Putnam County MS4 Coordinating Committee

P.O. Box 570 • 1142 Route 311 • Patterson NY 12563

Stormwater Improvement Study Final Report

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Report Prepared By:

Malcolm Pirnie, Inc.

104 Corporate Park Drive
White Plains NY 10602
914-694-2100

6542001

MALCOLM PIRNIE

We would like to extend a special thanks to Mr. Richard Williams, PCMS4CC Chairperson, Town of Patterson, for his assistance, guidance, and support during the course of this Study.

We would like to thank the members of the PCMS4CC for their direction, guidance, and review comments throughout this process. The PCMS4CC consists of the following individuals:

1. Mr. Bruce Barber, Cornerstone Associates, Town of Kent
2. Mr. John Karell, Town of Carmel Engineer
3. Mr. Graham Trelstad, AKRF Inc., Town of Southeast
4. Mr. Richard Williams, Town of Patterson
5. Mr. Gary Wulfhop, Town of Putnam Valley Asst. Highway Superintendent
6. Mr. Edward Barnett, Putnam County
7. Mr. Jeff Contelmo, Insite Engineering, Putnam County, Town of Carmel, Brewster CSD
8. Ms. Lauri Taylor, Putnam County

The information used to develop this Study was collected directly from each municipality with the purpose of determining conditions for the stormwater study. The following individuals provided the data to support the development of this report:

1. Mr. Todd Atkinson, J. Robert Folchetti and Associates
2. Mr. Anthony Caravetta, Town of Kent Highway Superintendent
3. Mrs. Katherine Doherty, Town of Kent Supervisor
4. Mr. Tom Fenton, Nathan L. Jacobson & Associates
5. Mr. Kevin Palmer, Town of Southeast Highway Superintendent
6. Mr. Michael Simone, Town of Carmel Highway Superintendent

Additional data collected by the New York City Department of Environmental Protection (NYCDEP) was also utilized during the course of this study. For permission to utilize the aforementioned data, we would like to thank Mr. Matthew Giannetta of the NYCDEP.

We would also like to thank Mr. Robert Capowski of the NYSDEC and Mr. Michael Meyer of the NYCDEP for their assistance with the project.

The following meetings and presentations were instrumental in the organization and development of this report:

1. April 27, 2009. At the PCMS4 kickoff meeting we covered the following items with the PCMS4CC members: identified roles and responsibilities; exchanged contact information; reviewed and confirmed the project objective; and discussed data needs and sharing via an FTP Site.

2. June 9, 2009. At this PCMS4CC meeting we covered the following items: reviewed the database design; summarized data collection; summarized staff interviews; provided a review of the Inventory Database; described the Preliminary Retrofit Inventory; discussed the Phase 1 Ranking and 20% draft; and discussed plans for field investigations.

3. August 11, 2009. At this PCMS4CC meeting we covered the following items: reviewed the results of Phase 1 Ranking (determination of Tier 1 and Tier 2 sites); discussed the site visits; and reviewed two typical phosphorus retrofit designs.

4. October 13, 2009. At this PCMS4CC meeting we covered the following items: reviewed the Phase 2 Ranking; discussed the 60% report; reviewed several site drawings; discussed cost estimates for site drawings; and discussed the P-load assessment strategy and the associated NYSDEC memorandum.

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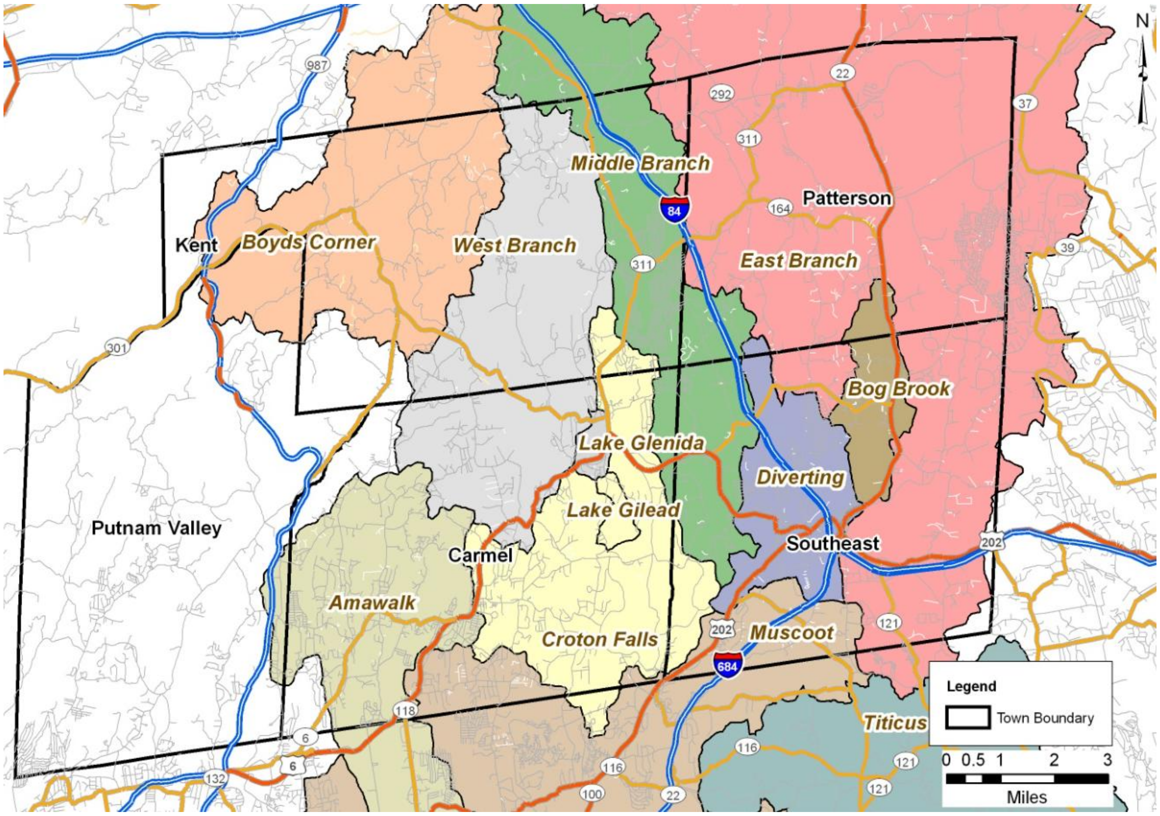
1. Introduction

1.1. Project Background and Document Summary

The Putnam County MS4 Coordinating Committee (PCMS4CC) on behalf of five of the East of Hudson Watershed Towns in Putnam County, is seeking to prepare a capital improvement program (CIP) to address stormwater management for the participating communities. The CIP will provide for stormwater retrofit improvements and other management practices to address phosphorus loads affecting water quality in the designated Towns located in the New York City East of Hudson (EOH) watershed. These phosphorus loads have been identified in the Total Maximum Daily Loads (TMDLs) for Reservoirs in the New York City Water Supply Watershed Report prepared by the New York State Department of Environmental Conservation (NYSDEC). The capital improvement program is intended to support the participating municipality's compliance with the State Pollution Discharge Elimination System (SPDES) General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s) (NYCDEC, 2008), and the TMDL. A copy of the SPDES General Permit for MS4s as well as all other regulatory drivers that relate to the following study are located in Appendix A.

The intent of this Stormwater Improvement Study (Study) is to identify costs and develop preliminary designs for other water quality improvement features which could potentially be installed (retro-fit) within the Study Area, Figure 1-1. These features would serve not only to improve the quality of the local lakes and streams, but would aid in the protection and improvement of the quality of water in the Croton Reservoir system by reducing the pollutant of concern (phosphorus), as identified in Technical Background For Retrofitting Practices EOH MS4 Heightened Criteria (NYSDECb, 2009) and in the Croton Watershed Phase II Phosphorus TMDL Implementation Plan (NYSDECa, 2009), copies of which are located in Appendix A.

Figure 1-1: PCMS4CC Stormwater Retrofit Study Area



The Study was divided into five tasks as follows:

1. Task 1 involved collecting all available stormwater infrastructure data and creating a Study Area wide database for use in the assessment. The infrastructure inventory is detailed in Section 2 of this report. Town employees were also contacted in order to acquire local knowledge of phosphorus and erosion problem areas in the Study Area for possible inclusion in the Study. GIS data including land use, aerial photos and parcel ownership layers were also collected for use in the Study.

2. Utilizing the data collected during Task 1, forty sites across the Study Area were identified then ranked at a screening level based on site and drainage area characteristics as part of Task 2. The selection of the 40 potential retrofit locations is detailed in Section 3 of this report. This ranking, described as the Phase 1 ranking, helped determine which 20 of the 40 proposed sites were best suited for field investigations and additional feasibility evaluations (Tier 1 sites) and are detailed in Section 4 of this report.

3. Field investigations were conducted in July 2009 at the Tier 1 sites as part of Task 3 of the Study and the findings are included in Section 5 of this report. It should be noted that during the field investigations at the Tier 1 sites, several changes were made to the list of potential sites based on conditions observed in the field; these changes are also described in Section 5 of this report.

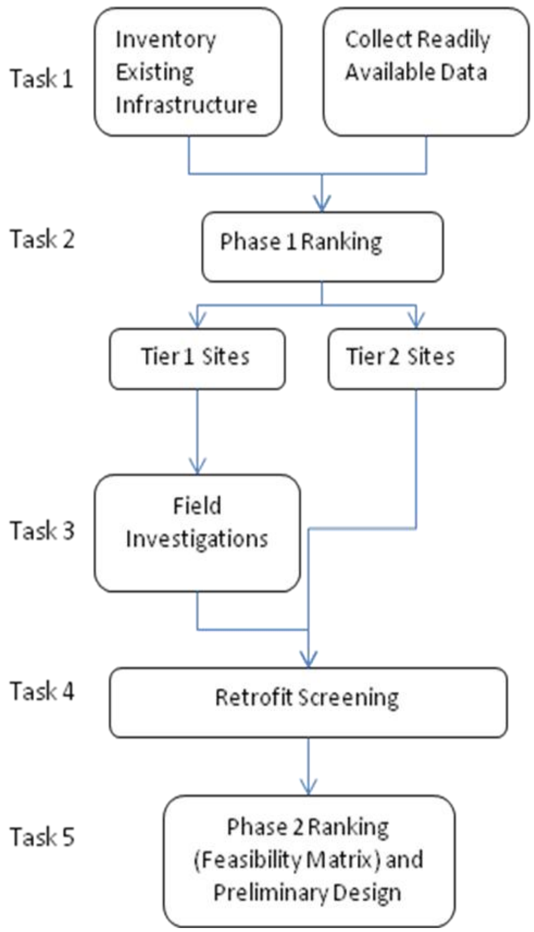
4. As part of Task 4, draft conceptual designs and associated total phosphorus (TP) load removals were developed for each of the potential retrofit locations in the Study. The draft conceptual designs are detailed in Section 6 of this report while the calculations of the total phosphorus load removal associated with each of the proposed retrofits are detailed in Section 7. Task 4 also included the calculation of the estimated costs associated with the proposed retrofits detailed in Section 8 of this report. The cost estimates are provided for each of the identified potential retrofit sites, based on the selected retrofit type at each location. The cost estimates include estimates of capital costs, as well as operations and maintenance costs.

5. Task 5 involved the development of a feasibility matrix for each of the proposed stormwater retrofits, allowing the PCMS4CC to be able to determine which retrofits were the most feasible. Factors included in the feasibility matrix include, but are not limited to: proximity to receiving water and associated water body class, existing TMDL requirements, visual impacts, potential public benefits and potential health and safety impacts of each retrofit. The ranking methodology for the Phase 2 ranking is detailed in Section 9, while the results of the Phase 2 ranking are included in Section 10.

   Section 10 also includes a discussion of the total potential phosphorus removal in the Study Area, estimated based on the potential retrofit sites and how that relates to the phosphorus removal goals, based on NYSDEC guidance. Section 11 of this report includes a list of recommendations for moving the Study forward and meeting the total phosphorus removal requirements in the PCMS4CC Study Area.

Figure 1-2 provides a graphical presentation of the various tasks and how they are connected.

Figure 1-2: Flow Chart of the Procedure used in the PCMS4CC Stormwater Improvement Study



1.2. Phosphorus Removal Goals

The NYSDEC goals for phosphorus removal in the NYCDEP East of Hudson Watershed are summarized in the Croton Watershed Phase II Phosphorus TMDL Implementation Plan (NYSDEC, January 2009a). As part of this plan, the NYSDEC presents minimum thresholds for phosphorus reduction which much be met for a plan to be approvable. The thresholds rely on the relative values of high-density development land use within the EOH watershed and the modeled load associated with high intensity development. Table 1-1 summarizes the modeled high intensity development (HID) load for each of the PCMS4CC towns by subbasin.

Table 1-1:
Modeled HID P-Load by Town and Watershed Basin in kg/yr (lb/yr)

Reservoir	Carmel	Kent	Patterson	Putnam Valley	Southeast
Middle Branch	5 (11)	88 (194)	12 (26)		45 (99)
East Branch		1 (2)	98 (216)		39 (86)
West Branch	30 (66)	36 (79)			
Muscoot	48 (106)				34 (75)
Croton Falls	106 (234)	25 (55)			2 (4)
Amawalk	190 (419)			0 (0)	
Boyds Corners		38 (84)		5 (11)	
Diverting			0 (0)		98 (216)
Bog Brook			1 (2)		3 (7)
Total	379 (836)	188 (415)	111 (245)	5 (11)	221 (487)

Source: Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2.

Table 1-2 summarizes the total modeled load per town along with the phosphorus reduction thresholds in the NYSDEC's Croton Watershed Phase II TMDL Implementation Plan. Based on the analysis in the Croton Watershed Phase II Phosphorus TMDL Implementation Plan (NYSDEC, January 2009a), the towns in the PCMS4CC are required to remove a total of 154.9 kg of TP from the EOH reservoir system over the next five years, starting in 2010. The total TP load reduction required by each town is to be removed in 20% increments over the 5 year period, resulting in a required annual TP load reduction of 31.0 kg/yr.

Table 1-2:
HID P-Loading and Associated Reduction Requirements for Retrofit Program in kg/yr (lb/yr)

	Total Modeled HID Load[1]	Annual Load Reduction[2]	5-Year Load Reduction[2]
Carmel	379 (836)	14.4 (31.8)	72.0 (158.8)
Kent	188 (415)	6.7 (14.8)	33.6 (74.1)
Patterson	111 (245)	3.4 (7.5)	17.2 (37.9)
Putnam Valley	5 (11)	0.2 (0.4)	1.0 (2.2)
Southeast	221 (487)	6.2 (13.7)	31.1 (68.6)
Total	904 (1993)	31.0 (68.3)	154.9 (341.6)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

2. Infrastructure Inventory

2.1. Data Sources

Data on existing infrastructure were provided by each of the towns. As the data for each of the participating municipalities is maintained separately by each town, data formats vary, including shapefiles and geodatabase files. The attributes available for each dataset varied greatly. Table 2-1 summarizes the format and attributes provided by each town.

Table 2-1:
Summary of Source Data

Town	Format	Attributes
Carmel	SDSFIE[1] compliant Geodatabase	Numerous, including: size, material, condition, GPS accuracy, receiving water body or structure, unique feature ID
Kent	Shapefiles[2]	No available attributes
Patterson	Shapefiles (multiple points and lines)	Type, size, remarks, receiving water body, operations and maintenance responsibility
Putnam Valley	GPS locations and descriptions	No electronic data received.
Southeast	Shapefiles (1 point shapefile)	Material, size, type, comments, date, and notes

1 Spatial Data Standards for Facilities, Infrastructure, and the Environment (SDSFIE) is a single Department of Defense standard intended to support use of data in analyses common for military installations, environmental applications, and civil works.

2 Data for the Town of Kent were obtained in draft format from the NYCDEP, with permission from Mr. Matthew Giannetta for use in this study during a phone conversation with Cindy How.

Additional hard copy data were provided to supplement the datasets. The hard copy data consisted primarily of information on recent stormwater retrofits and planned or ongoing retrofits.

Stormwater infrastructure data collected by the NYCDEP was utilized during the course of this assessment as well. This data was used to bolster the existing infrastructure data provided by each of the towns to create a more complete data set for use in the Study.

The source data were used to create a geodatabase representing existing stormwater infrastructure, as described in Section 2.2. Utilizing the above data, a list of recent and proposed retrofits in the PCMS4 Study Area was created. The list of recent and planned retrofit locations, along with GIS and other electronic deliverables is included as an electronic attachment in Appendix B.

2.2. Database Design

The database format selected for the Stormwater Infrastructure Inventory was a geodatabase with layers for key point features: Culvert End, Catch Basin, Stormwater BMP, Manhole, Swale, and Outfall. Line features (swales, pipes) received from the town were assumed for the purposes of this Study to be represented by the outlet point of the system. A summary of the fields included in the database for each layer is provided in Appendix C - Database Design. Table 2-2 summarizes the layers provided by each township and how they were assigned to layers in the database.

Table 2-2:
PCMS4CC Source Data Layers and Inventory Data Layers

TOWNSHIP	SOURCE LAYER	DATABASE LAYER
SOUTHEAST	Cross Culvert Discharge	CULVERT END
SOUTHEAST	Cross Culvert Intake	CULVERT END
SOUTHEAST	Curb Top Basin	CATCH BASIN
SOUTHEAST	Detention Pond	STORM BMP
SOUTHEAST	Discharge	OUTFALL
SOUTHEAST	Flat Top Basin	CATCH BASIN
SOUTHEAST	Intake	CATCH BASIN
SOUTHEAST	Manhole	MANHOLE
SOUTHEAST	Plunge Pool	STORM BMP
SOUTHEAST	Special	STORM BMP (11); MANHOLE (2)
SOUTHEAST	Swale	SWALE
PATTERSON	Catch Basins	CATCH BASIN
PATTERSON	Outfalls	OUTFALL
PATTERSON	Storm Basins	STORM BMP
PUTNAM LAKE	Outfalls	(included in Patterson Outfalls)
Kent	Points	CATCH BASIN
Kent	Points	MANHOLE
Kent	Points	OUTFALL
Kent	Points	SWALE
CARMEL	Discharge Point	OUTFALL
CARMEL	Headwall	OUTFALL
CARMEL	Inlet	CATCH BASIN
CARMEL	Junction	MANHOLE

The database attributes were selected based on the following criteria:

- Fields required to maintain data found in the source files provided by PCMS4CC;
- Fields required to record data that will be required in the selection and analysis of retrofit sites; and
- Fields that may be useful to the PCMS4CC in the future in stormwater infrastructure maintenance.

The database for the Stormwater Infrastructure Inventory was designed to retain as much of the original attribute information as possible. For the Towns of Southeast and Patterson, all attributes in the source data files were maintained inside the resulting database. For data received from the Town of Carmel, the complexity of the SDSFIE dataset exceeded the needs for the current project and a simpler format was selected. Data for the Town of Kent was incorporated from the NYCDEP dataset; this dataset has all infrastructure points in one file with types identified as one of several types. The types and the associated inventory data layer are listed in Table 2-3.

Table 2-3:
Kent Infrastructure Types

Type	Inventory Data Layer
Catch basin	CATCH BASIN
Ditch	CATCH BASIN (3)
Drain	OUTFALL (26)
Manhole	MANHOLE
Inlet	CATCH BASIN
Outlet	OUTFALL

Note that the NYCDEP review of the data indicates that the dataset may have errors related to infrastructure type; field verification of infrastructure type and characteristics is recommended.

3. Potential Stormwater Quality Retrofits

3.1. Methodology for Identifying Retrofit Sites

In order to satisfy the needs and recommendations of the PCMS4CC, potential stormwater quality retrofit locations in the PCMS4CC study area were selected considering multiple factors including:

- Known Problem Areas;
- Retrofit Location;
- Proximity to Waterbodies;
- Drainage Area Size;
- Land Cover; and
- Property Ownership.

Section 3.1.1 summarizes the overall procedure used to determine the sites selected for potential retrofits in the Study Area. Sections 3.1.2 to 3.1.7 provide additional information for each of these factors.

3.1.1. Summary of Procedure for Selecting Potential Retrofit Locations

The overall goal in selecting the proposed retrofit locations for inclusion in the Study was to provide a broad range of retrofit sites in order to provide the most comprehensive analysis possible to the PCMS4CC. To that end, retrofit sites were chosen that incorporated watersheds that varied in both size and land use description. Furthermore, sites were chosen that drained to the various watersheds in the EOH Watershed. The majority of the retrofit locations were sited on lands already owned by the Towns in the PCMS4CC, however, lands were also chosen on private land and land owned by other organizations in order to include an estimate of land acquisitions in the cost estimations as well. Finally, areas where known problems exist in each of the PCMS4CC Towns were included as well. Problems with erosion and potential TP loading (known algal growth, lack of stormwater controls, etc.) were favored over other identified problems, but all identified sites were considered for inclusion in the assessment.

Utilizing the above data, the proposed retrofit site selection was conducted in the following manner.

1. In step one of the site selection process, the known problem areas were identified and placed into the GIS framework developed for the Study. A cross section of

sites across the member towns, of different drainage sizes, land use distributions and water bodies that each drain to were selected. Problem areas on town property were given preference over problem areas located on non-town property.

2. Once the problem areas were identified, step two of the selection process involved the placing of additional retrofit locations on other town owned property in the Study Area, with all efforts made to include the factors in step one of the retrofit location selection.

3. Finally, in step three of the site selection process, the remaining retrofit locations, including the remaining identified problem areas were placed on private land and land owned by other entities in the Study Area.

The above procedure resulted in the selection of 40 potential retrofit locations across the Study Area, that had a range of contributing watershed sizes, a range of land use distributions, a range of property owners and a range of waterbodies that will be impacted by their implementation. This broad range of factors provides for a range of costs, potential removal rates and impacts on a range of waterbodies, giving the PCMS4CC a broad range of the available retrofit sites, allowing for a more informed decision on which sites to pursue for actual retrofit installation.

3.1.2. Known Problem Areas

The most important factor utilized in the selection of the potential retrofit locations was knowledge of problem areas within the PCMS4CC towns. Committee members were asked to provide the locations of problem areas within their community, as well as the types of issues that were known to impact water quality. A specific focus was placed on phosphorus and sediment related issues when including known problem areas in the retrofit analysis. Areas that were identified as having erosion or algal growth issues were favored over other identified problem areas as they were deemed most likely to provide a need and potential for phosphorus removal management practices. Additional considerations were made for locating potential retrofit sites in all of the watersheds that were identified as requiring TP reductions in the TMDL for the EOH watershed.

3.1.3. Retrofit Location

The location of each proposed retrofit site was also considered in the site selection process. In order to adequately represent each town in the PCMS4CC, potential retrofit sites were included throughout each of the member communities. Furthermore, Study sites were selected that drain into different watershed basins in the East of Hudson system, which allowed for the estimation of potential phosphorus reductions in each of these watershed basins.

3.1.4. Proximity to Waterbodies

Proximity to the waterbodies in the East of Hudson system was also considered when choosing potential retrofit locations in the study area. Sites in close proximity were chosen, as well as sites further away from the waterbodies in order to show their impact on phosphorus reduction in the PCMS4CC study area.

3.1.5. Drainage Area Size

The drainage area to each of the proposed retrofit locations was also considered in the site selection process. Locations that served as the outlet for a range of small, medium and large drainage areas were chosen for use in the study to determine the cost range of retrofits for a range of drainage areas.

3.1.6. Land Cover

Land cover was also considered in the site selection process. Sites were placed at the outlets of wooded/open land areas, residential areas and urban/ impervious areas. The inclusion of the different land use types located in the study area allowed for the determination of both the most effective areas in which to place retrofits, as well as an understanding of the expected performance and cost of retrofits in other similar areas in the watershed.

3.1.7. Property Ownership

Finally, ownership of the land in which the potential retrofits were to be placed was also considered in the selection process. The majority of the retrofits were placed on lands owned by the towns. However, to incorporate the impacts of land ownership on retrofit design and placement, several potential retrofit locations were placed on private lands as well as one site on lands owned by New York City. The site selected for inclusion that are located on private lands included known problem areas identified by the members of the PCMS4CC.

3.2. Description of Identified Retrofit Sites

The retrofit sites chosen for inclusion in the Study are shown in Figure 3-1 and are summarized in Table 3-1 and Table 3-2. The sites were selected to encompass all of the watershed basins within the PCMS4CC study area, as well as to represent multiple sites within each municipality. As shown in Figure 3-1, the sites chosen for use in the study are located throughout the 5 towns in the PCMS4CC study area, outlined in black and drain into 8 separate watersheds in the East of Hudson system, which are delineated by color.

