

Section 7

Development and Screening of Management Options

This section summarizes a comprehensive list of stormwater and watershed corrective measures, or “management options,” that the TTF Watershed Partnership judged to be potentially applicable to their watershed. This list serves as the starting point for the screening and evaluation steps (Section 7.2) that lead to the array of recommendations contained in the Implementation Guidelines (Section 8).

7.1 Menu of Options

A large amount of detailed information on these watershed management options is already available from existing sources. Rather than reproducing this information, this section provides references and links to these sources.

The options are grouped under the three targets introduced in Section 2 (with codes listed parenthetically for reference below and in the sections that follow):

Target A: Dry Weather Water Quality and Aesthetics

- Regulatory Approaches (AR1,2)
- Public Education and Volunteer Programs (AP1-3)
- Municipal Measures (AM1-7)
- Enhancing Stream Corridor Recreational and Cultural Resources (AO1)
- Monitoring, Reporting, and Further Study (AMR)

Target B: Healthy Living Resources

- Channel Stability and Aquatic Habitat Restoration (BM1-5)
- Lowland and Upland Restoration and Enhancement (BM6-9)
- Monitoring, Reporting, and Further Study (BMR)

Target C: Wet Weather Water Quality and Quantity

- Regulatory Approaches (CR1-9)
- Public Education and Volunteer Programs (CP1)
- Municipal Measures (CM1-9)
- Stormwater Management:
 - Source Control Measures (CS1-5)
 - Onsite and Regional Stormwater Control Facilities (CS6-16)
- Monitoring, Reporting, and Further Study (CMR)

7.1.1 Target A: Dry Weather Water Quality and Aesthetics

Target A is defined for Tookany/Tacony-Frankford Creek as focusing on trash removal and litter prevention, and the elimination of sources of sewage during dry weather. Streams should be aesthetically appealing (look and smell good), accessible to the public, and be an amenity to the community. Sewer odors occurring from dry weather sewer discharges in both combined and separate sewer areas should be remedied.

Regulatory Approaches

- AR1 On-Lot Disposal (Septic System) Management
- AR2 Pet Waste, Litter, and Dumping Ordinances

These typical pollution reduction and aesthetic ordinances are already in effect in many locations, and can be effective at controlling diffuse sources of pollutants. They are particularly important in urban watersheds; however, they must be consistently enforced to be effective.

Public Education and Volunteer Programs

- AP1 Public Education
- AP2 School-Based Education
- AP3 Public Participation and Volunteer Programs

Municipal Measures

- AM1 Capacity Management Operation and Maintenance (CMOM)
- AM2 Inspection and Cleaning of Combined Sewers
- AM3 Sanitary Sewer Rehabilitation
- AM4 Combined Sewer Rehabilitation
- AM5 Illicit Discharge, Detection, and Elimination (IDD&E)
- AM6 Stream Cleanup and Maintenance
- AM7 Household Hazardous Waste Collection

Enhancing Stream Corridor Recreational and Cultural Resources (AO1)

Preservation and enhancement of recreational and cultural resources may be integrated into comprehensive watershed management. These resources are part of the link between the human population and natural resources in a watershed. Strategies to provide access to water resources for recreational purposes encourage appreciation for and stewardship of these areas. Strategies to protect water-based historic structures should be implemented to insure that flooding and other impacts are avoided.

Monitoring, Reporting, and Further Study (AMR)

Monitoring and reporting under Target A include monitoring of progress toward achievement of objectives (as measured by indicators introduced in Section 4) and monitoring of implementation of recommended management measures. For example, Indicator 18 measures “tons of trash removed from streams and riparian areas” (a measure of option implementation) and derives a stream accessibility score for individual reaches of the creek (a measure of progress toward an objective).

7.1.2 Target B: Healthy Living Resources

Improving the ability of an urban stream to support viable habitat and fish populations focuses primarily on remediation of the more obvious impacts of urbanization on the stream. These impacts include loss of healthy riparian habitat, eroding and undercut banks, scoured streambed or excessive sediment deposits, channelized and armored stream sections, and invasive species. Encroaching development on the riparian buffer can leave little or no room for a vegetated buffer, while other open riparian areas are often left poorly managed. Biological monitoring indicates that the whole Tookany/Tacony-Frankford Watershed suffers from impaired aquatic habitat and does not meet its designated use as a warm water fishery. This impairment is due to severe water flow fluctuations, habitat alteration, point and non-point source pollution from urban development, hydromodification, and combined sewer overflows (PA DEP 2001).

The primary tool to address these problems is stream restoration. Restoration addresses poor instream habitat and biological impairment, focusing on improving channel stability, improving instream and riparian habitat, providing refuge that allows fish to avoid high velocity conditions during storms, and managing land within the stream corridor. Lowland restoration and enhancement addresses the problem of wetland loss and impairment. Nearly all wetlands in the watershed exhibit impaired functions that indicate extensive disturbance and deterioration.

The wet weather strategy includes both restoration of physical stream habitat and reduction of discharges from stormwater and combined sewage. These measures are complementary; stream restoration provides areas of lower flow where aquatic life can avoid higher flows, and discharge reduction helps limit velocities and protects the long-term investment in the restored stream. Targets B and C are intended to accomplish the restoration of physical stream habitat through control measures involving erosion, sediment accumulation, and flow variability.

Many of the stresses faced by aquatic life in urban streams are the result of alternating extremes of high and low flow, and the resulting sediment scour and deposition. While stormwater BMPs that promote infiltration do help to reduce these extremes, a recent modeling analysis conducted by PWD indicates that impervious cover would have to be reduced by half or more to have a significant effect. This result indicates that stream restoration measures may be a more feasible means of improving the aquatic habitat in the short term. Modern design techniques may create areas of reduced velocity where aquatic life is protected during high flow. Techniques appropriate to our area are summarized in “Guidelines for Natural Stream Channel Design for Pennsylvania Waterways,” by the Alliance for the Chesapeake Bay, March 2003. This publication is available online at <http://www.acb-online.org/toolkits.cfm>.

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 Improvement
- BM7* Invasive Species Management
- BM8* Biofiltration
- BM9* Reforestation

Monitoring, Reporting, and Further Study (BMR)

Monitoring and reporting under Target B includes monitoring of progress toward achievement of objectives (as measured by indicators introduced in Section 4) and monitoring of implementation of recommended management measures. For example, Indicator 3 measures the channel condition and trend for each reach of the stream. This indicator is both a measure of implementation and a measure of progress toward the goal of reducing streambank and stream channel deposition and scour to protect and restore the natural functions of aquatic habitat and ecosystems, streambanks, and stream channels.

7.1.3 Target C: Wet Weather Water Quality and Quantity

The third target is to restore water quality to meet fishable and swimmable criteria during wet weather. A comprehensive watershed management approach also must address flooding issues. The wet weather strategy includes both restoration of physical stream habitat and reduction of discharges from stormwater and combined sewage. These measures are complementary; stream restoration provides areas of lower flow where aquatic life can avoid higher flows, and discharge reduction helps limit velocities and protects the long-term investment in the restored stream. Targets B and C are intended to attend to restoration of physical stream habitat through control measures involving erosion, sediment accumulation, and flow variability.

