	Flow reduction	Groundwater infiltration reduction	X		
L.10	Flow reduction	Reduction of contractual flow	X		
L.11	Low impact development/ redevelopment/retrofit	Require existing resources inventory, sketch plan, initial meeting	X		
L.12	Low impact development/ redevelopment/retrofit	Require integrated site design	X		
L.13	Low impact development/ redevelopment/retrofit	Require post-construction stormwater management	X		
L.14	Low impact development/ redevelopment/retrofit	Post-construction inspection and enforcement	X		
L.15	Low impact development/ redevelopment/retrofit	Demonstration projects on public lands	X		
L.16	Low impact development/ redevelopment/retrofit	Large-scale implementation on public lands	X		
L.17	Low impact development/ redevelopment/retrofit	Street trees and street greening	X		
L.18	Low impact development/ redevelopment/retrofit	Revise stormwater rate structure	X		
L.19	Low impact development/ redevelopment/retrofit	Stormwater management incentives for retrofit	X		
L.20	Public education	Water efficiency		X	
L.21	Public education	Catch basin stenciling	X		
L.22	Public education	Community cleanup and volunteer programs	X		
L.23	Public education	Pet waste education	X		
L.24	Public education	Public notification and signage	X		
L.25	Public education	Litter and dumping education	X		
L.26	Public education	School-based education	X		
L.27	Good housekeeping	Loading, unloading, and storage of materials	X		

Number	Category	Option	Include in All Alternatives	Consider Including in Alternatives	Do Not Include in Alternatives
L.28	Good housekeeping	Spill prevention and response	X		
L.29	Good housekeeping	Street sweeping programs	X		
L.30	Good housekeeping	Vehicle & equipment management	X		
L.31	Good housekeeping	Private scrapyard inspection and enforcement	X		
L.32	Good housekeeping	Employee training	X		
L.33	Good housekeeping	Record keeping and reporting	X		
L.34	Good housekeeping	Flow diversion and exposure minimization structures	X		
L.35	Good housekeeping	Responsible bridge and roadway maintenance	X		
L.36	Pollution prevention	Require industrial pretreatment	X		
L.37	Pollution prevention	On-lot disposal (septic system) management	X		
L.38	Pollution prevention	Household hazardous waste collection	X		
L.39	Pollution prevention	Oil/water separator/WQ inlets			X
L.40	Pollution prevention	Industrial stormwater pollution prevention	X		
L.41	Pollution prevention	Litter and illegal dumping enforcement	X		
L.42	Pollution prevention	Require construction-phase stormwater/E&S controls	X		

7.0 WATER-BASED CONTROL MEASURES

7.1 IDENTIFICATION AND DESCRIPTION OF CONTROL MEASURES

Table 7-1 lists the water-based options being considered for implementation in the initial screening stage. Descriptions of these options follow.

Table 7-1: Water-Based Options

				Goals Addressed							
Number	Category	Option	IWMP*	Dry Weather WQ	Solids/Floatables	Recreation	Tributary Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
W.1	Instream	Dam modification/removal					X				X
W.2	Instream	Daylight orphaned storm sewers	X				X			X	X
W.3	Instream	Stream cleanup and maintenance	X				X				X
W.4	Instream	Channel stabilization and habitat restoration	X				X				X
W.5	Instream	Channel realignment and relocation	X				X				X
W.6	Instream	Plunge pool removal	X	X			X				X
W.7	Instream	Improvement of fish passage	X				X				X
W.8	Instream	Instream aeration		x							
W.9	Instream	Sidestream aeration									
W.10	Riparian	Constructed wetlands along stream corridors	X				X				X
W.11	Riparian	Wetland restoration along tidal rivers						X			X
W.12	Riparian	Enhance stream corridor recreational and cultural resources	X			X					X
W.13	Riparian	Wetland improvement	X				X				X
W.14	Riparian	Invasive species management	X				X				X
W.15	Riparian	Reforestation	X				X				X

*IWMP = Integrated Watershed Management Plan

W.1 Instream: Dam Modification/Removal

Dam removal and modifications are implemented to create and enhance fish habitat. These improvements are especially important to anadromous species, whose life cycles depend on upstream migration to fresh water. Modifications include partial removal, v-notches, and rock ramps. Removal of dams or modifications can increase the range of these species. In Philadelphia, migratory fish species such as American shad (*Alosa sapidissima*), striped bass (*Morone saxatilis*) and river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *A. aestivalis*) migrated through the Schuylkill River drainage until the construction of dams in the early 1800's.

W.2 Instream: Daylight Orphaned Storm Sewers
In a number of locations, separate storm sewers discharge flow directly to a combined sewer. When this situation occurs in a park or other public land and is near an existing stream, an opportunity exists to "daylight" the sewer and have it discharge directly to the stream, thereby allowing for additional capacity in the combined sewer.

W.3 Instream: Stream Cleanup and Maintenance
Keeping streams free of trash is a continuous activity. PWD has established a permanent Waterways Restoration Team. This team periodically removes trash and large debris from each of the tributaries on a rotating schedule. For reaches of stream within the City or along the City boundary, the team focuses on removal of litter and heavy debris, and maintenance of in-stream aquatic habitat improvement projects including fish ladders, fluvial geomorphologic restoration projects, and elimination of outfall plunge pools. PWD also partners with a number of watershed groups and nonprofit organizations to perform volunteer cleanups.

W.4 Instream: Channel Stabilization and Habitat Restoration
Bed conditions in stream channels subjected to urbanized flow often do not support a healthy aquatic ecosystem. High-velocity urbanized flows result in downcutting and widening of the bed over time, and deposition of fine sediments disrupts macroinvertebrate communities that are critical links in the aquatic food chain. Loss of pool and riffle sequences deprives fish of the variety of habitats they need to feed, spawn, and seek shelter from high flows. These channel changes tend to begin downstream and migrate their way upstream over a period of time.

Bed stabilization is recommended for those reaches that are currently degrading through incising or downcutting. Bed stabilization measures include rock/log vanes with grade control, rock/log cross vanes, and using naturally occurring boulders and bedrock. These measures reduce erosion by diverting high flows away from banks and by controlling the grade (slope) of the bed. They also stop downcutting from migrating upstream and restore habitat features that lead to healthy macroinvertebrate and fish communities.

The fine sediment that is deposited in the beds of many urban streams is often the result of bank erosion upstream. In addition to downcutting the stream bed, high-velocity urban flows result in steep, sometimes vertical banks that disconnect the stream from its historical floodplain. Using natural stabilization measures on banks also provide fish habitat and areas of reduced velocity during storms. A properly restored bank prevents further erosion, reconnects the stream to its floodplain (wetlands and riparian forest as appropriate), protects infrastructure located in the bank and provides fish habitat. It also may remove a hazardous and unsightly condition caused by a collapsing bank.

Bank stabilization measures can vary from small plantings to the installation of boulder walls, based on the severity of the erosion and whether it is localized or continues for some distance along a bank. Boulder structures are used in smaller channels that are eroding and over-widening to the point where property is, or is expected, to be lost. More natural bank stabilization methods such as bioengineering, root wads, plantings, logs, and woody structures are appropriate in areas where the bankfull width is limited and significant additional channel changes are not expected (future increases in the rate of erosion, sediment supply, tree fall, channel widening, and channel migration are not expected). These measures enhance aquatic habitat in addition to providing stabilization.

W.5 Instream: Channel Realignment and Relocation

In the most severely degraded reaches, stabilization of the existing bed and banks may not be possible, or migration of the stream channel may threaten valuable infrastructure. In these areas, realignment and relocation of the stream channel may be necessary. This measure increases stability by creating a new channel along a path that is natural for the stream to follow. The design of bed and bank structures is not constrained by existing conditions. In some cases, the existing channel makes an ideal site for a riparian wetland. Channel realignment and relocation is commonly implemented for portions of a channel rather than for an entire length of channel due to construction and maintenance costs, and the amount of disturbance that occurs to existing natural habitat. Stream channel realignment and relocation is best suited to consecutive severely degraded reaches.

W.6 Instream: Plunge Pool Removal

When stormwater and combined sewer outfalls discharge directly to the stream channel, they may create deep, poorly mixed pools. Because these pools are typically near the bank and not in the main flow, they can become poorly mixed during low flow. These pools often have increased odors and reduce the aesthetic quality of the stream. Biological activity in the sediment and water column can reduce dissolved oxygen (DO) to low levels, and this low-DO water can be flushed out and affect downstream areas during wet weather. The depression of DO is a function of both pollutant loads from the outfalls and in stream baseflow, and the physical condition of the channel. When DO is in an acceptable range in the well-mixed portion of the channel but not in nearby plunge pools, elimination of the plunge pools can be expected to eliminate the water quality condition that might affect the aquatic ecosystem.

W.7 Instream: Improvement of Fish Passage

Fish ladders and bypass channels are technologies built to provide passage for fish to swim around dams when dam removal/modifications are not feasible. These devices enhance habitat range for fish and provide spawning opportunities for anadromous fish. PWD has been involved with recent improvements to the Fairmount Dam Fishway on the Schuylkill River originally built in 1979.

W.8 Instream: Instream Aeration

Instream aeration is a technology developed to add oxygen to the water column in areas where slow, stagnant conditions occur in streams. Air can be added directly to stream or river flow using a diffusion system to increase dissolved oxygen levels for the improvement of fish habitat and water quality.

W.9 Instream: Sidestream Aeration

This option consists of adding air directly to a receiving waterway in order to increase dissolved oxygen concentration. Sidestream aeration is when flow is diverted to an offline aeration facility and re-diverted back to the stream or river.

W.10 Riparian: Constructed Wetlands along Stream Corridors

Wetland creation opportunities have been evaluated for many areas in the Cobbs and Tacony-Frankford Creek Watersheds where stream relocation and realignment are proposed. Because stream relocation and realignment typically involve extensive grading and replanting, new runoff patterns and hydrology can be created that are more similar to original riparian conditions, whereby the riparian corridor receives storm runoff sheet flow from the adjacent landscape. In addition, wetland habitats can be created that allow more diverse habitat. Wetlands are rich habitats that rely on saturated soils and vegetation adapted to these conditions. They could be recreated concurrently with channel realignment, bank restoration, and planting of more diverse native vegetation, including hydrophytic species adapted to saturated soil conditions.

W.11 Riparian: Wetland Restoration Along Tidal Rivers

Historically, freshwater tidal wetlands extended from Trenton, New Jersey to Chester, Pennsylvania, but urbanization has reduced the area by 95%, with only small remnants of freshwater tidal wetlands on the Pennsylvania side of the Delaware River. As part of an effort to identify tidal wetland restoration sites, PWD staff assessed the tidal sections of the Delaware and Schuylkill Rivers in 2006 and 2007. The locations for potential tidal wetland restoration have a gradual slope to littoral shelf and appropriate depth range, appropriate sediment characteristics, and the feasibility for wave/wake attenuation. Approximately 88 acres along the Delaware River and 30 along the Schuylkill River have been identified as potential for wetland creation or enhancement. The goal of this option is to improve the quality of water in the Schuylkill River as well as create habitat for aquatic life, herpifauna and migratory birds.

W.12 Riparian: Enhance Stream Corridor Recreational and Cultural Resources

Once dry weather water quality and aesthetics have been improved, the recreational value of stream and river corridors will be enhanced, and better accessibility becomes important. Measures include establishing and improving trails and greenways and protecting historic sites.

W.13 Riparian: Wetland Improvement

Existing wetlands may have a direct hydrologic relationship with the stream yet show degraded conditions at present. A wetland's hydrologic relationship with the waterway may be partially compromised or the wetland may exhibit somewhat degraded conditions because of the impacts of stormwater inflow to the wetland.

W.14 Riparian: Invasive Species Management

plan to control invasive plant species is necessary when restoring or enhancing wetlands and riparian forests. Invasive species provide little value to native animals that depend on native species for habitat and food. Japanese knotweed (Polygonum cuspidatum) is the one prevalent invasive species that was observed during the field reconnaissance. In many areas, knotweed, due to its aggressive nature, has already outcompeted native vegetation. Maintaining a healthy riparian plant community will retain biodiversity and support a healthy stream ecosystem.

W.15 Riparian: Reforestation

PWD's riparian corridor restoration and enhancement plans cover the width of the stream corridor from developed edge to developed edge, including both lowland and upland forest. Reforestation that occurs adjacent to the channel will provide wetland habitat and other associated benefits. Although priority reforestation areas consist of floodplains, steep slopes, and wetlands, smaller areas such as public rights-of-way, parks, schools, and neighborhoods also provide reforestation opportunities. Benefits of reforestation are numerous: cooler temperatures, rainfall interception, reduced runoff, reduced sediment load, reduced discharge velocities, increased groundwater recharge, increased species diversity and habitat, and improved air quality and aesthetics.

7.2 SCREENING CRITERIA

The following criteria are proposed for initial screening of options:

1. Options that are required by NPDES permit or other regulation are recommended for inclusion in all management alternatives

2. Options recommended for implementation in one of PWD's Integrated Watershed Management Plans are recommended for inclusion in all management alternatives

3. Other options must meet at least one stated goal of the LTCPU to be considered for inclusion in management alternatives. Options also must be technically feasible to implement and maintain

7.3 SCREENING RESULTS

The options listed above were considered as part of PWD's commitment to a balanced "land-water-infrastructure" approach for achieving watershed management and CSO control goals. Many of the water-based options focus on improving aquatic habitats including water quality. These water-based options are an important part of achieving the ultimate goal of regaining the resources in and around streams that have been lost due to urbanization, both within the City of Philadelphia and in the surrounding counties, while achieving full regulatory compliance in a cost-effective manner.

Table 7-2 contains the recommendations for each water-based option's inclusion in the alternatives analysis. All water-based options are included in the alternatives except for instream (W.8) and sidestream aeration (W.9). These were not included because they are only beneficial in areas where stagnated, pondlike conditions cause severe dissolved oxygen deficiencies.

Table 7-2: Recommendations for Water-Based Options

Number	Category	Option	Include in All Alternatives	Consider Including in Alternatives	Do Not Include in Alternatives
W.1	Instream	Dam Modification/Removal	X		
W.2	Instream	Daylight Orphaned Storm Sewers	X		
W.3	Instream	Stream Cleanup and Maintenance	X		
W.4	Instream	Channel Stabilization and Habitat Restoration	X		
W.5	Instream	Channel Realignment and Relocation	X		
W.6	Instream	Plunge Pool Removal	X		
W.7	Instream	Improvement of Fish Passage	X		
W.8	Instream	Instream Aeration			X
W.9	Instream	Sidestream Aeration			X
W.10	Riparian	Constructed Wetlands along Stream Corridors	X		
W.11	Riparian	Wetland Restoration Along Tidal Rivers	X		
W.12	Riparian	Enhance Stream Corridor Recreational and Cultural Resources	X		
W.13	Riparian	Wetland Improvement	X		
W.14	Riparian	Invasive Species Management	X		
W.15	Riparian	Reforestation	X		

8.0 INFRASTRUCTURE-BASED CONTROL MEASURES

8.1 IDENTIFICATION AND DESCRIPTION OF CONTROL MEASURES

Table 8-1 lists the infrastructure-based options being considered for implementation in the initial screening stage. Descriptions of these options follow.

Table 8-1 Infrastructure-Based Options

					Goals Addressed								
Number	Category	Option	Required	IWMP	Dry Weather WQ	Solids/Floatables	Recreation	Tributary Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
I.1	Nine Minimum Controls	Nine Minimum Controls	X	X	X	X					X	X
I.2	Operation and Maintenance	Inspection and Cleaning of Combined Sewers	X	X	X	X					X	
I.3	Operation and Maintenance	Combined Sewer Rehabilitation		X	X							
I.4	Operation and Maintenance	Regulator/Pump Station Inspection/Maintenance/Repairs	X								X	
I.5	Operation and Maintenance	Outfall Maintenance Program				X					X	
I.6	Operation and Maintenance	House Lateral Repairs										X
I.7	Sewer Separation	Permitted Discharge to Receiving Water for Waterfront Properties				X					X	
I.8	Sewer Separation	Separation of Sanitary Sewage and Stormwater on Development Sites				X					X	
I.9	Sewer Separation	Separate Street Runoff from Combined System				X					X	
I.10	Sewer Separation	Complete Separation into Sanitary and Storm Sewer Systems				X					X	
I.11	Sewer Separation	Permitted Discharge to Receiving Water for Waterfront Interstate Highways				X					X	
I.12	Outfall Consolidation/Elimination	Outfall and Regulator Consolidation				X					X	
I.13	Storage	Instream Storage Technologies				X					X	
I.14	Storage	In-Line Storage in Interceptor or Trunk Sewer				X					X	
I.15	Storage	Earthen Basins				X					X	
I.16	Storage	Offline Covered Storage Basins				X					X	
I.17	Storage	Offline Open Storage Basins				X					X	
I.18	Storage/Transmission	Deep Tunnels				X					X	
I.19	Storage/Transmission	Real Time Control		X		X					X	
I.20	Transmission	Parallel Interceptors				X					X	
I.21	Transmission	Remove Flow Bottlenecks				X					X	
I.22	Transmission	Diversion of Trunk Flow Directly to WPCP				X					X	
I.23	Treatment at Discharge Point	Vortex Separators				X					X	
I.24	Treatment at Discharge Point	Swirl Concentrators				X					X	

					Goals Addressed							
Number	Category	Option	Required	IWMP	Dry Weather WQ	Solids/Floatables	Recreation	Tributary Habitat	Tidal Habitat	Water Balance	Wet Weather WQ	Stewardship
I.25	Treatment at Discharge Point	Disinfection				X					X	
I.26	Treatment at Discharge Point	High Rate Treatment				X					X	
I.27	Treatment at Discharge Point	Screens				X						
I.28	Treatment at Discharge Point	Netting				X						
I.29	Treatment at Discharge Point	Booms				X						
I.30	Treatment at Discharge Point	Baffles				X						
I.31	Treatment in Receiving Water	Debris Skimming Vessels		X		X						
I.32	Treatment at Existing WPCP	Expand Primary Treatment Capacity				X					X	
I.33	Treatment at Existing WPCP	Expand Secondary Treatment and Disinfection Capacity				X					X	
I.34	Treatment at Existing WPCP	Flow Equalization				X					X	
I.35	Treatment at Existing WPCP	Expansion of Wet Weather Treatment Capacity				X					X	

I.1 Nine Minimum Controls

In the first phase of the PWD's CSO strategy, and in compliance with its NPDES permits, the PWD submitted CSO Documentation: Implementation of Nine Minimum Controls to the Pennsylvania Department of Environmental Protection on September 27, 1995. The nine minimum controls are low-cost actions or measures that can reduce CSO discharges and their effect on receiving waters, do not require significant engineering studies or major construction, and can be implemented in a relatively short time frame. To provide information needed for the development of the Nine Minimum Controls (NMC) program, the PWD instituted a $6.5 million project to upgrade its comprehensive system flow monitoring network. This program provides information necessary to identify and eliminate dry weather overflows, monitor system performance and operation, and configure and calibrate computer hydraulic models needed to develop the NMCs and long-term CSO control plans. This information provided the basis for the System Hydraulic Characterization Report that was submitted to the PADEP in June 1995 and provided the technical basis for the development of the NMC plan.

Extensive data from the PWD's Geographic Information System (GIS), flow monitoring system, the U.S. Army Corps of Engineer's Storage, Treatment, Overflow, Runoff Model (STORM), and the EXTRAN and RUNOFF blocks of the EPA Stormwater Management Model (SWMM) were used to support each phase of the CSO program. These tools were developed to support concept engineering through implementation and post-construction monitoring. The monitoring system, models, and GIS will serve as the basis for planning improvements and enhancing operation of the sewerage system over the long-term.

Using the above tools, the PWD's NMC program includes comprehensive, aggressive measures to maximize water quality improvements through the following measures:

NMC1. Review and improvement of on-going operation and maintenance programs

CSO Regulator Inspection & Maintenance Program
PWD has committed to demonstrating an improved follow-up response to sites experiencing a dry weather overflow. PWD has instituted a policy of next day follow-up inspection at sites that experience an overflow. PWD will conduct an evaluation of the effectiveness of twice-weekly inspections.
A database has been developed to document the maintenance performed on each CSO site. This system will ensure that proper regulator settings are maintained and system changes are documented. This database can also store scanned plan view and profile view drawings of CSO regulator and hydraulic control point chambers for inclusion in the field inspection report forms.

Additional components of the O&M program include:

- Pumping Station Maintenance
- Sewer Cleaning Contracts
- Inflow Prevention Program
- Tide Gate Inspection and Maintenance Program
- Emergency Overflow Weir Modification

NMC2. Measures to maximize the use of the collection system for storage

Use of the collection system for storage has long been recognized as a potentially cost-effective means to mitigate the occurrence and impacts of CSOs. PWD has been implementing in-system storage in Philadelphia's combined sewer system for nearly twenty years, using a variety of technologies.

- Reducing tidal inflows at regulators along the Southwest Main Gravity and the Lower Schuylkill West Side interceptors can reduce CSO overflows to Cobbs Creek by increasing available treatment capacity at the SWWPCP.
- A program to install tide gates or other backflow prevention structures at Cobbs Creek regulators to protect these regulators from potential inundation.
- Another approach that can be implemented to gain additional in-system storage is to raise the overflow elevation by physically modifying the overflow structure (*e.g.* raising an overflow weir). However, this approach must be implemented cautiously, since raising the overflow elevation also raises the hydraulic grade line in the combined trunk sewer during storm flows, and therefore increases the risk of basement and other structural flooding within the upstream sewer system due to backup or surcharge problems.

NMC3. Review and modification of PWD's industrial pretreatment program

Over the years, PWD has implemented a rigorous industrial pretreatment program. The effectiveness of this program has allowed the City to develop one of the largest and most successful biosolids beneficial reuse programs in the nation.

NMC4. Measures to maximize flow to the wastewater treatment facilities

As a minimum control, maximizing flow to the water pollution control plant (WPCP) means making simple modifications to the sewer system and treatment plant to enable as much wet weather flow as possible to reach the treatment plant and receive treatment. The secondary capacity of the treatment plant should be maximized, and all flows exceeding the capacity of secondary treatment should receive a minimum of primary treatment – and disinfection, when necessary. The most effective way to determine the ability of the WPCP to operate acceptably at incremental increases in wet weather flow, and to estimate the effect of the WPCP's compliance with its permit requirement, is to perform stress testing to determine optimum flows, loads, and operations of the plant's unit processes. Please refer to Supplemental Documentation Volumes 6, 7 and 8 (Stress Testing of the Northeast WPCP, Stress Testing of the Southeast WPCP and Stress Testing of the Southwest WPCP).

NMC5. Measures to detect and eliminate dry weather overflows

The operations and maintenance options discussed later in this section include ongoing measures to prevent dry weather discharges from the combined sewer system.

NMC6. Control of the discharge of solid and floatable materials

Solids are waterborne waste material and debris consisting of sand, gravel, silts, clay, and organic matter. Significant concentrations of solids are not only a visual nuisance, but can affect turbidity, dissolved oxygen, and carry pathogens in the receiving water. In addition, excessive amounts of solids can affect the combined sewer system by decreasing hydraulic capacity, thus increasing the frequency of overflows. Solids can enter the system through domestic and industrial wastewater, and debris washed from streets.

Floatables are waterborne waste material and debris (*e.g.*, plastics, polystyrene, and paper) that float at or below the water surface. Floatables seen in significant quantities are aesthetically undesirable and can cause beach closings, interfere with navigation by fouling propellers and water intake systems, and impact wildlife through entanglement and ingestion.

Floatables and solids control measures consist of non structural and structural technologies.

Non structural technologies include combined sewer system maintenance procedures such as sewer flushing, street sweeping, and catch basin cleaning. Public education, land

use planning and zoning, and ordinances are also considered non-structural technologies implemented to reduce solids and floatables entering the combined sewer system. These technologies are discussed under separate subsections and therefore will not be discussed further here.

Structural controls typically consist of abatement devices that would be constructed near the point of discharge. Technologies used for removing solids and floatables from CSOs include: Baffles, Booms, Catch Basin Modifications, Netting Systems, Swirl Concentrators, Screens, and Trash Racks. Modification of storm and combined sewer inlets for solids control, as well as catch basin and storm inlet maintenance are discussed under separate subsections.

Solids and floatables discharged from CSOs may represent a potentially significant impact to Philadelphia's creeks and streams. PWD currently expends considerable effort to minimize the potential discharge of solids and floatables.

- PWD performs over 50,000 inlet cleanings each year preventing many tons of street surface-related materials from discharging to waterways through CSOs. The significant pipe cleaning and grit removal activities conducted by the department also remove a great deal of material that otherwise might discharge through CSO outlets during wet weather.

- The continued practice of regularly cleaning and maintaining grit pockets at critical locations in the trunk and interceptor system is an important part of the CSO control strategy. Grit buildup reduces the hydraulic capacity of the interceptor both by constricting its cross sectional area, and by increasing its frictional resistance. For example, quarterly cleaning of the 100-foot deep siphon grit pocket located at the Central Schuylkill wastewater pumping station is a major undertaking requiring specialized equipment and the commitment of significant labor resources. This practice has been shown to reduce the hydraulic grade surface at the siphon, increasing the wet weather flow capacity to the SWWPCP. Prior to the institution of this cleaning practice, the grit pit at this location had not been cleaned regularly in over 40 years.

- Operation condition inspections of regulator chamber and backflow prevention devices are conducted for each structure approximately weekly, resulting in more than 10,000 inspections conducted each year. Additionally, comprehensive structural and preventative maintenance inspections are performed annually.

- Floatables will be monitored. If additional floatables control is warranted, then structural technologies will be considered. Structural technologies that would be considered first are catch basin modifications, including further enhancement of inlet grating and submerged outlet installations, netting systems, and static screens. More structurally intensive controls would be considered only if the application of the controls mentioned above proved not to be feasible under specific site requirements.

NMC7. Implementation of programs to prevent generation and discharge of pollutants at the source

Most of the city ordinances related to this minimum control are housekeeping practices that help to prohibit litter and debris from actually being deposited on the streets and within the watershed area. These options are discussed under Target A, including litter ordinances and illegal dumping policies and enforcement. If these pollutants eventually accumulate within the watershed, practices such as street sweeping and regular maintenance of catch basins can help to reduce the amount of pollutants entering the combined system and ultimately, the receiving water.

NMC8. Measures to ensure that the public is informed about the occurrence, location and impacts of CSOs

PWD has developed and will continue to develop a series of informational brochures and other materials about its CSO discharges and the potential effect on the receiving waters, in addition to information regarding dry weather flows from its stormwater outfalls. The brochures provide phone contacts for additional information. Also, the opportunity to recruit citizen volunteers to check or adopt CSO outfalls in their watersheds (*i.e.*, notifying the PWD of dry weather overflows, etc.) will be explored through the watershed partnership framework. Brochures and other educational materials discuss the detrimental effects of these overflows and request that the public report these incidences to the department. In addition, PWD has enlisted watershed organizations to assist it with this endeavor and to raise the level of awareness in its citizens about the function of combined and stormwater outfalls through a variety of educational mediums. The watershed partnerships are important for this kind of public/private effort to protect stream water quality. Lastly, the department's Waterways Restoration Team will investigate the feasibility of installing signs that can withstand nature and vandals at the department's outfalls.

A more recent development was discussion among the state, PWD and the Delaware Estuary Program, to begin a marina best management practices education program that, in addition to alerting recreational users of the Delaware and Schuylkill Rivers regarding questionable water quality following rain storms, will also provide tips and information to marina operators to ensure their practices are environmentally sound. To complement this effort, the PWD has completed RiverCast for the Schuylkill River due to the number of recreational activities that take place on the river year around. This system's educational message is similar to that of the marina program as the advisories are based upon rainfall, CSOs and upstream influences on water quality.

NMC9. Comprehensive inspection and monitoring programs to characterize and report overflows and other conditions in the combined sewer system.

Monitoring and characterization of CSO impacts from a combined wastewater collection and treatment system are necessary to document existing conditions and to identify water quality benefits achievable by CSO mitigation measures. Tables are compiled annually to represent average annual CSO overflow statistics as required in the NPDES Permit.

I.2 Operation and Maintenance: Inspection and Cleaning of Combined Sewers

Maintenance of sewers includes activities required to keep the system functioning as it was originally designed and constructed. Any reinvestment in the system, including routine maintenance, capital improvements for repair or rehabilitation, inspection activities, and monitoring activities are generally classified as maintenance.

An inspection program is vital to proper maintenance of a wastewater collection system. Without inspections, a maintenance program is difficult to design, since problems cannot be solved if they are not identified. Sewer inspections identify problems such as blocked, broken, or cracked pipes; tree roots growing into the sewer; sections of pipe that settle or shift so that pipe joints no longer match; and sediment and other material building up and causing pipes to break or collapse. The elements of an inspection program include flow monitoring, manhole inspections, smoke/dye testing, closed circuit television inspection, and private sector inspections. Private sector building inspection activities include inspection of area drains, downspouts, cleanouts, sump discharges and other private sector inflow sources into the system.

In addition to inspection, routine maintenance must also include sewer cleaning, root removal/treatment, cleaning of mainline stoppages, cleaning of house service stoppages, and inspections and servicing of pump stations.

I.3 Operation and Maintenance: Combined Sewer Rehabilitation

An inspection program may identify sections of sewer that are in poor condition and in need of major repair or replacement. Under the traditional method of sewer relief, a replacement or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline. While these traditional methods of sewer rehabilitation require unearthing and replacing the deficient pipe (the dig-and-replace method), trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer rehabilitation techniques offer a method of correcting pipe deficiencies that requires less restoration and causes less disturbance and environmental degradation than the traditional dig and-replace method.

I.4 Operation and Maintenance: Regulator/Pump Station Inspection/Maintenance/ Repairs

In order to keep the regulator and pumping stations optimized it is necessary to have routine site inspections and maintenance performed. It is not uncommon for debris and grit to interfere with regulator and pump operations and therefore, expansion and continuation of the current regulator and pumping station inspection and maintenance programs will allow for efficient detection of malfunctioning regulator and/or pumping stations. Presently, the maintenance and repair program relies on site inspections to identify faulty mechanisms, grit or debris build-up and/or damage to the regulator or pumping structure itself. The observations are documented and updated in a database to track repairs.

I.5 Operation and Maintenance: Outfall Maintenance Program

Because of the debris normally present in combined sewage, regulators are particularly susceptible to the accumulation of materials that cause clogging and blockages. Trash blockages at the entrance to the orifice of the interceptor increase head loss through the orifice and cause the majority of unnecessary overflows in passive regulators. Other causes of unnecessary diversions at regulators include weir plates or dams that are improperly set, damaged, or broken off. Similarly, tide gate failure can often be attributed to trash or debris becoming lodged in the gate, or corrosion of the gate or deterioration of the gate gaskets. Tide gate failure allows the receiving water to enter the CSS, reducing the storage and flow capacity.

Pump stations should be maintained to operate at the design conditions. Wet wells should be routinely cleaned because grit and solids deposition in the wet well can damage the pump or restrict the flow of wastewater into the pump.

I.6 Operation and Maintenance: House Lateral Repairs

The City of Philadelphia requires homeowners to maintain and repair lateral connections up to the point where the lateral connects to the city's sewer line. To facilitate prompt attention to failing laterals and to mitigate the financial strain of lateral repairs, PWD offers a homeowner's assistance program, the Homeowner's Emergency Loan Program (HELP). The homeowner must meet certain program requirements and may repay the city in interest free installments.

I.7 Sewer Separation: Permitted Discharge to Receiving Water for Waterfront Properties

Implementation of the LTCPU will coincide with a number of long-term planning efforts for Philadelphia's riverfronts. Redevelopment of these riverfronts provides a once-in-a-lifetime opportunity to modify and retrofit water resources infrastructure at minimal marginal cost while providing new amenities to the community. Since 2006, redevelopment sites have been required to separate sanitary sewage and stormwater in separate laterals prior to connection to public infrastructure. Sewer separation is the practice of separating the combined, single pipe system into separate sewers for sanitary and stormwater flows. In a separate system, stormwater is conveyed to a stormwater outfall for discharge directly into the receiving water. To free wet weather capacity in the combined sewer system, separate storm laterals can be connected to storm sewers built in conjunction with highway expansion projects (see Option I.11), or on large waterfront development sites discharged directly to a receiving water through a permitted outfall. Sanitary sewage can be conveyed to a WPCP for treatment.

Tidal Schuylkill River Master Plan: The Tidal Schuylkill River Master Plan was completed by the Schuylkill River Development Corporation in 2003. It includes a long-term vision for the tidal Schuylkill including stormwater management, water quality improvement, and habitat restoration; streetscaping, trails and greenways, marinas, boat launches, and docks; improved transportation and connections between neighborhoods and the river; a "sustainable riverfront" including new wetlands, restored wetlands, and treatment wetlands; protection and restoration of forest, native species, and buffers; modern shoreline stabilization best management practices; and public and private development

The North Delaware Riverfront Planning Process: The North Delaware Riverfront represents one of the City's unique assets with its spectacular views and amenities, convenient public transportation access and tremendous potential for growth in the form of new recreational opportunities, new riverfront neighborhoods, and ecological habitat restoration. The riverfront offers a prime site for the creation of a public greenway along the river's edge that would complement the distinctive riverfront features and bridges, broad river views, tidal flats and estuarine habitat, and fishing and boating facilities present. The Greenway would provide walking and bike trails, river road access, active recreational opportunities and overlooks, marinas and restaurants, with inland sites developed as new residential and mixed-use riverfront communities. The City's Vision Plan for the North Delaware – eleven miles from Penn Treaty Park to Glen Ford – is to transform much of the vacant, former industrial properties along the riverfront into a destination frontage that will bring new distinction and identity to the City and stimulate the economy and culture of the entire City.

Central Delaware Riverfront Planning Process: A Civic Vision for the Central Delaware. The process was led by PennPraxis of the School of Design of the University of Pennsylvania and authorized by executive order of Philadelphia Mayor John F. Street on October 12, 2006. The charge was to "create a civic vision for the central Delaware that balances the public good, access to the waterfront, open space and quality urban development." The hallmark of the work has been the civic-engagement process, which was designed and facilitated in collaboration with the Penn Project on Civic Engagement.

I.8 Sewer Separation: Separation of Sanitary Sewage and Stormwater on Development Sites

Incorporating sewer separation into all development sites allows for a cost-effective means to detach from the combined sewer design practice. The current stormwater development guidelines require sewer separation from all private development projects and at the very least, separation of sewer lines must be implemented to the trap line.

I.9 Sewer Separation: Separate Street Runoff from Combined System

Separating street runoff from the combined sewer system would require construction of a separate stormwater conveyance pipe to capture and convey captured runoff from surface streets only and would not be combined with sanitary flow conveyed by the existing CSS.

I.10 Sewer Separation: Complete Separation into Sanitary and Storm Sewer Systems Based on a comprehensive review of a community's sewer system, separating part or all of its combined systems into distinct storm and sanitary sewer systems may be feasible. Communities that elect for partial separation typically use other CSO controls in the areas that are not separated.

I.11 Sewer Separation: Permitted Discharge to Receiving Water for Waterfront Interstate Highways

Currently, stormwater runoff from the two interstate highways (I-95 and I-76) along Philadelphia's riverfronts is discharged to the combined sewer system, taking up wet weather capacity and increasing overflow from sewersheds along the waterfronts. The area represented by I-95 is approximately 2.1% of impervious area in the Delaware River Watershed. Currently, the PADOT has plans to expand the capacity of a portion of I-95 by adding new lanes. This major construction project provides an opportunity to incorporate a stormwater management component concurrently with the transportation component (Figure 8-1). In this concept, stormwater runoff from new and existing lanes will be diverted from the combined sewer system. New separate storm sewers will be constructed from I-95 to the waterfront, with stormwater quality treatment included as appropriate. This infrastructure can be sized to accommodate not just runoff from the highway, but runoff from future redevelopment projects along the waterfront. A similar concept will be considered along waterfront portions of I-76, although there are no current plans to expand this roadway.

I.12 Outfall and Regulator Consolidation

Where several outfalls are near each other, municipalities should investigate whether to consolidate them to a single location for storage and/or treatment. Consolidation can provide more cost-effective control of CSOs, minimizing the number of sites necessary for abatement facilities, and providing the institutional benefit of reducing the number of permitted outfalls. In waterfront areas where redevelopment is taking place and new public amenities are being created, elimination outfalls can remove an impediment to public use and enjoyment of the waterfront.

I.13 Storage: Instream Storage Technologies

The instream storage method involves using floating pontoons and flexible curtains to create an in-receiving water storage facility. CSO flows fill the facility by displacing the receiving water that normally occupies the storage facility. The CSO flows are then pumped to the collection system following a storm. The technology has been used for CSO control in Brooklyn, New York. This alternative involves permanently installing the floating pontoons in the receiving water near the CSO outlets. The feasibility of this technology, therefore, depends in part on whether the structure would be a hindrance to navigation. Other site-specific concerns include the availability of volume due to tidal variations in coastal waters and the need for protection from damage due to high winds or wave action.

I.14 Storage: In-Line Storage in Interceptor or Trunk Sewer

In-line storage is storage in series with the sewer (Urbonas and Stahre, 1993). In-line storage can be developed in two ways: (1) construction of new tanks or oversized conduits to provide storage capacity or (2) construction of a flow regulator to optimize storage capacity in existing conduits. The new tanks or oversized conduits are designed to allow dry weather flow to pass through, while flows above design peaks are restricted, causing the tank or oversized conduit to fill. A flow regulator on an existing conduit functions under the same principle, with the existing conduit providing the storage volume. Developing in-line storage in existing conduits is typically less costly than other, more capital-intensive technologies, such as offline storage/sedimentation, and is attractive because it provides the most effective utilization of existing facilities. The applicability of in-line storage, particularly the use of existing conduits for storage, is very site-specific, depending on existing conduit sizes and the risk of flooding due to an elevated hydraulic grade line. Examples of flow regulating technologies used to develop in-line storage were discussed previously.

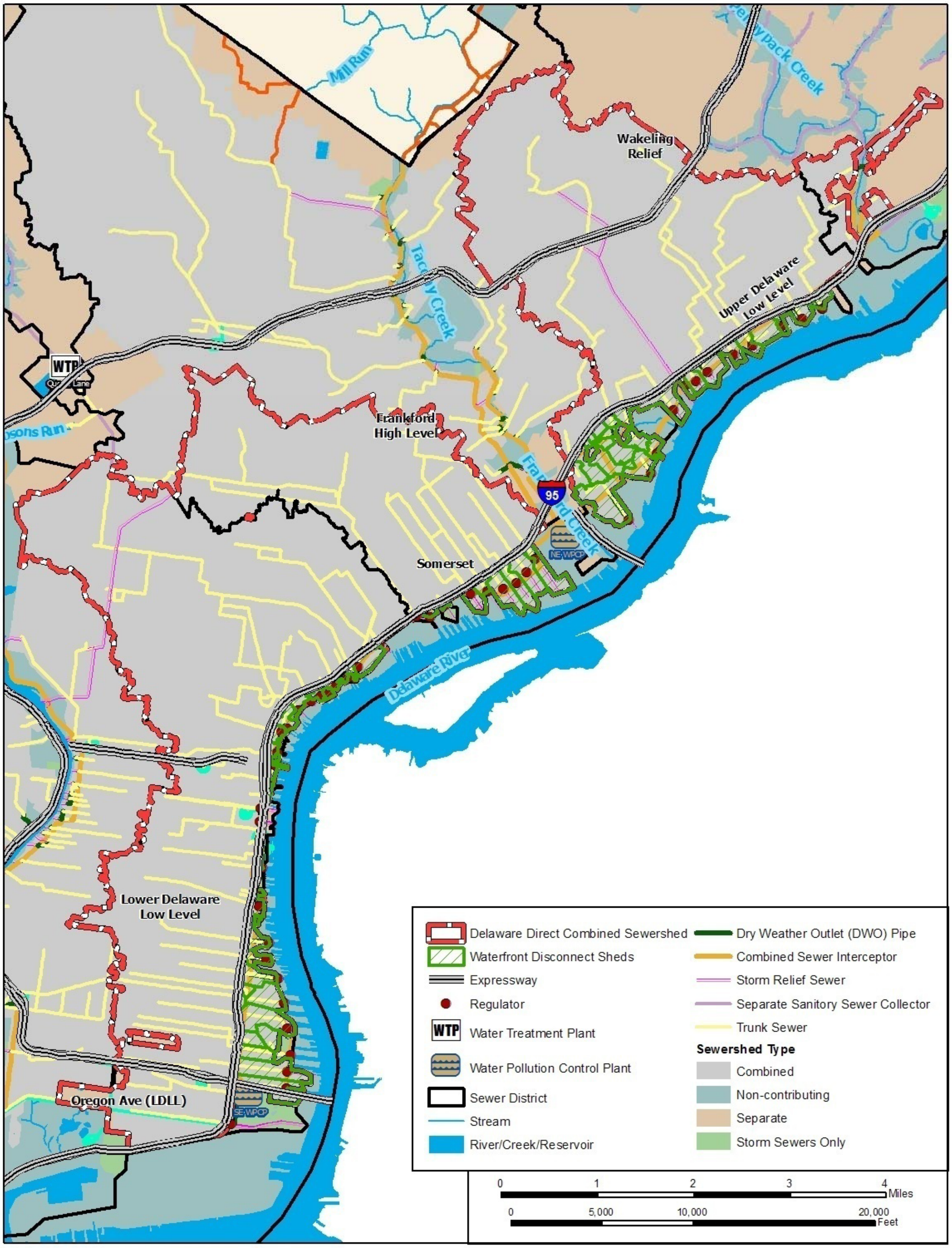


Figure 8-1 I-95 and Delaware Waterfront Combined-Sewered Areas

I.15 Storage: Earthen Basins

Generally, there are three types of earthen basins used in stormwater management design: Detention, Wet-Weather Retention and Infiltration. All basins are supplemented with some form of underdrain and emergency overflow structure to manage flow into the combined system. Detention basins are large areas of depression within a pervious location that remains dry except during wet-weather events. The detention basins capture wet-weather runoff during storm events and detain the runoff to attenuate peak flows into the combined system. Wet-weather retention basins always have a small pond of water and generally are vegetated. The retention pond allows for greater nutrient and solids removal than that of the detention basin. Infiltration basins are constructed with a more intricate underdrain system to facilitate nutrient and solids removal as well as infiltration and groundwater recharge of captured stormwater.

Earthen basins, as described above, may be implemented in a variety of sizes and locations to help meet stormwater management needs for large or small drainage areas. The flexibility of earthen basins allow for them to be used in conjunction with other stormwater management practices to reduce CSOs into receiving waters.

I.16 Storage: Offline Covered Storage Basins

Offline covered storage basins are concrete tanks that are connected in parallel to the combined sewer and receive flows only during wet weather periods. Covered basins are preferred over earthen basins or uncovered tanks because they provide better odor control and better safety conditions. Offline storage is more costly than online storage because parallel lines must be constructed and facilities for pumping the stored wastewater back to the sewer are usually required. However, offline storage is required where head loss in the downstream sewer is a concern and sedimentation or other treatment methods are desired.

Offline basins may be located at upstream or downstream locations in the combined sewer system. Advantages of upstream control include greater flexibility in selecting sites for facilities and more efficient control of flows to the downstream treatment facility. The primary advantage of downstream storage is that fewer facilities are required, resulting in lower construction and operation and maintenance costs. It may be possible to minimize costs further if storage capacity is available at the wastewater treatment plant.

I.17 Storage: Offline Open Storage Basins

Offline open storage basins are typically earthen. Offline storage is more costly than online storage because parallel lines must be constructed and facilities for pumping the stored wastewater back to the sewer are usually required. However, offline storage is required where head loss in the downstream sewer is a concern and sedimentation or other treatment methods are desired.

Offline RBs may be located at upstream or downstream locations in the combined sewer system. Advantages of upstream control include greater flexibility in selecting sites for facilities and more efficient control of flows to the downstream treatment facility. The primary advantage of downstream storage is that fewer facilities are required, resulting in lower construction and operation and maintenance costs. It may be possible to minimize costs further if storage capacity is available at the wastewater treatment plant.

I.18 Storage/Transmission: Deep Tunnels

Philadelphia has multiple outfalls and limited available space for near-surface facilities, making consolidation of outfalls on a regional basis using deep tunnels or other appropriate technologies a potentially cost effective storage and transmission approach. Depending on the geographic distribution of outfalls, subsurface geological conditions, and other factors, a deep tunnel alternative can include near-surface consolidation conduits or satellite near-surface storage/treatment facilities for remotely located outfalls. Alternatives involving deep tunnels should consider whether the tunnels will serve primarily as storage facilities to be pumped out to the WPCP at the end of a storm event or whether they will also serve to convey wet weather flows to the WPCP for treatment during a storm event.

I.19 Storage/Transmission: Real Time Control

PWD has been evaluating and implementing computer controlled CSO outfall/regulator gate facilities that use level monitors to control the position of the dry-weather outlet (DWO) gate and tide gate at each location for maximizing the utilization of in-system storage in the combined sewer system. These computer controlled outfall facilities apply real-time control (RTC) mechanisms to maximize in-system storage. The use of RTC allows the capture and delivery to the treatment works of flow at the maximum rate at which it can be treated. This approach is attractive in terms of optimizing the use of the existing sewer system to capture combined wastewater and minimize CSOs.

I.20 Transmission: Parallel Interceptors

Parallel interceptors provide increased transmission capacity to bring flows to a WPCP.

I.21 Transmission: Remove Flow Bottlenecks

PWD's collection system includes some localized instances where infrastructure does not have the capacity to convey the full flow from upstream. Examples include siphons and pipes of smaller diameter than upstream pipes. In these cases, localized replacement may be a cost-effective way to increase transmission capacity to the WPCP.

I.22 Transmission: Diversion of Trunk Flow Directly to WPCP

For a limited number of small sewersheds close to the WPCP, it may be possible to divert all trunk flow to the WPCP without regulation.

I.23 Treatment at Discharge Point: Swirl Concentrators

Swirl concentrators provide flow regulation and solids separation by inducing a swirling motion within a vessel. Solids are concentrated and removed through an underdrain, while clarified effluent passes over a weir at the top of the vessel. Types of swirl devices include the EPA swirl concentrator. Conceptually, the EPA swirl concentrator is designed to act as an in-line regulator device. In addition to flow routing or diversion, it removes heavy solids and floatables from the overflow. Each type of swirl unit has a different configuration of depth/diameter ratio, baffles, pipe arrangements, and other details designed to maximize performance.

I.24 Treatment at Discharge Point: Vortex Separators

The commercial vortex separators are based on the same general concept as the EPA swirl concentrator but include a number of design modifications intended to improve solids separation. The commercial designs have been applied as offline treatment units. Vortex separators placed at discharge points are intended for inorganic solids separation and removal prior to discharging. Separation is facilitated by a swirling motion similar to a centrifuge and the solids are settled out at the bottom of the unit. Vortex Separators are available for both in-line and offline treatment, are available in varying sizes and designs, which are based on the peak flow design event and on-site configuration requirements.

I.25 Treatment at Discharge Point: Disinfection

This process destroys or inactivates microorganisms in overflows, most commonly through contact with forms of chlorine. Various disinfection technologies are available both with and without chlorine compounds. Some of the more common technologies include gaseous chlorine, liquid sodium hypochlorite, chlorine dioxide, ultraviolet radiation, and ozone. For disinfection of CSOs, liquid sodium hypochlorite is the most common of the above technologies.

Dechlorination: A major disadvantage of chlorine-based disinfection systems is that the residual chlorine concentration can have a toxic effect on the receiving waters, due either to the free chlorine residual itself or to the reaction of the chlorine with organic compounds present in the effluent. With the relatively short contact times available at many CSO control facilities, disinfection residuals can be of particular concern and can require consideration of dechlorination alternatives. Two of the more common means for dechlorinating treated effluent are application of gaseous sulfur dioxide or liquid sodium bisulfite solution.

I.26 Treatment at Discharge Point: High Rate Treatment

High Rate Clarification

High rate clarification (HRC) processes have surface overflow rates greater than 20 gallons per minute per square foot (gpm/ft^2). Both the DensaDeg® and Actiflo® processes utilize ballasted flocculation to achieve these overflow rates.

DensaDeg® Ballasted Flocculation

The DensaDeg® process is a ballasted flocculation process that recirculates settled sludge as the ballast to achieve excellent TSS removal at a standard design surface overflow rate of 40 gpm/ft2 for wet-weather flow. The process consists of a rapid mix zone, reactor zone, and a clarifier/thickening zone. Wastewater enters the rapid mix zone along with a coagulant where flash mixing occurs. Polymer is added as a flocculating agent as the wastewater flows to the reactor zone, which is equipped with an axial flow impeller/ draft tube arrangement.

The water and flocculated sludge enter the clarification zone where most of the solids settle. The clarifier contains a lamella settling zone where most of the remaining solids are removed. The settled sludge is thickened, and part of the thickened sludge is recirculated back to the reactor zone to serve as a ballasting agent and nucleus for floc growth for improved settleability. The remaining sludge is wasted. The process is well suited for enhanced primary treatment of wet-weather flows in combined sewer systems. Suspended solids removal in excess of 90% of influent concentrations can be achieved consistently, and COD and BOD removal are often better than 60% depending on influent characteristics. Optimal treatment is typically achieved approximately 30 to 45 minutes after start-up. The start-up time is necessary to build up adequate sludge.

Advantages: The DensaDeg® process provides high removal efficiencies and is stable at variable influent flows and loads.

Disadvantages: Pilot testing is recommended for design optimization.

Actiflo® Ballasted Flocculation

The Actiflo® process is a ballasted flocculation process that utilizes microsand as the ballast to achieve excellent TSS removal at a standard design surface overflow rate of 60 gpm/ft^2 for wet-weather flow. The process consists of a coagulation zone, injection zone, maturation zone, and clarification zone. Wastewater enters the coagulation chamber along with a coagulant for flash mixing. Wastewater then flows to the injection tank where microsand and polymer are added. Microsand interacts with the destabilized particles and the polymer. The maturation tank is a gentle mixing zone that allows the formation of floc. The polymer promotes the formation of strong flocs around the microsand. The water and floc then flow to the clarification zone where the flocculated solids settle. Most of the solids settle at the bottom of this compartment. Lamella plate or tube settlers may be used to enhance removal of suspended solids. Solids that accumulate at the bottom of the clarification compartment are recycled to a hydrocyclone, where the lower density sludge is separated from the higher density microsand. The microsand is recycled to the injection tank, and the sludge leaves the system.

Advantages: The Actiflo® process provides high removal efficiencies and is stable at variable influent flows and loads.

Disadvantages: Actiflo® requires a 5 to 15 minute startup time since startup flows must be stored and fed back through unit or to the conventional treatment headworks. A minimum 4:1 turndown ratio (minimum flow through unit is 25% of capacity) is available for lower flows.

Biologically Enhanced High Rate Clarification (Bio HRC)

Biologically and chemically enhanced clarification (Bio CEC) incorporates a short duration biological contact tank upstream of chemically enhanced clarification (CEC) to achieve rapid uptake of soluble organic matter that would not be removed by only CEC. In this process, activated sludge from a plant's secondary process (RAS or WAS) is routed to a short-duration (5-10 minutes) contact basin where it blends with excess wet weather flows to achieve rapid uptake of soluble organic matter into the biomass. This mixture of biomass and influent wastewater is then treated through CEPT or HRC. The resulting CEPT or HRC sludge may be returned to the aeration basins or wasted. The nonproprietary technology is Bio CEPT, and the current proprietary technology is BioActiflo®.

Advantages: Soluble BOD uptake, Bioadsorption of colloidal and particulate matter, Potential reduction of CEPT and HRC chemical requirements, Lower foaming potential and Higher UV Transmittance.

Disadvantages: It is a relatively new process thus is relatively unproven at full-scale and little operational information is available.

Retention Treatment Basins (RTBs)

Retention treatment basins (RTBs) are satellite high rate treatment facilities designed to provide screening, settling, skimming (with a fixed baffle) and disinfection of combined sewer flows before discharge to a receiving water. Since RTBs are empty between wet-weather events, they also provide storage, which can completely capture combined sewer flows from small wet weather events for later dewatering and conveyance to the WPCP for treatment. RTBs can be designed with a variety of screen types, disinfection methods and basin geometries. The surface loading rates can also vary but are typically higher than rates used for design of primary clarifiers. RTBs can be constructed above or below grade but typically require at least an above grade process/control building. If pumping of the combined sewer flow is required, the pump station may be integral to the RTB facility or constructed as a separate structure.

Advantages: Relatively simple to operate and maintain.

Disadvantages: Large footprint of the structure occupies waterfront land that could otherwise provide public amenities.

I.27 Treatment at Discharge Point: Screens

Screens and trash racks consist of a series of vertical and horizontal bars or wires that trap floatables while allowing water to pass through the openings between the bars or wires. Screens can be installed at select points within a CSS to capture floatables and prevent their discharge in CSOs. Screens used for CSO control include mechanically cleaned permanent screens, static screens, traveling screens, or drum screens. Screens can also be divided into three categories according to the size of floatable material they are designed to capture. These are:

- Bar screens (> 2.5 centimeter [1 inch] openings)
- Coarse screens (0.5 - 2.5 centimeter [0.19 - 1 inch] openings)
- Fine screens (0.01 - 0.5 centimeter [0.004 - 0.19 inch] openings)

The screens most commonly used to control CSOs are trash racks (a type of bar screen primarily used as an end-of-pipe control) and coarse screens.

I.28 Treatment at Discharge Point: Netting

Two types of netting systems can be used to collect floatables in a CSS: in-line netting, and floating units. In-line netting can be installed at strategic locations throughout the CSS. The nets would be installed in underground concrete vaults containing one or more nylon mesh bags and a metal frame and guide system to support the nets. The mesh netting is sized according to the volume and types of floatables targeted for capture. The CSO flow carries the floatables into the nets for capture. Bags are replaced after every storm event. Floating units consist of an in-water containment area that funnels CSO flow through a series of large nylon mesh nets. Mesh size depends on the volume and type of floatables expected at the site. This system is passive and relies on the energy of the overflow to carry the floatables to the nets. However, nets must be located some distance from the outfall (often 15 meters [50 feet] or more) to allow floatables entrained in the turbulent CSO flow to rise to the flow surface and be captured. The nets are single use, and after an overflow, the nets are typically removed and taken to a disposal area.

I.29 Treatment at Discharge Point: Booms

Booms are containment systems that use specially fabricated floatation structures with suspended curtains designed to capture buoyant materials. Booms can also be designed to absorb oils and grease. They are typically anchored to a shoreline structure and the bottom, and they can be located downstream of one or more outfalls. Booms are sized based upon the expected volume of floatables released during a design-storm event. After a storm event, material captured in the boom can be removed manually, or with a vacuum truck or a skimmer vessel.

I.30 Treatment at Discharge Point: Baffles

Baffles are simple floatables control devices that are typically installed at flow regulators within the CSS. They consist of vertical steel plates or concrete beams that extend from the top of the sewer to just below the top of the regulating weir. During an overflow event, floatables are retained by the baffles while water passes under the baffles, over the regulator, and into the receiving water body. When the flow recedes below the bottom of the baffle, floatable material is carried downstream to the wastewater treatment plant.

I.31 Treatment in Receiving Water: Debris Skimming Vessels

Skimmer vessels are a very visible floatables control method that are easy for the general public to understand and support. Skimmer vessels are typically used to clean broad areas of open water. As a result, the floatable debris and litter collected comes from a variety of sources including CSOs, separate stormwater systems, and upstream sources. Financial assistance from sources other than the owner and operator of the CSS may be warranted.

I.32 Treatment at Existing WPCP: Expand Primary Treatment Capacity

Expansion of the primary treatment capacity of the WPCPs in all districts must take into account the average daily flow, the peak instantaneous flow and the maximum daily average flow that could potentially be delivered to each plant. Using this information the feasibility of expanding the plant to apply primary treatment to all flow being delivered must be evaluated with regard to spatial limitations of the plant expansion footprint, costing and a list of design options.

I.33 Treatment at Existing WPCP: Expand Secondary Treatment and Disinfection Capacity

Secondary treatment essentially has the primary effluent bypass primary treatment and either receives treatment at the existing secondary treatment structure (*e.g.* the chlorine contact basin) or at a new secondary treatment structure downstream of the existing chlorine contact unit. The bypass flowrate value, necessary WPCP improvements and cost considerations are assessed when evaluating this option.

I.34 Treatment at Existing WPCP: Flow equalization

Flow equalization within WPCPs is a technique in which the velocity of water to be treated is reduced and stabilized as it moves through each treatment process in the plant. The reduced velocity allows for maximum settling of floatables and reduces the adverse effects produced from high velocity inflow surges that could disrupt the efficiency of the wastewater treatment processes, such as thorough chemical mixing and settling processes.

I.35 Treatment at Existing WPCP: Expansion of Wet Weather Treatment Capacity

Expansion of the WPCP to increase Wet Weather treatment capacity requires defining a target treatment capacity for each district's WPCP. This target is determined from analyzing the maximum flow that may be delivered by the contributing collection of interceptor systems to that plant. Using this target value, a list of improvements necessary for the WPCP to meet the target is required. Finally, a conceptual design, cost estimate and construction timeline needs to be generated for each item in the list of improvements. For this LTCPU plant expansion was analyzed for each district and a number of different treatment capacity scenarios.

Stress testing was conducted for all three WPCPs and reports were completed in 2001; reports are available in Supplemental Documentation Volumes 6, 7 and 8 (Stress Testing of the Northeast WPCP, Stress Testing of the Southeast WPCP and Stress Testing of the Southwest WPCP). The following section briefly describes the above studies for each of the WPCPs.

Northeast Wastewater Treatment Plant Stress Testing Summary and Capital Improvement Options

The Northeast WPCP (NEWPCP) is located at Wheatsheaf Lane and Richmond Street in Philadelphia and is permitted to treat an average daily flow of 210 mgd, a maximum daily average flow of 350 mgd, and an instantaneous peak flow of 420 mgd. Since 2001, PWD has been actively planning and evaluating options to increase the capacity of the NEWPCP to treat wet-weather flows.

A hydraulic model of the NEWPCP was used to evaluate the feasibility of conveying additional wastewater through the primary treatment process during high-flow events. A SWMM model of the collection system was used to determine the maximum conveyance capacity of the FHL sewer. This maximum flow rate was carried forward to establish the maximum flow rate for analysis in the plant hydraulic model. This analysis showed that rehabilitation of the FHL sewer between the NEWPCP pre-treatment building (PTB) and an upstream point at regulator R18 would increase the potential flow delivery to NEWPCP through the FHL from 80 mgd to 205 mgd. This maximum FHL flow rate was used as the basis of all further hydraulic and process analysis resulting in a total target plant flow of 545 mgd.

A process design model (Pro2D) was used to evaluate predicted plant performance and determine maximum allowable flows without exceeding permit limits. The process model assumed a peak wet-weather flow rate of 435 mgd through secondary treatment. Flow greater than 435 mgd would receive only primary treatment and disinfection.

Maximizing flow to the WPCP is intended to ensure that optimum use is made of existing plant capacity. The National CSO Control Policy states that ". . . the long-term control plan should also consider expansion of WPCP secondary and primary capacity in the CSO abatement alternative analysis " (II.C.4). In some cases, it might be more cost-effective to expand existing WPCP facilities than to site separate facilities for CSO control. The National CSO Control Policy addresses the specific case where existing primary treatment capacity at a WPCP exceeds secondary treatment capacity and it is not possible to utilize the full primary treatment capacity without overloading the secondary facilities. For such cases, the National CSO Control Policy states that at the request of the municipality, EPA may allow an NPDES permit ". . . to authorize a CSO-related bypass of the secondary treatment portion of the WPCP for combined sewer flows in certain identified circumstances " (II.C.7). Under this provision, flows to the WPCP within the capacity of primary treatment facilities but in excess of the capacity of secondary treatment facilities may be diverted around the secondary facilities, provided that "... all wet weather flows passing the headworks of the WPCP will receive at least primary clarification and solids and floatables removal and disposal, and disinfection, where necessary, and any other treatment that can reasonably be provided" (II.C.7). In addition, the CSO-related bypass should not cause exceedance of WQS.

The results of the process model analysis recommend the wet-weather capacity upgrades be limited to a maximum of 550 mgd based on predicted process performance versus effluent limits. This demonstrates the ability of the plant process to handle the projected flow of 545 mgd and meet permitted effluent limits within the existing treatment process footprint.

Conceptual designs were developed for 11 capital improvement options (Table 8-2), each providing increased treatment or hydraulic capacity to achieve the 545 mgd target flow rate. Different combinations of the improvement options can be implemented to reach, first, the peak flow through secondary treatment (435 mgd) and, second, the peak flow through primary treatment (545 mgd), as described below.

Table 8-2 Improvement Options Summary

Improvement Number	Improvement Description
1	Frankford Grit Chamber Bypass Replacement
2	Frankford High Level Second Barrel Rehabilitation
3	New Conduit from Div B to Pre-Treatment Building (PTB)
4A	Additional Pretreatment at Northeast Side of PTB with Detritor grit removal technology -
4B	Additional Pretreatment at Southeast Side of PTB with Detritor grit removal technology
5	New Conduit from PTB to Set-1 PSTs
6A	New Conduit from PTB to Set-2 PSTs in Conjunction with 4A
6B	New Conduit from PTB to Set-2 PSTs in Conjunction with 4B
7	Reactivate Bypass Conduit from Div B to Set-2 PSTs with New Bar Screen and Grit Removal
8	New Influent Baffles in Set-2 PSTs
9	Remove Double Deck Effluent Channel in FST Set-2
10A	New Bypass Conduit from Set-1 PSTs to Plant Outfall with Disinfection Upstream of CCC
10B	New Bypass Conduit from Set-1 PSTs to Plant Outfall with Disinfection Downstream of CCC
11	High-Rate Treatment System

To achieve 435 MGD:

- Remove double-decker effluent channel in Set 2 Final Sedimentation Tanks (FSTs) (Improvement 9)
- Install new conduit between Preliminary Treatment Building (PTB) and one set of Primary Sedimentation Tanks (PSTs) - either Set 1 or Set 2 (Improvement 5 or 6A or B)

To achieve 545 MGD:

- Replace Frankford Grit Chamber Bypass (Improvement 1)
- Rehabilitate second barrel of the Frankford High Level Sewer (Improvement 2)
- Install new conduit between Diversion Chamber B and PTB area (Improvement 3)
- Install bypass from Primary Treatment to the Chlorine Contact Chamber (Improvement 10A or B

Either:

- Build High Rate Treatment facility (Improvement 11)

Or:

- Implement improvements within existing plant that could include a combination of the following:
  - Install new influent baffles in Set 2 PSTs (Improvement 8)
  - Reactivate bypass from Diversion Chamber B to Set 2 PSTs and build new preliminary treatment system for diverted flow (Improvement 7)
  - Expand PTB capacity by adding new bar screen and grit chamber (Improvement 4A or B)
  - Install new conduit between PTB and the other set of PSTs (Improvement 5 or 6A or B)

More details may be found in Supplemental Documentation Volumes 6 and 9.

In order to achieve a peak plant flow rate of 545 mgd, 110 mgd of the flow must be bypassed around secondary treatment, disinfected, and discharged to the plant outfall. This could be achieved by bypassing a portion of the primary effluent either to the existing Chlorine Contact Chamber or through a new additional Chlorine Contact Unit to points downstream of the existing Chlorine Contact Chamber.