Figure 3-1: Potential Stormwater Retrofit Sites in the PCMS4CC Study Area

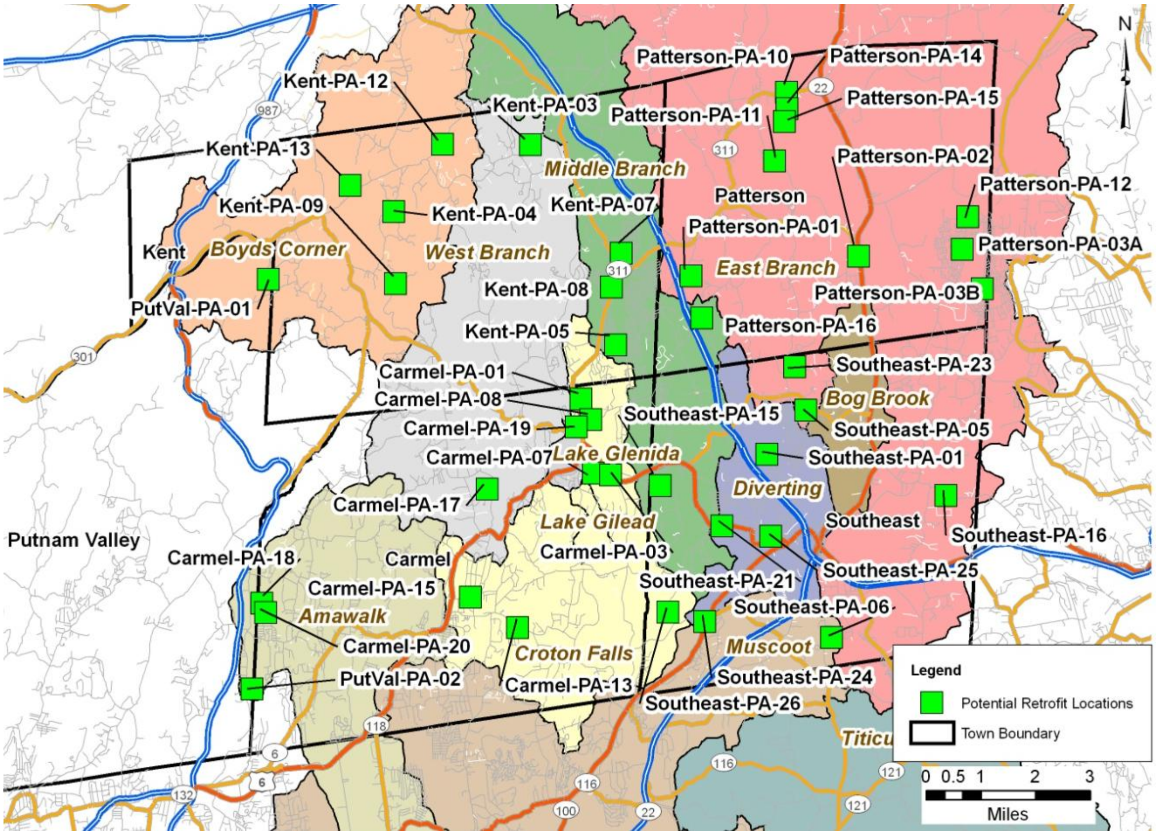


Table 3-1:
Sites Identified for Retrofit Analysis in the PCMS4CC Study Area

Site ID	Address
Carmel-PA-01	160 Rt. 52/ShopRite Site
Carmel-PA-03	Rt. 6 and Stoneleigh Ave./A+P
Carmel-PA-07	75 Seminary Hill Rd./Arms Acres
Carmel-PA-08	30 Fair St./Carmel H.S.
Carmel-PA-13	Piggott Rd. north of Circle Ct.
Carmel-PA-15	Casse Ct.
Carmel-PA-17	NE corner of Ann Rd.
Carmel-PA-18	Intersection of North and Orchard Rd.
Carmel-PA-19	Corner of Ridge Rd. and Fowler Ave.
Carmel-PA-20	Birch Rd., Lake Secor
Kent-PA-03	West of Intersection of Daffodil Ln. and Church Hill Rd.
Kent-PA-04	Intersection of Ponderosa and Nimham
Kent-PA-05	Intersection of S. Lakeshore/Towners
Kent-PA-07	Wooded area between Princeton and Terry Hill
Kent-PA-08	Intersection of Barret Hill and Rt. 52
Kent-PA-09	12 Cole Shears Ct.
Kent-PA-12	500 White Pond Rd.
Kent-PA-13	200 Farmers Mills Rd.
Patterson-PA-01	Commerce Drive
Patterson-PA-02	Jon Barret Rd./Robin Hill Corporate Park
Patterson-PA-03A	Club Court Park
Patterson-PA-03B	475 Lake Shore Drive
Patterson-PA-10	1142 Rt. 311/Town Hall
Patterson-PA-11	302 Cornwall Hill Rd./Highway Department
Patterson-PA-12	426 Havilland Dr./Sacred Heart Church
Patterson-PA-14	Townsend St.
Patterson-PA-15	South Street./Patterson Rec. Center
Patterson-PA-16	Fox Run./Fox Run Condos
PutVal-PA-01	208 Old Forge Road
PutVal-PA-02	Greenway Terrace
Southeast-PA-01	100 Pumphouse Rd.
Southeast-PA-05	Overlook Drive and Nancy Ln.
Southeast-PA-06	Seven Oaks Ln.
Southeast-PA-15	Intersection of Maple Rd. and Ivy Hill Rd.
Southeast-PA-16	120 Federal Hill Rd./Melrose School
Southeast-PA-21	2544 Carmel Avenue/Suburban Propane
Southeast-PA-23	54 Foggingtown Rd./Brewster High School
Southeast-PA-24	Intersection of Rt. 22 and Lower Mine Rd./Diverting Reservoir Spillway
Southeast-PA-25	97 Oak St./Wells Park
Southeast-PA-26	150 Reservoir Rd./Croton Reservoir Culvert

Table 3-2:
Drainage Area Information for Sites Identified for Retrofit Analysis

Site ID	Land Cover	Drainage Area Size (acre)	Ownership
Carmel-PA-01	impervious/parking	50.8	Private
Carmel-PA-03	impervious	20.7	Private
Carmel-PA-07	residential and large grass area	15.8	Public
Carmel-PA-08	mixed, large impervious areas and field areas	12.7	Public
Carmel-PA-13	residential sub-division	2.0	Public
Carmel-PA-15	residential	21.7	Public
Carmel-PA-17	residential	5.9	Public
Carmel-PA-18	municipal	4.1	Private
Carmel-PA-19	residential/commercial	11.8	Public
Carmel-PA-20	high density residential	5.3	Private
Kent-PA-03	residential/wooded	15.3	Private
Kent-PA-04	residential	4.0	Private
Kent-PA-05	high density residential	3.4	Public
Kent-PA-07	woods surrounded by med. density residential	3.9	Public
Kent-PA-08	high density residential	2.2	Public
Kent-PA-09	woods/residential	12.9	Public
Kent-PA-12	wooded area drains into lake under road	2.9	Public
Kent-PA-13	recreation area offset from road	22.3	Private
PutVal-PA-01	wooded area drains into lake under road	111.7	Private
PutVal-PA-02	residential area drains to catch basin network	43.5	Public
Patterson-PA-01	corporate park	12.6	Private
Patterson-PA-02	corporate park	6.6	Public
Patterson-PA-03	park and parking area	3.0	Public
Patterson-PA-03	residential	1.6	Private
Patterson-PA-10	parking lot	11.1	Public
Patterson-PA-11	parking lot and fleet storage	2.1	Public
Patterson-PA-12	multiple land covers	9.1	Private
Patterson-PA-14	impervious, parking lot and buildings	8.2	Private
Patterson-PA-15	multiple land covers	54.9	Public
Patterson-PA-16	residential sub-division	198.9	Public
Southeast-PA-01	wooded (possibly rec. land)	8.7	Public
Southeast-PA-05	residential	1.5	Public
Southeast-PA-06	residential	22.8	Public
Southeast-PA-15	residential	48.5	Private
Southeast-PA-16	school	8.6	Private
Southeast-PA-21	impervious area	12.4	Public
Southeast-PA-23	parking lot and rec. areas	17.7	Public
Southeast-PA-24	dirt surfaces	7.3	Public
Southeast-PA-25	multiple land covers	1.8	Public
Southeast-PA-26	wooded	36.2	Private

As shown in the table, the proposed retrofit locations have drainage areas ranging from 1.5 to 198.9 acres in size and include parklands, residential areas, urban areas and wooded areas. The majority of the sites, 25 in total, are located on public land, with the remaining 15 of the sites located on private land.

3.3. Potential Retrofit Types Available for the PCMS4CC Study

Several retrofit types were considered for use in the PCMS4CC study based on examples provided in the NYSDEC SPDES General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s) (GP-0-08-002). The NYSDEC recommends the following retrofits for use in stormwater projects:

- Better Site Design Approaches;
- Rehabilitation of Existing Storm Sewer Systems;
- Stabilizing Dirt Roads and Surfaces;
- Conversion of Existing Ponds to Extended Detention or Wetland Treatment Systems;
- Retrofit Abandoned Buildings;
- Retrofit Road Ditches to Enhance Open Channel Design;
- Control the Downstream Effects of Runoff from Existing Paved Surfaces;
- Control Stream Erosion by Reducing Flow into Streams;
- Upgrade Existing Conveyance System to Provide Water Quality/Quantity Control within the Drainage Structure; and
- Reforestation

Sections 3.3.1 to 3.3.9 provide additional information for each of these stormwater quality retrofit examples provided by the NYSDEC.

3.3.1. Better Site Design Approaches

Better site design (BSD) approaches were considered as part of the Study. BSD approaches typically involve diverting or retaining rainwater prior to offsite discharge. BSD approaches typically include such practices as rooftop disconnection, diversion of runoff to infiltration areas, soil decompaction, implementing riparian buffers, installing rain gardens and utilizing cisterns. It is proposed that the use of BSD approaches will provide 15-75% phosphorus removal from the associated drainage area, depending on specific application.

3.3.2. Rehabilitation of Existing Storm Sewer Systems

The rehabilitation of existing storm sewer systems was also considered for use in this Study. Storm sewer system rehabilitation refers to installing new infrastructure in order to facilitate phosphorus removal from stormwater runoff. Practices are typically installed in known problem areas and encompass a range of retrofits such as detention ponds, wetlands, filter systems, infiltration systems and proprietary practices such as underground stormwater storage systems or cisterns. Removal rates vary by practice. Infiltration systems for example, are assumed to remove approximately 60% of the phosphorus loading, depending on the system design. Filter systems are expected to perform in a similar manner as infiltration systems. Underground cisterns for stormwater detention however, are anticipated to remove approximately 75% of the phosphorus loading.

Utilizing retrofits that would be placed within the existing infrastructure was also considered in the PCMS4CC stormwater quality retrofit study analysis. Two such systems were considered for use in the Study: deep sump catch basins and hydrodynamic separators. Deep sump catch basins provide a wet storage volume which acts as a detention basin for particulates including phosphorus as well as an energy dissipater for stormwater flow. It is anticipated that deep sump catch basins will remove 15% of the phosphorus load in its associated drainage area. Hydrodynamic separators dissipate stormwater flow energy and allow for particle settling as well. They are expected to remove approximately 51% of the phosphorus in the associated watershed.

3.3.3. Stabilizing Dirt Roads and Surfaces

Also included in consideration for this Study was the stabilization of dirt roads and surfaces and includes replacing exposed soil with pervious pavement grass or stone as well as diverting flow around exposed soils via check dams and other diversion measures. In addition to the retrofit recommendations of the NYSDEC, the replacement of existing pavement with pervious pavement is also considered as stabilizing dirt roads and surfaces for the purpose of this Study. It is anticipated that the stabilization of exposed dirt surfaces will remove 20% of the phosphorus from the associated drainage area. The installation of porous pavement however, is anticipated to remove 70% of the total phosphorus in the drainage area.

3.3.4. Conversion of Existing Ponds to Extended Detention or Wetland Treatment Systems

Detention ponds installed in the past were designed to control water quantity release rates, with limited water quality improvements being considered in their design. Stormwater quality retrofits on existing detention ponds typically involve modifying the control structure, increasing the size of the existing pond, or adding additional pond space upstream of the existing pond via a forebay. The additional volume available in the pond would trap additional sediment and phosphorus prior to discharge into the watershed. Despite being cost and labor intensive, updating existing detention ponds in the Study Area to treat water quality as well as quantity would likely achieve significant phosphorus removal in the Study Area. It is anticipated that properly designed extended detention ponds will achieve 31% phosphorus removal, which accounts for the difference between the phosphorus removal associated with the typical detention pond design of the past (19%) and the phosphorus removal associated with the installation of a new extended detention pond (50%).

3.3.5. Retrofit Abandoned Buildings

Stormwater quality retrofits of abandoned buildings include demolishing existing buildings to create open space or constructing stormwater quality treatment systems inside the rehabilitated structures. Despite extensive efforts to locate such a site in the PCMS4CC study area, no suitable abandoned buildings were located and therefore, this type of retrofit will not be included in the retrofit analysis.

3.3.6. Retrofit Road Ditches to Enhance Open Channel Design

Road side ditch retrofit efforts typically involve the stabilization of known exposed erosion areas in the roadside ditches. When retrofit, unstable ground cover is typically stabilized via the addition of riprap or grass depending on the use of the area in question. Ground stabilization retrofits are simpler to accomplish over the majority of the other retrofits considered in this Study; however, less phosphorus and sediment are removed. When designed with check dams to dissipate flow velocity and energy, grassed swales achieve a phosphorus removal of approximately 30%. Rip rap lined swales however, will be considered to remove 20% of the phosphorus loading from the associated drainage area. The smaller amount of phosphorus removal in rip rap lined swales is due to the potential for erosion being greater in these swales as compared to stabilized grass lined swales.

3.3.7. Control the Downstream Effects of Runoff from Existing Paved Surfaces

Control of the downstream effects of runoff from paved surfaces was also considered in the retrofit study. In order to control the flooding and erosion associated with excessive runoff from existing paved surfaces, outfall stabilization retrofits are needed to reduce the amount of sediment and phosphorus in the stormwater. Outfall stabilization typically consists of rip rap protection installation as well as other culvert outlet amendments such as a splash pad. Furthermore, the replacement of existing culverts with properly stabilized culvert sections will also limit phosphorus and sediment loading into the waterbodies of the Study Area. Proper sizing of the replacement culvert along with inlet/outlet protection will likely reduce erosion and therefore reduce sediment and phosphorus loads from the watershed. Culvert replacement however, typically involves interrupting vehicle traffic as the majority of culverts convey water from one side of a roadway to the other. This interruption should be considered when deciding to install new culverts under roadways. Due to the similarities with rip rap lined swales, stabilized outfall retrofits are expected to remove 20% of the phosphorus loading in the drainage area. In addition, it is anticipated that the benefits of a properly functioning culvert will further reduce erosion and associated phosphorus loading by 5-10%.

3.3.8. Control Stream Erosion by Reducing Flows and/or Velocities into Streams

The benefits of reducing stormwater flows and/or velocities into the stream network were also considered as part of the retrofit study. Several methodologies are currently practiced in order to reduce the volume and velocity of stormwater flow entering streams and other waterbodies. Velocity dissipaters such as check dams in swales help to dampen the energy of stormwater flow, decreasing its erosive potential. Another retrofit used to limit the erosivity of stormwater flow is a plunge pool. Plunge pools provide an area for stormwater flow energy to dissipate as well as provide phosphorus removal similar to a small extended detention pond. It is anticipated that plunge pools will remove 50% of the phosphorus in the associated drainage area.

3.3.9. Reforestation

Reforestation of developed land in the study areas was also considered as part of the study effort. Because much of the watershed area is currently forested with most developed lands actively used, no sites for this retrofit type were identified. Therefore, the impacts of reforestation will not be considered in the remainder of the analysis.

3.4. Selection of Suggested Retrofit Types

In order to best represent the range of retrofits available for use by the PCMS4CC, several types of retrofits were suggested for use in the Study. Similar to the retrofit site selection process, the selection of potential retrofits was dependent on multiple factors. The types of retrofits ranged from cost and labor intensive efforts, such as installing a new detention basin, to low cost and labor efforts such as removing the asphalt from an existing swale and replacing it with a grassed swale.

The retrofits recommended for use at the selected sites are summarized in Table 3-3. As shown in the table, several sites have multiple potential retrofit options available for use. The table also indicates if the sites were identified by the towns of the PCMS4CC or by the engineering team.

Table 3-3:
Potential Retrofits for Identified Sites in the PCMS4CC Study Area

Site ID	Potential Retrofit Types	Selected By
Carmel-PA-01	Improve Existing Detention Pond, Install Deep Sump Catch Basin, Install Grass Swales	Town
Carmel-PA-03	Install Sand Filter, Improve Existing/Install Detention Pond, Install Grass Swales	Town
Carmel-PA-07	Install Detention Pond, Install Deep Sump Catch Basins, Install Grass Swales	Town
Carmel-PA-08	Install Cistern, Install Deep Sump Catch Basins, Install Grass Swales	Pirnie
Carmel-PA-13	Outfall Channel Stabilization, Install Detention Pond	Pirnie
Carmel-PA-15	Outfall Channel Stabilization	Pirnie
Carmel-PA-17	Install Plunge Pool, Install Outfall Stabilization	Pirnie
Carmel-PA-18	Install Grass Swales, install Detention Pond	Pirnie
Carmel-PA-19	Install Hydrodynamic Separator	Pirnie
Carmel-PA-20	Install Detention Pond, reroute drainage from surrounding area	Pirnie
Kent-PA-03	Outfall Channel Stabilization	Town
Kent-PA-04	Fix Detention Structure (design failure reported)	Town
Kent-PA-05	Ground Stabilization (erosion id'd)	Town
Kent-PA-07	Install Detention Pond, reroute drainage from surrounding area	Town
Kent-PA-08	Install Hydrodynamic Separator	Town
Kent-PA-09	Install Plunge Pool	Town
Kent-PA-12	Outfall Channel Stabilization	Pirnie
Kent-PA-13	Install Detention Pond, Install Grass Swales	Pirnie
Patterson-PA-01	Install Plunge Pool, Improve Existing Detention Pond, Install Grass Swales	Town
Patterson-PA-02	Improve Existing Detention Pond, Install Grass Swales, Install Deep Sump CBs	Town
Patterson-PA-03	Stabilize Area and reroute drainage, Install Deep Sump Catch Basins	Town
Patterson-PA-03	Install Grass Swales	Town
Patterson-PA-10	Install Deep Sump Catch Basins	Town
Patterson-PA-11	Install Detention Pond, Install Grass Swales	Pirnie
Patterson-PA-12	Install Grass Swales, Install Deep Sump Catch Basins	Pirnie
Patterson-PA-14	Improve Existing Detention Pond, Install Deep Sump Catch Basins	Pirnie
Patterson-PA-15	Install Grass Swales, Install Deep Sump Catch Basins	Pirnie
Patterson-PA-16	Install Cistern, Install Detention Pond, Install Hydrodynamic Separator	Pirnie
PutVal-PA-01	Resurface Road Surface and Improve under Drainage	Town
PutVal-PA-02	Install Deep Sump Catch Basins	Town
Southeast-PA-01	Outfall Channel Stabilization, Install Grass Swales	Town
Southeast-PA-05	Piping of Existing Swale	Town
Southeast-PA-06	Install Detention Pond, reroute drainage from surrounding area	Town
Southeast-PA-15	Outfall Channel Stabilization, Install Water Quality Improvements	Town
Southeast-PA-16	Install Cistern, Install Detention Pond	Town
Southeast-PA-21	Install Deep Sump Catch Basins, Install Grass Swales	Pirnie
Southeast-PA-23	Install Detention Pond, Install Deep Sump Catch Basins, Install Grass Swales	Pirnie
Southeast-PA-24	Install Grass Swales (soil stabilization)	Pirnie
Southeast-PA-25	Replace portion of Existing Parking Area with Pervious Pavement, Install DP	Pirnie
Southeast-PA-26	Install Plunge Pool	Pirnie

The complexity of implementing a retrofit was also considered when choosing potential retrofit practices. Due to size constraints, sites with smaller areas available for retrofit construction were typically assigned smaller and simpler potential retrofits such as stabilized swales or deep sump catch basins. Larger sites in the Study Area had the available area to include multiple potential retrofits on a single site.

3.5. Summary of Potential Stormwater Retrofits

As part of this study, the cost and phosphorus reduction at sites with multiple potential retrofits for consideration were evaluated for a single stormwater retrofit practice. The retrofits evaluated at each site were selected to represent the full range of options identified for the Study. Therefore, with the full range of options represented, the PCMS4CC will have the basis to extrapolate costs for additional retrofit locations within their jurisdiction.

The final retrofit types chosen for each site are provided in Table 3-4. To the greatest extent possible, different categories of retrofits were chosen for similar sites in both land cover and size. This methodology allowed each type of retrofit to be distinguished based on both cost and anticipated phosphorus removal potentials for similar sites. Conversely, similar retrofits were assigned to sites of various sizes in order to determine the potential impact of each retrofit type as it applied to the range of potential drainage area sizes in the Study Area. When possible, the majority of the retrofits chosen for each site in the Study Area were the retrofits that would provide the greatest reduction in phosphorus into the system. However, other factors such as ease of installation and relative size of the drainage area were also included in the proposed retrofit recommendation.

As shown in Table 3-4, there are 12 different types of retrofits proposed for use in the Study. The retrofits proposed for the Study cover 8 of the 10 major categories suggested for use in stormwater quality retrofits by the NYSDEC. The only categories suggested by the NYSDEC and not covered in this study are the retrofit of abandoned buildings and reforestation of abandoned developed lands. Suitable sites for both these retrofits were not found in the Study Area and were therefore not included in the remainder of the analysis. Furthermore, the retrofits proposed for this study also encompass the majority of the sub-categories suggested by the NYSDEC as well. As stated above, the application of retrofits ranged from complex to simple. One of the complex retrofit installations includes the installation of a detention pond and the rerouting of the drainage from the surrounding area (Carmel-PA-20). The rerouting of the drainage from an area can involve excavation, new infrastructure installation, roadway disruption, long construction periods and increased construction costs. One of the simple retrofit installations involves the installation of grassed swales (Patterson-PA-03). The installation of grassed swales typically involves minimal excavation or ground disturbance and is typically conducted along roadways, driveways and other access locations that minimize construction access difficulties.

Table 3-4:
Selected Retrofits for Identified Sites in the PCMS4CC Study Area

Unique ID	Potential Retrofit Types
Carmel-PA-01	Improve Existing Detention Pond
Carmel-PA-03	Install Sand Filter
Carmel-PA-07	Install Detention Pond
Carmel-PA-08	Install Cistern
Carmel-PA-13	Outfall Channel Stabilization
Carmel-PA-15	Outfall Channel Stabilization
Carmel-PA-17	Install Plunge Pool
Carmel-PA-18	Install Grass Swales
Carmel-PA-19	Install Hydrodynamic Separator
Carmel-PA-20	Install Detention Pond, reroute drainage from surrounding area
Kent-PA-03	Outfall Channel Stabilization
Kent-PA-04	Fix Detention Structure (design failure reported)
Kent-PA-05	Ground Stabilization (erosion id'd)
Kent-PA-07	Install Detention Pond, reroute drainage from surrounding area
Kent-PA-08	Install Hydrodynamic Separator
Kent-PA-09	Install Plunge Pool
Kent-PA-12	Outfall Channel Stabilization
Kent-PA-13	Install Detention Pond
Patterson-PA-01	Install Plunge Pool
Patterson-PA-02	Improve Existing Detention Pond
Patterson-PA-03A	Stabilize Area and reroute drainage to opposite side of road
Patterson-PA-03B	Install Grass Swales
Patterson-PA-10	Install Deep Sump Catch Basins
Patterson-PA-11	Install Detention Pond
Patterson-PA-12	Install Grass Swales
Patterson-PA-14	Improve Existing Detention Pond
Patterson-PA-15	Install Grass Swales
Patterson-PA-16	Install Cistern
PutVal-PA-01	Resurface Road Surface and Improve under Drainage
PutVal-PA-02	Install Deep Sump Catch Basins
Southeast-PA-01	Outfall Channel Stabilization
Southeast-PA-05	Piping of Existing Swale
Southeast-PA-06	Install Detention Pond, reroute drainage from surrounding area
Southeast-PA-15	Outfall Channel Stabilization
Southeast-PA-16	Install Cistern
Southeast-PA-21	Install Deep Sump Catch Basins
Southeast-PA-23	Install Detention Pond
Southeast-PA-24	Install Grass Swales (soil stabilization)
Southeast-PA-25	Replace portion of Existing Parking Area with Pervious Pavement
Southeast-PA-26	Install Plunge Pool

4. Phase 1 Ranking

4.1. Ranking Methodology

The methodology for Phase 1 ranking was developed based on the hard copy and electronic information provided by the towns prior to field investigations. The criteria selected for the Phase 1 ranking methodology are further described in Sections 4.1.1 through 4.1.13. Section 4.1.14 describes the how each criterion was weighted in the overall scoring and how the overall Phase 1 ranking was determined.

Phase 1 ranking was performed based on data provided by the PCMS4CC municipalities as well as readily-available GIS data. A list of the data and data sources used for the Phase 1 ranking are provided in Appendix D - GIS Data Sources.

4.1.1. Drainage Area Size

The drainage area size is a key factor determining the amount of runoff that contributes to a potential retrofit site. Once the potential retrofit sites were identified and the drainage areas delineated, the range of sizes were examined to determine the distribution in drainage area size. The drainage area sizes were broken down into ranges, with scores assigned as described in Table 4-1.

Table 4-1:
Drainage Area Size Ranking and Criteria

Size	Rank
0 - 2 acres	1
2 - 5 acres	2
5 - 10 acres	3
> 10 acres	4

4.1.2. Average Drainage Area Imperviousness

This metric represents the impervious percentage for the drainage area based on the average percent imperviousness. Based on work by Arnold and Gibbons (1996), water quality issues can result when a basin reaches 10% impervious area or greater. Therefore, the ranges were chosen to give basins with high percent impervious areas a higher priority for retrofits.

As in the case of the drainage size criteria, these ranges were selected once the drainage area for each site was evaluated, with range distinctions based on the range of observed values and professional judgment. The percent imperviousness values were broken down into ranges, with scores assigned as described in Table 4-2.

Table 4-2:
Drainage Area Impervious Ranking and Criteria

Percent Impervious	Rank
0 - 5 %	1
5 - 10 %	2
10 - 15 %	3
> 15 %	4

4.1.3. Existing TMDL Removal Requirements

The removal requirements from the Phase II TMDLs were summarized in the January 2009 NYSDEC Implementation Plan. Based on these requirements, ranks were assigned to sites in each basin as described in Table 4-3. This criterion reflects the overall removal requirements for the TMDL, as opposed to the removal associated with the MS4 requirements. The Existing TMDL Removal Requirements criterion reflects the importance of the watershed basins for overall phosphorus removal; the criterion identifying sources of high phosphorus is based on the load from high intensity development areas and therefore already reflects the MS4 requirements (i.e. one criterion reflects overall TMDL requirements and one reflects MS4 requirements).

Note that while West Branch and Boyd Corners basins are not currently water quality limited, they are included in the Implementation Plan as they feed downstream reservoirs which are water quality limited. As they drain into Croton Falls, they were assigned the same removal requirements and rank as the Croton Falls reservoir in the Phase I ranking methodology. The ranks were assigned roughly on quartiles.

Table 4-3:
Existing TMDL Removal Requirements Ranking and Criteria

Basin	Phase II TMDL Removal Requirements kg/yr (lb/yr)	Rank
Amawalk	122 (269)	1
Middle Branch	204 (450)	1
Boyd Corners	885 (1,951)	2
Croton Falls/Lake Gilead	885 (1,951)	2
West Branch/Lake Glenida	885 (1,951)	2
Diverting	983 (2,167)	3
East Branch	993 (2,189)	3
Muscoot	2058 (4,537)	4

4.1.4. Location within Phosphorus Limited Basin

This criterion was included in the proposal and is included here. However, as noted in the Croton Watershed Phase II Phosphorus TMDL Implementation Plan (NYSDEC, January 2009), all of the PCMS4CC towns are in phosphorus limited watersheds or those that feed into phosphorus limited watersheds. Therefore all basins comprising the PCMS4CC study area are included in the Implementation Plan, making the metric neutral in nature.

4.1.5. Documented Source of High Phosphorus

This factor was included to account for documented sources of high phosphorus. Table 2 of the NYSDEC Croton Watershed Phase II Phosphorus TMDL Implementation Plan provides the modeled load associated with High Intensity Development. The ranks were assigned based on the basin the potential retrofit falls within; Table 4-4 shows the ranks that were assigned.

Table 4-4:
Documented Source of High Phosphorus Ranking and Criteria

Modeled Load of Basin	Rank
<50 kg/yr (<110 lb/yr)	1
50-100 kg/yr (110-220 lb/yr)	2
100-200 kg/yr (220-441 lb/yr)	3
>200 kg/yr (> 441 lb/yr)	4

4.1.6. Ownership Type

The types of ownership for the potential retrofit site are expected to affect the cost and timeline for constructing a retrofit. Private ownership is expected to pose the most difficulties for implementation, with municipal ownership expected to be the most feasible for timely implementation. Land owned by municipal school districts may require more coordination and are therefore assigned a slightly lower score than general municipal lands. The ranking assigned to private versus public ownership types is provided in Table 4-5.

Table 4-5:
Ownership Type Ranking and Criteria

Ownership Type	Rank
Private	1
Public (Federal/State)	2
Public (County)	2
Public (Municipal - School)	3
Public (Municipal)	4

4.1.7. Current Land Use

The current land use of the retrofit site is viewed as an indication of what kinds of property may be more likely to have space for placement of a retrofit. The land uses associated with each property was based on the Real Property Service (RPS) code; a look up table of RPS code to specific land use and generalized land use categories used in the methodology is provided as Appendix E - Land Use Descriptions. Generalized land use categories include residential, commercial, open space, and vacant/abandoned. The rank assigned to each generalized land use category is provided in Table 4-6.

Table 4-6:
Current Land Use Type Ranking and Criteria

Land Use Type	Rank
Residential	1
Commercial/Industrial	2
Open Space	3
Vacant/Abandoned	4

4.1.8. Anticipated Stormwater Capture Ratio of Current Practice

While data on current practice design and anticipated capture ratio was fairly limited, if the capture ratio of the retrofit is known the rank is assigned based on a three tier system, with a value of 4 given to lower capture ratios. If the capture ratio is unknown, the age of the retrofit was used as a surrogate for anticipated capture ratio. A three tier system was implemented ranging from 1-3 (3 given to older stormwater management practices). The rank assigned to each type of stormwater management practice (SMP) is provided in Table 4-7.

Table 4-7:
Anticipated Capture Ratio Ranking and Criteria

	Rank
Anticipated Capture Ratio Known	
High Capture Ratio	2
Moderate Capture Ratio	3
Low Capture Ratio	4
Anticipated Capture Ratio Unknown	
< 5 years old	1
5-10 years old	2
10+ years old	3

If neither capture ratio nor age is known, the SMP will be given a value of 2 to represent the average capture ratio in the Study Area. If the retrofit represents the installation of a new SMP, a value of 4 will be assigned to the potential site. Note that neither capture ratio nor age was known for any of the selected retrofit sites; therefore a value of 2 was assigned to all sites with existing management practices.

4.1.9. Existing Management Practice – Ease of Retrofit

The general amount of construction required to install a suggested retrofit based on the existing SMP type is accounted for by the ranks described in Table 4-8, with easiest retrofits assigned the highest value. Potential retrofits identified at sites where there is no existing management practice are assigned a rank of 3, equivalent to the rank for a retrofitting a dry pond. This value was assigned because site characteristics for dry ponds would be nearly equivalent to a vacant lot, with construction issues likely to be similar. While there may be more uncertainties related to a new installation, the score of 3 is the median score and therefore a new installation would be considered neutral relative to other retrofit types.