Regulatory Approaches

- CR1 Requiring Better Site Design in New Development
 - Open Space Preservation Plan
 - Stream Buffer/Corridor Protection Ordinance
 - Wetlands Protection Ordinance
 - Steep Slope Ordinance
 - Cluster Development Ordinance
 - Transfer of Development Rights Ordinance
- CR2 Requiring Better Site Design in Redevelopment (may include options in CR1)
- CR3 Stormwater and Floodplain Management
- CR4 Industrial Stormwater Pollution Prevention
- CR5 Construction Stormwater Pollution Prevention
- CR6 Post-construction Stormwater Runoff Management
- CR7 Pollution Trading
- CR8 Use Review and Attainability Analysis
- CR9 Watershed-Based Permitting

Following is a brief discussion of each of those nine regulatory approaches toward reaching Target C, as outlined above.

CR1&2 – Requiring Better Site Design in New Development and Redevelopment

The regulatory authority for controlling land use is vested in the municipalities through their ability to develop ordinances that regulate zoning and development practices. In areas that are undergoing development pressures, these ordinances are some of the most effective tools for watershed protection. In fully developed, urban watersheds such as the Tookany/Tacony-Frankford Creek Watershed, they are less effective, and are needed primarily to help improve conditions in areas that are re-developing.

A variety of approaches to environmentally responsible land use controls have been developed in recent years, and some are being implemented in the areas adjacent to Philadelphia that are undergoing rapid development. The Delaware Valley Regional Planning Commission (DVRPC) has collected information on these practices and local applications on their web site at <http://www.dvrpc.org/planning/community/protectiontools.htm>.

CR3 – Stormwater and Floodplain Management

Ordinances that deal directly with the way that stormwater is handled and floodplains are

developed or re-developed are important in both developing and developed areas. Municipal ordinances for stormwater and floodplain management should be consistent with the “Comprehensive Stormwater Management Policy” (Document 392-0300-002) released by PA DEP in September 2002. This policy is intended “to more fully integrate post-construction stormwater planning requirements, emphasizing the use of ground water infiltration and volume and rate control best management practices (BMPs), into the existing NPDES permitting programs and the Stormwater Management Act (‘Act 167’) Planning Program.” The comprehensive policy is available on PA DEP’s web site at <http://www.dep.state.pa.us/dep/deputate/watermgmt/wc/Subjects/StormwaterManagement/GeneralInformation/default.htm>.

In late 2004, the municipalities of the Tookany/Tacony Frankford Watershed embarked on the process of developing an Act 167 plan. This will include developing and adopting a model ordinance intended to satisfy the requirements of both the Act 167 and NPDES Phase II programs. This model ordinance may be based on a recently completed model ordinance developed for the Darby-Cobbs Watershed, adapted to meet the needs of the TTF Watershed.

CR4 – Industrial Stormwater Pollution Prevention

Industrial stormwater pollution prevention includes attention to the following measures:

- Good Housekeeping
- Preventive Maintenance
- Visual Inspections
- Spill Prevention and Response
- Employee Training
- Record Keeping and Reporting
- Fueling
- Maintaining Vehicles and Equipment
- Painting Vehicles and Equipment
- Washing Vehicles and Equipment
- Loading and Unloading Materials
- Liquid Storage in Above-Ground Tanks
- Industrial Waste Management and Outside Manufacturing
- Outside Storage of Raw Materials, By-Products, or Finished Products
- Salt Storage
- Flow Diversion
- Exposure Minimization Structures (dikes, drains, etc.)
- Erosion Prevention and Sediment Control
- Infiltration Practices

Detailed guidance on these industrial measures is available in EPA publication 832-R-92-006, “Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices”, released in September 1992. Municipalities may choose to adopt more stringent controls at the local level, or may work with state authorities to enforce the existing requirements. These measures are also appropriate for commercial and government operations involved in similar activities. The publication mentioned above is available online at <http://nepis.epa.gov/pubtitleOW.htm>.

CR5 – Construction Stormwater Pollution Prevention

Stormwater pollution prevention during construction activities includes attention to the following measures:

- Sediment and Erosion Control Practices
- Good Housekeeping
- Waste Disposal
- Minimizing Offsite Vehicle Tracking of Sediments
- Sanitary/Septic Disposal
- Material Management
- Spill Response
- Control of Allowable Non-Stormwater Discharges
- Maintenance and Inspection
- Stormwater Management

Detailed guidance on these measures is available in PA DEP publication 363-2134-008, “Erosion and Sediment Pollution Control Program Manual,” released in April 2000. Municipalities may choose to adopt more stringent controls at the local level, or may work with state authorities to enforce the existing requirements. These measures are also appropriate for commercial and government operations involved in similar activities. The publication is available online at <http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralInformation/default.htm>.

CR6 – Post-construction Stormwater Runoff Management

Post-construction Stormwater Runoff Management is part of the NPDES Phase 2 stormwater management plan. (Options CR3 and CR6 have substantial overlap.)

CR7 – Pollution Trading

U.S. EPA is exploring market-based measures as a way of reaching targeted overall pollutant load reductions in a watershed. EPA’s “Final Water Quality Trading Policy,” released in January 2003, may be accessed at <http://www.epa.gov/owow/watershed/trading/tradingpolicy.html>. As this policy is adopted by the states and incorporated in regulations, it may increase incentives for cooperation and coordination between the municipalities and counties that share a watershed.

CR8 – Use Review and Attainability Analysis

U.S. EPA provides procedures for reviewing the applicability and attainability of designated uses. This process may be appropriate for urban watersheds like the Tookany/Tacony-Frankford. EPA document 833-R-01-002, “Coordinating CSO Long-Term Planning with Water Quality Standards Reviews,” provides a framework for the process in areas served by combined sewers. The document is available at <http://cfpub.epa.gov/npdes/cso/guidedocs.cfm>.

CR9 – Watershed-Based Permitting

A holistic watershed management approach provides a framework for addressing all stressors within a hydrologically defined drainage basin instead of viewing individual sources in isolation. Within a broader watershed management system, the watershed-based permitting approach is a tool that can assist with implementation activities. The utility of this tool relies

heavily on a detailed, integrated, and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals. The policy statement and implementation guidance, “Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Implementation Guidance,” finalized in 2004, are available at <http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm>.