Southeast Wastewater Treatment Stress Testing Summary

In order to increase the flow capacity of the SE WPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. According to stress testing results, the SE WPCP currently has a flow capacity of 240 mgd (Supplemental Documentation Volume 7 :Stress Testing of the Southeast WPCP.). With several process and hydraulic modifications, the SEWPCP's flow capacity can potentially reach 330 mgd (Table 8-3). The necessary improvements to achieve this flow were identified in the Stress Testing Report and are based on results of stress tests on unit processes, long-term monitoring of the plant, hydraulic modeling, and input from SEWPCP plant staff.

Table 8-3 Improvement Options Summary

Improvement Number	Improvement Description
1	Provide facilities for phosphorous addition to wastewater
2,3	Resolve capacity limitations associated with having one coarse bar rack out of service and hydraulic bottleneck at existing influent pump station
4	Replace existing primary clarifier effluent launders with new launders running parallel to flow to increase hydraulic capacity
5	Provide two gravity thickeners to perform offline sludge thickening and improve performance of the primary clarifiers
6	Provide an additional 71-MGD effluent pump at the effluent pumping station
8	Resolve hydraulic limitation between primary clarifiers and the aeration basins by adding pumps to pass greater flow and increase available head.

The current configuration of the influent wet wells limits the plant flow to 200 mgd when one coarse screen is out of service. To provide redundancy, Improvements 2 and 3 include the addition of two new bar screens and influent pumps with a capacity of 130 mgd. Due to the configuration and space limitations of the existing influent pump station, a new pump station will be needed for this new equipment. Since any new wet weather treatment facility will also require influent screening and pumping, a single building can be constructed to house all the new equipment. This new preliminary treatment building (PTB) will include the two new bar screens and influent pumps for the existing plant, as well as the additional units needed for the wet weather treatment train alternatives. A new conduit will be constructed from the new PTB to the head of the existing grit channels, carrying up to 130 mgd to the existing plant for treatment during either dry or wet weather conditions.

To increase the capacity of the existing primary clarifiers, Improvement 5 provides for the addition of offline sludge thickening. Currently, primary sludge is thickened in the clarifiers. The thickened sludge is pumped from the clarifiers to sludge storage tanks, which store the sludge until it is pumped to the Southwest WPCP for further treatment. The addition of separate gravity thickeners on site will eliminate the need to carry a sludge blanket in the primary clarifiers. This will eliminate scour of the solids from the sludge blanket during high surface overflow rates, allowing the clarifiers to maintain removal efficiencies during peak flows. The sizing of these gravity thickeners is based on a 55 percent removal efficiency in the existing clarifiers, a 0.5 percent solids concentration, and a solids loading rate of 30.7 $lb/ft^2/day$ for the thickeners. These assumptions are consistent with those for the wet weather treatment trains. Since the majority of the proposed wet weather treatment trains require gravity thickening also, all gravity thickeners for both the existing plant and the wet weather treatment facility will be located in the same area on site.

Southwest Wastewater Treatment Plant Stress Testing Summary

In order to increase the flow capacity of the SWWPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. From 2004 to 2007, the SWWPCP treated an average daily flow of 193 mgd, a maximum daily flow of 432 mgd, and an instantaneous peak flow of 489 mgd. The maximum plant flow sustained over 12 hours was 466 mgd. According to stress testing results and recommendations, the SWWPCP's flow capacity can potentially reach 540 mgd with several process and hydraulic modifications (Table 8-4). The necessary improvements to achieve this flow were identified in the 2001 Stress Testing Report and are based on results of stress tests on unit processes, long-term monitoring of the plant, hydraulic modeling, and input from SWWPCP plant staff . The improvements should lead to increasing the plant's capacity to a minimum of 540 mgd (Supplemental Documentation Volume 8: Stress Testing of the Southwest WPCP.).

Table 8-4 Improvement Options Summary

Improvement Number	Improvement Description
1	Replace caulking on secondary clarifier launders to improve flow distribution[1]
2	Provide preliminary treatment for the BRC centrate that is recycled to the plant
3	Modify existing RAS system in the secondary clarifiers
4	Provide four gravity thickeners for thickening of primary sludge (tentative location west of the Final Sedimentation Tanks)
5	Resolve hydraulic limitations between primary clarifiers and aeration basin
6	Provide an additional effluent pump at the effluent pumping station

[1]Represents a re-occurring continued maintenance procedure on launders to keep performance efficient

Wet Weather Treatment Alternatives

PWD also conducted a set of studies for each of the three WPCPs to study the cost effectiveness of further wet weather treatment expansion at the WPCPs and a report was generated in 2009. These reports can be found in Volumes 9, 10 and 11 (Analysis of Wet Weather Treatment Alternatives for Northeast WPCP, Analysis of Wet Weather Treatment Alternatives for Southeast WPCP and Analysis of Wet Weather Treatment Alternatives for Southwest WPCP). The following section briefly describes the above studies for each of the WPCPs.

Studies of various conceptual designs and corresponding costs for Wet Weather Treatment Alternatives have been developed. These studies were performed for all the three plants. The following sections provide a brief summary of the plant expansion analyses that were performed.

Northeast Wet Weather Treatment Alternatives

The wet weather treatment technologies for the SWWPCP evaluated are as follows:

1. Vortex Swirl Concentrators
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 69 million gallons per day (mgd) to 1100 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative. Currently, the NEWPCP has a flow capacity of 435 mgd. With several process and hydraulic modifications, as identified in the 2001 Stress Testing Report and the NEWPCP Flow Study, the capacity of the existing plant can potentially reach 650 mgd (Volumes 6 and 9 : Stress Testing of the Northeast WPCP and Analysis of Wet Weather Treatment Alternatives for Northeast WPCP). This work includes the construction of a 250-mgd secondary bypass from the existing primary sedimentation tanks to the chlorine contact chamber.

In sizing the wet weather treatment trains, it was assumed that these upgrades, costing $147 Million, will have been completed, increasing the plant's capacity to a minimum of 650 mgd. Any wet weather flow in excess of 650 mgd would be diverted to the new wet weather facility. To expand the flow capacity of NEWPCP beyond 650 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 650 mgd will be diverted to one of the new treatment trains, listed above, eventually blending with effluent from both the secondary system and the bypass from the existing plant. Conceptual designs and cost estimates were performed for each treatment train at various design flows.

Conceptual designs and cost estimates were developed at several design flows for each wet weather treatment train under evaluation (Table 8-5). These flows were selected based on the ability to meet permit requirements, the land area available onsite, and the maximum expected flow from the upgraded collection system. The Vortex/Swirl and Conventional Clarification trains were both flow-limited by permit requirements.

Table 8-5 Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1 - Vortex/Swirl Concentrators	69, 183
#2 - Conventional Clarifiers	160, 376
#3 - CEPT w/ Conventional Clarifiers	150, 300, 1000
#4 - Ballasted Flocculation	150, 500, 1100

While each flow scenario for each treatment train evaluated is sized to produce blended effluent concentrations compliant with permit limits, the resulting water quality differs widely between different scenarios. The TSS and BOD concentrations of the blended effluent for each treatment train and flow scenario is presented under Tables 8-6 and 8-7. In general, ballasted flocculation achieves the lowest TSS and BOD concentrations after treatment and can operate an unlimited number of times during the month while allowing the NEWPCP to continue to meet permit limits.

Table 8-6 TSS Concentrations for each Treatment Train and Flow Value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent TSS Concentration (mg/L)								
		Wet Weather Treatment Train Flow (mgd)								
		69	***150***	***160***	***183****	***300***	***376****	***500***	***1000***	***1100***
#1) Vortex/Swirl Concentrators	221	83			87					
#2) Conventional Clarifiers	142			83			82			
#3) CEPT w/ Conventional Clarifiers	63		67			66			65	
#4) Ballasted Flocculation	30		61					51		44

Notes: Based on the 95th percentile wet weather TSS concentration of 68 mg/L and a maximum of 650 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 99 mg/L to meet monthly TSS permit limits.

The Vortex-183 mgd and CEPT-376 mgd flow scenarios are only allowable assuming no secondary bypass at the plant. Thus, these concentrations assume a 95th percentile wet weather TSS concentration of 31 mg/L and a maximum of 435 MGD through the existing plant.

Table 8-7 BOD Concentrations for each Treatment Train and Flow Value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent cBOD Concentration (mg/L)								
		Wet Weather Treatment Train Flow (mgd)								
		69	***150***	***160***	***183****	***300***	***376****	***500***	***1000***	***1100***
#1) Vortex/Swirl Concentrators	117	37			49					
#2) Conventional Clarifiers	91			41			53			
#3) CEPT w/ Conventional Clarifiers	66		36			41			51	
#4) Ballasted Flocculation	55		34					40		45

Notes: Based on the 95th percentile wet weather cBOD concentration of 29 mg/L and a maximum of 650 MGD through the existing plant.

*The Vortex-183 mgd and CEPT-376 mgd flow scenarios are only allowable assuming no secondary bypass at the plant. Thus, these concentrations assume a 95th percentile wet weather cBOD concentration of 20 mg/L and a maximum of 435 MGD through the existing plant.

As shown in Figure 8-2, the capital costs for Trains #2 through#4 track each other very closely, with CEPT being slightly more expensive. Train #1, the vortex/swirl, appears least expensive and most cost effective as flows increase. Train #3, CEPT, appears slightly less cost effective than Train #4, Ballasted Flocculation, due to greater cost for piles due to its larger footprint (Figure 8-3).

The comparison of O&M costs for each treatment train is shown in Figure 8-4. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to the use of chemicals and the complexity of its system.

Taking construction, non-construction, and O&M costs into consideration, Figure 8-5 shows the present value of the total cost of each wet weather treatment train. This graph suggests that there is negligible cost difference between Train #3, CEPT, and Train #4, Ballasted Flocculation at this plant. As expected, Trains #1 and #2 are least expensive due to its low chemical usage and minimal O&M costs.

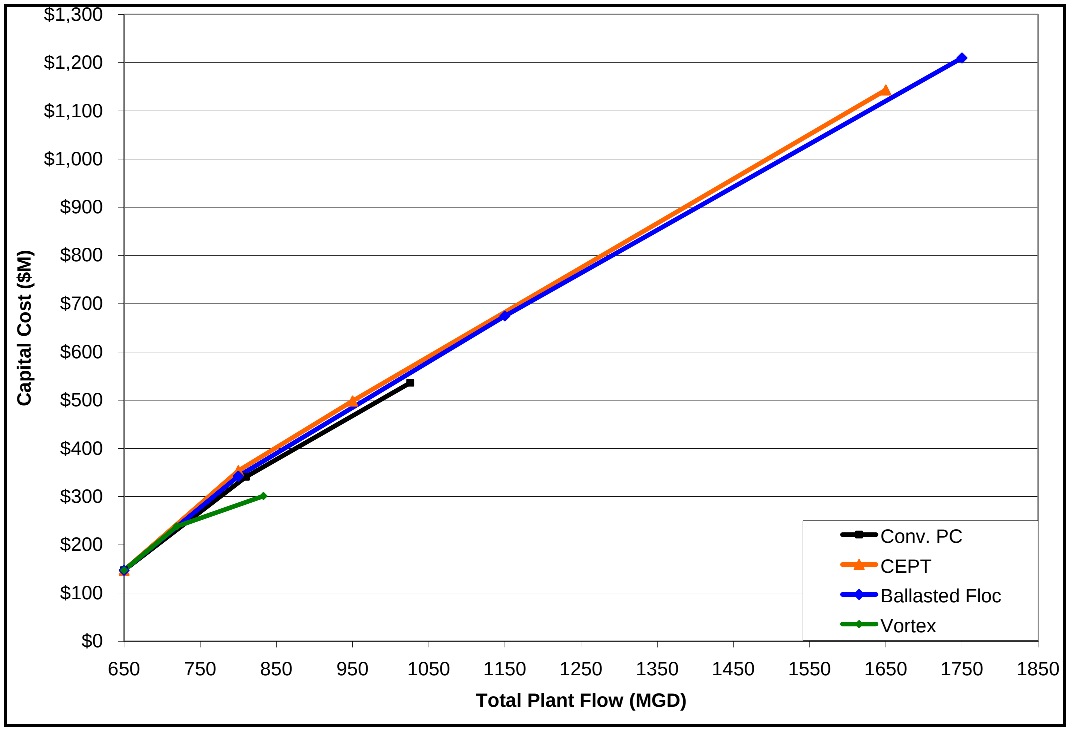


Figure 8-2 Comparison of Capital Costs for All Treatment Trains

Note: Capital cost presented includes cost of improvements recommended in the Stress Testing Report ($147 M). Total plant flow includes flow from both the conventional plant and the wet weather treatment facility.

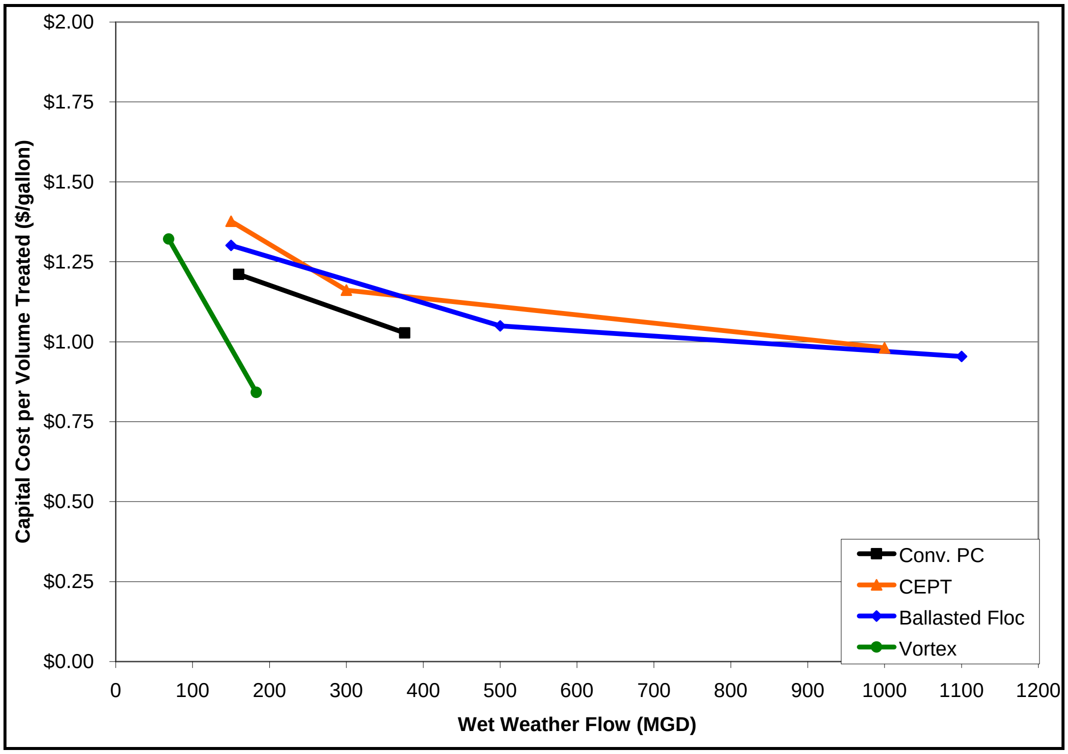


Figure 8-3 Comparison of Cost Effectiveness for All Treatment Trains

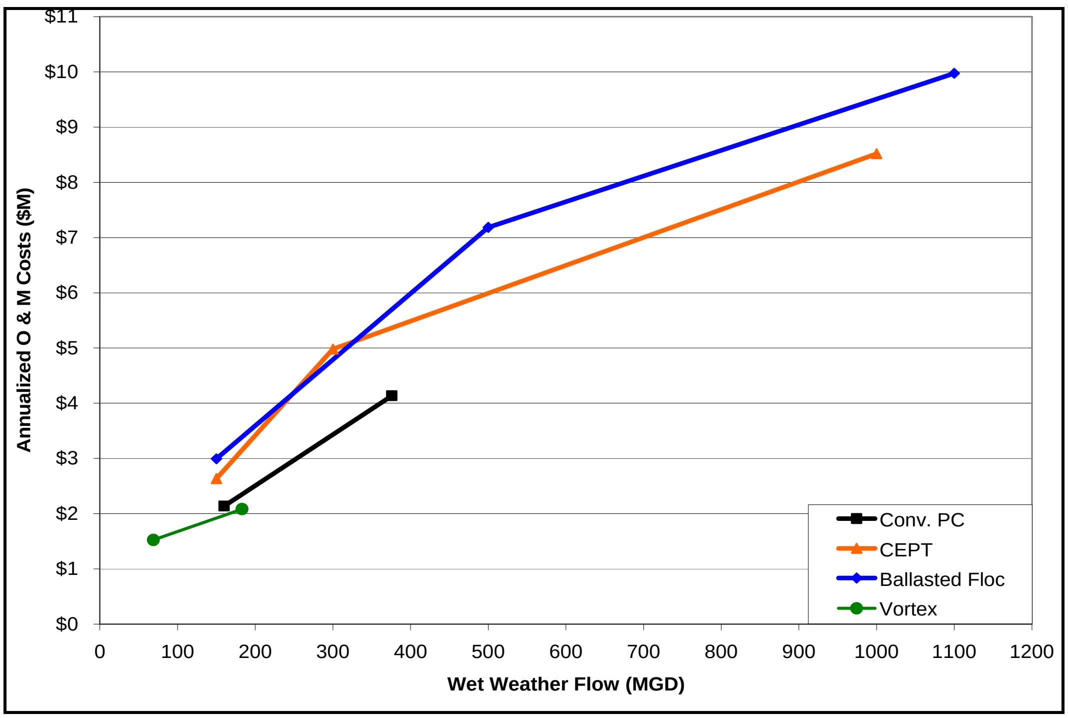


Figure 8-4 Comparison of Operations and Maintenance Costs for All Treatment Trains

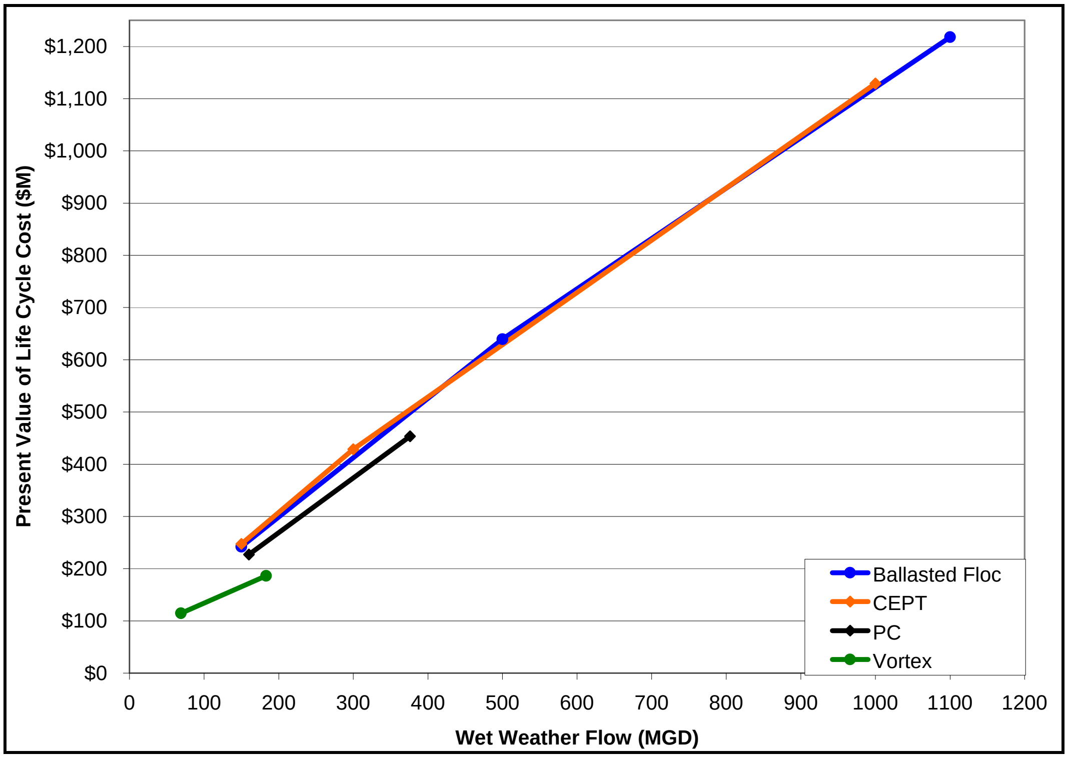


Figure 8-5 Comparison of Life-Cycle Costs for All Treatment Trains

Aside from capital, O&M, and lifecycle costs, there are numerous other criteria by which the treatment trains should be evaluated, including system reliability, community impacts, the ability to handle large variations in flow, land requirements, constructability, requirements for maintenance and operator attention, and sustainability. The main advantages and disadvantages for Treatment Trains #1 through#4, as evaluated are described in Table 8-8.

Table 8-8 Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #1:Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements no moving parts	• Maximum design flow may decrease if the assumed number of operating days per month is greater than 7. • Only cost competitive at high loading rates and low removal efficiencies.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • Maximum design flow may decrease if the assumed number of operating days is greater than 7.

Treatment Train	Pros	Cons
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Maximum design flow may decrease if assumed number of operating days is greater than 9. • Uses two additional chemical systems for coagulation and flocculation
Train #4: Ballasted Flocculation	• Can treat up to 1500 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

The costs for wet weather treatment at the NEWPCP should be analyzed with the costs of other wet weather treatment alternatives, such as improvements in the collection system, to determine which treatment train alternatives and flow regimes should be evaluated further. Treatment trains that are selected for further evaluation should undergo more detailed design and costing methods, water quality sampling, and bench and pilot scale testing, so that removal efficiencies, land requirements, capital costs, and O&M costs can be further refined.

Southeast Wet Weather Treatment Alternatives

The wet weather treatment technologies for the SEWPCP evaluated are as follows

1. Vortex Swirl Concentrators (at low and high loading rates)
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. CEPT with Plate Settlers (includes fine screening)
5. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 80 million gallons per day (mgd) to 1200 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative. In order to increase the flow capacity of the SEWPCP for wet weather conditions, the potential of maximizing flow through the existing plant was evaluated. According to stress testing results, the SEWPCP currently has a firm capacity of 240 mgd (Supplemental Documentation Volume 6: Stress Testing of the Southeast WPCP). With several process and hydraulic modifications, the SEWPCP's firm capacity can potentially reach 330 mgd. The necessary improvements to achieve this flow were identified in the Stress Testing Report and are based on results of stress tests on unit processes, long-term monitoring of the plant, hydraulic modeling, and input from SEWPCP plant staff. In sizing the wet weather treatment trains, it was assumed that the upgrades proposed in the Stress Testing Report will have been completed, increasing the plant's capacity to a minimum of 330 mgd. Thus, the baseline cost that is used in the wet weather treatment train cost estimates is $48.1 Million, which is reflected in the cost curves for each treatment train.

To expand the flow capacity of SEWPCP beyond 330 mgd for the treatment of wet weather flows, a separate wet weather treatment train will be required. Wet weather flows in excess of 330 mgd will be diverted to one of the new treatment trains, listed above, eventually blending with effluent from the existing plant. Conceptual designs and cost estimates were performed for each treatment train at various design flows.

The maximum allowable flow through each wet weather treatment train is a function of its removal efficiency, the achievable effluent concentration after blending, and the plant's continued ability to meet NPDES permit limits for weekly and monthly TSS and BOD concentrations. With the exception of the vortex/swirl train at high loading rates, the flows through the candidate wet weather treatment trains were not limited by permit requirements, assuming that the wet weather treatment facility operates for no more than seven days per month. Other design flow points were selected based on the existing collection system capacity, the existing outfall conduit capacity, and limits of available land on site and are indicated in the Table 8-9.

Table 8-9 Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1 - Vortex/Swirl Concentrators	
High Loading Rate:	80, 200, 380
Low Loading Rate:	80, 200, 900
#2 - Conventional Clarifiers	80, 200, 540, 900
#3 - CEPT w/ Conventional Clarifiers	80, 200, 470, 900
#4 - CEPT w/ Plate Settlers	80, 200, 900
#5 - Ballasted Flocculation	80, 200, 900, 1200

While each flow scenario for each treatment train evaluated is sized to produce blended effluent concentrations compliant with permit limits, the resulting water quality differs widely between different scenarios. In general, ballasted flocculation achieves the lowest TSS and BOD concentrations after treatment and can operate an unlimited number of times during the month and continue to meet permit limits.

The TSS and BOD concentrations of the blended effluent for each treatment train and flow scenario is shown in Tables 8-10 and 8-11.

Table 8-10 TSS concentrations for each treatment train and flow value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent TSS Concentration (mg/L)						
		Wet Weather Treatment Train Flow (mgd)						
		80	***200***	***380***	***470***	***540***	***900***	***1200***
#1) Vortex/Swirl Concentrators								
High Loading Rate:	154	59	81	99				
Low Loading Rate:	77	44	51				66	

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent TSS Concentration (mg/L) *Wet Weather Treatment Train Flow (mgd)*						
		80	***200***	***380***	***470***	***540***	***900***	***1200***
#2) Conventional Clarifiers	99	48	60			75	82	
#3) CEPT w/ Conventional Clarifiers	44	38	39		41		42	
#4) CEPT w/ Plate Settlers	42	37	38				40	
#5) Ballasted Flocculation	21	33	30				25	24

Notes: Based on the 95th percentile wet weather TSS concentration of 36 mg/L and a maximum of 330 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 99 mg/L, based on permit limits.

Table 8-11 BOD concentrations for each treatment train and flow value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent BOD Concentration (mg/L) *Wet Weather Treatment Train Flow (mgd)*						
		80	***200***	***380***	***470***	***540***	***900***	***1200***
#1) Vortex/Swirl Concentrators								
High Loading Rate:	100	38	52	64				
Low Loading Rate:	63	31	38				52	
#2) Conventional Clarifiers	74	38	52			71	79	
#3) CEPT w/ Conventional Clarifiers	47	28	32		37		41	
#4) CEPT w/ Plate Settlers	46	28	32				40	
#5) Ballasted Flocculation	36	26	28				33	33

Notes: Based on the 95th percentile wet weather BOD concentration of 23 mg/L and a maximum of 330 MGD through the existing plant. Allowable daily blended effluent BOD concentration on wet weather days is 106 mg/L, based on permit limits.

The capital cost estimates for the five treatment trains are shown in Figure 8-6. Train #4, CEPT with Plates, is the most expensive, followed by Train #1, vortex/swirl at low loading rates. Trains #2, 3, and 5 appear to have similar costs throughout the entire flow range, with Train 5 being slightly less costly. Translated into a cost per volume treated, all trains appear to become more cost effective as flow capacity increases (Figure 8-7). The comparison of O&M costs for each treatment train is shown in Figure 8-8. As expected, the O&M costs are lowest for vortex swirls at high loading and conventional clarifiers, which do not require chemical settling aids. Vortex swirls at low loading rates have the highest O&M costs for repair and maintenance of the large number of vortex units and gravity thickeners required. Taking construction, non-construction, and O&M costs into consideration, Figure 8-9 shows the present value of the total cost of each wet weather treatment train. Train #4, CEPT with Plates, remains most costly since it requires the highest capital and

O&M costs. Train #1, vortex/swirl concentrators, appears to be least costly from the life-cycle cost perspective, especially at lower flows. This is due to its low chemical usage and minimal operations and maintenance needs.

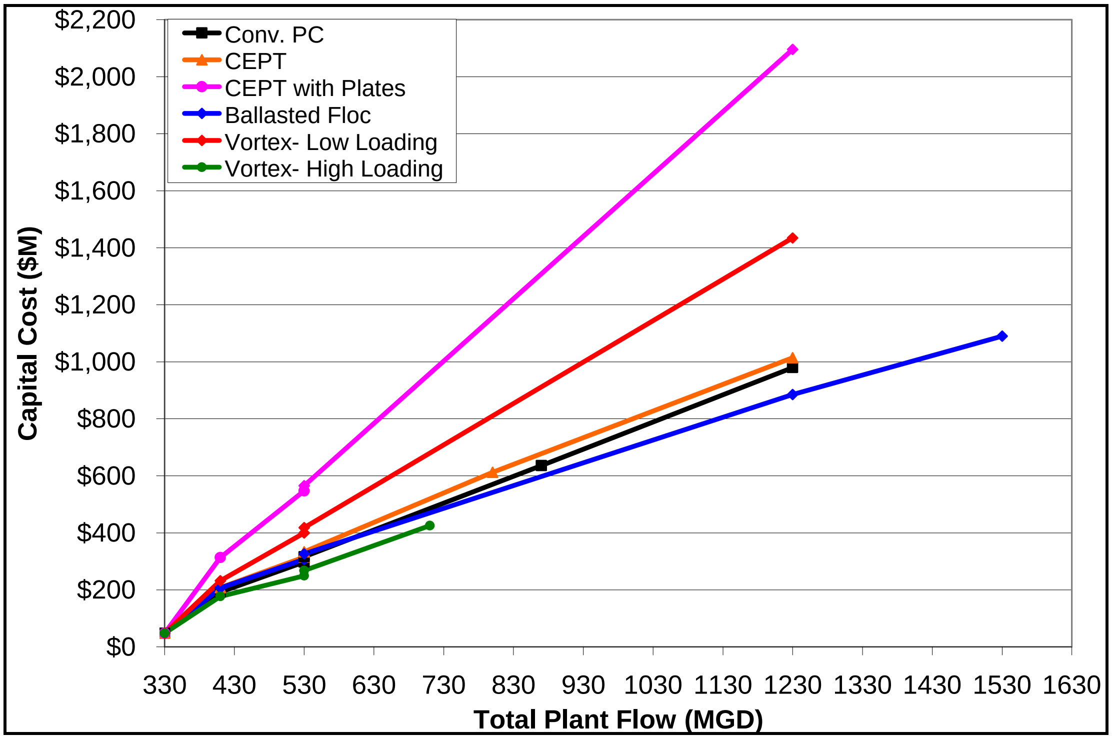


Figure 8-6 Comparison of Capital Costs for All Treatment Trains

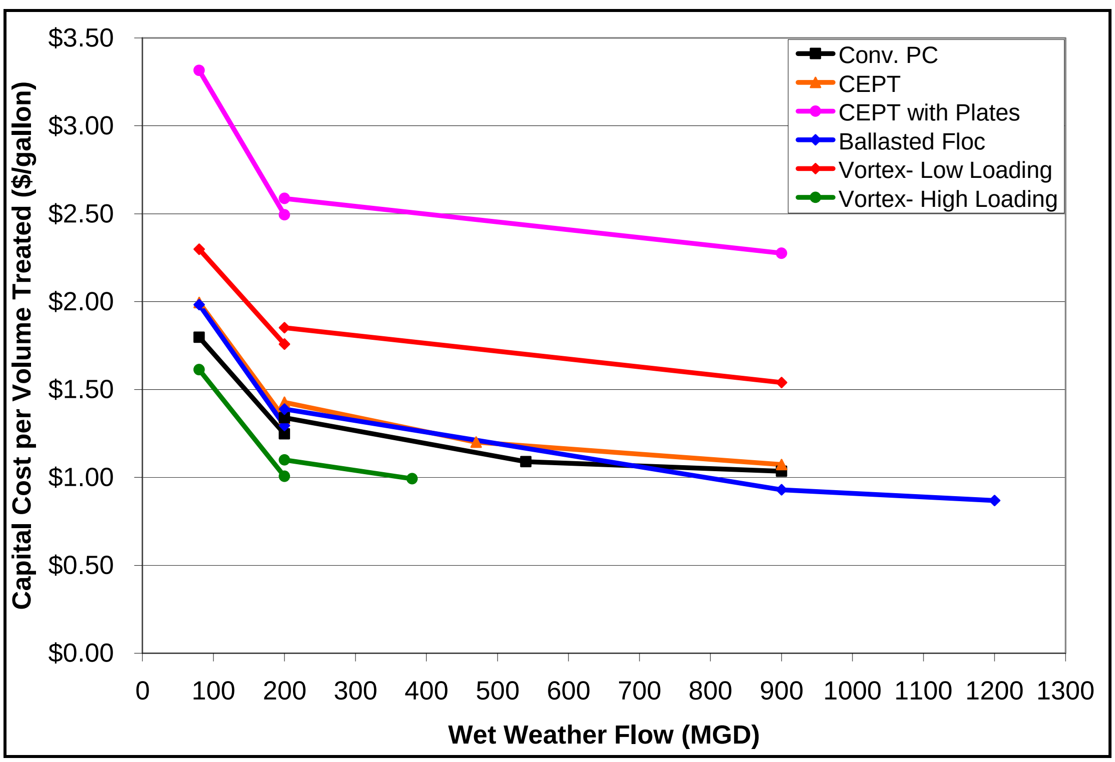


Figure 8-7 Comparison of Cost Effectiveness for All Treatment Trains

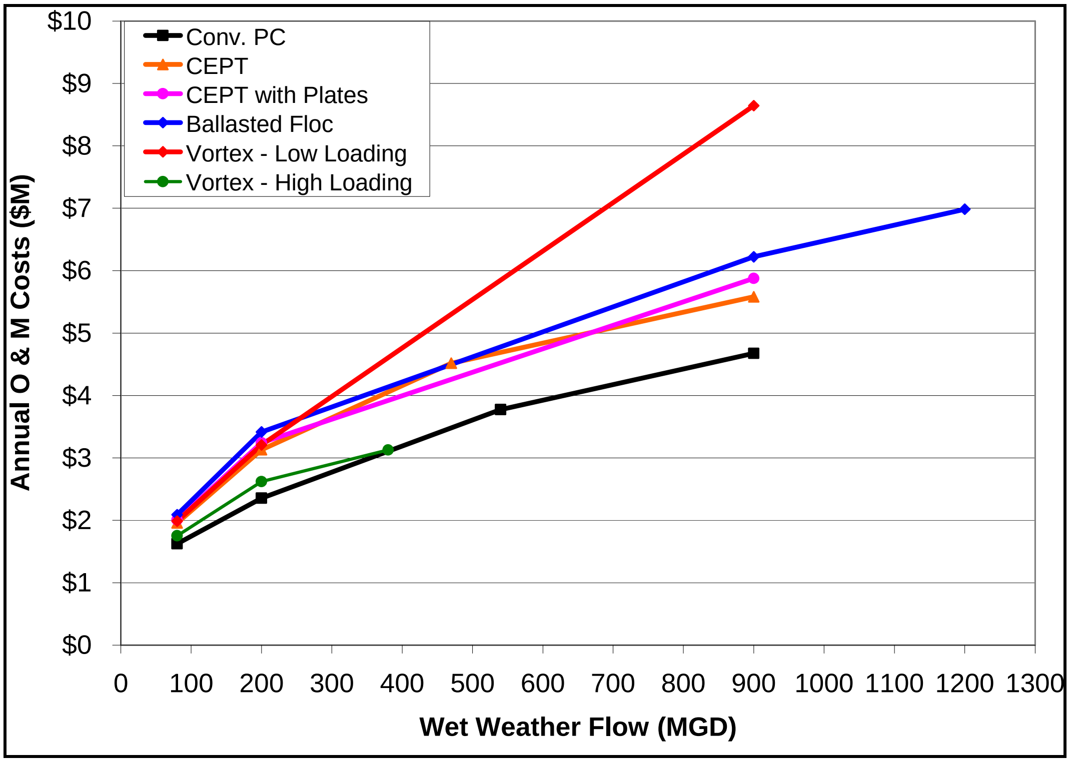


Figure 8-8 Comparison of Operations and Maintenance Costs for All Treatment Trains

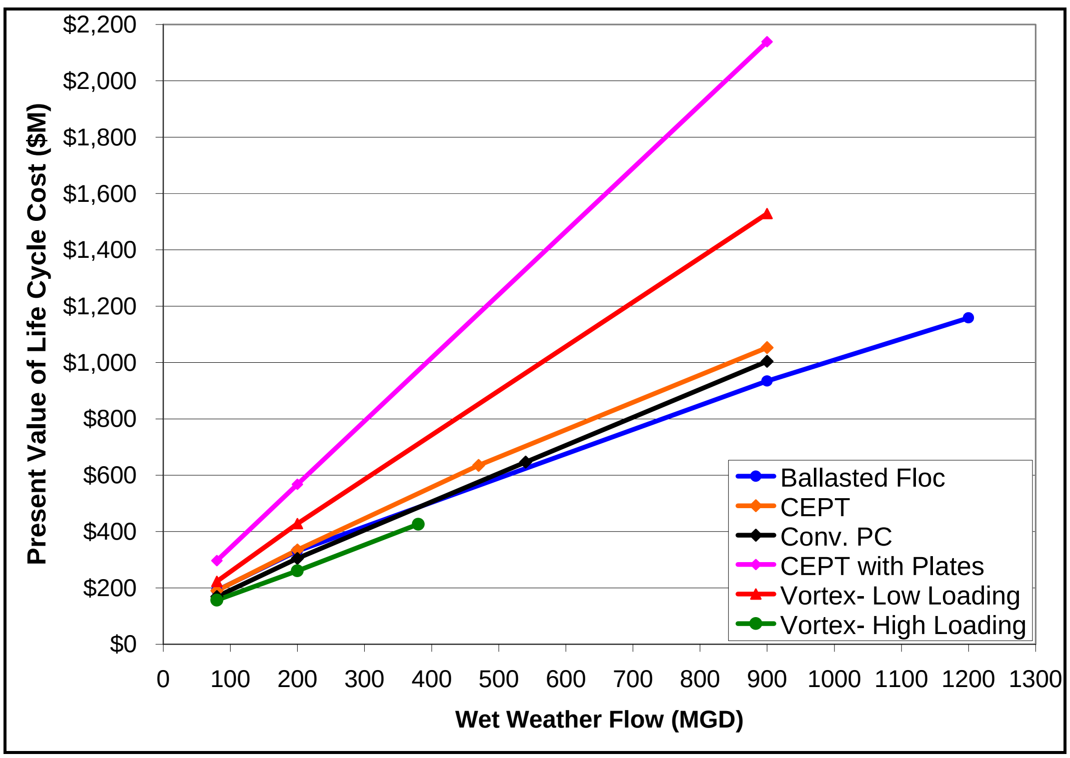


Figure 8-9 Comparison of Life-Cycle Costs for All Treatment Trains

Aside from capital, O&M, and lifecycle costs, there are numerous other criteria by which the treatment trains should be evaluated, including:

- Reliability of the system
- Community and environmental impacts or perception
- Ability to handle large variations in flow
- Land requirements
- Constructability
- Requirements for maintenance and operator attention
- Sustainability

The main advantages and disadvantages for Treatment Trains #1 through #5, as evaluated are described in Table 8-12.

The costs for wet weather treatment at the SEWPCP should be analyzed with the costs of other wet weather treatment alternatives, such as improvements in the collection system, to determine which treatment train alternatives and flow regimes should be evaluated further. Treatment trains that are selected for further evaluation should undergo more detailed design and costing methods, water quality sampling, and bench and pilot scale testing, so that removal efficiencies, land requirements, capital costs, and O&M costs can be further refined.

Southwest Wet Weather Treatment Alternatives.
The wet weather treatment technologies for the SWWPCP evaluated are as follows:

1. Vortex Swirl Concentrators
2. Conventional Clarifiers
3. Chemically Enhanced Primary Treatment (CEPT) with Conventional Clarifiers
4. Ballasted Flocculation (includes fine screening)

Conceptual treatment trains were developed for each treatment technology at various wet weather flows ranging from 220 million gallons per day (mgd) to 1740 mgd and cost curves for capital, operations and maintenance (O&M), and lifecycle costs were generated for each treatment train alternative.

Currently, the SWWPCP has a flow capacity of 400 mgd. With several process and hydraulic modifications, as identified in the Stress Testing Report, the capacity of the existing plant can potentially reach 540 mgd (Supplemental Documentation Volume 8: Stress Testing of the Southwest WPCP). In sizing the wet weather treatment trains, it was assumed that these upgrades, costing $64.60 Million, will have been completed, increasing the plant's capacity to a minimum of 540 mgd. Any wet weather flow in excess of 540 mgd would be diverted to the new wet weather facility.

Table 8-12 Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #1:Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements no moving parts	• Only cost competitive at high loading rates and low removal efficiencies • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • May exceed instantaneous blended effluent BOD concentration at high flows • Maximum design flow may decrease if the assumed number of operating days is greater than 7.
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Space limited • Uses chemicals • Can treat less flow on existing site than conventional clarifiers
Train #4: CEPT with Plates	• Can treat 900 mgd with available land on site • Lower chlorine dose possible due to high TSS removal efficiencies • Unlimited number of operating days per month	• High capital and O&M costs • Operators unfamiliar with technology • Labor intensive to clean plates • Uses chemicals
Train #5: Ballasted Flocculation	• Can treat up to 1200 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Second most labor intensive • Uses chemicals

The new wet weather facility is sited on two tracts of land currently utilized by the Biosolids Recycling Center (BRC), the Upper and Lower BRC areas. Due to the likely infeasibility in routing a new outfall conduit from the BRC area through the Philadelphia International Airport to the Delaware River, a new outfall conduit to the Schuylkill River is proposed to be constructed for the new wet weather treatment facility. Unlike the Southeast and Northeast WPCPs, effluent from the wet weather facility will not co-mingle with the effluent from the conventional plant. This means that the regulating agencies may view the new facility as a separate wet weather treatment facility requiring a new discharge permit. If blending of the two plant effluents is required or desired, the outfall for the existing plant could be relocated to the Schuylkill by constructing a new outfall conduit. The cost of this conduit, and thus co-mingling, is estimated at $155 million. Despite the difference in outfall locations, this assumes that the SWWPCP and its new wet weather facility will operate as one system.

Conceptual designs and cost estimates were developed for the design flows for each wet weather treatment train under evaluation (Table 8-13 shows the various design flows evaluated for each of the treatment trains). These flows were selected based on the ability to meet permit requirements (assuming co-mingling with existing plant), the capacity of the existing collection system, the land area available at the Upper and Lower BRC sites, and the maximum expected flow from the upgraded collection system.

Table 8-13 Design Flows Evaluated for each Wet Weather Treatment Train

Treatment Train	Design Flows Evaluated (mgd)
#1) Vortex/Swirl Concentrators	220, 702
#2) Conventional Clarifiers	220, 600, 1200
#3) CEPT w/ Conventional Clarifiers	220, 550, 1000
#4) Ballasted Flocculation	220, 980, 1740

Due to the varying removal efficiencies of each candidate treatment train, the resulting water quality differs widely between different trains. The TSS and cBOD concentrations of the effluent for each wet weather treatment train and flow scenario is presented in Tables 8-14 and 8-15. In general, ballasted flocculation provides the best treatment, achieving TSS and cBOD concentrations even lower than the existing plant.

Table 8-14 TSS Concentrations for each Treatment Train and Flow Value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent TSS Concentration (mg/L)							
		Wet Weather Treatment Train Flow (mgd)							
		220	***550***	***600***	***702***	***980***	***1000***	***1200***	***1740***
#1) Vortex/Swirl Concentrators	158	61			99				
#2) Conventional Clarifiers	102	45		64				77	
#3) CEPT w/ Conventional Clarifiers	45	29	34				37		
#4) Ballasted Flocculation	21	22				21			21

Notes: Based on the 95th percentile wet weather TSS concentration of 22 mg/L and a maximum of 540 MGD through the existing plant. Allowable daily blended effluent TSS concentration on wet weather days is 112 mg/L, to meet monthly TSS permit limits.

Table 8-15 BOD Concentrations for each Treatment Train and Flow Value.

Treatment Train	Wet Weather Treatment Train Effluent Conc. (mg/L)	Blended Effluent cBOD Concentration (mg/L)							
		Wet Weather Treatment Train Flow (mgd)							
		220	***550***	***600***	***702***	***980***	***1000***	***1200***	***1740***
#1) Vortex/Swirl Concentrators	75	27			46				
#2) Conventional Clarifiers	64	24		37				47	
#3) CEPT w/ Conventional Clarifiers	54	21	31				38		
#4) Ballasted Flocculation	49	20				34			39

Notes: Based on the 95th percentile wet weather cBOD concentration of 8 mg/L and a maximum of 540 MGD through the existing plant.

Figure 8-10 shows the capital costs for all the treatment trains and figure 8-11 shows the cost effectiveness of all the treatment trains. Of the four treatment trains, treatment train #3, CEPT, is the most expensive in terms of the capital cost estimates, followed by Trains #2 and #4, Conventional Clarification and Ballasted Flocculation, which appear similar in cost. The cost of Train #1, Vortex/Swirl, is significantly less expensive than the other three trains. Translated into a cost per volume treated, all trains appear to become more cost effective as flow capacity increases.

The reason that CEPT is more expensive than Ballasted Flocculation for the SWWPCP wet weather facility is likely due to the limited length and increased number of its clarifiers. The comparison of O&M costs for each treatment train is shown in figure 8-3. As expected, the O&M costs for vortex swirls and conventional clarifiers, which do not require chemical settling aids, are the lowest. Ballasted Flocculation has the highest O&M costs due to its chemical usage and the complexity of its system. Taking construction, non-construction, and O&M costs into consideration, Figure 8-4 shows the present value of the total cost of each wet weather treatment train. Again, CEPT and Ballasted Flocculation remain most costly due to their high capital and O&M costs (Figure 8-12). Train #1, vortex/swirl concentrators, is significantly less expensive compared with other technologies from the life-cycle cost perspective (Figure 8-13). This is due to its low chemical usage and minimal operations and maintenance needs.

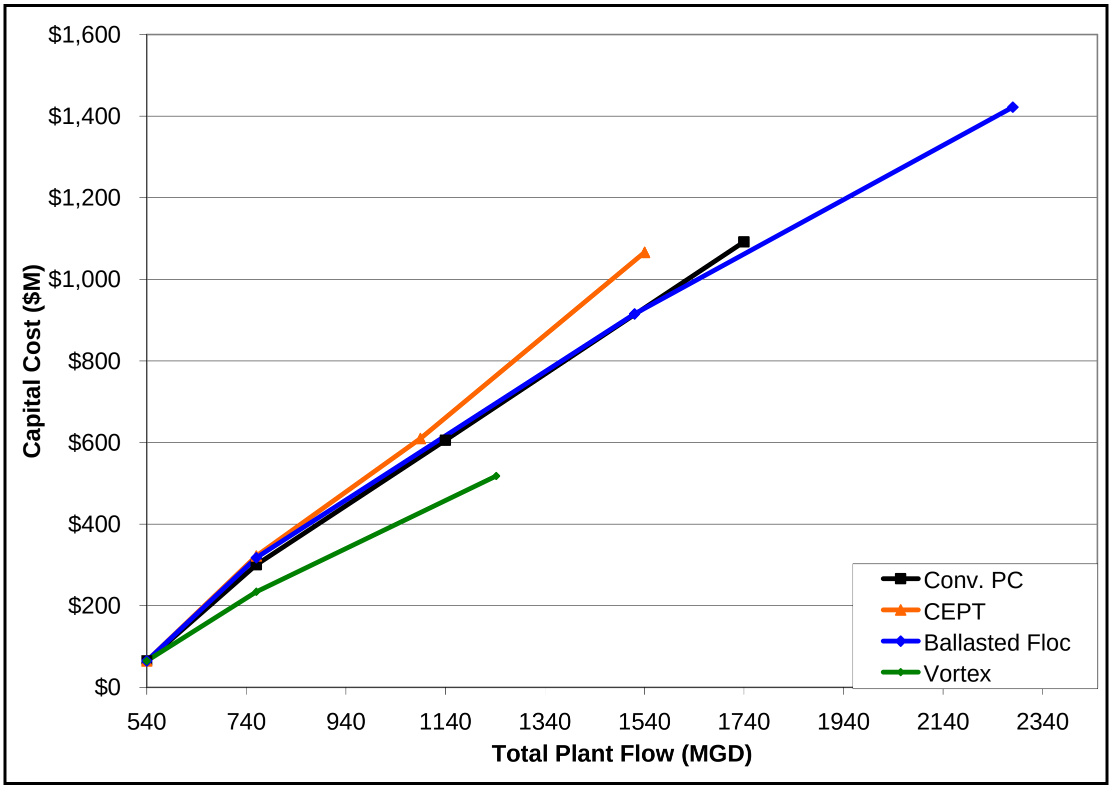


Figure 8-10 Comparison of Capital Costs for All Treatment Trains

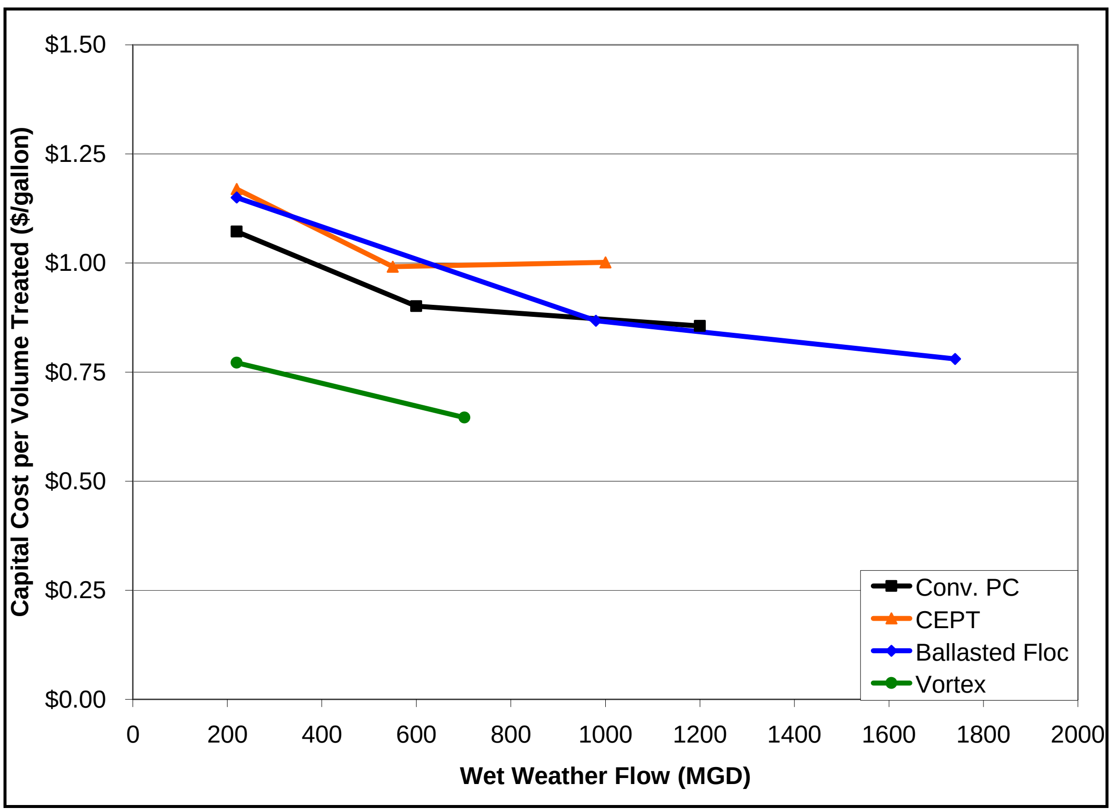


Figure 8-11 Comparison of Cost Effectiveness for All Treatment Trains

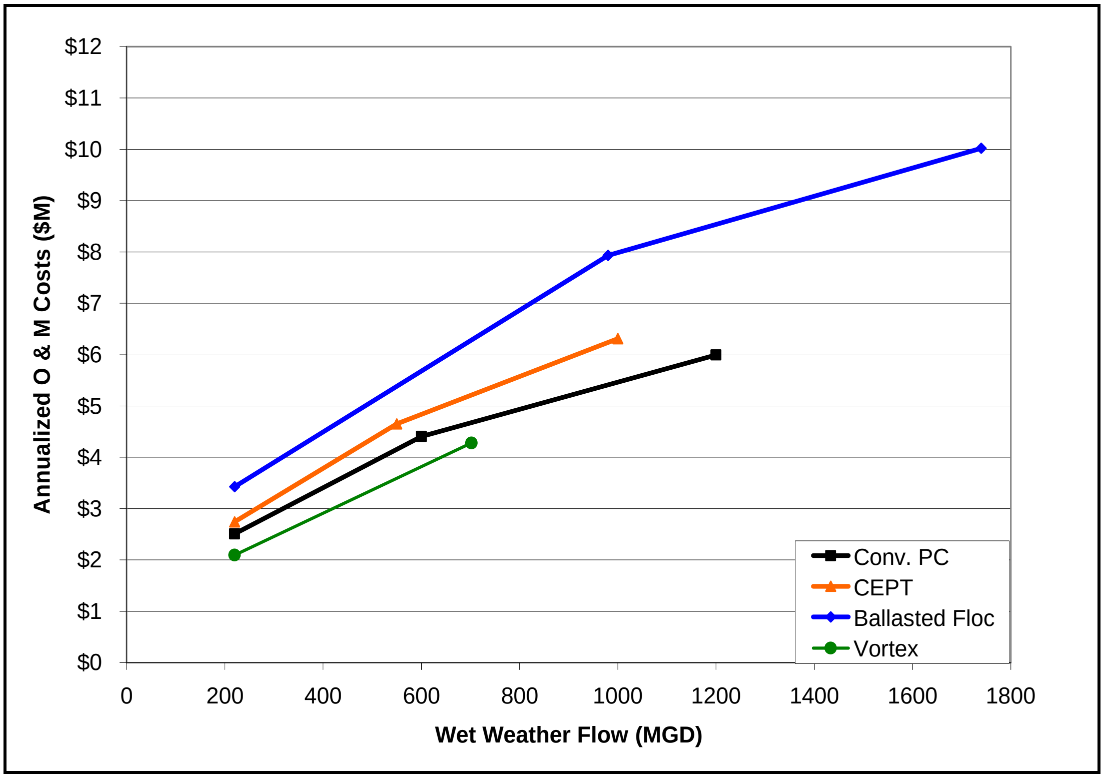


Figure 8-12 Comparison of Operations and Maintenance Costs for All Treatment Trains

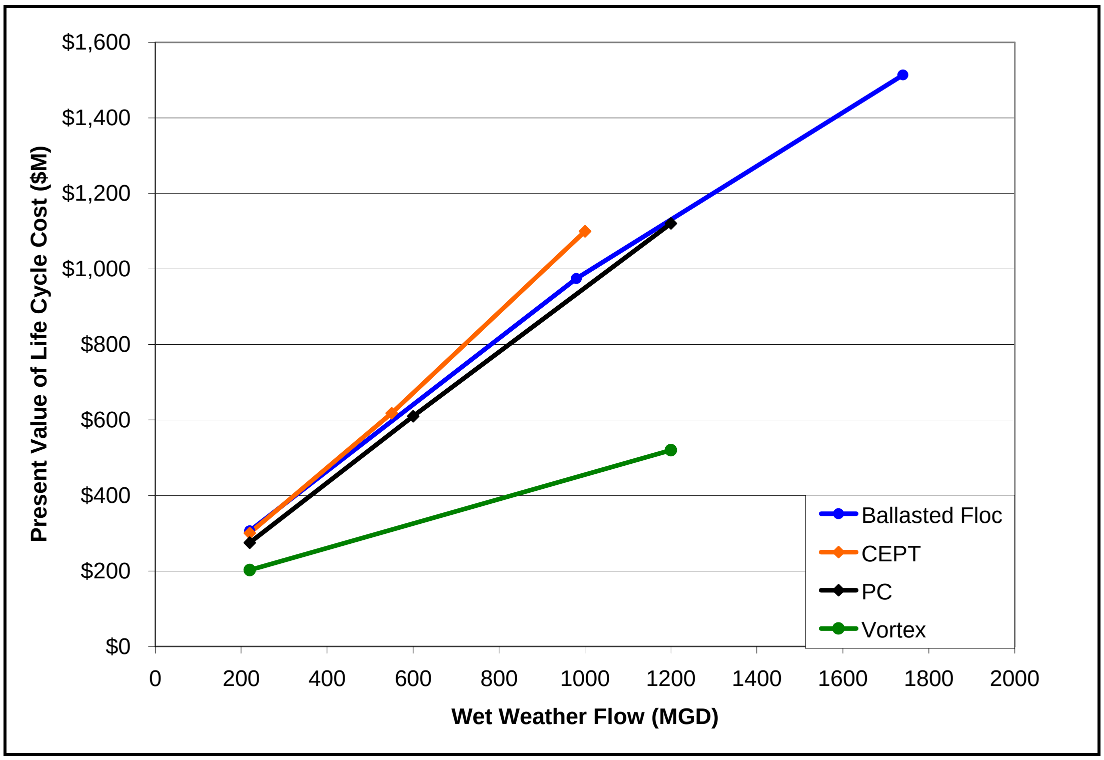


Figure 8-13 Comparison of Life-Cycle Costs for All Treatment Trains

Aside from capital, O&M, and lifecycle costs, there are numerous other criteria by which the treatment trains should be evaluated, including system reliability, community impacts, the ability to handle large variations in flow, land requirements, constructability, requirements for maintenance and operator attention, and sustainability. The main advantages and disadvantages for Treatment Trains #1 through #4, are evaluated and described in Table 8-16 below.

The costs for wet weather treatment at the SWWPCP should be analyzed with the costs of other wet weather treatment alternatives, such as improvements in the collection system, to determine which treatment train alternatives and flow regimes should be evaluated further. Treatment trains that are selected for further evaluation should undergo more detailed design and costing methods, water quality sampling, and bench and pilot scale testing, so that removal efficiencies, land requirements, capital costs, and O&M costs can be further refined.

8.2 Screening Criteria

The following criteria are proposed for initial screening of options:

1. Options that are required by NPDES permit or other regulation are recommended for inclusion in all management alternatives.
2. Options recommended for implementation in one of PWD's Integrated Watershed Management Plans are recommended for inclusion in all management alternatives.
3. Other options must meet at least one stated goal of the LTCPU to be considered for inclusion in management alternatives. Options also must be technically feasible to implement and maintain.

Table 8-16 Summary of Pros and Cons for Each Wet Weather Treatment Train

Treatment Train	Pros	Cons
Train #1:Vortex/Swirl Concentrators	• Simple operation • Low maintenance requirements no moving parts	• Maximum design flow may decrease if the assumed number of operating days per month is greater than 7. • Unless operated at lower loading rates, removal efficiency may not be high enough to operate alone without blending effluent with main plant effluent.
Train #2: Conventional Clarifiers	• Simple operation • Same technology as existing plant –operators familiar with equipment	• Space limited • Maximum design flow may decrease if the assumed number of operating days is greater than 9 per month.

Treatment Train	Pros	Cons
Train #3: CEPT	• Lower chlorine dose possible due to high TSS removal efficiencies • May be operated as Conventional Clarifiers if chemicals found to be unnecessary	• Operators unfamiliar with technology • Space limited • Can treat less flow on land available than conventional clarifiers • Uses two additional chemical systems for coagulation and flocculation
Train #4: Ballasted Flocculation	• Can treat up to 1740 mgd with available land on site • Highest removal efficiencies • Unlimited number of operating days per month • Lower chlorine dose possible due to high TSS removal efficiencies	• Operators unfamiliar with technology • Most labor intensive and complex system • Uses two additional chemical systems for coagulation and flocculation

8.3 Screening Results

Based on the information presented above, each of the potential options were placed in one of the three categories for inclusion, consideration, or exclusion. Table 8-17 contains the ratings assigned to each infrastructure-based option.

Table 8-17 Ratings Assigned to Infrastructure-Based Options

Number	Category	Option	Include in All Alternatives	Consider Including in Alternatives	Do Not Include in Alternatives
I.1	Nine Minimum Controls	Nine Minimum Controls	X		
I.2	Operation and Maintenance	Inspection and Cleaning of Combined Sewers	X		
I.3	Operation and Maintenance	Combined Sewer Rehabilitation	X		
I.4	Operation and Maintenance	Regulator/Pump Station Inspection/Maintenance/Repairs	X		
I.5	Operation and Maintenance	Outfall Maintenance Program	X		
I.6	Operation and Maintenance	House Lateral Repairs		X	
I.7	Sewer Separation	Permitted Discharge to Receiving Water for Waterfront Properties		X	
I.8	Sewer Separation	Separation of Sanitary Sewage and Stormwater on Development Sites	X		
I.9	Sewer Separation	Separate Street Runoff from Combined System		X	
I.10	Sewer Separation	Complete Separation into Sanitary and Storm Sewer Systems		X	
I.11	Sewer Separation	Permitted Discharge to Receiving Water for Waterfront Interstate Highways		X	
I.12	Outfall Consolidation/Elimination	Outfall and Regulator Consolidation		X	
I.13	Storage	Instream Storage Technologies		X	
I.14	Storage	In-Line Storage in Interceptor or Trunk Sewer		X	
I.15	Storage	Earthen Basins		X	
I.16	Storage	OffLine Covered Storage Basins		X	
I.17	Storage	OffLine Open Storage Basins		X	
I.18	Storage/Transmission	Deep Tunnels		X	
I.19	Storage/Transmission	Real Time Control	X		
I.20	Transmission	Parallel Interceptors		X	
I.21	Transmission	Remove Flow Bottlenecks		X	
I.22	Transmission	Diversion of Trunk Flow Directly to WPCP		X	
I.23	Treatment at Discharge Point	Vortex Separators		X	
I.24	Treatment at Discharge Point	Swirl Concentrators		X	
I.25	Treatment at Discharge Point	Disinfection		X	
I.26	Treatment at Discharge Point	High Rate Treatment		X	
I.27	Treatment at Discharge Point	Screens		X	
I.28	Treatment at Discharge Point	Netting		X	
I.29	Treatment at Discharge Point	Booms		X	
I.30	Treatment at Discharge Point	Baffles		X	
I.31	Treatment in Receiving Water	Debris Skimming Vessels	X		
I.32	Treatment at Existing WPCP	Expand Primary Treatment Capacity		X	
I.33	Treatment at Existing WPCP	Expand Secondary Treatment and Disinfection Capacity		X	
I.34	Treatment at Existing WPCP	Flow Equalization		X	
I.35	Treatment at Existing WPCP	Expansion of Wet Weather Treatment Capacity		X	

9 DEVELOPMENT AND COMPARISON OF ALTERNATIVES

9.1 ALTERNATIVE APPROACHES TO MEETING LTCPU GOALS

This section combines the watershed management and combined sewer overflow control options presented in Sections 6 through 8 into several alternatives. An alternative is a package of options that when implemented together will meet the goals of the Integrated Watershed Management Plan for a particular watershed. Within each watershed, a number of alternatives are evaluated in order to determine which provides the best balance between performance, cost, affordability, sustainability and social/environmental benefits, public support, and practical factors such as constructability. These evaluation factors are discussed in more detail in Section 5. Finally, the preliminary selected alternatives for each watershed are assembled into one system-wide alternative, refined, and optimized.

The engineering cost opinion and combined sewer overflow control effectiveness of each alternative is presented in the form of a cost-performance, or "knee-of-the-curve" plot. These plots allow a straightforward comparison of CSS performance and the present value of the cost of each alternative to the utility (Figure 9-1). However, these plots do not capture the full range of environmental, social, and economic costs and benefits of each alternative. Furthermore, comparing alternatives on a present value basis does not account for differences in time phasing and financing of each alternative. These factors are important in selecting an alternative and are examined following each cost-performance curve.