Table 4-8:
Existing Management Practice – Ease of Retrofit Ranking and Criteria

Retrofit Type	Rank
Culvert	1
Wet pond	2
Dry pond/New Installation	3
Catchbasin	4
Swales	5

4.1.10. Existing Management Practice – Typical Phosphorus Removal Capability

Management practices types with lower typical phosphorus removal capabilities receive higher scores under the Phase 1 ranking scheme. This places a higher priority on SMPs which currently do not remove much phosphorus that may be retrofitted to increase the phosphorus removal at the potential retrofit site. Table 4-9 describes the ranks assigned to existing management practices.

Table 4-9:
Existing Management Practice – Typical Phosphorus Removal Capability Ranking and Criteria

Retrofit Type	Rank
Wet pond	1
Dry pond	2
Swales	3
Catchbasin	4
Culvert	5

4.1.11. Proximity to Receiving Water

Sites with discharges closer to receiving water were assigned a higher priority during the retrofit ranking to reflect the higher likelihood that the discharge will directly impact the receiving water. Processes such as natural attenuation and infiltration have less time to occur before stormwater flow delivers the phosphorus load to the receiving waters. Table 4-10 describes the ranks assigned based on proximity to receiving waters.

Table 4-10:
Proximity to Receiving Water Ranking and Criteria

Proximity to Receiving Water	Rank
>500 feet from receiving water	1
Within 500 feet of receiving water	3

4.1.12. Receiving Water Body Class

The ranking assigned based on water quality classification of the receiving water reflects the regulatory priority of protecting the receiving water body. Table 4-11 describes the ranks assigned based on receiving water body class.

Table 4-11:
Receiving Water Body Class Ranking and Criteria

Water Quality Classification	Rank
C	1
B	2
AA, A	3

Note that all AA waters in the study area are reservoirs and that no Class D waters are located within the Study Area. The majority of streams in the area are Class C waters.

4.1.13. Proximity to Wetlands or Wetlands Buffer

The proximity of the potential retrofit installation site to a New York State Freshwater wetland or a National Wetlands Institute wetland was ranked based on the current understanding that the NYSDEC currently will not permit disturbance of existing wetlands for the installation of SMPs. Therefore, sites in or near wetlands receive lower ranking than those not in close proximity to wetlands or wetlands buffers. Table 4-12 describes how ranks were assigned based on the proximity of the retrofit site to a wetland or wetland buffer.

Table 4-12:
Proximity to Wetlands or Wetlands Buffer Ranking and Criteria

Distance to Wetlands or Wetlands Buffer	Rank
Within wetlands or 100-foot buffer	1
Within 100 feet of wetlands or 100-foot buffer	2
Further than 100 feet from buffer	3

Discussions of the effectiveness of degraded wetlands and the possibility of utilizing and improving degraded wetlands during the construction of SMPs have been held with the NYSDEC. The PCMS4CC has inquired whether the NYSDEC may relax the restriction on the placement of BMPs within the buffer. These criteria and ranges may change if NYSDEC allows placement of BMPs within the buffer.

4.1.14. Scalars and Overall Ranking

Scalar values are used to assign higher weights to the criteria that represent the drivers of the stormwater retrofit improvement study. Therefore, the highest values were given to those criteria directly related to phosphorus load or regulatory issues. Drainage area characteristics directly related to phosphorus loading included drainage area size and percent impervious; these factors were assigned the highest weighting factors to emphasize the load to each potential site. Regardless of which retrofit type is selected, these sites represent the highest potential for phosphorus removal of the sites identified in the Study. Both drainage area characteristics are assigned a weighting factor (scalar) of 5.

The high ranking for criterion related to regulatory issues reflects the importance of meeting regulatory requirements, the main impetus of this study. To reflect this, these criteria are assigned a scalar of 4.

Numerous site characteristics were identified. These include ownership type, current land use of the potential retrofit site, and existing management practices. These characteristics will affect the cost and feasibility of constructing a retrofit. These criteria were designed to reflect the desirability of installing a retrofit at the potential site. Note that selected retrofit types may reflect only one of multiple potential retrofits, this criteria does not strictly limit the amount of removal that may be achieved at a potential site. Due to the relatively large number of site characteristics, a smaller weighting factor was assigned so that the focus of the study remains on the drainage area characteristics and regulatory issues. The site characteristics criteria were therefore assigned a scalar of 2.

Environmental constraints reflect additional site characteristics which may affect the feasibility or desirability of placing a retrofit at the identified site. These criteria are assigned a lower weighting factor for multiple reasons, including more uncertainty of the impacts. For example, while a close proximity to receiving water body generally reflects a higher likelihood for discharge to directly impact the receiving water, the condition of the path from the outlet to the receiving water has a large impact on this and field investigations may be required to assess the effects. Similarly, scoring for proximity to wetlands was based on GIS data suited for screening level investigations, with field investigations recommended to better understand the impact on site selection. Therefore these criteria were assigned the lowest weights in the study, with a scalar value of 1.

Table 4-13 describes the scalar values assigned to each criterion. The score for each criterion is the product of the scalar value and the rank assigned to each potential retrofit site.

Table 4-13:
Scalars and Overall Ranking

Criteria Type	Criteria	Scalar	Low Rank	High Rank	Low	High
Drainage Area Characteristics	Drainage Area Size	5	1	4	5	20
	Drainage Area Percent Impervious	5	1	4	5	20
Regulatory Issues	Existing TMDL Regulatory Removal Requirements	4	1	4	4	16
	Within Phosphorus Limited Basin	4	0	0	0	0
	Documented Source of High Phosphorus	4	1	4	4	16
Site/Outfall Characteristics	Ownership Type	2	1	4	2	8
	Current Land use	2	1	4	2	8
	Anticipated Capture Ratio	2	1	4	2	8
	Existing SMP Type – Ease of Retrofit	2	1	5	2	10
	Existing SMP Type – Typical Phosphorus Removal	2	1	5	2	10
Environmental	Proximity to Receiving Water	1	1	3	1	3
	Receiving Water Body Class	1	1	3	1	3
	Proximity to Wetlands	1	1	3	1	3

The total ranking score calculated for each retrofit is the sum of the scores from all criteria. Overall total scores potentially range from 29 to 125, with higher scores indicating more desirable potential retrofit sites, based on the criteria included in this assessment.

4.2. Potential Retrofit Ranking

The weights and scores described in Section 4.1 were applied to the 40 identified potential retrofit sites. The scores for each criterion are provided in Table 4-14, along with the overall score for each site.

As stated previously, the total ranking scores could potentially range from 29 to 125, with higher scores indicating more desirable potential retrofit sites. The most desirable retrofits based on the analysis contained in this section were found to be Carmel-PA-13 and Southeast-PA-05, both of which received a ranking score of 103. The least desirable retrofit based on the analysis was found to be Kent-PA-09, with a resulting score of 62.

Table 4-14:
Potential Retrofit Site Phase 1 Ranking

Potential Site	Drainage Area Size	Average Drainage Area Impervious	Ownership Type	Current Land Use	Anticipated Stormwater Capture Ratio of Current Practice	Existing Management Practice – Ease of Retrofit	Existing Management Practice – Typical Phosphorus Removal Capability	Documented Source of High Phosphorus	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Total
Carmel-PA-01	4	2	1	2	2	2	1	3	3	1	3	2	**73**
Carmel-PA-03	4	2	1	2	2	2	1	3	1	2	3	2	**72**
Carmel-PA-07	4	3	1	4	4	3	1	3	1	3	3	2	**88**
Carmel-PA-08	1	4	3	2	4	3	1	3	3	2	3	2	**79**
Carmel-PA-13	4	4	4	3	2	5	3	3	3	3	3	2	**103**
Carmel-PA-15	2	4	4	1	2	5	3	3	1	3	2	2	**86**
Carmel-PA-17	1	4	1	1	2	5	3	2	1	3	3	2	**72**
Carmel-PA-18	3	2	4	2	4	3	1	4	1	1	3	1	**78**
Carmel-PA-19	2	4	4	3	2	4	4	2	3	3	2	2	**88**
Carmel-PA-20	4	2	4	3	4	3	1	4	3	3	1	1	**87**
Kent-PA-03	1	3	1	1	2	5	3	2	3	1	3	2	**67**
Kent-PA-04	1	4	1	3	2	3	2	1	1	1	3	2	**64**
Kent-PA-05	1	4	1	4	4	3	1	3	3	1	3	1	**74**
Kent-PA-07	1	1	4	4	4	3	1	3	3	1	3	1	**65**
Kent-PA-08	3	4	4	3	2	4	4	3	3	2	2	1	**92**
Kent-PA-09	1	1	4	3	2	5	3	1	3	1	2	2	**62**
Kent-PA-12	4	1	4	3	2	5	3	1	3	3	1	2	**78**
Kent-PA-13	4	1	4	3	4	3	1	1	3	1	3	2	**74**

Potential Site	Drainage Area Size	Average Drainage Area Impervious	Ownership Type	Current Land Use	Anticipated Stormwater Capture Ratio of Current Practice	Existing Management Practice – Ease of Retrofit	Existing Management Practice – Typical Phosphorus Removal Capability	Documented Source of High Phosphorus	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Total
PutVal-PA-01	4	1	1	4	2	5	3	1	3	2	1	2	**73**
PutVal-PA-02	2	2	4	3	2	4	4	4	3	1	3	1	**81**
Patterson-PA-01	4	2	1	2	2	2	1	3	3	2	1	3	**76**
Patterson-PA-02	3	4	1	3	2	2	1	3	3	1	1	3	**82**
Patterson-PA-03	2	3	1	3	2	5	3	3	3	1	3	3	**84**
Patterson-PA-03	1	4	1	3	2	5	3	3	3	2	2	3	**84**
Patterson-PA-10	1	4	4	2	4	3	1	3	3	1	3	3	**84**
Patterson-PA-11	3	2	4	2	4	3	1	3	3	1	3	3	**84**
Patterson-PA-12	1	4	1	2	4	3	1	3	1	1	3	3	**76**
Patterson-PA-14	2	4	4	2	2	2	1	3	3	1	3	3	**83**
Patterson-PA-15	2	4	3	2	4	3	1	3	3	1	3	3	**87**
Patterson-PA-16	4	3	1	3	4	3	1	3	3	1	1	1	**80**
Southeast-PA-01	1	4	4	2	2	5	3	3	3	1	3	3	**88**
Southeast-PA-05	4	4	4	3	2	5	3	3	1	1	3	3	**103**
Southeast-PA-06	4	2	4	3	4	3	1	4	3	1	1	4	**97**
Southeast-PA-15	2	4	4	3	2	5	3	3	3	4	1	1	**88**
Southeast-PA-16	3	3	1	2	4	3	1	3	3	1	3	3	**83**
Southeast-PA-21	4	4	1	2	4	3	1	3	3	3	1	3	**93**
Southeast-PA-23	2	4	3	2	4	3	1	3	3	1	1	3	**85**
Southeast-PA-24	1	4	2	3	4	3	1	4	3	3	3	4	**92**
Southeast-PA-25	4	4	4	3	4	3	1	3	3	1	2	3	**100**
Southeast-PA-26	1	2	4	3	2	5	3	3	3	3	3	2	**78**

4.3. Tier 1 and Tier 2 Sites

The Phase 1 ranking results were used as the main factor in selecting 20 sites that were designated as Tier 1 sites. Prior to selecting the 20 Tier 1 sites, it was decided that each town in the PCMS4CC would have an approximately equal number of Tier 1 sites visited during the field investigation portion of the Study. The top 3 sites within the towns of Carmel, Kent, Patterson, and Southeast were identified as Tier 1 sites based on the Phase 1 ranking. The top site from the town of Putnam Valley was also selected based on the Phase 1 ranking.

The additional 7 sites were selected to ensure a variety of retrofit types and site types were represented in the Tier 1 sites. For example, the Tier 1 sites include 5 existing swales, 4 existing wet/dry ponds, 2 existing catch basins, and 9 sites where no existing management practice has been identified.

A variety of proposed retrofit types are also included in the Tier 1 sites. The retrofit types proposed for use in this Study include:

- Improve existing detention ponds;
- Stabilize and re-route drainage;
- Stabilize outfall channel;
- Install new detention ponds (with or without re-routing drainage);
- Install a hydrodynamic separator;
- Install a plunge pool;
- Install deep sump catch basins;
- Install a cistern;
- Install grass swale(s);
- Piping of existing grass swale;
- Resurface road and improve underdrainage; and
- Replace existing pavement with pervious pavement.

Most of the proposed retrofit types are represented in the Tier 1 sites. The retrofit types not represented in Tier 1 include: installing sand filters; and resurfacing road and improve underdrainage. These retrofits are standard retrofit practices where cost can be estimated without intimate knowledge of the specific project sites. Therefore, project resources were focused on gaining a better understanding of proposed retrofits on Tier 1 sites where specific site information will allow for a better estimate of cost and associated phosphorus removal.

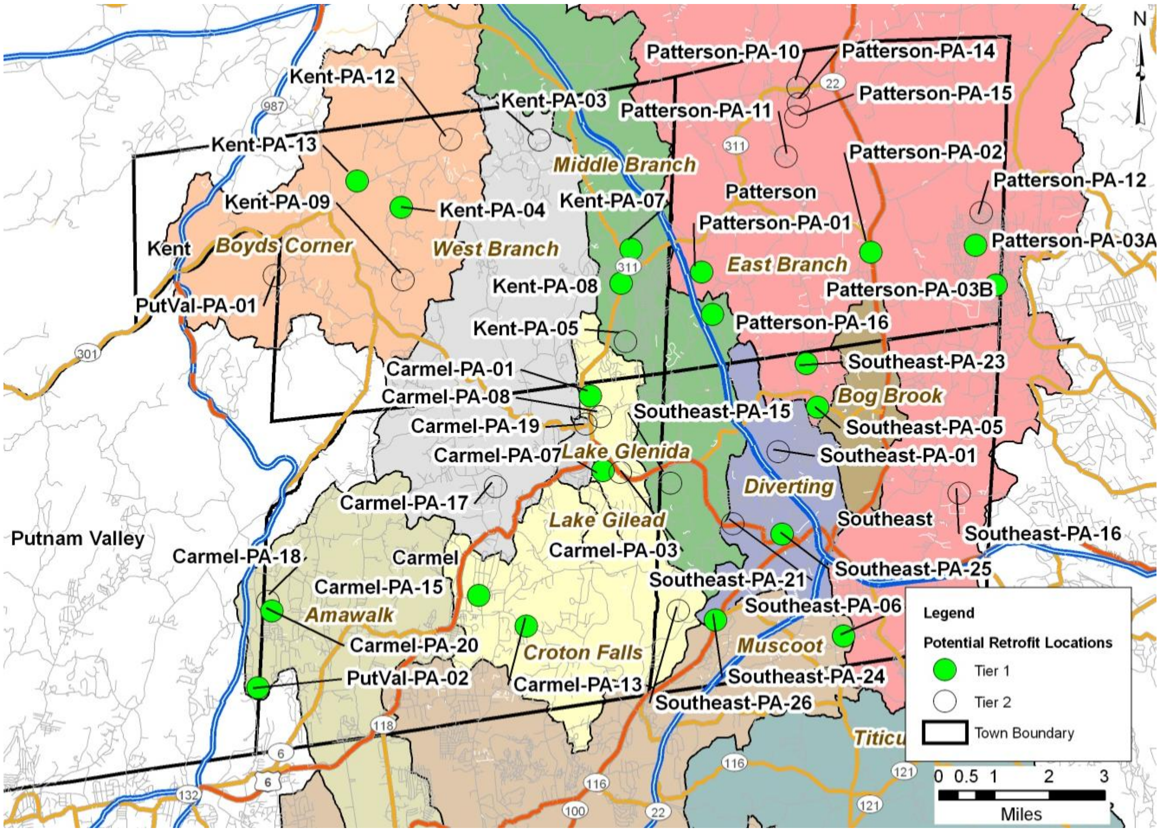
The Tier 1 sites also include a variety of public and private properties and a variety of recommended retrofit types. With the exception of Putnam Valley, with one Tier 1 site, each of the PCMS4CC municipalities has 4 or 5 Tier 1 sites identified. A summary of the selected Tier 1 sites is provided in Table 4-15 and Figure 4-1.

Table 4-15:
Tier 1 Sites

Site ID	Existing Management Practice	Proposed Retrofit
Carmel-PA-01	Wet Pond	Improve existing detention pond
Carmel-PA-07	None	Install detention pond
Carmel-PA-13	Swale	Outfall channel stabilization
Carmel-PA-15	Swale	Outfall channel stabilization
Carmel-PA-20	None	Install detention pond and re-route drainage
Kent-PA-04	Dry pond	Fix detention structure
Kent-PA-07	None	Install detention pond and re-route drainage
Kent-PA-08	Catch Basin	Install hydrodynamic separator
Kent-PA-13	None	Install detention pond
PutVal-PA-02	Catch Basin	Install deep sump catch basins
Patterson-PA-01	Wet Pond	Install plunge pool
Patterson-PA-02	Wet Pond	Improve Existing detention pond
Patterson-PA-03A	Swale	Stabilize area and re-route drainage
Patterson-PA-03B	Swale	Install grass swales
Patterson-PA-16	None	Install cistern
Southeast-PA-05	Swale	Piping of existing swale
Southeast-PA-06	None	Install detention pond and re-route drainage
Southeast-PA-23	None	Install detention pond
Southeast-PA-24	None	Install grass swales
Southeast-PA-25	None	Replace portion of existing parking lot with pervious pavement

Figure 4-1 shows the original Tier 1 sites. These 20 identified Tier 1 sites were selected for field investigations and the data collected during field investigations will be used during the Phase 2 ranking (Feasibility Matrix). The remaining sites are classified as Tier 2 sites. General observations from the field investigations will be used in evaluating the Tier 2 sites where applicable.

Figure 4-1: Tier 1 Sites Selected for Field Investigation



5. Field Investigations

5.1. Field Investigation

Field investigations were held during July 2009, with participation from representatives of each of the PCMS4CC municipalities. Representatives from each town in the PCMS4CC were encouraged to participate in the field investigations to provide local knowledge and insight of each of the Tier 1 sites. During the field investigations, adjustments to the list of Tier 1 sites, including the proposed retrofits, were made based on site conditions, site restrictions and input from the PCMS4CC representatives. The changes to the list of Tier 1 sites are discussed in Section 5.3.

The dates and personnel involved in each portion of the field visits are provided in Table 5-1.

Table 5-1:
Field Investigation Dates and Personnel

Municipality	Date	Personnel
Carmel	July 24, 2009	John Karell, Town of Carmel Engineer Jim Mangarillo, Malcolm Pirnie William Rosenzweig, Malcolm Pirnie
Kent	July 28, 2009	Bruce Barber, Town of Kent Consulting Engineer Katherine Doherty, Town of Kent Supervisor Tony Caravetta, Town of Kent Highway Superintendent Jim Mangarillo, Malcolm Pirnie William Rosenzweig, Malcolm Pirnie
Patterson	July 22, 2009	Richard Williams, Town of Patterson Planner Jim Mangarillo, Malcolm Pirnie William Rosenzweig, Malcolm Pirnie
Putnam Valley	July 28, 2009	Gary Wulfhop, Town of Putnam Valley Asst. Highway Superintendent Todd Atkinson, J. Robert Folchetti and Associates Jim Mangarillo, Malcolm Pirnie William Rosenzweig, Malcolm Pirnie
Southeast	July 23, 2009	Kevin Palmer, Town of Southeast Highway Superintendent Tom Fenton, Town of Southeast Consulting Engineer - Nathan L. Jacobson & Associates Jim Mangarillo, Malcolm Pirnie William Rosenzweig, Malcolm Pirnie

5.2. Site Visit Data Collection

Prior to the site visits, a database was developed for data entry during the investigations to ensure that all relevant information was collected at each site. Data were entered using the Environmental Systems Research Institute, Inc. (ESRI) ArcPad software package.

The information collected at all Tier 1 sites during these field investigations included:

- Current stormwater structure conditions;
- Existing site conditions including the presence of any structures, current onsite slope conditions, potential road access issues, and any fences inhibiting access;
- Current land use;
- Neighboring land uses;
- Existing utilities;
- Potential environmental concerns such as wetlands, streams, significant vegetation, habitat, or environmentally sensitive areas;
- Condition of inlet and outlet structures;
- Evidence of maintenance activities that have taken place since last site visit; and
- Photographs of pertinent elements such as inlet and outlet structures.

Additional information collected at each site included information specific to the recommended retrofit type. For example, notes on the area available for the use of pervious pavement or area available for the installation of wet ponds. Data on the specifics of drainage areas and additional issues that could impact the installation of the proposed retrofits were also collected as part of the field investigations.

Once the site visits were completed, the information collected during these visits was compiled into Appendix F – Field Investigation Notes and Appendix G – Draft Site Summary Sheets.

5.3. Modification of Tier 1 Sites

During the field investigation portion of the Study, adjustments to the list of Tier 1 sites, including the proposed retrofits, were made based on site conditions, site restrictions and input from the PCMS4CC representatives. The changes to the list of Tier 1 sites are detailed below for each of the member communities in the PCMS4CC.

5.3.1. Town of Carmel

No changes were made to the retrofit locations and types chosen for the Town of Carmel.

5.3.2. Town of Kent

Several changes were made to the Tier 1 sites chosen for the Town of Kent based on the results of the field investigation. Details for each of the changes are outlined below.

- The retrofit for Kent-PA-04 was originally identified as the repair of an existing detention structure. During the field investigation, no detention structure was found in the field. It was decided that the installation of a wet pond would utilize the available space and mitigate the excessive sediment transport noted at the site.

- The retrofit for Kent-PA-07 was originally identified as the installation of a detention pond with a reroute of drainage from the surrounding area. However, upon visiting the site, it was determined that the site was not feasible for use in the Study. The site was replaced with Kent-PA-31. Kent-PA-31 was chosen by the Town and identified as a problem area for sediment transport. The site is located along the Rte. 52 corridor in front of Putnam Stone and Mason Supply. The installation of a hydrodynamic separator was chosen for the retrofit at this site.

- The retrofit for Kent-PA-08 was originally identified as the installation of a hydrodynamic separator. However, conversations with both the Town Engineer and the Town Supervisor revealed that there is a retrofit already installed at this location. Rather than identifying a new retrofit location, a Tier 2 site was chosen for inclusion in the Tier 1 analysis. Kent-PA-08 was replaced with Kent-PA-12, which was identified as the installation of channel stabilization along a roadway near White Pond. Based on information gathered during the field investigation, the retrofit at this location was changed from the installation of channel stabilization between the outfall and the pond to the installation of a grassed swale upstream of the outfall, prior to crossing under the roadway.

The remaining Tier 1 sites identified in the Town of Kent were left unchanged including: Kent-PA-03, Kent-PA-05, Kent-PA-09, and Kent-PA-13.

5.3.3. Town of Patterson

Several changes were made to the Tier 1 sites chosen for the Town of Patterson based on the results of the field investigation. Details for each of the changes are outlined below.

- The retrofit for Patterson-PA-01 was identified as the installation of a plunge pool. Upon investigation of the site in the field, it was determined that it was not feasible to construct the plunge pool in the identified location. The retrofit site was moved across the road at the suggestion of Mr. Rich Williams, and it was changed to the installation of a grass swale and was renamed Patterson-PA-01B.

- The retrofit for Patterson-PA-02 was identified as the updating of an existing detention pond. The original site location however, was inaccessible. The site was moved across the road to an accessible existing detention pond and was renamed Patterson-PA-02B.

- The retrofit for Patterson PA-03A was identified as the stabilization of the ground surface and the rerouting of the drainage to a new area. During the field investigation, it was determined that there was no need for a retrofit at this location. At the suggestion of Mr. Williams, the site was moved to a nearby vacant property that the drainage from a significant area was routed through and was named Patterson-PA-03C. The retrofit identified for the new site was the installation of a wet detention pond.

- The retrofit identified for Patterson-PA-03B was identified as the replacement of an asphalt swale with an enhanced grass swale. We were unable to locate the original site and were directed to a site nearby where a large scour hole had developed at the outlet of a culvert along the roadway. The new site was identified as Patterson-PA-03D and was assigned the installation of the plunge pool in place of the existing scour hole.

The remaining Tier 1 sites identified in the Town of Patterson were left unchanged including: Patterson-PA-10, Patterson-PA-11, Patterson-PA-12, Patterson-PA-14, Patterson-PA-15, and Patterson-PA-16.

5.3.4. Town of Putnam Valley

No changes were made to the retrofit locations and types chosen for the Town of Putnam Valley.

5.3.5. Town of Southeast

Several changes were made to the Tier 1 sites chosen for the Town of Southeast based on the results of the field investigation. Details for each of the changes are outlined below.

- The retrofit identified for Southeast-PA-05 was identified as the piping of an existing swale that was identified as having erosion issues. During the field investigation, it was determined that piping of the swale would prevent some erosion, but downstream issues would persist. It was decided that alternative retrofits such as the installation of a plunge pool and an enhanced grassed swale would benefit both the site and help to mitigate downstream impacts as well.

- The retrofit identified for Southeast-PA-06 was identified as the installation of a detention pond and the rerouting of the drainage area. During the field investigation, it was determined the original site location was unsuitable for retrofit. The site was relocated on a different area of Seven Oaks Lane at the direction of the Town Engineer and the Town Highway Superintendant. The new location was sited in an existing vacant lot and identified as the installation of a detention pond and the rerouting of a stormwater outlet that collects stormwater from a large developed area. This new site was designated Southeast-PA-06B.

- The retrofit at Southeast-PA-23 was identified as the installation of a wet detention pond. During the field investigation, a dry detention facility was located onsite, and the retrofit type was changed to the updating of an existing detention pond.

The remaining Tier 1 sites identified in the Town of Southeast were left including: Southeast-PA-01, Southeast-PA-15, Southeast-PA-16, Southeast-PA-21, Southeast-PA-24, Southeast-PA-25 and Southeast-PA-26.

The updated Tier 1 retrofit sites are shown in Figure 5-1 are presented in Table 5-2.

Figure 5-1: Revised Tier 1 Sites

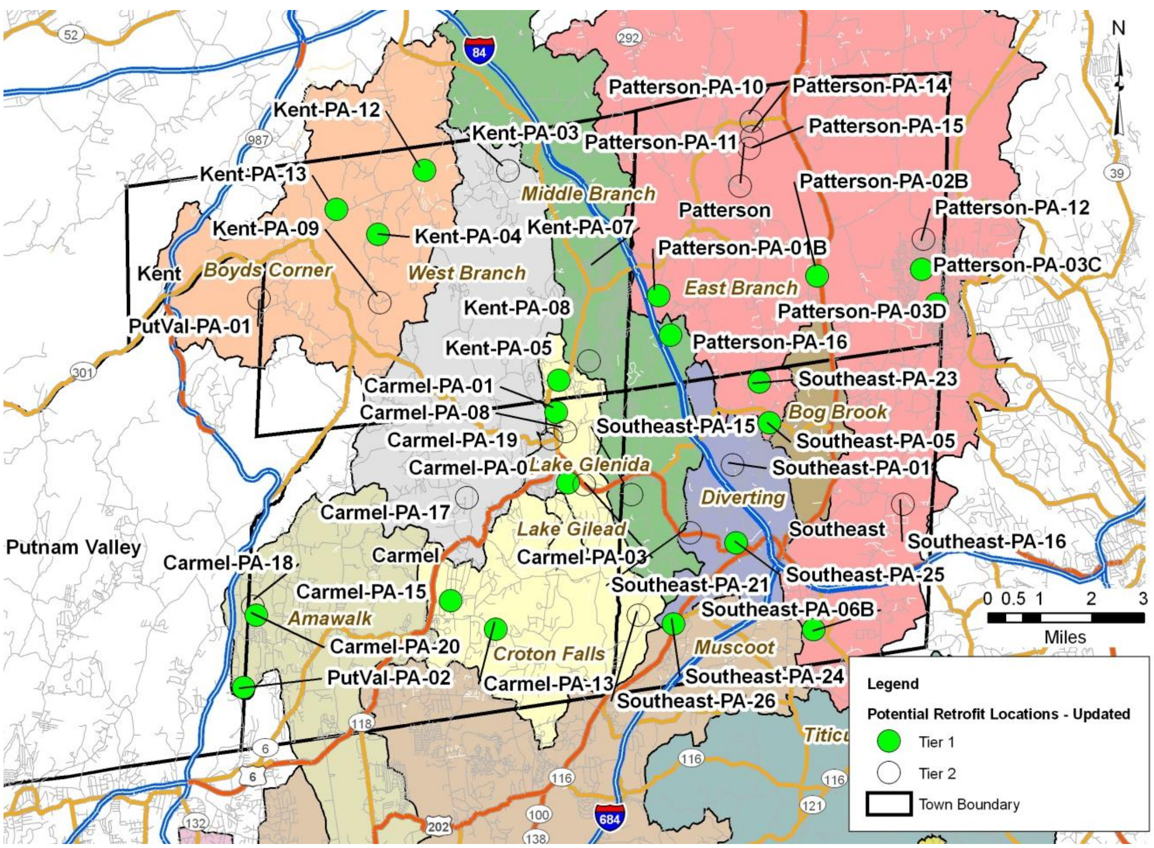


Table 5-2:
Updated Tier 1 Retrofit Sites in the PCMS4CC Study Area

Site ID	Existing Management Practice	Proposed Retrofit
Carmel-PA-01	Wet Pond	Improve existing detention pond
Carmel-PA-07	None	Install detention pond
Carmel-PA-13	Swale	Outfall channel stabilization
Carmel-PA-15	Swale	Outfall channel stabilization
Carmel-PA-20	None	Install detention pond and re-route drainage
Kent-PA-04	None	Improve existing detention pond
Kent-PA-12	None	Install grass swales
Kent-PA-13	None	Install detention pond
Kent-PA-31	None	Install hydrodynamic separator
PutVal-PA-02	Catch Basin	Install deep sump catch basins
Patterson-PA-01B	None	Install grass swales
Patterson-PA-02B	Dry Pond	Improve existing detention pond
Patterson-PA-03C	Catch Basin	Install detention pond
Patterson-PA-03D	None	Install plunge pool
Patterson-PA-16	None	Install cistern
Southeast-PA-05	Swale	Piping of existing swale
Southeast-PA-06B	None	Install detention pond and re-route drainage
Southeast-PA-23	None	Install detention pond
Southeast-PA-24	None	Install grass swales
Southeast-PA-25	None	Replace portion of existing parking lot with pervious pavement

Figure 5-2 and Table 5-3 present the locations and the complete list of the potential retrofit sites (Tier 1 and Tier 2 sites), with site names and addresses. The table incorporates all changes made to Tier 1 and Tier 2 sites based on the field investigations.