Public Education and Volunteer Programs

CP1 Public Education and Volunteer Programs

Municipal Measures

- CM1 Sanitary Sewer Overflow Detection
- CM2 Sanitary Sewer Overflow Elimination: Structural Measures
- CM3 Reduction of Stormwater Inflow and Infiltration to Sanitary Sewers
- CM4 Combined Sewer Overflow (CSO) Control Program
 - Nine Minimum Controls
 - Long Term CSO Control Plan
 - Watershed-Based Planning
- CM5 Catch Basin and Storm Inlet Maintenance
- CM6 Street Sweeping
- CM7 Responsible Landscaping Practices on Public Lands
- CM8 Household Hazardous Waste Collection
- CM9 Responsible Bridge and Roadway Maintenance

The first three measures above apply primarily to municipalities with separate sanitary sewer systems. The second measure, eliminating sanitary sewer overflow, is believed to be of critical importance in the Tookany/Tacony-Frankford Watershed. Inspection, cleaning, and when necessary, rehabilitation of aging sanitary sewers may be the single most important pollution reduction measure, and should be implemented immediately in this watershed. Reduction of pollutant loads due to stormwater may be of secondary importance if significant loads are being introduced by sanitary sewage.

Structural Stormwater Management Facilities

Detailed information on structural BMPs for stormwater management is available in various existing BMP manuals:

- PA DEP’s Comprehensive Stormwater Management Policy (see links in Appendix A):
<http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralInformation/default.htm>
- City of Philadelphia Stormwater BMP Manual: <http://www.phillyriverinfo.org>
- Center for Watershed Protection Stormwater Manager’s Resource Center:
<http://www.stormwatercenter.net/>
- Maryland Stormwater Design Manual:
http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp
- New Jersey: Best Management Practices for Control of Nonpoint Source Pollution:
<http://www.state.nj.us/dep/watershedmgt/bmpmanual.htm>

Stormwater Management**Source Control Measures**

- CS1 Reducing Effective Impervious Cover Through Better Site Design
- CS2 Porous Pavement and Subsurface Storage
- CS3 Green Rooftops
- CS4 Capturing Roof Runoff in Rain Barrels or Cisterns
- CS5 Increasing Urban Tree Canopy

The first option above, reducing effective impervious cover, refers to a variety of measures, including encouraging homeowners to reduce the size of paved areas on their properties. Use of porous pavement is an alternative to reduction of paved areas. Rooftops represent a large proportion of the impervious area in highly urbanized watersheds such as the Tookany/Tacony-Frankford; constructing rooftop gardens over public and private buildings can be an effective structural measure to reduce urban runoff. Though this technology is catching on slowly in the United States, there are some examples in Southeastern Pennsylvania to look to as models.

The Tookany/Tacony-Frankford Partnership implemented a rain barrel pilot program. Rain barrels are inexpensive but need to be implemented throughout a watershed and drained between storms to be effective as a runoff reduction measure. It is also important that their owners are properly trained and committed to operate and maintain them. Cisterns are similar to rain barrels in function; they also must be drained on a regular basis to provide effective stormwater control.

Tree planting and urban reforestation programs provide hydrologic benefits in addition to quality of life improvements. Leaf surfaces intercept some rainfall that might otherwise fall on impervious surfaces. The rainfall then either evaporates or is conveyed more slowly to the ground along plant stems and trunks. Trees located over or near impervious cover provide the greatest stormwater control benefits.

Municipalities have the opportunity to provide incentives for private landowners to implement these innovative measures through ordinances, tax incentives, or a stormwater fee linked to impervious cover.

Stormwater Management**Onsite and Regional Stormwater Control Facilities**

- CS6 Maintaining/Retrofitting Existing Stormwater Structures
- CS7 Modifying Catch Basins to Delay Stormwater Inflow
- CS8 Retrofitting Existing Sewer Inlets with Dry Wells
- CS9 Residential Dry Wells, Seepage Trenches, and Rain Gardens
- CS10 Infiltration Basins
- CS11 Vegetated Swales and Open Channels
- CS12 Bioretention Basins and Porous Media Filtration
- CS13 Treatment Wetlands: Onsite and Regional
- CS14 Dry Detention Basins
- CS15 Wet Retention Basins
- CS16 BMPs for Highway Runoff (may include various structural options in this list)

The options listed above (CS6-16) are documented in the state manuals. Most of them may be implemented on the small scale of an individual property. Residential dry wells are an inexpensive way to infiltrate residential roof runoff and provide a benefit distributed over the watershed. Infiltration basins are similar but typically used on a larger scale requiring more land. Porous media filters and bioretention basins are most often used to detain, treat, and infiltrate parking lot runoff. Rain gardens are similar to bioretention and can be implemented in backyards or public land such as school grounds. Proper design and maintenance, along with an effective public relations campaign, can alleviate typical concerns about mosquito control and basement flooding.

Retrofit of existing sewer inlets with dry wells is an innovative option that, while expensive, may be attractive in a completely urbanized area with very little land available for traditional BMPs. Using this technology, existing catch basins are retrofitted to provide some measure of storage and infiltration. With full implementation and favorable soil conditions, the resulting outflows may resemble the pre-development condition. The City of Portland, Oregon, has implemented this approach and has provided some documentation in its Stormwater Management Manual (<http://www.portlandonline.com/bes/index.cfm?c=35117>).

Dry detention and wet retention basins are traditional BMPs that typically provide detention and treatment functions but only limited infiltration. Their design is extensively documented in the state manuals. Constructed wetlands, either onsite or regional, provide even greater detention and treatment functions; in addition, they may provide a cooling function and removal of some stormwater through evapotranspiration.

Monitoring, Reporting, and Further Study (CMR)

Monitoring and reporting under Target C includes monitoring of progress toward achievement of objectives (as measured by indicators introduced in Section 4) and monitoring of implementation of recommended management measures. For example, Indicator 7 measures the percent of water quality samples where the state fecal coliform standard is met. This indicator is a measure of progress toward the goal of improved water quality in wet weather. Water Quality Concerns such as metals, TSS (total suspended solids), fecal coliform, and DO (dissolved oxygen) require further study to pinpoint sources. However, the problem can still be addressed (as most of the Target C options intend to do).

7.2 Screening of Options

The extensive lists of management options described above were developed to meet each of the goals and objectives established for the Tookany/Tacony-Frankford Watershed. Only those options deemed feasible and practical, however, were considered in the final list of management options. Options were evaluated in three steps:

- 1) Identification of Clearly Applicable Options (Section 7.2.1).** Some options were already being implemented or were mandated by a regulatory program. For some options, the planning team reached an early consensus that they were needed. These options did not require further evaluation.
- 2) Screening Based on Watershed Characterization (Section 7.2.2).** The extensive data analyses undertaken to characterize the watershed are summarized in Section 4 (Watershed Indicators: TTF Study Results), Section 5 (Problem Definition and Analysis), and Section 6 (Causes of Impairment). The results were used to evaluate the remaining options.
- 3) Detailed Evaluation of Structural Options (Section 7.2.3).** Structural best management practices (BMPs) for stormwater and combined sewage were subjected to a more rigorous modeling analysis. Effects on runoff volume, overflow volume, and pollutant loads were evaluated at various levels of coverage. That analysis is described in Section 7.3.

The table below lists the options chosen for each of those three evaluation steps.