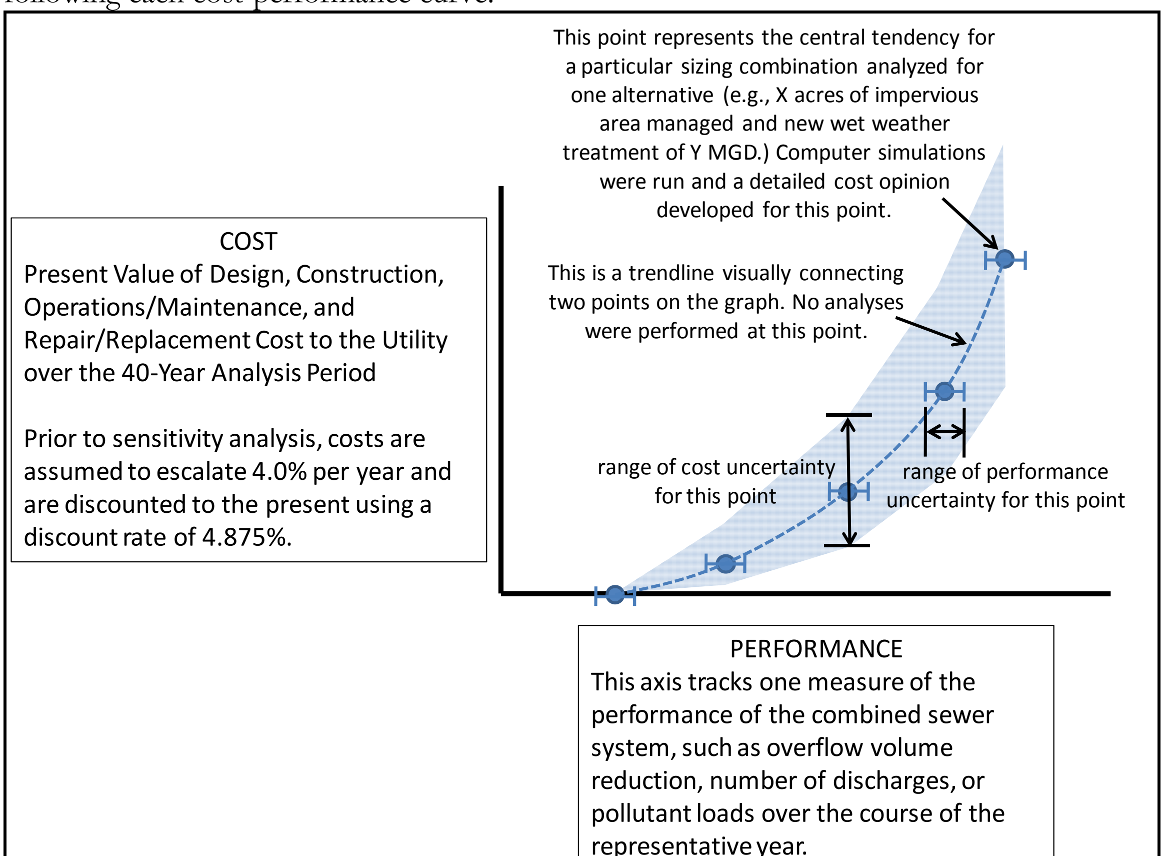


Figure 9-1 Interpretation of Cost-Performance Curves

Examination of the feasible alternatives for each of the watersheds resulted in the development of several alternative approaches to meeting program goals that can be applied in each of the watersheds. These alternatives are explained here in general terms that can be applied to all watersheds. More detailed descriptions, costs, and benefit information are then presented for each of the watersheds individually.

9.1.1 Complete Sewer Separation

Complete sewer separation is a stand-alone option (I.10) and alternative. An estimated present worth capital cost for this option for the combined area as a whole is $16 billion. This cost includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. However, this cost does not include pretreatment of stormwater or MS4 operation and maintenance activities. In order to comply with water quality standards, stormwater source controls may still be required similar to those being proposed in the combined-sewered areas.

This alternative is not cost-effective compared to other alternatives. Sewer separation may be considered on a smaller scale to solve localized problems, but large-scale sewer separation is not recommended.

9.1.2 Green Stormwater Infrastructure with Targeted Traditional Infrastructure

This alternative explores the range of combined sewer system performance, social and environmental benefits that can be achieved with green stormwater infrastructure in the absence of any new large-scale traditional infrastructure. The alternative seeks to reduce CSO frequency and volume through a range of land-based stormwater management techniques or source controls. As described in Section 6, these techniques are designed to reduce effective impervious area and reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

The alternative includes the options discussed below. Options are listed in Tables 9-1 and 9-2 and described in more detail in Sections 6 through 8.

- The full range of options recommended in the individual Integrated Watershed Management Plans for each watershed.
- Measures to improve water quality in dry weather, including rehabilitation of interceptor sewers to reduce leakage in dry and wet weather.
- Restoration of the riparian corridors: stream channels, streambanks, floodplain connection, wetlands, recreational access and trails in the TTF and Cobbs Creek Watersheds
- Tidal wetland restoration along the Delaware and Schuylkill Rivers.
- Measures to manage stormwater runoff from directly connected impervious surfaces on a large scale on both public and private land. Examples are discussed in detail in Section 6 and include street trees, sidewalk planters, rain gardens, porous pavement, and many more technologies. As the program progresses, PWD will monitor emerging technologies that have the potential to improve performance or decrease cost. Additionally, there is potential for the creation of wetlands and opportunities to consolidate adjacent outfalls.
- Stormwater management measures following redevelopment are assumed to mitigate 20% of directly connected impervious surfaces over the course of the planning period. These

controls are assumed to have only an administrative cost to PWD, although their cost to the private sector is tracked and accounted for.

- Measures to increase water pollution control plant capacity by taking full advantage of the hydraulic capacity of the existing facilities, including appropriate bypass of secondary treatment in wet weather.
- Continuation of partnerships and stakeholder processes in all watersheds, and coordination with upstream municipalities to reduce pollutant loads from other sources and wet weather flows.

Table 9-1 Options Included in All Alternatives other than Full Sewer Separation

L.1	Sump Pump Disconnect	L.38	Catch Basin and Storm Inlet Maintenance
L.2	Illicit Connection Control	L.39	Require Industrial Pretreatment
L.3	Roof Leader Disconnect Program	L.40	On-Lot Disposal (Septic System) Management
L.4	Offload Ground Water Pumpage	L.41	Household Hazardous Waste Collection
L.5	Stream Diversion	L.43	Industrial Stormwater Pollution Prevention
L.6	Groundwater Infiltration Reduction	L.44	Litter and Illegal Dumping Enforcement
L.7	Reduction of Contractual Flow	L.45	Require Construction-Phase Stormwater/E&S Controls
L.18	Water Conservation	W.1	Dam Modification/Removal
L.19	Catch Basin Stenciling	W.2	Daylight Orphaned Storm Sewers
L.20	Community Cleanup and Volunteer Programs	W.3	Stream Cleanup and Maintenance
L.21	Recycling Programs	W.4	Channel Stabilization and Habitat Restoration
L.22	Pet Waste Education	W.5	Channel Realignment and Relocation
L.23	Lawn & Garden Maintenance	W.6	Plunge Pool Removal
L.24	Public Notification and Signage	W.7	Improvement of Fish Passage
L.25	Litter and Dumping Education	W.10	Constructed Wetlands along Stream Corridors
L.26	School-Based Education	W.12	Enhance Stream Corridor Recreational and Cultural Resources
L.27	Loading, Unloading, and Storage of Materials	W.13	Wetland Improvement
L.28	Spill Prevention and Response	W.14	Invasive Species Management
L.29	Street Sweeping Programs	W.15	Reforestation
L.30	Vehicle & Equipment Management	I.1	Nine Minimum Controls
L.31	Private Scrapyard Inspection and Enforcement	I.2	Inspection and Cleaning of Combined Sewers (Interceptors)
L.32	Employee Training	I.3	Combined Sewer Interceptor Rehabilitation
L.33	Record Keeping and Reporting	I.4	Regulator/Pump Station Inspection/Maintenance/Repairs
L.34	Flow Diversion and Exposure Minimization Structures	I.5	Outfall Maintenance Program
L.35	Responsible Landscaping Practices on Public Lands	I.8	Separation of Sanitary Sewage and Stormwater on Development Sites
L.36	Responsible Bridge and Roadway Maintenance	I.19	Real Time Control
L.37	Catch Basin Modifications for Solids Control		

Table 9-2 Additional Options Included in Green Stormwater Infrastructure with Targeted Traditional Infrastructure Alternative

L.9	Require Existing Resources Inventory, Sketch Plan, Initial Meeting
L.10	Require Integrated Site Design
L.11	Require Post-Construction Stormwater Management
L.12	Post-Construction Inspection and Enforcement
L.13	Demonstration Projects on Public Lands
L.14	Large-Scale Implementation on Public Lands
L.15	Street Trees and Street Greening
L.16	Revise Stormwater Rate Structure
L.17	Stormwater Management Incentives for Retrofit
I.36	Expansion of Wet Weather Treatment Capacity (Primary Treatment Bypass)

9.1.3 Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

This alternative includes the same options as the previous alternative to address dry weather goals, restore living resources, and improve recreational opportunities. However, the alternative combines the large-scale green stormwater infrastructure approach with increased interceptor transmission capacity and increased wet weather wastewater treatment capacity. For a given combined sewer system percent capture level, a lower implementation level of green stormwater infrastructure is required compared to the Green Stormwater Infrastructure with Targeted Traditional Infrastructure alternative.

This alternative includes the options discussed below. Options are listed in Tables 9-1 and 9-3 and described in more detail in Sections 6 through 8.

- The full range of options recommended in the Cobbs and Tookany/Tacony-Frankford Integrated Watershed Management Plans.
- Measures to improve water quality in dry weather, including rehabilitation of interceptor sewers to reduce leakage in dry and wet weather.
- Restoration of the riparian corridor: stream channels, streambanks, floodplain connection, wetlands, recreational access and trails.
- Tidal wetland restoration along the Delaware and Schuylkill Rivers.
- Measures to manage stormwater runoff from directly connected impervious surfaces on a large scale on both public and private land. Examples are discussed in detail in Section 6 and include street trees, sidewalk planters, rain gardens, porous pavement, and many more technologies. As the program progresses, PWD will monitor emerging technologies that have the potential to improve performance or decrease cost. Additionally, there is potential for the creation of wetlands and opportunities to consolidate adjacent outfalls.
- Stormwater management measures following redevelopment are assumed to mitigate 20% of directly connected impervious surfaces over the course of the planning period. These controls are assumed to have no cost to PWD, although their cost to the private sector is tracked and accounted for.
- Proposed expansion of water pollution control plants to include a secondary treatment bypass where appropriate and, depending on the peak capacity needed, additional high rate treatment.

- New interceptors would provide additional transmission capacity along the same routes taken by existing interceptors. In the TTF and Cobbs Creek Watersheds, construction would be completed in conjunction with stream and stream corridor restoration.
- Continuation of partnerships and stakeholder processes in all watersheds, and coordination with upstream municipalities to reduce pollutant loads and wet weather flows entering the watershed.

Table 9-3 Additional Options Included in Green Stormwater Infrastructure with Increased Transmission and Treatment Alternative

L.9	Require Existing Resources Inventory, Sketch Plan, Initial Meeting
L.10	Require Integrated Site Design
L.11	Require Post-Construction Stormwater Management
L.12	Post-Construction Inspection and Enforcement
L.13	Demonstration Projects on Public Lands
L.14	Large-Scale Implementation on Public Lands
L.15	Street Trees and Street Greening
L.16	Revise Stormwater Rate Structure
L.17	Stormwater Management Incentives for Retrofit
I.20	Parallel Interceptors
I.36	Expansion of Wet Weather Treatment Capacity

9.1.4 Large-Scale Centralized Storage Alternative

This alternative seeks to reduce CSO volume, frequency, and duration using a traditional tunnel storage system. Combined sewage is stored temporarily and dewatered to the existing water pollution control plants. This alternative includes options to address dry weather goals, restoration of living resources, and improved recreational opportunities. However, if this alternative is selected it may be necessary to reassess the cost, affordability, and benefits of these programs in combination with a tunnel. This alternative does not include a significant amount of Green Stormwater Infrastructure for stormwater management.

The Large-Scale Centralized Storage alternative includes the options discussed below.

- The full range of options recommended in the TTF and Cobbs Creek Integrated Watershed Management Plans.
- Measures to improve water quality in dry weather, including rehabilitation of interceptor sewers to reduce leakage in dry and wet weather.
- Restoration of the riparian corridor in the TTF and Cobbs Creek Watersheds: stream channels, streambanks, floodplain connection, wetlands, recreational access and trails.
- Tidal wetland restoration along the Delaware and Schuylkill Rivers.
- Storage tunnels and associated infrastructure approximately parallel to existing interceptor sewers and perpendicular to existing trunk sewers. A minimum length for each tunnel is fixed by the location of trunk sewers it would intercept. Tunnel inner diameters studied include a range from the approximate minimum feasibly constructible (about 15 feet) to the maximum feasibly constructible (about 35 feet). Additionally, there is potential to consolidate adjacent outfalls.
- Continuation of partnerships and stakeholder processes in all watersheds, and coordination with upstream municipalities to reduce pollutant loads and wet weather flows entering the watershed.

9.1.5 Large-Scale Satellite Treatment Alternative

The Large-Scale Satellite Treatment alternative seeks to reduce CSO volume, frequency, and duration using satellite treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, treated, disinfected, and discharged to the creek. This alternative includes options to address dry weather goals, restoration of living resources, and improved recreational opportunities. However, if this alternative is selected it may be necessary to reassess the cost, affordability, and benefits of these programs in combination with large-scale satellite treatment. This alternative does not include green infrastructure for stormwater management.

Large-Scale Satellite Treatment alternative includes the options discussed below. Options are listed in Tables 9-1 and 9-4 and described in more detail in Sections 6 through 8.

- The full range of options recommended in the TTF Integrated Watershed Management Plan.
- Measures to improve water quality in dry weather, including rehabilitation of interceptor sewers to reduce leakage in dry and wet weather.
- Restoration of the riparian corridor in the TTF and Cobbs Creek Watersheds: stream channels, streambanks, floodplain connection, wetlands, recreational access and trails.
- Tidal wetland restoration along the Delaware and Schuylkill Rivers.
- Satellite treatment facilities and associated infrastructure. These facilities would be sited to take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Three technologies are considered: retention treatment basins, ballasted flocculation, and swirl/vortex systems.
- New conveyance conduits to transmit more flow to the treatment facilities.
- Continuation of partnerships and stakeholder processes in all watersheds, and coordination with upstream municipalities to reduce pollutant loads and wet weather flows entering the watershed.

Table 9-4 Additional Options Included in the Large-Scale Satellite Treatment Alternative

I.20	Parallel Interceptors
I.26	Disinfection
I.27	High Rate Treatment
I.36	Expansion of Wet Weather Treatment Capacity

9.2 Benefits and External Costs of Alternative Approaches

A key goal of PWD's *Green City, Clean Waters* program is to maximize the sustainability of the urban water resources system and to maximize benefits to the public of the money spent on reducing combined sewer overflows. A traditional engineering analysis of sewer system performance, capital costs, and operations and maintenance costs forms the core of the alternatives analysis and selection process, and will be presented later in this document. However, traditional analyses do not guarantee that benefits will be maximized because they leave out key variables that affect urban quality of life and long-term sustainability of the urban system.

PWD's *Green City, Clean Waters* program is designed to provide many benefits beyond the reduction of combined sewer overflows, so that every dollar spent provides a maximum return in benefits to the public and the environment. Traditional engineering economic analysis compares the construction cost of various alternatives to the effectiveness of those alternatives, such as percent capture of combined sewage. In this traditional framework, the alternative that meets the performance goal at least cost will be selected for construction. However, the traditional framework misses a number of costs and benefits that may not affect the utility directly, but affect the environment and the public at large. To fully understand these economic, environmental, and social benefits, PWD has undertaken a Triple Bottom Line analysis. The results of this analysis affect alternative selection by showing that some alternatives have significant benefits that are not accounted for in the traditional framework, while others have significant costs.

9.2.1 Green Stormwater Infrastructure Enhances Recreation and Restores Ecosystems

Green Stormwater Infrastructure Enhances Recreation

Throughout the Fairmount Park system, residents enjoy recreation along Philadelphia's stream corridors and waterfronts, but some areas do not live up to their full potential. Improved access, appearance, and opportunities in these areas will make them more desirable destinations for the public. Recreation also will be more desirable along newly greened neighborhood streets and public places (Figure 9-2).

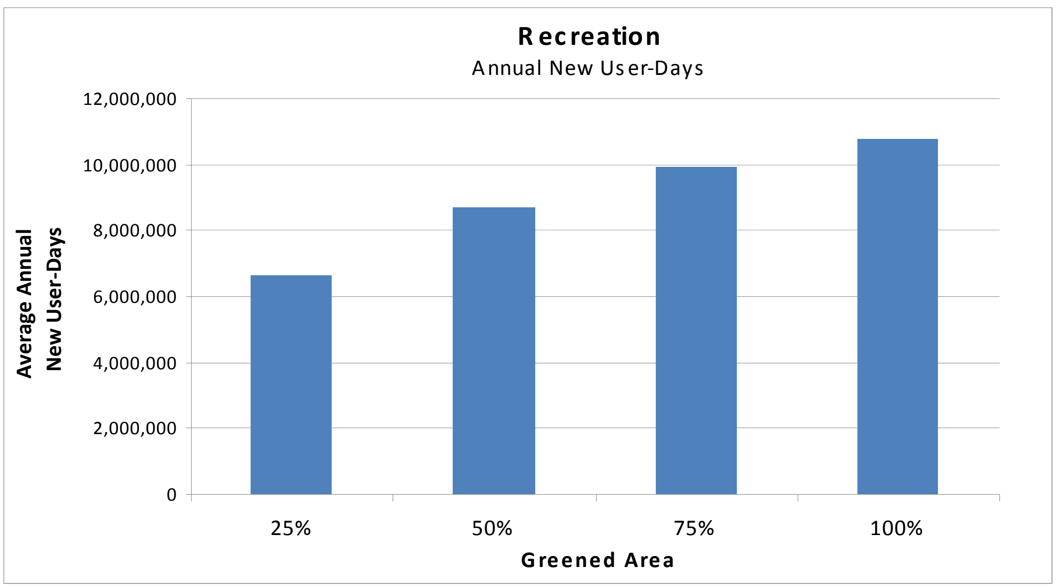


Figure 9-2 Recreational Benefits

Green Stormwater Infrastructure Restores Ecosystems

Green stormwater infrastructure improves ecosystems in two ways. First, by restoring a water cycle more similar to a natural watershed, green stormwater infrastructure allows rain to soak into the ground and return to streams slowly. This provides a natural water quality filter and limits erosion of stream channels caused by high flows, both of which benefit aquatic species. Second, PWD's green stormwater infrastructure approach includes physical restoration of stream channels and streamside lands, including wetlands, to restore habitat needed for healthy ecosystems (Figure 9-3).

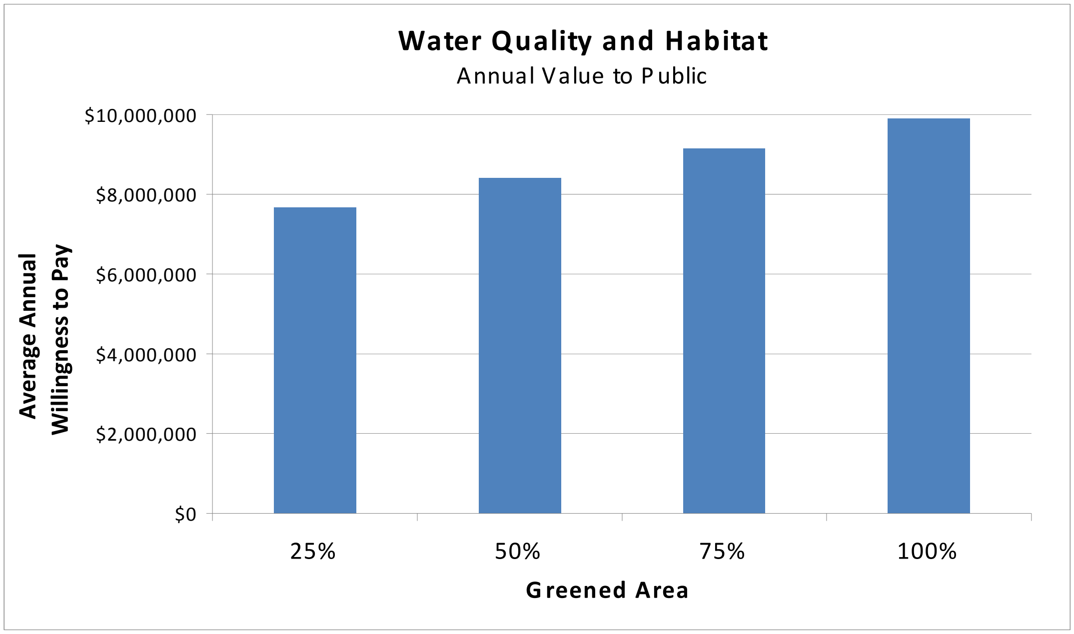


Figure 9-3 Water Quality and Habitat Benefits

9.2.2 Green Stormwater Infrastructure Improves Neighborhoods

Green Stormwater Infrastructure Improves Community Quality of Life

Trees and parks are an important part of the recipe that together can make an urban neighborhood into an inviting, exciting place to live, work and play. Residents clearly recognize and value this quality of life effect of urban vegetation, and yet it is difficult to assign it an economic value. One way to estimate a value is to study property values in areas that are close to parks and greenery (Figure 9-4).

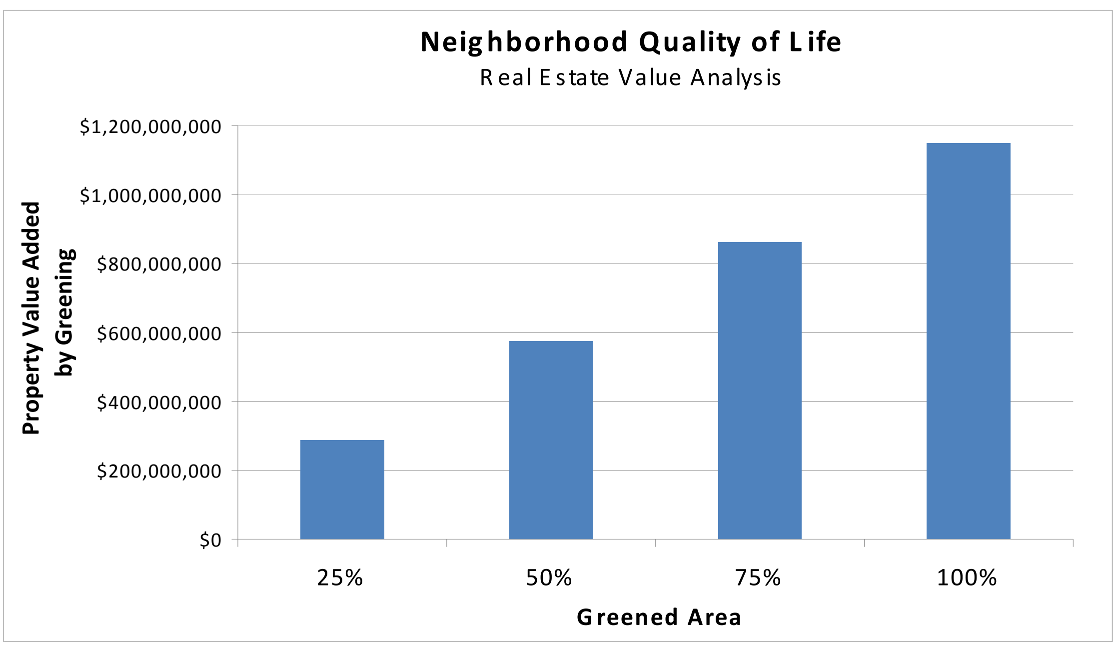


Figure 9-4 Quality of Life Benefits

Green Stormwater Infrastructure Jobs Reduce the Social Cost of Poverty

Governments at all levels incur significant costs in coping with poverty, and Philadelphia is no exception. Green stormwater infrastructure creates jobs which require no prior experience and are therefore suitable for individuals who might be otherwise unemployed and living in poverty. These new jobs create a benefit to society in reduced poverty-related costs, in addition to the wages paid to the individual workers (Figure 9-5). The stabilizing and transforming effects of green stormwater infrastructure in neighborhoods further reinforce and support the benefits of providing employment to a population that is outside the labor force. Green stormwater infrastructure is not by itself the solution to poverty, but it is a valuable tool in the toolbox of poverty reduction.

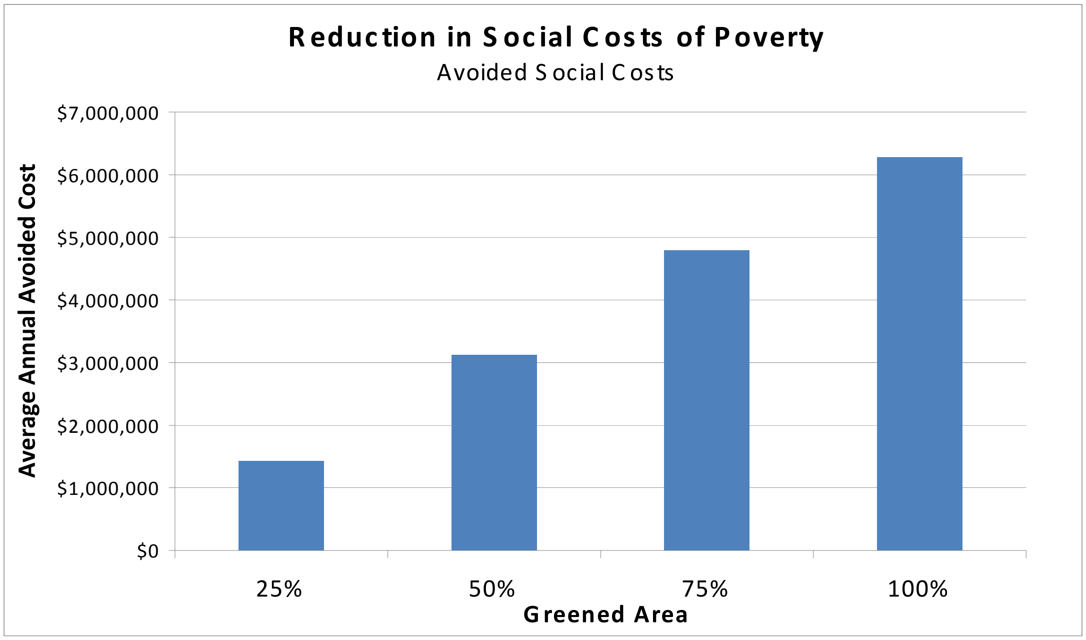


Figure 9-5 Benefits from Green Jobs

9.2.3 Green Stormwater Infrastructure Improves Public Health

Green Stormwater Infrastructure Reduces Effects of Excessive Heat

Heat waves are a fixture of summers in Philadelphia, including some severe enough that they have resulted in over 100 premature deaths (for example, the summer of 1993). These events may be more frequent and severe in the future due to climate change. Green stormwater infrastructure (for example, trees, green roofs, and bioretention sidewalks) reduces the severity of extreme heat events in three ways - by creating shade, by reducing the amount of heat absorbing pavement and rooftops, and by emitting water vapor – all of which cool hot air. This cooling effect will be sufficient to actually reduce heat stress-related fatalities in the city during extreme heat wave events (Figure 9-6).

Green Stormwater Infrastructure Improves Air Quality

Like many major cities in the United States, US EPA currently classifies the Philadelphia metropolitan area as exceeding federal air quality standards for both ozone (smog) and fine particles (soot). Known health impacts of these air pollutants include premature death, hospitalization for respiratory diseases, heart attacks, and lost work and school days (Figure 9-7). Green stormwater infrastructure will improve Philadelphia's air quality in two ways – by reducing emissions of pollutants (such as SO_2) and by removing ozone and particulates from the air. Reductions in energy and vehicle use will reduce emissions of pollutants. Once in the air, some ozone and particles are taken into the leaves of trees as they "breathe." Leaves also trap additional fine particulates, which then wash off in the rain or fall with the autumn leaf drop.

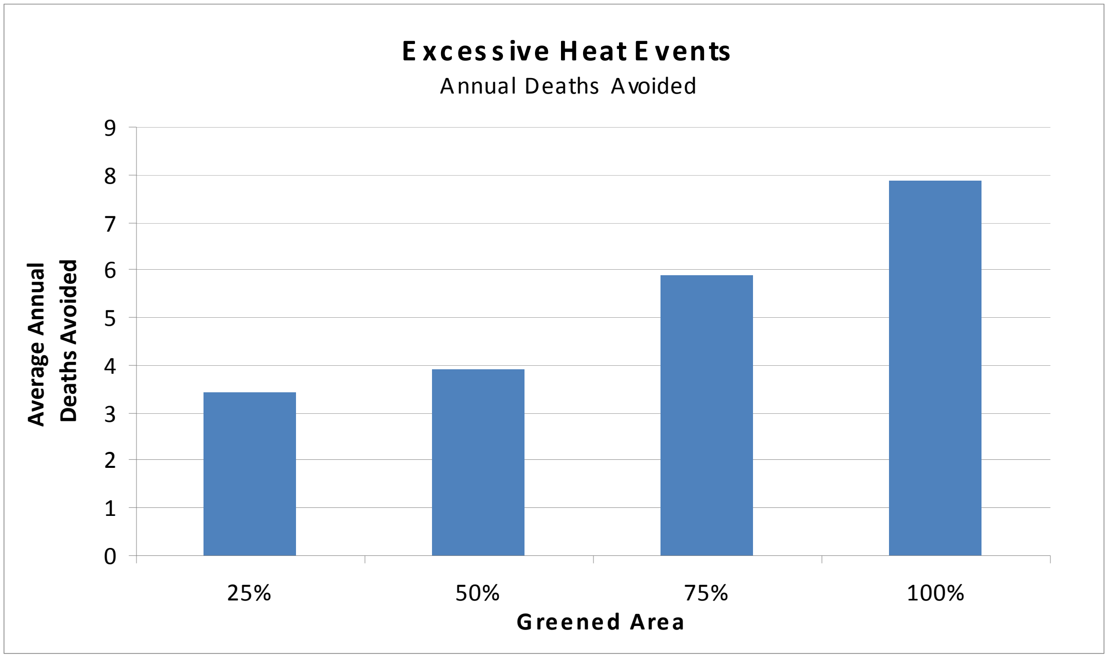


Figure 9-6 Reduction of Excessive Heat Related Deaths

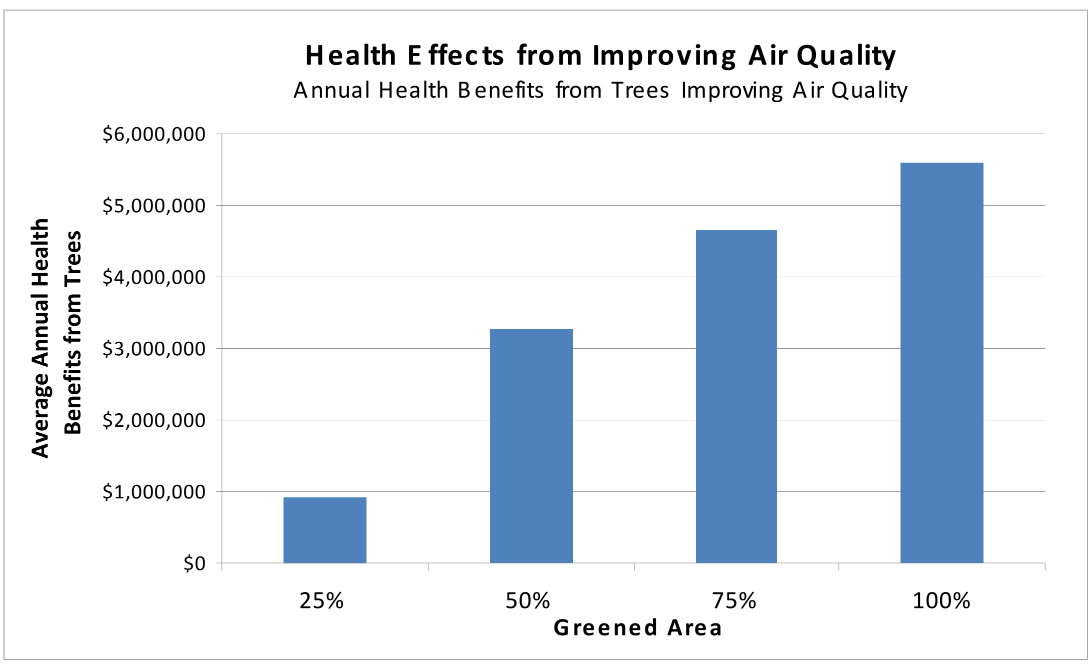


Figure 9-7 Health Benefits from Improved Air Quality

9.2.4 Green Stormwater Infrastructure Saves Energy and Offsets Climate Change

Green stormwater infrastructure reduces energy use, fuel use, and carbon emissions (Figure 9-8) in two ways. First, the cooling effects of trees and plants shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Second, rain is managed where it falls in systems of soil and plants, reducing the energy needed for traditional systems to store, pipe, and treat it. Growing trees also act as carbon "sinks", absorbing carbon dioxide from the air and incorporating it into their branches and trunks.

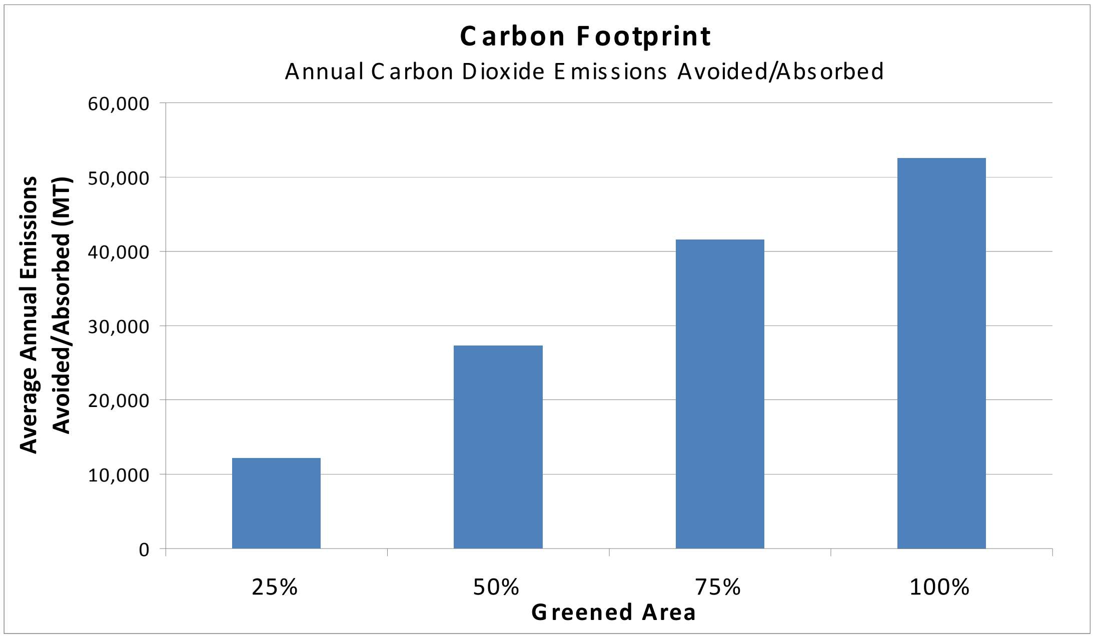


Figure 9-8 Reduction of Carbon Dioxide Emissions

9.2.5 Qualitative Factors of Green Stormwater Infrastructure

In addition to capital costs, operations and maintenance costs, external costs, and benefits, a number of factors must be considered which are qualitative in nature. Tables 9-5 through 9-9 summarize these factors for each of the alternatives.

Table 9-5 Qualitative Factors for Green Stormwater Infrastructure with Targeted Traditional Infrastructure

Qualitative Factor	Rating	Discussion
Public Support	Medium	Public is supportive of concept, sometimes hesitant of neighborhood disruption.
Construction Feasibility	High	Construction uses routine equipment and methods.
Operation Feasibility	Medium	The technology is simple but routine maintenance is needed on a large scale.
Reliability and Past Performance of Technology	High	The likelihood of failure is moderate but consequences are low.
Complexity and Difficulty of Solution	High	The alternative requires difficult coordination of many phases, technologies, sites, or contracts.
Coordination and Consistency with other PWD and City Programs	High	This alternative directly supports and benefits from many other urban greening initiatives.

Table 9-6 Qualitative Factors for Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

Qualitative Factor	Rating	Discussion
Public Support	Medium	Public is supportive of concept, sometimes hesitant of neighborhood disruption.
Construction Feasibility	High	Construction uses routine equipment and methods.
Operation Feasibility	Medium	The technology is simple but routine maintenance is needed on a large scale.
Reliability and Past Performance of Technology	High	The likelihood of failure is moderate but consequences are low.
Complexity and Difficulty of Solution	High	The alternative requires difficult coordination of many phases, technologies, sites, or contracts.
Coordination and Consistency with other PWD and City Programs	High	This alternative directly supports and benefits from many other urban greening initiatives, including stream corridor restoration.

Table 9-7 Qualitative Factors for Large-Scale Centralized Storage Alternative

Qualitative Factor	Rating	Discussion
Public Support	Low	The public has a limited understanding of how they benefit from this alternative.
Construction Feasibility	Low	Construction is high-risk and requires a specialty contractor.
Operation Feasibility	Low	The technology is unfamiliar. New staff, skills, and training are required.
Reliability and Past Performance of Technology	High	The likelihood of failure and consequences of failure are both low.
Complexity and Difficulty of Solution	Medium	The alternative requires only one contract but extremely long duration, multi-phase construction.
Coordination and Consistency with other PWD and City Programs	Medium	This alternative may reinforce flood abatement programs but not urban greening initiatives.

Table 9-8 Qualitative Factors for Large-Scale Satellite Treatment Alternative

Qualitative Factor	Rating	Discussion
Public Support	Low	The public has a limited understanding of how they benefit from this alternative.
Construction Feasibility	Medium	Construction is moderately difficult or risky.
Operation Feasibility	Medium	The technology is familiar but requires skilled staff working at multiple locations and transport of chemicals.
Reliability and Past Performance of Technology	Low	The likelihood of failure is low/moderate but consequences are high for aquatic life.
Complexity and Difficulty of Solution	Medium	The alternative requires construction and operation at several sites.
Coordination and Consistency with other PWD and City Programs	Low	This alternative does not support greening initiatives, occupies park or waterfront land, and may jeopardize habitat and aquatic life.

9.3 Tookany-Tacony/Frankford Creek Watershed

This section presents costs and benefits of each alternative in the TTF Watershed. For each alternative two graphs are presented (Figure 9-9 to 9-16), the first is a summary of cost to PWD and the second is a summary of the total private and public cost compared with the net benefits.

9.3.1 Green Stormwater Infrastructure with Targeted Traditional Infrastructure

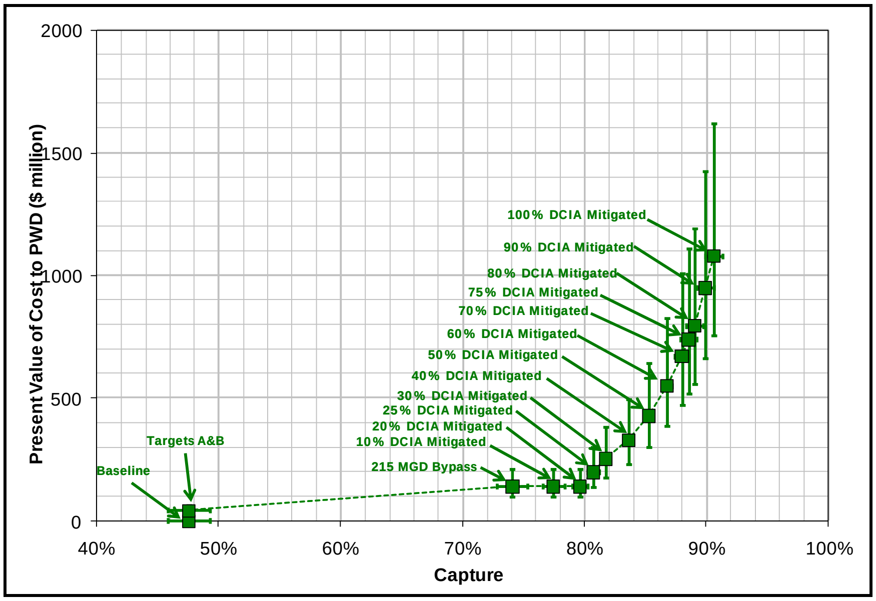


Figure 9-9 TTF Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Performance Curve

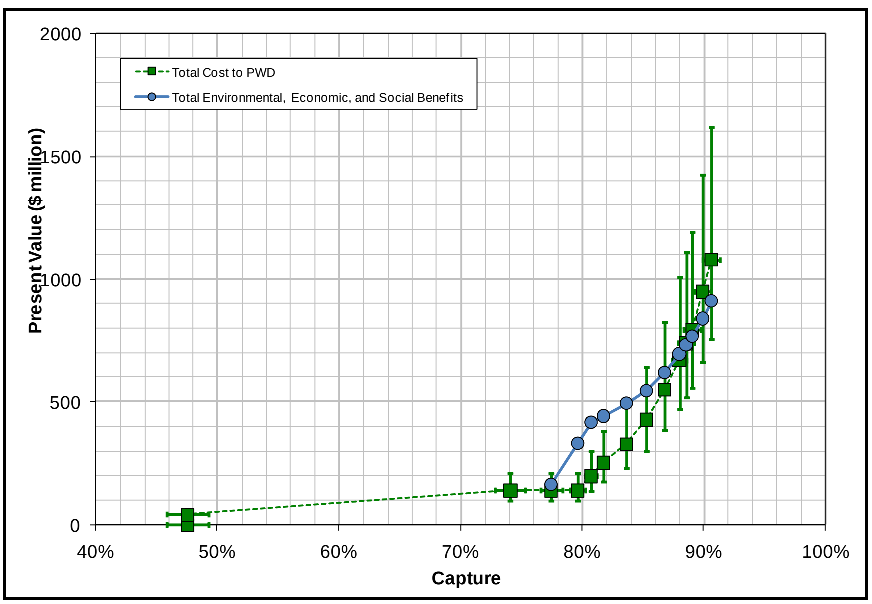


Figure 9-10 TTF Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Benefit Comparison

9.3.2 Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

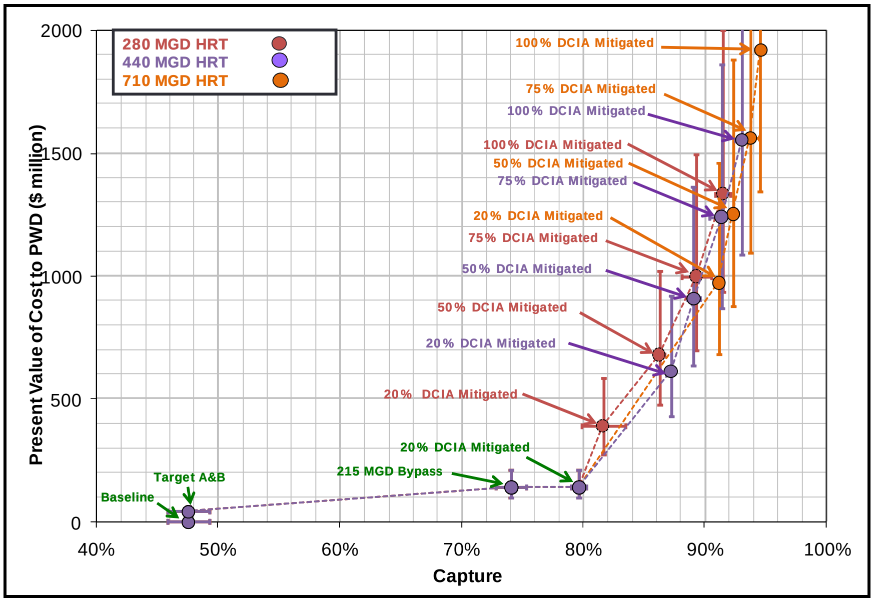


Figure 9-11 TTF Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Performance Curve

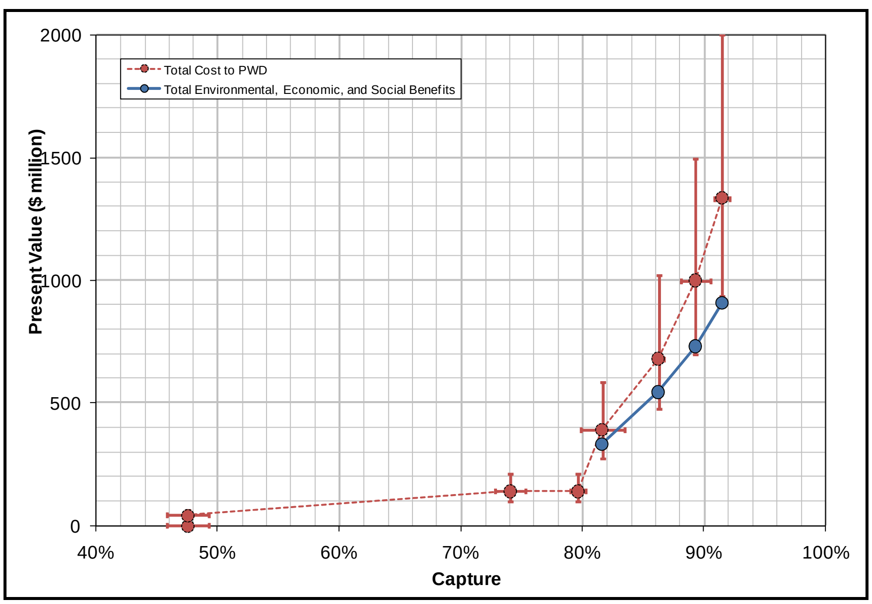


Figure 9-12 TTF Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Benefit Comparison

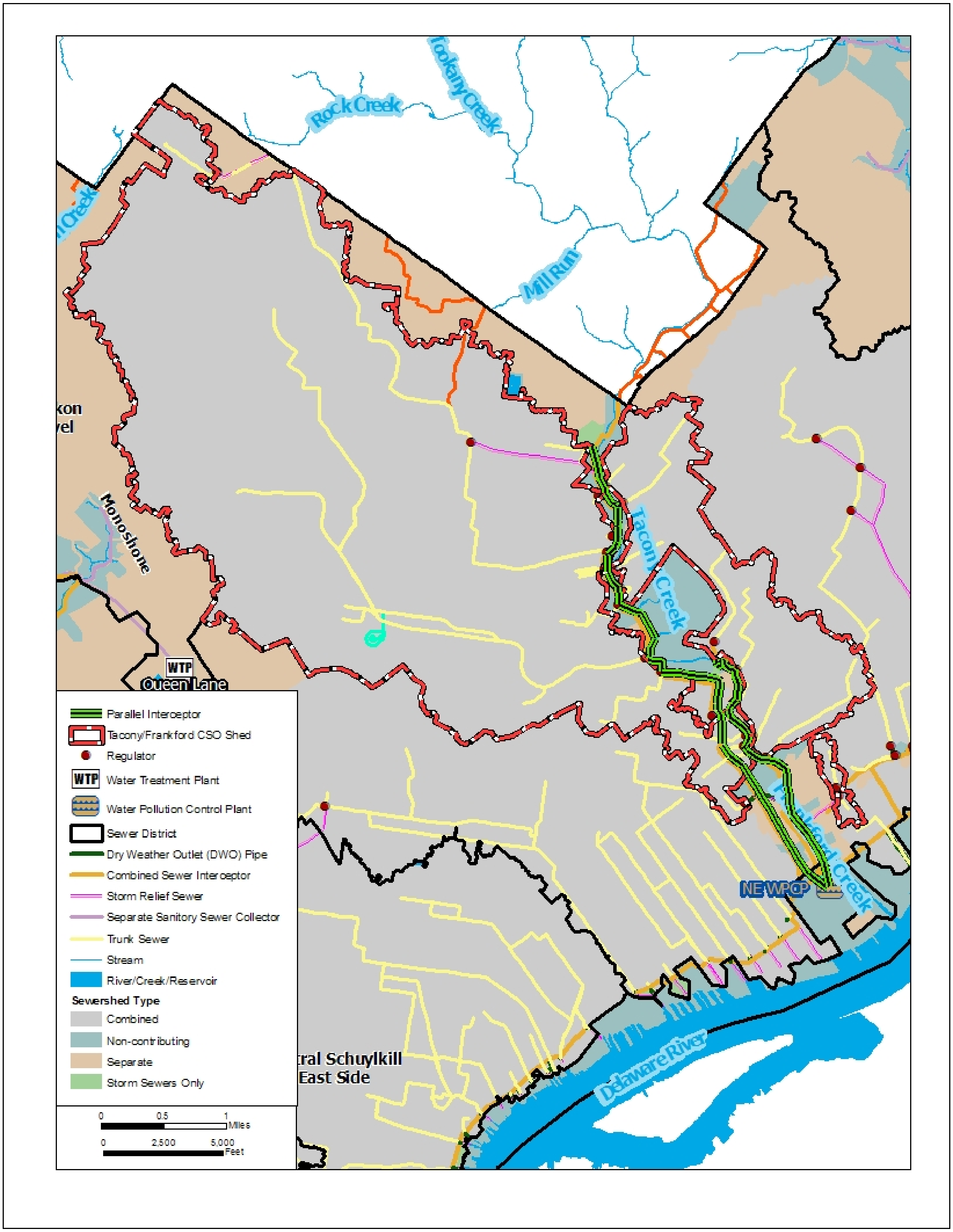


Figure 9-13 Location of TTF Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Alternative

9.3.3 Large-Scale Centralized Storage Alternative

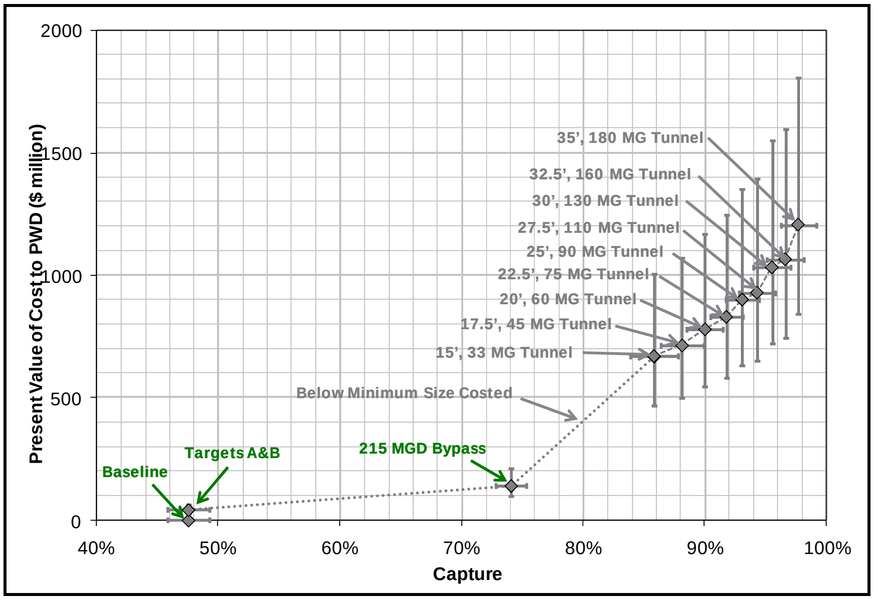


Figure 9-14 TTF Large-Scale Centralized Storage Alternative Cost-Performance Curve

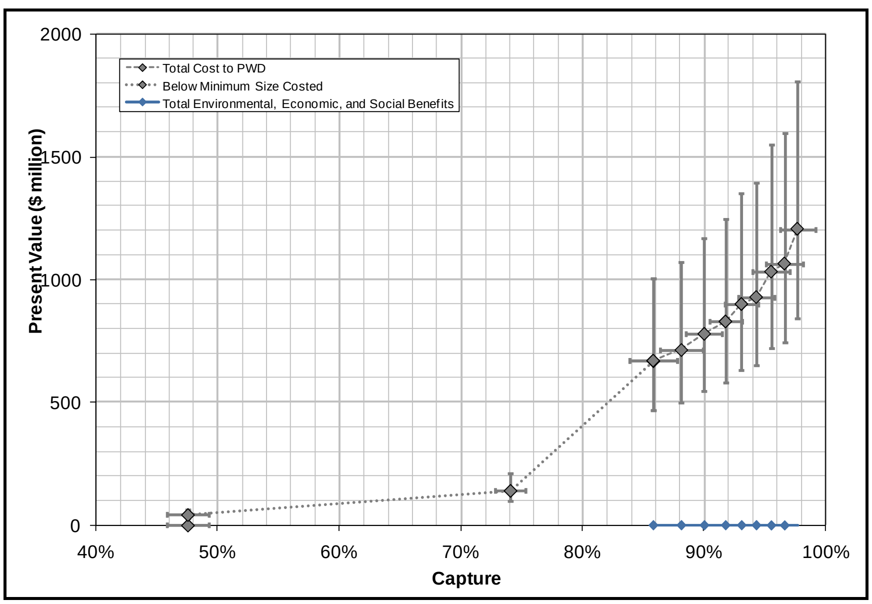


Figure 9-15 TTF Large-Scale Centralized Storage Alternative Cost-Benefit Comparison

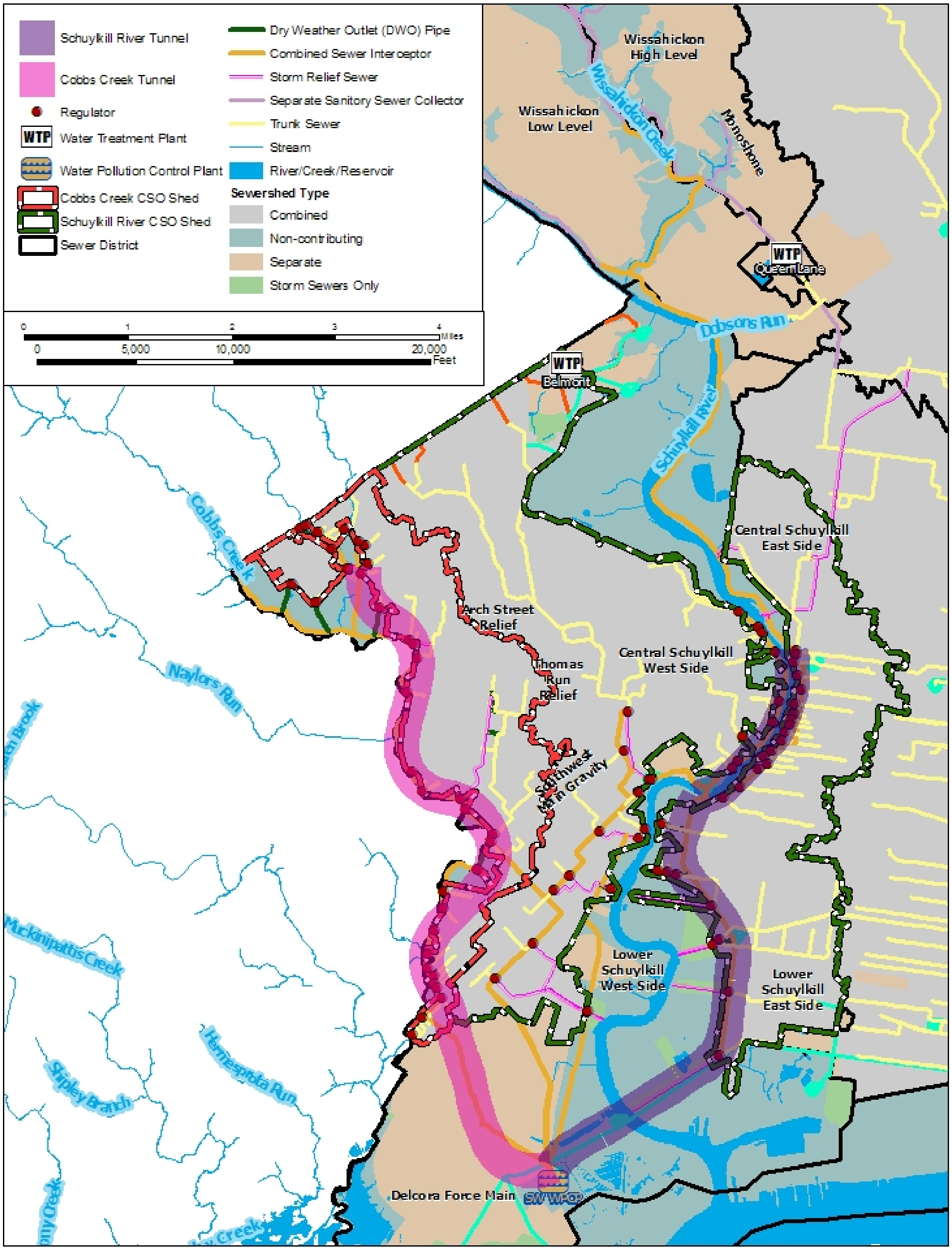


Figure 9-16 Location of TTF Large-Scale Centralized Storage Alternative

9.3.4 Large-Scale Satellite Treatment Alternative

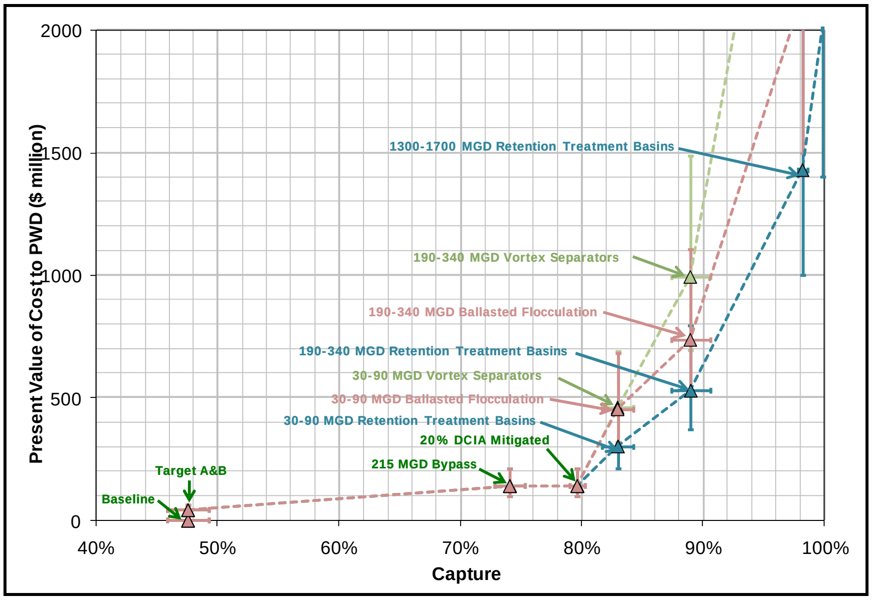


Figure 9-17 TTF Large-Scale Satellite Treatment Alternative Cost-Performance Curve

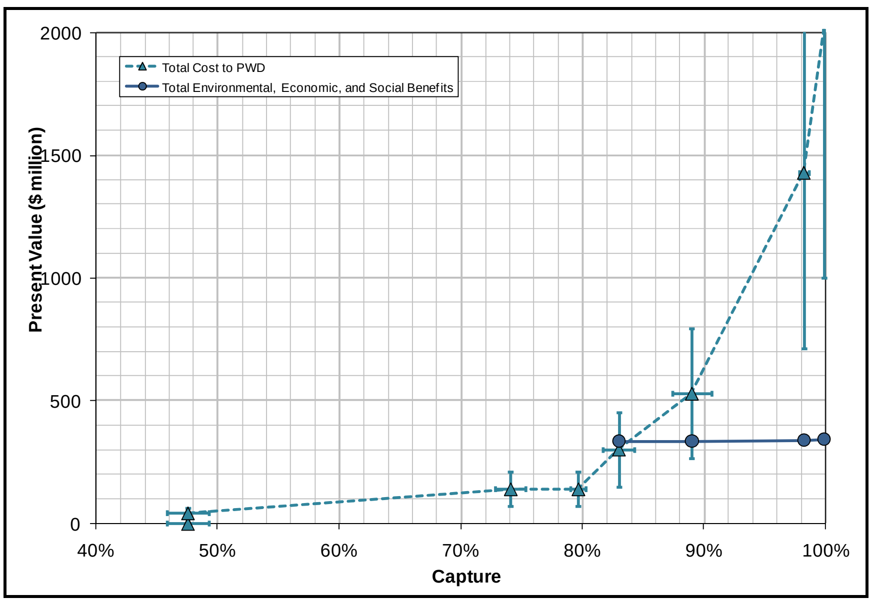


Figure 9-18 TTF Large-Scale Satellite Treatment Alternative Cost-Benefit Comparison

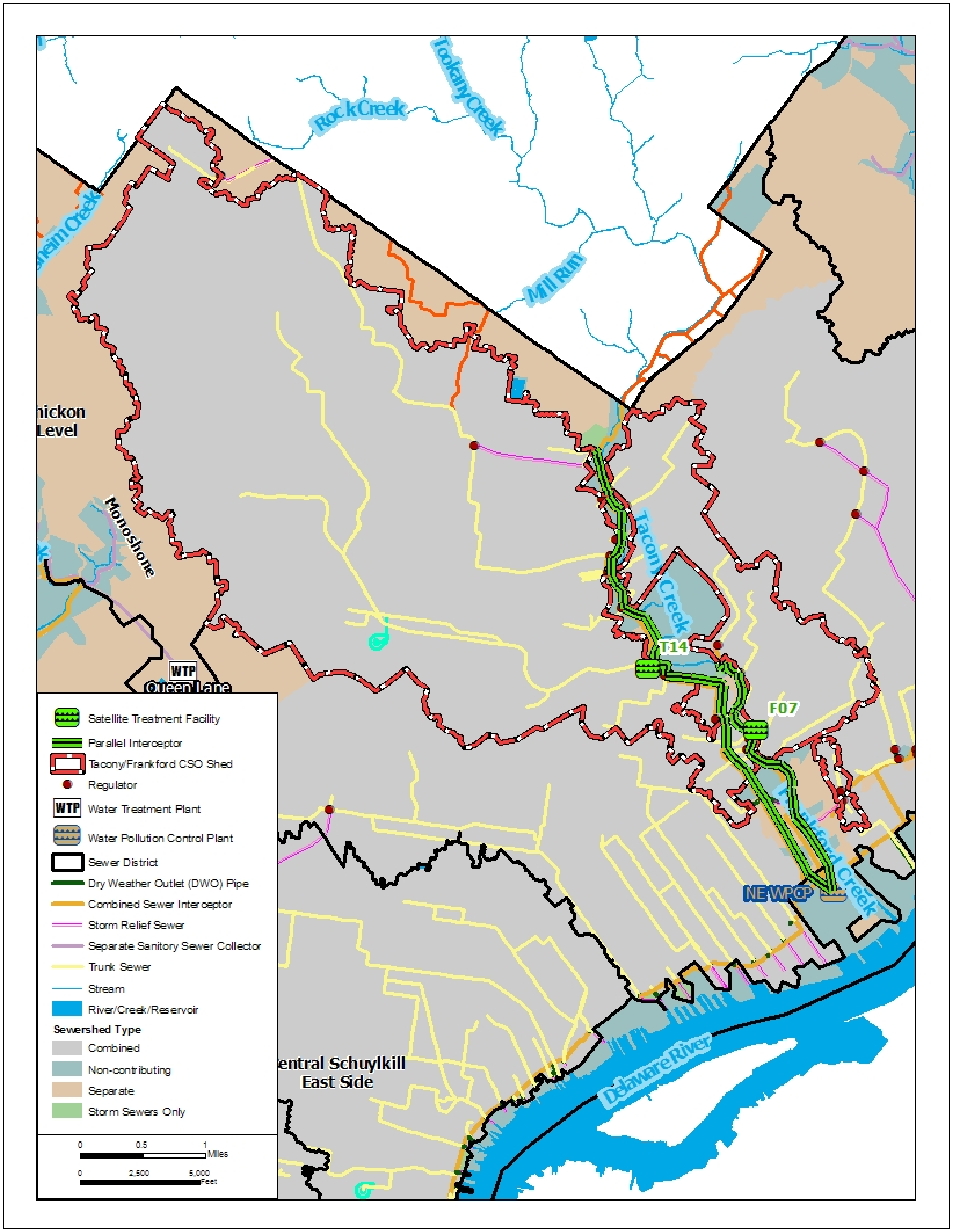


Figure 9-19 Location of TTF Large-Scale Satellite Treatment Alternative

9.4 COBBS CREEK WATERSHED

This section presents costs and benefits of each alternative in the Cobbs Watershed. For each alternative, a map (if applicable) and two graphs are presented (9-17 to 9-17). The first graph is a summary of cost to PWD and the second graph is a summary of the total private and public cost compared with the net benefits.

