POLLUTANT REDUCTION PLAN
FOR THE CHESAPEAKE BAY
SOUTH MIDDLETON TOWNSHIP, CUMBERLAND COUNTY, PA

South Middleton Township
530 Park Drive
Boiling Springs, PA 17007
717.258.5324

NPDES MS4 New Permittee
September 15, 2017

Prepared by
RETTEW Associates, Inc.
3020 Columbia Avenue
Lancaster, PA 17603
800.738.8395
rettew.com
RETTEW Project No. 016872003

RETTEW

SUMMARY

South Middleton Township has prepared this Pollutant Reduction Plan (PRP) for stormwater discharges of nutrients and sediment to surface waters in the Chesapeake Bay Watershed to meet the requirements set forth by Pennsylvania's Department of Environmental Protection (PA DEP). As an MS4 community, South Middleton Township must comply with Appendix D of the PAG-13 Individual Permit and must attach this PRP to the Notice of Intent (NOI) for Individual Permit Coverage. South Middleton Township has invited public participation in the planning process by making this PRP available for a 30-day public review and comment period. A copy of all written comments received and the record of consideration of each one is included in Section A of this document.

This PRP calculates the existing loading of stormwater pollutants generated from within that portion of the urbanized area which discharges stormwater through MS4 outfalls, in lbs/year; calculates the minimum required reduction in loading, in lbs/year; selects best management practices (BMPs) to reduce the loading rates; and demonstrates that the selected BMPs will achieve the minimum reductions. The pollutants of concern and associated required reductions for the Chesapeake Bay are sediment (10%), phosphorus (5%), and nitrogen (3%). PA DEP allows using a presumptive approach in which it is assumed that a 10% reduction in sediment will accomplish a 5% reduction in phosphorus and a 3% reduction in nitrogen.

To improve water quality and meet the required pollutant reductions, South Middleton Township has identified six stormwater BMPs that when implemented will exceed the required pollutant reductions. The Township will implement a combination of the identified projects, three bioswales, two dry detention basins, and a streambank stabilization project on an UNT to Boiling Spring Lake to meet the minimum required pollutant reductions. The proposed bioswales promote groundwater infiltration and are planted with native vegetation which filters pollutants and uptakes nutrients. The proposed dry extended detention basins temporarily store stormwater runoff for up to three days and minimize sediment pollution by allowing ample time for suspended solids to settle out in the basin rather than being discharged downstream. The planned streambank stabilization projects may include re-grading the streambank to eliminate eroding banks and planting native trees, shrubs, and perennial grasses to provide permanent stabilization. The expected water quality benefits include minimizing excessive erosion and sedimentation and the associated nutrient delivery to the stream that occurs during storm events. These proposed BMP types will increase biodiversity and provide food and habitat for native wildlife.

South Middleton Township will prepare and submit updates on the progress of implementing this PRP with the MS4 Annual Report due each year to PA DEP by September 30th.

TABLE OF CONTENTS

Section A

SECTION A - PUBLIC PARTICIPATION

South Middleton Township has promoted public participation and involvement in water quality decisions by making the Pollutant Reduction Plan (PRP) available for public review and comment as required. A complete copy of the PRP was made available for public review on July 14, 2017, 64 days prior to the submission deadline on September 16, 2017. This meets the PA DEP requirement that the PRP be published at least 45 days prior to the submission deadline. A public notice was posted in The Sentinel containing a description of the Plan, where it may be reviewed by the public, and the length of time made available for the receipt of comments. The municipality accepted both written and verbal comments from the public until August 14, 2017, 30 days after the public notice was posted.

The Township received written comments from two residents during the 30-day public comment period. The first comment expresses concern with the existing herbicides being applied along Township roads to control vegetative growth. The second comment suggests that the Township reach out to the Chesapeake Bay Foundation to assist with funding the proposed stormwater BMPs identified in this Plan.

Based on consideration of these comments, the Township will evaluate the options being used to control unwanted vegetation along municipal roadways and will investigate all options to fund implementation of the proposed stormwater BMPs.

No changes were made to the PRP based on these written comments.