Table 7.1 Options Chosen for Initial Screening and Detailed Evaluation

Option	Clearly Applicable	Screening	Detailed Model Evaluation
Target A	X*		
Target B	X		
Target C – Regulatory Approaches			
CR1 Requiring Better Site Design in New Development		X	
CR2 Requiring Better Site Design in Redevelopment	X		
CR3 Stormwater and Floodplain Management	X		
CR4 Industrial Stormwater Pollution Prevention	X		
CR5 Construction Stormwater Pollution Prevention	X		
CR6 Post-Construction Stormwater Runoff Management	X		
CR7 Pollution Trading		X	
CR8 Use Review and Attainability Analysis		X	
CR9 Watershed Based Permitting		X	
Target C – Public Education and Volunteer Programs			
CP1 Public Education and Volunteer Programs	X		
Target C – Municipal Measures			
CM1 Sanitary Sewer Overflow Detection	X		
CM2 Sanitary Sewer Overflow Elimination: Structural Measures	X		

* All Target A options except Option AM7, Household Hazardous Waste Collection, which was eliminated due to results of cost-benefit analysis.

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Table 7.1 Options Chosen for Initial Screening and Detailed Evaluation (continued)

Option	Clearly Applicable	Screening	Detailed Model Evaluation
CM3 Reduction of Stormwater Inflow and Infiltration to Sanitary Sewers	X		
CM4 Combined Sewer Overflow (CSO) Control Program	X*		X**
CM5 Catch Basin and Storm Inlet Maintenance	X		
CM6 Street Sweeping	X		
CM7 Responsible Landscaping Practices on Public Lands	X		
CM8 Household Hazardous Waste Collection	X		
CM9 Responsible Bridge and Roadway Maintenance	X		
Target C – Stormwater Management			
Source Control Measures			
CS1 Reducing Effective Impervious Cover Through Better Site Design			X
CS2 Porous Pavement and Subsurface Storage			X
CS3 Green Rooftops			X
CS4 Capturing Roof Runoff in Rain Barrels or Cisterns			X
CS5 Increasing Urban Tree Canopy	X		
Onsite and Regional Stormwater Control Facilities			
CS6 Maintaining/Retrofitting Existing Stormwater Structures		X	
CS7 Modifying Catch Basins to Delay Stormwater Inflow		X	
CS8 Retrofitting Existing Sewer Inlets With Dry Wells			X
CS9 Residential Dry Wells, Seepage Trenches, and Rain Gardens			X
CS10 Infiltration Basins			X
CS11 Vegetated Swales and Open Channels		X	
CS12 Bioretention Basins and Porous Media Filtration			X
CS13 Treatment Wetlands: Onsite and Regional			X
CS14 Dry Detention Basins		X	
CS15 Wet Retention Basins			X
CS16 BMPs for Highway Runoff		X	
Target C – Monitoring			
CMR Monitoring, Reporting, and Further Study	X		

** CSO program in place; model evaluation conducted to quantify benefits.

7.2.1 Clearly Applicable Options: Targets A, B, and C

Some options were already being implemented or were mandated by a regulatory program before preparation of the integrated plan began. For other options, the planning team reached an early consensus that they were needed. These options did not require further evaluation:

- **Virtually all Target A options.** Measures to reduce litter and improve recreational activities along the stream corridor are a clear priority of stakeholders. Due to deteriorating infrastructure and localized areas of low dissolved oxygen that have been identified in the creek, measures to eliminate dry weather sewage discharges are necessary. (Option AM7, Household Hazardous Waste Collection, was eliminated due to results of cost-benefit analysis.)
- **All Target B options.** The results of watershed characterization and experiences in other urban watersheds indicate that some restructuring of the streams and stream corridors will be required to restore designated uses.
- **Selected Target C options.** Regulatory approaches CR2 through CR6 are being addressed by the Pa. Act 167 planning program already underway in the TTF Watershed. Many of these measures are also required under the NPDES program. Public education and volunteer programs (Option CP1) are a critical component of any approach to integrated watershed management. In addition, most of the municipal measures listed under Target C, including the City of Philadelphia's Long Term CSO Control Program, are already being implemented in the watershed. Recommendations for these programs will be to continue or improve upon existing efforts.

7.2.2 Results of Target C Screening Based on Watershed Characterization

CR1 Requiring Better Site Design in New Development

Result: Not Recommended

Discussion:

Based on the analysis of land use and ownership presented in Section 4 (Indicator 1), the potential for new development in the TTF Watershed is limited. Concepts of low impact development may be applied on larger redevelopment sites (Option CR2), but extensive planning for new development is not necessary.

CR7 Pollution Trading

Result: Not Recommended

Discussion:

The Tookany/Tacony-Frankford Creek is currently listed by the PA DEP as impaired for one or more designated uses, not requiring a TMDL. Without a TMDL in place, the “driver” for initiating pollution trading does not exist. If a TMDL were to be enacted, the EPA’s “Water Quality Trading Assessment Handbook” (EPA 841-B-04-001) could be used to provide an analytical framework to assess the conditions and water quality problems and determine whether water quality trading (WQT) could be effectively used.

CR8 Use Review and Attainability Analysis

CR9 Watershed Based Permitting

Result: Recommended for Further Study

Discussion:

The U.S. Environmental Protection Agency has endorsed these innovative options for improving the water resources environment in practical, sustainable, and cost-effective ways. Taken together, these three options represent a powerful opportunity for regulatory change in the watershed.

CS6 Maintaining/Retrofitting Existing Stormwater Structures

Result: Recommended

Discussion:

PWD performed an inventory of existing privately owned stormwater control basins in 2000. The results found seven confirmed structures within the Philadelphia portion of the watershed. Retrofit of existing basins, including maintenance and modification of outlet structures, can often increase the benefits from an older structure at minimal cost. This option is recommended and will be discussed in detail in the implementation section.

CS7 Modifying Catch Basins to Delay Stormwater Inflow

Result: Not Recommended

Discussion:

This option delays entry of stormwater runoff into street inlets and catch basins,

providing some level of detention while temporarily storing water on roadways. Based on discussions with stakeholders and local officials, this option is unpopular due to public perception. Other forms of detention are preferred.

CS11 *Vegetated Swales and Open Channels*

Result: Not Recommended

Discussion:

Vegetated swales and open channels are an attractive option as an alternative to traditional infrastructure in areas with new development. They are generally not applicable on smaller sites or on redevelopment sites. This option is not recommended except in very limited cases to be determined on a site-by-site basis.

CS14 *Dry Detention Basins*

Result: Not Recommended

Discussion:

Wet retention and infiltration basins are generally recommended over dry detention basins. Wet retention provides more effective water quality treatment in most cases. Dry extended detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and are ineffective at removing soluble pollutants. If a standing pool is not desired, designing for infiltration is recommended. This option is not recommended except in limited cases to be determined on a site-by-site basis.