9.4.1 Green Stormwater Infrastructure with Targeted Traditional Infrastructure

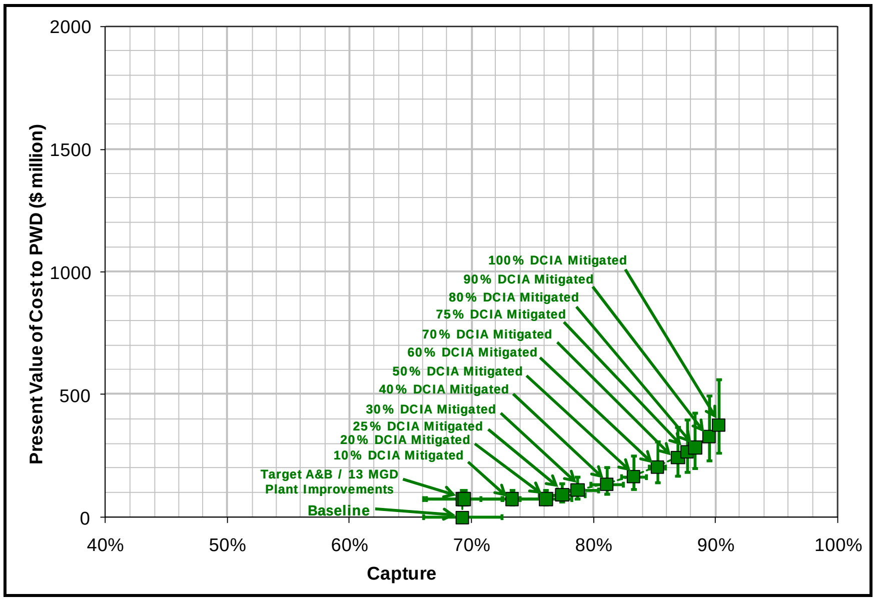


Figure 9-20 Cobbs Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost- Performance Curve

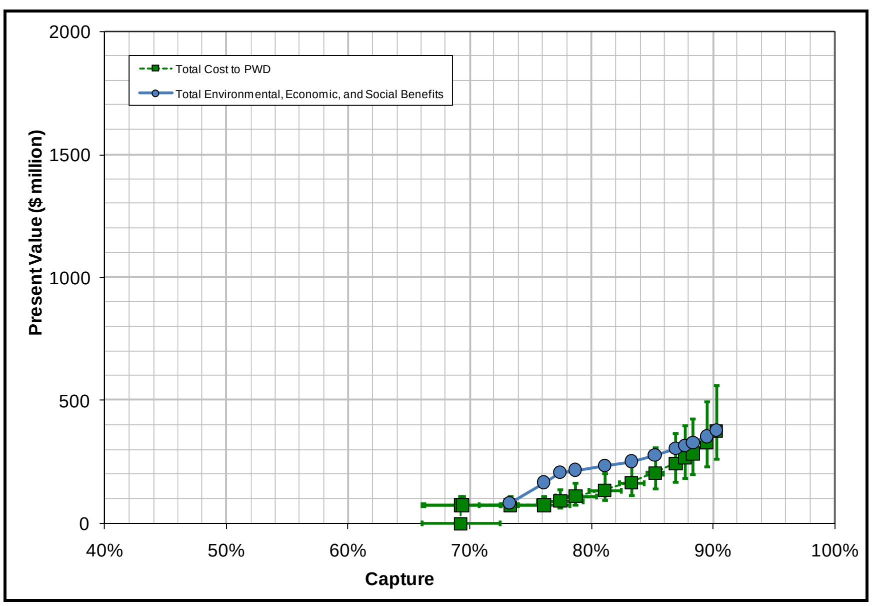


Figure 9-21 Cobbs Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost- Benefit Comparison

9.4.2 Cobbs Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

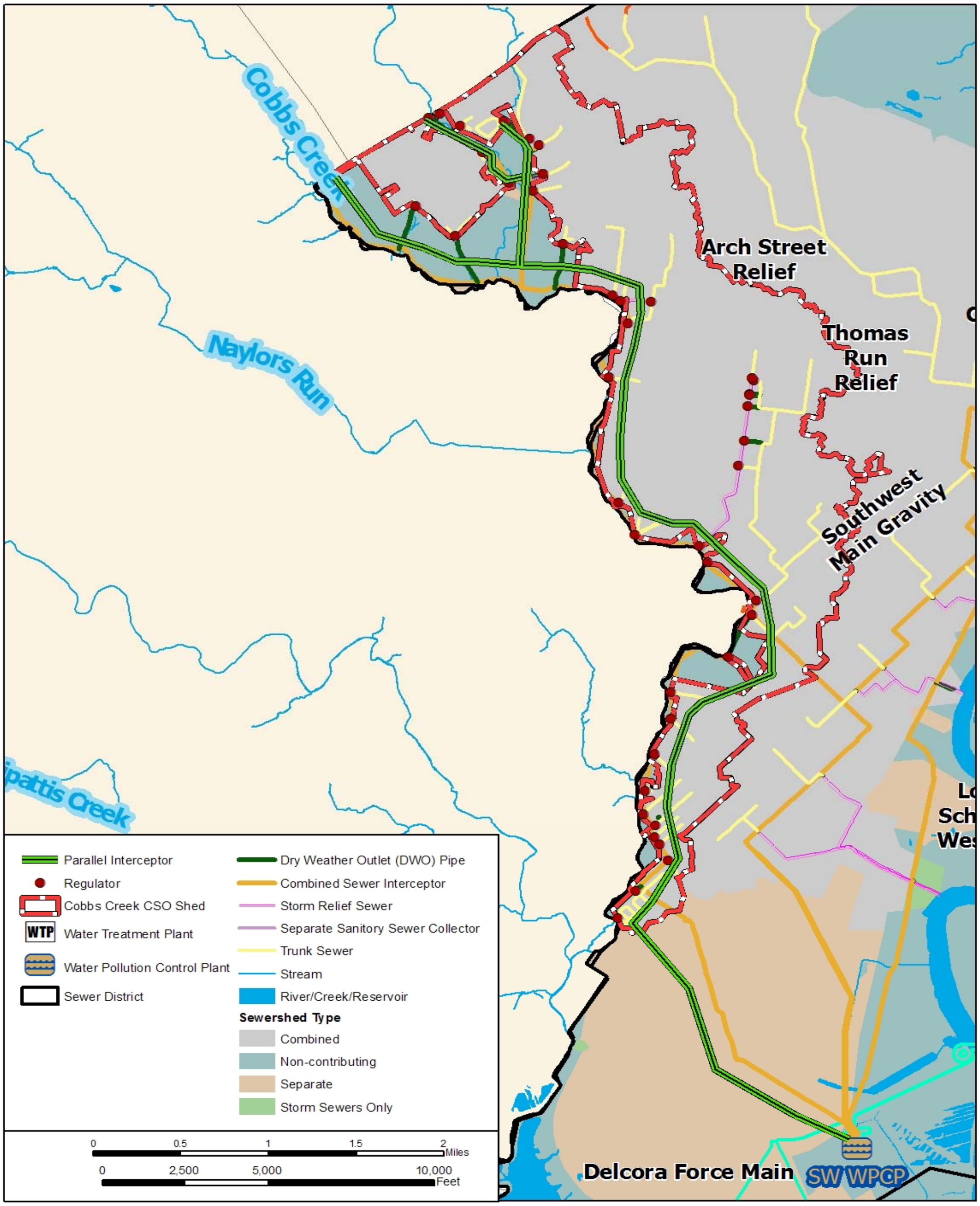


Figure 9-22 Location of Cobbs Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Alternative

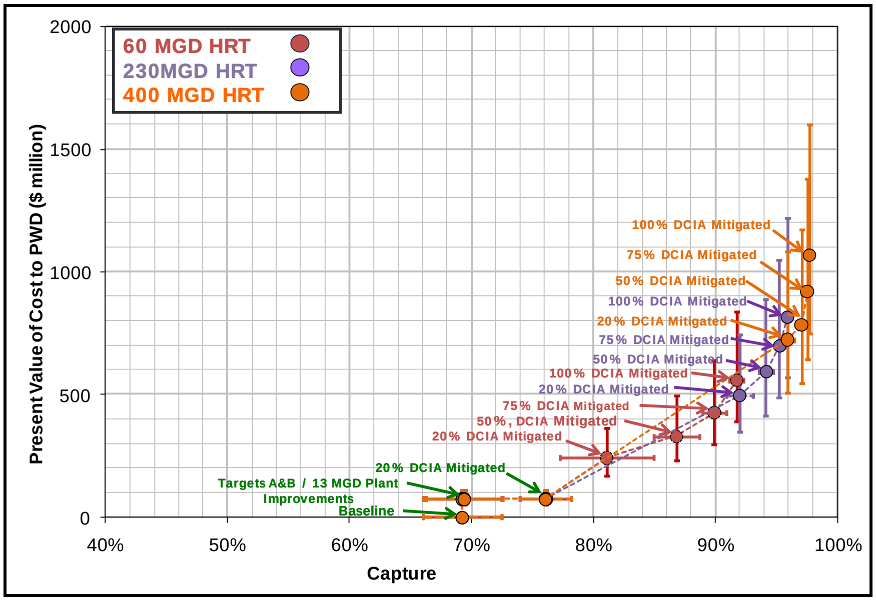


Figure 9-23 Cobbs Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Performance Curve

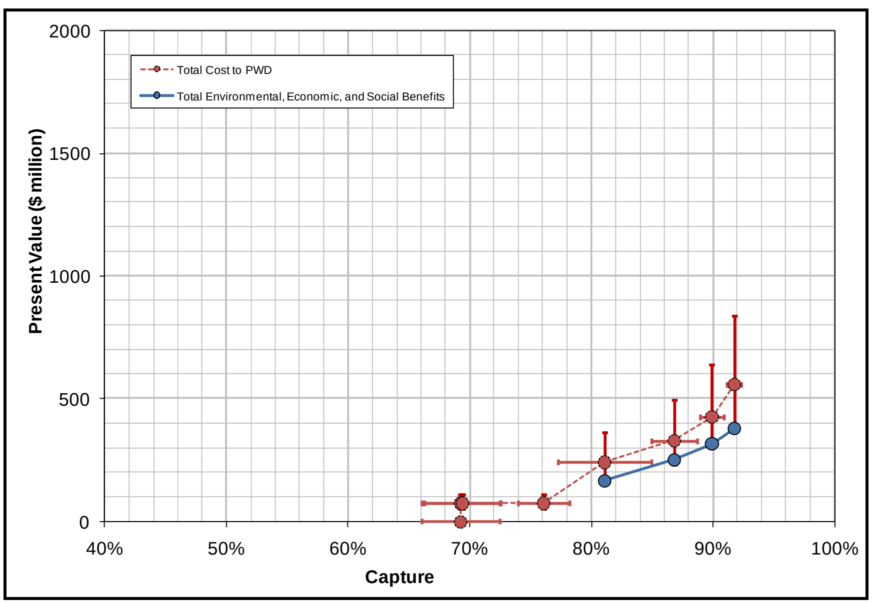


Figure 9-24 Cobbs Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Benefit Comparison

9.4.3 Cobbs/Schuylkill Large-Scale Centralized Storage Alternative

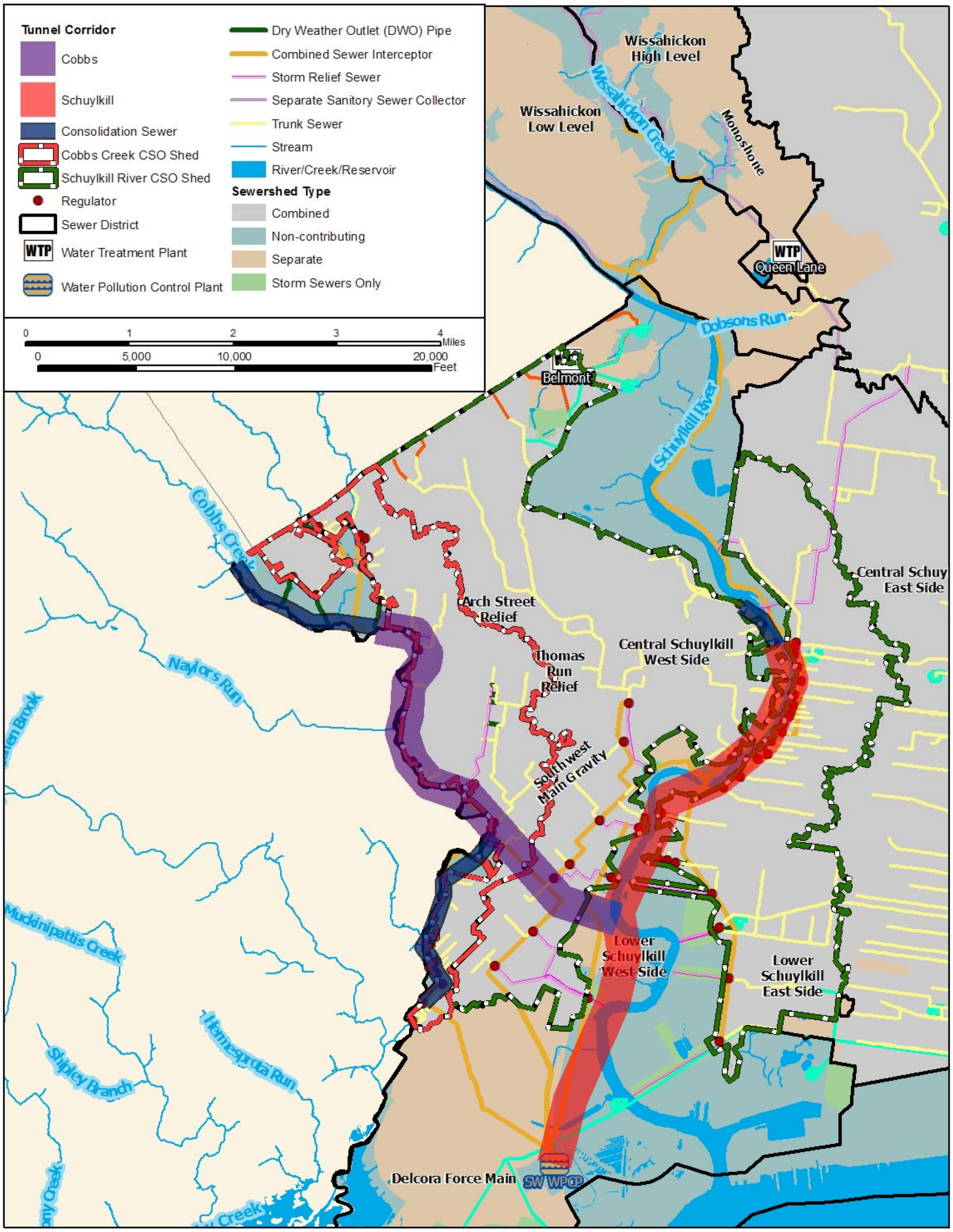


Figure 9-25 Location of Cobbs/Schuylkill Large-Scale Centralized Storage Alternative

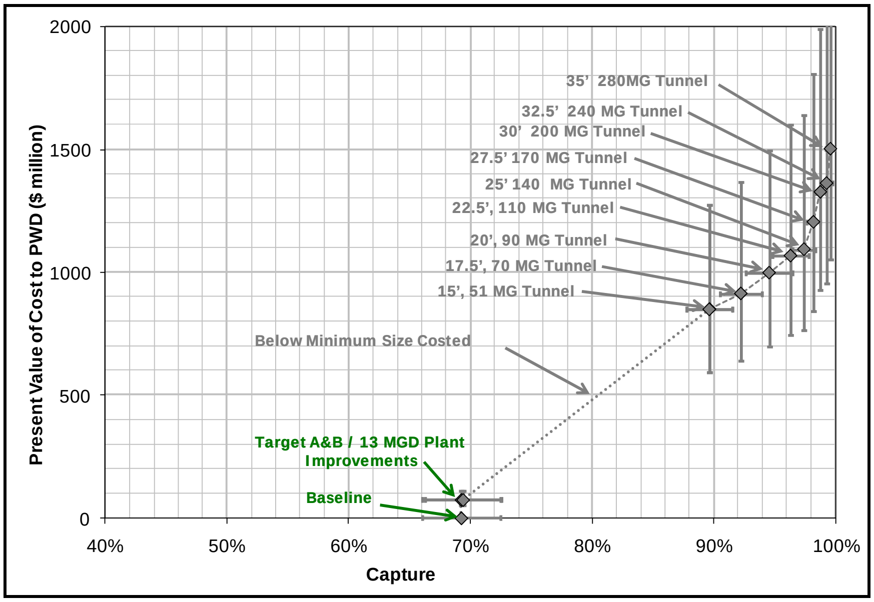


Figure 9-26 Cobbs Large-Scale Centralized Storage Alternative Cost-Performance Curve

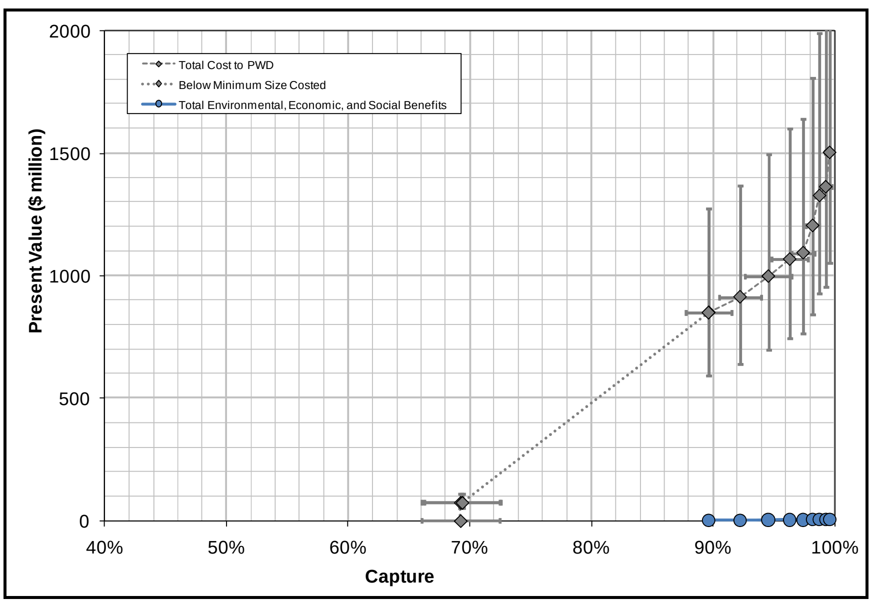


Figure 9-27 Cobbs Large-Scale Centralized Storage Alternative Cost-Benefit Comparison

9.4.4 Large-Scale Satellite Treatment Alternative

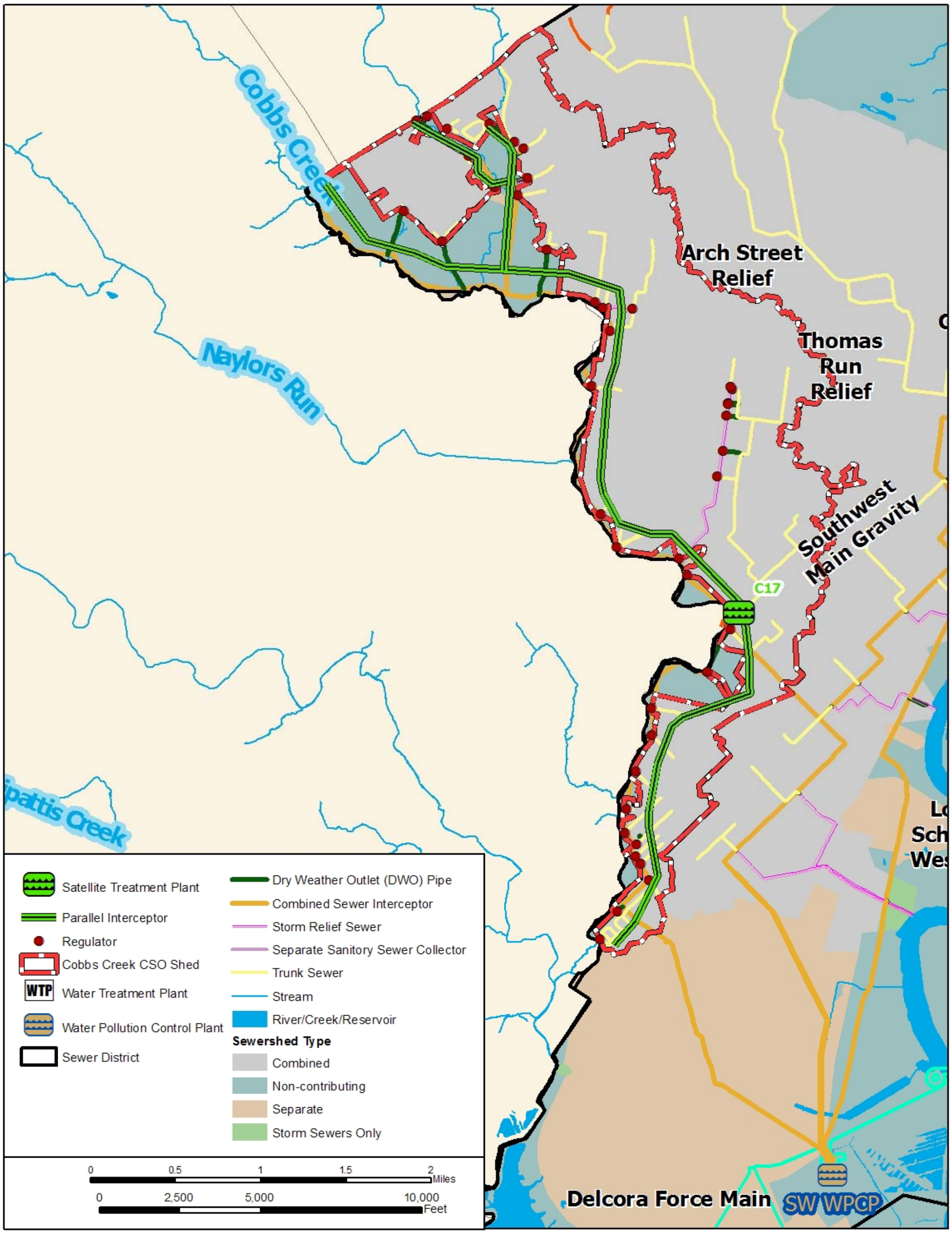


Figure 9-28 Location of Large-Scale Satellite Treatment Alternative

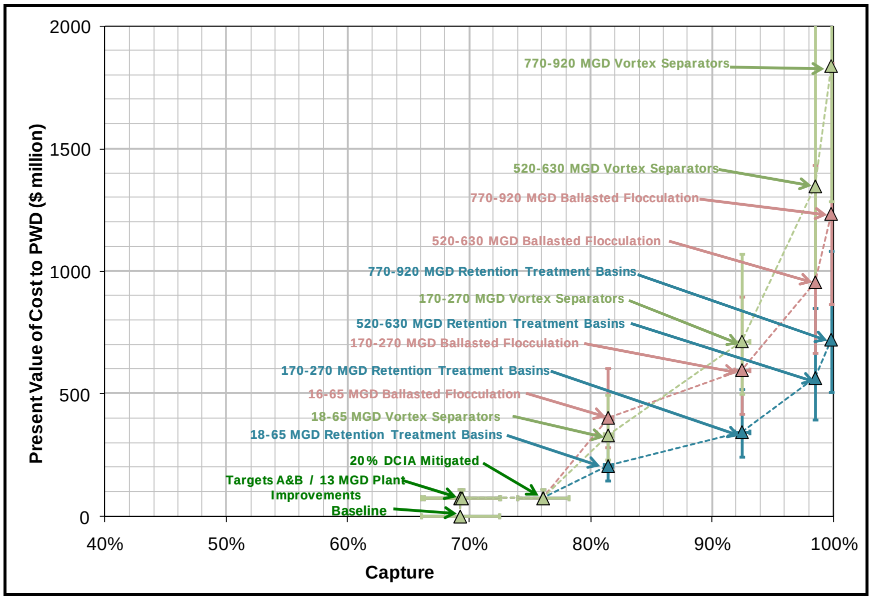


Figure 9-29 Cobbs Large-Scale Satellite Treatment Alternative Cost-Performance Curve

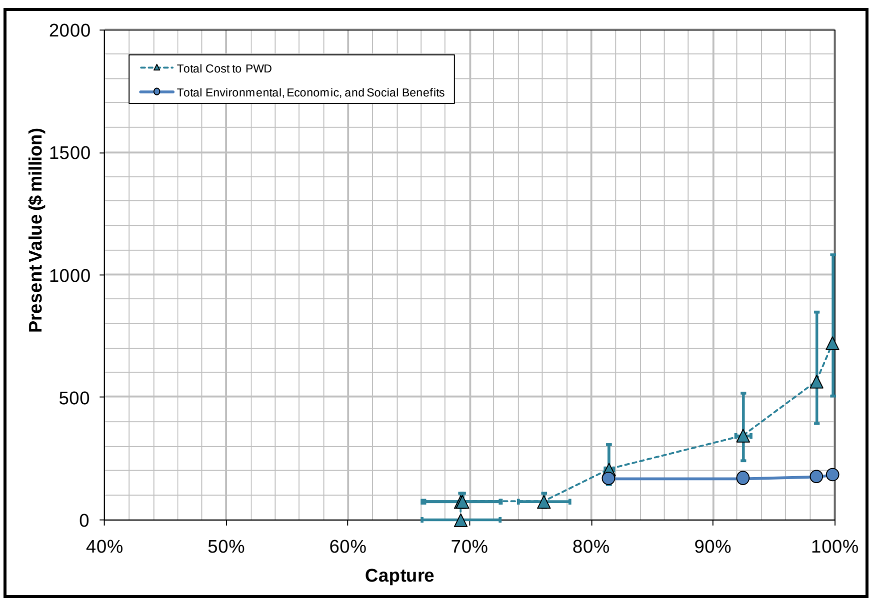


Figure 9-30 Cobbs Large-Scale Satellite Treatment Alternative Cost-Benefit Comparison

9.5 DELAWARE RIVER DIRECT WATERSHED

This section presents costs and benefits of each alternative in the Delaware River Watershed. For each alternative, a map (if applicable) and two graphs are presented (9-28 to 9-38). The first graph is a summary of cost to PWD and the second graph is a summary of the total private and public cost compared with the net benefits.

9.5.1 Green Stormwater Infrastructure with Targeted Traditional Infrastructure

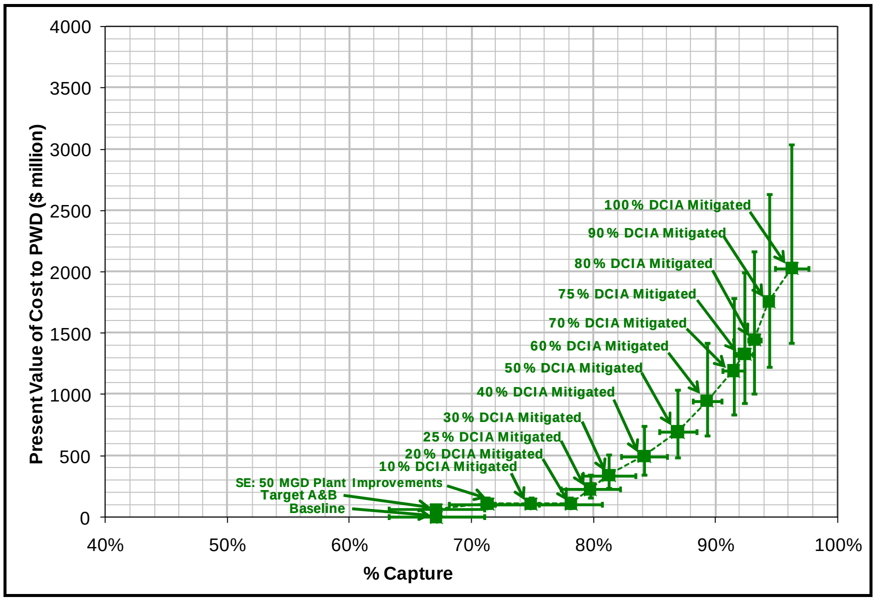


Figure 9-31 Delaware Direct Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Performance Curve

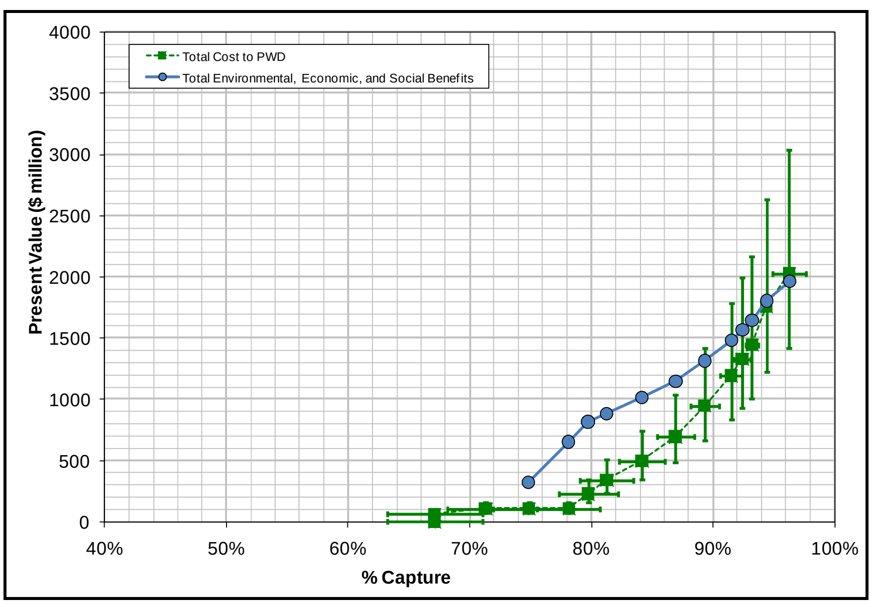


Figure 9-32 Delaware Direct Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Benefit Comparison

9.5.2 Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

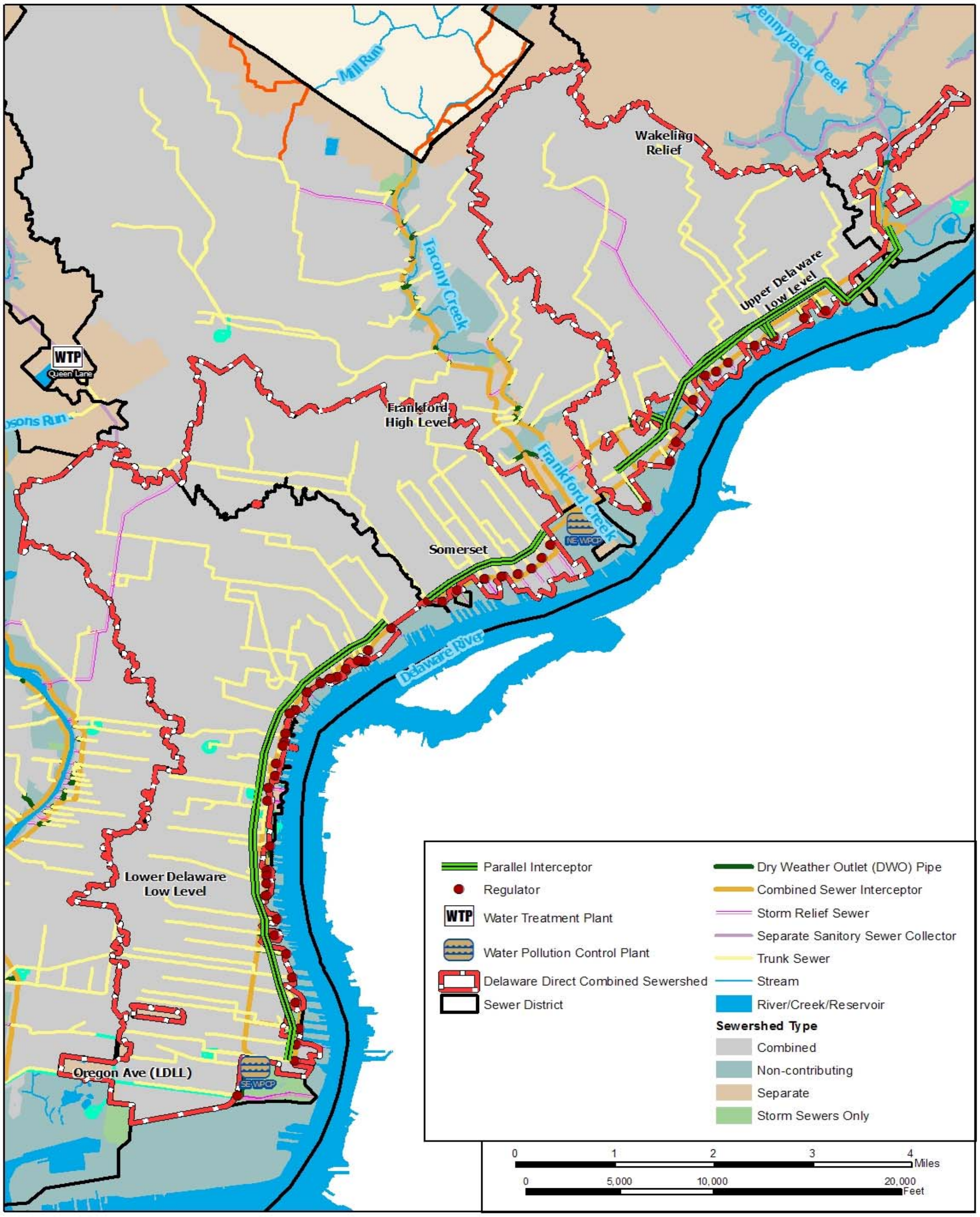


Figure 9-33 Location of Delaware Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Alternative

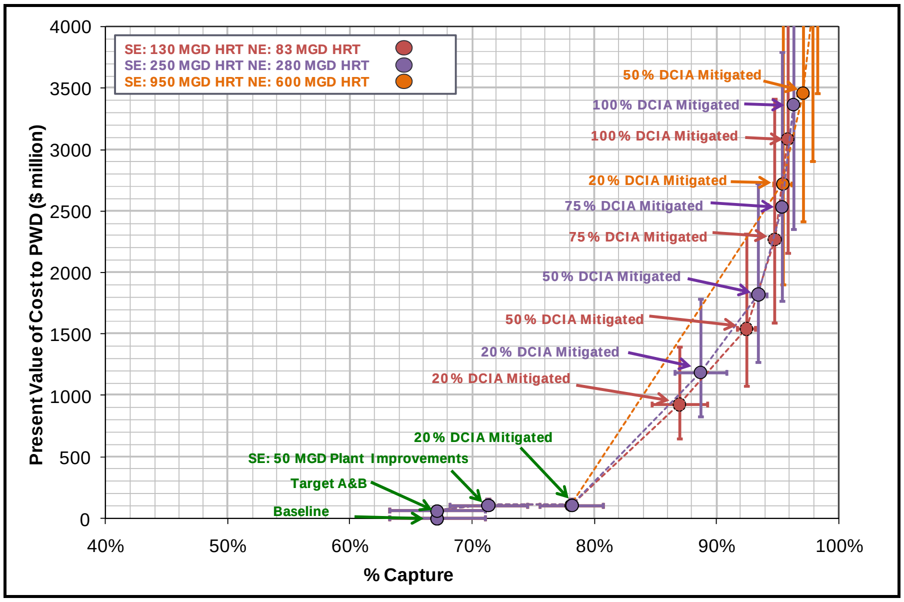


Figure 9-34 Delaware Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Performance Curve

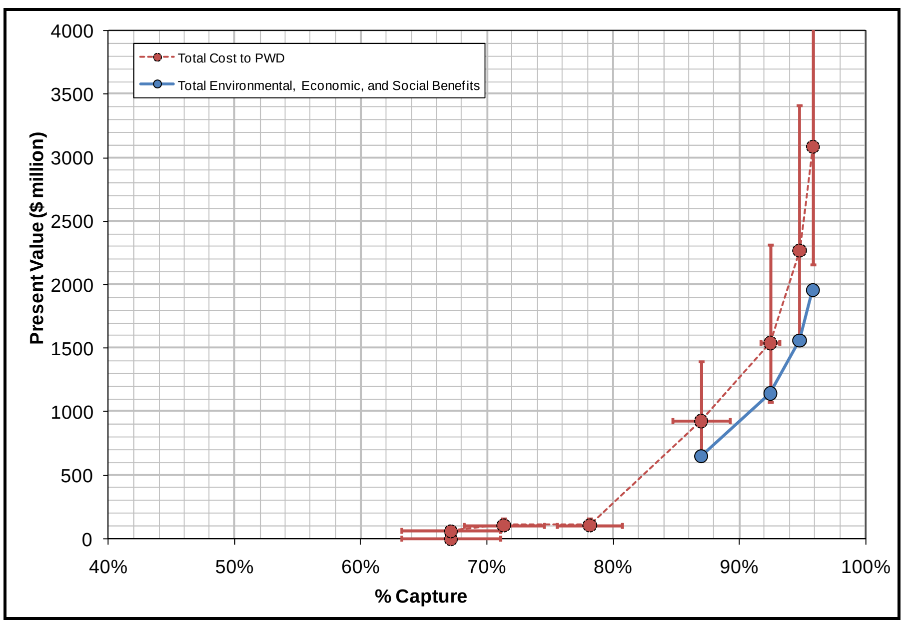


Figure 9-35 Delaware Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Benefit Comparison

9.5.3 Large-Scale Centralized Storage Alternative

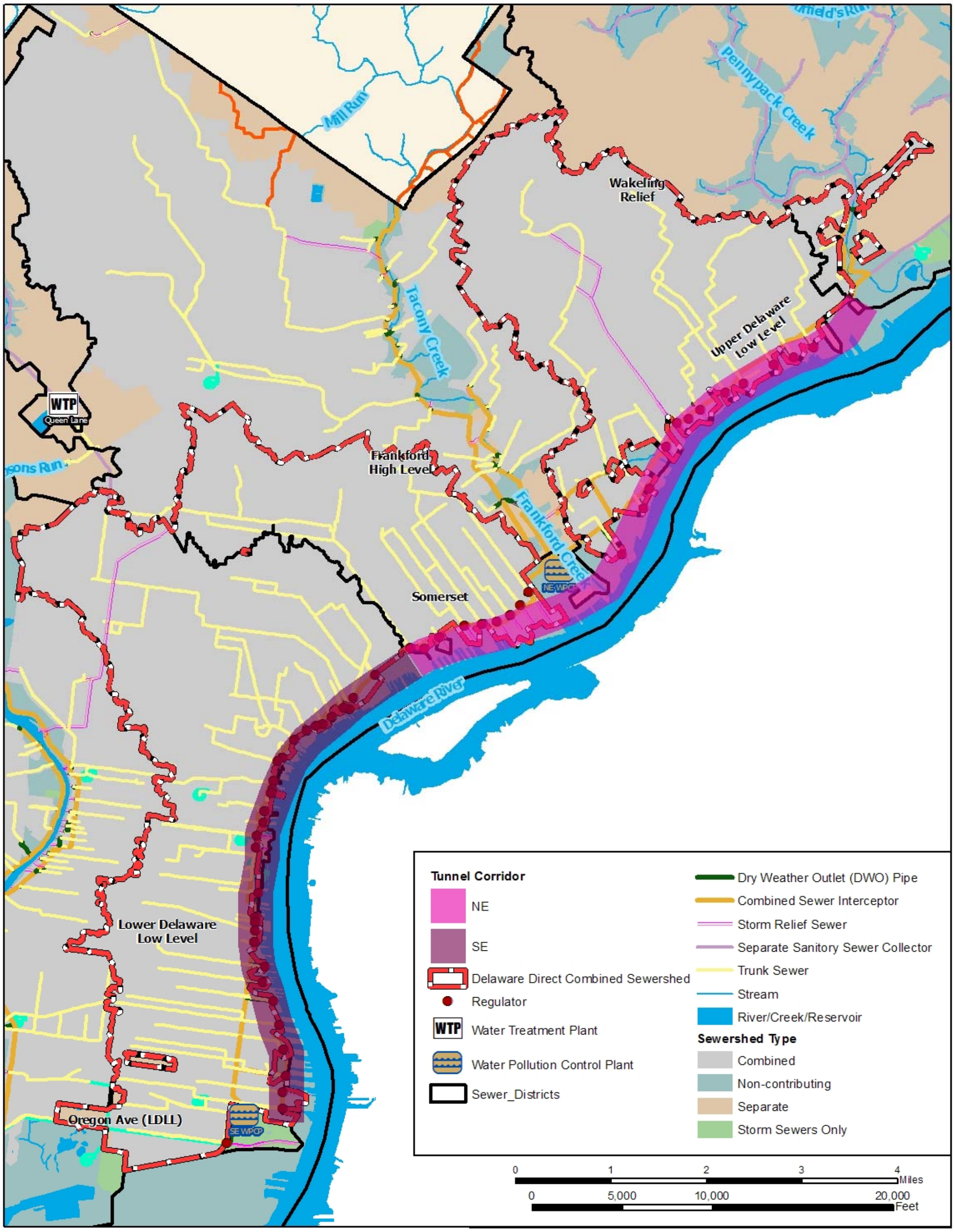


Figure 9-36 Location of Delaware Direct Large-Scale Centralized Storage Alternative

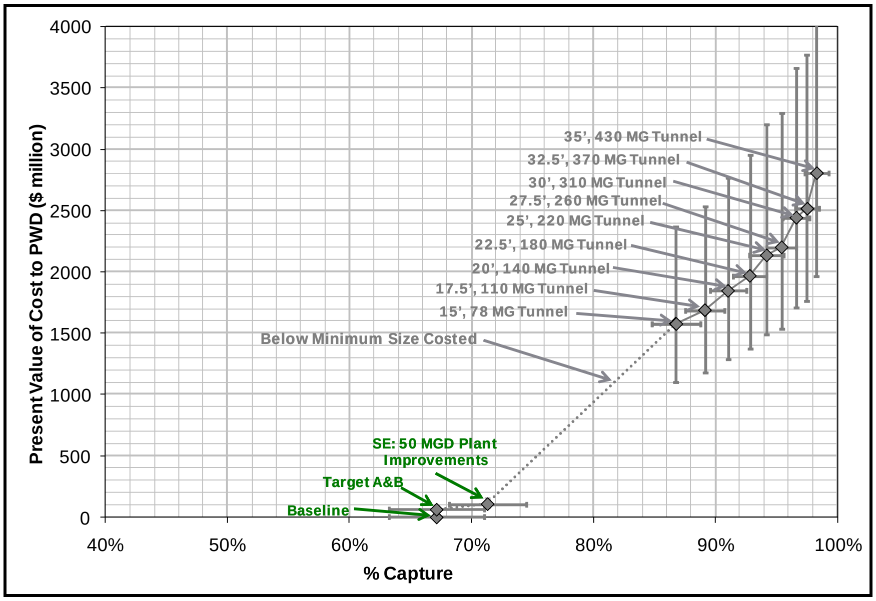


Figure 9-37 Delaware Direct Large-Scale Centralized Storage Alternative Cost-Performance Curve

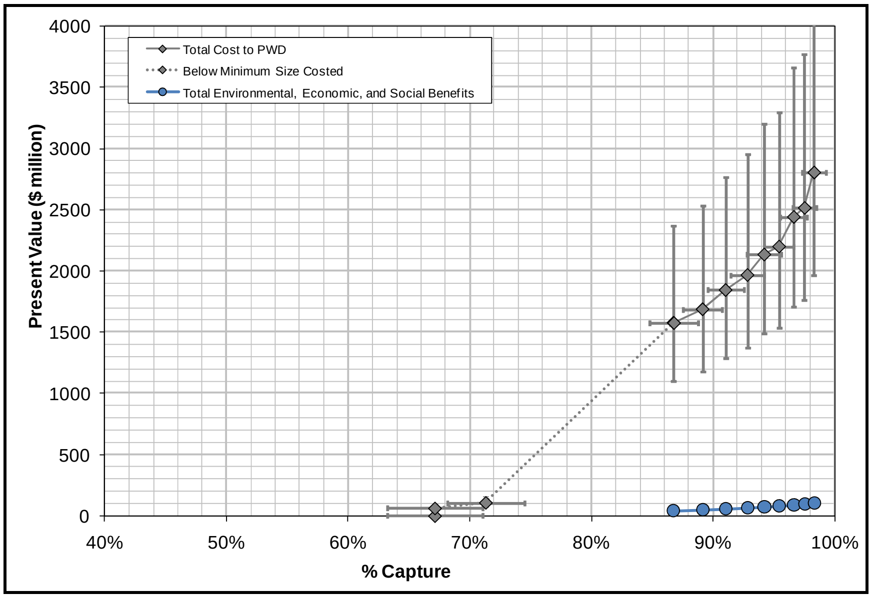


Figure 9-38 Delaware Direct Large-Scale Centralized Storage Alternative Cost-Benefit Comparison

9.5.4 Large-Scale Satellite Treatment Alternative

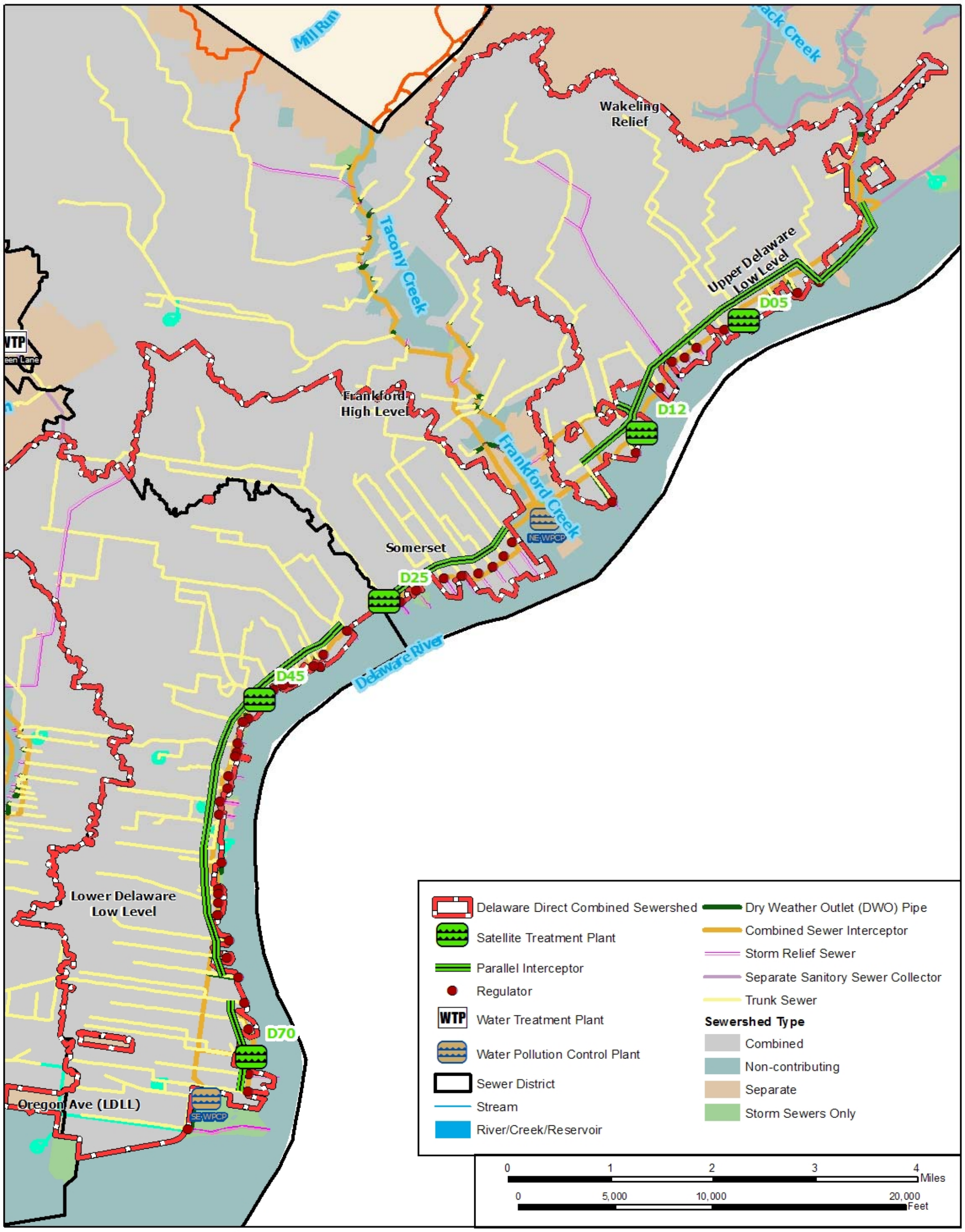


Figure 9-39 Location of Delaware Direct Large-Scale Satellite Treatment Alternative

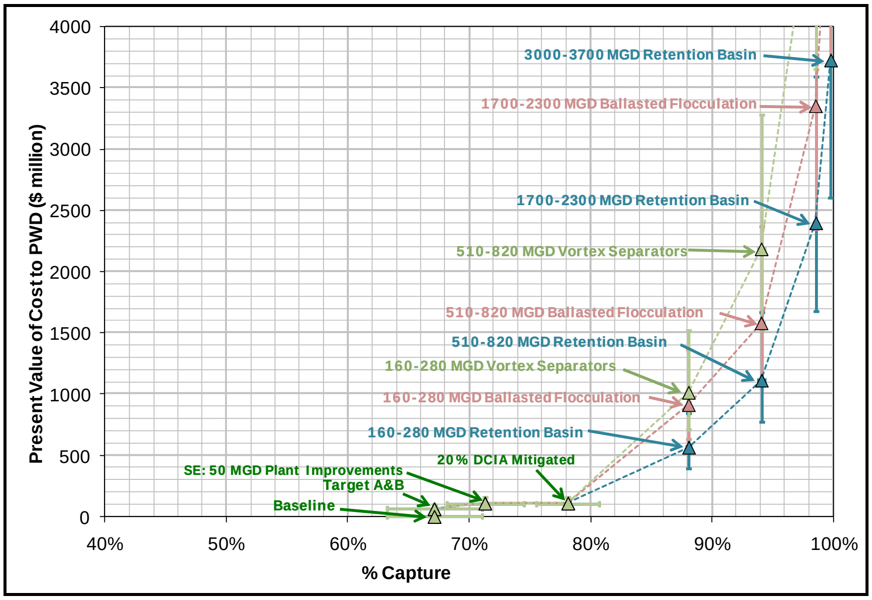


Figure 9-40 Delaware Direct Large-Scale Satellite Treatment Alternative Cost-Performance Curve

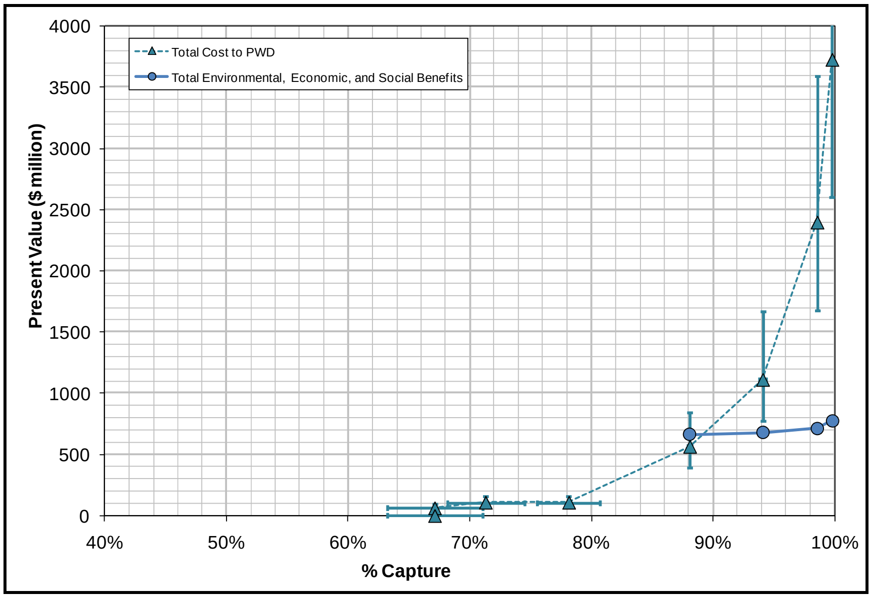


Figure 9-41 Delaware Direct Large-Scale Satellite Treatment Alternative Cost-Benefit Comparison

9.6 Schuylkill River Direct Watershed

This section presents costs and benefits of each alternative in the Schuylkill River Watershed. For each alternative, a map (if applicable) and two graphs are presented (9-39 to 9-49). The first graph is a summary of cost to PWD and the second graph is a summary of the total private and public cost compared with the net benefits.

9.6.1 Green Stormwater Infrastructure with Targeted Traditional Infrastructure

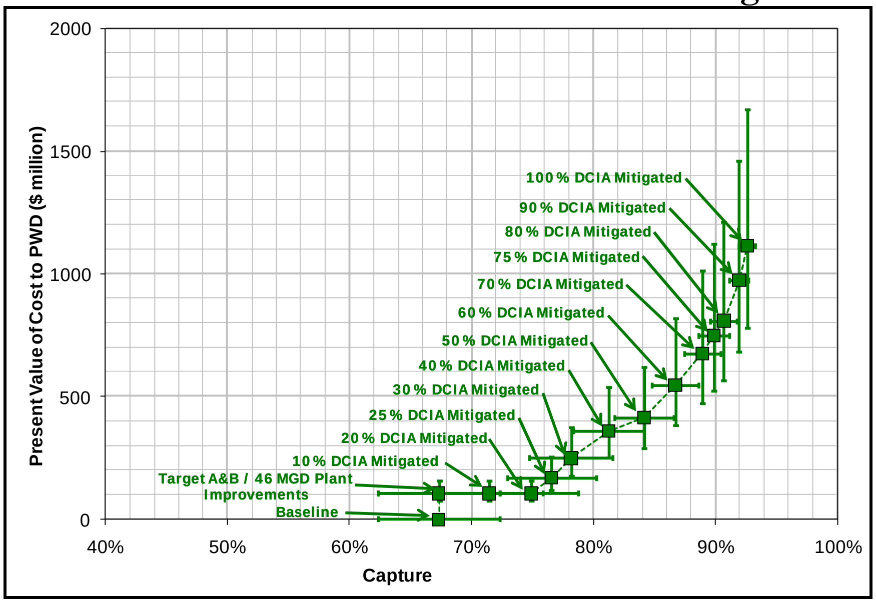


Figure 9-42 Schuylkill Direct Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Performance Curve

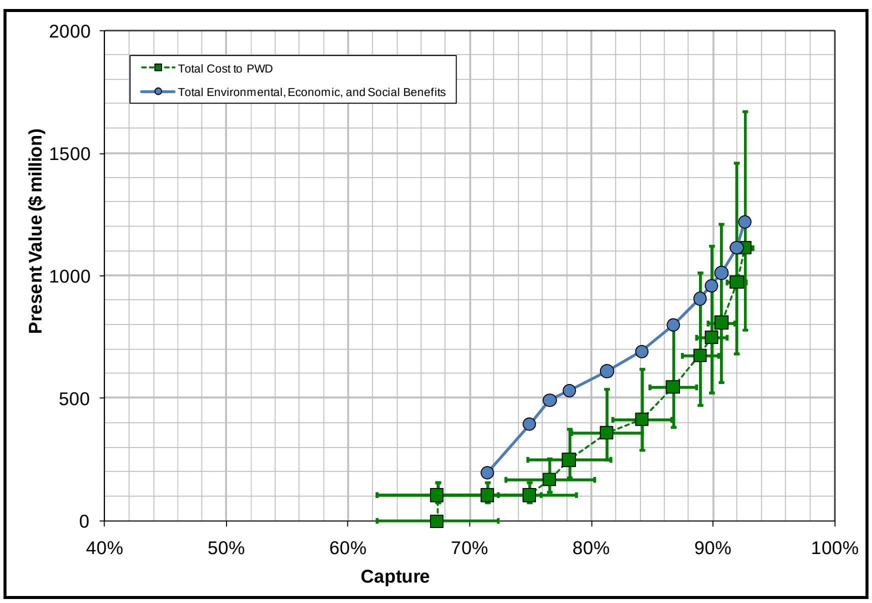


Figure 9-43 Schuylkill Direct Green Stormwater Infrastructure with Targeted Traditional Infrastructure Cost-Benefit Comparison

9.6.2 Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity

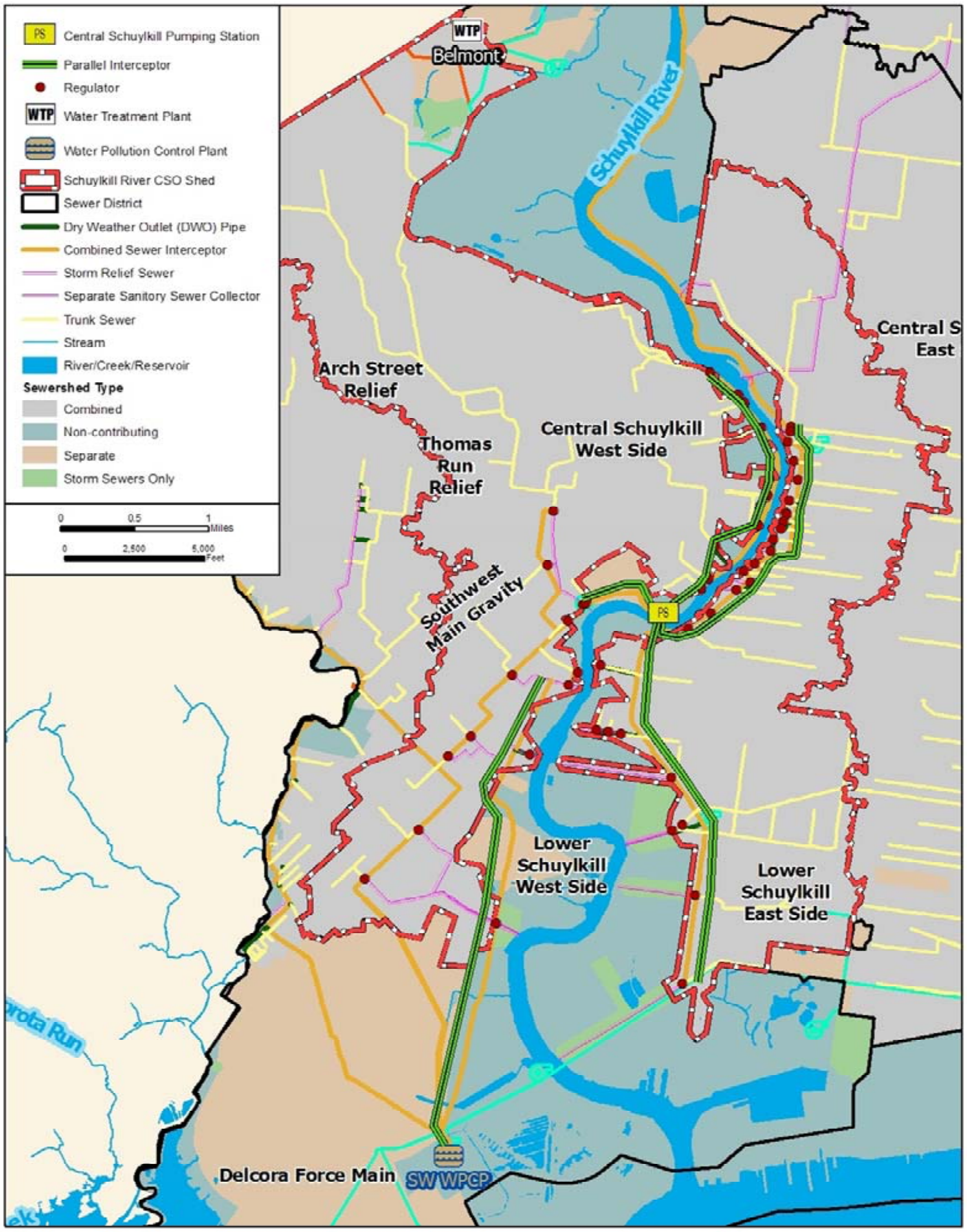


Figure 9-44 Location of Schuylkill Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Alternative

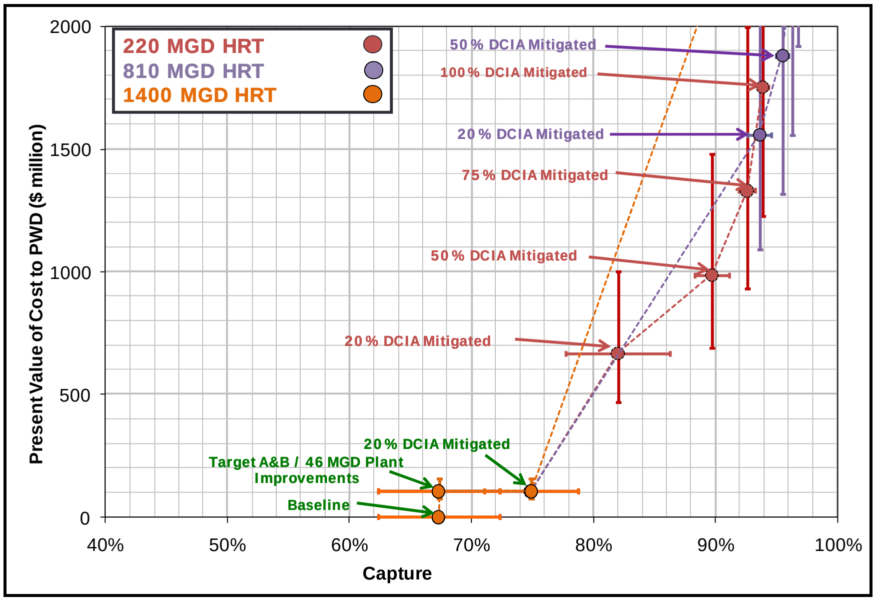


Figure 9-45 Schuylkill Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Performance Curve