Figure 5-2: Revised PCMS4CC Retrofit Locations

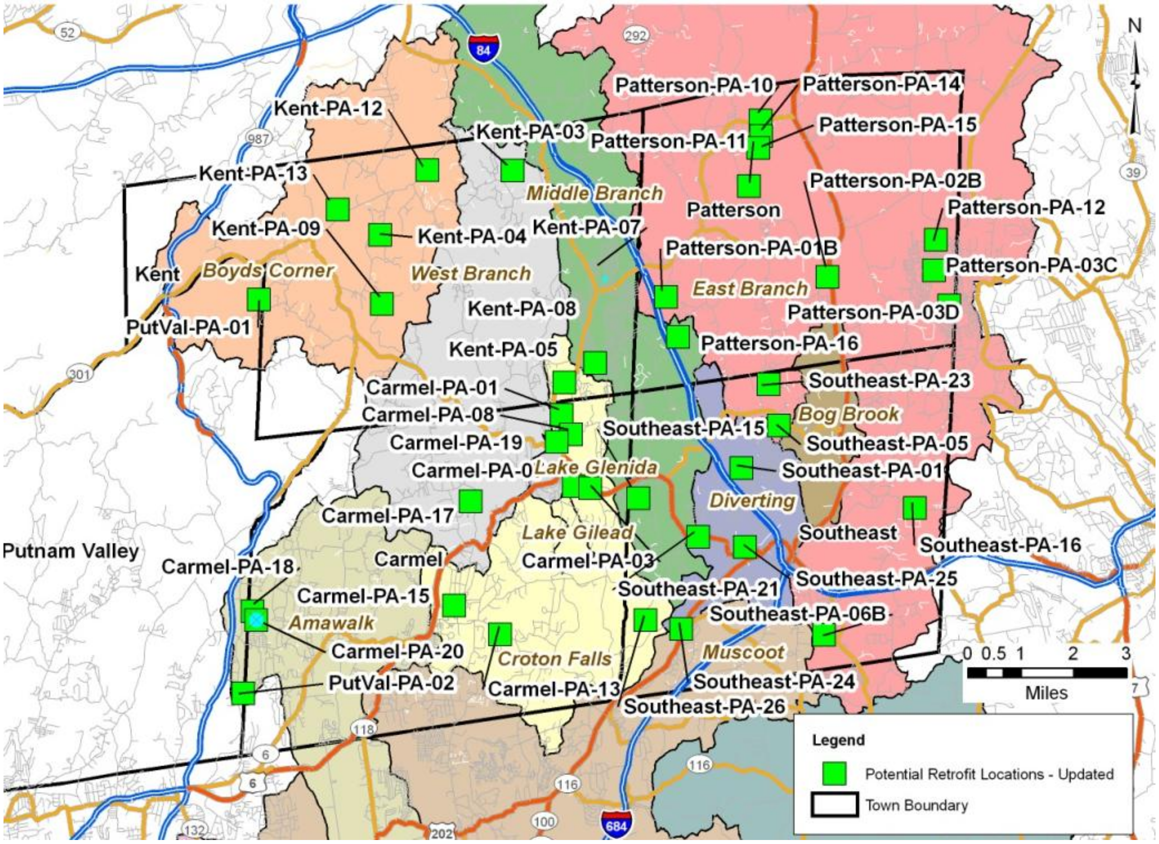


Table 5-3:

Updated Retrofit Sites in the PCMS4CC Study Area

Unique ID	Name	Address
Carmel-PA-01	Rt. 52 ShopRite Center	160 Rt. 52, Carmel
Carmel-PA-03	A+P at Rt. 6	Rt. 6 and Stoneleigh Ave, Carmel
Carmel-PA-07	Arms Acres	75 Seminary Hill Rd, Carmel
Carmel-PA-08	Carmel CSD - High School Campus	30 Fair St, Carmel
Carmel-PA-13	Piggott Sub Div	Piggott Rd N of Circle Ct., Mahopac
Carmel-PA-15	Casse Ct.	Casse Ct., Mahopac
Carmel-PA-17	Ann Rd.	NE corner of Ann Rd., Carmel
Carmel-PA-18	Orchard Rd.	Intersection of North and Orchard Rd., Mahopac
Carmel-PA-19	Lake Gleneida	Corner of Ridge Rd and Fowler Ave, Carmel
Carmel-PA-20	Lake Secor	Birch Rd, Lake Secor, Mahopac
Kent-PA-03	Daffodil/Church	W of Int. of Daffodil Ln. and Church Hill Rd., Kent

Unique ID	Name	Address
Kent-PA-04	Ponderosa/Nimham	Int. of Ponderosa Rd. and Nimham Rd., Kent
Kent-PA-05	S. Lakeshore Dr/Towners	Int. of S. Lakeshore Dr. and Towners Rd., Kent
Kent-PA-09	Cole Shears Ct.	12 Cole Shears Ct., Kent
Kent-PA-12	White Pond	500 White Pond Rd., Kent
Kent-PA-13	Farmers Mills	200 Farmers Mills Rd., Kent
Kent-PA-31	Putnam Stone and Mason Supply	301 Rt. 52, Kent
Patterson-PA-01B	Commerce Drive	Commerce Drive, Patterson
Patterson-PA-02B	Robin Hill Corporate Park	Jon Barret Rd, Patterson
Patterson-PA-03C	Kenton Rd	11 Kenton Rd, Patterson
Patterson-PA-03D	Lake Shore Drive	475 Lake Shore Drive, Patterson
Patterson-PA-10	Town Hall	1142 Rte 311, Patterson
Patterson-PA-11	Cornwall Hill	302 Cornwall Hill Rd., Patterson
Patterson-PA-12	Havilland Church	426 Havilland Dr., Patterson
Patterson-PA-14	Townsend St.	Townsend St., Patterson
Patterson-PA-15	South Street School	South St., Patterson
Patterson-PA-16	Fox Run Condos	Fox Run, Patterson
PutVal-PA-01	Lake Sagamore	208 Old Forge Road, Put Valley
PutVal-PA-02	Greenway Terrace	Greenway Terrace, Put Valley
Southeast-PA-01	Pumphouse Rd.	100 Pumphouse Rd, Brewster
Southeast-PA-05	Overlook Drive	Overlook Drive and Nancy Rd., Brewster
Southeast-PA-06B	Seven Oaks Ln.	44 Seven Oaks Ln., Brewster
Southeast-PA-15	Maple Rd./Ivy Hill Rd.	Intersection of Maple Rd and Ivy Hill Rd, Brewster
Southeast-PA-16	Melrose School	120 Federal Hill Rd., Brewster
Southeast-PA-21	Carmel Ave.	2544 Carmel Avenue, Brewster
Southeast-PA-23	Brewster CSD	54 Foggingtown Rd., Brewster
Southeast-PA-24	Reservoir Staging Area	Intersection of Rt. 22 and Lower Mine Rd, Brewster
Southeast-PA-25	Oak St.	97 Oak St, Brewster
Southeast-PA-26	Croton Res Culvert	150 Reservoir Rd, Brewster
Note – Sites altered from the original site location are italicized in the above table.		

Updated retrofit types are listed in Table 5-4 through Table 5-8. As detailed above, despite the significant number of changes in the locations and types of Tier 1 retrofits, a broad distribution of retrofit types and sizes has been maintained. Furthermore, many of the updated retrofit locations are located near the originally identified locations, maintaining the geographic variability present in the initially identified locations as well.

The maintenance of the geographic variability in the proposed retrofit locations is seen both in Figure 5-1and in the list of basins which each of the potential retrofits fall within.

Table 5-4:
Updated Retrofits for Identified Sites - Town of Carmel

Unique ID	Retrofit Types	Tier	Basin
Carmel-PA-01	Improve Existing Detention Pond	1	Croton Falls
Carmel-PA-03	Install Sand Filter	2	Croton Falls
Carmel-PA-07	Install Detention Pond	1	Croton Falls
Carmel-PA-08	Install Cistern	2	Croton Falls
Carmel-PA-13	Outfall Channel Stabilization	1	Croton Falls
Carmel-PA-15	Outfall Channel Stabilization	1	Croton Falls
Carmel-PA-17	Install Plunge Pool	2	West Branch
Carmel-PA-18	Install Grass Swale	2	Amawalk
Carmel-PA-19	Install Hydrodynamic Separator	2	Croton Falls
Carmel-PA-20	Install Detention Pond, reroute drainage from surrounding area	1	Amawalk

Table 5-5:
Updated Retrofits for Identified Sites - Town of Kent

Unique ID	Retrofit Types	Tier	Basin
Kent-PA-03	Install Plunge Pool	2	West Branch
Kent-PA-04	Install Detention Pond	1	Boyds Corner
Kent-PA-05	Ground Stabilization (erosion id'd)	2	Middle Branch
Kent-PA-09	Install Plunge Pool	2	Boyds Corner
Kent-PA-12	Install Grass Swale	1	Boyds Corner
Kent-PA-13	Install Detention Pond	1	Boyds Corner
Kent-PA-31	Install Hydrodynamic Separator	1	Croton Falls

Table 5-6:
Updated Retrofits for Identified Sites - Town of Patterson

Unique ID	Retrofit Types	Tier	Basin
Patterson-PA-01B	Install Grass Swales	1	East Branch
Patterson-PA-02B	Improve Existing Detention Pond	1	East Branch
Patterson-PA-03C	Install Detention Pond	1	East Branch
Patterson-PA-03D	Install Plunge Pool	1	East Branch
Patterson-PA-10	Install Deep Sump Catch Basins	2	East Branch
Patterson-PA-11	Install Detention Pond	2	East Branch
Patterson-PA-12	Install Grass Swale	2	East Branch
Patterson-PA-14	Improve Existing Detention Pond	2	East Branch
Patterson-PA-15	Install Grass Swale	2	East Branch
Patterson-PA-16	Install Cistern	1	Middle Branch

Table 5-7:
Updated Retrofits for Identified Sites - Town of Putnam Valley

Unique ID	Retrofit Types	Tier	Basin
PutVal-PA-01	Resurface Road Surface and Improve under Drainage	2	Boyds Corner
PutVal-PA-02	Install Deep Sump Catch Basins	1	Amawalk

Table 5-8:
Updated Retrofits for Identified Sites - Town of Southeast

Unique ID	Retrofit Types	Tier	Basin
Southeast-PA-01	Install Plunge Pool	2	Diverting
Southeast-PA-05	Install Plunge Pool and Grass Swale	1	East Branch
Southeast-PA-06B	Install Detention Pond	1	East Branch
Southeast-PA-15	Install Plunge Pool	2	Middle Branch
Southeast-PA-16	Install Cistern	2	East Branch
Southeast-PA-21	Install Deep Sump Catch Basins	2	Diverting
Southeast-PA-23	Improve Existing Detention Pond	1	East Branch
Southeast-PA-24	Install Grass Swales (soil stabilization)	1	Muscoot
Southeast-PA-25	Replace portion of Existing Parking Area with Pervious Pavement	1	Diverting
Southeast-PA-26	Install Plunge Pool	2	Croton Falls

Note – Sites altered from the original retrofit type are italicized in Table 5-4 through Table 5-8

The changes made to the locations of the above retrofits, as well as additional data collected during the field investigations, resulted in the need to update the drainage areas associated with each Tier 1 site. Furthermore, the specification of the site installation locations of the Tier 2 retrofits also resulted in several drainage areas that were required to be updated in the analysis. The updated drainage areas for each of the sites are detailed in Table 5-9 through Table 5-13. Also detailed in these tables are the justifications utilized in the updating of the drainage areas associated with each of the identified retrofit locations. Note that only the sites included in the current Study are included in the table below.

Table 5-9:
Updated Drainage Area Information for Sites Identified for Retrofit Analysis – Town of Carmel

Unique ID	Original Area (Acres)	Updated Area (Acres)	Notes
Carmel-PA-01	50.8	63.0	updated based on outlet location
Carmel-PA-03	20.7	32.1	updated based on outlet location
Carmel-PA-07	15.8	9.4	updated based on outlet location
Carmel-PA-08	2.0	15.7	updated based on outlet location
Carmel-PA-13	21.7	21.7	
Carmel-PA-15	5.9	5.7	updated based on additional site info
Carmel-PA-17	4.1	4.1	
Carmel-PA-18	11.8	9.2	updated based on additional site info
Carmel-PA-19	5.3	5.3	
Carmel-PA-20	15.3	17.0	updated based on outlet location

Table 5-10:
Updated Drainage Area Information for Sites Identified for Retrofit Analysis – Town of Kent

Unique ID	Original Area (Acres)	Updated Area (Acres)	Notes
Kent-PA-03	4.0	4.0	
Kent-PA-04	3.4	33.7	updated based on field visit
Kent-PA-05	3.9	4.1	
Kent-PA-09	2.9	2.9	
Kent-PA-12	22.3	8.4	updated based on outlet location
Kent-PA-13	111.7	38.9	updated based on outlet location
Kent-PA-31	NA	6.0	added site

Table 5-11:
Updated Drainage Area Information for Sites Identified for Retrofit Analysis – Town of Patterson

Unique ID	Original Area (Acres)	Updated Area (Acres)	Notes
Patterson-PA-01B	43.5	41.3	new site location
Patterson-PA-02B	12.6	4.5	new site location
Patterson-PA-03C03C	6.6	15.5	new site location - now C
Patterson-PA-03D03D	3.0	8.8	new site location - now D
Patterson-PA-10	1.6	1.6	
Patterson-PA-11	11.1	12.4	
Patterson-PA-12	2.1	2.1	
Patterson-PA-14	9.1	8.4	updated based on infrastructure
Patterson-PA-15	8.2	8.4	updated after review of contours
Patterson-PA-16	54.9	12.2	updated based on outlet location

Table 5-12:
Updated Drainage Area Information for Sites Identified for Retrofit Analysis – Town of Putnam Valley

Unique ID	Original Area (Acres)	Updated Area (Acres)	Notes
PutVal-PA-01	198.9	3.2	updated after review of contours
PutVal-PA-02	8.7	3.6	updated based on field visit

Table 5-13:
Updated Drainage Area Information for Sites Identified for Retrofit Analysis – Town of Southeast

Unique ID	Original Area (Acres)	Updated Area (Acres)	Notes
Southeast-PA-01	1.5	2.9	updated based on outlet location
Southeast-PA-05	22.8	16.9	new site location
Southeast-PA-06B	48.5	21.7	new site location - now B
Southeast-PA-15	8.6	8.6	
Southeast-PA-16	12.4	12.4	
Southeast-PA-21	17.7	17.7	
Southeast-PA-23	7.3	9.2	updated based on field visit
Southeast-PA-24	1.8	1.8	
Southeast-PA-25	36.2	0.3	updated based on field visit and retrofit type
Southeast-PA-26	4.7	4.7	

In addition to the notes in the table, several assumptions were made when delineating the finalized watershed areas. The retrofit identified for PutVal-PA-01 was the installation of a stable underdrain system along with road surface stabilization. As the stabilized underdrain system will only minimize erosion from a localized area, the contributing area was limited in size to represent the area that would realistically be treated by the installation of a stable underdrain system. It was determined that the area to be treated was approximately 1 percent of the total watershed area of approximately 400 acres.

Similarly, the channel to be stabilized at Southeast-PA-01 carries flow from a lake, into a wetland. As the retrofit is a channel stabilization project, it will not remove additional phosphorus from the water exiting the lake. Therefore, only the watershed area that drains into the channel itself, excluding the area that drains into the lake was included in the area estimation for this location.

5.4. Summary of Field Investigation Findings

As detailed above, several changes were made to both the types and locations of retrofits that were identified and sited during the Tier 1 site investigations. Despite the significant number of changes in the locations and types of Tier 1 retrofits, a broad distribution of retrofit types and sizes has been maintained in the Study. Furthermore, many of the updated retrofit locations are located near the originally identified locations, maintaining the geographic variability present in the initially identified locations as well. When assessing the updated watershed size distribution across the retrofit installation locations, a broad distribution is maintained as well.

Based on the results of the field investigation and the assessment of the Tier 2 site locations, the majority of the proposed retrofit sites are readily accessible for construction purposes. There are a few sites that have minor access problems, including Carmel-PA-01 and Patterson-PA-02B. However, there are also a few sites that have significant access problems including Carmel-PA-17, Kent-PA-03 and Southeast-PA-05.

Several other sites such as Carmel-PA-07 and Southeast-PA-06B are located on private land; however accessing the site once permission is granted will be simple. Additionally, the construction of several of the proposed retrofit sites will impede traffic on public roadways including Carmel-PA-19, Kent-PA-04, PutVal-PA-02 and others. Two sites, Patterson-PA-03D and Southeast-PA-01 are located along the shoreline of a water body, which will require a more delicate approach than the majority of sites during the construction of the proposed retrofits.

6. Conceptual Designs

6.1. Tier 1 Conceptual Designs

The data collected from the field investigations described in Section 5 above was crucial to the development of the conceptual designs as shown in the Site Summary Sheets included in Appendix G. Tier 1 sites included several retrofit types, ranging from the complex (e.g. detention ponds) to simple (e.g. grass swales). The data collected during site visits was used to lay out limits of the retrofits at Tier 1 sites, which provided a more accurate assessment of cost and a more reliable estimate of feasibility considering site limitations such as topography, obstructions, and constructability. Limits of the retrofits to be installed were clearly delineated by GPS data and supplemented with the use of the photographs taken during the field investigation. Another benefit of the field investigations was the ability to discern potential conflicts such as the location of existing utilities that were not visible in the aerial imagery.

There were, however, limitations to the conceptual designs, including the lack of details for sizes of structures. For instance, hydrology of the contributing watershed was not accounted for as part of the conceptual design. Items such as drainage area, land use, and soil types for runoff curve number and time of concentration were not considered to determine retrofit size. Therefore water quality volumes, depths, and areas of pond components were not calculated. Calculation of these items would be required for a final design.

GIS data that were used for the preparation of the Tier 1 Site Summary Sheets included:

- Putnam County property line data;
- Putnam County aerials flown in 2007, 1-foot color resolution. For some of the sites, 2-foot color resolution photographs were used when the 1-foot images were not available;
- Federal and State data of hydrologic features including wetlands and streams;
- Data collected during the field investigations;
- Storm drainage features available for each Town; and
- USGS 5-foot contours.

6.2. The Conceptual Designs for the Tier 2 Sites

Unlike Tier 1 sites, all proposed retrofits were shown based on inspection of the aerial imagery with no site visits conducted at the Tier 2 sites. This drastically limited the reliability of the limits of the structures such as grassed swales and detention ponds. However, most of the Tier 2 sites were simple retrofits such as hydrodynamic separators, grassed swales, and plunge pools. As these sites were point or linear features, it was easier to approximate locations based solely on the limits of the aerial imagery. Unlike the Tier 1 sites, it was not possible to show any potential conflicts other than what was visible from the aerial imagery or to show existing underground or minor drainage conveyances that were not available from the GIS data.

As with the Tier 1 sites, details for sizes of structures were not calculated. For instance, hydrology of the contributory watershed was not accounted for as part of the conceptual design. Items such as drainage area, land use, and soil types for runoff curve number and time of concentration were not considered to determine retrofit size. Therefore water quality volumes, depths, and areas of pond components were not calculated. Calculation of these items would be required for a final design.

GIS data that were used for the preparation of the Tier 2 Site Summary Sheets included:

- Putnam County property line data;
- Putnam County aerials flown in 2007, 1-foot color resolution. For some of the sites, 2-foot color resolution photographs were used when the 1-foot images were not available;
- Federal and State data of hydrologic features including wetlands and streams;
- Storm drainage features available for each Town; and
- USGS 5-foot contours.

7. Phosphorus Removal Estimates

7.1. Phosphorus Loading and Reduction Approach

In order to estimate the potential phosphorus load reduction achieved by each of the proposed stormwater retrofits, both the phosphorus loading from the contributing watersheds as well as the associated phosphorus removal rates achieved by each of the retrofits must be determined.

While the NYSDEC recommends using established programs such as WinSLAMM and WTM to determine the magnitude of the TP loading from the contributing watersheds, as well as the TP removals achieved by each of the identified retrofits, other methods of determining phosphorus removal have also been deemed acceptable. Due to the planning level focus of the Study, specifically the generalized nature of the retrofit designs, the use of WinSLAMM or WTM in the Study was determined not to be feasible, as each requires specific design information that was not developed as a part of this effort. Instead, a more generalized approach was used for determining both the contributing TP load and the associated TP removal capacity for each of the proposed retrofits as detailed below. Through consultation with the NYSDEC, an acceptable approach for the screening level analysis was selected.

7.2. Phosphorus Loading Estimation Methodology

The watershed-based TP loading for each of the proposed retrofits in the Study was determined using The Simple Method to Calculate Urban Stormwater Loads (Simple Method) developed by Schueler (1987). The Simple Method estimates watershed pollutant loads for constituents as a product of annual runoff volume and average observed pollutant concentrations based on annual rainfall, percent impervious cover, the percentage of rainfall events that produce runoff, and the average phosphorus concentration in runoff.

In equation form:

$$L = 2.72(P/12)(P_j)(R_v)(C)(A)$$

L = Annual phosphorus load of the sub-basin (lb/year)

P = Average rainfall (in/year)

P_j = Fraction of Rainfall Events that Produce Runoff

R_v = Runoff coefficient, dimensionless [See Equation 2]

C = Concentration of phosphorus in runoff – flow weighted mean (mg/L)

A = Sub-basin area (acres)

2.72 = Unit conversion factor from (ft*mg/L*acre*yr) to lb/yr

Where the Runoff Coefficient is calculated by the following equation through the (Schueler Relation)

$$R_v = 0.05 + 0.009I$$

R_v = Runoff Coefficient (dimensionless)

I = Site imperviousness (%)

7.2.1. Annual Rainfall

In order to calculate the annual runoff volume routed to each of the proposed retrofit locations, both the average annual rainfall in the Study Area and an estimate of the percent imperviousness in the contributing watersheds were required. The average annual rainfall in the Study Area was determined to be 45 inches (NYCDEP, 1997).

7.2.2. Percent Imperviousness

The percent imperviousness values in the contributing watersheds were determined utilizing the default imperviousness values provided in the Simple Method, which provides default impervious area percentages for generalized land use categories. These default values were used to develop percent imperviousness values for the generalized land uses present in each of the contributing watersheds in the Study Area, Table 7-1.

Table 7-1:
Percent Imperviousness Values for Land Uses in the Study Area

Land Use	Percent Imperviousness (%)[1]
Agriculture	5 [2]
Commercial	85
Forested	5
Residential	20 [3]
Urban	60 [4]
Water	100 [5]

1 - values are default model values from The Simple Method unless otherwise noted
2 - assumed to be the same as forested
3 - based on the average between Low Density and Medium Density Residential Land Use default values
4 - based on Multi-Family Residential imperviousness default value
5 - based off of TR-55 Methodology

7.2.3. Pollutant Loading

The Simple Method provides default pollutant concentrations for generalized land use categories as well. Similar to the development of the percent imperviousness values, the Simple Method default values were utilized to develop average TP concentrations in stormwater for the generalized land uses present in the Study Area, Table 7-2.

Table 7-2:
TP Concentrations in Stormwater for Land Uses in the Study Area

Land Use	TP Concentration (mg/L)[1]
Agriculture	0.4 [2]
Commercial	0.2
Forested	0.15
Residential	0.4
Urban	0.26
Water	0

1 - values are default model values from The Simple Method unless otherwise noted
2 - assumed to be the same as Residential

7.2.4. Study Area Land Use

To determine the percent imperviousness and the average TP concentrations values discussed in Section 7.2.2 and Section 7.2.3 the amount of each type of generalized land use needed to be evaluated.

The land use classifications in each of the contributing watersheds were determined utilizing the Land Use/Land Cover (LU/LC) dataset developed by the New York City Department of Environmental Protection for the East of Hudson watershed in 2001. The resulting land use types in each of the contributing watersheds were then classified into one of the generalized land use categories above utilizing the land use classification matrix provided in Appendix H. The matrix categorizes the land use classification in the 2001 LU/LC data set into the generalized land use categories based on expected behaviors in terms of both percent imperviousness estimates and TP concentrations in stormwater.

Utilizing the Simple Method in conjunction with the above calculations and values, the TP loading from each of the contributing watersheds was determined and are presented by Town in Table 7-3 through Table 7-7.

Table 7-3:
TP Loading Estimates, Town of Carmel

Site ID	Area	TP Load	
	(acre)	(lb/yr)	(kg/yr)
Carmel-PA-01	63.0	35.7	16.2
Carmel-PA-03	32.1	16.4	7.4
Carmel-PA-07	9.4	8.1	3.7
Carmel-PA-08	15.7	17.3	7.8
Carmel-PA-13	21.7	12.3	5.6
Carmel-PA-15	5.7	3.8	1.7
Carmel-PA-17	4.1	3.4	1.5
Carmel-PA-18	9.2	8.2	3.7
Carmel-PA-19	5.3	3.9	1.8
Carmel-PA-20	17.0	10.3	4.7
Total	**183.3**	**119.3**	**54.1**

Table 7-4.
TP Loading Estimates, Town of Kent

Site ID	Area	TP Load	
	(acre)	(lb/yr)	(kg/yr)
Kent-PA-03	4.0	1.0	0.5
Kent-PA-04	33.7	7.0	3.2
Kent-PA-05	4.1	2.8	1.3
Kent-PA-09	2.9	0.4	0.2
Kent-PA-12	8.4	1.5	0.7
Kent-PA-13	38.9	9.9	4.5
Kent-PA-31	6.0	8.3	3.8
Total	**98.0**	**31.0**	**14.1**

Table 7-5:
TP Loading Estimates, Town of Patterson

Site ID	Area	TP Load	
	(acre)	(lb/yr)	(kg/yr)
Patterson-PA-01B	41.3	10.6	4.8
Patterson-PA-02B	4.5	5.8	2.6
Patterson-PA-03C	15.5	9.4	4.3
Patterson-PA-03D	8.8	5.9	2.7
Patterson-PA-10	1.6	2.2	1.0
Patterson-PA-11	12.4	7.9	3.6
Patterson-PA-12	2.1	1.8	0.8
Patterson-PA-14	8.4	7.7	3.5
Patterson-PA-15	8.4	6.1	2.8
Patterson-PA-16	12.2	7.0	3.2
Total	**115.2**	**64.4**	**29.2**

Table 7-6:
TP Loading Estimates, Town of Putnam Valley

Site ID	Area	TP Load	
	(acre)	(lb/yr)	(kg/yr)
PutVal-PA-01	3.2	0.5	0.2
PutVal-PA-02	3.6	2.5	1.1
Total	**6.8**	**3.0**	**1.4**

Table 7-7:
TP Loading Estimates, Town of Southeast

Site ID	Area	TP Load	
	(acre)	(lb/yr)	(kg/yr)
Southeast-PA-01	2.9	1.3	0.6
Southeast-PA-05	16.9	11.3	5.1
Southeast-PA-06B	21.7	12.1	5.5
Southeast-PA-15	8.6	3.3	1.5
Southeast-PA-16	12.4	4.9	2.2
Southeast-PA-21	17.7	9.1	4.1
Southeast-PA-23	9.2	12.1	5.5
Southeast-PA-24	1.8	1.5	0.7
Southeast-PA-25	0.3	0.3	0.2
Southeast-PA-26	4.7	0.9	0.4
Total	**96.2**	**56.8**	**25.8**

As shown above, the proposed retrofit locations are exposed to a total phosphorus load of 124.5 kg/yr (274.6 lb/yr). The retrofits in the Town of Putnam Valley are exposed to the lowest annual TP load of 1.4 kg/yr (3.0 lb/yr) and the retrofits in the Town of Carmel are exposed to the highest annual TP load of 54.1 kg/yr (119.3 lb/yr).