CS16 *BMPs for Highway Runoff*

Result: Not Recommended

Discussion:

Transportation infrastructure in the watershed is dominated by city streets rather than highways. In most cases, there is not sufficient space available on roadway shoulders for significant storage to be created. In some cases, medians and islands in intersections may be appropriate for infiltration. These cases will be discussed under option CS12, Bioretention Basins and Porous Media Filtration.

7.2.3 Detailed Evaluation of Target C Structural Options

Structural options such as best management practices (BMPs) for stormwater and combined sewage were subjected to a rigorous modeling analysis. Effects on runoff volume, overflow volume, and pollutant loads were evaluated at various levels of coverage. In this way, the BMPs could be assessed for their cost-effectiveness when implemented in the TTF Watershed. BMPs that appear to cost-effectively decrease stormwater flows or combined sewer overflows, or significantly reduce pollutant loading during wet weather, were subjected to a series of model runs. BMPs were simulated at various levels of implementation within the watershed, and the results are represented graphically. For the assumed level of implementation, the results in terms of pollutant reduction and amount of stormwater treated were then combined with planning level cost estimates, and the options were subsequently ranked according to their cost effectiveness.

Figure 7.1 compares the effectiveness of the BMPs at volume removal (through infiltration and/or evapotranspiration) at their maximum feasible implementation levels. Two measures are capable of reducing total discharge to the receiving water (the sum of stormwater runoff and CSO) by more than 12%. Porous pavement with subsurface storage removes the volume primarily through infiltration, while real time control (RTC) reduces combined sewer overflow.

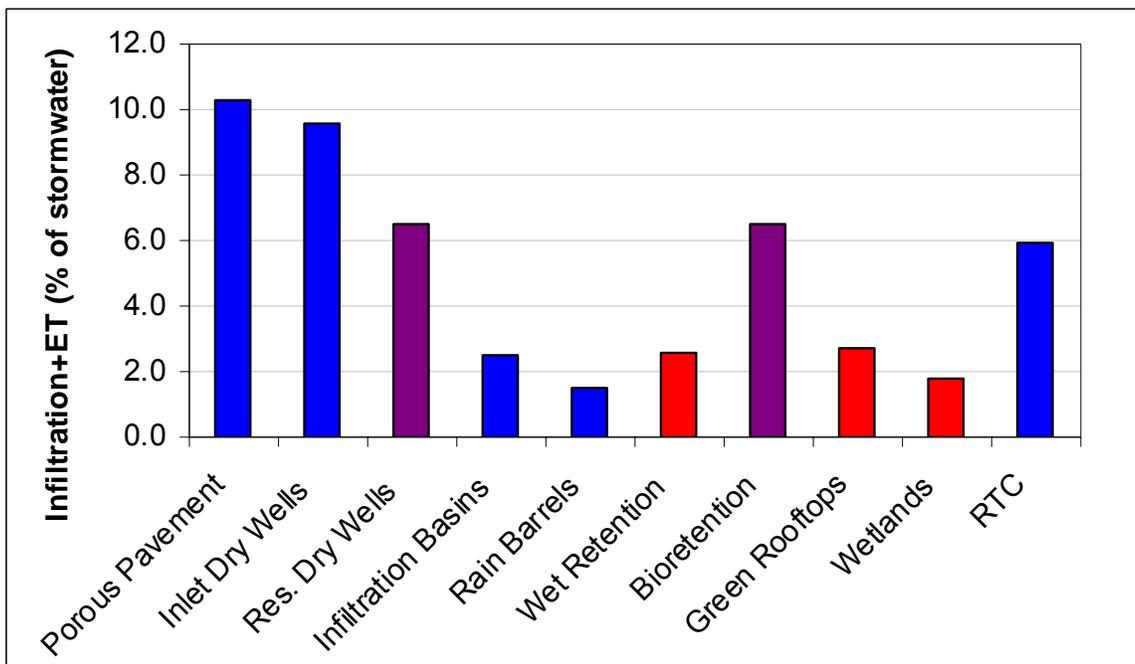


Figure 7.1 Potential Stormwater Volume Removal at Maximum Feasible Coverage

Figure 7.1 represents a range of impervious area draining to BMPs, from existing conditions (46% DCIA, or Directly Connected Impervious Area) to the maximum feasible coverage (varies by BMP). Levels of feasible coverage are chosen to be ambitious but realistic. For example, dry wells may not be technically feasible for all residences due to available space and other site constraints; for planning purposes, the maximum feasible level of coverage for the long term was assumed to be 25% for the TTF Watershed. Table 7.2 ranks the relative ability of each of the

BMPs to store stormwater, treat stormwater, or remove TSS, based on simulations of the maximum feasible level implementation of each of the BMPs. The rankings represent total volume and mass on a watershed basis over the one-year continuous simulation; they are a function of both technical effectiveness and feasible level of coverage. This ranking is independent of cost considerations.

Table 7.2 BMP Performance at Maximum Feasible Coverage

BMP Ranking	Potential Storage	Volume Removed	Load Reduction
Highest	Porous Pavement	Porous Pavement	Porous Pavement
	Wet Retention	Inlet Dry Wells	Res. Dry Wells
	Infiltration Basins	Bioretention	Bioretention
	Bioretention	Res. Dry Wells	Inlet Dry Wells
	Inlet Dry Wells	Real Time Control	Real Time Control
	Res. Dry Wells	Green Rooftops	Wet Retention
	Green Rooftops	Wet Retention	Infiltration Basins
	Wetlands	Infiltration Basins	Green Rooftops
	Rain Barrels	Wetlands	Wetlands
Lowest		Rain Barrels	Rain Barrels

Figure 7.2 shows the amount of storage that could be built in the TTF Watershed given the maximum feasible coverage for each BMP. At the simulated depth of 1 foot, subsurface storage under parking facilities represents approximately 45% of the storage that could feasibly be built. However, rain falling on the parking lot above the storage will not be sufficient to fill the storage. The full storage amount will be active only if additional runoff is directed into it. Infiltration and wet retention basins represent the second largest potential storage volume at approximately 15% of the total. Dry wells intercepting runoff from residential rooftops add 4%.