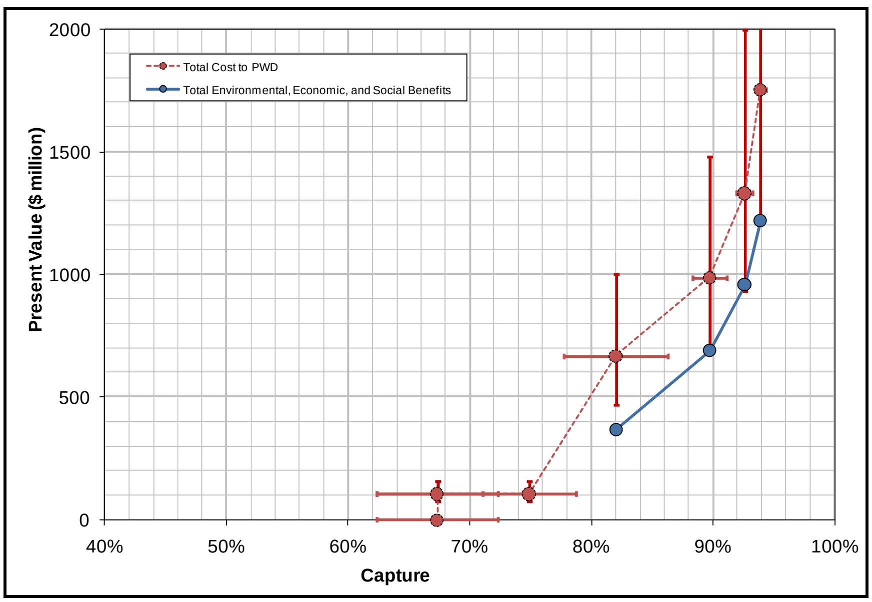


Figure 9-46 Schuylkill Direct Green Stormwater Infrastructure with Increased Transmission and Treatment Capacity Cost-Benefit Comparison

9.6.3 Large-Scale Centralized Storage Alternative

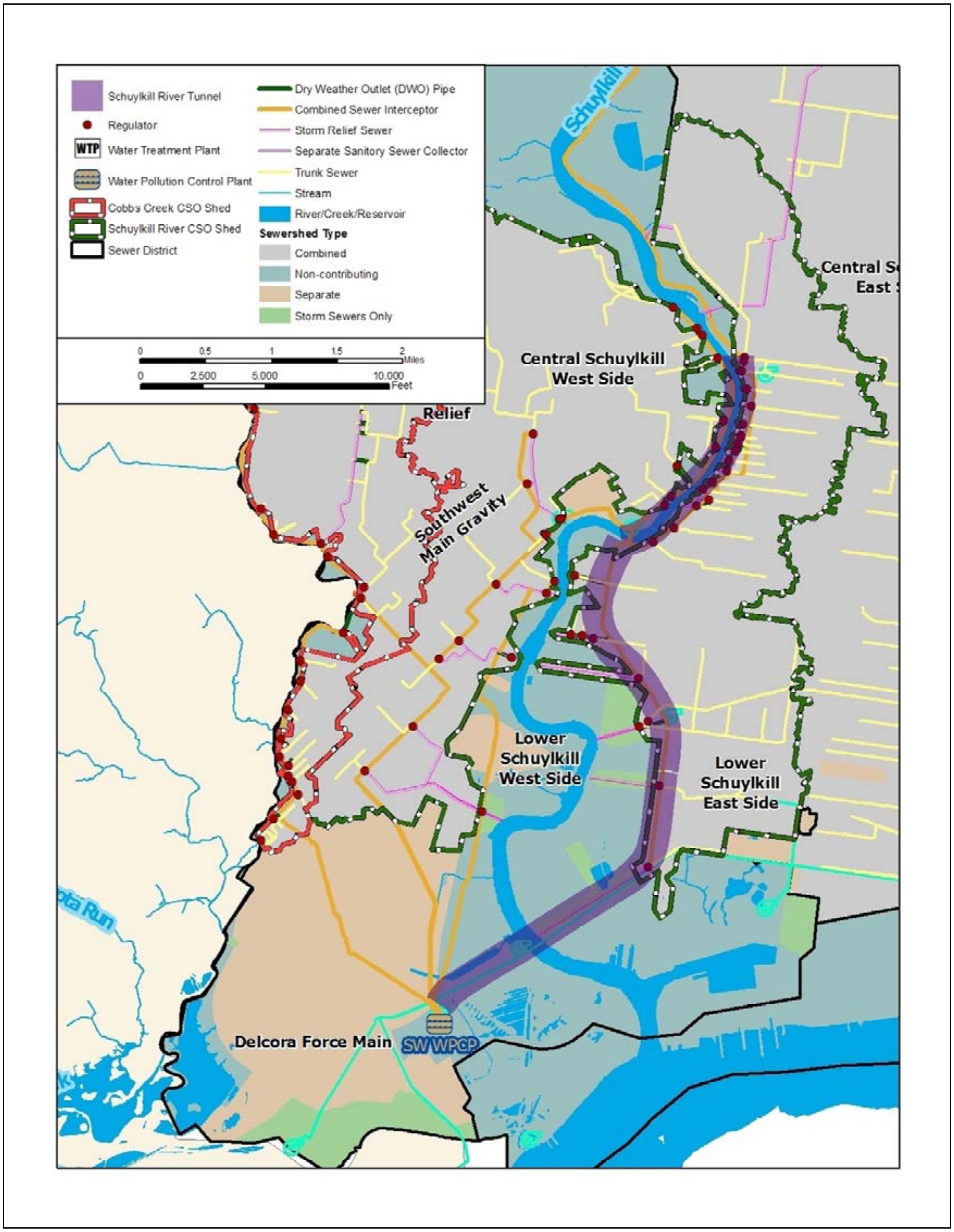


Figure 9-47 Location of Schuylkill Direct Large-Scale Centralized Storage Alternative

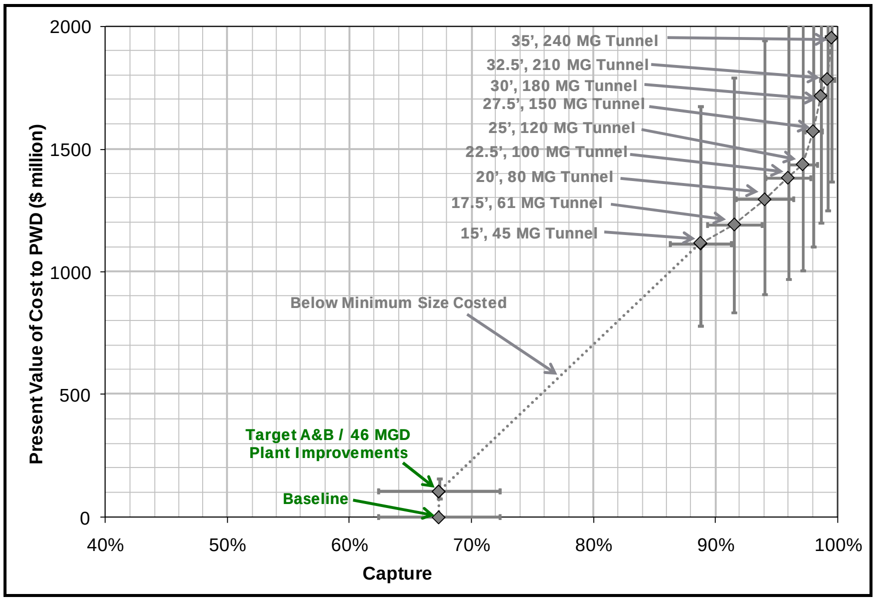


Figure 9-48 Schuylkill Direct Large-Scale Centralized Storage Alternative Cost-Performance Curve

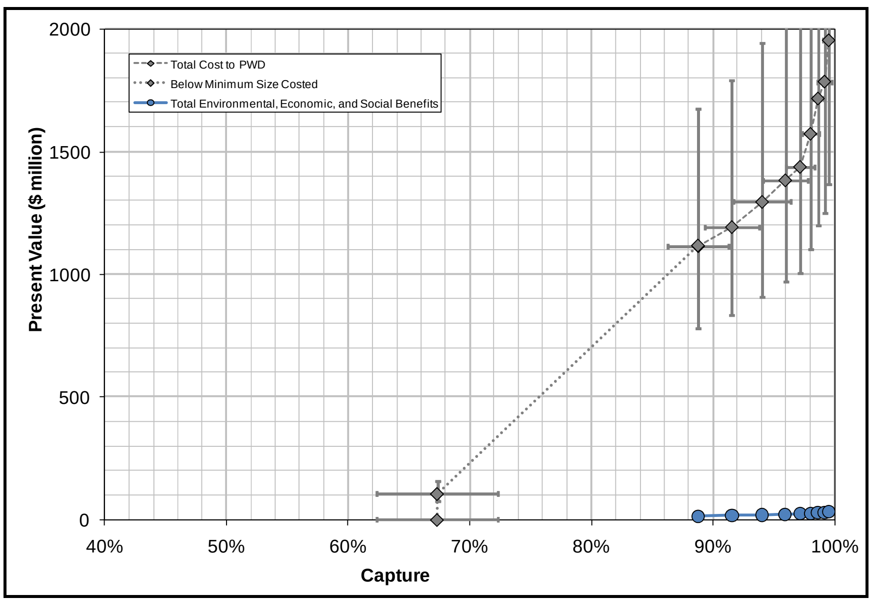


Figure 9-49 Schuylkill Direct Large-Scale Centralized Storage Alternative Cost-Benefit Comparison

9.6.4 Large-Scale Satellite Treatment Alternative

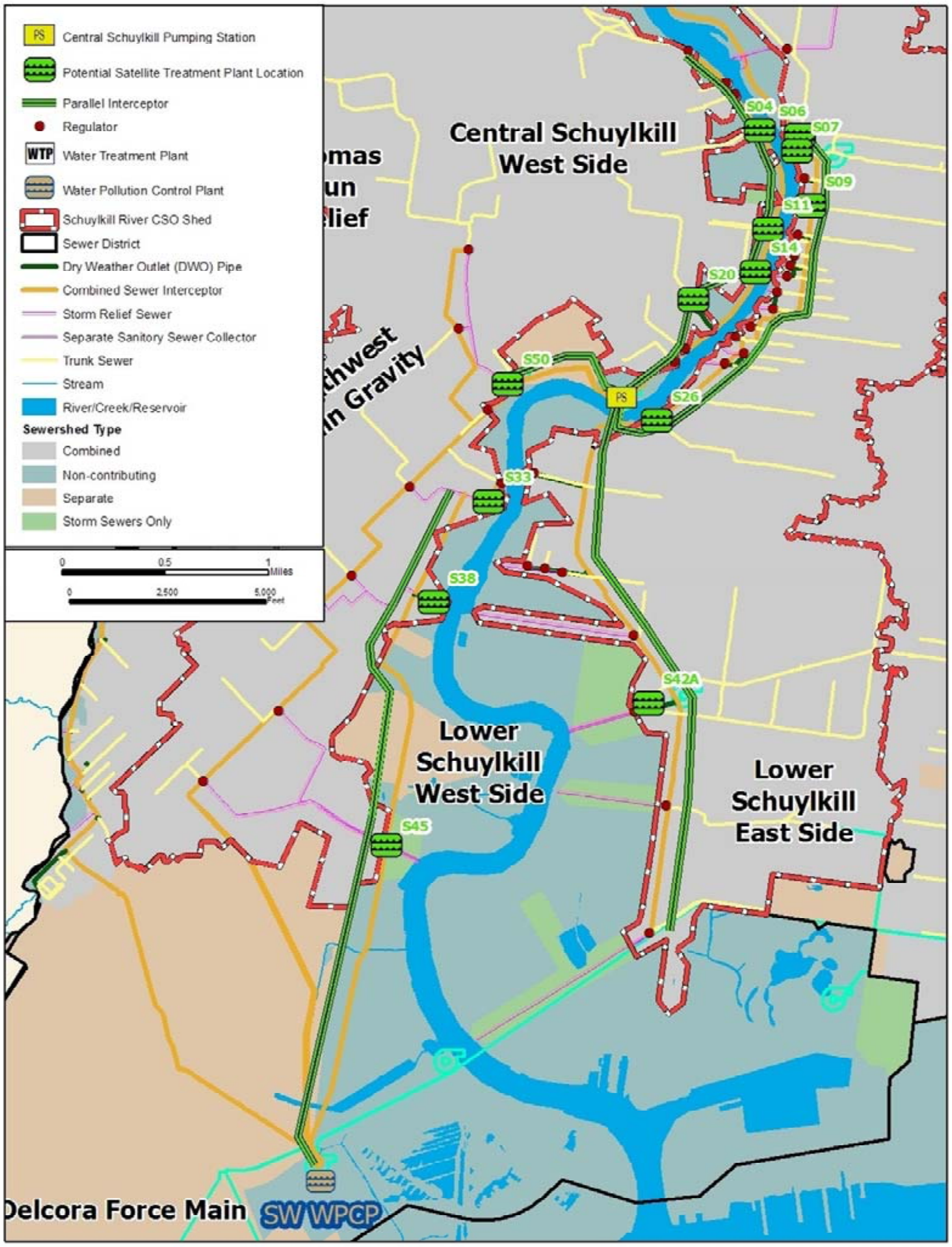


Figure 9-50 Location of Schuylkill Direct Large-Scale Satellite Treatment Alternative

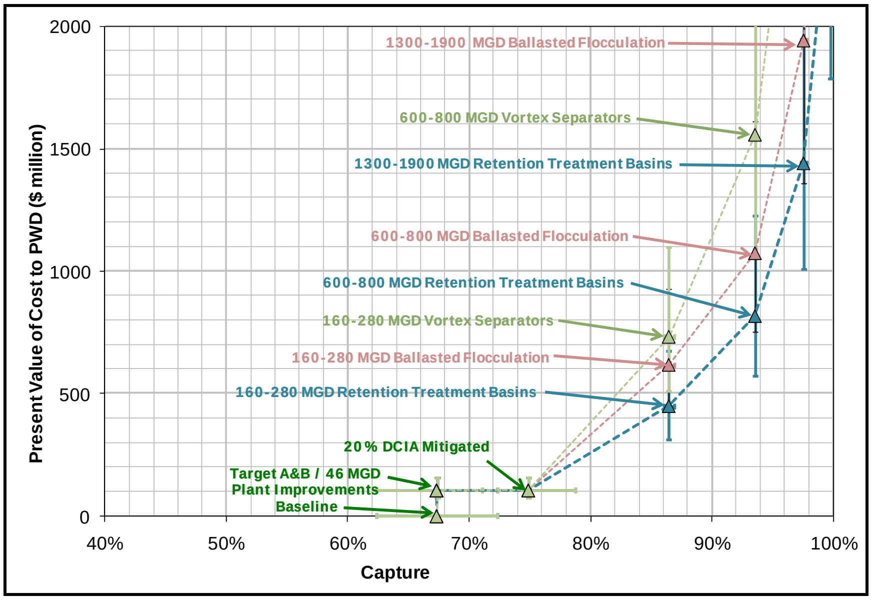


Figure 9-51 Schuylkill Direct Large-Scale Satellite Treatment Alternative Cost-Performance Curve

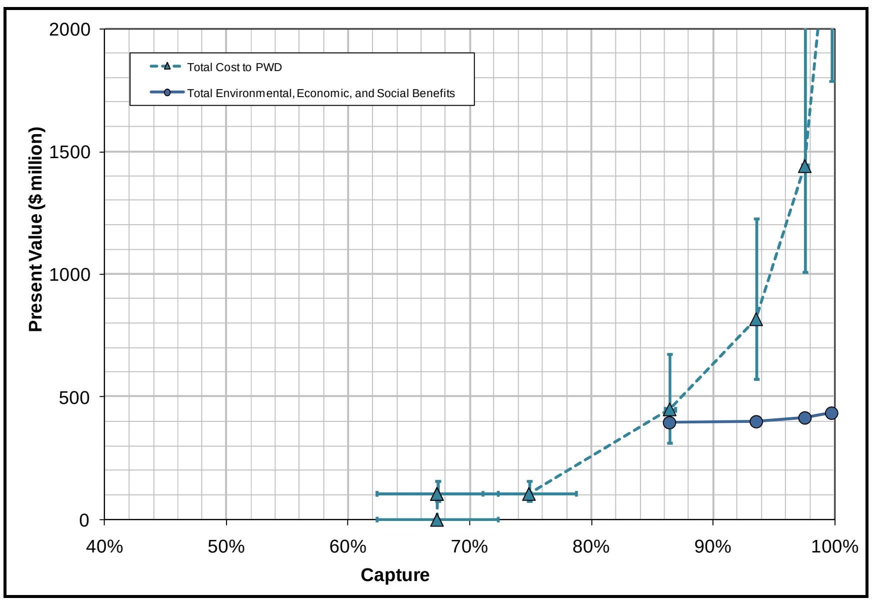


Figure 9-52 Schuylkill Direct Large-Scale Satellite Treatment Alternative Cost-Benefit Comparison

10 RECOMMENDED PLAN ELEMENTS

10.1 SUMMARY OF THE ALTERNATIVES EVALUATION

This section summarizes the results of the alternatives analysis and presents the rationale for the selected alternative. The alternative evaluation process is designed to select the alternative that represents the best balance among performance, cost, affordability, sustainability, social/ environmental benefits, public support and practical factors such as constructability. The detailed cost and benefit information presented in Section 9 and the screening criteria presented in Section 5 are used to compare the alternatives. Of equal importance to these factors, however, is the opportunity that PWD's selected alternative provides to address modern challenges to managing water resources and infrastructure in a sustainable way. That supports PWD's larger goal of helping the City to recreate itself as a 21st Century Sustainable City. PWD's recommended alternative provides a clear pathway to a sustainable and resilient future while strengthening the utility, broadening its mission and complying with environmental laws and regulations.

10.1.1 Evaluating Within a Watershed Planning Context

PWD developed their concept of regional watershed management planning after recognizing that, as the downstream most entity in each of the watersheds draining to the City of Philadelphia, the necessary long-term sustainable improvements to water quality and habitat within each waterway could not be achieved cost effectively without watershed-wide stakeholder and agency support.

Watershed management fosters the coordinated implementation of programs that address and manage stormwater, while also looking to control sources of pollution, reduce polluted runoff, promote managed growth in the City and surrounding areas, protect the region's drinking water supply, and improve fishing and other recreational opportunities. This must be accomplished while addressing a multitude of overlapping regulatory requirements, including the United States Environmental Protection Agency's (US EPA's) Combined Sewer Overflow (CSO) Control Policy, Phase I and Phase II Stormwater Regulations, PA Act 167 Stormwater Management, Total Maximum Daily Loads (TMDLs), PA Act 537 Sewage Facilities Planning and drinking water source protection programs. The planning must take place within the context of a host of non-regulatory planning processes and initiatives, including existing municipal and conservation planning efforts such as River Conservation Plans, Open Space Plans, and municipal comprehensive plans. Just as important, the planning process must address stakeholder goals. Implementation of this Long Term CSO Plan Update (LTCPU) commitment is just one part of PWD's larger, watershed-based commitment.

PWD has committed to development of Integrated Watershed Management Plans (IWMPs) for each of the five major tributary streams of the Schuylkill and Delaware Rivers that drain through the City of Philadelphia, including the Cobbs, Tookany/Tacony-Frankford (TTF), Wissahickon, Pennypack and Poquessing. Most recently, PWD has committed to developing watershed-based plans for the City of Philadelphia portions of the Schuylkill and Delaware River systems as well. To date, IWMPs have been developed for the Cobbs and TTF Watersheds.

PWD's IWMP development process is based on a carefully crafted approach to meeting the challenges of watershed management in an urban setting. The primary intent of the planning process is to improve the environmental health and safe enjoyment of the watershed on a region-wide scale by sharing resources and through cooperation among residents and other stakeholders. PWD offers the residents and stakeholders a number of resources, as this multifaceted planning approach requires a tremendous amount of coordination, characterization and planning, which the watershed stakeholders build on through the IWMP process.

The IWMPs are built upon a solid, scientific foundation composed of water quality monitoring (including both wet and dry weather samples), macroinvertebrate and fish bioassessments, physical stream surveys (fluvial geomorphology as well as streamside infrastructure) and computer modeling of stormwater flows and pollutant loading. Based on these extensive physical, chemical and biological assessments, the plans explore the nature, causes, and severity of water quality impairments in the watershed and opportunities for improvement. IWMPs present logical and affordable pathways to restore and protect the beneficial and designated uses of these urban waterways.

10.1.1.1 Environmental Implementation Targets

In an ideal world, flowing streams and rivers would remain in harmony with the surrounding environment. Streambanks would remain stable with lush, vegetative protection. Fish and benthic invertebrates (bugs) would thrive within their in-stream habitat. The floodplains surrounding the streams would be accessible, and within them one would find a mix of wetlands and mature forest cover.

Unfortunately, for the urban waterways of the Philadelphia area, streams have fallen victim to years of the effects of compounding urbanization. As populations and development have increased within and surrounding Philadelphia, so has impervious cover. This has resulted in a significant increase in stormwater runoff to be managed by existing infrastructure, ultimately making its way to these urban streams. This increase has created a “flashy” regime in these urban streams, meaning that they go from very low streamflows during dry weather to extremely high flows during rain events. This effect has ravaged the stream systems, causing erosion and scouring of streambanks such that habitat has been all but destroyed for benthic invertebrate and fish populations.

Development of watershed planning goals through the stakeholder led IWMP process resulted in the establishment of three implementation targets for watershed improvement and restoration based on consideration of ecology and human health. Targets help PWD to break the overwhelming end goal of “significantly improving watershed conditions” into three distinct measurable pieces on which PWD can consistently assess performance during the implementation period.

The targets are used to help in the evaluation of each of the alternatives under consideration.

> ***Target A:*** *Improvement of Stream Quality, Aesthetics and Recreation During “Dry” Weather.* Achievement of this target is focused on meeting water quality standards in the stream during dry weather periods, which is when PWD believes that watershed stakeholders are most likely to be recreating streamside. In a given year, this is observed close to 65% of the time. Achievement of this target would involve the elimination of dry weather discharges to the stream from outfalls as well as removal of trash and litter from the waterway, improvement of public access to the waterways, and enhancement of streamside recreational opportunities including streamside trails and open space.

Each alternative being evaluated includes management options to address dry weather water quality, aesthetics and recreation. Because all the alternatives contain similar measures to address Target A objectives, there is no clear differentiation between alternatives based on this criterion unless the cost of wet weather controls limits PWD's ability to implement these options due to financial hardship.

> ***Target B:*** *Preservation and Enhancement of Healthy Living Resources.*
> Part of what makes a stream so valuable is its healthy aquatic environment, which results in diverse macroinvertebrate and fish populations. Implementation projects to achieve this target are aimed not only at restoration of habitat, but also measures to provide the opportunity for these organisms to seek refuge and avoid the high velocities of streamflow during storms. Achievement of this target will increase the population, health, and diversity of the benthic invertebrate and fish species within the stream.

Alternatives with green stormwater infrastructure restore a more natural water balance, including increasing the minimum groundwater fed baseflows in creeks and streams. Traditional infrastructure alternatives do not meet goals for restoration of living resources due to hydrologic alterations. The resulting lack of groundwater recharge will reduce dry weather stream baseflows needed for a healthy aquatic community. Additionally, depending on design, a tunnel or treatment system would concentrate remaining overflows at a smaller number of points than does the existing system, resulting in increased channel and bank erosion at those locations. Although it may be possible to design a stream channel to mitigate some of these effects, this lack of hydrologic variation is not conducive to a functioning stream ecosystem. Additionally, for alternatives that include dispersed treatment at consolidated outfalls along the tributary systems, the possibility of a failed dechlorination system could overwhelm the modest baseflow with chlorinated flows, resulting in a fish kill and other related environmental damage.

> ***Target C:*** *Improvement of Wet Weather Water Quality and Quantity.*
> During rainstorms a great deal of stormwater is piped to urban streams – resulting in abrupt changes in water quantity and quality. Alternatives that include green stormwater infrastructure tools will reduce the impact of these abrupt changes by managing stormwater where it hits the ground, thereby reducing the amount of stormwater that reaches the waterways.

The mixes of technologies included in all alternatives are capable of capturing and treating at least 80% of combined sewage in a year representative of long-term climatic conditions when considered on a combined sewer system (CSS)-wide basis. Comparing only capital, operations and maintenance costs of the alternatives does not necessarily lead to a clear choice. Within the range of uncertainty inherent in the analysis, several alternatives may be roughly equivalent in terms of cost-effectiveness when measured as combined sewage overflow avoided per dollar spent once implementation is complete. However, the Green Stormwater Infrastructure with Targeted Traditional Infrastructure Alternative begins to provide benefits immediately as the many small scale projects are continuously added throughout the 20-year implementation period. This ultimately results in greater cumulative benefits over time. Also, there is a minimum constructible size for many of the traditional management options considered. For example, implementing a system of tunnels to serve all four watersheds results in a present value capital cost beginning at approximately $5 billion for tunnels intercepting all trunk sewers and having minimum constructible diameters of 15 ft. Building large-scale transmission and treatment infrastructure is estimated to begin at close to $4 billion in capital and O&M cost dictated by the length of existing interceptor sewers, assuming that at a minimum a new system would double existing wet weather capacity.

10.1.2 Affordability and Financial Capability Limits our Choice

PWD currently spends upwards of $150 million each year renewing and upgrading its existing facilities. In addition to these recurring costs, Philadelphia anticipates spending further funds over the coming years to meet evolving drinking water quality goals and stormwater management criteria under the Clean Water Act. Under the current economic climate, securing capital funding for PWD's existing, on-going programs, much less new initiatives, is a challenge. That is why, when money does become available, it is ever more critical to ensure that every dollar is leveraged to satisfy the myriad of issues facing this water utility.

A financial capability assessment for the LTCPU was prepared using criteria suggested by the US EPA. The US EPA's approach calls for an evaluation of costs of the proposed improvements against Philadelphia residents' median household income. In general, the US EPA considers wastewater costs above two percent of median household income to be an unacceptable cost burden to ratepayers. The affordability and financial capability analysis presented in Section 11 identifies an upper limit on the level of spending that PWD and its rate payers can sustain without severe hardship. Socioeconomic analyses generally point to slow economic growth in the Philadelphia region for the next 20 years. The trends highlighted in the analysis provided in Section 11 are predictive of an increasing burden on ratepayers for wastewater treatment costs prior to the enactment of any CSO compliance measures by the PWD. It is important for PWD, the PADEP and the US EPA to negotiate a level of CSO control and an implementation schedule that recognizes the financial burden on ratepayers and the permittee that will result from CSO compliance measures, and that the affordability of the selected alternative must be one of the considerations in selecting the preferred alternative. Of the alternatives studied, only the Green Stormwater Infrastructure with Targeted Traditional Infrastructure Alternative includes a constructible scenario providing management for all four watersheds that can be implemented within reasonable limits of affordability for the ratepayers of Philadelphia.

Costs for implementing even this most affordable of alternatives are estimated to be $1.6 billion at the end of the twenty year implementation period ($1.0 billion in 2009 dollars). Based on this estimate and implementation schedule, the affordability assessment determined that the LTCPU would result in a cost to City of Philadelphia residents well above the upper limit of US EPA's median household income affordability criteria.

10.1.3 Green Stormwater Infrastructure: An Emerging Trend

In selecting the best alternative for meeting the City's obligations for controlling CSO events, PWD considers it critical to embed the CSO program in the larger context of city-wide objectives for a more livable and sustainable city. Philadelphia, like many major American cities, is faced with an array of economic, social, and environmental challenges. These challenges require that government agencies break out of their traditional roles of providing narrowly defined services and seek to work together toward larger goals. PWD's LTCPU rightly focuses on significantly reducing CSOs, thereby making Philadelphia's creeks and rivers cleaner and healthier. But as the single largest investment of environmental dollars in the City over the next 20 years, it presents a unique opportunity to be much more than just a water quality improvement program. The selected alternative must be part of a larger city-wide effort to reverse the decline in the physical infrastructure of the City. It must be designed to provide additional benefits beyond the reduction of CSOs, so that every dollar spent provides a maximum return in benefits to the City.

To maximize benefits, the LTCPU must be seen in the broader context of Philadelphia's movement to re-invent itself as a more sustainable 21st century city. The current mayor has outlined an ambitious agenda through the City's GreenWorks initiative aimed at transforming Philadelphia into the "greenest city in America" by reversing years of decline. This will take a transformation in the way city agencies work together, and will need to align city government, non-governmental organizations and residents in a joint effort towards achieving a common goal of a more livable, sustainable city that reduces its energy needs, improves the economic condition of its citizens, and manages its natural resources to the greatest extent possible. PWD's CSO program will become a critical element in achieving this goal.

Of the alternatives considered, only the selected alternative, Green Stormwater Infrastructure with Targeted Traditional Infrastructure*,* also supports numerous US EPA initiatives at a time when the nation's cities need 21st Century solutions to aging infrastructure problems. US EPA Administrator Lisa Jackson identified five priorities for the administration including:

1. Protecting America's water
2. Improving air quality
3. Reducing greenhouse gas emissions
4. Cleaning up hazardous-waste sites
5. Managing chemical risks

PWD's selected alternative, rolled out to the public under the name *Green City, Clean Waters,* will address four out of five of these priorities.

The City of Philadelphia's LTCPU is being developed under a new, emerging, regulatory context described in recent green stormwater infrastructure guidance and policy documents developed by the US EPA. The US EPA signed the "Green Stormwater Infrastructure Statement of Intent" in April 2007 and followed with the production of two memos including "Using Green Stormwater Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and other Water Programs" and "Use of Green Stormwater Infrastructure in Permits and Enforcement". These US EPA memos strongly support the use of green stormwater infrastructure approaches in lieu of traditional infrastructure when possible by encouraging state and federal policy to integrate green stormwater infrastructure into permitting and enforcement activities.

In March 2009, Administrator Jackson charged the US EPA Office of Water with leading a new Urban Waters initiative. The focus of this program will be to promote stewardship of urban waterways in the communities that surround them, especially in areas not historically targeted by environmental outreach. The goals of the Urban Waters Initiative are to achieve water quality goals of fishable/swimmable/drinkable rivers, improve public health and the environment and quality of life, and sustain community improvements over multiple generations. This initiative will help restore urban waterways in Environmental Justice communities. Only the selected alternative (Green Stormwater Infrastructure with Targeted Traditional Infrastructure) embodies the intent of this new US EPA initiative. PWD will follow this initiative as it develops and will seek opportunities for partnership synergies.

Also, the US EPA has recently joined forces with the US Department of Housing and Urban Development and the Department of Transportation through an Interagency Partnership for Sustainable Communities, focusing national attention to improve access to affordable housing, more transportation options, and lower transportation costs while protecting the environment in communities nationwide. Philadelphia's unique approach to CSO requirements helps promote their goal of livable communities by investing in healthy, safe and walkable neighborhoods and coordinates all levels of policy to support existing communities. This is yet another initiative that would dovetail with the *Green City, Clean Waters* program, presenting opportunities to partner and where possible, leverage dollars such that both agencies are able to stretch their limited funding further and are able to get more out of each investment.

Seen in this context, selecting the best alternative for the LTCPU provides a unique opportunity to align itself with the larger vision of a sustainable city, broadening PWD's role in the City while leveraging the dollars spent to comply with environmental laws and regulations to reach the wider goals of economic stimulation and the rebuilding of the City's infrastructure.

Clearly the primary benefit of the CSO control program is an improvement in water quality and aquatic ecosystem health meeting both the letter and the spirit of the Clean Water Act. There are, however, differences between the way benefits accrue to the green alternative vs. the traditional infrastructure alternative. Figure 10-1 illustrates these differences over the implementation period. Because of the great expense associated with a storage based program such as the tunnel alternative, it would have to be constructed in phases, by watershed, and affordability would dictate that only a portion of the tunnel alternative could be completed in the first 20 years. The graph illustrates the advantage in performance over time associated with the dispersed, small scale implementation of green stormwater infrastructure, which captures increasing percentages of combined sewage as it is implemented. The tunnel alternative only provides capture upon completion, which is shown here in construction stages to fit within affordability guidelines. If one considers that the cumulative volume of CSOs captured is represented by the area beneath the respective curves, it is clear that the small scale implementation of green stormwater infrastructure results in greater benefit over the implementation period. The traditional infrastructure approach does not capture any additional combined sewage until completion of construction in the last years, while increases in the capture percentage begin to accrue to the green approach from the first year of implementation.

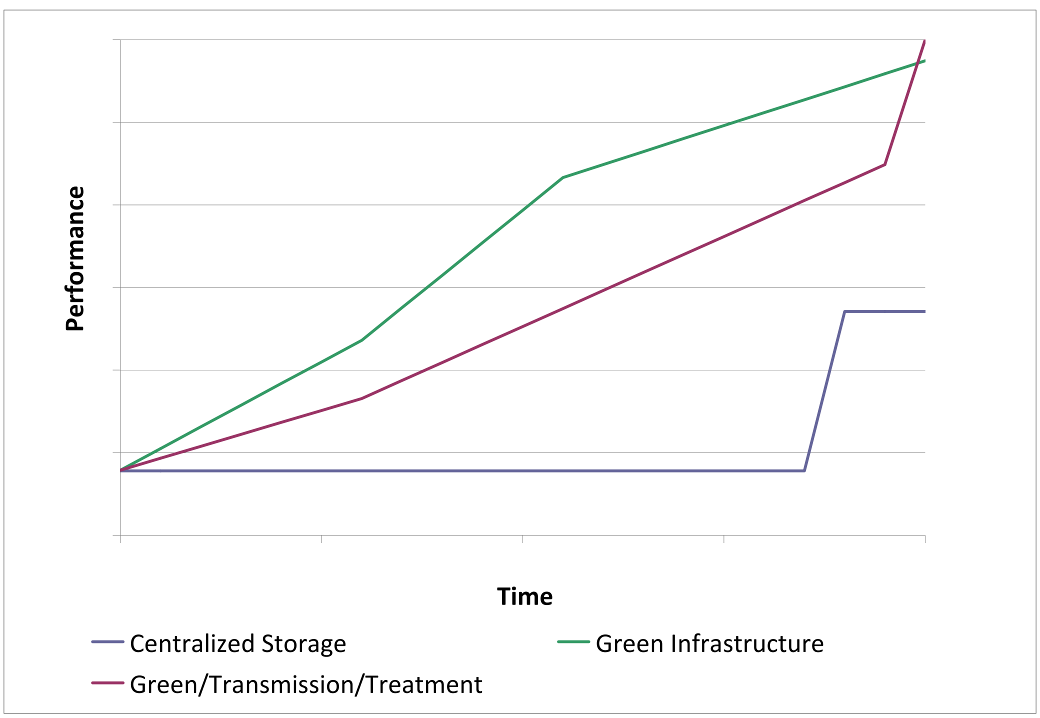


Figure 10-1 Comparison of Performance Over Time of Three Alternative Types Evaluated for the City of Philadelphia

Only the Green Stormwater Infrastructure with Targeted Traditional Infrastructure Alternative will provide improvements in dry weather water quality and aesthetics, stream corridor restoration measures, and significant environmental, social, and economic benefits at an affordable cost. Additionally, this is the only alternative that adapts to climate change by mitigating the urban heat island effect and helps mitigate climate change both by sequestering carbon in trees and by saving energy. Construction and operation of traditional storage, transmission, and treatment systems result in a net increase in energy usage, air pollutant emissions, and greenhouse gases. These alternatives neither mitigate nor adapt to global warming.

10.1.4 Triple Bottom Line: Environmental, Social, and Economic Benefits

The strictly traditional infrastructure-based alternatives all provide no additional benefits outside of the control of CSOs and associated water quality improvements. The green stormwater infrastructure aspect of the selected alternative does provide these important benefits. As described in Section 9, PWD has undertaken a Triple Bottom Line (TBL) analysis of the environmental, social, and economic benefits of the program. This TBL accounting means expanding the traditional financial reporting framework to take into account ecological and social performance so that the total benefits can be evaluated against the financial investment. TBL accounting attempts to describe the social and environmental impact of PWD's proposed infrastructure investment such that they can account for not only the water quality benefit that the infrastructure would produce, but also the additional environmental and societal benefits generated by the various alternatives evaluated.

Although these environmental, social, and health benefits are difficult to quantify, PWD felt it was important to gather information in an attempt to comprehensively compare the green approach with other traditional infrastructure alternatives. Understanding the full societal costs and benefits is important in justifying the program with the ratepayers, who will ultimately pay for this initiative. With the help of leading environmental economists, PWD compared the alternatives to help quantify the social benefits. After 20 years beyond the implementation period, the total net social benefits of PWD's $1.6 billion plan add up to a present value of $2.2 billion (Figure 10-2).

PWD considers the selection of the alternative that relies primarily on green stormwater infrastructure a responsible investment for the City. The benefits associated with the green stormwater infrastructure within the selected alternative Green Stormwater Infrastructure with Targeted Traditional Infrastructure are discussed below.

Green Stormwater Infrastructure Enhances Recreation

Throughout the Fairmount Park system, residents enjoy recreation along Philadelphia's stream corridors and waterfronts, but some areas do not live up to their full potential. Improved access, appearance, and opportunities in these areas will make them more desirable destinations for the public (Figure 10-3). Recreation also will be more desirable along newly greened neighborhood streets and public places. Philadelphians enjoy recreation along stream corridors and waterfronts today such as the Forbidden Drive along the Wissahickon Creek and The Schuylkill River Trail. *Green City, Clean Waters* will improve aquatic habitat and accessibility to the Tacony Creek and the Cobbs Creek and allow them to realize their full potential. Improved access, appearance, and opportunities in these areas will make them more desirable destinations for the public; in fact it is estimated that use of Fairmount Park lands will be increased by 10% due to the implementation of PWD's *Green City, Clean Waters* program. Recreation also will be more desirable along newly greened neighborhood streets and public places.

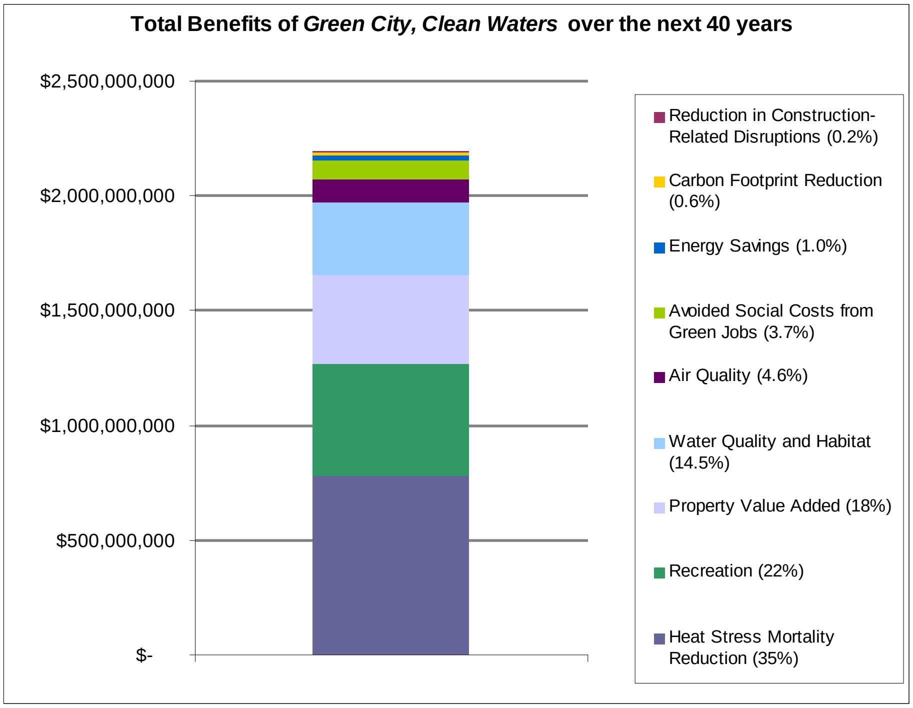


Figure 10-2 After 40 Years, the *Green City, Clean Waters* Program Will Create More Than $2.2 Billion of Social Benefits

Figure 10-3 A Vision of Cobbs Creek Looking Toward Woodland Avenue Dam Illustrating Habitat Restoration and Recreation Enhancements

Green Stormwater Infrastructure Restores Ecosystems

Green stormwater infrastructure improves ecosystems in two ways. First, by allowing rain to soak into the ground and return slowly to streams, green stormwater infrastructure restores a water cycle more similar to a natural watershed. This provides a natural water quality filter and limits erosion of stream channels caused by high flows, both of which benefit aquatic species. Second, PWD's green stormwater infrastructure approach includes physical restoration of stream channels and streamside lands, including wetlands, to restore habitat needed for healthy ecosystems (Figure 10-4).

Figure 10-4 Before and After a Stream Restoration of Exposed Interceptor Pipe Along Marshall Road in the Cobbs Creek Watershed

Improvements to water quality and habitat have been valued at $8.5 million over the next 40 years from:

- 45 ac of wetlands restored
- 148 ac of wetlands created
- 7.7 mi of stream restored in the Cobbs Creek Watershed
- 3.4 mi of stream restored in the TTF Watershed

Green Stormwater Infrastructure Improves Community Quality of Life
Trees and parks are an important part of the recipe that together can make an urban neighborhood into an inviting, exciting place. Residents clearly recognize and value this quality of life effect of urban vegetation. One way to estimate a value is to study property values in areas that are close to parks and greenery. It is estimated that values of homes near parks will be increased by $390 million over the next 40 years.

Green Stormwater Infrastructure Jobs Reduce the Social Cost of Poverty
Governments at all levels incur significant costs in coping with poverty, and Philadelphia is no exception. Green stormwater infrastructure creates jobs which require no prior experience and are therefore suitable for individuals who might be otherwise unemployed and living in poverty; in fact it is estimated that due to the *Green City, Clean Waters* program 250 people will be employed with green jobs each year. These new jobs create a benefit to society in reduced poverty-related costs, in addition to the wages paid to the individual workers. The stabilizing and transforming effects of green stormwater infrastructure in neighborhoods further reinforce and support the benefits of providing employment to a population that is outside the labor force. Green stormwater infrastructure is not by itself the solution to poverty, but it is a valuable tool in the toolbox of poverty reduction.

Green Stormwater Infrastructure Reduces Effects of Excessive Heat
Heat waves are a fixture of summers in Philadelphia, including some severe enough that they have resulted in over 100 premature deaths (for example, the summer of 1993). These events may be more frequent and severe in the future due to climate change. Green stormwater infrastructure (for example, trees, green roofs, and bioretention sidewalks) reduces the severity of extreme heat events in three ways - by creating shade, by reducing the amount of heat absorbing pavement and rooftops,

and by emitting water vapor – all of which cool hot air. This cooling effect will be sufficient to actually reduce heat stress-related fatalities in the City during extreme heat wave events. It is estimated that more than 140 excessive heat related fatalities could be avoided over the next 40 years.

Green Stormwater Infrastructure Improves Air Quality
Like many major cities in the United States, US EPA currently classifies the Philadelphia metropolitan area as exceeding federal air quality standards for both ozone (smog) and fine particles (soot). Known health impacts of these air pollutants include premature death, hospitalization for respiratory diseases, heart attacks, and lost work and school days. Green stormwater infrastructure will improve Philadelphia's air quality in two ways – by reducing emissions of pollutants (such as SO_2) and by removing ozone and particulates from the air. Reductions in energy and vehicle use will reduce emissions of pollutants. Once in the air, some ozone is taken into the leaves of trees as they "breathe." Leaves also trap additional fine particulates, which then wash off in the rain or fall with the autumn leaf drop. When trees are fully grown, improved air quality will reduce on average 1 to 2 premature deaths and 20 asthma attacks per year as well as to reduce up to 250 days of work loss or school absence per year.

Green Stormwater Infrastructure Saves Energy and Offsets Climate Change
Green stormwater infrastructure reduces energy use, fuel use, and carbon emissions in two ways. First, the cooling effects of trees and plants shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. Second, rain is managed where it falls in systems of soil and plants, reducing the energy needed for traditional systems to store, pipe, and treat it. Growing trees also act as carbon "sinks", absorbing carbon dioxide from the air and incorporating it into their branches and trunks. Implementation of the *Green City, Clean Waters* program will result in 1.5 billion pounds of carbon dioxide emissions avoided or absorbed over the next 40 years – the equivalent of removing close to 3,400 vehicles from Philadelphia's roadways each year.

10.1.5 Qualitative Evaluation Factors
In addition to the performance, cost, affordability, and TBL considerations previously described, a number of other, more qualitative criteria were used in comparing alternatives.

Public Support
Public feedback expressed the strongest support for alternatives that manage stormwater and CSO primarily through green stormwater infrastructure. Thus far, at the numerous public and stakeholder meetings during which PWD described the various alternatives under consideration for addressing the Clean Water Act requirements, the public has emerged as strongly supportive of measures that included a larger degree of green stormwater infrastructure. For example, the participants in the PWD's *Green City, Clean Waters* public participation program have expressed overwhelming support for green stormwater infrastructure as the preferred approach to reducing CSOs in Philadelphia. Over ninety-two percent of the more than 700 survey respondents responded positively to the green stormwater infrastructure approach. All stakeholders, from suburban watershed partners to City residents living within the CSO drainage area desire an approach that promotes multiple community benefits and creates truly sustainable watersheds and cleaner, safer and more accessible waterways. In addition, the political backing for the green approach is strong, as witnessed in the Mayor's Sustainable City initiative and GreenWorks plan.

Feasibility, Reliability, and Complexity
All alternatives present challenges in terms of feasibility of construction and operation. Technologies needed to construct and operate green stormwater infrastructure are straightforward and use relatively simple technologies, but institutional and political barriers exist that need to be reduced over time. Technologies associated with wastewater collection and treatment are considered more complex but highly reliable. Construction of storage tunnels is technically challenging and risky, although operation is considered reliable.

Each alternative will result in considerable disruption to traffic as well as to residential and commercial areas, although this will be to varying degrees and durations. For example, installation of green stormwater infrastructure techniques on a given block of street could cause a change in traffic pattern for several weeks. Because green stormwater infrastructure will be installed in many locations, the disruptions will be scattered throughout the system, however much of the installation will be carried out in conjunction with other public works such as street paving, sewer repair, and underground utility repairs. Thus the disruption will not be significantly greater than what would already be occurring for other reasons. The building of a large-scale storage tunnel could cause a disruption of traffic patterns and accessibility for a number of years, but in a smaller disturbance area along the rivers and creeks. According to the Triple Bottom Line analysis performed to evaluate various CSO mitigation alternatives for the City of Philadelphia, the difference in vehicle delay from construction and maintenance in hours of delay are roughly 250,000 hours for an alternative managing runoff from one-third of impervious surfaces as opposed to a 620,000,000 hour delay with a 30 foot diameter tunnel alternative.

The technology needed for maintenance of green stormwater infrastructure is simple but needs to be applied frequently on a large scale. Green stormwater infrastructure measures may fail occasionally on a local scale (*e.g.*, clogging of a release structure,) but the consequences of these small-scale failures are low and are easily corrected by routine maintenance.

Coordination and Consistency with other PWD and City Programs
Green stormwater infrastructure complements City of Philadelphia sustainability and redevelopment goals. These programs include redevelopment of vacant and abandoned lands and efforts to both mitigate and adapt to climate change. Traditional infrastructure interferes with many of these goals by occupying waterfront land and increasing air pollution and greenhouse gas emissions.

The green stormwater infrastructure clearly complements some of the larger, regional initiatives such as the East Coast Greenway Trail Network ("the Greenway"). The Greenway is a multi-user trail network connecting urban centers along the East Coast of the United States from Canada to Key West. This spine route consists of a series of locally owned and managed trails, linked to form a continuous greenway, easily identified by the public through signage, maps, and user guides. The Schuylkill River Trail is a multi-use trail that runs from Philadelphia to Pottsville. The downtown Philadelphia portion, called Schuylkill Banks, is managed by the Schuylkill River Development Corporation. The East Coast Greenway will eventually use the proposed extension of the Schuylkill River Trail as the long-term regional trail plan unfolds.

Adaptability and Expandability
Alternatives involving green stormwater infrastructure are more adaptable and expandable than larger scale, traditional storage alternatives. As they are implemented over a long period of time, conditions can be periodically reevaluated to identify design and programmatic changes that are needed. New technologies can be integrated as they are developed because of the small scale of the projects being implemented. One key advantage to green stormwater infrastructure is that as

development accelerates, stormwater control linked to the development also accelerates. Transmission and storage options can only be adapted to some extent. For example, transmission capacity can be initially oversized (at increased cost) to allow for the possibility that future treatment needs may be greater than expected. New treatment capacity can be added in the form of independent treatment trains. The large-scale storage alternative is the most difficult of any of the alternatives to adapt and expand to changing conditions.

10.2 Selected Alternative

After more than two years of significant engineering and economic analysis and evaluation, the Green Stormwater Infrastructure with Targeted Traditional Infrastructure Alternative was shown to be the clear choice for the City of Philadelphia due to the many environmental, social, and economic benefits that can be realized, its ability to improve all four watersheds and remain within affordability guidelines, and the fact that benefits begin accruing immediately – thereby producing benefits for city residents long before the traditional infrastructure approach would. At the close of the 20 year implementation period, PWD will have invested approximately $1.6 billion ($1.0 billion in 2009 dollars) to initiate the largest green stormwater infrastructure program ever envisioned in this country, thereby providing for the capture of 80% of the mixture of sewage and stormwater that would otherwise flow into portions of the Schuylkill and Delaware Rivers, and the Tacony, Frankford and Cobbs Creeks.

The selected alternative includes the three main elements:

- A commitment to green stormwater infrastructure; converting 34% of the CSS drainage area of the City to greened acres
- Stream corridor restoration and preservation (implementation of Target A and B commitments in each watershed)
- Wet weather treatment plant upgrades

Additional resources will be expended by PWD toward implementing their core mission and could be considered “leveraged” toward addressing this larger *Green City, Clean Waters* program.

This programmatic commitment of $1.6 billion ($1.0 billion in 2009 dollars) is in addition to the numerous commitments already in place, including:

- Approximately $200 million already spent toward 1997 LTCP commitments (including Nine Minimum Controls, capital projects and watershed planning)
- Approximately $2 million dollars committed annually to conducting the Stormwater Plan Review Program
- Approximately $55.8 million dollars committed to relining streamside interceptor pipes in the Cobbs and TTF watersheds – as outlined in the IWMP commitments
- Approximately $2 million dollars committed annually to public outreach and education (including support of the Fairmount Waterworks Interpretive Center, Fairmount Park Commission Environmental Education)

The true value of the *Green City, Clean Waters* program is likely to exceed $3 billion with the addition of leveraged dollars and activities implemented by stakeholders and partners. Of equal importance, even after the close of this 20 year implementation period, the practices put in place will continue to produce greened acres, achieving additional cumulative reductions in combined sewer overflows to the City’s rivers and streams.

The Green City, Clean Waters Program:
PWD's *Green City, Clean Waters* program is the much talked about philosophy of the land-water-infrastructure approach made real. We have deemphasized the use of traditional infrastructure as it is cost prohibitive while missing the restoration mark, instead pledging our precious investments into greening the City as a means to provide specific benefits to the residents of the City of Philadelphia while meeting ecological restoration goals.

The PWD's vision *Green City, Clean Waters* is to unite the City of Philadelphia with its water environment, creating a green legacy for future generations while incorporating a balance between ecology, economics, and equity.

This plan commits the City to significantly reducing the negative impacts of stormwater on the effectiveness of PWD's sewer collection system. PWD's strategy will be to reduce the amount of impervious surfaces in the City on an annual basis by changing the way that the landscape interacts with stormwater by enhancing City surfaces with natural features. PWD will measure progress through greened acres that capture and manage the first inch of stormwater.

The basic principles underlying the City's *Green City, Clean Water* approach are:

- Utilizing rainwater as a resource by recycling, re-using, and recharging long neglected groundwater supplies rather than piping it to the streams and rivers
- Maintaining and upgrading one of the nation's oldest water infrastructure system
- Transforming the City's rivers and streams into recreation destinations and green open space for visitors and City residents
- Preserving and restoring habitat for aquatic species within the City's urban stream corridors
- Collaborating to revitalize the City with a focus on sustainability
- Energizing the City's residents, partnerships, public and regulatory partners to adopt and join us in the watershed-wide strategy

PWD's Commitment:
As previously described, PWD's recommended alternative includes three main components:
- A commitment to green stormwater infrastructure
- Stream corridor restoration and preservation
- Wet weather treatment plant upgrades

A detailed description of each component follows.

10.2.1 Green Stormwater Infrastructure
The use of sustainable and natural design that is green stormwater infrastructure will bring about the renewal and expansion of the urban form. Acknowledging the symbiotic relationship between land use and water resources, PWD's definition of green stormwater infrastructure includes a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some cases release a portion of it slowly back into the sewer system.

Green stormwater infrastructure examples include bioretention planters in sidewalks and parking lots, green roofs, roof leaders that run off into lawns and rain gardens (Figure 10-5). These vegetated features manage rain where it hits the ground similar to the way a natural system such as a forest or a meadow would handle the rain runoff. PWD sincerely believe in the efficacy of using nature's own designs in which rainwater is an essential component for a thriving ecosystem. Once rainwater is removed from the natural system, it is only a matter of short time before the natural system fails. This is the unintended consequence of traditional infrastructure that separates rainfall from the earth.

Green stormwater infrastructure also involves the restoration of physical habitats in stream channels, along stream corridors, and on riverfronts. Restoration of stream habitats and riverfronts can also be combined with commitments to improve public access and amenities along the stream corridors. Public stewardship can only be guaranteed when the public is given the opportunity to see, touch and experience the streams healed by PWD's efforts. These practices are critical to PWD's larger restoration vision; without them, the ecosystem damage resulting from two centuries of urbanization will not be reversed.

This approach has been shown to be the most environmentally beneficial and economically favorable way to remediate the effect of more than 200 years of urbanization on the City's waterways. By investing in green stormwater infrastructure and other innovative, cost-saving strategies to manage stormwater, PWD is not only ensuring the rebirth of the City's ecological resources but is also striving to provide a host of other environmental, social and economic benefits that will catalyze PWD's success in achieving the sought after reality of "Greenest City in America."

A robust green stormwater infrastructure based program that commits to greening 34% of the impervious areas within the CSS is the cornerstone of PWD's wet weather water quality program.

An important performance goal used throughout this document is the achievement of a "greened acre." This greened acre includes the area of the stormwater management feature itself and the area that drains to it (or the stormwater feature's own little watershed). Each greened acre will manage the first inch of runoff from one impervious acre of the combined sewer service area. About one million gallons of rain fall on an acre over the course of a typical year. Of this, PWD's designs are intended to remove about 80-90%, or 0.8 to 0.9 million gallons of stormwater, preventing its discharge into the City's waterways.

PWD would like to see more than one third of the CSS drainage's impervious cover included in a green approach to stormwater management within the next 20 years. Ambitious goals call for a program that touches on every aspect of development and redevelopment in the city, and a timeline that envisions a city transforming itself over several decades. This cannot be done by PWD alone, but will require a coordinated effort across all city agencies, as well as the private sector, to achieve the ambitious goals of the program. A significant portion of PWD's $1.6 billion investment over the next 20 years will be invested in green stormwater infrastructure, and will also leverage PWD's ratepayer investment in a way that provides multiple additional community benefits.

Figure 10-5 Graphic of a City Neighborhood with Green Stormwater Infrastructure Components Implemented (Source: WRT Designs)

PWD has developed a number of "Green Programs," each with a number of associated implementation tools – including policy changes, regulatory tools, funding commitments and incentives through which the transformation from impervious acre to greened acre will occur.

PWD's Green Toolbox Includes Eight Green Programs:

- Green Streets
- Green Schools
- Green Public Facilities
- Green Public Open Spaces
- Green Industry, Institutions, Commerce and Business
- Green Driveways and Alleys
- Green Parking
- Green Homes

Key to the success of PWD's strategy is that it focuses on the treatment of publicly-owned land, such as city properties, streets and right-of-ways, which constitute 45% of the impervious land area of the City. With that in mind, the initial approach to achieving management of impervious cover is to focus efforts on publicly owned impervious cover and the larger, more commercial properties, and to use programs addressing impervious cover on smaller private properties to increase the level of control as needed. Over the course of the implementation horizon, additional programmatic elements will be explored and developed.

The Green Stormwater Infrastructure Program can be thought of as a series of individual programs, each targeting a different generator of stormwater (impervious cover category). The target at year 20 is to have put sufficient measures in place to manage the first inch of stormwater for one-third of all impervious cover in the CSS drainage area of the City of Philadelphia. Implementation of the program will need to review progress at a series of decision points, one every five years for the 20 year implementation period, as part of an adaptive management approach. The program will need to be flexibly applied, with targeted impervious cover controls adapting to changing economic, technical, and social conditions.

Figure 10-6 shows the breakdown of impervious cover in the city, organized around the green stormwater infrastructure programs planned for implementation. Of importance is the fact that parking, roads, and sidewalks make up a significant portion of the impervious cover. Much of this impervious cover can be managed through facilities located on public property or public right of way, a critical point in assessing the feasibility of the program and in designing measures to achieve the target of controlling the first inch of rainfall on 34% of all impervious cover in the city. With that in mind, the initial approach to achieving management of 34% of impervious cover is to focus efforts on publically owned impervious cover and the larger, more commercial properties, and to use programs addressing impervious cover on smaller private properties to increase the level of control as needed.

A description of each of the various green programs with their primary implementation tools follows.

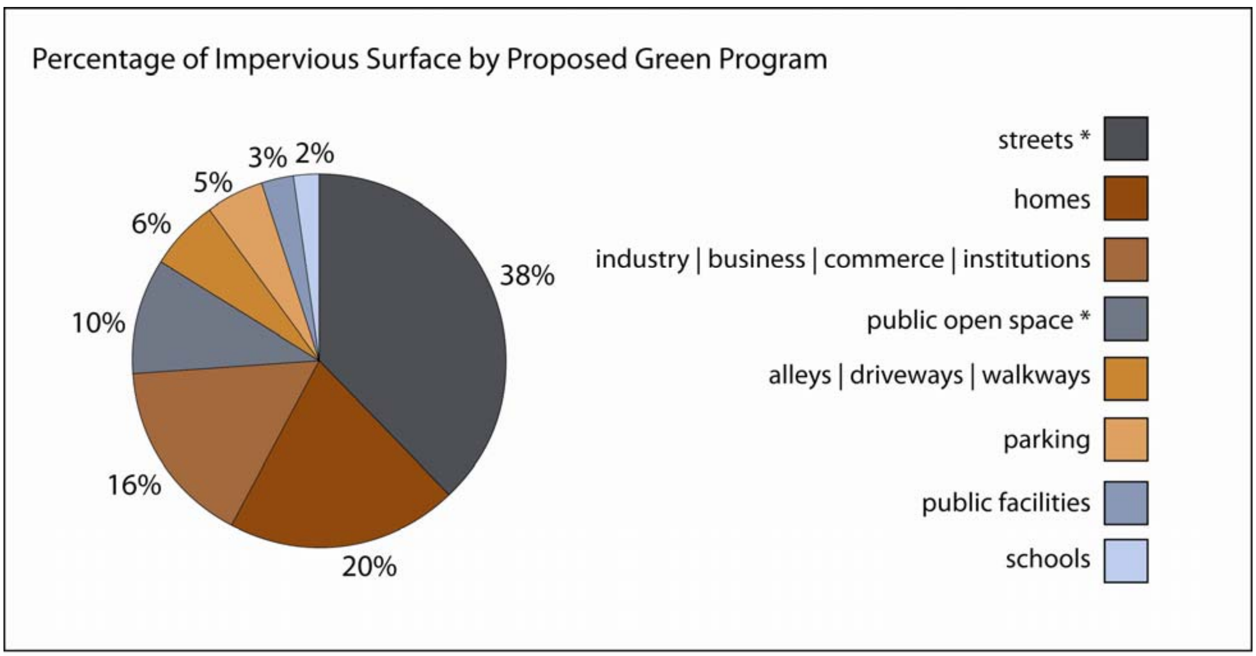


Figure 10-6 Breakdown of Impervious Cover Within the CSS Area of the City by the City's Green Program Implementation Tools

* Please note that the "Streets" category does not include streets adjacent to public open space; these streets are included in the impervious surface percentage associated with "Public Open Space"

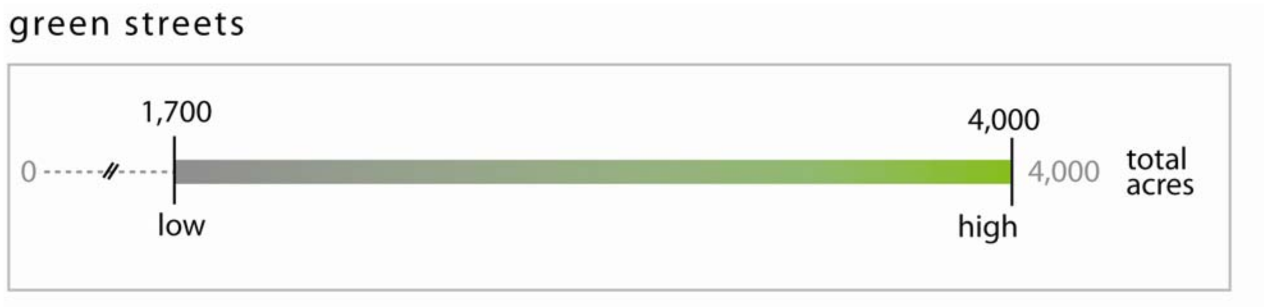


Figure 10-7 Vision of "Before and After Greening" of a South Philadelphia Street (Source: WRT Designs)

Figure 10-8 Examples of Street Greening Elements and Practices

Streets and sidewalks are by far the largest single category of public impervious cover, accounting for roughly 38% of the impervious cover within the combined sewer service area. (Note: impervious cover associated with streets in front of parks was not included in this percentage; these streets will be included in the "Green Public Open Space" Program) A green street acts as a natural stormwater management system, capturing rain or melting snow (runoff), allowing it to soak into soil, filtering it and at the same time, reducing the amount of stormwater that would otherwise go into Philadelphia's combined sewer pipes (Figures 10-7 and 10-8).

PWD is designing stormwater management systems while maintaining the primary function of the street for vehicles and pedestrians. These greened acres will provide additional societal benefits on City streets, such as shading, cooling, traffic calming, and visual enhancement.

Some of the green stormwater infrastructure tools in the green streets tool box include street trees and the "pit" they are planted in, sidewalk trenches, planters, sidewalk bump-outs and bulb-outs (sidewalk extensions), and porous pavement. Street tree pits and trenches capture the flow of stormwater from the street and sidewalk, letting it soak into the soil to water the trees. They provide shade, improve air quality, absorb noise and beautify the neighborhoods.

Through the use of sidewalk planters, stormwater runoff from the street and sidewalk is directed to the planter through a curb opening allowing stormwater to be absorbed by the plant and soil materials. Sidewalk planters help protect the City's waterways by filtering and reducing stormwater runoff.

The use of porous pavement allows the stormwater runoff to soak right through the sidewalks, while providing the same structural support as traditional pavement. This is a tool that at the surface might not look "green" to the eye, but still provides stormwater management benefits.

PWD is working to align its green stormwater infrastructure practices with street greening programs associated with the ambitious greening goals of GreenWorks. Coordination of PWD's program with other city programs will encourage maximum effectiveness. Ultimately, the Green Streets program should result in setting a "green standard" for streets within the City. Partners include PennDOT and the City of Philadelphia Streets Department as well as special districts to help with maintenance.