7.3. Phosphorus Removal Estimation Methodology

Once the watershed loadings determined, they were used to estimate the resulting phosphorus removal from each of the proposed retrofits using published removal values for each of the proposed retrofits utilized in the Study. Similar to the estimation of the TP loading to each of the proposed retrofits, a simple approach to determining the TP loading removal achieved by each proposed retrofit. This simple approach was determined to be appropriate for the planning level nature of the Study. As discussed previously, while the NYSDEC recommends using established programs such as WinSLAMM to determine the TP loading reduction, this simple approach was discussed and accepted by the NYSDEC for this screening level study.

Several literature sources were reviewed to determine appropriate TP removal values including:

- Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices;
- Reducing the Impacts of Stormwater Runoff from New Development; and
- The Runoff Reduction Method.

After consultation with the NYSDEC, acceptable values for TP removal were selected. The resulting TP removals associated with each of the retrofit types are shown in Table 7-8. Note that when a proposed retrofit is replacing an existing retrofit, the difference between the two removal rates is used as the estimated TP load reduction rate in the Study.

Table 7-8:
TP Reduction for Potential Retrofit Types

Retrofit Type	TP Load Reduction	Source	Notes
Improve Existing Detention Pond	31%	Reducing the Impacts of Stormwater Runoff from New Development	Wet Pond Removal - Dry Pond Removal
Install Sand Filter	60%	CWP - Runoff Reduction Technical Memo	Filtering Practice
Install Detention Pond	50%	Reducing the Impacts of Stormwater Runoff from New Development	Design 5
Install Cistern	75%	CWP - Runoff Reduction Technical Memo	Rain Tank/Cistern
Outfall Channel Stabilization	20%	CWP - Runoff Reduction Technical Memo	Wet Swale
Install Plunge Pool	50%	Reducing the Impacts of Stormwater Runoff from New Development	assumed to be equivalent to Wet Pond Design 4
Install Grass Swale(s)	30%	Reducing the Impacts of Stormwater Runoff from New Development	Design 14
Install Hydrodynamic Separator	51%	Reducing the Impacts of Stormwater Runoff from New Development	assumed to be equivalent to wet pond based on documented TSS removals
Install Detention Pond, reroute drainage from surrounding area	50%	Reducing the Impacts of Stormwater Runoff from New Development	Design 5
Ground Stabilization	15%	multiple	assumed to be equivalent to lowest presented TP reduction value
Install Deep Sump Catch Basins	15%	multiple	none
Resurface Road Surface and Improve under Drainage	25%	CWP - Runoff Reduction Technical Memo	assumed to be equivalent to outfall channel stabilization plus 5 percent of roadway stabilization
Install Plunge Pool and Grass Swale	65%	Reducing the Impacts of Stormwater Runoff from New Development	analyzed in series, TP*Plunge Pool Removal=TP1 TP1*Grass Swale Removal=TP2
Replace portion of Existing Parking Area with Pervious Pavement	70%	Reducing the Impacts of Stormwater Runoff from New Development	Design 8

7.4. Summary of TP Loading and Predicted TP Reduction

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized by town in Table 7-9 through Table 7-13. The calculation of both the TP loading as well as the associated TP loading reduction achieved at each proposed retrofit location are provided in digital form in Appendix I.

Table 7-9:
TP Loading and Reduction Estimates, Town of Carmel

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Carmel-PA-01	63.0	35.7	16.2	Improve Existing Detention Pond	31	11.1	5.0
Carmel-PA-03	32.1	16.4	7.4	Install Sand Filter	60	9.8	4.5
Carmel-PA-07	9.4	8.1	3.7	Install Detention Pond	50	4.0	1.8
Carmel-PA-08	15.7	17.3	7.8	Install Cistern	75	13.0	5.9
Carmel-PA-13	21.7	12.3	5.6	Outfall Channel Stabilization	20	2.5	1.1
Carmel-PA-15	5.7	3.8	1.7	Outfall Channel Stabilization	20	0.8	0.3
Carmel-PA-17	4.1	3.4	1.5	Install Plunge Pool	50	1.7	0.8
Carmel-PA-18	9.2	8.2	3.7	Install Grass Swale(s)	30	2.5	1.1
Carmel-PA-19	5.3	3.9	1.8	Install Hydrodynamic Separator	51	2.0	0.9
Carmel-PA-20	17.0	10.3	4.7	Install Detention Pond, reroute drainage from surrounding area	50	5.2	2.3
Total	**183.3**	**119.3**	**54.1**			**52.4**	**23.8**

Table 7-10:
TP Loading and Reduction Estimates, Town of Kent

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Kent-PA-03	4.0	1.0	0.5	Install Plunge Pool	50	0.5	0.2
Kent-PA-04	33.7	7.0	3.2	Install Detention Pond	50	3.5	1.6
Kent-PA-05	4.1	2.8	1.3	Ground Stabilization	15	0.4	0.2
Kent-PA-09	2.9	0.4	0.2	Install Plunge Pool	50	0.2	0.1
Kent-PA-12	8.4	1.5	0.7	Install Grass Swale(s)	30	0.5	0.2
Kent-PA-13	38.9	9.9	4.5	Install Detention Pond	50	4.9	2.2
Kent-PA-31	6.0	8.3	3.8	Install Hydrodynamic Separator, Reroute Drainage	51	4.2	1.9
Total	**98.0**	**31.0**	**14.1**			**14.3**	**6.5**

Table 7-11:
TP Loading and Reduction Estimates, Town of Patterson

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Patterson-PA-01B	41.3	10.6	4.8	Install Grass Swale(s)	30	3.2	1.4
Patterson-PA-02B	4.5	5.8	2.6	Improve Existing Detention Pond	31	1.8	0.8
Patterson-PA-03C	15.5	9.4	4.3	Install Detention Pond	50	4.7	2.1
Patterson-PA-03D	8.8	5.9	2.7	Install Plunge Pool	50	2.9	1.3
Patterson-PA-10	1.6	2.2	1.0	Install Deep Sump Catch Basins	15	0.3	0.1
Patterson-PA-11	12.4	7.9	3.6	Install Detention Pond	50	4.0	1.8
Patterson-PA-12	2.1	1.8	0.8	Install Grass Swale(s)	30	0.5	0.2
Patterson-PA-14	8.4	7.7	3.5	Improve Existing Detention Pond	31	2.4	1.1
Patterson-PA-15	8.4	6.1	2.8	Install Grass Swale(s)	30	1.8	0.8
Patterson-PA-16	12.2	7.0	3.2	Install Cistern	75	5.3	2.4
Total	**115.2**	**64.4**	**29.2**			**27.0**	**12.2**

Table 7-12:
TP Loading and Reduction Estimates, Town of Putnam Valley

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
PutVal-PA-01-2	3.2	0.5	0.2	Resurface Road Surface and Improve under Drainage	25	0.1	0.1
PutVal-PA-02	3.6	2.5	1.1	Install Deep Sump Catch Basins	15	0.4	0.2
Total	**6.8**	**3.0**	**1.4**			**0.5**	**0.2**

Table 7-13:
TP Loading and Reduction Estimates, Town of Southeast

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Southeast-PA-01	2.9	1.3	0.6	Install Plunge Pool	50	0.6	0.3
Southeast-PA-05	16.9	11.3	5.1	Install Plunge Pool and Grass Swale	65	7.3	3.3
Southeast-PA-06B	21.7	12.1	5.5	Install Detention Pond	50	6.1	2.8
Southeast-PA-15	8.6	3.3	1.5	Install Plunge Pool	50	1.6	0.7
Southeast-PA-16	12.4	4.9	2.2	Install Cistern	75	3.7	1.7
Southeast-PA-21	17.7	9.1	4.1	Install Deep Sump Catch Basins	15	1.4	0.6
Southeast-PA-23	9.2	12.1	5.5	Improve Existing Detention Pond	31	3.8	1.7
Southeast-PA-24	1.8	1.5	0.7	Install Grass Swale(s)	30	0.5	0.2
Southeast-PA-25	0.3	0.3	0.2	Pervious Pavement	70	0.2	0.1
Southeast-PA-26	4.7	0.9	0.4	Install Plunge Pool	50	0.4	0.2
Total	**96.2**	**56.8**	**25.8**			**25.6**	**11.6**

As shown in Table 7-9 through Table 7-13, if the PCMS4CC enacts all of the proposed retrofits, an estimated TP load reduction of 54.3 kg/yr (119.7 lb/yr) will be achieved. Several important facts can be drawn by the results of the TP loading and associated TP loading reductions calculated above.

- The Town of Carmel will achieve the greatest magnitude of annual TP load reduction of 23.8 kg/yr (52.4 lb/yr);
- The Town of Putnam Valley will achieve the least amount of annual TP load reduction of 0.2 kg/yr (0.5 lb/yr);
- The TP loading reduction requirements required by the EOH Enhanced Phosphorus reduction standards are 154.9 kg/year (341.6 lb/yr) or 31.0 kg/yr (68.3 lb/yr) over each of the next five years (2010-2015)
- The proposed retrofits are shown to achieve approximately 35% of the required TP loading reduction in the area.
- Based on the requirements set forth by the NYSDEC, if all of the proposed retrofits are enacted, the PCMS4CC will achieve slightly less than the requirements of the first two years of TP load reductions.

Additional assessments on the costs of the proposed retrofits and the impacts of the proposed retrofits on the reduction requirements for individual watersheds are detailed in Sections 8 through 10 of this report.

8. Cost Estimates

8.1. Cost Estimate Methodology

Preliminary construction cost estimates have been developed for each of the recommended retrofits at each of the potential retrofit sites along with annual operation and maintenance costs. To assist in the development of the construction capital costs the Association for the Advancement of Cost Engineer's (AACE) International guidelines were utilized. A Class 4 estimating approach was used, which allows for a 30-40% construction cost contingency. Class 4 estimates are usually prepared for detailed strategic planning, project screening, alternative scheme analyses, confirmation of economic and/or technical feasibility, and preliminary budget approval.

These preliminary construction cost estimates include and are based on capital costs to furnish and install retrofit equipment, mobilization, costs to develop the site, installation of equipment/retrofits, site restoration, soil erosion and sediment control, contractor's labor, contractor's overhead and profit and indirect "soft" contract administrative costs (i.e. engineering design, land surveys, permitting, financing fees, legal fees, professional construction administrative services, etc). A 35% construction cost contingency and a compounded 4% escalation factor has been included to each of the potential retrofit sites for year-1 through year-5. Budgetary engineering design cost was calculated by using 15% of the construction budget estimate, 10% for surveying, 10% for environmental permitting, 8% or 20% administrative fee (i.e. financing, legal fees, etc) and 15% for professional construction administrative services. These indirect administrative costs and engineering costs are based on the widely accepted practices, experience and judgments as accepted by the engineering profession in New York State and are in accordance with AACE guidelines.

A compounded 4% escalation factor has also been applied to the annual operation and maintenance for each year. To assist in the development of the annual operation and maintenance costs the New York State Department of Environmental Conservation (NYSDEC) Stormwater Management Design Manual and the Standards for Erosion and Sediment Control Manual were referenced to develop the operation and maintenance costs.

Recent land acquisition costs have been provided by the Town of Southeast. In order to determine the land acquisition costs for this project and to acquire private land it was estimated that $3.58 per square foot be used in determining the cost for half and full-acre sites; $78,000 and $156,000, respectively. The Town of Patterson has provided specific land value data for locations in their portion of the Study Area as well. A compounded 4% escalation factor has also been applied to land acquisition cost for each year.

Note that the costs summarized in Section 8 and discussed in throughout the remainder of this report include land acquisition costs and other fees to install a retrofit on private property. However, depending on how each of the Towns will implement future stormwater programs, these costs could potentially be removed from the cost estimate.

8.2. Cost Estimates

The unit costs utilized for the cost estimation for each of the retrofit installations are shown in Table 8-1. The costs presented in this table are typical values used to assist in determining the estimated construction costs of each retrofit. However, these unit costs fluctuate depending on site specific characteristics and/or retrofit complexity. Additional cost estimation support information is located in Appendix J.

Table 8-1:
Unit Costs Used in Retrofit Construction Cost Estimation

Unit	Cost/Unit
Excavation	$15.00 - $20.00/CY
Hydro Seeding	$3.50 - $5.00/SF
Topsoil (Screened)	$45.00 - $60.00/CY
Concrete (Unreinforced/Reinforced)	$70.00 - $350.00/CY
Rip Rap Stone (3 to 6 inch diameter)	$90.00/CY
Pervious Pavers	$40.00/SF
Soil Erosion & Sediment Control (i.e. hay bales & silt fencing)	$35.00 - $45.00/LF (installed cost)

The costs presented in Table 8-1 were utilized in creating the cost estimates for each of the proposed retrofit installations. Table 8-2 depicts the preliminary construction costs for each site and/or municipality, annual operation and maintenance costs and land acquisition costs for each of the identified potential retrofits. The costs presented in the table are listed with their present day (Year 1) values; costs listed in each of the periods are not the cost per year, but the cost should the retrofit be constructed during that year. Based on the Table, the total costs for all projects can potentially range from $5.87 million in year 1 (assuming all retrofits were installed in Year 1) to a maximum of $6.87 million (assuming all retrofits were installed in Year 5). The costs in Years 2 through 5 reflect a compounded 4% escalation factor, which has been applied to the capital costs, land acquisition costs, and annual operation and maintenance for each year. Detailed cost breakdowns for each site, are provided in Appendix J. The escalated costs are provided to help PCMS4CC realize costs over the period of their 5-year plan.

Table 8-2:
PCMS4CC Potential Retrofit Costs

SITE		RETROFIT TYPE	Estimated Capital Cost (including Administrative Fees)[1]					Budgetary Land Acquisition Costs					Estimated Operations & Maintenance Costs				
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
1	Carmel PA-01	Improve Existing Detention Pond	$ 140,400	$ 146,100	$ 151,800	$ 157,900	$ 164,300	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 5,000	$ 5,200	$ 5,400	$ 5,600	$ 5,800
2	Carmel PA-03	Install Sand Filter	$ 126,700	$ 131,600	$ 136,900	$ 142,400	$ 148,000	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 5,500	$ 5,700	$ 5,900	$ 6,100	$ 6,300
3	Carmel PA-07	Install Detention Pond	$ 133,300	$ 138,600	$ 144,200	$ 150,000	$ 155,900	$ 156,000	$ 162,200	$ 168,700	$ 175,400	$ 182,400	$ 5,200	$ 5,400	$ 5,600	$ 5,800	$ 6,000
4	Carmel PA-08	Install Cistern	$ 60,500	$ 63,000	$ 65,500	$ 68,100	$ 70,900	0	0	0	0	0	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
5	Carmel PA-13	Outfall Channel Stabilization	$ 130,400	$ 135,700	$ 141,000	$ 146,600	$ 152,700	0	0	0	0	0	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
6	Carmel PA-15	Outfall Channel Stabilization	$ 87,000	$ 90,400	$ 93,900	$ 97,700	$ 101,300	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
7	Carmel PA-17	Install Plunge Pool	$ 57,500	$ 59,800	$ 62,100	$ 64,600	$ 66,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
8	Carmel PA-18	Install Grass Swale(s)	$ 69,000	$ 71,600	$ 74,500	$ 77,500	$ 80,700	0	0	0	0	0	$ 3,200	$ 3,300	$ 3,400	$ 3,500	$ 3,600
9	Carmel PA-19	Install Hydrodynamic Separator	$ 77,000	$ 80,100	$ 83,400	$ 86,700	$ 90,200	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 7,600	$ 7,900	$ 8,200	$ 8,500	$ 8,800
10	Carmel PA-20	Install Detention Pond & Reroute Drainage	$ 187,100	$ 194,600	$ 202,300	$ 210,400	$ 218,700	0	0	0	0	0	$ 5,600	$ 5,800	$ 6,000	$ 6,200	$ 6,400
		Subtotal	$ 1,068,900	$ 1,111,500	$ 1,155,600	$ 1,201,900	$ 1,249,600	$ 546,000	$ 567,700	$ 590,200	$ 613,900	$ 638,400	$ 49,700	$ 51,700	$ 53,700	$ 55,700	$ 57,700
11	Kent PA-03	Install Plunge Pool	$ 59,700	$ 62,000	$ 64,500	$ 67,100	$ 69,800	0	0	0	0	0	$ 4,400	$ 4,600	$ 4,800	$ 5,000	$ 5,200
12	Kent PA-04	Install Detention Pond	$ 152,800	$ 158,800	$ 165,200	$ 171,800	$ 178,700	$ 156,000	$ 162,200	$ 168,700	$ 175,400	$ 182,400	$ 7,200	$ 7,500	$ 7,800	$ 8,100	$ 8,400
13	Kent PA-05	Ground Stabilization	$ 63,900	$ 66,500	$ 69,200	$ 72,000	$ 74,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 3,200	$ 3,300	$ 3,400	$ 3,500	$ 3,600
14	Kent PA-09	Install Plunge Pool	$ 61,600	$ 64,200	$ 66,700	$ 69,400	$ 72,400	0	0	0	0	0	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
15	Kent PA-12	Install Grass Swale(s)	$ 105,400	$ 109,500	$ 113,900	$ 118,500	$ 123,000	0	0	0	0	0	$ 5,600	$ 5,800	$ 6,000	$ 6,200	$ 6,400
16	Kent PA-13	Install Detention Pond	$ 128,000	$ 132,900	$ 138,200	$ 143,700	$ 149,300	0	0	0	0	0	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
17	Kent PA-31	Install Hydrodynamic Separator	$ 111,100	$ 115,500	$ 120,000	$ 124,800	$ 129,800	0	0	0	0	0	$ 7,400	$ 7,700	$ 8,000	$ 8,300	$ 8,600
		Subtotal	$ 682,500	$ 709,400	$ 737,700	$ 767,300	$ 797,900	$ 234,000	$ 243,300	$ 253,000	$ 263,100	$ 273,600	$ 36,600	$ 38,100	$ 39,600	$ 41,100	$ 42,600
18	Patterson PA-01B	Install Grass Swale(s)	$ 51,200	$ 53,200	$ 55,400	$ 57,600	$ 59,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
19	Patterson PA-02B	Improve Existing Detention Pond	$ 136,900	$ 142,400	$ 148,000	$ 153,900	$ 159,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
20	Patterson PA-03C	Install Detention Pond	$ 133,100	$ 138,300	$ 143,900	$ 149,700	$ 155,400	$ 15,300	$ 15,900	$ 16,500	$ 17,200	$ 17,900	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
21	Patterson PA-03D	Install Plunge Pool	$ 114,400	$ 119,000	$ 123,800	$ 128,800	$ 133,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
22	Patterson PA-10	Install Deep Sump Catch Basins	$ 73,300	$ 76,200	$ 79,300	$ 82,500	$ 85,800	0	0	0	0	0	$ 2,000	$ 2,100	$ 2,200	$ 2,300	$ 2,400
23	Patterson PA-11	Install Detention Pond	$ 132,600	$ 137,900	$ 143,300	$ 149,000	$ 155,100	0	0	0	0	0	$ 5,500	$ 5,700	$ 5,900	$ 6,100	$ 6,300
24	Patterson PA-12	Install Grass Swale(s)	$ 49,600	$ 51,700	$ 53,700	$ 55,800	$ 58,100	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 2,400	$ 2,500	$ 2,600	$ 2,700	$ 2,800
25	Patterson PA-14	Improve Existing Detention Pond	$ 117,700	$ 122,300	$ 127,200	$ 132,300	$ 137,600	0	0	0	0	0	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
26	Patterson PA-15	Install Grass Swale(s)	$ 104,000	$ 108,100	$ 112,400	$ 116,900	$ 121,400	0	0	0	0	0	$ 4,400	$ 4,600	$ 4,800	$ 5,000	$ 5,200
27	Patterson PA-16	Install Cistern	$ 166,100	$ 172,700	$ 179,600	$ 186,800	$ 194,100	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
		Subtotal	$ 1,078,900	$ 1,121,800	$ 1,166,600	$ 1,213,300	$ 1,261,200	$ 405,300	$ 421,400	$ 438,000	$ 455,700	$ 473,900	$ 41,500	$ 43,300	$ 45,100	$ 46,900	$ 48,700
28	PutVal PA-01	Resurface Roadway & Replace Culvert	$ 203,500	$ 211,600	$ 220,000	$ 228,800	$ 237,900	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,200	$ 4,400	$ 4,600	$ 4,800	$ 5,000
29	PutVal PA-02	Install Deep Sump Catch Basins	$ 237,900	$ 247,500	$ 257,300	$ 267,600	$ 278,400	0	0	0	0	0	$ 5,000	$ 5,200	$ 5,400	$ 5,600	$ 5,800
		Subtotal	$ 441,400	$ 459,100	$ 477,300	$ 496,400	$ 516,300	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 9,200	$ 9,600	$ 10,000	$ 10,400	$ 10,800
30	Southeast PA-01	Install Plunge Pool	$ 58,900	$ 61,300	$ 63,800	$ 66,400	$ 68,900	0	0	0	0	0	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
31	Southeast PA-05	Install Plunge Pool & Grass Swale	$ 99,200	$ 103,100	$ 107,300	$ 111,600	$ 116,000	0	0	0	0	0	$ 5,600	$ 5,800	$ 6,000	$ 6,200	$ 6,400
32	Southeast PA-06B	Install Detention Pond	$ 112,800	$ 117,200	$ 121,800	$ 126,700	$ 131,800	0	0	0	0	0	$ 4,800	$ 5,000	$ 5,200	$ 5,400	$ 5,600
33	Southeast PA-15	Install Plunge Pool	$ 63,000	$ 65,400	$ 68,000	$ 70,700	$ 73,700	0	0	0	0	0	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
34	Southeast PA-16	Install Cistern	$ 49,600	$ 51,700	$ 53,700	$ 55,800	$ 58,100	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
35	Southeast PA-21	Install Deep Sump Catch Basins	$ 179,200	$ 186,300	$ 193,800	$ 201,600	$ 209,700	$ 78,000	$ 81,100	$ 84,300	$ 87,700	$ 91,200	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
36	Southeast PA-23	Improve Existing Detention Pond	$ 127,200	$ 132,400	$ 137,600	$ 143,100	$ 148,700	0	0	0	0	0	$ 5,200	$ 5,400	$ 5,600	$ 5,800	$ 6,000
37	Southeast PA-24	Install Grass Swale(s)	$ 55,500	$ 57,800	$ 60,000	$ 62,400	$ 64,900	0	0	0	0	0	$ 3,200	$ 3,300	$ 3,400	$ 3,500	$ 3,600
38	Southeast PA-25	Install Permeable Pavement	$ 195,100	$ 202,900	$ 211,000	$ 219,400	$ 228,100	0	0	0	0	0	$ 3,600	$ 3,700	$ 3,800	$ 4,000	$ 4,200
39	Southeast PA-26	Install Plunge Pool	$ 63,000	$ 65,400	$ 68,000	$ 70,700	$ 73,700	0	0	0	0	0	$ 4,000	$ 4,200	$ 4,400	$ 4,600	$ 4,800
		Subtotal	$ 1,003,500	$ 1,043,500	$ 1,085,000	$ 1,128,400	$ 1,173,600	$ 156,000	$ 162,200	$ 168,600	$ 175,400	$ 182,400	$ 42,400	$ 44,200	$ 46,000	$ 47,900	$ 49,800
TOTAL PROJECT COSTS			$ 4,275,200	$ 4,445,300	$ 4,622,200	$ 4,807,300	$ 4,998,600	$ 1,419,300	$ 1,475,700	$ 1,534,100	$ 1,595,800	$ 1,659,500	$ 179,400	$ 186,900	$ 194,400	$ 202,000	$ 209,600

[1] Administrative costs include engineering design, land survey, permitting, financing fees, legal fees, professional construction administrative services, etc.

When analyzing the costs of constructing the retrofits proposed in this Study, several important facts can be drawn. All of the below values are based on cost estimates for construction during Year 1 (i.e. all construction occurring in Year 1 or value in "2009 dollars").

- The total cost of constructing the proposed retrofits is approximately $4.28 million;
  - Patterson has the greatest capital costs ($1.08 million);
  - Putnam Valley has the smallest capital costs ($441,400);
- The proposed land acquisition costs across the PCMS4CC Towns in approximately $1.42 million on top of the construction cost estimations;
  - Carmel has the greatest land acquisition costs ($546,000);
  - Putnam Valley has the smallest land acquisition costs ($78,000);
- The total operations and maintenance costs across the PCMS4CC Towns is approximately $179,400
  - Carmel has the greatest operations and maintenance costs ($49,700);
  - Putnam Valley has the smallest operations and maintenance costs ($9,200);

9. Feasibility Matrix

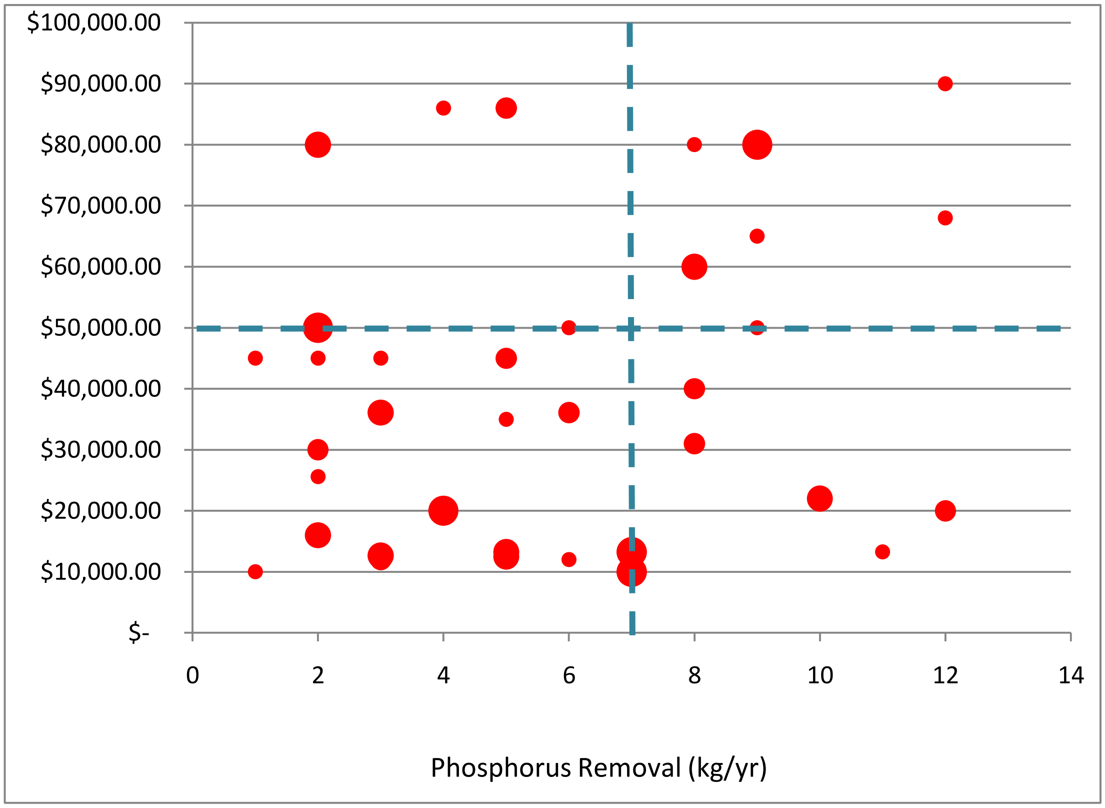
9.1. Feasibility Matrix Methodology

The Phase 2 methodology has been developed to facilitate decision making by PCMS4CC in selecting sites for retrofit implementation as part of their 5-year plan pursuant to their MS4 permit requirements. To do this, a Feasibility Matrix is being developed that focuses on phosphorus removal and associated costs. However, the criteria also include factors accounted for in Phase 1 Ranking as identified in Section 4 of this report and several additional items including visual/aesthetic concerns and public health and safety.