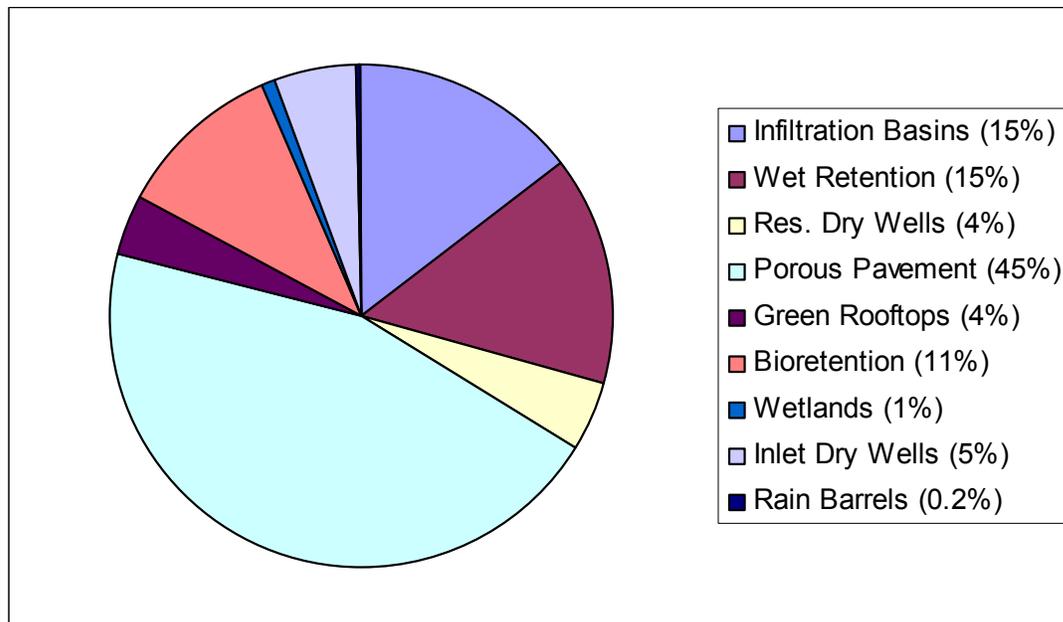


Figure 7.2 Maximum Storage Volume Feasible for Tookany/Tacony-Frankford Watershed

To gain some insight into the cost-effectiveness of various BMPs in the watershed under study, the precise hydraulic modeling results were combined with construction cost estimates. Literature values for costs of some BMPs are available in terms of storage volume. For others, literature values for cost in terms of area or operational unit were combined with model assumptions to obtain approximate costs. Operation and maintenance costs were not included in the current study.

While the hydrologic and hydraulic simulations were performed at a high level of precision, the costs used in this analysis were approximately order-of-magnitude in precision. The purpose of the cost-effectiveness analysis was to identify groups of BMPs that are highly effective, moderately effective, and of limited effectiveness in combined and separate-sewered areas. The values are specific to the climate, development pattern, soil conditions, and sewage systems in the Tookany/Tacony-Frankford Watershed. They are appropriate for long-term planning locally but are not recommended for detailed facilities cost estimating.

Model results were processed to produce relationships between storage volume, discharge reduction, load reduction, and cost. Some BMPs appear to be more efficient at pollutant removal, while others are more efficient at reducing the volume of stormwater reaching the stream; both are objectives of the TTFIWMP. Because the cost-load relationship is approximately linear, it is possible to present the results in the simplified form of approximate cost per gallon of discharge or pound of pollutant eliminated.

Subsurface storage facilities for combined sewage were examined as part of this study, but the cost-discharge and cost-load relationships were found to be nonlinear and could not be presented in the same form as the other results.

The results of the cost-effectiveness analysis are shown in Tables 7.3 and 7.4 (next page). Table 7.3 shows the estimated cost per gallon of stormwater treated and the cost per pound of TSS removed for simulations of feasible levels of implementation for each type of BMP under consideration. The results show that there is a wide range of costs, and that costs differ depending on whether a BMP is implemented in a CSO area or in an area served by separate storm sewers. Table 7.4 shows the list of options, ranked from most cost-effective to least cost-effective, grouped into highly effective, moderately effective, and least effective options.

Table 7.3 Planning-Level Cost-Effectiveness

BMP	WATER QUALITY			WATER QUANTITY		
	TSS Removed			Volume Infiltrated/Evap/Captured		
	Separate (\$/lb)	Combined (\$/lb)	Watershed (\$/lb)	Separate (\$/10 ³ gal)	Combined (\$/10 ³ gal)	Watershed (\$/10 ³ gal)
Wetlands	3.07	1.43	1.80	3.02	1.38	1.75
Wet Retention	19.95	14.39	16.14	27.07	17.78	20.52
Rain Barrels	17.65	3.75	5.41	35.80	2.87	4.47
Inf. Basin	26.21	16.86	19.57	40.29	19.95	24.83
Real Time Control	N/A	5.98	N/A	N/A	4.20	N/A
Residential Dry Wells	19.40	11.47	13.64	44.91	10.38	14.81
Bioretention	42.46	22.09	27.16	60.95	20.86	28.03
Inlet Dry Wells	563.23	37.98	59.60	464.23	26.71	42.17
Green Rooftops	495.50	363.01	405.15	326.32	255.23	278.86
Porous Pavement	146.59	89.75	105.69	97.55	63.60	73.56

The most cost-effective discharge and pollutant reduction strategy is obtained by building the most inexpensive BMP to its maximum feasible level, followed by the next most inexpensive, until wet weather goals are met. Ultimately, other factors (e.g., public vs. private ownership, institutional arrangements for maintenance, degree and length of construction disturbance, feasibility of implementation, socio-political perceptions) must also be considered.

Table 7.4 Cost-Effectiveness of Options (High, Medium, Low)

WATER QUALITY		WATER QUANTITY	
TSS Removed		Volume Infiltrated/Evaporated/Captured	
Separate	Combined	Separate	Combined
Wetlands	Wetlands	Wetlands	Wetlands
Rain Barrels	Rain Barrels	Wet Retention	Rain Barrels
Residential Dry Wells	Real Time Control	Rain Barrels	Real Time Control
Wet Retention	Residential Dry Wells	Inf. Basin	Residential Dry Wells
Inf. Basin	Wet Retention	Residential Dry Wells	Wet Retention
Bioretention	Inf. Basin	Bioretention	Inf. Basin
Porous Pavement	Bioretention	Porous Pavement	Bioretention
Green Rooftops	Inlet Dry Wells	Green Rooftops	Inlet Dry Wells
Inlet Dry Wells	Porous Pavement	Inlet Dry Wells	Porous Pavement
	Green Rooftops		Green Rooftops

The results of the simulations support a number of general conclusions about the implementation of BMPs in the TTF Watershed. (**Note:** These numbered comments are referenced in summary Table 7.7, at end of Section 7.)

1. The cost of runoff volume reduction is higher in separate-sewered than in combined-sewered areas because temporary storage and release results in additional capture at CSO regulator structures. Larger cost differences between CSO and separate storm sewer

areas occur where evapotranspiration and/or infiltration are minor functions of the BMP (e.g., retrofitting sewer inlets with dry wells).

2. Generally speaking, if pollutant removal is significant for a given BMP, the cost difference between separate and CSO areas is smaller. One example is wetlands, due to water column pollutant attenuation.
3. Traditional BMPs like infiltration basins and wet retention basins can be effective where land is available. These facilities typically have much larger capacities, are regional in nature, and exhibit economies of scale. They are not thought to be practical alternatives for the TTF Watershed, but were included in our modeling simulations for completeness.
4. For the combined-sewered areas, real time control (RTC) is among the most competitive options in terms of both volume and load reduction. The RTC configuration being considered is highly specific to the TTF Watershed, and these results may not hold generally for other watersheds.
5. In highly urbanized areas, storage under parking facilities may be the only practical option to achieve large storage volumes. Porous pavement is one way to direct runoff from the parking lots themselves into the storage facility, while runoff from nearby rooftops can be piped into the facility.