In developing a concept for rolling out a large-scale green streets program, PWD has begun to evaluate streets in terms of categories by street widths. PWD has begun this process by dividing streets into four categories by width, where a given width has associated with it a set of design considerations. PWD chose four streets in South Philadelphia to serve as the "model" streets for evaluating their street width concept. Streets and widths evaluated are as follows:

- Streets 2-19 ft wide – Iseminger Street
- Streets 20-29 ft wide – Dickinson Street
- Streets 30-49 ft wide – Snyder Street
- Streets 50+ ft wide – Washington Avenue

For each of these "model streets" PWD had a photo-simulation developed (Figures 10-9 through 10-12) so that consideration could be given to things like "street furniture" (*i.e.*, bike racks, utility boxes/poles, trash receptacles, newspaper boxes, etc.) and utility conflicts as various green stormwater infrastructure components are considered for application.

Figure 10-9 Streets 2-19 ft wide – Iseminger Street (Source: WRT Designs)

Figure 10-10 Streets 20-29 ft wide – Dickinson Street (Source: WRT Designs)

Figure 10-11 Streets 30-49 ft wide – Snyder Street (Source: WRT Designs)

Figure 10-12 Streets 50+ ft wide – Washington Avenue (Source: WRT Designs)

PWD then used these pre-defined street widths to evaluate streets throughout the CSS drainage area for applicability of these various green street tools. PWD has begun to map the opportunities for implementing green streets. Maps have been prepared that identify these four categories of street width, and standard designs are being prepared appropriate for each type of street. Figure 10-13 shows an example of a green street planning map for the CSS drainage area of the TTF Watershed.

In addition to the street planning maps, developing and making standard designs for green streets is critical to implementing green stormwater infrastructure on a large scale. PWD has already developed a portfolio of standard details, one of which is shown in Figure 10-14. These standard designs provide a variety of approaches for all types of streets, and will help to make the large scale implementation of green stormwater infrastructure more efficient.

Many standard details are as simple as adding tree trenches to increase tree cover, which provides some measure of stormwater capture. Others are more ambitious redesigns that include tree trenches, planters, and underground infiltration/retention facilities, resulting in a completely new form for Philadelphia's commercial and residential streets.

Because implementation of the *Green City, Clean Waters* program will depend highly on green streets, PWD has already started collaborating with the Streets Department and other utilities so that all projects will become streamlined and coordinated. PWD will design tree trenches and bump-outs to streets already slated for improvements. When both utility and road work can be done on each street at the same time, it lessens the project costs and the inconvenience to residents.

Additionally, the Fairmount Park Commission already has an extensive street tree program. PWD will build on a successful history of working together with the Fairmount Park Commission by designing street tree trenches to be installed as new street trees are installed. Not only will these trenches increase the life expectancy of the trees, they will capture even more urban runoff in the underground drainage system. The same efficiencies can be realized by installing curbside green stormwater infrastructure such as bump-outs where possible when the City replaces or installs Americans with Disabilities Act mandated ramps on the sidewalks.

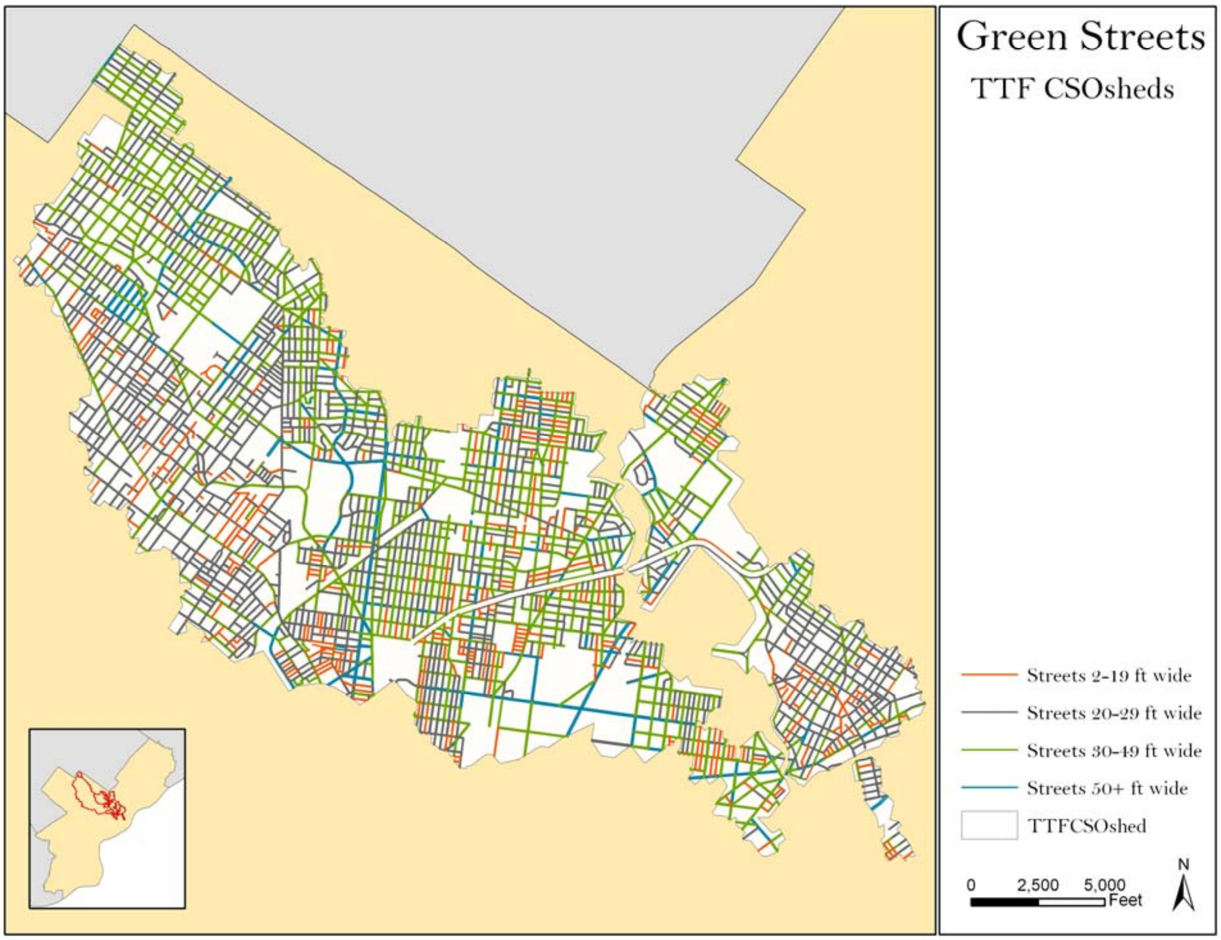


Figure 10-13 Green Street Planning Map Illustrating Different Categories of Street Width within the CSS Drainage of the TTF Watershed

PWD is preparing standard designs, and is working on appropriate regulations and incentives to retrofit streets whenever the opportunity arises such as when the following occur:

- PWD water/sewer infrastructure repair/replacement
- PWD storm flood relief related construction
- Cable/gas/phone infrastructure repair/replacement
- Routine repaving by either the Philadelphia Streets Department or PennDOT

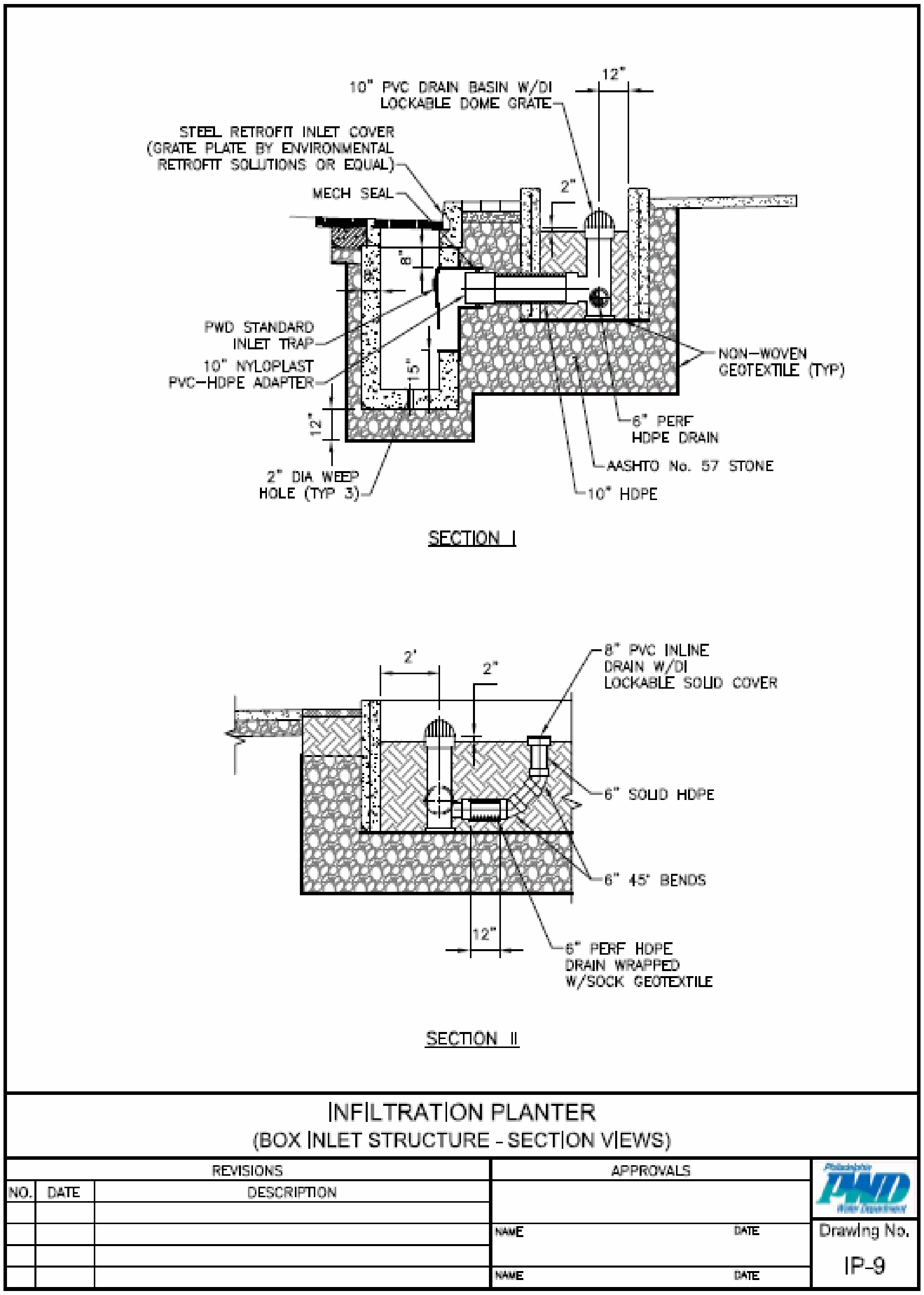


Figure 10-14 Standard Detail for Infiltration Planter

In addition to city streets, discussions are proceeding with PennDOT to take all runoff from Interstate I-95 within the city from its current discharge to the combined sewer system and discharge directly to the Delaware River. This would be a complete separation of the Route 95 corridor runoff, to be implemented as part of the planned Route 95 reconstruction. Further, the infrastructure constructed through this process will be sized such that ample capacity will exist for disconnecting parcels located between I-95 and the Delaware River. As properties are redeveloped over the coming years, they will be able to disconnect from the combined sewer system and connect to this new separate system.

Schools make up 2% of all impervious cover in the City, but because they are highly visible and associated with education, making them critical components in a green stormwater infrastructure program, they present a high priority target for greening. The goal is to retrofit up to half of all schools in the City in the coming 20 years. PWD plans to support the retrofitting of up to 5 school campuses per year, utilizing an array of stormwater measures such as rain gardens, green roofs, rain barrels and cisterns. Perhaps the most important and biggest opportunity here includes the use of pervious pavement and trees on both parking and recreational facilities on school properties, transforming what are now heat trapping asphalt surfaces into more welcoming, cooler, green islands (Figures 10-15 and 10-16).

The greening of schoolyards will require specific designs for each campus. These designs can include green stormwater approaches such as porous pavement, rain gardens, green roofs, and cisterns, but also could be expanded to include improvements to water efficiency that reduce sewage flows.

Figure 10-15 Porous Pavement Examples

The primary tools for this include:

- Providing design services through PWD contractors
- Incentives associated with the new stormwater rates
- Stormwater regulations for new construction
- Potential for funding of green sidewalks and streets around the school property.

Figure 10-16 Visualization of a Potential Schoolyard Greening Project (Source: WRT Designs)

Public parcels make up 3% of impervious cover within the CSS drainage. The value in retrofitting them with green stormwater infrastructure to manage stormwater is primarily to lead by example as envisioned in Figure 10-17. This cannot be underestimated, both for establishing the credibility of the program in the eyes of the public, and to demonstrate the effectiveness of the measures to remaining skeptical individuals within the development community. PWD is leading this initiative by evaluating opportunities for the greening of its own facilities (Figure 10-18). Additionally, PWD also encourages the installation of green streets surrounding major public facilities to maximize the potential stormwater management benefits.

Retrofit of existing facilities will require close coordination with other city agencies to evaluate opportunities for facilities such as Parks & Recreation buildings and structures, and Police and Fire facilities.

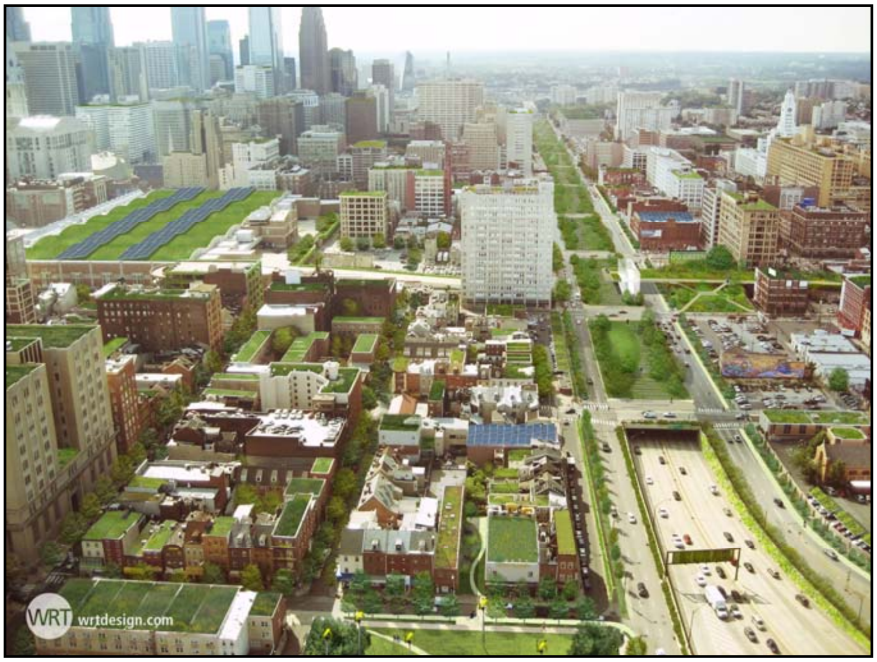


Figure 10-17 Photosimulation of Green Stormwater Infrastructures on Public Facilities

Figure 10-18 Examples of Philadelphia Public Property Green Retrofits

Compliance with the stormwater regulations provides the framework for all renovation projects on public property. Every opportunity will be utilized to include green stormwater approaches for all significant capital improvement work on City property to bring them in compliance with the Stormwater Regulations. To increase the effectiveness of the program associated with city facilities, PWD will encourage the city to refurbish the streets surrounding each of the major facilities undergoing construction using one of the green street designs. This will significantly increase the effectiveness of the retrofit and provide opportunities for public education on stormwater management at each City facility.

Parking lots, at 5% of the impervious cover, present a great opportunity to reduce stormwater runoff. (Please note: The Green Parking Program is composed of free-standing parking lots only; parking associated with retail or other facilities is included as a part of the impervious cover associated with that facility.) Parking lots have a significant visual impact on the city, and green parking lots can contribute to the overall improvement in the appearance of the City's commercial and business districts. A variety of stormwater measures can be used to renovate parking lots, including vegetative strips, infiltration beds, trees, porous pavement, sand filters, and even green roofs on parking garages (Figure 10-19).

The benefits of green parking are just now being realized, including reduced summer temperatures and no loss of parking space during and after storms due to standing water. Parking lots have a significant visual impact on the city, and green parking lots can contribute to the overall improvement in the appearance of the city's commercial and business districts.

Figure 10-19 Examples of Green Retrofit Parking Projects

City-owned parking facilities will be targeted as a demonstration of the City's commitment to green stormwater infrastructure. A city financed program of parking lot retrofits will be evaluated. Private parking lots can be retrofitted through the incentives provided by PWD's Parcel Based Billing Initiative. This program resulted in a reallocation of stormwater fees and should make retrofits aimed at reducing stormwater fees more attractive such that private parking lots might begin to seek opportunities for retrofit. The City may also consider an ordinance that will mandate a green buffer around all parking facilities that can also serve as a stormwater infiltration measure.

Figure 10-20 Photosimulation of Green Stormwater Infrastructure on Public Facilities and Adjacent Streams

Public Open Space is not a large contributor to impervious cover, making up only about 10% of the city's impervious cover. Impervious cover associated with the park lands itself is quite low, but PWD sees opportunities for utilizing the streets surrounding these parcels to route and manage stormwater from the surrounding areas where this can be done without adversely impacting the quality of the public land itself (Figure 10-20 and 10-21).

PWD has worked with greening recreational centers that are already community focal points and often in need of restoration or upgrade.

Figure 10-21 Stormwater Management through Green Practices on Public Land

Vacant land, while not all publicly owned, presents a unique opportunity for stormwater management. There are over 40,000 vacant parcels of land in the City. These present an opportunity both for permanent green redevelopment, as well as for more temporary measures such as the creative use of vacant parcels for management of stormwater from surrounding areas. In addition, there are many areas of the city ready for redevelopment, including areas of abandoned or substandard housing, abandoned industrial areas, or outdated commercial facilities. High priced and ever scarcer energy is changing the way Americans live, making older urban centers more and more attractive places to live and work. As a result, the rate of redevelopment in the city is expected to impact 1% or more of the city's impervious cover each year. Making all redevelopment projects contribute to a greener city will be critical to meeting ambitious green stormwater infrastructure goals.

Figure 10-22 shows a mixed industrial and residential section of a Philadelphia neighborhood with vacant properties highlighted in yellow. This neighborhood has an 11% vacancy rate. Due to the large number of vacant properties, this neighborhood has many opportunities for neighborhood revitalization, which can lead to an expansion of the PWD customer base. The vacancies also provide placement for the installation of green stormwater infrastructure technology.

Figure 10-22 Vacant Property Redevelopment Opportunities

Besides the redevelopment of vacant land, currently used public land also represents an opportunity for improved stormwater management.

- Bikeways/Trails can serve as linear elements in the landscape, and are closely associated with the Green Plan. All bikeways and trails should be designed for zero stormwater discharge (Figure 10-23)

- Parks are often associated with Philadelphia's creeks and rivers. In addition to onsite management of stormwater, they present opportunities for wetland creation/restoration, and stream restoration
- Plazas are central meeting places in the city. Stormwater measures should be designed to aid in the greening of the plazas through the use of planters and tree pits
- Golf courses should all be required to manage stormwater onsite. In addition, they should all participate in the Audubon Cooperative Sanctuary Program for Golf Courses to reduce water use and the use of pesticides and herbicides

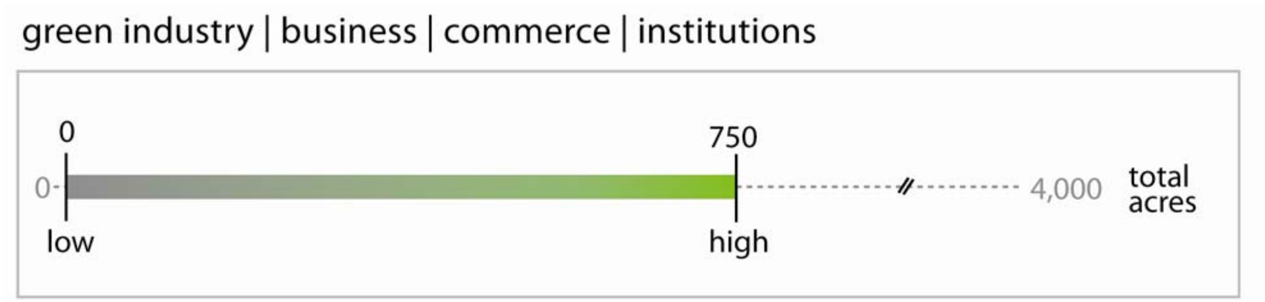
PWD's progressive new stormwater regulations and the restructuring of its stormwater rates to tie fees to impervious cover will play an ever increasing role in the greening of Philadelphia and are the most effective tools for greening private land. The new regulations requiring the first inch of rainfall to be controlled onsite will have a great impact on the city's stormwater and CSO programs by bringing all new development and redevelopment projects in line with the new regulations. However, PWD is considering additional ways to improve and strengthen its stormwater programs by potentially reducing the minimum area to trigger the stormwater regulations to 5000 ft^2.

Figure 10-23 Examples of Green Public Trails, Paths and Bike Routes

Additional incentives are being considered to further stimulate innovative stormwater designs, including:

- Fee in lieu: allowing stormwater controls to be transferred to another location if efficiency is improved
- Green permit expediting: green designs are fast tracked through the permit review process
- Evaluate the potential for linking green stormwater infrastructure to other incentives related to zoning, such as density/setback incentive bonuses for increased stormwater control beyond the minimum requirements

Limited, appropriate, and compatible use of recreation and other open space for the management of stormwater from surrounding areas is also under consideration.



Land subject to the Green Industry, Business, Commerce and Institutions Program makes up about 16% of the City's impervious cover. Philadelphia's industrial, business, commercial and institutional properties hold significant opportunities for green stormwater infrastructure implementation. Generally, because implementation of this program is within the control of private entities, PWD will undertake a supporting role in seeing it developed programmatically. Many industries, businesses and commercial buildings would be expected to face upgrades and renovations within the 20 year time frame, making a high rate of compliance with stormwater regulations a reasonable expectation. Also, one clear incentive for private entities to consider installation of green stormwater infrastructure will be PWD's new stormwater rate structure, which ties impervious cover to the stormwater fee. PWD anticipates that this will result in multiple existing large private, non-residential properties to retrofit their properties with stormwater management infrastructure in order to receive a credit in the stormwater portion of their bill. This could prove particularly effective for parking lots that previously have not received a water bill.

PWD also intends to encourage the use of green stormwater infrastructure, where possible provide tools and incentives to make their use easier and more attractive, and if possible to provide incentives for the retrofit of existing facilities. Additionally, PWD will evaluate LEED certification to see how credits are being allocated to stormwater management features. PWD might consider working with the United States Green Building Council (USGBC) to reevaluate the way that these credits are distributed in order to make the stormwater management component a more integral portion of the program.

A program to target properties and buildings owned by churches, hospitals, universities, and sports stadiums presents another highly visible opportunity for green stormwater infrastructure. Much like large commercial or industrial properties (Figure 10-24), this program will rely on compliance with the City's Stormwater Regulations for new facilities as well as the incentive for retrofit of existing facilities provided by the new stormwater rate structure. In addition, many major universities, including the

Figure 10-24 Green Business Greening Example (Source: WRT Designs)

University of Pennsylvania, have embarked on ambitious sustainability initiatives. Where possible PWD will seek to partner with these entities in order to produce synergies and stretch limited dollars. This may present opportunities to work with each university to separate all stormwater from the sewer system for onsite, green solutions.

Other opportunities might include greening the large areas of impervious cover associated with the sports stadium complexes and the Convention Center, which attract millions of visitors each year. When certain large facilities are renovated or constructed anew, complete separation of the facility's sanitary and storm sewers might be possible, and could even be combined with green measures.

Other incentives are being considered, including:

- Providing design services though PWD contracts
- Evaluating opportunities for public/private partnerships for the management of stormwater runoff from the public right-of-way on private property in exchange for the funding of a green stormwater infrastructure retrofit

Figure 10-25 Before and After Alley Greening and Implementation of Porous Pavement with Underdrain of a Philadelphia Alley (Source: WRT Designs)

Philadelphia has many smaller alleys located behind houses and commercial buildings that are currently impervious and drain to the storm and combined sewers via stormwater inlets. Though land under this program makes up about 6% of all impervious cover in the City, it may offer relatively inexpensive solutions for infiltration or collection of roof runoff. These often underutilized areas present an opportunity to either use the alleys for infiltration, or to convey stormwater to green stormwater infrastructure located at the end of an alley. In addition to the alleys, there are often walkways providing access to backyards of homes, and driveways for single family homes and row houses that present other opportunities for onsite stormwater controls.

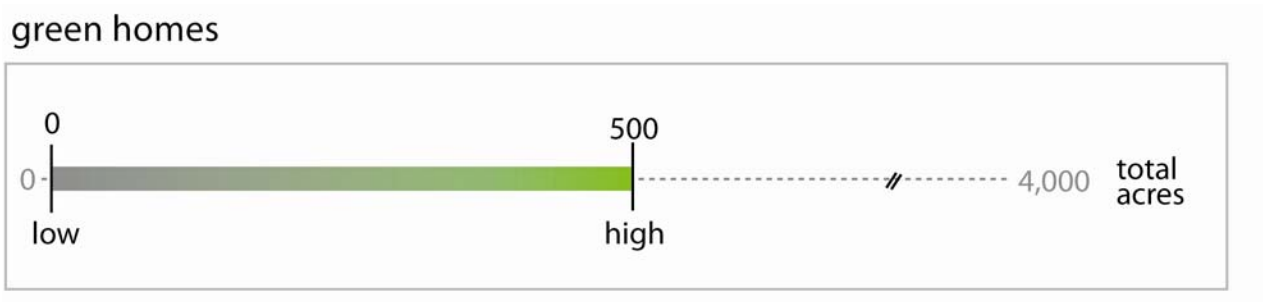


Figure 10-26 Photosimulation of Green Stormwater Infrastructure on Residential Properties (Source: WRT Designs)

Residential roofs make up 20% of all impervious cover in the City. The key to success for this program may lie in the simplicity of smaller scale solutions, many of which can be carried out by the homeowners themselves and can achieve benefits at a minimal cost.

Projects, such as the use of rain barrels, have already proven popular in pilot programs, and if successful on a larger scale, can ultimately affect a significantly larger amount of impervious cover. Additionally, more ambitious and costly measures are also possible, including the installation of a green roof (Figure 10-26) or capturing stormwater in larger cisterns for reuse.

Public education is a key to increasing participation in residential stormwater measures such as:

- Installing rain barrels to collect roof runoff
- Disconnecting downspouts to direct runoff to pervious areas or small, dug drywells
- Using site slopes to direct stormwater runoff to rain gardens

Examples of a couple of these elements are shown in Figure 10-27 and Figure 10-28 below.

To supplement the Green Homes Program, more ambitious and costly measures are also possible, including installing a green roof, or capturing stormwater in larger cisterns for reuse. Stormwater fees are not likely to be effective in stimulating these solutions, and PWD might consider evaluating creation of tools to encourage implementation.

Figure 10-27 Green Stormwater Management Practices for Homeowners

Reductions in the contribution of wastewater from homes to the sewers can also have a significant impact on CSOs. The City is embarking on an ambitious program of energy reduction through weatherization of homes throughout the city.

PWD will also evaluate potential for developing a sidewalk replacement grant program that would share the cost of greening sidewalks in front of private properties, ranging from modest measures such as planters and tree pits, to more ambitious approaches such as the installation of pervious paving and subsurface storage.

Figure 10-28 Examples of a Rain Garden and Disconnected Rain Spout for Residential Areas

Summary
This is how PWD envisions unfolding their Plan. PWD has some clear ideas and has implemented many of the solutions through a variety of demonstration projects with the assistance of their partners, although the precise application of which tools and where they will be applied has not yet been determined. What is truly exciting about this Plan is that it has the power to change forever the way the City renews its streets and neighborhoods. Many of these green technologies have been proven successful, but are untried on such a city-wide scale. This Plan contains built-in milestones that allow PWD to measure progress with each element every few years and adapt as necessary. Where less progress is measured with the use of a given tool, another will be implemented. Because of the numerous possible tools available for greening acres, the Plan is by its very nature adaptive.

10.2.2 Stream Corridor Restoration and Preservation; Achievement of Targets A and B

Restoration and Preservation of riverfronts, stream habitats and corridors can be combined with efforts to improve public access and amenities along the water corridors. Implicit in this effort are aspirations to re-connect Philadelphians with the City's extensive river network. Included in PWD's recommended approach is a commitment to restoration of 7.7 mi of the stream corridor along the Cobbs Creek and 3.4 mi of stream corridor restoration along the Tacony Creek. Where applicable-wetland preservation, enhancement and creation within these corridors will offer the additional benefits of mitigating the adverse impacts of stormwater runoff and increase the ecological connectivity within the region.

The Delaware and Schuylkill Valleys serve as important junctions for anadromous fish and avian migratory activities. As such, efforts by PWD to commit to the restoration of a number of acres of tidal wetlands along the Schuylkill and Delaware Rivers will have ecological impacts that extend beyond the region and into the Delaware Bay and beyond. Additionally, in order to facilitate recreation on the Delaware River, the PWD will support local efforts to increase public riverfront access and recreation by moving or consolidating CSO outfalls to eliminate odors and improve aesthetics. Depending on site-specific conditions at locations, outfalls may be modified by consolidating with another downstream outfall or extending the outfall away from the river's edge further into the Delaware River channel. PWD will seek to identify locations where CSO outfalls may be consolidated or extended in order to enhance recreational opportunities.

What follows is a description of individual commitments made toward achievement of Targets A and B in each of PWD's four watersheds within the CSS drainage area.

10.2.1 Improving Dry Weather Water Quality, Aesthetics and Recreation

Target A addresses water quality requirements of the Clean Water Act in streams and rivers during dry weather conditions, as well as stream and river aesthetics and river related recreation.

10.2.2.1 TTF Creek Watershed

The TTF IWMP, completed in 2005, included a long-term commitment to Target A implementation measures (Table 10-1).

Table 10-1 TTF IWMP Target A Commitments

Tookany/Tacony-Frankford Watershed			
	Included in PWD Base Program	New Annual Cost	One-Time cost
Public Education and Volunteer Programs			
AP2 School-Based Education	$370,000 annual	$150,000	
AP3 Public Participation and Volunteer Programs			
Municipal Measures			
AM1-4 Sewer Evaluation, Cleaning, Relining/Rehabilitation	$24,000,000 one-time cost plus $530,000 annual		
AM5 Illicit Discharge, Detection, and Elimination (IDD&E)	$5,000,000 one-time cost plus $210,000 annual		
AM6 Stream Cleanup and Maintenance	$170,000 annual	$30,000	$20,000
AO1 Enhancing Stream Corridor Recreational and Cultural Resources*		$0	$0
Monitoring and Reporting			
AMR Monitoring, Reporting, and Further Study	$20,000 annual		
Target A Total Annual Costs and Operations & Maintenance (2009 Dollars)	$1,090,000	$180,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$3,100,000
Total New One Time Costs for Target A			$20,000
Total Target A Commitment			**$54,600,000**
Total Target A Commitment in LTCPU			**$3,120,000**

* PWD funding has not been allocated for enhancement of recreational and cultural resources, though efforts will be sought to support these initiatives

Public Education

<u>Public Participation and Volunteer Programs</u>

PWD supports the TTF Watershed Partnership, a 501(c)3 organization financially through annual membership dues, and programmatically by offering resources and technical assistance to this group throughout the year. This organization was formed with the mission of implementing the recommendations of the IWMP and leads the efforts to connect the community to the watershed by engaging volunteers and educating residents on stormwater and watershed management. PWD additionally maintains the http://www.phillyriverinfo.org website for posting of Partnership related information, meeting minutes, presentations, announcements, etc.

Additionally, PWD has launched a robust public outreach and education program through their *Green City, Clean Waters* Campaign called the Model Neighborhood Initiative. This initiative is aimed at transforming neighborhoods of Philadelphia into model green communities that manage stormwater in innovative ways. These neighborhoods will showcase green stormwater infrastructure elements, such as street trees trenches, sidewalk planters, and bump outs/curb extensions.

School-Based Education

PWD will continue to support the Tookany-Tacony/Frankford Watershed Partnership in providing school-based education and volunteer programs. Additionally, the Fairmount Water Works Interpretive Center hosts school groups and teacher trainings to promote watershed concepts. For each watershed, an area-weighted percentage of Water Works funding has been allocated into the Target A commitment. PWD will continue to lead the *Green City, Clean Waters* program to engage the public and receive feedback on issues surrounding the LTCPU implementation and will use this watershed partnership as one of the vehicles for taking this message to the public.

Municipal Measures

Inspection Cleaning and Rehabilitation of Sewers

Sewers are assessed to identify segments in need of rehabilitation, particularly where leakage is directly flowing into the stream. Maintenance of sewers includes activities required to keep the system functioning as it was originally designed and constructed. Any reinvestment in the system, including routine maintenance, capital improvements for repair or rehabilitation, inspection activities, and monitoring activities is classified as maintenance. The single largest component of the Target A commitment in the TTF Watershed is to reline almost seven miles of combined sewer interceptor that runs along the mainstem of the creek.

Illicit Discharge, Detection, and Elimination (IDD&E)

The water quality of the TTF is also impacted by separate sewered areas. In keeping with the watershed approach, the separate sewered area of the TTF watershed has been a priority area for the PWD Defective Lateral Program over the past decade. This commitment to continuation of the program within this watershed is aimed at elimination of dry weather flows to the creek resulting from illicit sewer connections. The program will continue as required in the City of Philadelphia Stormwater Permit.

Stream Cleanup and Maintenance

Stream cleanup and maintenance is performed by the PWD Waterways Restoration Team (WRT). The WRT will continue to inspect and assess the conditions of sewage infrastructure along the Tacony/Frankford and its tributaries, collect litter and large debris, identify, prioritize and maintain a list of obstructions, aesthetic nuisances, and debris removal needs, and investigate right-of-way complaints.

Recreational and Cultural Resources

Enhancing Stream Corridor Recreational and Cultural Resources

PWD will support the enhancement of recreational and cultural resources along the Tacony/Frankford Creek and local initiatives by providing partnership support and technical assistance.

The Frankford Greenway Master Plan:

As part of Target A objectives in the TTF Creek Watershed, PWD supported the development of the Frankford Greenway Master Plan, which is an effort to reconnect residents with the waterway in a very underutilized area. The planning area includes a 2.7 mi stretch of Frankford Creek in Northeast Philadelphia. Unlike the upstream portion of this watershed's drainage area, this portion of the creek is not surrounded by planned or existing park lands. The Frankford Creek has been channelized with large concrete walls and bottom, and is inaccessible due to private land ownership. This plan is intended to improve stream ecology, provide recreational opportunities, preserve the history of the corridor, provide riparian buffer, manage storm water, and provide connectivity for and to surrounding communities (Figures 10-29 through 10-31).

PWD has not committed funding to support implementation of this plan, however as PWD moves forward with implementation of land-based and instream restoration commitments, opportunities to support the vision as laid out by this plan will be evaluated and synergies sought.

Figure 10-29 Before and After Visioning of Aramingo Avenue & Frankford Creek (Source: Frankford Greenway Master Plan, 2008)

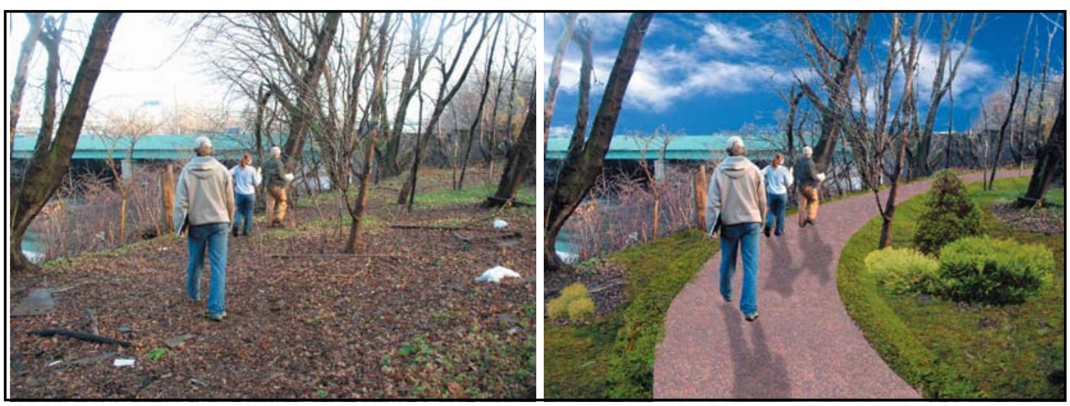


Figure 10-30 Before and After Visioning of Frankford Creek, Just North of Aramingo Avenue (Source: Frankford Greenway Master Plan, 2008)

Figure 10-31 Before and After Visioning of What a Trail Could Look Like Underneath the Interstate Ramps Along Frankford Creek (Source: Frankford Greenway Master Plan, 2008)

10.2.2.2 Cobbs Creek Watershed

The Cobbs Creek IWMP (CC IWMP), completed in 2004, included a long-term commitment to Target A implementation measures (Table 10-2).

Table 10-2 CC IWMP Target A Commitments

Cobbs Creek Watershed			
	Included in PWD Base Program	**New Annual Cost**	**One-Time cost**
Public Education and Volunteer Programs			
AP2 School-Based Education	$370,000 annual	$150,000	
AP3 Public Participation and Volunteer Programs			
Municipal Measures			
AM1-4 Sewer Evaluation, Cleaning, Relining/Rehabilitation	$10,000,000 one-time cost plus $500,000 annual		
AM6 Stream Cleanup and Maintenance	$170,000 annual	$20,000	$20,000
AO1 Enhancing Stream Corridor Recreational and Cultural Resources*		$0	$0
Monitoring and Reporting			
AMR Monitoring, Reporting, and Further Study	$20,000 annual		
Target A Total Annual Costs and Operations & Maintenance (2009 Dollars)	$1,060,000	$170,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$2,900,000
Total New One Time Costs for Target A			$20,000
Total Target A Commitment			**$34,800,000**
Total Target A Commitment in LTCPU			**$2,920,000**

* PWD funding has not been allocated for enhancement of recreational and cultural resources, though efforts will be sought to support these initiatives

Public Education

School-Based Education

Public education and participation is an important element of the CC IWMP as well as the LTCPU. PWD will continue to support the Darby-Cobbs Watershed Partnership in their school-based watershed education and volunteer programs. Additionally, the Fairmount Water Works Interpretive Center hosts school groups and teacher trainings to promote watershed concepts. For each watershed, an area-weighted percentage of Water Works funding has been allocated into the Target A commitment. PWD will continue to lead the *Green City, Clean Waters* program to engage the public and receive feedback on issues surrounding the LTCPU implementation and will use this watershed partnership as one of the vehicles for taking this message to the public.

Public Participation and Volunteer Programs

PWD supports and continues to convene the Darby-Cobbs Watershed Partnership. This organization leads the efforts to connect the community to the watershed by engaging volunteers and educating residents on stormwater and watershed management. PWD additionally maintains the http://www.phillyriverinfo.org website for posting of Partnership related information, meeting minutes, presentations, announcements, etc.

Additionally, PWD has launched a robust public outreach and education program through their *Green City, Clean Waters* Campaign called the Model Neighborhood Initiative. This initiative is aimed at transforming neighborhoods of Philadelphia into model green communities that manage stormwater in innovative ways. These neighborhoods will showcase green stormwater infrastructure elements, such as street tree trenches, sidewalk planters, and bump outs/curb extensions.

Municipal Measures

Inspection Cleaning and Rehabilitation of Sewers

Sewers are assessed to identify segments in need of rehabilitation, particularly where leakage is directly flowing into the stream. PWD will continue to regularly inspect and clean the combined sewer infrastructure in the Cobbs Creek Watershed to reduce dry weather flows. Maintenance of sewers includes activities required to keep the system functioning as it was originally designed and constructed. Any reinvestment in the system, including routine maintenance, capital improvements for repair or rehabilitation, inspection activities, and monitoring activities is classified as maintenance. The single largest component of the Target A commitment in the Cobbs Creek Watershed is relining of almost six miles of interceptor pipes that run along the mainstem of the creek.

Stream Cleanup and Maintenance

Stream cleanup and maintenance will be conducted by the PWD WRT. The WRT will continue to inspect and assess the conditions of sewage infrastructure along the Cobbs Creek and its tributaries, collect litter and large debris, identify, prioritize and maintain a list of obstructions, aesthetic nuisances, and debris removal needs, develop and maintain a corrective plan, and investigate right of way complaints.

Recreational and Cultural Resources

Enhancing Stream Corridor Recreational and Cultural Resources

PWD will support the enhancement of recreational and cultural resources and local initiatives along Cobbs Creek by providing partnerships support and technical assistance.

10.2.2.3 Delaware Direct Watershed

An IWMP planning process for the portion of the Delaware River Watershed within the City of Philadelphia (also called the Delaware Direct Watershed Drainage) was initiated in winter, 2008. Specific commitments to dry weather water quality improvements have not yet been defined for this watershed, however, numerous visions have been set forth for revitalizing the Delaware Riverfront. The forthcoming IWMP will support these visions and will seek to compliment them where possible.

Target A is defined for the Delaware Direct as focusing on the removal of solids, floatables and large debris in addition to the facilitation of local efforts to increase recreational and cultural opportunities along the river. As the Delaware Waterfront is redeveloped and becomes a local attraction, it should be aesthetically appealing and accessible to the public in order to be an amenity to the community. Commitments set forth to address Target A in the Delaware Direct Watershed are described in Table 10-3.

Table 10-3 Planning-Level Cost Estimates for Target A Options in the Delaware Direct Watershed

Delaware Direct Watershed			
	Included in PWD Base Program	**New Annual Cost**	**One-Time cost**
Public Education and Volunteer Programs			
AP2 School-Based Education	$370,000 annual	$200,000	
AP3 Public Participation and Volunteer Programs			
Municipal Measures			
AM6 Stream Cleanup and Maintenance		$67,000	$50,000
AM8 CSO Outfall elimination/consolidation			$29,00,000
AO1 Enhancing Stream Corridor Recreational and Cultural Resources*		$0	$0
Target A Total Annual Costs and Operations & Maintenance (2009 Dollars)	$370,000	$267,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$4,600,000
Total New One Time Costs for Target A			$29,050,000
Total Target A Commitment			**$42,250,000**
Total Target A Commitment in LTCPU			**$33,650,000**

* PWD funding has not been allocated for enhancement of recreational and cultural resources, though efforts will be sought to support these initiatives

Public Education

<u>School-Based Education</u>

The Fairmount Water Works Interpretive Center hosts school groups and teacher trainings to promote watershed concepts. Additionally, PWD will continue to lead the *Green City, Clean Waters* program to engage the public and receive feedback on issues surrounding the LTCPU implementation and will use this watershed partnership as one of the vehicles for taking this message to the public.

<u>Public Participation and Volunteer Programs</u>
PWD has launched a robust public outreach and education program through their *Green City, Clean Waters* Campaign called the Model Neighborhood Initiative. This initiative is aimed at transforming neighborhoods of Philadelphia into model green communities that manage stormwater in innovative ways. These neighborhoods will showcase green stormwater infrastructure elements, such as street trees trench, sidewalk planters, and bump outs/curb extensions.

Municipal Measures
<u>Stream Cleanup and Maintenance</u>
Target A in the Delaware Direct IWMP currently will be developed to focus on the removal of litter and floatables in the Delaware River to improve aesthetics and recreation. Staffing of the WRT may need to be expanded to assist removing debris along the banks of the Delaware River.

<u>Floatables Control:</u>
PWD has made a number of significant commitments to control the discharge of solids and floatables within these waterways. The City maintains a robust program for the cleaning of inlets and catch basins, which includes the inspection and cleaning of approximately 79,000 stormwater inlets throughout the City of Philadelphia.

The City also maintains two floatables skimming vessels aimed at reduction of floatables and improvement of both water quality and aesthetics of the receiving streams. The use of a skimmer vessel allows for a mobile control program capable of managing debris at various locations, increasing the effectiveness of this control measure. In addition, the boat is a visible control, and increases the public awareness and education of floatables impacts.

Floatables Skimming Vessel – R.E. Roy is a 39-ft, front-end loader, single hull, shallow draft, debris skimming vessel with a hydraulically controlled grated bucket and a 5.6 cubic yard on-board (Figure 10-32).

The vessel is operated approximately five days per week, 8 months of the year. The vessel's main purpose is to perform general debris collection and removal on both the Delaware and Schuylkill Rivers. The vessel is also used to clean up for and serve as a public relations highlight at events such as the Schuylkill Regatta.

The PWD has also purchased a pontoon vessel that is being used as a workboat on the Upper Schuylkill, Lower Schuylkill, and Delaware Rivers within Philadelphia. The vessel is used to retrieve floating trash and debris from the waterways within the service area. The debris is hand netted from the water surface by employees standing on the vessel deck. The hand nets are emptied into 30-gallon debris containers on the deck, and the containers are offloaded by hand. The pontoon vessel can be utilized in tight spaces found in marinas, among piers, and in near shore areas. This small pontoon vessel is used as a companion vessel to the larger floatables skimming vessel already being operated in Philadelphia.

The operational area of the Pontoon Vessel includes:

1. The Lower Schuylkill above Fairmount Dam up to Flatrock Dam (7.2 mi)
2. The Lower Tidal Schuylkill down to the confluence with the Delaware River (8.1 mi)
3. The Delaware River from the confluence up to the Philadelphia City boundary (18.8 mi)

Figure 10-32 Floatables Skimming Vessel in Operation

Figure 10-33 Floatables Pontoon Vessel in Operation

An additional skimmer vessel will be purchased and staffed twice a week during the nine month outdoor recreational season. These additional resources will remove floatables in the Tidal River and accommodate increased river access along the Delaware Waterfront.

CSO Outfall consolidation and extension

Outfall consolidation/extension is the most expensive Target A option in the Delaware Direct and likely to occur as the riverfront is re-developed. In order to facilitate recreation on the Delaware River, the Philadelphia Water Department will support local efforts to increase public riverfront access and recreation by moving CSO outfalls to eliminate odors and improve aesthetics. Depending on site-specific conditions at locations, outfalls may be consolidated with another downstream outfall or extending the outfall away from the river's edge further into the Delaware River channel.

Outfall consolidation projects will be conducted as conflicts with recreation or access to the river arise. Each consolidation project will include a different number of outfalls consolidated, typically ranging from two to four and will cost $10-$12 million. The LTCPU commitment includes a total of $29 million to implement outfall relocation/consolidation, which would support two major consolidation projects along the Delaware Waterfront. The more outfalls that can be consolidated in each project, the greater the savings. Based on planning level costs estimates, up to 10 outfalls can be consolidated, eliminating up to 7 CSO outfalls, or 11% of the CSO outfalls on the Delaware River. These eliminated outfalls represent nearly half of the highest priority outfalls based on conflicts with recreational use. Specific outfalls to be consolidated or relocated have not been determined; this level of planning and assessment will take place over the coming years.

Enhancing Stream Corridor Recreational and Cultural Resources
Strategies to protect water-based historic structures are currently outlined in the Civic Vision and North Delaware planning efforts. These plans will become more fully developed through further local planning efforts. In addition to consolidating outfalls as described above, PWD will continue to support the enhancement of recreational and cultural resources along the Delaware River by providing partnership support and technical assistance.

The City of Philadelphia maintains a strong commitment to supporting implementation of the visions set forth by other stakeholder initiatives focused on enhancing recreational opportunities along the Schuylkill and Delaware Rivers. PWD has evaluated the following plans for the Schuylkill and Delaware riverfront areas and will seek to complement these efforts where possible:

- North Delaware Riverfront, Philadelphia: A Long-Term Vision for Renewal and Redevelopment – 2001
- North Delaware Riverfront Greenway Master Plan – 2005
- New Kensington CDC Community Plan – 2008
- A Civic Vision for the Central Delaware (Figure 10-34) – 2007
- An Action Plan for the Central Delaware – 2008
- Northern Liberties Waterfront Plan – 2007
- Northern Liberties Neighborhood Plan – 2005
- Neighbors Allied for the Best Riverfront – Ongoing
- Navy Yard Master Plan – 2004
- Tidal Schuylkill River Master Plan – 2003
- Schuylkill River Heritage Area Planning - Ongoing

PWD has not committed funding to support implementation of these plans, however as PWD moves forward with implementation of land-based and instream restoration commitments, opportunities to support the vision as laid out by these plans will be evaluated and synergies sought.

Figure 10-34 Visions of a "Greened" Delaware Riverfront with Ample Public Recreational Facilities (Source: Civic Vision for the Central Delaware, 2007)

10.2.2.4 Tidal Schuylkill

An IWMP planning process for the portion of the Schuylkill River Watershed within the City of Philadelphia was initiated in winter, 2008. Specific commitments to dry weather water quality improvements have not yet been defined for this watershed, however, numerous visions have been set forth for revitalizing the riverfront. The forthcoming IWMP will support these visions and will seek to compliment them where possible.

Target A is defined for the Tidal Schuylkill watershed as focusing on the removal of solids, floatables and large debris in addition to the facilitation of local efforts to increase recreation along the Schuylkill River. Commitments set forth to address Target A in the Tidal Schuylkill Watershed are described in Table 10-4.

Table 10-4 Planning-Level Cost Estimates for Target A Options in the Tidal Schuylkill River Watershed

Tidal Schuylkill Watershed			
	Included in PWD Base Program	New Annual Cost	One-Time cost
Public Education and Volunteer Programs			
AP2 School-Based Education	$370,000 annual	$200,000	
AP3 Public Participation and Volunteer Programs			
Municipal Measures			
AM6 Stream Cleanup and Maintenance		$67,000	$50,000
AO1 Enhancing Stream Corridor Recreational and Cultural Resources*		$0	$0
AM8 CSO Outfall elimination/consolidation			$29,000,000
Target A Total Annual Costs and Operations & Maintenance (2009 Dollars)	$370,000	$267,000	
Total Present Value of New Annual Costs and O&M (20 Years)	$4,600,000		
Total New One Time Costs for Target A	$29,050,000		
Total Target A Commitment	**$42,250,000**		
Total Target A Commitment in LTCPU	**$33,650,000**		

* PWD funding has not been allocated for enhancement of recreational and cultural resources, though efforts will be sought to support these initiatives

Public Education

<u>School-Based Education</u>

The Fairmount Water Works Interpretive Center hosts school groups and teacher trainings to promote watershed concepts. For each watershed, an area-weighted percentage of Water Works funding has been allocated into the Target A commitment. PWD will continue to lead the *Green City, Clean Waters* program to engage the public and receive feedback on issues surrounding the LTCPU implementation and will use this watershed partnership as one of the vehicles for taking this message to the public.

Public Participation and Volunteer Programs

PWD has launched a robust public outreach and education program through their *Green City, Clean Waters* Campaign called the Model Neighborhood Initiative. This initiative is aimed at transforming neighborhoods of Philadelphia into model green communities that manage stormwater in innovative ways. These neighborhoods will showcase green stormwater infrastructure elements, such as street trees trenches, sidewalk planters, and bump outs/curb extensions.

Municipal Measures

Stream Cleanup and Maintenance

While the implementation of wet weather controls will reduce the sources of floatable debris, Target A of the Schuylkill River IWMP will focus on the removal of litter and floatables in the Schuylkill River to improve aesthetics and recreation. An additional pontoon skimmer vessel will be purchased and staffed twice a week during the nine month outdoor recreational season. These additional resources will remove floatables in the Tidal Schuylkill River and accommodate for the

increased river access and recreational use as the banks of the Schuylkill River are developed. Additionally, the WRT may also need to be expanded to assist removing debris along the edges of the Tidal Schuylkill River.

CSO Outfall consolidation and extension

Outfall consolidation/extension is the most expensive Target A option and likely to occur as The Tidal Schuylkill Master Plan is further developed and realized. In order to facilitate recreation on the Schuylkill River, the Philadelphia Water Department will support local efforts to increase public riverfront access and recreation by moving CSO outfalls to eliminate odors and improve aesthetics. Depending on site-specific conditions at each location, outfalls may be consolidated by piping flow downstream to the next outfall to the following outfall or extending the outfall away from the river's edge further into the Schuylkill River channel.

Outfall consolidation projects will be conducted as conflicts with recreation or access to the river arise. Each consolidation project will include a different number of outfalls consolidated, typically ranging from two to four and will costs $10-$12 Million. The LTCPU commitment includes a total of $29 Million for the Schuylkill River to implement outfall relocation/consolidation, which would support two major consolidation projects to take place. The more outfalls that can be consolidated in each project, the greater the savings. Based on planning level costs estimates, up to 10 outfalls can be consolidated, eliminating up to 7 CSO outfalls, or 18% of the CSO outfalls on the Schuylkill River. These eliminated outfalls represent a majority of the highest priority outfalls based on conflicts with recreational use. Specific outfalls to be consolidated or relocated have not been determined; this level of planning and assessment will take place over the coming years.

Enhancing River Corridor Recreational and Cultural Resources

Strategies to provide access to cultural and water resources for recreational purposes, as proposed in the Tidal Schuylkill River Master Plan, encourage appreciation for and stewardship of these areas. PWD will support the enhancement of recreational and cultural resources along the Schuylkill River and local initiatives by providing partnership support and technical assistance. PWD has not committed funding to support implementation of this plan; however, as PWD moves forward with implementation of land-based and instream restoration commitments, opportunities to support the vision as laid out by this plan will be evaluated and synergies sought.

10.2.3 Restoring Living Resources

Target B addresses improvements to the number, health, and diversity of benthic macroinvertebrate and fish species in Philadelphia's waterways. Achieving Target B objectives will require investment in habitat improvement and measures to provide the opportunity for organisms to avoid high velocities during storms. Improving the ability of an urban stream to support viable habitat and fish populations must focus primarily on the elimination or remediation of the more obvious impacts of urbanization (Figure 10-35). These include loss of riparian habitat, eroding and undercut banks, scoured streambed or excessive silt deposits, channelized and armored stream sections, trash buildup, and invasive species.

Restoration and Preservation of riverfronts, stream habitats and corridors can be combined with efforts to improve public access and amenities along the water corridors. Implicit in this effort are aspirations to re-connect Philadelphians as well as the landscape- with the City's vast river network. The Delaware and Schuylkill Valleys serve as important junctions for anadromous fish and avian migratory activities.

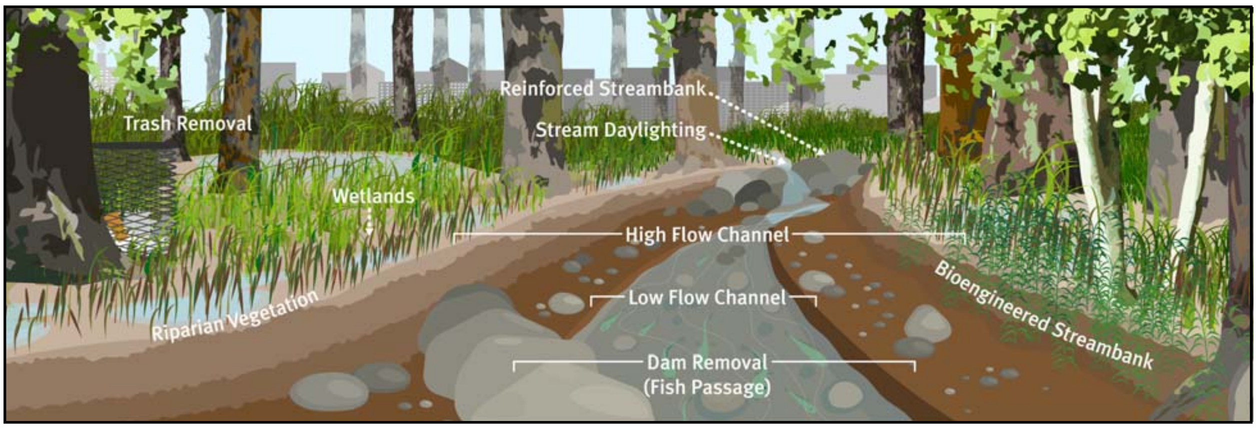


Figure 10-35 Vision for a Restored Stream Corridor (Source: WRT Designs)

PWD is currently assembling a Watershed Project Registry to identify and study areas for future stream restoration, wetland creation, wetland enhancement (including invasive plant management), tidal wetland creation/restoration, stream daylighting and preservation projects (Figure 10-36). This effort will ensure a steady progression towards the greater goal of making Philadelphia one of the greenest cities in the country as well as realizing the full ecological potential of the Fairmount Park system, which could one day serve as the model for urban forestry and river management.

In the tidal rivers, impairment of living resources has not been identified as a problem, but the opportunity for the restoration of lost habitat will be key elements of the IWMPs.

As defined by the IWMPs, Target B measures include the following:

Channel Stability and Aquatic Habitat Restoration

BM1 Bed Stabilization and Habitat Restoration
BM2 Bank Stabilization and Habitat Restoration
BM3 Channel Realignment and Relocation
BM4 Plunge Pool Removal
BM5 Improvement of Fish Passage

Lowland and Upland Restoration and Enhancement

BM6	Wetland Creation and Enhancement
BM7	Invasive Species Management
BM8	Biofiltration
BM9	Reforestation

Measure to achieve Target B objectives are discussed below by watershed.

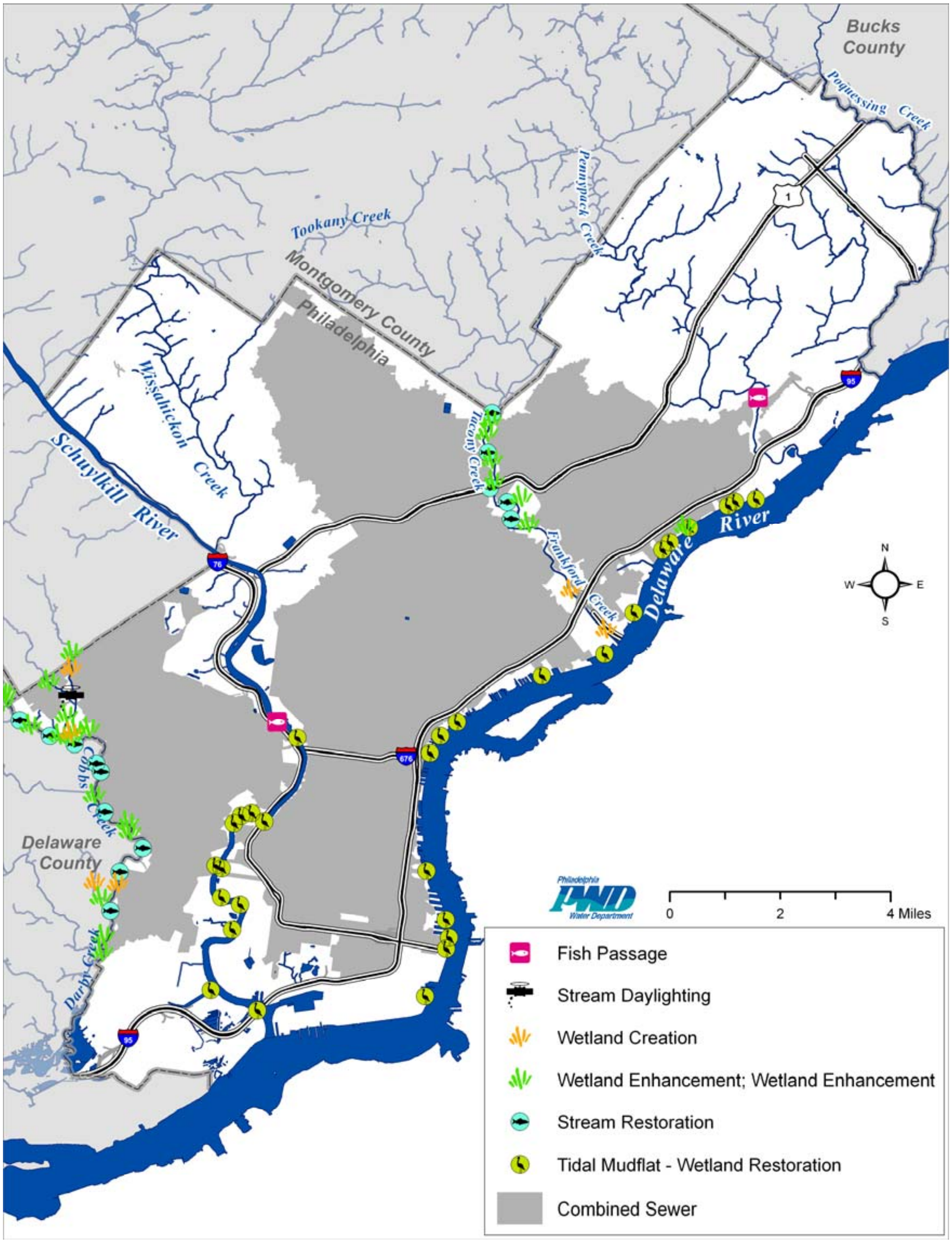


Figure 10-36 PWD's Proposed Stream Corridor Preservation and Restoration Sites

10.2.3.1 TTF Creek Watershed

The TTF IWMP, completed in 2005, included a long-term commitment to Target B implementation measures (Table 10-5).

Table 10-5 TTF IWMP Target B Commitments

Tookany/Tacony-Frankford Watershed			
	Included in PWD Base Program	New Annual Cost	One-Time cost
Channel Stability and Aquatic Habitat Restoration			
BM1-BM3, BM6-9 Bed and Bank Stabilization and Habitat Restoration' Wetland Creation and Enhancement		$9,300	$25,000,000
Monitoring and Reporting			
BMR Monitoring, Reporting, and Further Study	$23,400 Annual		
Target B Total Annual Costs and Operations & Maintenance (2009 Dollars)	$23,400	$9,300	
Total Present Value of New Annual Costs and O&M (20 Years)			$160,000
Total New One Time Costs for Target B			$25,000,000
Total Target B Commitment			**$25,700,000**
Total Target B Commitment in LTCPU			**$25,160,000**

Stream and Habitat Restoration Planning (BM1- BM9)

PWD has committed to implementing stream and habitat restoration along the TTF Creek from the Montgomery County boundary to the Juniata Golf Course, the beginning of the channelized portion of the waterway. This amounts to a roughly 3.4 mi length of stream to be evaluated for restoration.

In 2008, PWD contracted with an engineering firm to guide the long-term vision of aquatic ecological restoration work planned in the Tacony Creek Watershed. Over the next 20 years, PWD intends to implement natural stream channel and wetland design work along the 3.4 mi of the main stem of Tacony Creek within the City of Philadelphia. The anticipated benefits of this riparian corridor work will include reduced stream bank erosion, channel deposition and scour, restoring the natural functions of aquatic habitat and ecosystems to the greatest degree possible.

Additionally, in 2009 PWD worked with consultants to develop a vision for the TTF Creek Watershed as "Fertile Ground for a Destination Watershed: Laying the groundwork for restoring the TTF Creek corridor toward a vision of creek health and community wealth" (available online at http://www.phillyriverinfo.org). This vision covers the entire TTF Creek from its headwaters in Montgomery County through the confluence with the Delaware River.

Plunge Pool Removal (BM4)

In addition to Target A initiatives, the WRT also performs instream habitat restoration and plunge pool removal.

10.2.3.2 Cobbs Creek Watershed

The CC IWMP, completed in 2004, included a long-term commitment to Target B implementation measures (Table 10-6).