Attachments
A1: A copy of the public notice
A2: The record of all written and verbal comments

Attachment A1: A copy of the public notice

PROOF OF PUBLICATION

State of Pennsylvania, County of Cumberland

Kimberly Kamowski, Print Sales & Marketing Manager, of The Sentinel, of the County and State aforesaid, being duly sworn, deposes and says that THE SENTINEL, a newspaper of general circulation in the Borough of Carlisle, County and State aforesaid, was established December 13th, 1881, since which date THE SENTINEL has been regularly issued in said County, and that the printed notice or publication attached hereto is exactly the same as was printed and published in the regular editions and issues of THE SENTINEL on the following day(s):
June 19, 2017

COPY OF NOTICE OF PUBLICATION

PUBLIC NOTICE

As per requirements for the Township's MS4 permit application, a copy of South Middleton Township's Pollutant Reduction Plan for stormwater discharges of nutrients and sediment to local surface waters and the Chesapeake Bay will be presented and the Board shall accept comments upon the Plan at the regularly scheduled Board of Supervisors meeting on July 13, 2017 at 6:00 pm at the Township Office located at 520 Park Drive, Boiling Springs, PA 17007. This Plan includes stormwater system maps; the existing loading rates of sediment, phosphorus, and nitrogen; the required pollutant reductions as identified by PA DEP; proposed stormwater BMPs to achieve the minimum required pollutant reductions, the project sponsors, partners, and probable funding sources for each BMP; and the responsible parties for operation and maintenance of each BMP. The Plan will then be available at the Township Office during a public review and comment period, which shall begin on July 14, 2017 and shall continue until August 14, 2017. Comments must be made in writing and received on or before August 14, 2017.

Sandra Quickel
Township Secretary
South Middleton Township Board of Supervisors

Affiant further deposes that he/she is not interested in the subject matter of the aforesaid notice or advertisement, and that all allegations in the foregoing statement as to time, place and character of publication are true.

[signature]

Sworn to and subscribed before me this
20th day of June 2017.

Bethany M. Holtry
Notary Public

My commission expires:

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Bethany M. Holtry, Notary Public
Carlisle Boro, Cumberland County
My Commission Expires Sept. 26, 2019
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

Attachment A2: The record of all written and verbal comments

August 11, 2017

Comment submitted on the subject of:
South Middleton Township
"Pollutant Reduction Plan for the Chesapeake Bay"

Extensive herbicide use along township roads, at certain locations, is facilitating the deposit of sediment and debris into local waterways. The attached photos are provided, as a small sample, to illustrate the effects of continued long term use. A significant curtailment of this practice could help in reaching the sediment reduction goal outlined in the township's proposed pollutant reduction plan.

It appears the application of herbicides along the sides of many township roads is done in areas which are deemed difficult or impossible to mow roadside vegetation with the equipment available to do the job. Areas targeted are those around telephone poles, road signs, drainage pipes, rock outcroppings, and roadside tree lines. As the photos show, the repetitive application of herbicides year after year onto the same locations has eliminated any vegetation from wide areas around the targeted objects. This wide exposure of soil, particularly on steep roadside banks, increases the likelihood that erosion of the soil will take place. A return of vegetation in a number of these locations could reduce the amount of sediment and debris that could ultimately end up in our waterways.

Sincerely,
Mike Hepler
622 Whiskey Springs Road
Boiling Springs, PA 17007

The Letort

Bonnybrook Road

Photo 1

Drain outlet

The Letort

Looking north toward Union Quarries on Bonnybrook Road from the area next to the Letort.

Photo 2

The Letort

at Bonnybrook Road
Moderate rain event
1:20 PM

Photo 3

Sediment ? → in water.

← The drain

<u>The Letort</u>

Bonnybrook Road.
After the heavy rain
event overnight on
August 4 + 5.