The cost analysis of options in areas of separate storm sewers shows:

6. Wetlands and rain barrels are the most cost effective options for TSS removal on a cost per pound basis. Wetlands and wet retention are the most cost effective on a cost per gallon stormwater removed basis.
7. Dry wells in sewer inlets and green rooftops are particularly expensive for both TSS and discharge reduction. Porous pavement is expensive for TSS removal, but is more cost effective as a volume control measure.

The cost analysis of options in areas of combined sewers shows:

8. Wetlands, rain barrels, residential dry wells, and real time control are all relatively cost-effective options on the basis of cost-per-pound of TSS removed and cost-per-gallon of stormwater removed.
9. Green rooftops are the more expensive choice either on the basis of TSS removal or on the basis of dollars per gallon stormwater treated. Dry wells in sewer inlets are only moderately expensive in combined sewer areas (in contrast with separate sewer areas).
10. It is clear that the most expensive options in combined-sewered areas cost less than the most expensive options in separate-sewered areas. Because hydraulic detention is the most important mechanism in combined-sewered areas, there is less difference in cost-effectiveness between the different types of BMPs.
11. In combined areas, the regulator structures represent an investment already made in pollution reduction. Thus, money spent on stormwater BMPs results in greater load and volume reductions per additional dollar spent than in separate areas without stormwater controls. To meet an overall load reduction target in watersheds with both combined and separate areas, it may be more efficient to focus on the combined areas.

Table 7.5 lists ten measures, a feasible implementation level for each, and discharge and pollutant load reductions that are possible with each. These results may be used as a guide for individual municipalities or a watershed organization to select suitable BMPs.

Table 7.5 Maximum Feasible Discharge and Pollutant Reduction

Target C	Maximum Feasible Implementation	Volume Reduction		Pollutant Reduction	
		CSO	Stormwater		
Municipal Measures					
CM4 Combined Sewer Overflow (CSO) Control Program					
	• Real Time Control	2 sites	5.9%	N/A	6.1%
Structural Stormwater Management Facilities					
Source Control Measures					
	CS1 Reducing Impervious Cover Through Better Site Design	1% reduction in DCIA	0.5%	0.5%	1.0%
	CS2 Porous Pavement and Subsurface Storage	50% of parking lots	8.0%	3.3%	11.6%
	CS3 Green Rooftops	5% of rooftops	1.8%	0.9%	2.7%
	CS4 Capturing Roof Runoff in Rain Barrels or Cisterns	10% of homes	1.4%	0.1%	1.8%
	CS5 Increasing Urban Tree Canopy	5% of watershed area	0.3%	0.3%	0.5%
Onsite and Regional Stormwater Control Facilities					
	CS8 Retrofitting Existing Sewer Inlets with Dry Wells	100% of inlets	6.9%	0.3%	7.5%
	CS9 Residential Dry Wells, Seepage Trenches, Rain Gardens	school grounds; 25% of homes	5.7%	0.8%	10.4%
	CS12 Bioretention Basins and Porous Media Filtration	50% of parking lots	6.3%	2.1%	11.6%
	CS13 Treatment Wetlands: Onsite and Regional	100% of identified potential	1.4%	0.4%	2.5%

Notes:

- 1) Volume reductions are % of total discharge (sum of CSO and stormwater).
- 2) “Maximum Feasible” considers technical feasibility and social acceptance, but not cost.

In spite of its cost, subsurface storage under parking lots is recommended because it is one of the few practical options in the most urban areas. Green rooftops are not recommended as a short-term management strategy due to the high cost and practical constraints they currently impose on private land owners. However, they may become more cost-effective in the future due to economies of scale and increased local availability of materials and expertise. For these reasons, the watershed planning team has recommended that local government implement demonstration projects on public buildings and consider incentives for private land owners. In the near term, the benefit of these projects will be primarily educational rather than technical.

While effectiveness and cost may be the two most important criteria used to assess and choose BMPs, feasibility and sociopolitical factors ultimately play a role. These factors were evaluated using a simpler method. Table 7.6 assigns a rating to assess the effect of each factor on the BMPs studied; the significance of the possible ratings is explained below.

Table 7.6 Evaluation Criteria Applied to Individual BMPs

	Technical Feasibility	Time to Implement	Legal Feasibility	Social/Political Support	Construction Disturbance	Maintenance
Real Time Control	●	●	●	●	●	●
Structural CSO Storage	●	◐	●	◐	○	○
Constructed Wetlands	●	●	○	◐	◐	◐
Rain Barrels	◐	◐	○	●	●	○
Residential Dry Wells	◐	◐	○	○	●	●
Bioretention/Porous Media Filter Systems	●	○	○	●	◐	◐
Green Rooftops	○	○	○	◐	○	○
Porous Pavement	◐	○	○	●	○	◐
Dry Wells in Sewer Inlets	◐	○	○	●	○	●

Legend

Excellent	●
Good/Fair	◐
Poor	○

Technical Feasibility

- Excellent ● The technology has been widely and successfully applied. Several local contractors will have experience with the technology.
- Good/Fair ◐ The technology has been successfully applied in other cities or has been successfully demonstrated locally. At least one local contractor will have experience with the technology.
- Poor ○ The technology has been applied in only a few pilot or demonstration programs. It may be impossible to find an experienced local contractor.

Length of Time to Implement

- Excellent ● The technology can be implemented in 2 years or less.
- Good/Fair ◐ The technology can be implemented in 2 to 5 years.
- Poor ○ The technology takes more than 5 years to implement.

Feasibility within the Legal Structure

- Excellent ● Existing laws require or provide an incentive for implementation. For example, measures proposed may overlap with the “six minimum controls” required by NPDES Phase II regulations.
- Poor ○ Existing laws do not affect or do provide disincentives for different aspects of the plan. For example, a local ordinance may discourage infiltration.

Social/Political Support

- Excellent ● Overall, the measure proposed will be seen as positive by a majority of stakeholders (citizens, local governments, and non-profits).
- Good/Fair ◐ The measure has both positive and negative aspects.
- Poor ○ Overall, the measure proposed will be seen as negative by a majority of stakeholders (citizens, local governments, and non-profits).

Construction Disturbance

- Excellent ● Pavement removal is not required or is minimal. Effects on parking, traffic patterns, and noise are minimal. Rain barrels are one example.
- Good/Fair ◐ Some pavement removal is required. Effects on parking, traffic patterns, and noise are moderate.
- Poor ○ Construction will require removal of large amounts of pavement (streets, parking lots) and/or significantly affect parking, movement of people and vehicles, and the noise level. Examples include porous pavement and installation of dry wells in sewer inlets.