Table 10-6 The CCIWMP Commitment to Target B

Cobbs Creek Watershed			
	Included in PWD Base Program	**New Annual Cost**	**One-Time cost**
Channel Stability and Aquatic Habitat Restoration			
BM1-BM3, BM6-9 Bed and Bank Stabilization and Habitat Restoration' Wetland Creation and Enhancement		$41,000	$53,000,000
BM5 Improvement of Fish Passage			$150,000
Monitoring and Reporting			
BMR Monitoring, Reporting, and Further Study	$23,400 Annual		
Target B Total Annual Costs and Operations & Maintenance (2009 Dollars)	$23,400	$41,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$700,000
Total New One Time Costs for Target B			$53,000,000
Total Target B Commitment			**$54,300,000**
Total Target B Commitment in LTCPU			**$53,700,000**

Stream and Habitat Restoration Planning (BM1- BM9)

PWD has committed to implementing stream and habitat restoration along the Cobbs Creek from the Montgomery County boundary to the confluence of the Cobbs Creek with the Darby Creek. Though the Cobbs Creek forms the Philadelphia County boundary, PWD has committed to restoring both banks of the creek as it would not support habitat establishment to only implement restoration practices on the Philadelphia side of the creek. This amounts to a roughly 7.1 mi length of stream to be evaluated for restoration.

In 2008, PWD contracted with a team of consulting firms to guide the long-term vision of aquatic ecological restoration work planned in the Cobbs Creek Watershed. Over the next 20 years, PWD intends to implement natural stream channel and wetland design work along the main stem of the Cobbs Creek within the City of Philadelphia. The anticipated benefits of this riparian corridor work will include reduced stream bank erosion, channel deposition and scour and restoring the natural functions of aquatic habitat and ecosystems to the greatest degree possible.

Additionally, in 2008 PWD worked with consultants to develop a vision for the Cobbs Creek Watershed as "A Gateway to Many Places and to Cleaner Water" (available online at http://www.phillyriverinfo.org). This vision evaluated the Cobbs Creek corridor from the northern-most portion of the watershed within the City of Philadelphia including the East and West branches of Indian Creek all the way down to the confluence of the Cobbs Creek with the Darby Creek. This corridor was broken into seven segments – and each was evaluated for its own opportunities for habitat and recreational creation and enhancement.

Fish Passage on Cobbs Creek

The PWD is investigating the option of a project to create fish passage on the Cobbs Creek. The purpose of the Cobbs Creek Fish Passage Restoration Project would be to investigate, select, design and construct the best alternative to reestablish fish passage on Cobbs Creek. Two small dams represent opportunities to improve fish passage on Cobbs Creek. The lower dam, Woodland Dam, located close to the Cobbs Creek Parkway and Woodland Avenue, is the first impediment to fish passage on Cobbs Creek. It is a low concrete structure below which the creek is tidal. The upper dam, Millbourne Dam, situated on Cobbs Creek near 65th and Race Streets is a rock structure. Both dams are managed by the Fairmount Park. This currently is a potential project and will become an active project depending on available funding from sources including the U.S. Army Corps of Engineers.

10.2.3.3 Delaware and Schuylkill Rivers

Commitments set forth to address Target B in the Delaware Direct and Tidal Schuylkill Watersheds are described in Tables 10-7 and 10-8.

Table 10-7 Planning-Level Costs for Target B Options in the Delaware Direct Watershed

Delaware Direct Watershed			
	Included in PWD Base Program	New Annual Cost	One-Time cost
Lowland Restoration and Enhancement			
BM6 Wetland Creation and Enhancement		$212,000	$25,000,000
Target B Total Annual Costs and Operations & Maintenance (2009 Dollars)		$212,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$3,700,000
Total New One Time Costs for Target B			$25,000,000
Total Target B Commitment			**$28,700,000**
Total Target B Commitment in LTCPU			**$28,700,000**

Table 10-8 Planning-Level Costs for Target B Options in the Tidal Schuylkill River

Tidal Schuylkill Watershed			
	Included in PWD Base Program	New Annual Cost	One-Time cost
Channel Stability and Aquatic Habitat Restoration			
BM5 Improvement of Fish Passage	$140,450		$300,000
BM6 Wetland Creation and Enhancement		$112,000	$14,200,000
Target B Total Annual Costs and Operations & Maintenance (2009 Dollars)	$140,450	$112,000	
Total Present Value of New Annual Costs and O&M (20 Years)			$2,000,000
Total New One Time Costs for Target B			$14,500,000
Total Target B Commitment			**$19,700,000**
Total Target B Commitment in LTCPU			**$16,500,000**

Tidal Wetland Restoration

Both the Delaware and Schuylkill Rivers are tidally influenced within Philadelphia's combined sewer area. Since there are few tributaries in the extremely urban drainage areas to the Delaware and Schuylkill Rivers, Target B focuses on habitat restoration along the main stem of these tidal rivers. Historically, freshwater tidal wetlands extended from Trenton, New Jersey to Chester, Pennsylvania, but urbanization has reduced the tidal wetland area by 95%, with only small remnants of freshwater tidal wetlands on the Pennsylvania side of the Delaware River.

In 2006 and 2007, aquatic biologists from the PWD conducted a field assessment of the inter-tidal areas in the Delaware and Schuylkill Rivers. Existing tidal wetlands and areas with potential for habitat enhancement and restoration were mapped. Existing vegetation within each of these areas was identified and recorded in a geo-spatial database. The locations for potential tidal wetland restoration and creation were selected when the following criteria were found in the tidal shores of the Delaware and Schuylkill Rivers:

1. Gradual slope to littoral shelf and appropriate depth range
2. Appropriate sediment characteristics
3. Ability for wave/wake attenuation

The inter-tidal assessment identified approximately 27 ac in the Delaware that need vegetative enhancement or invasive species removal. Another 61 ac in the Delaware and 30 ac in the Schuylkill have been identified as locations where conditions support creation or restoration. The identified sites are exposed during low tide as unvegetated mudflats and partially inundated during high tide. Restoration will entail introducing appropriate wetland vegetation into areas flooded to a maximum of 3 ft during high tide. The restoration of tidal wetlands and shoreline protection will improve the quality of water, as well as create vital habitat for aquatic life, herpifauna and migratory birds. Shoreline protection and wave attenuation is essential for the success of establishing tidal wetlands in this area. Additional studies will need to be conducted to assess the wave energy at each site. PWD will commit to creation/restoration of up to 60% of potential shoreline wetlands identified by PWD Aquatic Biologists.

Fairmount Dam Fishway

In addition to the tidal wetland restoration in the tidal Schuylkill River, habitat for fish species, especial migratory fishes, continues to be enhanced through the improvements of the Fairmount Dam fishway. The Fairmount Dam is situated within the Philadelphia City limits on Fairmount Park property. The fish ladder was constructed between 1977 and 1979 on the western side of the Fairmount Dam. The fish ladder has been maintained historically by the voluntary efforts of the Friends of the Fairmount Fish Ladder. The effects of time and natural forces damaged the fish ladder and the degradation severely limits the ladder's efficiency at passing migratory fish species. In 2002, the PWD partnered with the Philadelphia District Army Corps of Engineers to improve and revitalize the Fairmount Dam Fish Ladder, pursuant to Section 1135 of the Water Resources Development Act of 1986. By 2009, the fish ladder restoration project was completed, including the creation of an outdoor educational area adjacent to the fishway. The PWD will continue to monitor fish in the tidal Schuylkill River and passage through the Fairmount Dam fishway.

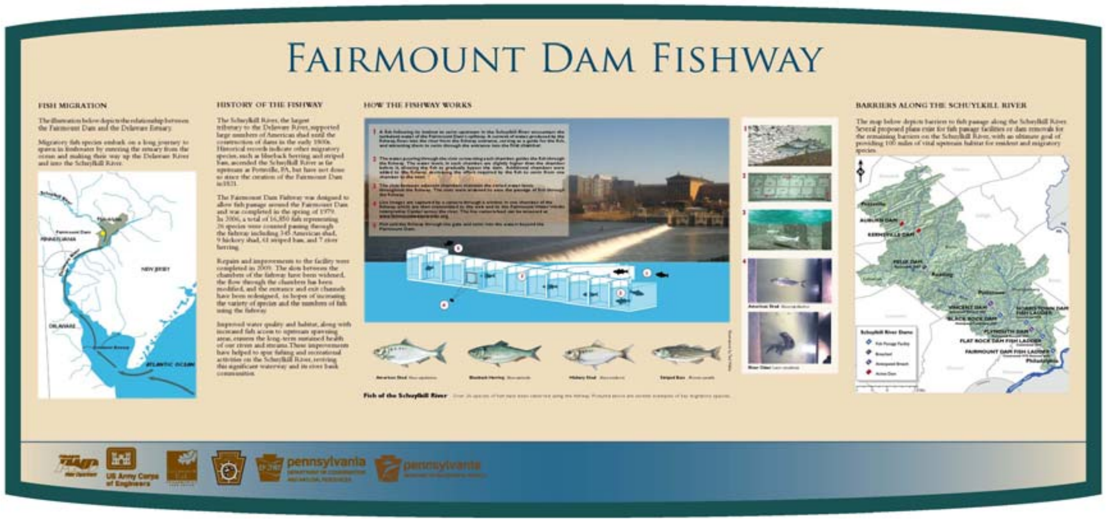


Figure 10-37 Fairmount Dam Fishway Interpretive Sign

10.2.3 Expansion of Wet Weather Treatment Capacity at WPCPs

The City's recommended alternative includes some traditional infrastructure to maximize the combined sewer overflow reduction benefits of the program. The expansion of wet weather treatment capacity at all three of PWD's existing water pollution control plants is recommended and includes the following commitments:

- Expansion of the Northeast Water Pollution Control Plant to include a 215 million gallon/day secondary treatment bypass
- Expansion of the Southwest Water Pollution Control Plant to include a 60 million gallon/day increase in secondary treatment capacity
- Expansion of the Southeast Water Pollution Control Plant to include a 50 million gallon/day increase in the secondary treatment capacity through process and hydraulic improvements

These plant upgrades will allow PWD to better utilize existing transmission capacity to capture and treat sewage.

These are complex projects that PWD has spent several years evaluating through the use of hydraulic and hydrologic computer modeling and facilities planning. Thus far PWD has obtained preliminary designs for these upgrades, but will work over the coming years to develop the necessary final designs, including detailed surveying and geotechnical investigations in order to move forward with construction of these upgrades. Results of preliminary planning are discussed in detail in Section 6.

Figure 10-38 Image of PWD's Southwest Water Pollution Control Plant

10.3 Performance of the Selected Alternative

Green stormwater infrastructure is efficient at reducing the volume of CSO and increasing percent capture of combined sewage. The selected alternative will result in both immediate and continuous progress in increasing percent capture, resulting in approximately 80% capture after 20 years. Figure 10-39 shows the percent capture by watershed after implementation of the recommended program, with percent capture ranging from a low of 79.4% for the Schuylkill watershed to a high of 80.3% for the TTF and Delaware watersheds.

The 80% capture represents a reduction in volume of CSOs of between 5.2 and 8.0 billion gallons per year, a significant decrease in the amount of combined sewage discharged to Philadelphia's waterways (Figure 10-40). This also represents a mean reduction in the duration of overflows of between 37 to 44 hours per year across all outfalls in the city, a one third reduction in duration of CSOs.

CSO frequency (average annual number of overflows per year) is best characterized as a range across all outfalls in a system. Figure 10-41 is an explanatory figure for box plots of this range, showing the percentiles represented by the symbols in the plot. Figure 10-42 shows the expected distribution of the frequency of overflows across all outfalls in the city's CSO system, by watershed, upon reaching the 20-year milestone of 34% of impervious cover managing the first inch of rainfall.

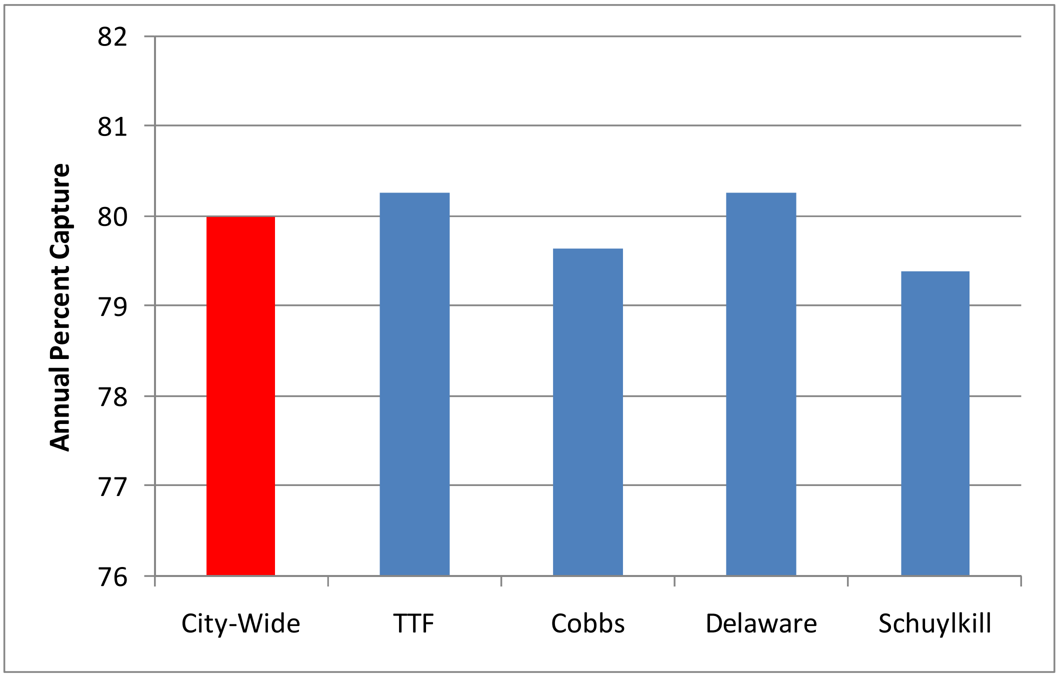


Figure 10-39 Selected Alternative Average Annual Percent Capture

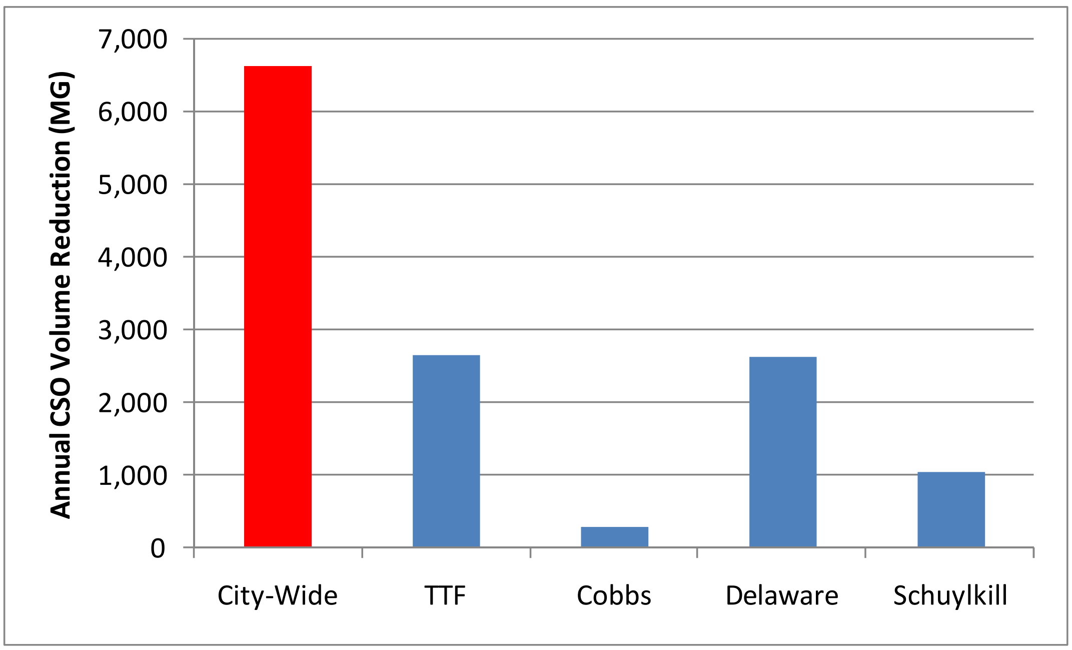


Figure 10-40 Selected Alternative Average Annual CSO Volume Reduction Relative to Baseline

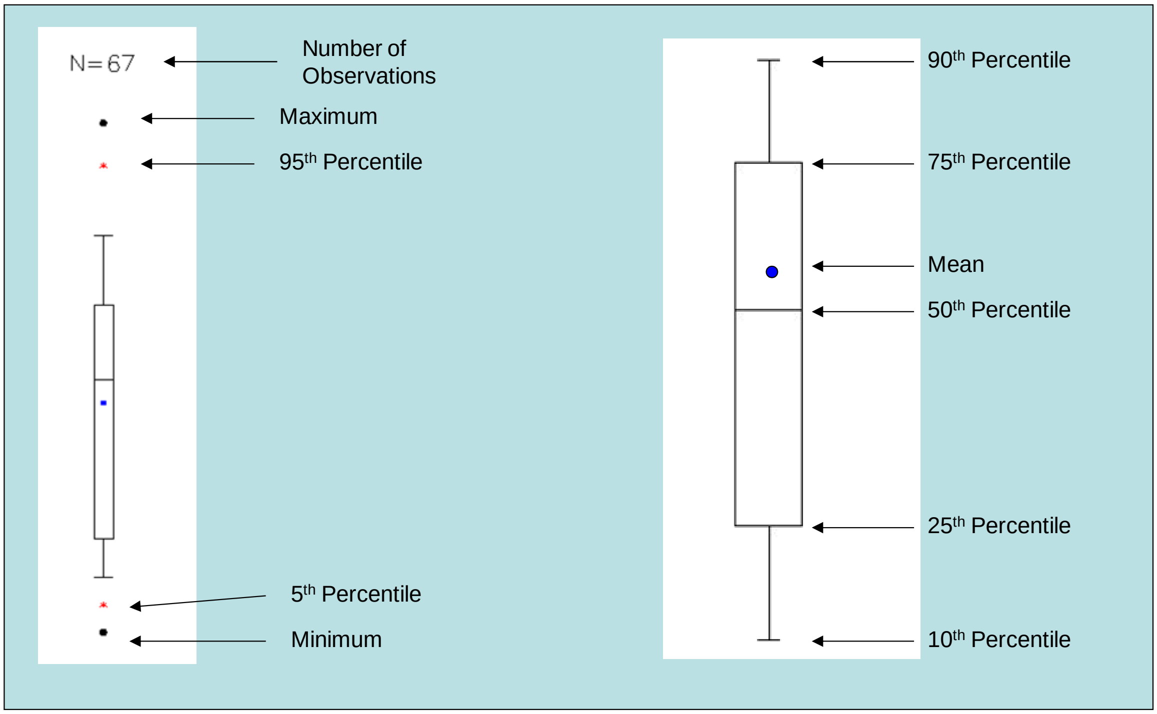


Figure 10-41 Explanation of Symbols Used on CSO Frequency Box Plots

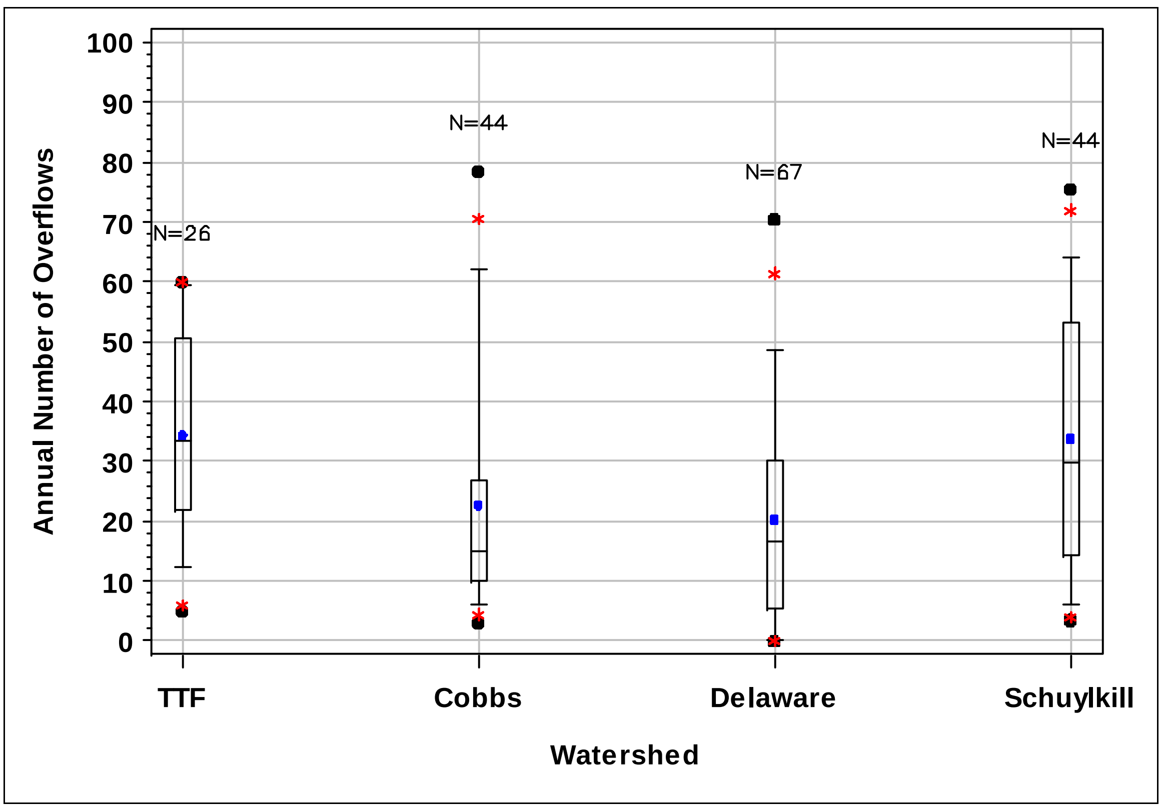


Figure 10-42 Selected Alternative Average Annual CSO Frequency at all Outfalls

10.4 Initiating the Green Stormwater Infrastructure Program

The Water Department will play a critical role in helping the City of Philadelphia achieve its goal to be the Greenest City in America. The City currently has the necessary building blocks for a greener future; it is a city of neighborhoods with walkable streets, a regional transit structure, a huge park system, success in revitalization of vacant lands and historically significant and ecologically valuable rivers. Fortunately, this plan coincides with and can support recommendations coming from a variety of city initiatives such as:

- A new Zoning Reform Commission Report to rethink the zoning that has trapped the city in 20th century development patterns
- New stormwater regulations that redefine the way the city addresses stormwater
- A community-driven vision and a series of plans to redevelop the waterfronts of the Schuylkill and Delaware Rivers to attract visitors and residents
- An ambitious GreenWorks program that recognizes the many benefits of green urban space and the need for city agencies to collaborate
- Numerous smaller scale initiatives focusing on sustainability, green jobs creation, neighborhood beautification, and urban agriculture

Together these inter-related initiatives will help realize Philadelphia's ambitious green vision. The co-benefit of these programs – human health, aesthetics, ecological restoration, economic growth and a more vibrant city – are significant and real. PWD's challenge is to instill green stormwater infrastructure into design, construction, operation and maintenance of the City's systems (transit, streets, universities, schools); to grow and nurture the City's natural systems (parks, rivers, streams, wetlands); and to protect public health systems.

The first five years of implementation of the *Green City, Clean Waters* program will prove to be the most critical in terms of putting the mechanisms in place that will support the program over the years to come. These first years will focus on establishing the framework and building the momentum that will launch innovative programs that cross city agencies as an everyday standard. In the initial 5-year period, PWD intends to meet a 5-year benchmark for converting impervious cover to greened acres of between 1600 and 1700 ac of the combined sewer drainage area. This will require a significant effort, and will include many "organizational" steps.

LEED Certification

PWD will evaluate LEED Certification and their allocation of credits to the various components of the certification program in order to assess whether they believe that enough weight is being given to the stormwater component. If determined insufficient, PWD will consider working with the United States Green Building Council (USGBC) to evaluate the potential for redistributing these credits in order to make stormwater management a more important component of this certification.

Watershed Partnerships

One of the benefits of having watershed partnerships already established is that PWD already has trusted relationships with their suburban neighbors. This should prove beneficial as the City begins to explore opportunities for regional cooperation and permitted/contractual relations are updated. Another component might involve further evaluation of the City's wholesale contracts with outside communities in light of potential Infiltration & Inflow issues.

Risk Analysis
Ensuring the health of Philadelphia's citizens is paramount. Within this initial 5 years of the implementation period, PWD will investigate the risk associated with recreational use of the City's waterways as they relate to CSO discharges. The City will not only evaluate currently utilized recreational locations, but also areas likely to become recreational locations in the future as the riverfronts are redeveloped and public access is improved. Related to this investigation, PWD may initiate a Water Quality Standards Attainment Review, but do this in a way that respects the public's very basic desire for streams that look good and are without odor.

Regulatory and Policy Roadblocks
PWD will also begin to evaluate the regulatory and policy related changes that will be needed over the coming years in order to support the greening of the City that is envisioned. This includes the evaluation of the City's Plumbing Code, Zoning Code, Licenses and Inspections and Planning Department requirements. PWD will also consider working closely with the development community to better understand current obstacles to green development within the City.

Interagency Cooperation
PWD is laying the groundwork for partnerships with the Philadelphia Housing Authority, The Office of Housing and Commercial Development and private developers. At minimum, the current stormwater regulations ensure all new large development will move towards PWD's goal of green acres, but building partnerships will help us exceed minimal standards and look for cost-effective opportunities to maximize green elements. With each new development, opportunities to increase the amount of green stormwater infrastructure can be evaluated. Assuming a redevelopment rate of 1% per year, 5,000 to 6,000 ac within the combined sewer system drainage will be converted from impervious acres to greened acres during the 20 year program.

Another important partnership that will develop as a result of this program is between PWD, Philadelphia Industrial Development Corporation (PIDC), Department of Commerce and Special Districts such as Center City District. These partnerships will help transform the commercial corridors and business parks in the City. Adding stormwater management to the existing beautification projects could reduce overall maintenance costs, calm traffic and add beauty to corridors. The greener, safer corridors could draw new customers and retailers, creating additional local and green jobs which would in turn promote safety in the City.

Some of the largest landowners in Philadelphia include Institutions of health, learning, and worship. Many of these campuses such as hospitals, universities and churches have already been leading the field of environmental sustainability. Not only can they easily incorporate greening into their mission, they are often willing to go far beyond required stormwater management. This means a few property owners can transform the City in a big way.

These are just a few examples of the many exciting developments and synergistic relationships budding in Philadelphia. As the city grows its green identity, more residents will be drawn to move into Philadelphia. When the City flourishes, it will increase base revenue for PWD to support more greening, drive up property values, and enhance awareness of the benefits of green stormwater infrastructure, creating a positive feedback loop that helps the program thrive. The greening of Philadelphia benefits the environment as a whole. Since existing cities can provide homes to a greater number of people with an overall smaller ecological footprint, this approach protects further development in areas in the headwaters of the City's watersheds.

10.5 MEETING THE PROGRAM COST

As previously described, a financial capability assessment for the City of Philadelphia's Long Term Control Plan Update was prepared using criteria suggested by the US EPA (see Section 11). The US EPA's approach calls for an evaluation of costs of the proposed improvements against Philadelphia citizen's median household income. In general, the US EPA considers wastewater costs above two percent of median household income to be an unacceptable cost burden to ratepayers. Implementing the LTCPU selected alternative will require PWD to spend an estimated $1.6 billion at the end of the twenty year implementation period ($1.0 billion in 2009 dollars). Based on this estimate and implementation schedule, the affordability assessment determined that the LTCPU would result in a cost to City of Philadelphia residents well above the upper limit of US EPA's median household income economic burden criterion.

In order to maximize effectiveness of this PWD investment, preliminary policy structures have been put in place over the past 10 years since the original LTCP was adopted by the City of Philadelphia to help leverage a great deal of additional funding toward its Clean Water Act commitments. These are structures that PWD instituted and programmatically supports, but for which the majority of greened acres will not be paid for by PWD's rate payers.

The first and most significant source of leveraged dollars comes from the development community. Because of the City's updated stormwater regulations adopted in January, 2006, every development/redevelopment project initiated within the City limits with an area of disturbance greater than 15,000 ft^2 must manage the first inch of runoff from the site – which is the same measure that PWD is utilizing for their greened acres concept. There are many areas of the city ready for redevelopment, including areas of abandoned or substandard housing, abandoned industrial areas, or outdated commercial facilities. High priced and ever scarcer energy is changing the way Americans live, making older urban centers more and more attractive places to live and work. As a result, the rate of redevelopment in the city is expected to impact 1% or more of the city's impervious cover each year. Making all redevelopment projects contribute to a greener city will be critical to meeting ambitious green stormwater infrastructure goals. With a city-wide redevelopment rate of roughly 1% annually, PWD sees an additional roughly $1.1 Billion dollar investment in 2009 dollars being applied toward the City's greening goals.

Another policy related tool that will help to achieve additional greened acres city-wide is the new Parcel Based Billing Initiative, which has resulted in a stormwater rate reallocation, to be phased in over the coming years. This reallocation has impacted some customers much more than others – at times causing the monthly water bill to increase 4-fold or more. PWD has been targeting these customers with a program aimed at evaluating the Top 50 parcels affected by the rate reallocation in order to evaluate them for potential achievement of "stormwater credits" on their utility bill resulting from retrofits on the property to manage the first inch of runoff. This program involves the offer of free design assistance and site evaluation by a PWD contractor in order to identify potential stormwater management opportunities that might exist on the site – and to perform a cost-benefit analysis in order to help the property owner to weigh the cost of the retrofit against the annual savings on the water bill. PWD believes that the rate reallocation will result many of these large parcels being retrofitted to manage the first inch of runoff – producing additional greened acres.

10.6 Adaptive Management with Decision Points

PWD's selected alternative is an innovative, decentralized approach to CSO control. As such, it will need to be carefully monitored and adjusted as needed to ensure success. Thus, the proposed approach for implementation is adaptive management of the program, with specified decision points where course corrections are possible. PWD's proposed adaptive management includes:

- Taking near term actions to improve water quality
- Experimenting with a variety of green stormwater infrastructure tools aimed at meeting water quality objectives
- Data collection and analysis on initial projects
- Reassessment of appropriate actions and adaptation of the program to improve effectiveness at pre-determined decision points

The recommended plan elements have preliminary milestones – including percentage of impervious cover within the CSS drainage area managed utilizing the various green program elements. These implementation tools will be periodically adapted, as needed, based on information about these elements of the program as implementation proceeds. PWD will utilize newly acquired information to steadily increase the cost-effectiveness of the program to achieve CSO control objectives.

10.6.1 Adaptive Management Rationale

A traditional CSO approach based solely on tanks and tunnels can often be completed within a 20-year timeframe to achieve the targeted number of overflows per year. With a limited number of large scale projects, this approach does not warrant adaptive management implementation, but would rely on more standard project management techniques. PWD believes, however, that the traditional approach no longer meets today's environmental and social goals, nor is it affordable and cost effective. Some of the most obvious shortcomings of the traditional approach when applied to Philadelphia are:

- Even at a cost of more than twice the affordability limit for the city, it only represents a partial solution that will not address water quality in all the watersheds
- Does not allow the city to simultaneously address water quality in the non-CSO areas in an integrated program
- Does not coincide with social programs focusing on the creation of entry level green collar jobs
- No longer matches with US EPA's broader goals of sustainability, consuming significant energy on an annual basis for as long as the tunnels and tanks are used
- Reduces stream baseflow, thus damaging the very habitat the program is designed to protect
- Does not offer the significant secondary benefits associated with a Triple Bottom Line accounting that a green stormwater infrastructure program would offer
- Benefits to water quality only start at the completion of the projects (15 to 20 years in the future)
- Once completed, it is a static solution with fixed benefits which cannot be easily adapted to changing conditions or the challenges imposed by climate change

As an alternative, the mixed approach of combining green stormwater infrastructure with targeted traditional infrastructure provides numerous benefits and advantages, including:

- Improving the natural resources of the city
- Enhancing the community through the development of new standards in sustainable urban design
- Providing significant improvements to air quality, waste product reuse, urban heat island mitigation, carbon sequestration, and energy conservation
- Offering the flexibility for continuous improvement and change to meet the challenges of climate change as new technologies are developed and existing approaches are refined through experience
- Immediate benefits from the start of the program, with benefits continuously increasing over time
- Offsets the considerable cost of the program with significant social and environmental benefits that have almost comparable dollar value to the cost

Because the program is innovative, based on multiple, small scale projects carried out by a variety of responsible agencies and parties, it will need to be implemented using the principles of adaptive management, as discussed in Section 5.

10.6.2 Adaptive Management Action Plan and Interim Milestones

The adaptive management action plan provides for progress tracking and reporting every 5 years, with actual progress compared to expected progress at each 5-year decision point. This is shown in Figure 10-43. Overall, the program is expected to control runoff on 34% of impervious cover after 20 years.

At each 5-year assessment point, progress will be compared to the following expected milestones:

<u>Year 5:</u>

- A target of 5.5% impervious cover managed, including design and construction of at least one project in each of the green program categories
    - 144 ac of impervious cover transformed to greened acres by PWD
    - A plan update for the most efficient green stormwater infrastructure projects to achieve the year 10 milestone
- 6 mi of interceptor rehabilitated/relined
- 2 mi of streams restored
- 10% of water pollution control plant treatment upgrades completed
- Budgeted dollars expended by target date: $47.2 million

<u>Year 10:</u>

- A target of 13.3% impervious cover managed through green stormwater infrastructure projects using projects in each of the green program categories deemed cost effective
    - 804 ac of impervious cover transformed to greened acres by PWD
    - A plan update for the most efficient green stormwater infrastructure projects to achieve the year 15 milestone.
- 7 mi of interceptor rehabilitated/relined
- 4 mi of streams restored
- 30% of water pollution control plant treatment upgrades completed
- Budgeted dollars expended by target date: $382.7 million

Year 15:

- A target of 22% impervious cover managed through green stormwater infrastructure projects using projects in each of the green program categories deemed cost effective
    - 1,064 ac of impervious cover transformed to greened acres by PWD
    - A plan update for the most efficient green stormwater infrastructure projects to achieve the year 20 milestone
- 4.5 mi of streams restored
- 65% of water pollution control plant treatment upgrades completed
- Budgeted dollars expended by target date: $862.1 million

Year 20:

- A target of 34% impervious cover managed through green stormwater infrastructure projects using projects in each of the green program categories deemed cost effective
    - 2,012 ac of impervious cover transformed to greened acres by PWD
- 100% of water pollution control plant treatment upgrades completed
- Budgeted dollars expended by target date: $1.621 billion

In addition to the 5-year reporting periods, PWD will leave open the possibility to incorporate smaller adaptive management changes within each annual report to suggest and implement minor adjustments to the program by re-setting the percentages of targeted impervious cover within the individual green program elements, by considering design changes to increase storage at some of the green stormwater infrastructure sites, or adjustments to the stream restoration and dry weather flow options.

10.6.3 Meeting the Affordability Challenge

Over time, factors such as household incomes; energy, raw material and labor costs; and the cost of capital tend to revert to long-term trends. However, history shows that economic conditions and financial markets can be extremely volatile from year to year. In a given year, this volatility can have a significant impact on the financial capability of a community to finance public infrastructure improvements without economic hardship. In Combined Sewer Overflows: Guidance for Long Term Control Plan, US EPA provides a prescriptive formula for calculation of financial capability. By fixing assumptions for economic and financial variables over the planning period, this guidance does not allow a utility any flexibility to adapt to changing economic circumstances.

A flexible, adaptive approach to financial capability analysis will be considered to maximize PWD's chances of success in implementing its chosen program. Periodically, PWD proposes to reassess its affordability and financial capability analysis in light of any new information. Local economic conditions will be assessed including changes in household income, revenue, capital spending in response to new regulations or requirements, construction and operating costs, and PWD's financial position and cost of capital. Adjustments to the program will be considered to either increase the rate of progress toward goals or decrease spending to avoid economic hardship.

10.6.4 Monitoring and Evaluation Plan

In order to carry out the reassessments every five years, data and information on the progress of the selected alternative will be gathered, with the information provided in annual reports. The data and information will be analyzed and compared to expected benchmarks every 5 years, with the results used to adjust the program as needed and to provide the plan update for the following 5-year period.

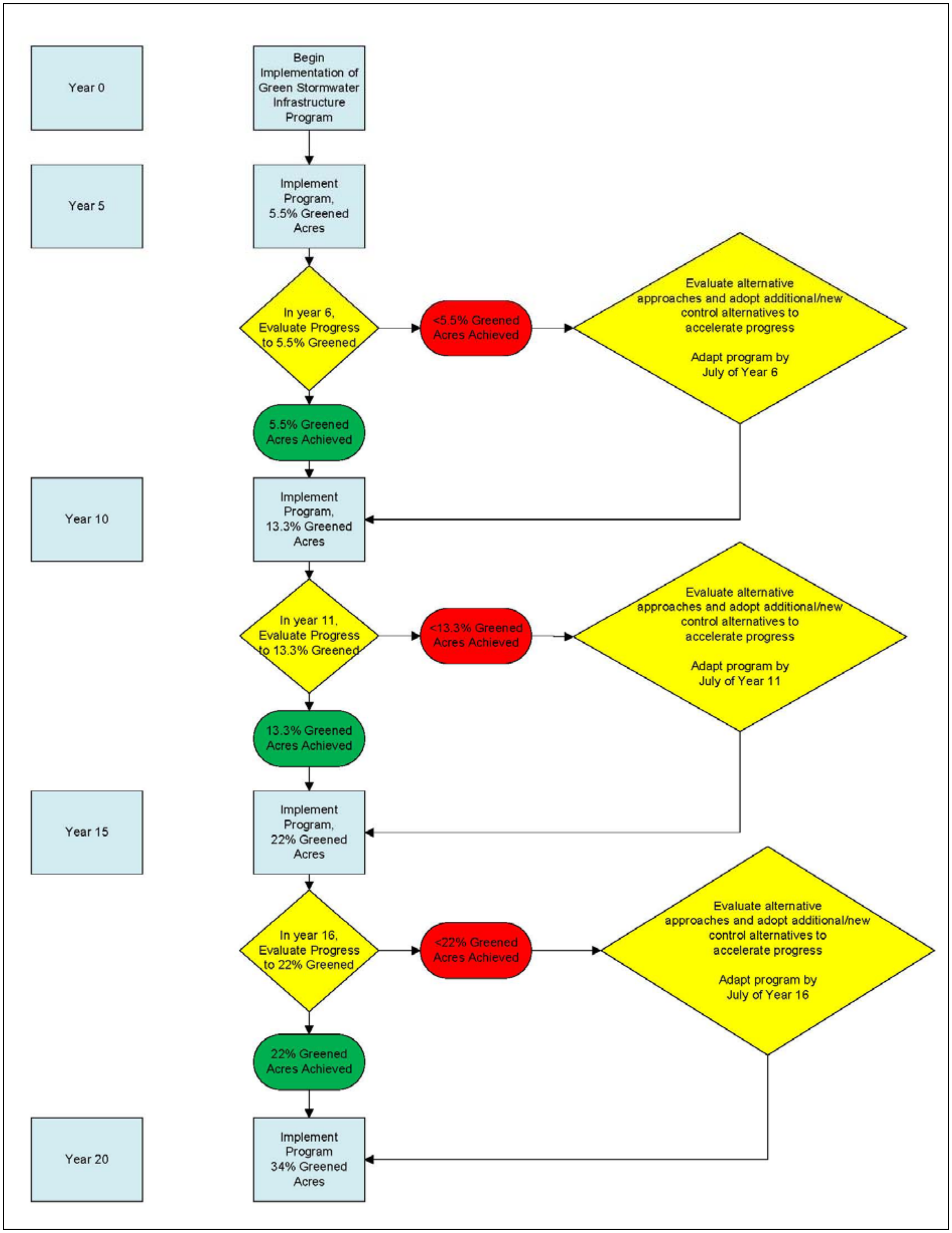


Figure 10-43 Flow Path of Decision Points

10.6.4.1 Project Progress Monitoring

Long-term monitoring of combined sewer flows is the key to verifying that green stormwater infrastructure is performing as expected. When implemented on a large scale, green stormwater infrastructure is intended to alter the urban water budget to a state more similar to a natural system such as a forest or meadow. Rain that falls on this altered system can take one of three main pathways – interception by vegetation or depression storage on impervious surfaces, leading to eventual evaporation; infiltration into soil, leading to eventual uptake and transpiration by plants, or continuation to groundwater recharge; or direct runoff to the combined sewer system. Of these three pathways, stormwater flows in the combined sewer system are the easiest to monitor. Evapotranspiration and infiltration are difficult to measure in the field, particularly on a large scale.

The process for verification of long-term green stormwater infrastructure performance compares measured stormwater volumes to those predicted by PWD's calibrated hydrologic and hydraulic model. A model is necessary to estimate what the runoff volume would have been during the monitored period if no controls had been implemented. First, sewer flows are monitored downstream of a catchment containing significant green stormwater infrastructure. These flows are separated into their components – base wastewater flow, groundwater inflow, and stormwater – using the tools described in Section 5. This process establishes an estimate of stormwater runoff that occurred during the monitored period. Second, PWD's calibrated hydrologic and hydraulic combined sewer system model is run using measured precipitation for the same period covered by the sewer monitoring data. A simulation is run with a condition that matches the amount of green stormwater infrastructure actually implemented to date. To determine the effectiveness of the controls, measured runoff is compared to runoff predicted by the model. Controls are performing as expected when the measured water budget is similar to the water budget predicted by the model, within a reasonable range of uncertainty inherent in both the measured and modeled results.

In addition to using the models to assess green stormwater infrastructure effectiveness, PWD will monitor the progress of planned projects covering the entire range of green stormwater infrastructure projects, as well as any traditional storage and treatment capacity projects planned as part of the selected alternative. General categories of information to be collected to monitor project progress include:

- Lists of completed stormwater control projects, types of controls implemented, and area of impervious cover managed by each project
- Expenditures and maintenance actions carried out during the 5-year periods including miles of sewers relined
- Maps of stream channel, riparian corridor, or other ecological restorations carried out, including acreage improved and expected habitat improvements
- Total acres of impervious cover managed by watershed, compared to the expected acres from the prior 5-year Plan update
- Miles of streams restored compared to the schedule and target number of miles restored within each watershed

PWD will provide an Evaluation Plan every 5 years. The Evaluation Plan will review monitoring results and milestone attainment every year, list projects completed, and acreage of impervious cover managed. The Plan will discuss any revisions to the original implementation schedule including which planned actions were not implemented and why they were not implemented. The Evaluation Plan will then provide alternative directions and adaptation strategies for those projects and measures that are proving less effective or more difficult to implement than originally anticipated.

With eight green programs to choose from at differing levels of implementation, the distribution of projects, types of projects, and designs will be adjusted to meet the next milestone as needed.

10.6.5 Green Stormwater Infrastructure Maintenance

Because of the dispersed nature of the green stormwater infrastructure, it will be important to develop a maintenance plan to ensure that the green stormwater infrastructure projects operate according to design and that they continue to operate and provide the storage, infiltration, and evapotranspiration for their useable life. Maintenance of green stormwater infrastructure is relatively simple, but is specific to the type design. PWD has developed a BMP manual that provides guidance for maintenance of urban stormwater best management practices. This manual, and subsequent updates, will provide the guidance for maintenance of all green stormwater infrastructure practices that are part of the LTCPU.

Typical maintenance activities might include:

- Mowing and/or trimming of vegetation
- Periodic inspection of vegetated planters or strip components expected to receive and/or trap debris and sediment for clogging and excessive debris and sediment accumulation;
- Periodic inspection of vegetated areas for erosion, scour, and unwanted growth. Unwanted growth (*i.e.*, invasive species) should be removed with minimum disruption to the planting soil bed and remaining vegetation.
- Inspection of level spreading devices or inlets for trapped sediment or other flow impeding conditions
- Raking of filter media surface for the removal of trash and debris from control openings
- Inspection of filter media for standing water (filter drainage is not optimal) and discoloration (organics or debris have clogged filter surface)
- Removal of the top few inches of filter media and cultivation of the surface when filter bed is clogged
- Cleaning out accumulated sediment from storm inlets

PWD has planned for over $100 million in operation and maintenance expenditures for green stormwater infrastructure as part of the overall cost of the program. This money will be used to fund maintenance activities over the 20 year implementation period and establish mechanisms for this to continue far beyond. But PWD's green stormwater infrastructure program is a composite of public and private initiatives, and its plans for maintenance should take advantage of this. To this end, a neighborhood approach to maintaining green stormwater infrastructure such as rain gardens, street trees, planters, porous pavement, and green roofs is proposed and will be evaluated. PWD will work with existing and to be formed special, neighborhood service districts to develop, train, and keep staff for these important tasks. These districts can also include cooperation of major universities for certain areas of the city.

A critical link in integrating the green stormwater infrastructure program with Philadelphia's ambitious sustainability goals is to use green stormwater infrastructure to stimulate the creation of Green Collar jobs to perform these maintenance functions. This will entail working with City Government job creation programs, as well as NGOs such as the American Cities Foundation.

10.6.6 Assessment of Attainability of Water Quality Standards

PWD's *Green City, Clean Waters* program is not just aimed at achievement of water quality standards compliance, but also to achieve the true end goals of the Clean Water Act: to have healthy streams where aquatic life can prosper; to make these streams pleasant, accessible and safe when people are recreating in and around them; to protect, preserve and maintain these streams against the challenges of sedimentation, erosion and the careless disposal of trash; to improve the riparian habitat and to make stream corridors a great asset for everyone to enjoy.

The watershed approach, recommended by the National CSO Control Policy, addresses all these issues confronting urban streams - in dry and wet weather - whether they fall within or outside the direct control of the Clean Water Act. The approach allows PWD to consider all of the societal and environmental benefits and impacts. In Combined Sewer Overflows: Guidance for Long Term Control Plan, US EPA encourages permittees "to consider innovative and alternate approaches and technologies that achieve the objectives of the Policy and the Act." PWD's watershed-based, green stormwater infrastructure-focused approach to address CSOs accomplishes exactly that.

Therefore, PWD has viewed its CSO LTCPU, as it has all of its Non-Point Discharge Elimination System (NPDES) permits and other obligations, as elements within the context of a far broader integrated watershed management approach. The IWMPs were crafted after extensive input from the community and numerous stakeholders. The goals, and the strategies employed to achieve them, go well beyond nominal compliance with Water Quality Standards and look to achieve a broad array of environmental and societal goals that the community values and respects.

The National CSO Control Policy recognizes the site specific nature of CSOs and their impacts and provides the necessary flexibility to tailor controls to local situations. PWD believes it will be able to demonstrate that after the LTCPU has been implemented it will have achieved not only the broader endpoints of the ambitious goals contained in the IWMPs but also the more narrowly focused compliance with the health risk goals of Water Quality Standards. PWD believes that after implementation of the LTCPU it will be able to demonstrate that the level of protection provided by the Water Quality Standards has been achieved.

PWD has begun a preliminary study to document recreation occurring along waterways and potential health implications of that recreation. PWD would like to develop this data in a more comprehensive fashion and looks forward to working with US EPA, PADEP and local Health Department authorities in planning and conducting further studies.

While PWD believes that the protective goal of the Water Quality Standards can be achieved, it recognizes that there is a possibility that achieving this goal may take longer than 20 years. Should additional time be needed to achieve wet weather water quality goals, PWD will work with PADEP in developing a Water Quality Standards Attainment Review to review and possibly revise the Water Quality Standards.

10.7 IMPLEMENTATION SCHEDULING

A number of factors are considered in deciding how watershed and combined sewer overflow management measures will be implemented over the long term. Factors include continuing implementation of the Nine Minimum Controls, high-priority areas and activities, public input, financial capability, and logistical factors. Implementation is phased to begin realizing environmental, social, and economic benefits as early in the program as possible. Finally, it is important to identify all the entities involved in implementation and define the role that each will play.

The scheduling approach first considers priorities expressed by PWD, regulatory agencies, public, and watershed partners as follows:

- Priorities expressed by the public, by watershed partnerships, or in IWMPs will be considered
- Implementation of measures to improve water quality, aesthetics, and recreational opportunities in dry weather will begin early in the process
- Restoration of living resources (including stream and stream corridor restoration) will begin early in the process
- Implementation of green stormwater infrastructure will begin immediately. Environmental, social, and economic benefits of these investments in Philadelphia's neighborhoods will begin to accrue from the first day of program implementation
- Projects will be scheduled to complement other urban greening and redevelopment projects occurring throughout the drainage area. For example, green stormwater infrastructure might be installed at a school when the school district is conducting major renovations or landscaping
- Relocation of a PWD outfall might take place concurrently with construction of a waterfront trail or development by another entity

For each management option, implementation is broken down into a number of steps:

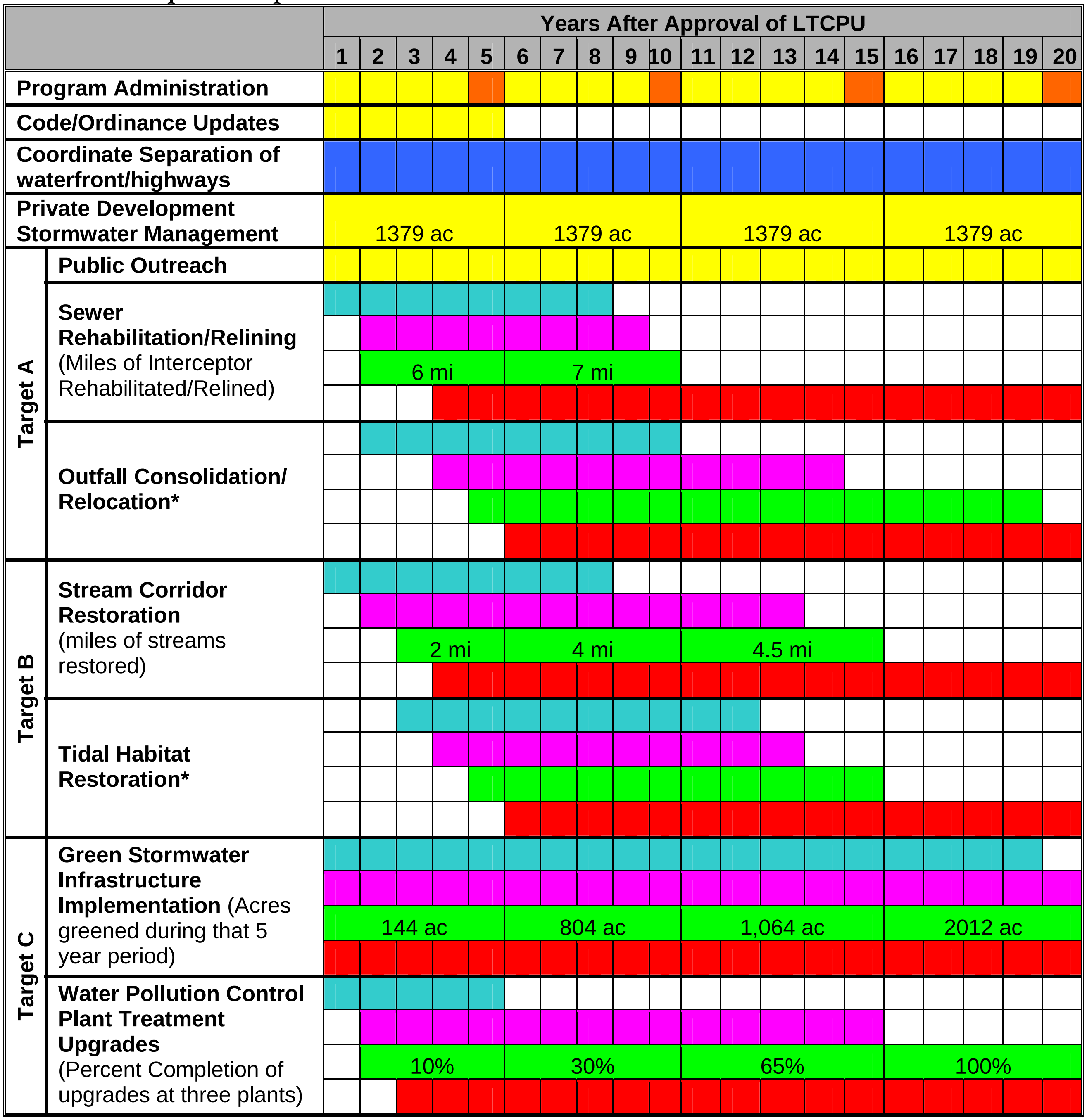
- Research, development, and demonstration: For green stormwater infrastructure and other innovative technologies, research best practices and examples from peer cities nationally and internationally. Design, construct, build, and monitor projects on a small scale, then apply lessons learned on a larger scale
- Develop standard details and specifications: For green stormwater infrastructure, develop standard details and specifications that can be replicated on a large scale with only minor modifications
- Review and revise local codes, ordinances, and policies: Review codes and ordinances that present unnecessary barriers to green stormwater infrastructure. Examples may include plumbing and building codes and ordinances governing the public right-of-way. Identify and work to resolve barriers to green stormwater infrastructure implementation on private land or through public-private partnerships. Develop interagency agreements between relevant public agencies and authorities
- Facility planning and site investigation: For traditional infrastructure, acquire more highly detailed information needed for detailed design. Examples include geotechnical investigations, detailed modeling of hydraulics and siting of structures
- Site-specific design: For infrastructure projects, develop detailed plans and specifications needed to construct a system. For green stormwater infrastructure, this step may consist of modification of standard details and specifications

- Permitting and land acquisition: For structural projects and stream restoration, acquire necessary environmental permits. Acquire land for structures if necessary
- Construction: For structural projects, oversee the bidding process, arrange financing, give notice to proceed, and oversee construction
- Operation: For structural facilities, operation begins after completion of construction. For many nonstructural practices, operation is ongoing throughout the life of the project
- Review of private redevelopment plans and enforcement of stormwater ordinance: Throughout the implementation period, PWD will continue to oversee implementation of its stormwater regulations following redevelopment of private lands

A proposed schedule of implementation for the structural elements of the LTCPU is presented in Table 10-9. The implementation schedule sets Philadelphia on a path to achieve the goals of the IWMPs. Along this path, unexpected events will occur and the schedule may have to be adjusted accordingly. The following list summarizes a range of uncertainties that may affect the implementation schedule:

- Changes to the Clean Water Act, National CSO policy; US EPA, PADEP, or Delaware River Basin Commission rules, regulations, or water quality standards
- Changes to PWD's CSO NPDES permits
- Additional regulatory requirements imposed on PWD, and funded by its rate payers, such as Safe Drinking Water Act regulations, TMDLs, changes to the NPDES MS4 Permit, or capacity management requirements
- Consent orders or agreements
- Economic conditions, changes in rate payer income, changes in the financial condition or bond rating of PWD, borrowing costs
- Construction cost escalation
- Timing of permits and land acquisition for construction of facilities
- Additional findings of the facilities planning or detailed design stages

Table 10-9 Proposed Implementation Schedule



* Implementation schedule subject to coordination with riverfront redevelopment

- **On-going Implementation**
- **Reporting Milestones**
- **Coordinate and Schedule with other entities**
- **Facility Planning and Site Investigation**
- **Design**
- **Construction**
- **Operations & Maintenance**

11 FINANCIAL CAPABILITY

11.1 INTRODUCTION

The United States Environmental Protection Agency (US EPA) suggests that a financial capability assessment should be included in the CSO Long Term Control Plan (LTCP) in order to establish the burden of compliance on both ratepayers and the permittee. The assessment in this section follows the guidelines and methodology as described in the US EPA's "Combined Sewer Overflows – Guidance for Financial Capability Assessment and Schedule Development," published February 1997. The purpose of the financial capability assessment is twofold.

First, the affordability process contemplates balancing the pace of environmental improvement with the financial and economic capability of the permittee. The process allows flexibility in scheduling completion of CSO compliance measures, based on the financial capability of the area served. Second, a financial capability can support the determination of funding needs by agencies providing loan and grant monies for capital projects.

The financial capability assessment is a two phased process. The residential indicator is the percentage of median household income (MHI) expended on wastewater management. The financial capability indicator is an assessment of the permittee's debt burden, socioeconomic conditions, and financial operations. These two measures are subsequently entered into a financial capability matrix, suggested by US EPA, to determine the level of financial burden that the existing wastewater management system and the CSO control measures will place on residential customers and the permittee. The US EPA matrix appears in Table 11-8 at the end of this section.

In addition to following guidelines for these two measures, US EPA encourages inclusion of any information that would have a financial impact on CSO compliance by the permittee in the capability report. This assessment, therefore, includes extensive discussion of socioeconomic trends in the Philadelphia area because of the financial challenges that the City and the region faces.

11.2 PHASE 1 - CALCULATION OF THE RESIDENTIAL INDICATOR

PWD has projected future revenue requirements and associated rates, taking into account current and future costs to operate, maintain, and replace the PWD's system, currently outstanding debt service, and future debt service resulting from anticipated and identified capital improvements. The focus for evaluating the impact of the residential indicator is the next 20 years (FY 2029)[1], however it is anticipated that elements of the LTCPU implementation program will continue well beyond this 20 year timeframe.

PWD has developed its financial projections consistent with the manner in which it develops rate projections, with expenses, revenues and capital costs stated in future year dollar terms

[1] The City of Philadelphia's fiscal year runs from July 1st through June 30th.

(*i.e.*, inflated to the future year). Thus, household bills in 2015 (for example), reflect what PWD estimates households are projected to pay in that year. For purposes of the affordability analysis, these future household rates are compared to projected household incomes (also projected to future year dollars) in those specific years. The approach keeps all cost figures on a consistent basis and provides PWD with a realistic picture of actions required to raise needed revenue and comply with its ultimate requirements.

In developing these projections, PWD has sought to estimate the future burden of the LTCPU in addition to the full utility system's long term needs for wastewater and water service, as currently understood. Although PWD provides both water and wastewater (including stormwater) service, they have traditionally maintained separate water and wastewater rates, in accordance with standard cost-of-service criteria. PWD has evaluated the impact of the LTCPU by estimating those capital and operation and maintenance (O&M) costs in conjunction with an estimate of other costs anticipated to be incurred by the utility over the next 20-plus years. The associated rates for wastewater and stormwater are then estimated on an average household basis. The residential indicator is based on that average annual cost per household relative to projected MHI for each year over the forecast period.

11.2.1 Key Assumptions

The key assumptions used to develop these projections are:

- The combined sewer area is located within the City limits of Philadelphia, therefore the determination of the residential indicator is based on the retail cost of wastewater service for households in the City of Philadelphia served directly by PWD. The cost of contract sales to wholesale customers outside of the City is anticipated to increase in response to increased costs of service for non-LTCPU related activities
- The projected average growth in MHI is 2.29%. Since 1989, MHI in Philadelphia has grown at a rate which is below both those of the state (2.94%) and national (3.18%) levels. This appears to be a consistent and long-term trend resulting from structural elements of the Philadelphia's demographic and economic makeup, rather than just being the result of cyclical or outlying occurrences. Metered sales (for water/wastewater customers) and associated billable discharges to the wastewater system have been trending downward (*e.g.*, billed water consumption declined approximately 5.4% for FY 2000 to FY 2008). To provide for a conservative estimate, the residential indicator projections assume that consumption will stabilize at current levels
- Costs associated with O&M (including labor and materials) are anticipated to grow at rates experienced in recent years. The costs for O&M of PWD's existing wastewater system are estimated to increase at 4.7% per year throughout the planning period. The inflation rate for the O&M costs for LTCPU related projects is projected to be 3.87%
- Future costs for capital projects are inflated at an annual rate of 3.87%. For the most recent 10 year period, the Engineering News Record City Cost Index – Philadelphia construction cost index and the building cost index have increased at an average annual rate of 4.1% and 3.9% respectively

- The PWD's capital improvement program for non-LTCPU related projects reflects continued investments in facility upgrades and replacements throughout the entire system. The estimated costs for the non-LTCPU capital improvements are approximately $3.7 billion (water and sewer - 2009 dollars) through Philadelphia's FY 2029 (ending June 30, 2029). The primary capital expenditures generally consist of the following: improvements to water and wastewater treatment plants; rehabilitations and replacement of water mains; rehabilitation and replacement of old sewers and construction of new sewers to relieve unsanitary conditions; and construction of new storm flood relief sewers and storage tanks
- PWD assumes the funding for its capital program will be financed primarily through the issuance of revenue bonds through the municipal bond market, supplemented through PennVest financings. PWD will also utilize pay-as-you-go funding and, to the extent available, miscellaneous grants. Best practices vis-à-vis the municipal bond market requires that PWD's capital debt be structured with various interest rates and maturities. Therefore, rather than specifying an assumed interest rate and bond duration, PWD's Financial Capability analysis utilizes long term experience in defining an annual cost per unit of principal borrowed. PWD has determined that a capital cost factor of 8.059% is appropriate. Costs of O&M associated with the LTCPU were synchronized with the implementation schedule and with escalation factors generally resembling historical cost escalation for PWD's overall O&M program
- Revenue projections for this financial capability assessment rely on PWD's existing cost-of-service based rate structure with forecast revisions reflecting the proportional increase in wastewater and stormwater costs due to implementation of the LTCPU as well as a continuation of the non-rate revenues the City currently generates

As detailed in Section 10 of this report, PWD is proposing green infrastructure with targeted traditional infrastructure as its preferred alternative. The recommended plan seeks to reduce CSO frequency and volume through a range of land-based stormwater management techniques or source controls. As described in previous sections, this option will be implemented in stages through 2029. The total capital need for the LTCPU program is $902 million (Table 11-1), and the total O&M need through 2029 for the LTCPU as it is implemented is $98 million, both stated in 2009 dollars.

The LTCPU capital program will be implemented within the context of PWD's overall capital improvement program, also summarized in Table 11-1. Total capital expenditures through 2029 of approximately $4.6 billion (2009 dollars) for improvements to the water and wastewater systems are projected. Of these projected capital expenditures, around $3.4 billion or 73 % are projected for wastewater and wet weather; including $902 million for the implementation of the recommended LTCPU through 2029. The remaining projected wastewater expenditures go towards system renewal, replacement, rehabilitation and improvements necessary for adequate and compliant services.

PWD assumes the continuation of its ongoing program related to water main and sewer rehabilitation and replacement and treatment plant upgrades throughout the 20 year period. PWD will also pursue an aggressive storm flood relief program that is intended to be completed within the next decade. The cost of that program is not included in the estimate

Table 11-1 PWD Capital Improvements Program (in billion $) 2010-2029

Capital Program	Present Dollar Value (2009 Dollars)
Water Treatment and Distribution	$1.22
Wastewater Treatment and Collection	$2.12
Storm Flood Relief	$0.36
Long Term Control Plan	$0.90
Total Capital Cost	**$4.60**

for the LTCPU, although it is expected to have a beneficial impact on the City's ability to manage wet weather flows in the future.

11.2.2 Projected Revenue Requirements and Rate Impacts

For FY 2009 through FY 2029, the annual revenue requirement for PWD's wastewater system is expected to increase by about $720 million, from approximately $350 million to $1.07 billion in 2029. Annual wastewater system debt service in 2029 is projected to be approximately $366 million. This amount compares to current (2009) annual wastewater system debt service costs of approximately $130 million.

PWD is empowered and required under the Philadelphia Home Rule Charter to establish rates for water, wastewater and stormwater at levels that provide sufficient revenue to meet all operating expenses of the water, wastewater and stormwater systems, including interdepartmental charges for services provided to the PWD, and debt service requirements on all obligations issued for the PWD, including specific bond ordinance covenants.