Photo 4

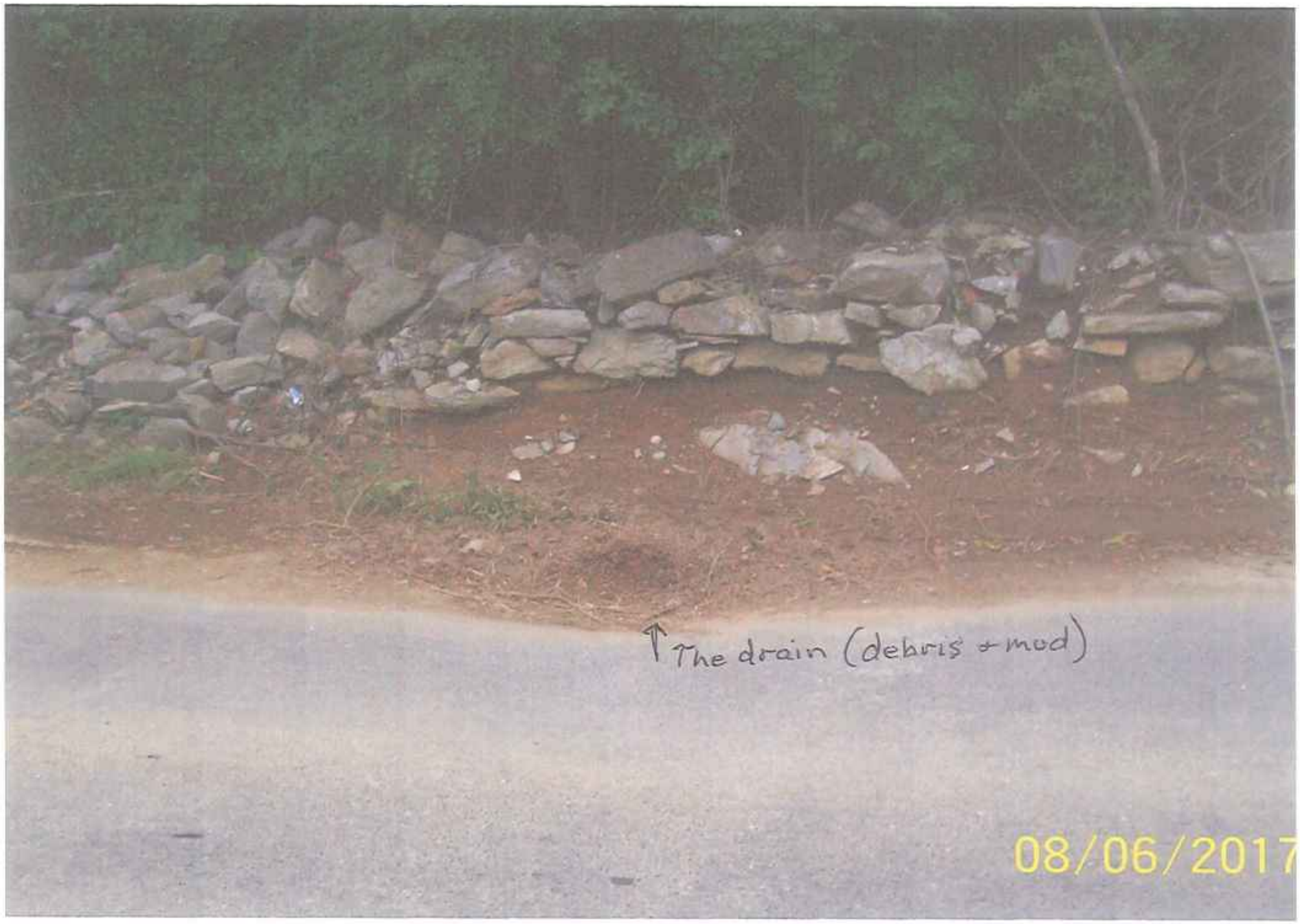

Photo 5

<u>The Letort</u>

Just south of the
bridge on Bonnybrook Road

A "before" photo

The Letort

Same pole as previous Photo

Photo 6

The Letart

Photo 7

Same pole as in photos 5 + 6. A "before" photo.

The Letart

Photo 8

The same pole after the heavy rain event overnight August 4 + 5

No vegetation to stabilize the bank material. The outflow came from the soybean field above the bank.

Photo 9

The Letort

The midway point below The pole in photo 8 and the Letort. Drainage ditch created by repeated runoff up the road.