Maintenance – Cost and Institutional Considerations

- Excellent ● Maintenance can be performed through existing programs and existing funding. For example, maintenance of retrofit sewer inlets can be integrated into current sewer maintenance.
- Good/Fair ◐ Private land owners will be responsible for minor maintenance chores (e.g., minor landscape maintenance for a bioretention basin that would have been a parking island anyway). Public agencies can handle maintenance with existing staff and budget, and/or will dedicate staff time to outreach, workshops, etc.
- Poor ○ Existing public programs, staff, and funding will not cover maintenance, or maintenance will be a large burden on private land owners. Or, frequent maintenance is absolutely critical to BMP effectiveness, as with rain barrels.

7.3 Recommended Options

At the end of this section, Table 7.7 summarizes options recommended for full implementation, options recommended for conditional implementation, and options that are not recommended. Those recommended for conditional implementation include most of the structural stormwater and combined sewage management measures. (Note: Each “Conditional” recommendation in Table 7.7 is accompanied by a numbered reference to one or more of the various conclusions presented in Section 7.2.3, below Table 7.4.)

Target A: Options for Dry Weather Water Quality and Aesthetics

For the Tookany/Tacony-Frankford Creek, the focus of Target A is trash removal, litter prevention, and elimination of sources of sewage during dry weather. Because the options under consideration are aimed at the total elimination of trash and dry weather sources of sewage, no complex analysis was required to help define the program or assess its potential benefits. Virtually all options related to this target are recommended for implementation.

Streams should be aesthetically appealing (i.e., look and smell good), accessible to the public, and an amenity to the community. Access to and interaction with the stream during dry weather have the highest priority, because dry weather flows occur about 60-65% of the time during the course of a year, and is also the time 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 be similar to background concentrations in groundwater. Many urban streams rarely meet water quality standards for bacteria, and urban streams often have significant BOD (biological or biochemical oxygen demand) problems, even during baseflow or dry weather conditions.

Target B: Options for Healthy Living Resources

Improving the ability of an urban stream to support viable habitat and fish populations focuses primarily on the elimination of the more obvious impacts of urbanization on the stream. These include loss of riparian habitat, eroding and undercut banks, scoured streambeds or excessive silt deposits, channelized and armored stream sections, trash buildup, and invasive species. The primary tool to accomplish this is stream and stream corridor restoration. Restoration focuses on improving channel stability, improving instream and riparian habitat, providing refuges for fish from high velocity conditions during storms, and managing land within the stream corridor. Because designated uses in the stream cannot be restored without these options, all options grouped under Target B are recommended for implementation.

Target C: Options for Wet Weather Water Quality and Quantity

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. Stormwater generally does not have DO (dissolved oxygen) problems, but sampling data indicate that concentrations of metals (such as copper, lead, and zinc) and bacteria do not meet water quality standards during wet weather. These pollutants are introduced by both stormwater and wet weather sewer overflows (CSOs and SSOs).

Target C options also must address flooding issues. Where water quality and quantity problems both exist, options must 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 will also help protect the investment in stream restoration made as part of the implementation of Target B options.

Options recommended for Target C are divided into two groups, as shown in Table 7.7 below. The first group includes options recommended for *full* implementation. These options include a range of ordinances and regulatory measures and public education measures related to existing municipal infrastructure, selected source controls, and possibilities for pollution trading and use review. The municipal measures focus on the elimination of sanitary sewer overflows and the causes of overflows such as blockages and excessive infiltration.

The second group of Target C options includes structural measures designed to achieve specific, measurable discharge and pollutant load reductions. These options are recommended on a *conditional* basis, based on conclusions of screening and modeling studies. (As noted above, each of the “Conditional” recommendations is linked to one or more of the numbered conclusions listed in Section 7.2.3.)

Table 7.7 Summary of Recommended Options

Option	Recommended	Not Recommended	Conditional
Target A	X*		
Target B	X		
Target C – Regulatory Approaches			
CR1 Requiring Better Site Design in New Development		X	
CR2 Requiring Better Site Design in Redevelopment	X		
CR3 Stormwater and Floodplain Management	X		
CR4 Industrial Stormwater Pollution Prevention	X		
CR5 Construction Stormwater Pollution Prevention	X		
CR6 Post-Construction Stormwater Runoff Management	X		
CR7 Pollution Trading		X	
CR8 Use Review and Attainability Analysis	X		
CR9 Watershed Based Permitting	X		
Target C – Public Education and Volunteer Programs			
CP1 Public Education and Volunteer Programs	X		
Target C – Municipal Measures			
CM1 Sanitary Sewer Overflow Detection	X		
CM2 Sanitary Sewer Overflow Elimination: Structural Measures	X		
CM3 Reduction of Stormwater Inflow / Infiltration to Sanitary Sewers	X		
CM4 Combined Sewer Overflow (CSO) Control Program	X		
CM5 Catch Basin and Storm Inlet Maintenance	X		
CM6 Street Sweeping	X		
CM7 Responsible Landscaping Practices on Public Lands	X		
CM8 Household Hazardous Waste Collection	X		
CM9 Responsible Bridge and Roadway Maintenance	X		
Target C – Monitoring			
CMR Monitoring, Reporting, and Further Study	X		

* All Target A options except Option AM7, Household Hazardous Waste Collection, which was eliminated due to results of cost-benefit analysis.

(Continued on next page)

Table 7.7 Summary of Recommended Options (continued)

Option	Recommended	Not Recommended	Conditional*
Target C – Stormwater Management			
Source Control Measures			
CS1 Reducing Effective Impervious Cover Through Better Site Design	X		
CS2 Porous Pavement and Subsurface Storage			urban areas (5,7)
CS3 Green Rooftops			demonstration projects (7,9)
CS4 Capturing Roof Runoff in Rain Barrels or Cisterns			public relations campaign required (6,8)
CS5 Increasing Urban Tree Canopy	X		
Onsite and Regional Stormwater Control Facilities			
CS6 Maintaining/Retrofitting Existing Stormwater Structures	X		
CS7 Modifying Catch Basins to Delay Stormwater Inflow		X	
CS8 Retrofitting Existing Sewer Inlets With Dry Wells			CSO areas (1,7,9)
CS9 Residential Dry Wells, Seepage Trenches, and Rain Gardens			inexpensive in combined areas (8)
CS10 Infiltration Basins		X**	
CS11 Vegetated Swales and Open Channels		X	
CS12 Bioretention Basins and Porous Media Filtration			inexpensive in combined areas (7)
CS13 Treatment Wetlands: Onsite and Regional			site permitting (2,6,8)
CS14 Dry Detention Basins		X	
CS15 Wet Retention Basins		X**	
CS16 BMPs for Highway Runoff		X	

* **Note:** The parenthetical numbers under the “Conditional” column refer to the numbered conclusions of the BMP simulations, as listed in Section 7.2.3.

** Under the current conditions of the TTF Watershed, these measures are not recommended; however, in the event of large-scale redevelopment within the watershed, these BMPs could be considered.