The Feasibility Matrix methodology uses a 3-dimensional approach to presenting the desirability of retrofit placement at each of the 40 sites. Along the two major axes are phosphorus removal (in kg/year) and cost. These items are expected to be estimated for each site based on site characteristics and the recommended retrofit site based off of the site conceptual drawings. The third "axis" represents the Phase 2 score, a value based on several criteria that may indicate the level of public support or opposition that may be encountered to retrofit placement. Figure 9-1 presents a visual example of the resulting Feasibility Matrix. The Phase 2 score is represented in this figure by the size of the dots; larger dots represent sites with a higher score (i.e. higher potential for public support) and smaller dots represent a lower score (i.e. lower potential for public support).

The Feasibility Matrix may be broken down into four quadrants, with the most desirable quadrant being the lower right (I: low cost, high removal) and the least desirable being the upper left (III: low removal, high cost). Several sites are expected to fall in the lower left quadrant (II: low removal, low cost); these sites may be considered the "low-hanging fruit" which may also include sites where time constraints make them more desirable Year 1 sites (sites whose installation will make them readily available for meeting the Year 1 phosphorus reduction requirements). Sites in the upper right quadrant (IV: high removal, high cost) may be required to meet removal requirements.

Figure 9-1: Example Feasibility Matrix



9.2. Phosphorus Removal

Modeling efforts to quantify the amount of phosphorus removed for each of the 40 potential retrofit sites resulted in an estimate of the phosphorus load reduced at each site in kg/year upon completion of retrofit installation. These values were affected by local topography, area available for retrofit placement, retrofit type, upstream drainage area characteristics, and existing stormwater infrastructure type. Phosphorus loading and removal were modeled using the Simple Method and established percent removal criteria for stormwater management practices. The modeling efforts are described in Section 7.

9.3. Cost

As detailed in Section 8, estimates for the cost associated with capital investments as well as operations and maintenance were estimated for each of the 40 potential retrofit sites. These cost estimates account for the type of construction associated with each retrofit type and include factors such as access issues for constructability and site acquisition of private lands.

9.4. Phase 2 Scoring Methodology

As mentioned previously, the Phase 2 score combines some of the Phase 1 criteria, as well as additional visual/aesthetic criteria, as well as public health and safety concerns. The site characteristics used in Phase 2 scoring are described below

9.4.1. Phase 1 Criteria

Several of the Phase 1 criteria directly affect either the phosphorus removal expected from a retrofit site or the cost associated with a retrofit site. For example the drainage area size and percent impervious are critical factors in determining the phosphorus loading and removal associated with potential retrofits. Likewise, ownership type is part of the cost estimates due to the cost of acquiring private properties. To prevent double-counting these factors during the Phase 2 ranking, these parts of the Phase 1 score are "zeroed out" by applying a scalar of 0.

Items that are removed from Phase 2 scoring (i.e. zeroed out) include:

- Drainage area;
- Percent impervious in the drainage area;
- Anticipated capture ratio;
- Existing management practice type;
- Documented source of high phosphorus;
- Ownership type; and
- Current land use.

The remaining Phase 1 criteria retain the values and scalars assigned during Phase 1 scoring. These criteria include:

- Proximity to receiving water,
- Receiving water body class,
- Proximity to wetlands,
- Location within a phosphorus limited basin, and
- Existing TMDL Regulatory Removal Requirements.

Note that while most of the remaining Phase 1 criteria have scalar values of 1, the TMDL regulatory removal requirements criteria had a scalar value of 4 during the Phase 1 ranking. A scalar of 1 is being applied to this and all additional criteria discussed below to provide an equal weighting to all Phase 2 criteria.

9.4.2. Visual Criteria

Visual changes may affect the ability for the PCMS4CC to gain public support for the installation of retrofits that have been identified in this study. The potential visual and aesthetic changes, both positive and negative, are accounted for in the following criteria.

9.4.2.1. Visual Impact – Aesthetics

Some retrofits represent no real visual change to the area and some retrofits represent changes to the area that may be considered positive, negative, or neutral. Visual impact is based on aesthetics and is subjective. However, the general criteria described in Table 9-1 were used to characterize aesthetic visual impact:

Table 9-1:
Visual Impact (Aesthetics) Ranking and Criteria

	Rank
Visible change, negative impact	1
No visible change	2
Visible change, neutral impact	2
Visible change, positive impact	3

Negative impact - constructed retrofit is visible with a decrease in quantity of quality natural vegetation. (Note that this does not include reduction of nuisance plants).

No visible change - retrofit installation will be primarily underground or equivalent visually to the existing conditions (e.g. deep sump catch basins)

Neutral impact - While a change is visible, the amount of disturbed area and general vegetation remain the same.

Positive impact - improvement of natural vegetation or correction of visual blight.

For Tier 2 sites where no field investigation was conducted, the sites were assumed to be in fair condition (i.e. not overgrown, but not pristine).

9.4.2.2. Visual Impact – Affected Residential Population

Public support from residential property owners in close proximity to the potential retrofit site may depend on the number of people in the vicinity of the site. Table 9-2 shows the rankings which were used.

Table 9-2:
Visual Impact (Affected Residential Population) Ranking and Criteria

Population density within 1/4 mile	Rank
Densely populated (=>2000 people/mi2)	1
Moderately populated (500-2000 people/mi2)	2
Sparsely populated (<500 people/mi2)	3

Population density is based on US Census bureau projections from the 2000 survey. Ranges of population densities are based on typical values found for the 1/4 mile buffer of the retrofit site from Census Block Groups.

9.4.2.3. Visual Impact – Affected Commercial Population

The population affected by the placement of a retrofit also includes nearby businesses and their customers. Table 9-3 shows the ranking that were used for the potential visual impact on the commercial population, which may also affect public support. Smaller distances are used to represent the potential concern of business owners on how their revenue may be affected.

Table 9-3:
Visual Impact (Affected Commercial Population)

Distance to Commercial Property	Rank
Within 500 feet	1
500-1000 feet	2
Greater than 1000 feet	3

Distance from a commercial property will be used as an indicator for how many commercial business owners and customers would be affected. Retrofits further from commercial properties are assumed to have less impact on commercial business owners or customers.

9.4.2.4. Visual Impact – Construction

While construction impact is temporary, the inconvenience of changes to traffic patterns may increase public resistance to retrofit construction. Longer durations of construction are associated with lower scores, as being less preferable for retrofit installation. Table 9-4 provides an estimate of the construction time associated with each retrofit. These time frames are an approximate and include the time for mobilization, testing, substantial completion, and final acceptance.

Table 9-4:
Approximate Construction Period by Retrofit Type

Type	Months
Ground Stabilization	3
Improve Existing Detention Pond	3
Install Cistern	4
Install Deep Sump Catch Basins	3
Install Detention Pond	6
Install Detention Pond, reroute drainage from surrounding area	9-12
Install Grass Swales	3
Install Grass Swales (soil stabilization)	3
Install Hydrodynamic Separator	3-6
Install Plunge Pool	3-6
Install Plunge Pool and Grass Swale	3-6
Install Sand Filter	3
Outfall Channel Stabilization	3
Replace portion of Existing Parking Area with Pervious Pavement	1
Resurface Road Surface and Improve under Drainage	3

Table 9-5 shows the ranking that were used for visual impacts due to construction, which are based on expected durations from start to finish (i.e. times including mobilization, testing, substantial completion, and final acceptance). The durations listed in Table 9-5 were based on the typical periods expected for construction, discussed during the process of cost estimates, with the understanding that the durations are estimates based on retrofit type and are not site specific.

Table 9-5:
Visual Impact (Construction) Ranking and Criteria

Duration of Construction	Rank
≥ 6 months	1
3-6 months	2
< 3 months	3

The PCMS4CC may also wish to note that the duration of construction will also affect their efforts in planning construction for retrofit types with higher construction periods, as these retrofits will require a longer lead time before construction is completed and sites may be counted towards MS4 yearly removal requirements.

9.4.3. Public Benefit Criteria

9.4.3.1. Potential Public Benefit – Correct Drainage Problems

During the process of identifying 40 potential retrofit sites, the PCMS4CC members identified several sites with known existing drainage problems or issues. These sites were noted as having flooding/erosion/design failure issues and score with a higher priority for retrofits. Table 9-6 shows the ranking that was used for sites with known drainage problems.

Table 9-6:
Potential Public Benefit (Existing Drainage) Ranking and Criteria

Existing Drainage Problem	Rank
No problem identified	1
Flooding/erosion/design failure Identified by town	4

9.4.3.2. Potential Public Benefit – Treatment of Multiple Pollutants

While the pollutant of interest for this study is phosphorus, removal of additional pollutants may be beneficial. Retrofit types with the ability to remove additional pollutants receive higher scores.

Estimates for the amount of additional pollutants removed by each retrofit type are provided in Table 9-7. Pollutants examined included total nitrogen, bacteria, metals, and pesticides. The sum of the percent removal for each of the additional pollutants, shown in the Total column, was used as an indicator of the overall potential to remove additional pollutants. Note that the removal of these additional pollutants is not modeled in this study.

Table 9-7:
Retrofit Types and Treatment of Multiple Pollutants

BMP Type	TN	Bacteria	Metals	Pesticides[a]	Total
HDS	5%[b]	0%[b]	10%[b]	17%	32%
Channel Stabilization	5%[c]	0%[c]	10%[c]	17%	32%
Deep Sump Catch Basins	5%[c]	0%[c]	10%[c]	17%	32%
WQ Swale	30%[d]	10%[d]	10%[d]	17%	67%
Plunge Pool	30%[d]	0%	30%[d]	17%	77%
Dry Water Quantity Pond	30%[d]	0%[c]	50%[d]	17%	97%
Dry Facilities	30%[e]	0%[c]	50%[e]	17%	97%
Cistern	25%	60%	50%[d]	17%	152%
Wet Pond	30%[d]	70%[f]	70%[d]	17%	187%
Wetland	30%[g]	70%[g]	70%[d]	17%	187%
Filters	50%[d]	37%[h]	90%[d]	34%	211%
Infiltration	70%[d]	90%[d]	70%[d]	83%	313%
Porous Pavement	70%[d]	90%[d]	90%[d]	83%	333%

a – Values based on mid-point of ranges found in CalTrans Treatment BMP Technology Report (2007)
b – Data from NJCAT Technology Verification (2005)
c – Values assumed to be equal to lowest literature value compared to other retrofits
d – Values from NYSDEC, Reducing the Impacts of Stormwater runoff from New Development (1993)
e – Values assumed to be equivalent to Dry Pond
f – Values as listed in WTM (Caraco, 2002)
g – Values assumed to be equivalent to Wet Pond
h – Values assumed to be equivalent to Infiltration

Table 9-8 shows the ranking based on a retrofit type's ability to remove additional pollutants.

Table 9-8:
Potential Public Benefit (Pollutant Treatment) Ranking and Criteria

Capability of Retrofit to Treat Pollutants	Rank
Treats Phosphorus and TSS and minimal amounts of additional pollutants (Total < 50)	1
Reduces low-moderate amounts of additional pollutants (Total 50-175)	2
Reduces moderate-high amounts of additional pollutants (Total > 175)	3

9.4.4. Health and Safety Criteria

Standing water may be perceived as a public health concern as a breeding ground for mosquitoes, which may affect the ability to gain public support for retrofit installation. For this reason, sites which eliminate standing water score higher (more preferable) for retrofit placement. Table 9-9 shows the ranking that were assigned to sites based on the perceived potential to affect public health.

Table 9-9:
Health and Safety Impacts Ranking and Criteria

Status of Standing Water	Rank
Standing water added	1
No standing water	2
Existing standing water corrected	3

Note that with good maintenance or other measures, the potential impact of standing water on public health may be mitigated.

9.4.5. Local Permitting Criteria

Local permitting criteria may affect the time required for planning and installation of retrofits, as well as the land available for retrofit placement. The PCMS4CC representatives were asked to indicate if any local permitting issues such a setbacks or other zoning or permitting requirements would affect the placement or final design of retrofits at each site. The feedback received from the PCMS4CC representatives were incorporated into the ranking.

Table 9-10 shows the ranking that was applied to each site based on the comments received from the PCMS4CC representatives. Note that state and federal permit requirements should be investigated for all sites selected by PCMS4CC for retrofit installation and that state and federal permit requirements for each site are assumed to be equal and are therefore not ranked or scored. Also note that all sites fall within the NYCDEP East of Hudson Watersheds and would therefore be subject to review by the NYCDEP.

Table 9-10:
Local Permitting Issues Ranking and Criteria

Local Permitting Issues	Rank
No local permitting issues anticipated	3
Potential local permitting issues	1

9.5. Phase 2 Scoring

The results of the Phase 2 scoring methodology are presented by Town in Table 9-11 through Table 9-15. As discussed in Section Phase 1 Criteria, the effect of scalars has been removed in the Phase 2 ranking by applying a scalar of 1 to all criteria included in the Phase 2 scoring. The results of the Phase 2 scoring are applied in the Feasibility Matrix discussed in Section 10.1.

Table 9-11:
Phase 2 Scoring by Potential Retrofit Site – Town of Carmel

Unique ID	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Visual Impact – Aesthetics	Visual Impact – Affected Residential Population	Visual Impact – Affected Commercial Population	Visual Impact – Construction	Potential Public Benefit – Correct Drainage Problems	Potential Public Benefit – Treatment of Multiple Pollutants	Health and Safety Criteria	Local Permitting Criteria	Phase 2 Score
Carmel-PA-01	3	1	3	2	3	2	1	3	1	3	1	3	**26**
Carmel-PA-03	1	2	3	2	2	2	1	3	1	3	2	3	**25**
Carmel-PA-07	1	3	3	2	1	2	1	1	1	3	1	3	**22**
Carmel-PA-08	3	2	3	2	2	2	1	2	1	2	2	3	**25**
Carmel-PA-13	3	3	3	2	1	2	3	3	1	1	2	3	**27**
Carmel-PA-15	1	3	2	2	3	2	2	3	1	1	2	1	**23**
Carmel-PA-17	1	3	3	2	1	1	3	2	1	2	1	3	**23**
Carmel-PA-18	1	1	3	1	2	2	3	3	1	2	2	3	**24**
Carmel-PA-19	3	3	2	2	2	2	1	2	1	1	2	1	**22**
Carmel-PA-20	3	3	1	1	1	3	3	1	1	3	2	1	**23**

Table 9-12:
Phase 2 Scoring by Potential Retrofit Site – Town of Kent

Unique ID	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Visual Impact – Aesthetics	Visual Impact – Affected Residential Population	Visual Impact – Affected Commercial Population	Visual Impact – Construction	Potential Public Benefit – Correct Drainage Problems	Potential Public Benefit – Treatment of Multiple Pollutants	Health and Safety Criteria	Local Permitting Criteria	Phase 2 Score
Kent-PA-03	3	1	3	2	1	1	3	3	4	1	2	3	**27**
Kent-PA-04	1	1	3	2	1	1	3	1	4	3	1	3	**24**
Kent-PA-05	3	1	3	1	1	3	1	3	4	2	2	3	**27**
Kent-PA-09	3	1	2	2	1	1	3	2	4	2	1	1	**23**
Kent-PA-12	3	3	1	2	2	1	3	3	1	2	2	1	**24**
Kent-PA-13	3	1	3	2	2	1	3	1	1	3	2	3	**25**
Kent-PA-31	3	2	2	2	2	2	1	2	4	1	3	1	**25**

Table 9-13:
Phase 2 Scoring by Potential Retrofit Site – Town of Patterson

Unique ID	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Visual Impact – Aesthetics	Visual Impact – Affected Residential Population	Visual Impact – Affected Commercial Population	Visual Impact – Construction	Potential Public Benefit – Correct Drainage Problems	Potential Public Benefit – Treatment of Multiple Pollutants	Health and Safety Criteria	Local Permitting Criteria	Phase 2 Score
Patterson-PA-01B	3	2	1	2	2	1	1	3	1	2	2	1	**21**
Patterson-PA-02B	3	1	3	1	2	1	1	3	1	3	1	3	**23**
Patterson-PA-03C	3	2	1	3	2	3	3	1	4	3	1	1	**27**
Patterson-PA-03D	3	1	1	3	3	3	3	2	4	2	1	1	**27**
Patterson-PA-10	3	1	3	3	2	2	1	3	1	1	1	3	**24**
Patterson-PA-11	3	2	2	3	2	1	1	1	1	3	1	1	**21**
Patterson-PA-12	3	1	3	3	2	3	1	3	1	2	2	3	**27**
Patterson-PA-14	3	1	3	3	2	2	1	3	1	3	2	3	**27**
Patterson-PA-15	1	1	3	3	2	2	1	3	1	2	2	3	**24**
Patterson-PA-16	3	1	3	3	2	1	3	2	1	2	2	3	**26**

Table 9-14:
Phase 2 Scoring by Potential Retrofit Site – Town of Putnam Valley

Unique ID	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Visual Impact – Aesthetics	Visual Impact – Affected Residential Population	Visual Impact – Affected Commercial Population	Visual Impact – Construction	Potential Public Benefit – Correct Drainage Problems	Potential Public Benefit – Treatment of Multiple Pollutants	Health and Safety Criteria	Local Permitting Criteria	Phase 2 Score
PutVal-PA-01	3	1	3	3	1	1	3	3	4	1	3	3	**29**
PutVal-PA-02	3	1	1	1	2	2	3	3	1	1	1	1	**20**

Table 9-15:
Phase 2 Scoring by Potential Retrofit Site – Town of Southeast

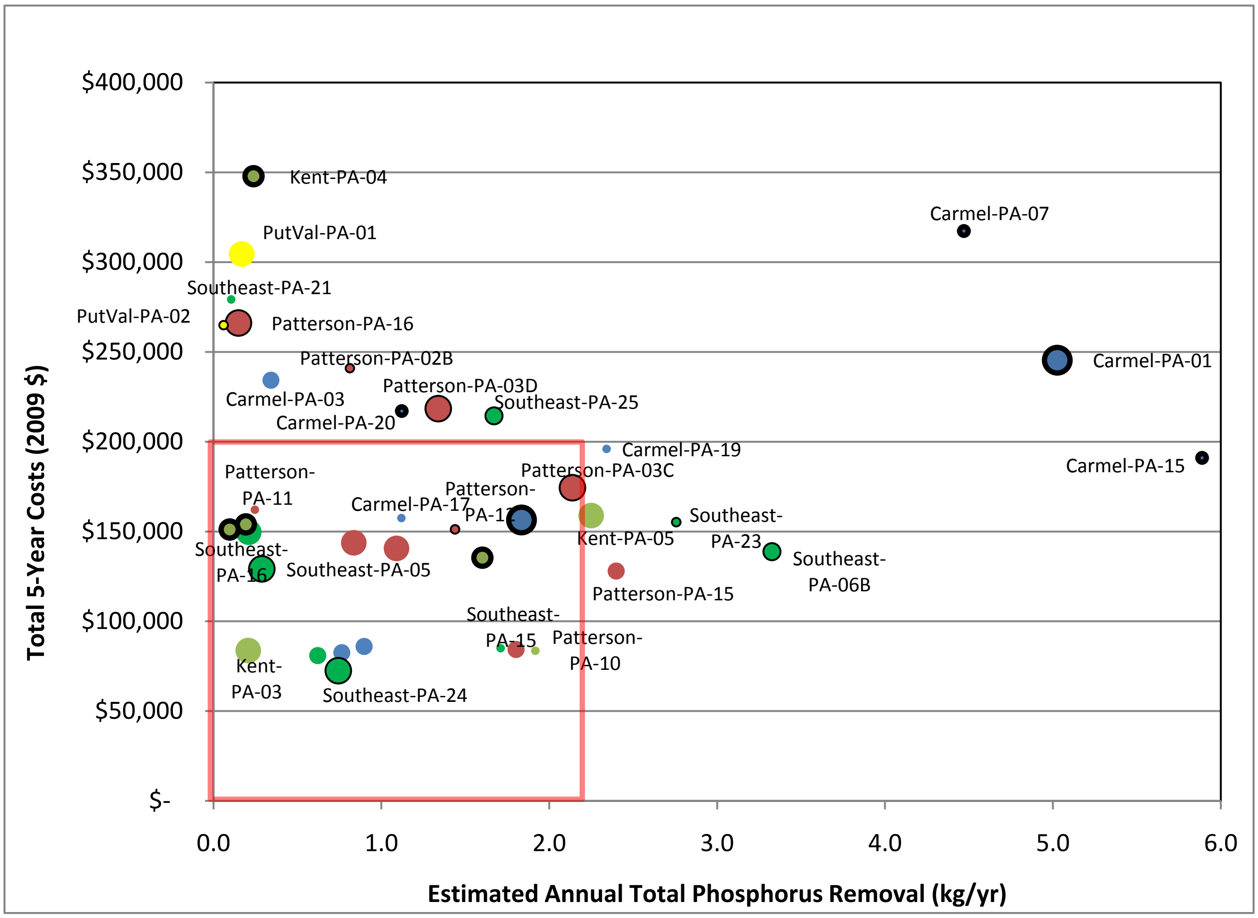
Unique ID	Proximity to Receiving Water	Receiving Water Body Class	Proximity to Wetlands or Wetlands Buffer	Existing TMDL Removal Requirements	Visual Impact – Aesthetics	Visual Impact – Affected Residential Population	Visual Impact – Affected Commercial Population	Visual Impact – Construction	Potential Public Benefit – Correct Drainage Problems	Potential Public Benefit – Treatment of Multiple Pollutants	Health and Safety Criteria	Local Permitting Criteria	Phase 2 Score
Southeast-PA-01	3	1	3	3	1	3	3	3	1	1	2	1	**25**
Southeast-PA-05	1	1	3	3	2	3	3	2	4	2	2	3	**29**
Southeast-PA-06B	3	1	1	4	1	1	3	1	4	3	1	1	**24**
Southeast-PA-15	3	4	1	1	1	2	3	3	1	1	2	1	**23**
Southeast-PA-16	3	1	3	3	2	1	1	2	4	2	2	3	**27**
Southeast-PA-21	3	3	1	3	2	1	1	3	1	1	1	1	**21**
Southeast-PA-23	3	1	1	3	2	1	1	3	1	3	1	1	**21**
Southeast-PA-24	3	3	3	4	2	1	3	3	1	2	2	3	**30**
Southeast-PA-25	3	1	2	3	2	3	1	3	1	3	2	1	**25**
Southeast-PA-26	3	3	3	2	1	1	3	2	1	2	1	3	**25**

When analyzing the Phase 2 scoring above, it is shown that range of the total scores varies from 20 (PutValley-PA-02) to 30 (Southeast-PA-24). Retrofit locations with higher Phase 2 scores are more likely to indicate a higher level of public support for retrofit placement due to the retrofit directly benefiting the public in terms of health and safety concerns, while impacting them minimally in terms of their obstruction both during construction as well as for the life of the retrofit. Alternatively, retrofit locations with a low score are less likely to achieve public support of retrofit placement due to the lack of perceived benefit the public in terms of health and safety and will likely impact the lives of the neighboring area adversely, either during construction, for the life of the retrofit or both.

10.1. Feasibility Matrix Results

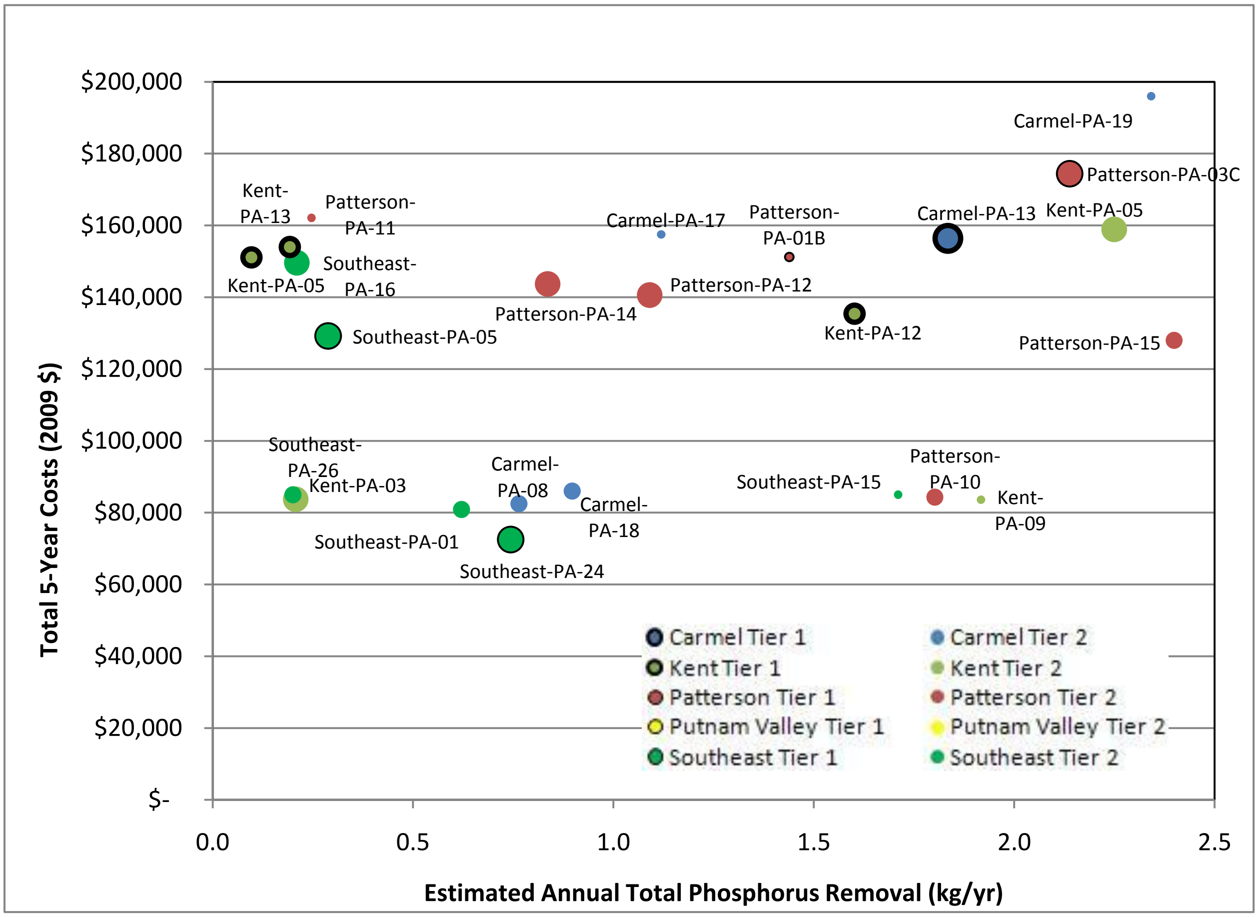
The feasibility matrix described in Section 9 is shown in Figure 10-1 and Figure 10-2. The estimated phosphorus removal is shown along the x-axis. The cost, shown on the y-axis, is based on the total cost of the retrofit over 5 years, assuming it is installed in Year 1; it is the sum of the current value (Year 1) capital and land acquisition costs, as well as the total cost to maintain the retrofit for a period of 5-years.

Figure 10-1: Feasibility Matrix by Phase 2 Ranking



Several retrofits fall in the lower left portion of the graph, outlined by the red box in Figure 10-1. Due to the dense number of points, these retrofits are not labeled in Figure 10-1; they are shown and labeled by site number in Figure 10-2. These retrofits represent relatively low removals at low costs.