PWD estimates that the typical household in the City currently pays approximately $400 annually for wastewater services, including stormwater. The most recently available U.S. Census data for MHI in Philadelphia is $35,431 for 2007. Based upon the projected annual MHI growth of 2.29%, the estimated 2009 MHI would be $37,072. PWD customers are currently (2009) paying approximately 1.10% of their income for wastewater charges. In addition to the general rates, special rates are applicable to certain properties or customer groups as prescribed by ordinance. Charges are also administered for municipal fire protection and private fire protection and for industrial dischargers of high strength wastewater. Service to customers located outside the City is on a wholesale basis through contracts with various municipalities, authorities and townships. Each wholesale contract has been negotiated on a case-by-case basis, and has a different cost structure and variations in the method for adjusting those wholesale charges to reflect changes in their cost of service.

Under the US EPA guidance, a key measure of affordability is the residential indicator: the ratio of the wastewater cost per household to MHI. The residential indicator is compared to US EPA-defined criteria to determine whether costs impose a low, mid-range, or high impact on residential users. Table 11-2 shows US EPA's residential indicator criteria, which define a "low" impact as a cost per household less than 1.0% MHI, a "mid-range" impact between 1.0 and 2.0%, and "high" impact as greater than 2.0% of MHI.

Table 11-2 US EPA Residential Indicator

Residential Indicator	Cost per Household
Low	Less than 1.0% of MHI
Mid-Range	1.0-2.0% of MHI
High	Greater than 2.0% of MHI

Implementation of the PWD's LTCPU projects along with other necessary wastewater system capital improvements require wastewater system rates to be increased at an annualized rate of approximately 6.18%. The cumulative effects of these increases are shown graphically on Figure 11-1. The primary measure of the affordability (wastewater cost as percent of MHI), the residential indicator, is currently around 1.1%. The residential indicator is expected to rise to approximately 2.27% by 2029); based upon projected average annual household wastewater costs of approximately $1,321 and a projected MHI of approximately $58,305. As may be noted in Figure 11-1, the cost, demographic and economic trends will result in continued increases in the percentage of household income to be expended on wastewater services well beyond 2029.

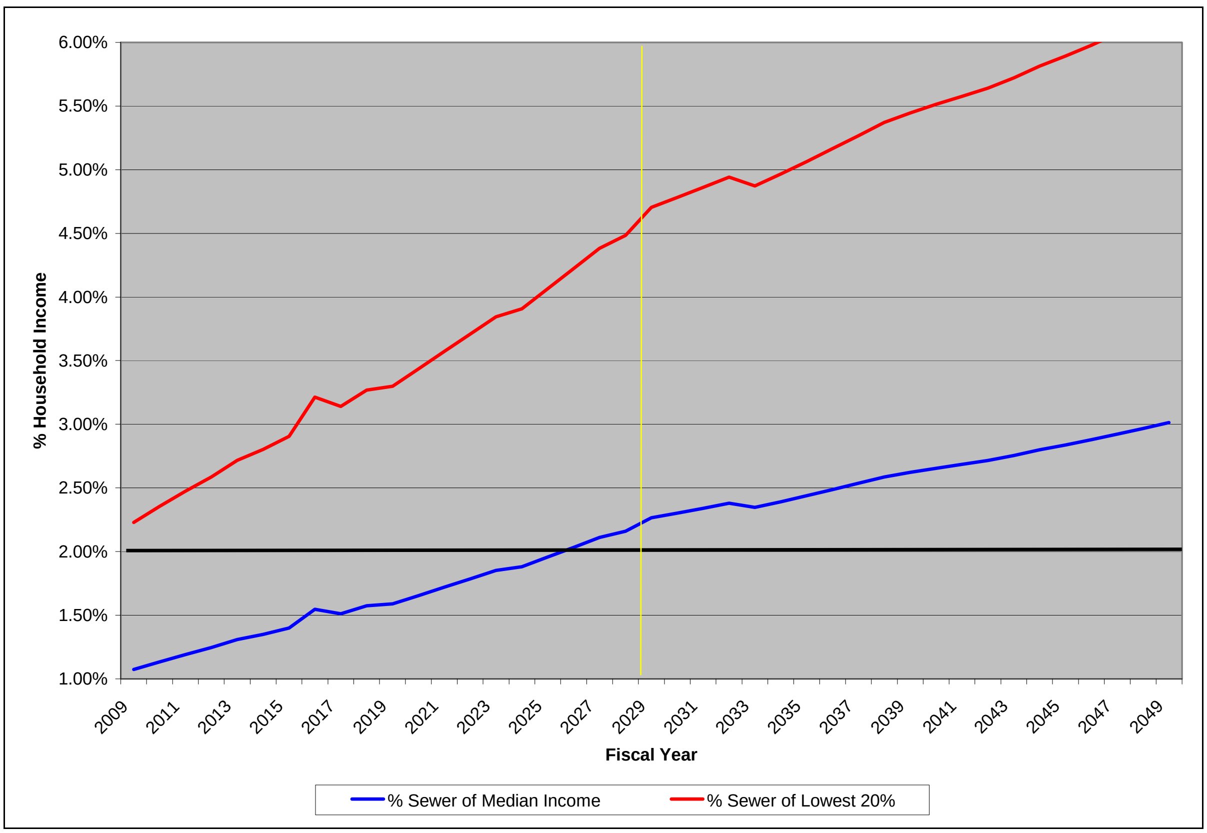


Figure 11-1 Residential Indicator, 2009-2029 Recommended Plan, 2009-2020 Implementation

US EPA's residential indicator is based upon the City's MHI. By definition, one half of the households (approximately 279,000) have household incomes that are less than the current $37,072 median and will be less than the $58,305 MHI that is projected for 2029. At an average of approximately 2.5 residents per household, the lower half of the MHI population for the City would total approximately 698,000. Therefore, a group that would comprise the 16th largest cities within the U.S., (exceeding major cities such as Boston, Baltimore, Washington D.C., and Seattle), would be paying more than 2.27% of their incomes for wastewater services in 2029.

The financial impact of the LTCPU implementation and other LTCPU costs on the lower income population of Philadelphia will be significant. The projected 2029 MHI for the lowest 20% MHI group is less than $38,000. This group would be paying between 3.5% of their MHI (upper limit of the second quintile) to 7.0% MHI (first quintile) in 2029. This group includes around 158,000 households representing a population of around 396,000. This number is larger than the populations of major cities such as Cincinnati, Minneapolis, Honolulu, Pittsburgh, and Toledo. The disparate impact of the implementation of the LTCPU and other necessary wastewater capital improvements upon the City's varying income areas is shown on Figure 11-2. The map shows the projected Residential Indicators for the 368 census tracts within the City of Philadelphia in 2029.

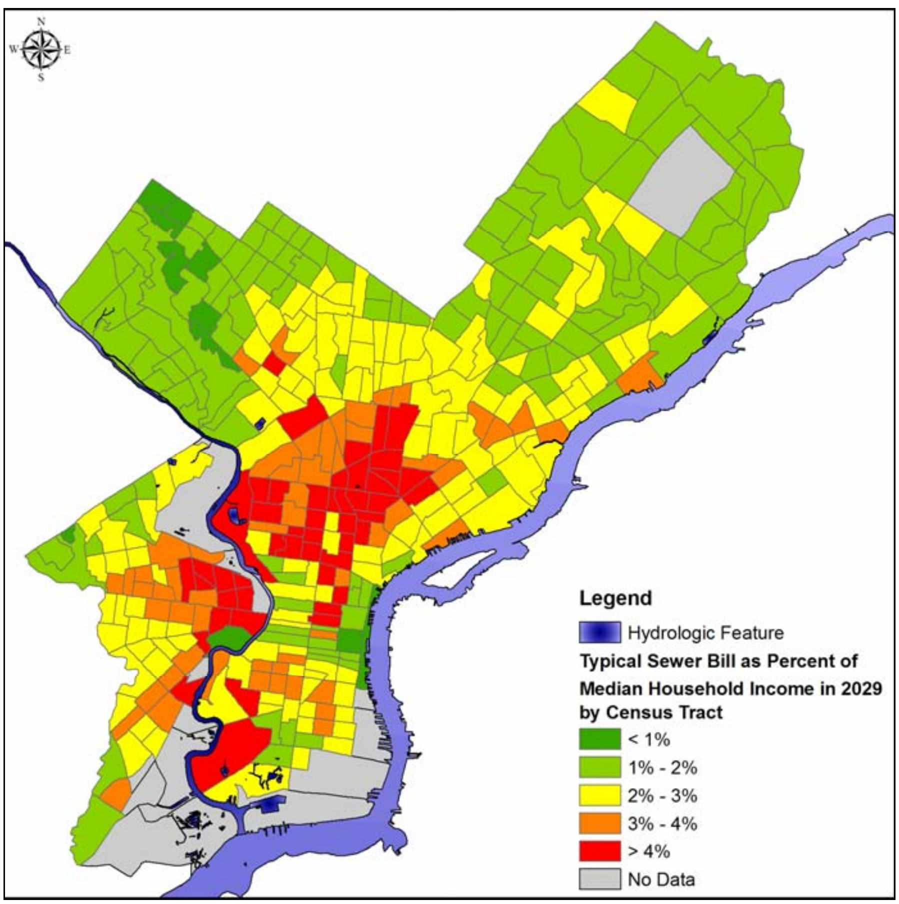


Figure 11-2 Projected Residential Indicator by Census Tract (2029)

11.2.3 Financing Assumptions

The projections of burden and the residential indicator are sensitive to assumptions regarding debt financing. PWD has traditionally funded its capital programs with a combination of traditional debt (revenue backed bonds), existing reserve funds, grant funding (when available), and the state revolving fund (PennVEST). Although this combination of funding mechanisms may continue to be available, it is assumed that the predominant funding source will be traditional debt (revenue bonds issued through the municipal bond market) supplemented by pay as you go funding and limited grants.

11.2.4 Grant Availability

Although PWD will pursue available grant programs, the financial analysis does anticipate grant funding for CSO controls. The amount of grant funding that may become available is expected to be relatively minor in comparison to the projected capital expenditures for the LTCPU.

11.3 PHASE 2 - CALCULATION OF PERMITTEE FINANCIAL CAPABILITY INDICATORS

The second phase of the financial capability assessment - calculation of the financial capability indicator for the permittee – includes six items that fall into three general categories of debt, socioeconomic, and financial management indicators. The six items are:

- Bond rating
- Total net debt as a percentage of full market real estate value
- Unemployment rate
- MHI
- Property tax revenues as a percentage of full market property value
- Property tax revenue collection rate

Each item is given a score of three, two, or one, corresponding to ratings of strong, mid-range, or weak, according to US EPA-suggested standards. The overall financial capability indicator is then derived by taking a simple average of the ratings. This value is then entered into the financial capability matrix to be compared with the residential indicator for an overall capability assessment). Table 11-3 contains the six criteria and the ratings that categorize the permittee as strong, mid-range, or weak in each category. Shaded areas of this table indicate the City of Philadelphia's position in each category. Indicators with shading in two ratings such as the bond rating category reflect a score between the two ratings. A discussion of each item follows.

Table 11-3 US EPA Permittee Financial Capability Indicator Benchmarks

Indicator	Strong	Mid-Range	Weak
Bond rating	AAA-A (S&P) or Aaa-A (Moody's)	BBB (S&P) Baa (Moody's)	BB-D (S&P) B-C (Moody's)
Overall net debt as a percent of full market property value	< 2%	2% to 5%	> 5%
Unemployment rate	> one percentage point below the national average	± one percentage point of national average	> one percentage point above the national average
MHI	More than 25% above adjusted national MHI	± 25% of adjusted national MHI	> 25% below adjusted national MHI
Property tax revenues as a percent of full market property value	< 2%	2% to 4%	> 4%
Property tax collection rate	> 98%	94% to 98%	< 94%

(Blue areas indicate City of Philadelphia ratings)

Bond Rating – Indicator 1

General obligation debt, which is debt backed by the full faith, credit, and taxing power of the City of Philadelphia, has been rated by Moody's Investors Service at Baa1, by Standard & Poor's Corporation at BBB, and by Fitch Investors Service at BBB+.

The PWD issues debt pursuant to the City's Restated General Water and Wastewater Revenue Bond Ordinance of 1989 ("General Ordinance"), which superseded the General Water and Wastewater Revenue Bond Ordinance of 1974 ("Prior Ordinance"). PWD's debt is a special obligation of the City, secured along with previously issued water and wastewater revenue bonds, by a pledge of and security interest in all project revenues established in various funds and accounts, all as defined in the General Ordinance.

PWD's debt is currently rated as A3 by Moody's Investors Service, A by Standard and Poor's and A- by Fitch.[2] Based on the current credit rating of the City and PWD the overall bond rating is between strong and mid-range.

Net Debt as Percent of Full Market Value – Indicator 2

Total net debt includes overlapping debt, which is the indebtedness of the School District of Philadelphia and the City of Philadelphia General Bonded Debt in addition to the City of Philadelphia. School District debt totaled $2,634 million and bonded debt totaled $4,136 million on June 30, 2008, for total overlapping debt of $6.77 billion. The percent of total net debt to full market value was 37.30%. The calculation of the above percentage is based on a deduction of $255.7 million in sinking fund monies from outstanding debt. Self-sustaining debt (*i.e.*, revenue-backed bonds) are also excluded from total debt outstanding. Overall net debt as a percent of full market property value places the City of Philadelphia in the weak range on this measure.

[2] Source: OFFICIAL STATEMENT relating to $140,000,000 City of Philadelphia, Pennsylvania Water and Wastewater Revenue Bonds, Series 2009A (page 59)

Unemployment Rate – Indicator 3
The unemployment rate for the City of Philadelphia was 7.2% in 2008. The unemployment rate for the Commonwealth of Pennsylvania in 2008 was 5.4%, and the national rate for 2008 was 5.8%.

According to US EPA guidelines, a local variance of greater than 1% from the national rate indicates a weak financial capability. Philadelphia maintained an unemployment rate greater than 1% of the national average for the year 2008. Most recent data from the Department of Labor, Bureau of Labor Statistics shows the unemployment rate for Philadelphia to be as high as 9.7% in March 2009, its highest rate since 1993 and remaining ahead of the state and national averages.

MHI – Indicator 4
The most recent data (2007) from the Census Bureau estimate Philadelphia's MHI to be $35,431. US EPA guidelines suggest that a variance of greater than 25% below the national MHI figure constitutes a weak rating. Pennsylvania's MHI estimate was $47,913 and the national estimate was $50,007 over the same period of time, percent differences of nearly 32 and 36%, respectively.

Property Tax Revenues as a Percent of Full Market Property Value – Indicator 5
The City of Philadelphia assessed valuation is 29.22% of the full market value of real estate. A tax of 33.05 mills is levied on the assessed valuation. Therefore, the property tax levy is 3.305% of assessed valuation, or approximately 1.0% of full market value set by the State Tax Equalization Board. The projected full market value for 2008 was $41.67 billion. The result shows current year real estate collections to be approximately 0.85% of full market value. Table 11-4 shows assessed valuation, full markets value, tax levy and current year tax collections for real estate taxes.

The US EPA financial capability assessment makes no provision for measuring a local tax burden other than the real estate tax. This gives Philadelphia an artificially strong rating in the property tax revenues as a percent of full market value category.

However, the City of Philadelphia is somewhat unique in that real estate collections are not its primary source of income. The earned income tax levied by the City comprised 23% of the operating revenues in FY 2008, while the property tax only accounted for 6% of revenue. The City's current earned income tax rate is 4.22% of residents' wages. Although real estate taxes are comparatively low, Philadelphia taxpayers are heavily burdened by other local levy, including a Philadelphia sales tax.

Analysis by a Pew Foundation study[3] documents that the total tax burden per household in Philadelphia are about double the average for comparable large cities. For a family of three earning $50,000 annually, the tax burden in Philadelphia is 17.3% compared to the large city average of 8.8%. The total tax burdens for ten cities in the Pew study are shown on Table 11-5.

---

3 Philadelphia 2009 – The State of The City. The Pew Charitable Trusts – Philadelphia Research Initiative; page 13 (http://www.pewtrusts.org)

Table 11-4 City of Philadelphia, 2003-2008 Adjusted Real Estate Valuation, Real Estate Taxes Levied, and Collection Rates (in millions $)

Year	Total Taxable Assessed Valuation	Full Market Value based on State Tax Equalization Board	Adjusted Gross Real Estate Taxes Levied	Amount Collected in Year of Levy	Current Year Property Tax Revenue Collection Rate	Real Estate Tax Collected as Percent of Full Market Value
2008	12,175	41,667	391.1	355.901	91.0%	0.85%
2007	11,615	39,696	391.1	347.5	88.9%	0.88%
2006	11,431	39,600	385.6	339.6	88.1%	0.86%
2005	11,032	37,153	373.5	350.3	93.8%	0.94%
2004	10,946	36,856	372.5	340.9	91.5%	0.92%
2003	10,621	35,384	359.4	326.8	90.9%	0.92%

Source: Pennsylvania State Tax Equalization Board, FY 2008 CAFR, and City of Philadelphia Yearly Supplemental Reports

Table 11-5 Comparison of Large City Tax Burdens (Family of Three with $50,000 Income)

City		Tax Burden	% Income
1	Philadelphia	$8,629	17.3
2	Baltimore	$7,105	14.2
3	Detroit	$6,180	12.4
4	Columbus	$5,589	11.2
5	Houston	$4,398	8.8
6	New York	$4,259	8.5
7	Boston	$3,892	7.8
8	Washington	$3.590	7.2
9	Chicago	$3,547	7.1
10	Phoenix	$3,403	6.8
	Average	**$4,423**	**8.8**

Source: Philadelphia 2009 – The State of The City The Pew Charitable Trusts – Philadelphia Research Initiative; page 13 (http://www.pewtrusts.org)

The residential indicator is a national screening parameter and does not account for localized factors which erode the effective household income. The high total tax burden facing Philadelphia households reduces their effective household income. Consequently, measuring the household burden imposed by wastewater costs as a percentage of the MHI (estimated in 2009 to be $37,072 and projected to be $58,305 in 2029) may underestimate the financial burden of the projected wastewater costs per household. As was noted in an analysis of the impacts of CSO controls in the Boston region:

> *"The greater are the costs of other necessities as a share of MHI, the greater will be the economic burden associated with sewer charges equal to a given percent of MHI."* [4]

[4] Assessment of the Economic Impact of Additional Combined Sewer Overflow Controls in the Massachusetts Water Resource Authority Service Area (page 13) prepared by Robert N. Stavins, Genia Long, and Judson Jaffee. Analysis Group Incorporated, August 2004.

The impacts of the tax burden in Philadelphia are further exacerbated by the relatively high cost of living in Philadelphia. The American Chamber of Commerce Researchers Association Cost of Living Index for Philadelphia was 1.249 in 2006[5] (*i.e.*, the cost of living in Philadelphia is approximately 25% higher than the national average). The estimated U.S. MHI in 2009 is approximately $52,500 or 41% higher than the Philadelphia MHI. Thus, the household at the median Philadelphia income faces costs of living that are 25% higher than the national average while earning an income that is about 71% of the national median income.

Property Tax Collection Rate – Indicator 6

Real estate tax collections had shown a pattern of increase since the rate was lowered to 34.74 mills on assessed valuation in 2003, however, the collection rate dropped below 90% for 2006 and 2007. The US EPA criterion for a strong rating in this category is a collection rate of more than 98%. Philadelphia's rate is estimated to be 91%, which places it in the weak range for real estate tax collections.

Summary of the Six Municipal Financial Capability Indicators

The City of Philadelphia received a financial capability rating of 1.58, according to the scores on the six items included in the assessment. This is based on a strong-to-mid-range rating of "2.5" on its bond rating; weak ratings of "1" on overall net debt as a percent of full market property value, unemployment rate, MHI, and property tax collection rate; and the strong rating of "3" on its property tax revenues as a percent of full market value of real estate. The 1.58 rating represents the simple average of those scores.

11.4 ADDITIONAL SOCIO-ECONOMIC TRENDS IN THE PWD SERVICE AREA

In addition to following US EPA guidelines for completion of the financial capability assessment matrix, a discussion of socioeconomic trends in the PWD service area is essential to the consideration of scheduling and compliance levels with CSO guidelines. Approximately 70% of the service area population consists of City of Philadelphia residents, and neighboring counties served are limited in the flows that can be sent to PWD's wastewater treatment plants. Therefore, this discussion includes socioeconomic trends in Bucks, Delaware, and Montgomery Counties, but it is focused primarily on demographic and employment conditions and projections for Philadelphia.

Philadelphia's Demographic and Economic Trends

This section advances an analysis of demographic and economic changes that have taken place in Philadelphia and the surrounding suburban counties during the years 1980 to 2008 and for the forecast period of 2010 to 2035. Emphasis is placed upon demographic and economic changes as they impact Philadelphia County. Demographic and economic trends that are analyzed include population, age of population, the number of households, household composition, and income levels.

---

5 American Chamber of Commerce Research Association Cost of Living Index, http://www.coli.org.

Population
Population levels are a significant indicator in any analysis of demographic and economic changes. Philadelphia's population is depicted in Table 11-6 for the historic period 1980 through 2007 and the forecast period of 2010 through 2035. During the period 1990 to 2000, the population of Philadelphia decreased significantly from 1,585,577 to 1,517,549, a 4.5% decline. As illustrated in Table 11-6, the Delaware Valley Regional Planning Commission (DVRPC) has projected a small increase in the City of Philadelphia's population for the forecasted period 2010-2035. However, most recent census data indicates that the City's population has continued its dramatic decline with a currently estimated population of 1,454,382. Therefore, unless there is a reversal of this trend, the estimated projections for the year 2035 would need to be adjusted significantly downward. In this event, the PWD would anticipate a reduction in the number of residential customers and a corresponding increase in the burden on the remaining households. The Philadelphia County population trend is a reasonable basis for predicting that residential demand for wastewater service in Philadelphia County is not likely to increase significantly during the forecast period.

Table 11-6 Philadelphia County Population Levels 1980-2035

1980 Census	1,688,210
1990 Census	1,585,577
2000 Census	1,517,549
2005 – 2007 Census Estimate	1,454,382
2010 Forecast	1,475,613
2020 Forecast	1,474,268
2030 Forecast	1,478,065
2035 Forecast	1,480,023

Source: DVRPC, Analytical Data report "Regional, County, and Municipal Population and Employment Forecasts, 2005-2035," July 2007

Minority Population
The proportion of minority population in the PWD service area varies between 8.9% in Bucks County and 57.3% in Philadelphia based on most recent Census data. Philadelphia's minority population is over 31% higher than the national average and over 41% higher than the state average. A portion of that population experiences lower incomes, slower growth in income, and greater difficulty meeting the increased burden of utility costs.

Age of Population
The age of the local population is also a significant factor in this analysis. In this regard, it should be noted that in 1980, approximately 14% of all Philadelphians were 65 years of age or older (elderly), and in 1990 the number rose to 15.2%. In 2000, the percentage of elderly in the local population decreased to 14.1%, and the most recent data estimate a 13.0% elderly population. The national average is estimated to be 12.5%, so despite the decrease in elderly population within the City, it still remains above average.

An increase in the elderly population is evident in the suburban counties served by the permittee. The elderly population in the surrounding counties increased from 13.8% to

14.3% during the 1990 to 2000 time period. According to the DVRPC[6], based on population forecasts and the current age distribution, the percent of elderly within Philadelphia and its surrounding communities will increase to roughly 19% of the population by 2025. The DVRPC estimates that the elderly population within Philadelphia will be around 15%, and as high as 22% in Bucks County. As the baby boomer generation ages, the percentage of elderly should increase dramatically.

This trend of the locally aging population is alarming since there appears to be a historic positive correlation in Philadelphia between the percentage of the elderly population and the percentage of the population living in poverty. This is evident in Philadelphia County, based upon population and demographic trends observed between 1970 and 2000. Along with the increased percentage of elderly population, the number of residents living in poverty went from just less than 12% to more than 22%.[7]

It can be reasonably projected, based on the foregoing, that the permittee's customer base will consist of an increasing number of elderly persons, who in many instances are living on limited incomes. Further, an aging customer base indicates limits on future economic expansion.

Number of Households

Another significant factor in this analysis of demographic and economic trends is the number of established households in Philadelphia County. In 1980, 1990, and 2000, there were 634,665, 600,740, and 590,238 households in Philadelphia, respectively. Most recent Census data estimates 557,985 households. The consistent decrease in the number of households is not surprising given the general decline in Philadelphia's population. However, this trend is more alarming when viewed in conjunction with the changes in local household composition, addressed in the following section. These factors suggest that significant income growth in Philadelphia will be unlikely during the forecast period.

Household Composition

Family households in Philadelphia numbered 352,331 in 2000, compared to 378,048 in 1990 and 415,891 in 1980. In 2000, 189,291 such households were headed by two parents, compared to 227,187 in 1990 and 280,619 in 1980. The number of female-headed households in this mix was 131,332 in 2000, compared to 122,370 in 1990 and 113,489 in 1980. This is significant because two parent households tend to have higher incomes than non-family households and family households headed by single parents[8]. Illustrative of this point is in the 12 months prior to the last census estimates, 34% of female-headed families in Philadelphia were below the poverty line compared to only 8.5% of married couple families.

---

6 DVRPC, "The Aging of the Baby Boomers: Elderly and Near-Elderly Population Characteristics," January 2007.

7 In this same context, it should be noted that a significant percentage of children in Philadelphia County live in poverty. In 2006, roughly 35 percent of all children in Philadelphia lived in poverty. This is also an indicator that many households served by the permittee operate under severe economic constraints at present.

8 US Census Bureau, "Income, Poverty, and Health Insurance Coverage in the United States: 2007."

As noted previously, recent trends reflect a drop in total number of households, which includes an 18% decrease in family households. However, most recent census data estimates that the decrease in the number of married couple families is over 16% since 2000, while the female-headed households have barely dropped 10%. Combined with an increase in non-family households of nearly 17%, the result is a proportional increase in households with historically lower earning potential.

Taken together with the above average population of elderly in the service area, these household composition trends do not forecast significant income growth. An examination of the historical and recent income levels further illustrates this point.

Income Levels

Personal income per capita in Philadelphia decreased from $17,430 in 1990 to $16,509 in 2000, compared to a regional increase from $18,383 to $27,789 over the same period of time. Recent census estimates show that Philadelphia's per capita income has increased to $19,875, still significantly lower than the regional and national per capita income estimates of $34,019 and $26,178, respectively. Despite the increase in per capita income, 16.5% of the families in Philadelphia, including 136,277 households, must sustain themselves on incomes below $15,000.

As shown in Figure 11-3, MHI in Philadelphia has significantly lagged behind the national level since the 1970s. Since 1989, MHI in Philadelphia has grown at a rate which is below both those of the state (2.94%) and national (3.18%) levels. This appears to be a consistent and long-term trend resulting from structural elements of the Philadelphia's demographic and economic make-up, rather than being the result of cyclical or outlying occurrences. It is reasonable to expect that this trend in income levels and growth will continue into the future.

From 1990 to 2000, the percentage of all persons with incomes below the poverty level in Philadelphia increased from 20.3% to 22.9%. This trend has continued with the most recent census figure at 24.5%. Given the local increase in unemployment due to the recent economic climate, it is possible that in the near future the number of Philadelphians living in poverty could increase dramatically.

Employment Trends in Philadelphia

Future income growth in Philadelphia is dependent upon prospective economic trends, driven in large part by employment. The affordability of PWD's LTCPU is tied to such economic trends.

The data assembled by the DVRPC in their study entitled "Regional, County, and Municipal Population and Employment Forecasts, 2005-2035", indicates that Philadelphia will experience minimal growth in employment during the forecast period. This estimate focuses on long-term trends and assumptions, and should be evaluated with actual data as available to address any potential long-term shifts that may occur due to the current economic climate and eroding job market. The projected changes in job numbers by employment sector for Philadelphia appear in Table 11-7.

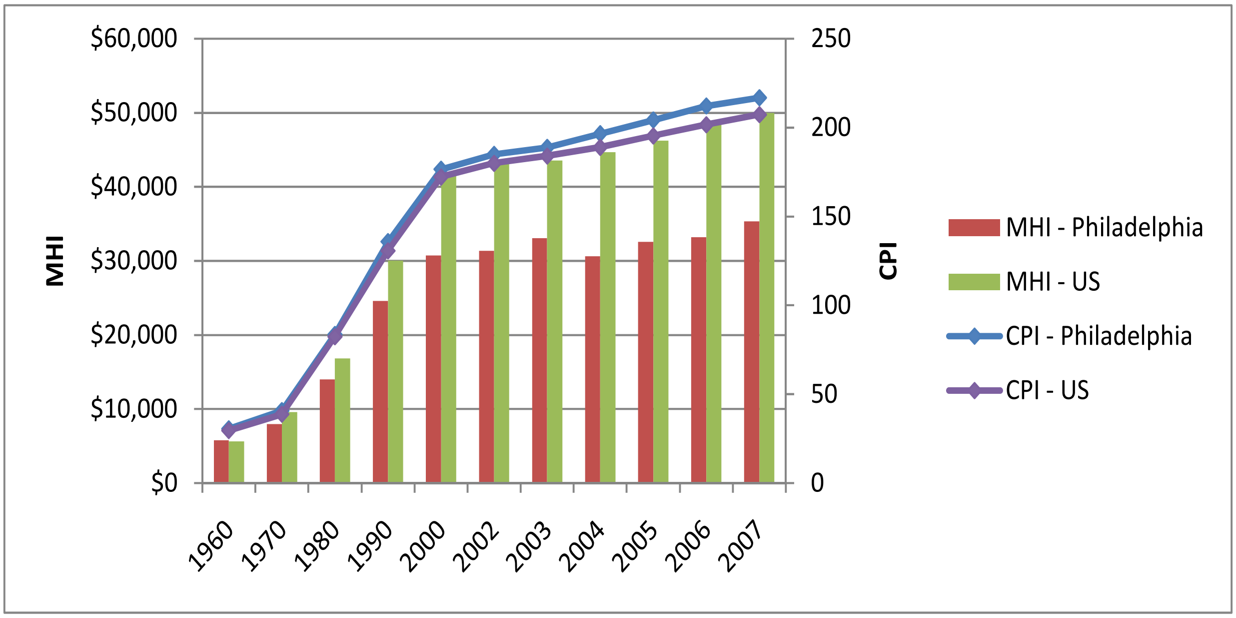


Figure 11-3 MHI Trends and Comparisons

Employment composition in Philadelphia is also not substantially changed in any employment sector during the forecast period, as shown in Table 11-7, although small increases and decreases are shown in some job sectors. Total job forecasts and employment sector forecasts indicate a reversal of past trends, in which employment levels dropped overall. It bears emphasis, however, that Philadelphia County has yet to experience the sizable upward employment trend projected in the above data and the current uncertainty in the job market will negate short-term growth estimates and may potentially hinder long term employment level growth.

11.5 The Financial Capability Matrix

It was established previously in the Phase One (Residential Indicator) analysis that Philadelphia's residential indicator is projected to fall into the high-range category on the financial capability matrix. The Phase two analysis on the assessment of the financial capability indicators placed Philadelphia in the mid-range category for current conditions. The intersection of these two ratings on the EPA financial capability matrix places the City of Philadelphia in the category of high financial burden, as shown on Table 11-8.

In addition to these strictly numerical measures, socioeconomic trends in the Philadelphia area require careful consideration as level and scheduling of CSO control expenditures are determined.

11.6 Conclusions and Implications

PWD will be implementing the innovative approach to combined sewer overflow controls detailed elsewhere within this document within the context of its financial and demographic reality. This reality may be summarized by the unprecedented needs for capital reinvestments in the City's water and sewer systems juxtaposed with structural economic and

Table 11-7 Philadelphia County Employment Forecasts by Sector

Sector	2005	2010	2015	2020	2025	2030	2035
Agriculture & Mining	977	919	866	848	806	765	764
Construction	24,172	20,895	20,302	21,436	21,022	20,504	20,557
Manufacturing	50,335	50,077	48,118	49,208	47,549	45,819	45,805
Transportation / Utilities	33,892	33,515	32,770	31,995	31,502	30,941	31,026
Wholesale	23,505	22,881	22,373	22,092	21,706	21,261	21,275
Retail	97,010	91,230	89,277	87,867	86,642	85,260	85,365
FIRE	61,588	54,847	53,678	53,644	53,217	52,406	52,767
Services	318,831	335,615	346,195	342,303	351,950	360,385	361,570
Government	117,048	112,106	110,674	117,046	116,745	116,015	116,454
Federal/Military	677	715	709	700	692	683	685
Total	**728,035**	**722,800**	**724,962**	**727,139**	**731,831**	**734,039**	**736,268**

Source: DVRPC Employment Forecasts by Sector, based on 2009 economic model run by DVRPC.

Table 11-8 The Financial Capability Matrix at Year 2029

Permittee Financial Capability Indicators Score (Socioeconomic, Debt and Financial Indicators)	**Residential Indicator**		
	Low (Below 1.0%)	**Mid-Range (Between 1.0 and 2.0%)**	**High (Above 2.0%)**
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	Medium Burden	**High Burden**
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

(Blue areas indicate City of Philadelphia ratings)

demographic changes that will continue to erode both PWD's ability to finance required capital investments and the citizen's ability to afford them.

As noted above, PWD's current capital improvements for its water and sewer systems total $4.6 billion through 2029. This includes $3.7 billion for its current systems required to maintain current levels of service and regulatory compliance; and approximately $900 million (2009 dollars) in new capital expenditures for the implementation of the LTCPU recommended alternatives.

The anticipated tripling of the PWD's annual wastewater system revenue requirements from approximately $350 million in 2009 to over $1 billion in 2029 will be paid for by a rate base whose income is projected to increase by less than 60% during the same period. The results of this will be burden measured as the residential indicator of 2.27% of the median income. A population equivalent to cities larger than Boston, Washington D.C., Baltimore and Seattle will pay more than 2.27% of their household income for wastewater services. The lowest quintile of the households, a population larger than cities such as Cincinnati, Minneapolis, Pittsburgh or Toledo will face annual wastewater costs totaling between 3.55 to upwards of 7% of their household incomes.

It is reasonable to expect that an implementation schedule (through 2029) imposing residential burdens well above 2.27% for populations the size of major American cities is untenable. The municipal financing market likely would agree with such a conclusion. PWD might face insurmountable difficulties in financing their capital needs as outlined above.

These realities suggest an implementation schedule extending beyond the 2029 deadline. Indeed, through its Green Infrastructure approach to CSO control, PWD fully intends to continue to expand the green features within the City so that control levels will increase and improve well beyond 2029. PWD's Green Infrastructure approach is uniquely suited for incremental and modular implementation and the scheduling context is a completely different paradigm than that of a traditional infrastructure control strategy. A storage and conveyance tunnel, for example, would be of little or marginal benefit before it is fully constructed and operated. CSO control and the resulting water quality benefits would not occur until initiation of operation of at least large portions of the program. In such cases, the regulatory and environmental imperatives might push towards a discrete short term (ten to twenty) year timeframe. PWD's approach however provides for immediate compliance and water quality benefits that will grow annually. The proposed implementation schedule will allow the City of Philadelphia and its watersheds to achieve these benefits within the constraints that the nation's changing economics and demographics have dealt it.

12 POST-CONSTRUCTION MONITORING

12.1 INTRODUCTION

Post-construction monitoring is intended to provide sufficient information to estimate the effectiveness of the control measures constructed during the 20-year implementation phase of the City's CSO Long Term Control Plan Update (LTCPU). It includes measures appropriate for determining the success of the *Green City, Clean Waters* program in achieving the goals of the integrated watershed management plans and in meeting the water quality requirements of the Clean Water Act.

The development and implementation of efforts both to measure the progress of runoff control projects and to monitor the effectiveness of those projects in meeting program objectives is described in Section 10. The continuing regional receiving waters sampling and monitoring described in Section 3 includes measures of water chemistry and living resources. The results of these efforts will be evaluated continuously to facilitate the adaptive management of the City's LTCPU, and will provide a continuous evaluation of program success throughout the 20-year implementation period.

As the LTCPU implementation period draws to a close, PWD will develop a detailed post-implementation status report, including the results of an intensive post-construction monitoring effort. A post-implementation monitoring plan describing the proposed intensive monitoring effort will be submitted to the Pennsylvania Department of Environmental Protection in 2027 for review and approval. That plan will be based on the results of evaluations of the success factor monitoring conducted throughout the LTCPU implementation period, and on water quality parameters monitoring procedures and water quality standards as they exist at that time. The post-implementation intensive monitoring program will take place over the course of a two-year period beginning in 2029 and ending in 2031, resulting in a report documenting the degree of program success based on the metrics that will be prescribed in the monitoring plan, and those that are developed during the period of monitoring.

The efforts to produce the post-implementation status report will need to identify and evaluate critical program success factors. Those success factors require objective, measurable and quantifiable indicators that likely will fall into three categories:

- Administrative
- Control performance
- Receiving water conditions

12.2 ADMINISTRATIVE MEASURES

Administrative measures track the implementation and progress of the LTCPU in terms of accounting-based factors recorded on a watershed basis. Examples of accounting-based factors include, by watershed:

- Area greened - area of impervious cover mitigated attributable to the green programs
- Volume of source control storage constructed
- Length and value of stream corridor restored or improved
- Area and value of wetlands created or enhanced
- Habitat area created or restored and associated value
- Annual mass of solid materials removed from storm inlets

- Annual removal of debris from waterways (tons of debris removed)
- Number of projects completed
- Maintenance effort expended
- Private-sector development plans reviewed
- Constructed projects progress compared to implementation schedule
- Running sum of benefits – mass of carbon sequestered/avoided, etc.
- Other measure as appropriate.

12.3 CONTROL PERFORMANCE MEASURES

12.3.1 Source Control Performance Monitoring

Performance monitoring of structural elements will be integrated into the design of a number of the green stormwater controls constructed during the 20-year LTCPU implementation period. These typically include small monitoring chambers at outflow control points that provide for the installation of devices to record the depth of water in the storage beds over time, and the depth of flow over or through the hydraulic control devices. The monitoring technique tracks the filling and emptying of the storage provided by the stormwater control structure, allowing for evaluations of the effectiveness of the hydraulic control and the effectiveness of the storage and release process, relative to the design goals.

The monitoring and assessment of individual control performance provides valuable information to refine control measure design standards, to refine predictive hydraulic models, and to inform the process leading to decision points in the adaptive management process.

12.3.2 Sewer System Monitoring

Continuing the monitoring of the combined sewer system response to precipitation provides a direct measure of the cumulative performance of controls at the sewershed level and provides information for the continuing process of validating the hydrologic and hydraulic models of the sewer system.

The sewer system monitoring that will be available for the post-implementation monitoring efforts will include the following sources at fixed long-term monitoring locations:

- Water Pollution Control Plan influent flow data including hourly flow quantities and daily water quality monitoring of suspended solids, biochemical oxygen demand, and fecal coliform
- Outlying community metering chamger flow data
- Permanent metering of water levels at selected locations such as CSO regulators, along interceptors, and in key locations that conrol the hydraulic grade line in the systm
- Pumping station records

In addition to these sources of data from fixed long-term monitoring locations, PWD's continuous portable flow monitoring program will be focused on the goals of the post-implementation monitoring plan. The plan will detail the portable flow monitoring program design in terms of monitor location; frequency and duration of deployments; and deployment number and schedule over the two year post-implementation monitoring period.

Flow monitoring locations primarily target combined trunk sewers draining sewersheds where stormwater green infrastructure is implemented. PWD will implement a synoptic instrumentation deployment program covering a representative area within selected sewershed drainage areas. The deployment duration goal will be twelve continuous months intended to capture a full range of hydrologic conditions and wet weather event sizes and durations.

The data collected during the post-implementation compliance monitoring period will be evaluated and used to further validate the hydrologic and hydraulic models that in turn will be used to evaluate the effectiveness of the controls.

12.4 Receiving Water Quality Measures

Receiving water monitoring and sampling will continue to be conducted directly by PWD staff and the United States Geologic Survey (USGS). It is assumed that monitoring and sampling programs conducted by the Delaware River Basin Commission (DRBC) and the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce will continue.

The PWD, through its cooperative agreements with the USGS, will continue to provide hydrologic and water quality monitoring data in the form of continuous 15-minute stream stage measurement and flow estimation, and water quality data, as described in Section 3.

At this point in time, it is not possible to know what degree of monitoring and sampling information will be available from other agencies. The post-implementation plan will identify data necessary to characterize receiving water quality, and to the degree that is not available from other agencies, the plan will be provide for collection of that data by the PWD.

REFERENCES

American Chamber of Commerce Research Association. 2009. *Cost of Living Index*. Website: http://www.coli.org.

Association of Metropolitan Sewerage Agencies. 2002. *Preparation of Integrated Water Quality Monitoring and Assessment Reports: Recommendations for Clean Water Act § 303(d) and §305(b) Methodologies and Reporting.*. pp.16-38.

Ball, J. 1982. "Stream Classification Guidelines for Wisconsin." *Wisconsin Department of Natural Resources Technical Bulletin*. Wisconsin Department of Natural Resources. Madison, Wisconsin. Platts et al., 1983.

Barbour, M. T.; J. Gerritsen; B. D. Snyder; and J. B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable rivers: Periphyton, Benthic Macroinvertebrates, and Fish*. US Environmental Protection Agency, Office of Water, EPA/841/B-99-002, Washington, DC.

Barbour, M. T.; J. B. Stribling; and J.R. Carr. 1995. *The Multimetric Approach for Establishing Biocriteria and Measuring Biological Condition*. pp.63-80. In W.S. Davis and T.P. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, Florida.

Biggs, B. J. F. 2000. Eutrophication of Streams and Rivers: Dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American Benthological Society 19: 17-31.

Biggs, B. J. F. and M. E. Close. 1989. Periphyton Biomass Dynamics in a Gravel Bed river: The relative effect of flow and nutrients. *Freshwater Biology* 22: 209-231.

Borchardt, M. A. 1996. *Nutrients*. pp. 183-227. In Algal Ecology. (R. J. Stevenson, M. L. Bothwell, and R. L. Lowe, eds). Academic Press, San Diego. p. 183-227

Butler, R. L.; E. L. Cooper; J. K. Crawford; D. C. Hales; W. G. Kimmel; and C. C. Wagner. 1973. *Fish and Food Organisms in Acid Mine Waters of Pennsylvania*. U.S. Environmental Protection Agency EPA-R3-73-032.

CDM. 2006a. "Evaluation of NEXRAIN data." *Technical Memorandum*.

CDM. 2006b. "SE Drainage District Baseline Model." *Technical Memorandum*.

CDM. 2006c. "RTK_Dist_Memo_061113."*Technical Memorandum*.

Chetelat, J.; F. R. Pick; A. Morin; and P. B. Hamilton. 1999. "Periphyton Biomass and Community Composition in Rivers of Different Nutrient Status." *Canadian Journal of Fisheries and Aquatic Sciences*. 56: 560-569.

City of Philadelphia. 2009. *Pennsylvania Water and Wastewater Revenue Bonds*. Series 2009A, p 59.

Clements, W.H.; D.S. Cherry; and J. Cairns, Jr. 1990. Macroinvertebrate Community Responses to Copper in Laboratory and field Experimental Streams. *Arch. Environ. Contam. Toxicol.* 19(3):361-365.

Clements, W.H.; D.S. Cherry; and J. Cairns, Jr. 1988. "The Impact of Heavy Metals on Macroinvertebrate Communities: A comparison of observational and experimental results." *Canadian Journal of Fisheries and Aquatic Sciences*. 45:2017-2025.

Common Wealth of Pennnsylvania Department of Environmental Protection. 2001. Pennsylvania Code, Title 25 Environmental Protection, Chapter 93 Water Quality Standards Version: (324889) No. 388 Mar. 07. Website: http://www.pacode.com/secure/data/025/025toc.html.

Daniels, R.; K. Riva-Murray; D. Halliwell; D. Vana-Miller; and M. Bilger. 2002. " An Index of Biological Integrity for Northern Mid-Atlantic Slope Drainages." *Transactions of American Fisheries Society*. 131: 1044-1060.

Darby-Cobbs Watershed Partnership. 2007. *Cobbs Creek Integrated Watershed Management Plan.* Website: http://phillyriverinfo.org/Watersheds.

Darby-Cobbs Watershed Partnership. 2004. *Cobbs Creek Integrated Watershed Management Plan.* Website: http://www.phillyriverinfo.org.

Delaware River Basin Comission. 2008a. *Administrative Manual — Part III Water Quality Regulations.*

Delaware River Basin Commission. 2008b. *State of the Basin Report.*

Delaware River Basin Commission 2008c. *Fish Advisory Information.* Website: http://www.state.nj.us/drbc/toxics_info.htm.

Delaware River Basin Commission. 1998. *Development of a Hydrodynamic and Water Quality Model for the Delaware River.*

Delaware Valley Regional Planning Commission. 2007a. *The Aging of the Baby Boomers: Elderly and Near-Elderly Population Characteristics.*

Delaware Valley Regional Planning Commission. 2007b. *Regional, County, and Municipal Population and Employment Forecasts, 2005-2035.*

Di Toro, D.M.; H.E. Allen; H.L. Bergman; J.S. Meyer; P.R. Paquin; and R.C. Santore, 2001. "A Biotic Ligand Model of the Acute Toxicity of Metals." I. *Technical Basis, Environmental Toxicology and Chemistry.* 20:2383-2396.

Dodds, W. K.; V. H. Smith; and K. Lohman. 2002a. "Nitrogen and Phosphorus Pelationships to Benthic Algal Biomass in Temperate Streams." *Canadian Journal of Fisheries and Aquatic Sciences.* 59: 865-874.

Dodds, W. K.; A. J. Lopez; W. B. Bowden; S. Gregory; N. B. Grimm; S. K. Hamilton; A. E. Hershey; E. Marti; W. H. McDowell; J. L. Meyer; D. Morrall; P. J. Mulholland; B. J. Peterson; J. L.

Tank; H. M. Valett; J. R. Webster; and W. Wollheim. 2002b. "N Uptake as a Function of Concentration in Streams." *Journal of the North American Benthological Society*. 21: 206-220.
Dodds, W. K.; J. R. Jones; and E. B. Welch. 1998. "Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus." *Water Research* 32: 1455-1462.

Dodds, W. K.; V. H. Smith; and B. Zander. 1997. "Developing Nutrient Targets to Control Benthic Chlorophyll Levels in Streams: A case study of the Clark Fork River." *Water Research*. 31: 1738-1750.

Edwards, T.K.; and G.D. Glysson. 1988. *Field Methods for Measurement of Fluvial Sediment: U.S. Geological Survey Open-File Report*. pp. 86-531, 118.

Fairchild, G. W. and J. W. Sherman. 1993. "Algal Periphyton Response to Acidity and Nutrients in Softwater Lakes: Lake comparison vs. nutrient enrichment approaches." *Journal of the North American Benthological Society*. 12: 157-167.

Fairchild, G. W., J. W. Sherman, and F. W. Acker. 1989. The Effects of Nutrients (N, P, C) Enrichment, Grazing, and Depth upon Littoral Periphyton of a Softwater Lake. *Hydrobiologia*. 179: 69-83.

Fairmount Park Commission. 1999. "Natural Land Restoration Master Plan Vol. II Park-Specific Master Plan." *Tacony Creek Park Master Plan.*

Faulkner, G.; F. Horner; and W. Simonis. 1980. The Regulation of the Energy-Dependent Phosphate Uptake by the Blue-Green Aalga Anacystis nidulans. Planta 149: 138-143.

Francouer, S. N. 2001. "Meta-analysis of lotic Nutrient Amendment Experiments: Detecting and quantifying subtle responses." *Journal of the North American Benthological Society*. 20: 358-368.

Gerba, C.P. 1976. "Effect of Sediments on the Survival of Escherichia coli in Marine Waters." *Appl. Environ. Microbiol.* 32: 114.

Goldman, J. C. 1979. "Temperature Effects on Steady-State Growth, Phosphorus Uptake, and the Chemical Composition of a Marine Phytoplankter." *Microbial Ecology*. 5: 153-166.

Greenberg, A. E.; L. S. Clesceri; A. D. Eaton; and M. A. H. Franson (eds). 1992. "Standard Methods for the Examination of Water and Wastewater (18th)." *American Public Health Association*. Washington, D.C.

Grimm, N. B. and S. G. Fisher. 1986. "Nitrogen Limitation in a Sonoran Desert Stream." *Journal of the North American Benthological Society*. 5: 2-15.

Halliwell, D. B.; R. W. Langdon; R. A.; J. P. Kurtenbach; and R. A. Jacobson. 1999. "Classification of Freshwater Fish Species of the Northeastern United States for Use in the Development of IBIs." T. P. Simon (ed.). *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*. CRC Press, Boca Raton, Florida. pp. 301-337.

Hill, W. R. and A. W. Knight. 1988a. "Nutrient and Light Limitation of Algae in Two Northern California Streams." *Journal of Phycology*. 24: 125-132.

Hill, W.R. and A.W. Knight. 1988b. "Concurrent Grazing Effects of Two Stream Insects on Periphyton." *Limnology and Oceanography*. 33:15-26.

Huber, W.C. and R.E. Dickinson. 1988. *Stormwater Management Model User's Manual*. Version 4, EPA/600/3-88/001a (NTIS PB88-236641/AS), Environmental Protection Agency, Athens, GA.

Huff, F. A. and J. R. Angel. (1992). "Rainfall Frequency Atlas of the Midwest." *Illinois State Water Survey*, Bulletin 71.

Jones, J. R., M. M. Smart, and J. N. Burroughs. 1984. *Factors Related to Algal Biomass in Missouri Ozark Streams*. Verh. Int. Ver. Limnol (International Association of Theoretical and Applied Limnology) 22: 1867-1875.

Karr, E. A., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. "Assessing Biological Integrity in Running Waters: A mMethod and its Rationale", Special publication 5. *Illinois Natural History Survey*.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 66: 21-27.

Kemp, M. J. and W. K. Dodds. 2002. " The Influence of Ammonium, Nitrate, and Dissolved Oxygen Concentrations on Uptake, Nitrification, and Denitrification Rates Associated with Prairie Stream Substrata." *Limnology and Oceanography*. 47: 1380-1393.

Kjeldsen, K. 1994. *The Relationship Between Phosphorus and Peak Biomass of Benthic Algae in Small Lowland Streams*. Verh. Int. Ver. Limnol. Limnol (International Association of Theoretical and Applied Limnology) 25: 1530-1533.

Kreeger, D., R. Tudor, J. Sharp, S. Kilham, D. Soeder, M. Maxwell-Doyle, J. Kraeuter, D. Frizzera, J. Hameedi and C. Collier. 2006. White Paper on the Status and Needs of Science in the Delaware Estuary. Partnership for the Delaware Estuary, Report #06-01. 72 pp. http://www.delawareestuary.org/scienceandresearch/datasetsandreports/index.asp

LaPoint, T.W.; S.M.Melancan; and M.K. Morris. 1984. "Relationships among Observed Metals Concentrations, Criteria, and Benthic Community Structural Responses in 15 Streams." *J. Water Pollut. Control Fed.* 56:1030-1038.

Lohman, K.; J. R. Jones; and B. D. Perkins. 1992. "Effects of Nutrient Enrichment and Flood Frequency on Periphyton Biomass in Northern Ozark Streams." *Canadian Journal of Fisheries and Aquatic Sciences*. 49: 1198-1205.

Lohman, K.; J. R. Jones; and C. Baysinger-Daniel. 1991. "Experimental Evidence for Nitrogen Limitation in a Northern Ozark Stream." *Journal of the North American Benthological Society*. 19: 14-23.

Majumdar, D.K.; Millar, E.W.; Sage, L.E. eds. 1988. *Ecology and Restoration of the Delaware River Basin*. The Pennsylvania Academy of Science. Typehouse, Phillipsburg, NJ.

Manning, M.J.; D.R.G. Farrow; and F.D. Arnold. 1977. *National Pollutant Discharge Inventory,Publicly Owned Treatment Works in Coastal Areas of the US*. National Oceanic and Atmospheric Administration (NOAA). Rockville, MD.
Moore, C.; S. Vallabhaneni and E. Strand. 2002. *SHAPE User's Guide*. CDM, p. 82.

Morel, F.M.M. and J.G. Hering. 1993. Principles and Applications of Aquatic Chemistry. John Wiley and Sons, New York.

Morin, A. and A. Cattaneo. 1992. Factors Affecting Sampling Variability of Freshwater Periphyton and The Power of Periphyton Studies. *Canadian Journal of Fisheries and Aquatic Sciences*. 49: 1695-1703.

Myers, R.D., J. Smullen, J. Cromwell, B. Raucher, and M. Cammarata. 2009. "Balancing Green and Traditional Infrastructure for Sustainable Urban Wet Weather Management." *SIWW Paper*.

NatureServe. 2006. *NatureServe Explorer: An Online Encyclopedia of Life [Web Application]*. Version 6.1. NatureServe, Arlington, Virginia. May 2, 2007. Website: http://www.natureserve.org/explorer.
National Marine Fisheries Service. 1998. *Final Recovery Plan for the Shortnose Sturgeon, Acipenser brevirostrum*.

New Jersey Department of Environmental Protection. 2006. *2006 Fish Consumption Advisories*. Website: http://www.state.nj.us/dep/dsr/2006fishadvisorybrochure.pdf.

Ormsbee, L. 1989. "Rainfall Disaggregation Model for Continuous Hydrologic Modeling." *Journal of Hydraulic Engineering*, 115(4).

Pensylvania Department of Environmental Protection. 2007. *Commonwealth of Pennsylvania Fish Consumption Advisories*. Website: http://www.depweb.state.pa.us/watersupply/cwp/view.asp?a=1261&q=453946.

Pensylvania Department of Environmental Protection. 2004a. *Pennsylvania Integrated Water Quality Monitoring and Assessment Report*.

Pennsylvania Department of Environmental Protection. 2004b. *Pennsylvania DEP's Six-Year Plan for TMDL Development*. Bureau of Water Supply and Wastewater Management. Website: http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/TMDL/TMDL_6yearplan.pdf.

Pennsylvania Department of Environmental Protection. 2003. 303d list if impaired streams (GIS data layer). Website: http://www.dep.state.pa.us/watermanagement_apps/tmdl/default.aspx and http://www.epa.gov/reg3wapd/tmdl/303list.html#P.

Perillo, J. A.. and Butler, L. H. 2009. "Evaluating the Use of Fairmount Dam Fish Passage Facility with Application to Anadromous Fish Restoration in the Schuylkill River, Pennsylvania." *Journal of Pennsylvania Academy of Sciences*. 83(1):24-33.

Peterson, C. G. and N. B. Grimm. 1992. "Temporal Variation in Enrichment Effects During Periphyton Succession in a Nitrogen-limited Desert Stream Ecosystem." *Journal of the North American Benthological Society*. 11: 20-36.

Pew Charitable Trusts, The – Philadelphia Research Initiative, 2009. *Philadelphia: The state of the city*. p. 13. Website: http://www.pewtrusts.org.

Philadelphia Water Department (PWD). 2009 (in progress). *Delaware Direct Rivers Conservation Plan.* Website: http://www.phillyriverinfo.org.

Philadelphia Water Department. 2007. *Delaware Source Water Protection Plan*. Website: http://www.phillyriverinfo.org.

Philadelphia Water Department. 2004a. *Darby-Cobbs Watershed Comprehensive Characterization Report: July 2004 Update.* Darby-Cobbs Watershed Partnership.

Philadelphia Water Department. 2004b. *Schuylkill Source Water Protection Plan.* Website: http://www.phillyriverinfo.org.

Philadelphia Water Department (PWD). 2002-2006. *Annual Drinking Water Quality Report.* Website: http://www.phillyriverinfo.org.

Philadelphia Water Deparment. 2002. *Darby-Cobbs Watershed Comprehensive Characterization Report.* Darby-Cobbs Watershed Partnership. Website: http://www.phillyriverinfo.org.

Philadelphia Water Department. 2000a. *Technical Memorandum No. 1: Historical Water Quality for the Darby and Cobbs Creek Watersheds.* Website: http://www.phillyriverinfo.org.

Philadelphia Water Department. 2000b. *Technical Memorandum No. 2: Analysis of 1999 Monitoring Data for the Darby and Cobbs Creek Watershed.* Website: http://www.phillyriverinfo.org.

Plafkin, J. L.; M. T. Barbour; K. D. Porter; S. K. Gross; and R. M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic macroinvertebrates and fish.* EPA/440/4-89-001. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Platts, W. S. 1979. "Relationships Among Stream Order, Fish Populations, and Aquatic Geomorphology in an Idaho River Drainage." *Fisheries.* 4:5-9.

Pringle, C. M. 1987. "Effects of Water and Substratum Nutrient Supplies on Lotic Periphyton Growth: An Integrated Bioassay." *Canadian Journal of Fisheries and Aquatic Sciences.* 44: 619-629.

Rhee, G. Y. and I. J. Gotham. 1981a. "The Effect of Environmental Factors on Phytoplankton Growth: Temperature and the interactions of temperature with nutrient limitation." *Limnology and Oceanography* 26: 635-648.

Rhee, G. Y. and I. J. Gotham. 1981b. The Effect of Environmental Factors on Phytoplankton Growth: Light and the interactions of light with nitrate limitation." *Limnology and Oceanography.* 26: 649-659.

Robert N. S.; G. Long; and J. Jaffee. 2004. *Assessment of the Economic Impact of Additional Combined Sewer Overflow Controls in the Massachusetts Water Resource Authority Service Area.* Analysis Group Incorporated. p. 13.

Schwartz, J., R. Levin, and R. Goldstein. 2000. "Drinking Water Turbidity and Gastrointestinal Illness in the Elderly of Philadelphia." *Journal of Epidemiology and Community Health.* Website: http://jech.bmj.com/cgi/reprint/54/1/45.
Smullen, J.T., Shallcross, A.L. and Cave, K.A. 1999. Updating the U.S. Nationwide Urban Runoff Quality Database, Water Science and Technology, 39, No. 12, pp. 9-16.

Socolofsky, Adams and Entekhabi. 2001. "Disaggregation Of Daily Rainfall For Continuous Watershed Modeling." *Journal of Hydrologic Engineering*, 6(4).

Stankowski, S.J. 1974. *Magnitude and Frequency of Floods in New Jersey with Effects of Urbanization.* Special report 38, U.S. Geological Survey. Trenton, New Jersey.

Terrene Institute. 1998. "A Clean Sweep Now Possible". *Runoff Report.* Alexandria, VA. Vol. 6 No. 4.

Threlfall J., P. Cowpertwait, H. Strandner and I. Clifforde. 1999. "Temporal And Spatial Rainfall Model Simulations For Integrated Urban Wastewater System Modelling." *Third DHI Software Conference & DHI Software Courses.* Helsingør, Denmark, 7 to 11 June 1999.

Tookany-Tacony-Frankford Watershed Partnership. 2007. *Tookany/Tacony-Frankford Integrated Watershed Management Plan.* Website: http://phillyriverinfo.org/Watersheds.

Tookany/Tacony-Frankford Watershed Partnership. 2005a. *Tookany/Tacony-Frankford Watershed Comprehensive Characterization Report.* Website: http://www.phillyriverinfo.org.

Tookany/Tacony-Frankford Watershed Partnership. 2005b. *Tookany/Tacony-Frankford Integrated Watershed Management Plan.* Website: http://www.phillyriverinfo.org.

Urbonas, B. and P. Stahre. 1993. *Stormwater: Best Management Practices and Detention for Water Quality, Drainage, and CSO Management.* Englewood Cliffs, NJ: PTR Prentice Hall.

U.S. Army Corps of Engineers Hydrologic Engineering Center. 1977. *Storage, Treatment, Overflow, Runoff Model "STORM" Users Manual.*

U.S. Census Bureau. 2007. *Income, Poverty, and Health Insurance Coverage in the United States: 2007.*

U.S. Environmental Protection Agency. 2007. *Computer Tools for Sanitary Sewer System Capacity Analysis and Planning.* National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. EPA/600/R-07/111.

U.S. Environmental Protection Agency (US EPA). 2006a. *National Recommended Water Quality Criteria.* Website: http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf

U.S. Environmental Protection Agency (US EPA). 2006b.*The National Listing of Fish Advisories*. Website: http://www.epa.gov/waterscience/fish/advisories.

U.S. Environmental Protection Agency (US EPA) Regions II and III. 2004a. *Total Maximum Daily Loads for Polychlorinated Biphenyls (PCBs) for Zones 2-5 of the Tidal Delaware River*. Website: http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/DelawareRiver/index.htm.

U.S. Environmental Protection Agency (US EPA). 2004b. "Combined Sewer Overflow (CSO) Control Policy." *Federal Register*. 75(59): 18688-18698. Website: http://www.epa.gov/npdes/pubs/owm0111.pdf

U.S. Environmental Protection Agency (US EPA) Regions II and III. 2003. "Executive Summary" *Total Maximum Loads for Polychlorinated Bipheynls (PCBs) For Zones 2 - 5 of the Tidal Delaware River* . pp. 1-16. Website: http://www.epa.gov/reg3wapd/tmdl/pa_tmdl/DelawareRiver/ExecutiveSummary.pdf .

U.S. Environmental Protection Agency (US EPA), Office of Water. 1996. Watershed Approach Framework. (EPA doucment number 840S96001). Website: http://www.epa.gov/owow/watershed/framework.html.

U.S. Environmental Protection Agency, Office of Water. 1995. Combined Sewer Overflows: Guidance for Long-Term Conrol Plan. (document number EPA/832-B-95-002). Washington, DC.

U.S. Fish and Wildlife Service (USFWS). 2001. *Bog Turtle (Clemmys muhlenbergii) Recovery Plan*.

U.S. Fish and Wildlife Service(USFWS). 1998. "Endangered and Threatened Wildlife and Plants; Proposed Rule to Remove the Peregrine Falcon in North America From the List of Endangered and Threatened Wildlife." *Federal Register*. 165(63): 45446 – 45463.

U.S. Fish and Wildlife Service (USFWS). 1993. *Dwarf Wedge Mussel (Alasmidonta Heterodon) Recovery Plan*.

van Donk, E. and S. S. Kilham. 1990. "Temperature Effects on Silicon- and Phosphorus-Limited Growth and Competitive Interactions among Three Diatoms." *Journal of Phycology*. 26: 40-50.

Van Donsel, D.J.; Geldreich, E.D.; and N.A. Clarke. 1967. "Seasonal Variations in Survival of Indicator Bacteria in Soil and their Contribution to Stormwater Pollution." *Applied Microbiology*. 15, 1362-1370 (1967).

Warnick, S.L., and H.L. Bell. 1969. "The Acute Toxicity of some Heavy Metals to Different Species of Aquatic Insects." *J. Water Pollut. Control Fed.* 41:280-284.

Welch, E. B.; J. M. Jacoby; R. R. Horner; and M. R. Seeley. 1988. Nuisance Biomass Levels of Periphytic Algae in Streams. *Hydrobiologia*. 157: 161-168.

Whiteside, B. G. and McNatt, R. M. 1972. Fish Species in Relation to Stream Order and Physio-Chemical Conditions in the Plum Creek Drainage Basin." *Amer. Midi. Nat.* 88:90-101.

Winterbourn, M. J. 1990. "Interactions Among Nutrients, Algae, and Invertebrates in a New Zealand Mountain Stream." *Freshwater Biology*. 23: 463-474.

Wynne, D. and G.-Y. Rhee. 1986. "Effects of Light Intensity and Quality on the Relative N and P Requirement (the Optimum N:P Ratio) of Marine Phytoplanktonic Algae." *Journal of Plankton Research*. 8: 91-108.