Figure 10-2: Feasibility Matrix by Phase 2 Ranking (Detail)



For potential retrofit sites falling on private lands, the cost for land acquisition represents a significant portion of the overall estimated cost. The Towns may elect to pursue acquisition of the land through eminent domain or other means. Figure 10-3 and Figure 10-4 show the revised feasibility matrix should they pursue this course.

Figure 10-3: Feasibility Matrix by Phase 2 Ranking (No Land Acquisition)

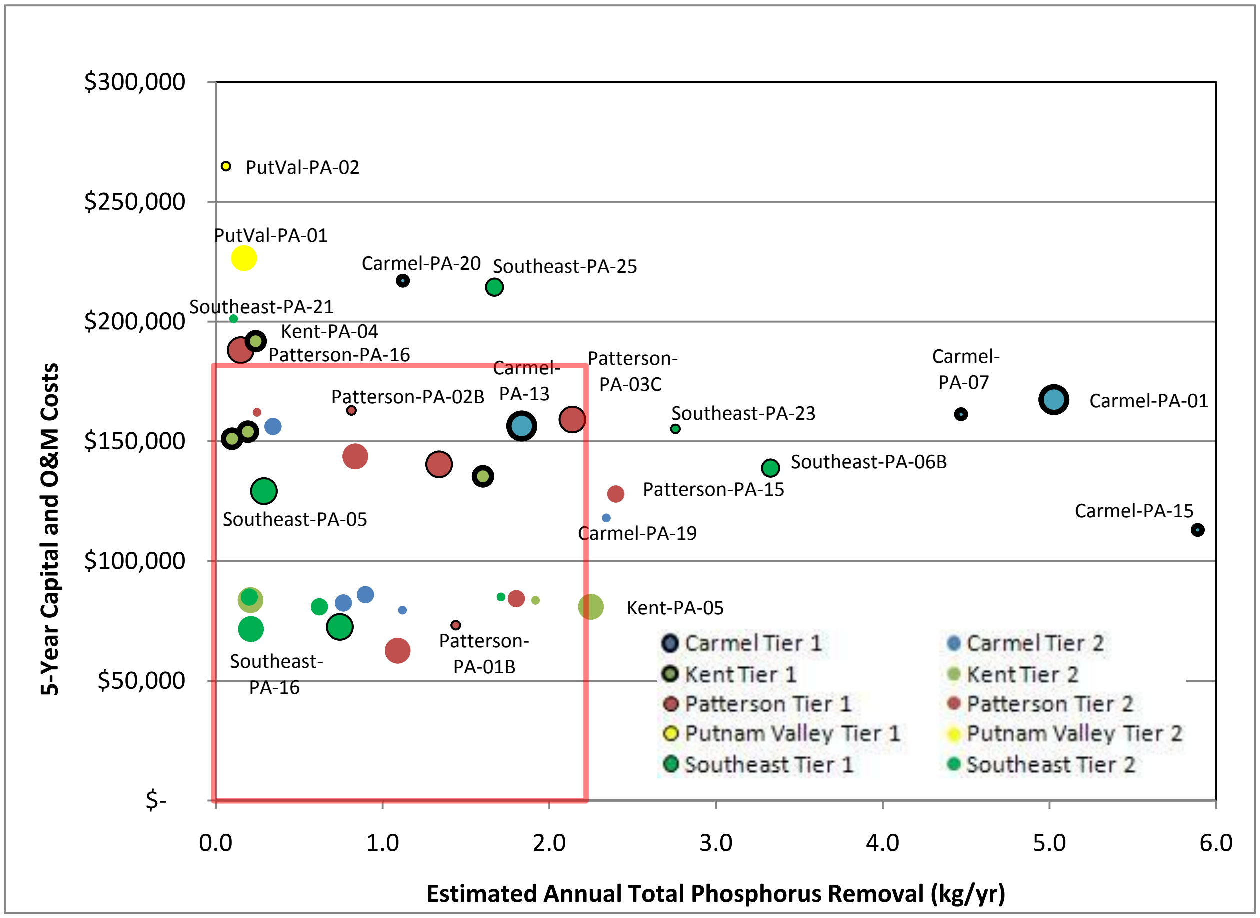
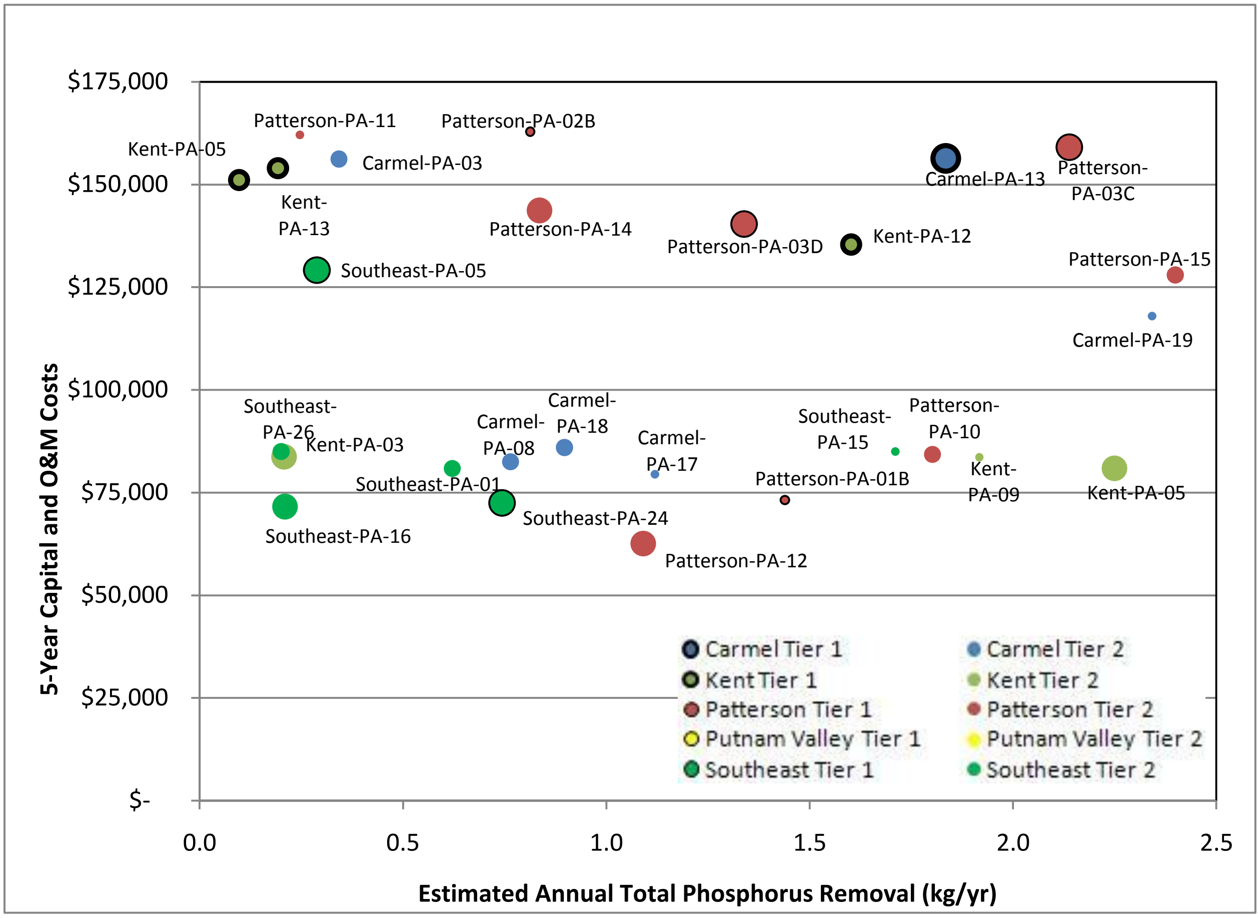


Figure 10-4: Feasibility Matrix by Phase 2 Ranking (No Land Acquisition, Detail)



As discussed in Section 9.1, the most cost effective removal is associated with potential retrofits falling in the lower right portion of the charts (high removal, low cost). A more detailed discussion of phosphorus removal and associated costs are found below in Section 10.2.

10.2. Phosphorus Removal and Cost Analysis

The annual TP removals achieved by each of the proposed retrofits in the Study Area are presented in Table 10-1. The removals are separated by type and organized by increasing contributing area for a given retrofit type.

As shown in the table below, as the contributing area increases, the amount of TP removal typically increases as well. However, variations in contributing area land use distribution and associated TP loading patterns allow for variation in the typically upward trend between drainage area size and associated TP removal.

Table 10-1:
TP Removal Achieved by Each Retrofit Type

Retrofit	TP Removal (lb)	TP Removal (kg)	Drainage Area (acre)	Site ID
Ground Stabilization	0.4	0.2	4.1	Kent-PA-05
Improve Existing Detention Pond	1.8	0.8	4.5	Patterson-PA-02B
	2.4	1.1	8.4	Patterson-PA-14
	3.8	1.7	9.2	Southeast-PA-23
	11.1	5.0	63.0	Carmel-PA-01
Install Cistern	5.3	2.4	12.2	Patterson-PA-16
	3.7	1.7	12.4	Southeast-PA-16
	13.0	5.9	15.7	Carmel-PA-08
Install Deep Sump Catch Basins	0.3	0.1	1.6	Patterson-PA-10
	0.4	0.2	3.6	PutVal-PA-02
	1.4	0.6	17.7	Southeast-PA-21
Install Detention Pond	4.0	1.8	9.4	Carmel-PA-07
	4.0	1.8	12.4	Patterson-PA-11
	4.7	2.1	15.5	Patterson-PA-03C
	5.2	2.3	17.0	Carmel-PA-20
	6.1	2.8	21.7	Southeast-PA-06B
	3.5	1.6	33.7	Kent-PA-04
	4.9	2.2	38.9	Kent-PA-13
Install Grass Swale(s)	0.5	0.2	1.8	Southeast-PA-24
	0.5	0.2	2.1	Patterson-PA-12
	0.5	0.2	8.4	Kent-PA-12
	1.8	0.8	8.4	Patterson-PA-15
	2.5	1.1	9.2	Carmel-PA-18
	3.2	1.4	41.3	Patterson-PA-01B
Install Hydrodynamic Separator	2.0	0.9	5.3	Carmel-PA-19
	4.2	1.9	6.0	Kent-PA-31

Retrofit	TP Removal (lb)	TP Removal (kg)	Drainage Area (acre)	Site ID
Install Plunge Pool	0.2	0.1	2.9	Kent-PA-09
	0.6	0.3	2.9	Southeast-PA-01
	0.5	0.2	4.0	Kent-PA-03
	1.7	0.8	4.1	Carmel-PA-17
	0.4	0.2	4.7	Southeast-PA-26
	1.6	0.7	8.6	Southeast-PA-15
	2.9	1.3	8.8	Patterson-PA-03D
Install Plunge Pool and Grass Swale	7.3	3.3	16.9	Southeast-PA-05
Install Sand Filter	9.8	4.5	32.1	Carmel-PA-03
Outfall Channel Stabilization	0.8	0.3	5.7	Carmel-PA-15
	2.5	1.1	21.7	Carmel-PA-13
Replace portion of Existing Parking Area with Pervious Pavement	0.2	0.1	0.3	Southeast-PA-25
Resurface Road Surface and Improve under Drainage	0.1	0.1	3.2	PutVal-PA-01

10.2.1. Costs per TP Removal Assessment

The costs per pound of TP removal achieved by each of the proposed retrofits are presented in Table 10-2. The capital cost of each of the proposed retrofits for Year 1 was normalized by the TP removal achieved at each of the retrofit sites, creating a Cost per TP load removal estimate for each of the proposed retrofit types.

It is important to note that in the table below, several retrofits were not estimated to remove one (1) pound or more of phosphorus, eliminating the ability in the table to directly compare contributing areas and cost. For example, the table does not state that it will cost $150,960 to remove a pound of TP with a ground stabilization project that has a 4.1 acre contributing area. Instead, drainage areas are included in the table for comparative purposes between the same type of retrofits that have varying contributing areas and associated TP removal.

As shown in the table, there is a significant range of costs that are associated with TP removal in the Study Area achieved by the proposed retrofits. The costs are impacted by numerous factors including site accessibility, required construction techniques, and unit costs, all which impact the associated cost of installation of a given retrofit. When looking at the costs of TP removal for a given retrofit type, it is shown that, in general, as the contributing areas increases, the cost per pound of TP removal decreases.

Table 10-2:
Cost per TP Removal Achieved by Each Retrofit Type

Retrofit	Cost / TP Removal ($/lb) [1]	Cost / TP Removal ($/kg)	Drainage Area (acre)	Site ID
Ground Stabilization	150,960	332,866	4.1	Kent-PA-05
Improve Existing Detention Pond	76,561	168,817	4.5	Patterson-PA-02B
	49,063	108,183	8.4	Patterson-PA-14
	33,804	74,538	9.2	Southeast-PA-23
	12,697	27,997	63.0	Carmel-PA-01
Install Cistern	31,472	69,395	12.2	Patterson-PA-16
	13,493	29,751	12.4	Southeast-PA-16
	4,670	10,296	15.7	Carmel-PA-08
Install Deep Sump Catch Basins	223,908	493,718	1.6	Patterson-PA-10
	641,612	1,414,755	3.6	PutVal-PA-02
	131,181	289,254	17.7	Southeast-PA-21
Install Detention Pond	33,029	72,829	9.4	Carmel-PA-07
	33,448	73,752	12.4	Patterson-PA-11
	28,290	62,380	15.5	Patterson-PA-03C
	36,317	80,079	17.0	Carmel-PA-20
	18,601	41,016	21.7	Southeast-PA-06B
	43,360	95,610	33.7	Kent-PA-04
	25,863	57,029	38.9	Kent-PA-13
Install Grass Swale(s)	120,041	264,691	1.8	Southeast-PA-24
	91,449	201,646	2.1	Patterson-PA-12
	230,990	509,334	8.4	Kent-PA-12
	56,554	124,702	8.4	Patterson-PA-15
	28,022	61,788	9.2	Carmel-PA-18
	16,175	35,666	41.3	Patterson-PA-01B

Retrofit	Cost / TP Removal ($/lb) [1]	Cost / TP Removal ($/kg)	Drainage Area (acre)	Site ID
Install Hydrodynamic Separator	39,018	86,035	5.3	Carmel-PA-19
	26,342	58,085	6.0	Kent-PA-31
Install Plunge Pool	288,897	637,017	2.9	Kent-PA-09
	92,931	204,912	2.9	Southeast-PA-01
	113,721	250,756	4.0	Kent-PA-03
	34,195	75,400	4.1	Carmel-PA-17
	142,933	315,168	4.7	Southeast-PA-26
	38,515	84,926	8.6	Southeast-PA-15
	38,846	85,656	8.8	Patterson-PA-03D
Install Plunge Pool and Grass Swale	13,553	29,884	16.9	Southeast-PA-05
Install Sand Filter	12,884	28,409	32.1	Carmel-PA-03
Outfall Channel Stabilization	115,501	254,681	5.7	Carmel-PA-15
	52,854	116,544	21.7	Carmel-PA-13
Replace portion of Existing Parking Area with Pervious Pavement	837,506	1,846,700	0.3	Southeast-PA-25
Resurface Road Surface and Improve under Drainage	1,532,820	3,379,868	3.2	PutVal-PA-01

1 – Only capital costs were used in the assessment of the Cost per TP removal calculations. O+M and Acquisition costs are not included in the above assessment.

10.2.2. Achievement of Removal Goals by Town

As described in Section 1.2, the annual phosphorus removal minimum threshold for approvable plan is 31.0 kg/yr for the PCMS4CC area. Over the course of 5 years, this would total a required phosphorus removal of 154.9 kg/yr. As shown in Table 10-3, the sites identified in this report represent sufficient removal to cover almost two years of the 5-year plan. Additional retrofit sites would need to be identified in order to address the 5-year phosphorus removal requirement.

Table 10-3:
Estimated Phosphorus Loading and Required Removal by Town

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Carmel	379 (836)	14.4 (31.8)	72.0 (158.8)	26.3 (58.1)	45.7 (100.7)
Kent	188 (415)	6.7 (14.8)	33.6 (74.1)	7.2 (15.9)	26.4 (58.2)
Patterson	111 (245)	3.4 (7.5)	17.2 (37.9)	13.6 (29.9)	3.6 (8.0)
Putnam Valley	5 (11)	0.2 (0.4)	1.0 (2.2)	0.3 (0.6)	0.7 (1.6)
Southeast	221 (487)	6.2 (13.7)	31.1 (68.6)	12.9 (28.4)	18.2 (40.2)
Total	904 (1993)	31.0 (68.3)	154.9 (341.6)	54.3 (119.7)	100.6 (221.8)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

10.2.3. Phosphorus Removal by Town and Basin

Table 10-4 through Table 10-8 summarizes the estimated phosphorus removal per basin associated with of the potential retrofit sites included in this study. The amount of modeled load by the NYSDEC (January 2009a) is also shown in Table 10-4 through Table 10-8, with the percent reduction in load estimated should all potential retrofits in this study be implemented.

Table 10-4:
Estimated Phosphorus Removal by Subbasin - Town of Carmel

Basin	Modeled HID P-Load by Town and Watershed Basin	Estimated Removals for Potential Sites (kg/yr)	Percent of Modeled Load removed
Middle Branch	5	-	0%
West Branch	30	0.8	3%
Muscoot	48	-	0%
Croton Falls	106	19.6	18%
Amawalk	190	3.5	2%
Total	379	23.8	6%

Table 10-5:
Estimated Phosphorus Removal by Subbasin - Town of Kent

Basin	Modeled HID P-Load by Town and Watershed Basin	Estimated Removals for Potential Sites (kg/yr)	Percent of Modeled Load removed
Middle Branch	88	0.2	0%
East Branch	1	-	0%
West Branch	36	0.2	1%
Croton Falls	25	1.9	8%
Boyds Corners	38	4.2	11%
Total	188	6.5	3%

Table 10-6:
Estimated Phosphorus Removal by Subbasin - Town of Patterson

Basin	Modeled HID P-Load by Town and Watershed Basin	Estimated Removals for Potential Sites (kg/yr)	Percent of Modeled Load removed
Middle Branch	12	2.4	20%
East Branch	98	9.9	10%
Bog Brook	1	-	0%
Total	111	12.3	11%

Table 10-7:
Estimated Phosphorus Removal by Subbasin - Town of Putnam Valley

Basin	Modeled HID P-Load by Town and Watershed Basin	Estimated Removals for Potential Sites (kg/yr)	Percent of Modeled Load removed
Amawalk	0	0.2	-
Boyds Corners	5	0.1	1%
Total	5	0.2	5%

Table 10-8:
Estimated Phosphorus Removal by Subbasin - Town of Southeast

Basin	Modeled HID P-Load by Town and Watershed Basin	Estimated Removals for Potential Sites (kg/yr)	Percent of Modeled Load removed
Middle Branch	45	0.7	2%
East Branch	39	9.5	24%
Muscoot	34	0.2	1%
Croton Falls	2	0.2	10%
Diverting	98	1.0	1%
Bog Brook	3	-	0%
Total	221	11.6	5%

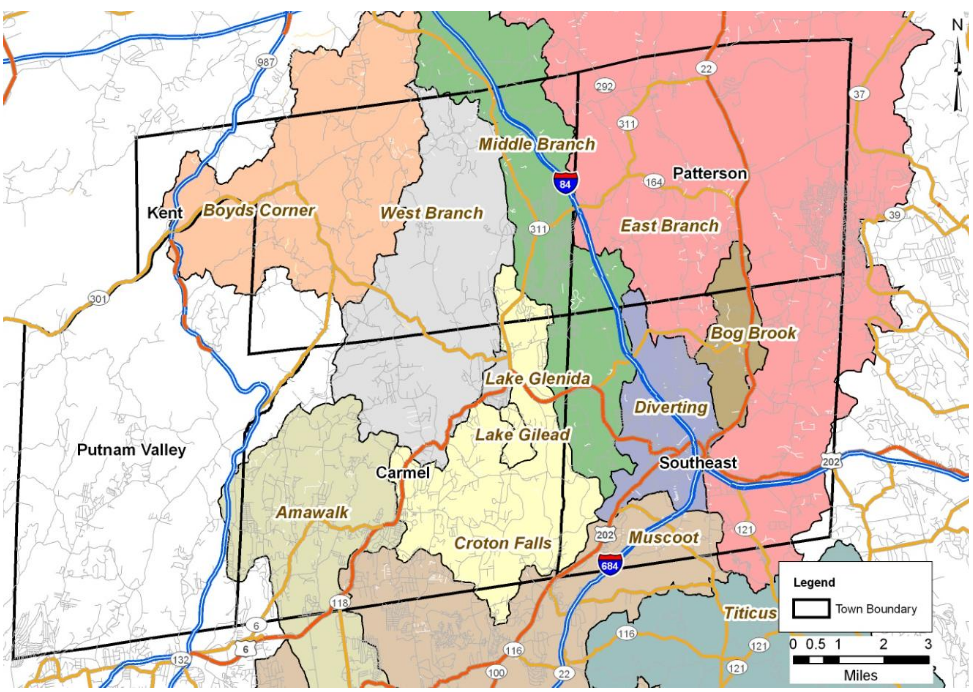
- Utilizing the results of the above analyses, several conclusions can be drawn regarding the outcome of the Study. As shown in the analysis above, there are several potential retrofit sites that are classified as having a low cost and a high removal rate. Two examples of low cost and high removal potential retrofit sites are:
  - Patterson-PA-15; and
  - Southeast-PA-06B
- There are several sites that are classified as having a high cost and a low removal rate. Three examples of high cost and low removal potential retrofit sites are:
  - Kent-PA-04
  - Southeast-PA-21
  - PutVal-PA-01
- There is a general trend in the data that shows that the larger the drainage area to a proposed retrofit, the greater the amount of TP can be removed from the area.
  - There are variables that impact this trend such as land use distribution and associated percent imperviousness values.
- There is a general trend in the data that shows that for a given retrofit, the larger the contributing drainage area, the lower the cost per pound of phosphorus removed from the system.
  - There are variables that impact this trend including land use distributions and construction limitations

11. Findings and Recommendations

11.1. Summary of Findings

The intent of this Stormwater Improvement Study (Study) is to identify costs and develop preliminary designs for water quality improvement features which could potentially be installed (retrofit) within the Study Area. These phosphorus loads have been identified in the Total Maximum Daily Loads (TMDLs) for Reservoirs in the New York City Water Supply Watershed Report prepared by the New York State Department of Environmental Conservation (NYSDEC). The Study is intended to support the participating municipality's compliance with the TMDL as well as the requirements listed in the State Pollution Discharge Elimination System (SPDES) General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s). The locations of the PCMS4CC communities along with the associated EOH Reservoir watersheds are presented in Figure 11-1.

Figure 11-1: PCMS4CC Stormwater Retrofit Study Area



The NYSDEC goals for phosphorus removal in the NYCDEP East of Hudson Watershed are provided in the Croton Watershed Phase II Phosphorus TMDL Implementation Plan. The phosphorus loading and associated reduction goals are summarized in Table 11-1.

Table 11-1:
HID P-Loading and Associated Reduction Requirements for Retrofit Program in kg/yr (lb/yr)

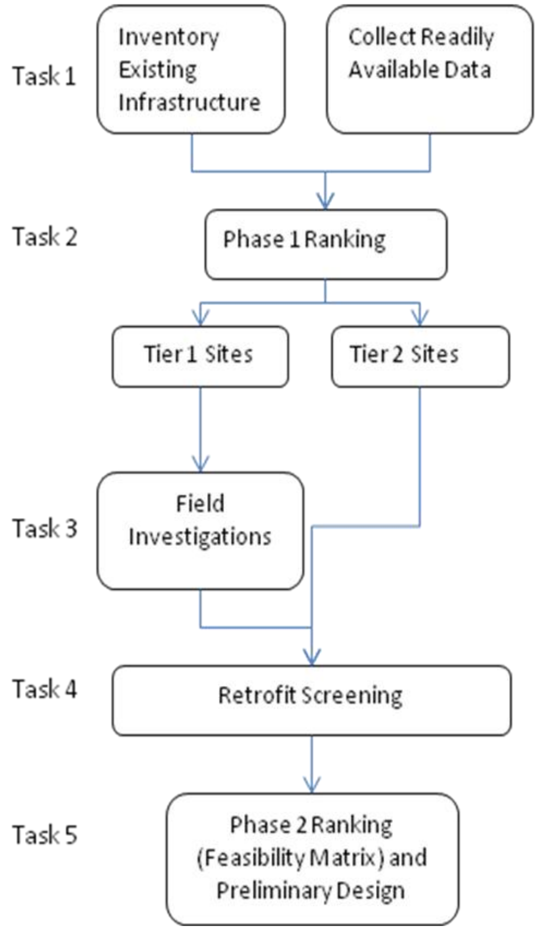
	Total Modeled HID Load[1]	Annual Load Reduction[2]	5-Year Load Reduction[2]
Carmel	379 (836)	14.4 (31.8)	72.0 (158.8)
Kent	188 (415)	6.7 (14.8)	33.6 (74.1)
Patterson	111 (245)	3.4 (7.5)	17.2 (37.9)
Putnam Valley	5 (11)	0.2 (0.4)	1.0 (2.2)
Southeast	221 (487)	6.2 (13.7)	31.1 (68.6)
Total	904 (1993)	31.0 (68.3)	154.9 (341.6)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

The Study was divided into five tasks as shown in Figure 11-2.

- Task 1 involved collecting all available stormwater infrastructure data and creating a Study Area wide database for use in the assessment as detailed in Section 2.

Figure 11-2: Flow Chart of the Procedure used in the PCMS4CC Stormwater Improvement Study

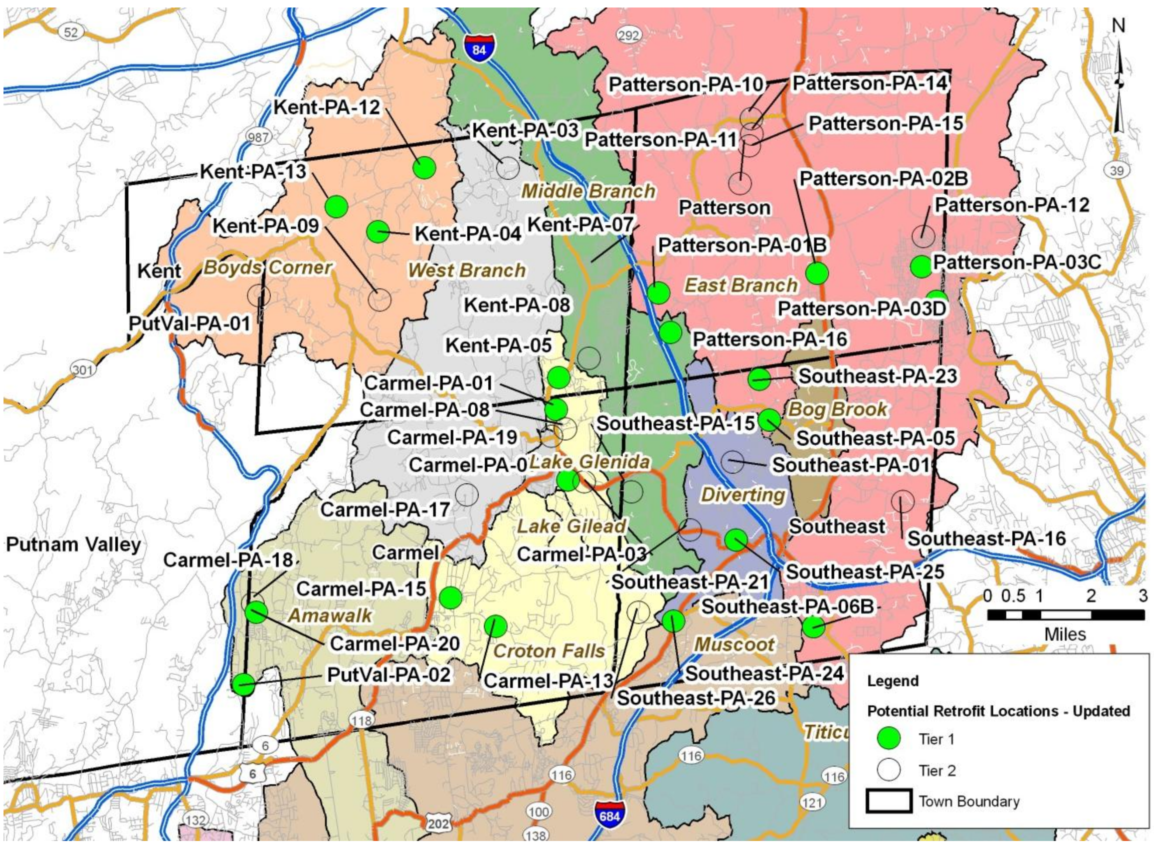


- Utilizing the data collected during Task 1, forty sites across the Study Area were identified and then ranked at a screening level based on site and drainage area characteristics as part of Task 2, summarized in Section 3.
  - Proposed retrofit locations were chosen such that each of the reservoir watersheds in the EOH system that are occupied by the PCMS4CC Communities was included in the Study.
  - The type of retrofit chosen for each potential location was selected such that the assessment would provide a broad range of retrofit types, contributing watershed sizes and contributing watershed land use distributions, allowing for the extrapolation of costs and effectiveness of the potential retrofits to additional locations if desired by the PCMS4CC.
  - The screening level ranking, described as Phase 1 ranking, helped determine which 20 of the 40 proposed sites were best suited for field investigations and

additional feasibility evaluations (Tier 1 sites) and are detailed in Section 4 of this report.

- Field investigations were conducted in July 2009 at the Tier 1 sites as part of Task 3 of the Study and the findings are included in Section 5 of this report.
  - It should be noted that during the field investigations at the Tier 1 sites, several changes were made to the list of potential sites based on conditions observed in the field; these changes are also described in this report.
  - The resulting Tier 1 and Tier 2 proposed retrofit locations are presented in Figure 11-3.

Figure 11-3: Revised Tier 1 and Tier 2 Proposed Retrofit Sites



- Task 4 of the Study involved the development of draft conceptual designs and associated total phosphorus (TP) load removals for each of the potential retrofit locations in the Study as detailed in Section 6 and Section 7 of this report respectively.

  - The phosphorus loading at each of the proposed retrofit locations was estimated utilizing the The Simple Method to Calculate Urban Stormwater Loads (Simple Method) developed by Schueler (1987).
  - The phosphorus load reduction associated with each of the proposed retrofit types as detailed in Table 7-8, were estimated based on published removal rates.
  - Task 4 also included the calculation of the estimated costs associated with the proposed retrofits detailed in Section 8 of this report.
    - The cost estimates are provided for each of the identified potential retrofit sites, based on the selected retrofit type at each location.
      - These include estimates of capital costs, as well as operations and maintenance costs.
- Task 5 involved the development of a feasibility matrix for each of the proposed stormwater retrofits, allowing the PCMS4CC to be able to determine which retrofits were the most feasible.
  - Factors included in the feasibility matrix include, but are not limited to: proximity to receiving water and associated water body class, existing TMDL requirements, visual impacts, potential public benefits and potential health and safety impacts of each retrofit.
  - The feasibility rankings allow for a municipality to determine the potential impacts of the construction of each of the retrofits, and when necessary may help to choose one over another, when all other factors are equal.
  - The ranking methodology for the Phase 2 ranking is detailed in Section 9, while the results of the Phase 2 ranking are included in Section 10.
    - Section 10 of the report also includes a discussion of the total potential phosphorus removal estimated based on the potential retrofit sites and how that relates to the phosphorus removal goals, based on NYSDEC guidance.

11.1.1. Town of Carmel – Phosphorus Loading, Reduction and Cost Assessment

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized in Table 11-2. As shown, if all of the proposed retrofits are installed, the Town of Carmel will achieve a phosphorus reduction of 23.8 kg/yr (52.4 lb/yr).

Table 11-2:
TP Loading and Reduction Estimates, Town of Carmel

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Carmel-PA-01	63.0	35.7	16.2	Improve Existing Detention Pond	31	11.1	5.0
Carmel-PA-03	32.1	16.4	7.4	Install Sand Filter	60	9.8	4.5
Carmel-PA-07	9.4	8.1	3.7	Install Detention Pond	50	4.0	1.8
Carmel-PA-08	15.7	17.3	7.8	Install Cistern	75	13.0	5.9
Carmel-PA-13	21.7	12.3	5.6	Outfall Channel Stabilization	20	2.5	1.1
Carmel-PA-15	5.7	3.8	1.7	Outfall Channel Stabilization	20	0.8	0.3
Carmel-PA-17	4.1	3.4	1.5	Install Plunge Pool	50	1.7	0.8
Carmel-PA-18	9.2	8.2	3.7	Install Grass Swale(s)	30	2.5	1.1
Carmel-PA-19	5.3	3.9	1.8	Install Hydrodynamic Separator	51	2.0	0.9
Carmel-PA-20	17.0	10.3	4.7	Install Detention Pond, reroute drainage from surrounding area	50	5.2	2.3
Total	**183.3**	**119.3**	**54.1**			**52.4**	**23.8**

The costs associated with the installation of the proposed retrofits in Year 1 are summarized in Table 11-3. As shown, the proposed retrofits will cost the Town approximately $1.07 million in capital costs and $546,000 in land acquisition costs for a total of $1.61 million with an additional $50,000/yr in maintenance costs.

Table 11-3:
Town of Carmel Potential Retrofit Costs

SITE	RETROFIT TYPE	Year 1 Values		
		Capital Cost	Land Acquisition Costs	Estimated Annual Operations & Maintenance Costs
Carmel PA-01	Modify Existing Detention Pond	**$140,400**	**$78,000**	**$5,000**
Carmel PA-03	Install Sand Filter	**$126,700**	**$78,000**	**$5,500**
Carmel PA-07	Install Detention Pond	**$133,300**	**$156,000**	**$5,200**
Carmel PA-08	Install Cistern	**$60,500**	**-**	**$4,000**
Carmel PA-13	Install Grass Swale & Rip Rap Check Dam	**$130,400**	-	**$4,800**
Carmel PA-15	Install Grass Swale & Rip Rap Check Dam	**$87,000**	**$78,000**	**$4,800**
Carmel PA-17	Install Plunge Pool	**$57,500**	**$78,000**	**$4,000**
Carmel PA-18	Install Grass Swale	**$69,000**	-	**$3,200**
Carmel PA-19	Install Hydrodynamic Separator	**$77,000**	**$78,000**	**$7,600**
Carmel PA-20	Install Detention Pond	**$187,100**	-	**$5,600**
Total Town of Carmel		**$1,068,900**	**$546,000**	**$49,700**

The required total phosphorus load reductions along with the estimated removals achieved by the retrofits for the Town of Carmel as well as the remaining phosphorus reduction required in the Town are presented in Table 11-4. As shown, the proposed retrofits achieve 23.8 kg/yr (52.4 lb/yr) of phosphorus reduction, or approximately 33% of the five-year TP reduction requirements in the Town. Additionally, the installation of the proposed retrofits will allow the Town to achieve less than the requirements of the first two years of the phosphorus reduction requirements.

Table 11-4:
Town of Carmel Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Carmel	379 (836)	14.4 (31.8)	72.0 (158.8)	23.8 (52.4)	48.2 (106.4)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Based on the tables above, the Town of Carmel will need to reduce their annual phosphorus loading by an additional 48.2 kg/yr (106.4 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was estimated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the Town of Carmel will need to spend an additional $ 5.06 million on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

11.1.2. Town of Kent – Phosphorus Loading, Reduction and Cost Assessment

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized in Table 11-5. As shown, the Town of Kent will achieve a phosphorus reduction of 6.5 kg/yr (14.3 lb/yr), if all of the proposed retrofits are installed.

Table 11-5:
TP Loading and Reduction Estimates, Town of Kent

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Kent-PA-03	4.0	1.0	0.5	Install Plunge Pool	50	0.5	0.2
Kent-PA-04	33.7	7.0	3.2	Install Detention Pond	50	3.5	1.6
Kent-PA-05	4.1	2.8	1.3	Ground Stabilization	15	0.4	0.2
Kent-PA-09	2.9	0.4	0.2	Install Plunge Pool	50	0.2	0.1
Kent-PA-12	8.4	1.5	0.7	Install Grass Swale(s)	30	0.5	0.2
Kent-PA-13	38.9	9.9	4.5	Install Detention Pond	50	4.9	2.2
Kent-PA-31	6.0	8.3	3.8	Install Hydrodynamic Separator, Reroute Drainage	51	4.2	1.9
Total	**98.0**	**31.0**	**14.1**			**14.3**	**6.5**

The costs associated with the installation of the proposed retrofits are summarized in Table 11-6. As shown, the proposed retrofits will cost the Town approximately $683,000 in capital costs and $234,000 in land acquisition costs for a total of $917,000 with an additional $37,000/yr in maintenance costs.

Table 11-6:
Town of Kent Potential Retrofit Costs

SITE	RETROFIT TYPE	Year 1 Values		
		Capital Cost	Land Acquisition Costs	Estimated Annual Operations & Maintenance Costs
Kent PA-03	Install Plunge Pool & Check Dam	**$59,700**	**-**	**$4,400**
Kent PA-04	Install Detention Pond	**$152,800**	**$156,000**	**$7,200**
Kent PA-05	Install Stabilization Fabric	**$63,900**	**$78,000**	**$3,200**
Kent PA-09	Install Plunge Pool	**$61,600**	**-**	**$4,000**
Kent PA-12	Install Enhanced Swale	**$105,400**	**-**	**$5,600**
Kent PA-13	Install Detention Pond	**$128,000**	**-**	**$4,800**
Kent PA-31	Install Hydrodynamic Separator, Reroute Drainage	**$111,100**	**-**	**$7,400**
Total Town of Kent		**$682,500**	**$234,000**	**$36,600**

The required total phosphorus load reductions along with the estimated removals achieved by the retrofits for the Town of Kent as well as the remaining phosphorus reduction required in the Town are presented in Table 11-7. As shown, the proposed retrofits achieve 6.5 kg/yr (14.3 lb/yr) of phosphorus reduction, or approximately 19% of the five-year TP reduction requirements in the Town. Additionally, the installation of the proposed retrofits will allow the Town to achieve slightly less than the requirements of the first year of the phosphorus reduction requirements.

Table 11-7:
Town of Kent Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Kent	188 (415)	6.7 (14.8)	33.6 (74.1)	6.5 (14.3)	27.1 (59.8)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Based on the tables above, the Town of Kent will need to reduce their annual phosphorus loading by an additional 27.1 kg/yr (59.8 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was estimated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the Town of Kent will need to spend an additional $ 2.84 million on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

11.1.3. Town of Patterson – Phosphorus Loading, Reduction and Cost Assessment

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized in Table 11-8. As shown, the Town of Patterson will achieve a phosphorus reduction of 12.2 kg/yr (27.0 lb/yr), if all of the proposed retrofits are installed.

Table 11-8:
TP Loading and Reduction Estimates, Town of Patterson

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Patterson-PA-01B	41.3	10.6	4.8	Install Grass Swale(s)	30	3.2	1.4
Patterson-PA-02B	4.5	5.8	2.6	Improve Existing Detention Pond	31	1.8	0.8
Patterson-PA-03C	15.5	9.4	4.3	Install Detention Pond	50	4.7	2.1
Patterson-PA-03D	8.8	5.9	2.7	Install Plunge Pool	50	2.9	1.3
Patterson-PA-10	1.6	2.2	1.0	Install Deep Sump Catch Basins	15	0.3	0.1
Patterson-PA-11	12.4	7.9	3.6	Install Detention Pond	50	4.0	1.8
Patterson-PA-12	2.1	1.8	0.8	Install Grass Swale(s)	30	0.5	0.2
Patterson-PA-14	8.4	7.7	3.5	Improve Existing Detention Pond	31	2.4	1.1
Patterson-PA-15	8.4	6.1	2.8	Install Grass Swale(s)	30	1.8	0.8
Patterson-PA-16	12.2	7.0	3.2	Install Cistern	75	5.3	2.4
Total	**115.2**	**64.4**	**29.2**			**27.0**	**12.2**

The costs associated with the installation of the proposed retrofits are summarized in Table 11-9. As shown, the proposed retrofits will cost the Town approximately $1.08 million in capital costs and $405,000 in land acquisition costs for a total of $1.48 million with an additional $42,000/yr in maintenance costs.

Table 11-9:
Town of Patterson Potential Retrofit Costs

SITE	RETROFIT TYPE	Year 1 Values		
		Capital Cost	Land Acquisition Costs	Estimated Annual Operations & Maintenance Costs
Patterson PA-01B	Install Grass Swale	**$51,200**	**$78,000**	**$4,000**
Patterson PA-02B	Modify Existing Detention Pond	**$136,900**	**$78,000**	**$4,800**
Patterson PA-03C	Install Detention Pond	**$133,100**	**15,300**	**$4,800**
Patterson PA-03D	Expand Plunge Pool	**$114,400**	**$78,000**	**$4,800**
Patterson PA-10	Replace Catch Basins (Deep Sump Type)	**$73,300**	**-**	**$2,000**
Patterson PA-11	Install Detention Pond	**$132,600**	**-**	**$5,500**
Patterson PA-12	Install Grass Swale	**$49,600**	**$78,000**	**$2,400**
Patterson PA-14	Clean/Modify Existing Detention Pond	**$117,700**	**-**	**$4,800**
Patterson PA-15	Install Grass Swale	**$104,000**	**-**	**$4,400**
Patterson PA-16	Install CSD Units & Piping	**$166,100**	**$78,000**	**$4,000**
Total Town of Patterson		**$1,078,900**	**$405,300**	**$41,500**

The required total phosphorus load reductions along with the estimated removals achieved by the retrofits for the Town of Patterson as well as the remaining phosphorus reduction required in the Town are presented in Table 11-10. As shown, the proposed retrofits achieve 12.2 kg/yr (27.0 lb/yr) of phosphorus reduction, or approximately 71% of the five-year TP reduction requirements in the Town. Additionally, the installation of the proposed retrofits will allow the Town to achieve slightly less than the requirements of the first four years of the phosphorus reduction requirements.

Table 11-10:
Town of Patterson Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Patterson	111 (245)	3.4 (7.5)	17.2 (37.9)	12.2 (27.0)	5.0 (11.0)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Based on the tables above, the Town of Patterson will need to reduce their annual phosphorus loading by an additional 5.0 kg/yr (11.0 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was estimated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the Town of Patterson will need to spend an additional $ 522,000 on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

11.1.4. Town of Putnam Valley – Phosphorus Loading, Reduction and Cost Assessment

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized in Table 11-11. As shown, the Town of Putnam Valley will achieve a phosphorus reduction of 0.2 kg/yr (0.5 lb/yr), if all of the proposed retrofits are installed.

Table 11-11:
TP Loading and Reduction Estimates, Town of Putnam Valley

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
PutVal-PA-01	3.2	0.5	0.2	Resurface Road Surface and Improve under Drainage	25	0.1	0.1
PutVal-PA-02	3.6	2.5	1.1	Install Deep Sump Catch Basins	15	0.4	0.2
Total	**6.8**	**3.0**	**1.4**			**0.5**	**0.2**

The costs associated with the installation of the proposed retrofits are summarized in Table 11-12. As shown, the proposed retrofits will cost the Town approximately $441,000 in capital costs and $78,000 in land acquisition costs for a total of $519,000 with an additional $9,000/yr in maintenance costs.

Table 11-12:
Town of Putnam Valley Potential Retrofit Costs

SITE	RETROFIT TYPE	Year 1 Values		
		Capital Cost	Land Acquisition Costs	Estimated Annual Operations & Maintenance Costs
Putnam Valley PA-01	Restore Roadway & Replace Culvert	**$203,500**	**$78,000**	**$4,200**
Putnam Valley PA-02	Replace Catch Basins	**$237,900**	**-**	**$5,000**
Total Town of Putnam Valley		**$441,400**	**$78,000**	**$9,200**

The required total phosphorus load reductions along with the estimated removals achieved by the retrofits for the Town of Putnam Valley as well as the remaining phosphorus reduction required in the Town are presented in Table 11-13. As shown, the proposed retrofits achieve 0.2 kg/yr (0.5 lb/yr) of phosphorus reduction, or approximately 23% of the five-year TP reduction requirements in the Town. Additionally, the installation of the proposed retrofits will allow the Town to achieve approximately one year of the phosphorus reduction requirements.

Table 11-13:
Town of Putnam Valley Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Putnam Valley	5 (11)	0.2 (0.4)	1.0 (2.2)	0.2 (0.5)	0.8 (1.7)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Based on the tables above, the Town of Putnam Valley will need to reduce their annual phosphorus loading by an additional 0.8 kg/yr (1.7 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was estimated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the Town of Putnam Valley will need to spend an additional $ 81,000 on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

11.1.5. Town of Southeast – Phosphorus Loading, Reduction and Cost Assessment

The resulting TP loading prior to the installation of the proposed retrofit as well as the associated TP loading reduction achieved at each proposed retrofit are summarized in Table 11-14. As shown, the Town of Southeast will achieve a phosphorus reduction of 11.6 kg/yr (25.6 lb/yr), if all of the proposed retrofits are installed.

Table 11-14:
TP Loading and Reduction Estimates, Town of Southeast

Site ID	Area	TP Load		Proposed Retrofit	Load Reduction	TP Load Reduction	
	(acre)	(lb/yr)	(kg/yr)		%	(lb/yr)	(kg/yr)
Southeast-PA-01	2.9	1.3	0.6	Install Plunge Pool	50	0.6	0.3
Southeast-PA-05	16.9	11.3	5.1	Install Plunge Pool and Grass Swale	65	7.3	3.3
Southeast-PA-06B	21.7	12.1	5.5	Install Detention Pond	50	6.1	2.8
Southeast-PA-15	8.6	3.3	1.5	Install Plunge Pool	50	1.6	0.7
Southeast-PA-16	12.4	4.9	2.2	Install Cistern	75	3.7	1.7
Southeast-PA-21	17.7	9.1	4.1	Install Deep Sump Catch Basins	15	1.4	0.6
Southeast-PA-23	9.2	12.1	5.5	Improve Existing Detention Pond	31	3.8	1.7
Southeast-PA-24	1.8	1.5	0.7	Install Grass Swale(s)	30	0.5	0.2
Southeast-PA-25	0.3	0.3	0.2	Pervious Pavement	70	0.2	0.1
Southeast-PA-26	4.7	0.9	0.4	Install Plunge Pool	50	0.4	0.2
Total	**96.2**	**56.8**	**25.8**			**25.6**	**11.6**

The costs associated with the installation of the proposed retrofits are summarized in Table 11-15. As shown, the proposed retrofits will cost the Town approximately $1.00 million in capital costs and $156,000 in land acquisition costs for a total of $1.16 million with an additional $42,000/yr in maintenance costs.

Table 11-15:
Town of Southeast Potential Retrofit Costs

SITE	RETROFIT TYPE	Year 1 Values		
		Capital Cost	Land Acquisition Costs	Estimated Annual Operations & Maintenance Costs
Southeast PA-01	Install Plunge Pool	**$58,900**	**na**	**$4,000**
Southeast PA-05	Install Plunge Pool & Check Dam	**$99,200**	**na**	**$5,600**
Southeast PA-06B	Install Detention Pond	**$112,800**	**na**	**$4,800**
Southeast PA-15	Install Plunge Pool	**$63,000**	**na**	**$4,000**
Southeast PA-16	Install Cistern	**$49,600**	**$78,000**	**$4,000**
Southeast PA-21	Replace Catch Basins	**$179,200**	**$78,000**	**$4,000**
Southeast PA-23	Modify Existing Detention Pond	**$127,200**	**na**	**$5,200**
Southeast PA-24	Install Grass Swale	**$55,500**	**na**	**$3,200**
Southeast PA-25	Install Permeable Pavement	**$ 195,100**	**na**	**$3,600**
Southeast PA-26	Install Plunge Pool	**$ 63,000**	**na**	**$4,000**
Total Town of Southeast		**$1,003,500**	**$156,000**	**$42,400**

The required total phosphorus load reductions along with the estimated removals achieved by the retrofits for the Town of Southeast as well as the remaining phosphorus reduction required in the Town are presented in Table 11-16. As shown, the proposed retrofits achieve 11.6 kg/yr (25.6 lb/yr) of phosphorus reduction, or approximately 37% of the five-year TP reduction requirements in the Town. Additionally, the installation of the proposed retrofits will allow the Town to achieve slightly more than the requirements of the first two years of the phosphorus reduction requirements.

Table 11-16:
Town of Southeast Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Southeast	221 (487)	6.2 (14)	31.1 (68.6)	11.6 (25.6)	19.5 (43.0)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Based on the tables above, the Town of Southeast will need to reduce their annual phosphorus loading by an additional 19.5 kg/yr (43.0 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was estimated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the Town of Southeast will need to spend an additional $ 2.04 million on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

11.1.6. Summary for all the PCMS4CC Communities

As shown in Sections 11.1.1 to 11.1.5, if the PCMS4CC enacts all of the proposed retrofits, an estimated TP load reduction of approximately 54.3 kg/yr (119.7 lb/yr) will be achieved, as detailed in Table 11-17.

Table 11-17:
PCMS4CC Estimated Phosphorus Loading and Required Removal

	Total Modeled HID Load kg/year[1] (lb/yr)	Annual Load Reduction kg/yr[2] (lb/yr)	5-Year Load Reduction kg/yr[2] (lb/yr)	Removal from Identified Retrofits kg/yr (lb/yr)	Remaining Removal Needed for 5-year Goals kg/yr (lb/yr)
Total	904 (1993)	31.0 (68.3)	154.9 (341.6)	54.3 (119.7)	100.6 (221.8)

1 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 2
2 - Croton Watershed Phase II Phosphorus TMDL Implementation Plan, NYSDEC, January 2009a, Table 3.

Several important facts can be drawn by the results of the TP loading and associated TP loading reduction summarized above.

- The TP loading reduction requirements required by the EOH Enhanced Phosphorus reduction standards are 154.9 kg/year (341.6 lb/yr) or 31.0 kg/yr (68.3 lb/yr) over each of the next five years (2010-2015)
- The proposed retrofits are shown to achieve approximately 35% of the required TP loading reduction in the area.
- Based on the requirements set forth by the NYSDEC, if all of the proposed retrofits are enacted, the PCMS4CC will achieve less than the requirements of the first two years of TP load reductions.
- The Town of Carmel will achieve the greatest magnitude of annual TP load reduction (23.8 kg/yr or 52.4 lb/yr);
- The Town of Putnam Valley will achieve the least amount of annual TP load reduction (0.2 kg/yr or 0.5 lb/yr);

When analyzing the costs of constructing the retrofits proposed in this Study, several important facts can be drawn:

- The total cost of constructing the proposed retrofits in Year 1 cost is approximately $4.3 million;
  - Patterson has the greatest capital costs ($1,078,900);
  - Putnam Valley has the smallest capital costs ($441,400);
- The proposed land acquisition costs in Year 1 costs across the PCMS4CC Towns in approximately $1.42 million on top of the construction cost estimations;

- Carmel has the greatest land acquisition costs ($546,000);
- Putnam Valley has the smallest land acquisition costs ($78,000);

- The total operations and maintenance costs across the PCMS4CC Towns is approximately $179,400
  - Carmel has the greatest operations and maintenance costs ($49,700);
  - Putnam Valley has the smallest operations and maintenance costs ($9,200);

The phosphorus reductions and cost estimates (in Year 1 costs) for both the installation of the proposed retrofits as well as the phosphorus reductions required to meet the regulatory requirements in the PCMS4CC Study Area are summarized in Table 11-18. Based on the table, the PCMS4CC will need to reduce their annual phosphorus loading by an additional 100.6 kg/yr (221.8 lb/yr). The average cost for phosphorus reduction across the Study (capital and land acquisition only) was calculated to be approximately $47,500/lb TP. Utilizing the average cost of phosphorus reduction across the Study, the PCMS4CC will need to spend an additional $ 10.55 million on phosphorus reductions. It is important to note however, that costs will vary by site and the additional costs is an estimate only.

Table 11-18:
PCMS4CC Phosphorus Removal Cost Estimates (Year 1 Costs)

		kg/yr	lb/yr	Capital and Land Acquisition Cost ($)
	Required TP Reductions	154.9	341.6	16,244,390
TP Reductions Achieved by Proposed Retrofits	**Carmel**	23.8	52.4	1,614,900
	Kent	6.5	14.3	916,500
	Patterson	12.2	27.0	1,484,200
	Putnam Valley	0.2	0.5	519,400
	Southeast	11.6	25.6	1,159,500
	Total	54.3	119.7	5,694,500
Additional TP Reductions Required for Compliance	**Carmel**	48.2	106.4	5,059,769
	Kent	27.1	59.8	2,843,132
	Patterson	5.0	11.0	521,876
	Putnam Valley	0.8	1.7	80,921
	Southeast	19.5	43.0	2,044,192
	Total	100.6	221.8	10,549,890

11.2. Recommendations

As the phosphorus retrofit program moves forward, the PCMS4CC should consider undertaking a number of steps. In particular, member communities should reach consensus on the following issues:

- Develop an approach on how to fund the retrofit program. This can include:
  - Development of a localized stormwater user fee;
  - Establishment of standardized fees; or
  - Creation of a regional funding entity (e.g. enterprise fund).

- Develop a strategy to create a uniform regulatory approach throughout the PCMS4CC territorial jurisdiction. In particular the PCMS4CC communities can decide on pursuing a specific statutory template that includes implementing:
  - Low impact development (LID);
  - Best Management Practices (BMPs); and
  - Regional ordinance development (e.g., restrict phosphorus fertilizers).

- Develop a region-wide stormwater management plan which:
  - Assesses the effectiveness of each municipality's stormwater management plan and identifies the most effective methods for consideration in a regional stormwater management plan;
  - Includes all the communities in the entire East of Hudson (EOH) Watershed; and
  - Includes a formula for establishing priorities for installing the retrofit improvements.

- Develop a region-wide GIS database which encompasses either PCMS4CC watershed or the entire EOH watershed which includes:
  - Tracking of retrofits installed and load reductions achieved to date;
  - Long term planning on retrofits to be installed and the associated load reduction; and
  - Identifying additional sites and the cost and load reduction associated with each.

12. References

Arnold, C.A. and Gibbons, C.J. (1996). "Impervious Surface Coverage: There Emergence of a Key Environmental Indicator". *Journal of the American Planning Association* (62-2) Spring 1996. P243-258.

Caraco, D. Watershed Treatment Model (WTM) User's Guide – Version 3.1 Center for Watershed Protection (CWP), 2002. (downloaded from http://www. stormwatercenter.net/monitoring%20and%20assessment/watershed_treatment_ model.htm)

California Department of Transportation (CalTrans). Treatment BMP Technology Report CTSW-RT-07-167.02.02, April 2007

Hirschman, D., Collins, K. and Schueler, T. (2008). "Technical Memorandum: The Runoff Reduction Method." The Center for Watershed Protection. April 18, 2008 26 p.

New Jersey Corporation for Advanced Technology (NJCAT). NJCAT TECHNOLOGY VERIFICATION Aqua-Swirl Concentrator and Aqua-Filter Stormwater Treatment Systems, September 2005. (downloaded from http://www.state.nj.us/ dep/dsr/bscit/AquaShield_Verification.pdf)

New York City Department of Environmental Protection (NYCDEP) Guidance for Phosphorus Offset Programs. March 1997. 32p.

New York City Department of Environmental Protection (NYCDEP) Final Draft East of Hudson Regional Stormwater Entity Proposed Grant Program. April 2009.

New York State Department of Environmental Conservation (NYSDEC) SPDES General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s) (GP-0-08-002). May, 2008. 91p.

New York State Department of Environmental Conservation (NYSDEC) New York State Standards and Specifications for Erosion and Sediment Control. August 2005 406p.

New York State Department of Environmental Conservation (NYSDEC). Reducing the Impacts of Stormwater Runoff from New Development, 2nd Edition, 1993.

New York State Department of Environmental Conservation (NYSDEC) New York State Stormwater Management Design Manual. April 2008 544p.

New York State Department of Environmental Conservation (NYSDECa), Division of Water, "Croton Watershed Phase II Phosphorus TMDL Implementation Plan." January 2009. http://www.dec.ny.gov/docs/water_pdf/jan09crotontmdl.pdf

New York State Department of Environmental Conservation (NYSDECb), Division of Water, "Technical Background for Retrofitting Practices EOH MS4 Heightened Criteria." January 2009. http://www.dec.ny.gov/docs/water_pdf/jan09retrofit.pdfhttp://www.dec.ny.gov/docs/water_pdf/jan09retrofit.pdf

Schueler, T. (1987). "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices". Publ. No. 87703. Metropolitan Washington Council of Governments, Washington, DC.