Photo 10

<u>The Letort</u>

The bottom end of the drainage ditch. shows muddy water heading for the Letort after a moderate rainfall event at 1:15PM.

The Letort

Photo 11

South on Bonnybrook,
on the hill above the Letort.
Extensive tree line erosion

Photo 12

The Letort

South on Bonnybrook,
on the hill above the Letort

Looking south on Bonnybrook Road.

Photo 13

South Spring Garden St.

The eroded bank allows runoff from rains to flow freely to the intersection with Spring Garden St. During heavy rains the water then flows across Bonnybrook and down Spring Garden towards the old Watercress Farm. (waterway)

Looking down S. Spring Garden
From the intersection with Bonnybrook Road.

Photo 14

Photo 15

Looking south on Bonnybrook Road
Just past the intersection with
S. Spring Garden St.

The 5th telephone pole, south on Bonnybrook from the intersection with Spring Garden St.
After the rain event the night of August 4 into the 5th.

Photo 16

Runoff from the field opened a hole in the bank. In part, the limited amount of vegetation on the bank allowed for the washout. The slope of the field wasn't factored in when prepping the field for planting. The rocks were laying on the road edge. The runoff would flow toward the intersection with Spring Garden St.

Rockledge Drive
down to the Rt. 174 intersection

Photo 17

Photo 18

Rockledge Drive example

treeline management

Rockledge Drive

Photo 19

Rockledge Drive

Photo 20

Whiskey Springs Road

On the steep grade south of Whiskey Spring Run.

Photo 21

Whiskey Springs Road

On the steep grade south of Whiskey Spring Run.

Photo 22

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Shop (http://www.cbf.org/join-us/more-ways-to-give/shop-for-the-bay/)

Native Plantings & Stream Buffers

Like Follow

The Importance of Rivers and Streams

Five major rivers—the Susquehanna, Potomac, Rappahannock, York, and James—provide nearly 90 percent of the fresh water to the Chesapeake Bay. These and the hundreds of thousands of creeks and streams that feed them, provide vital habitat for many aquatic species, including anadromous fish species like shad and sturgeon,turtles and amphibians, and important plants and grasses.

The Problem

Stormwater runoff from farmland and urban and suburban areas wash nutrients—often excessive amounts of them—into our streams and rivers eventually leading to the Bay. Too much of these nutrients (nitrogen and phosphorus in particular) do great harm to our waters' critters, plants, and underwater life.

What We're Doing About It

Pennsylvania (/how-we-save-the-bay/programs-initiatives/pennsylvania/)

- Pennsylvania Programs & Initiatives (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/)
  - Buffer Bonus Program (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/susquehanna-watershed-restoration/buffer-bonus-program.html)
  - Conservation Reserve Enhancement Program (CREP) (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/susquehanna-watershed-restoration/crep-conservation-reserve-enhancement-program.html)
  - Resource Enhancement and Protection Program (REAP) (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/susquehanna-watershed-restoration/reap.html)
  - Mountains-to-Bay Grazing Alliance (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/multi-state-grazers-alliance.html)

By building and restoring forested buffers (multiple rows of native trees, shrubs, and grasses) along streams and rivers, we are able to capture and filter out the pollution from runoff through these buffers. They also provide important habitat for wildlife and aquatic species, stabilize stream banks against erosion, and help keep rivers cool in summer.

In addition CBF creates living shorelines along river and Bay waterfront with native wetland plants and grasses. These areas help restore habitat, prevent erosion, capture sediment, and filter pollution.

- Susquehanna Watershed Restoration (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/susquehanna-watershed-restoration/)
- Potomac Watershed Restoration (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/potomac-watershed-restoration/)
- Native Plantings & Stream Buffers (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/native-plantings-and-stream-buffers.html)
- Volunteers Create Pollution-Reduction Demonstration Project at Oregon Dairy (http://www.cbf.org/how-we-save-the-bay/programs-initiatives/pennsylvania/volunteers-create-pollution-reduction-demonstration-project-at-oregon-dairy.html)

Stay up to date about the Bay!

Email Address GO

What You Can Do

Learn

VoiCeS Frederick (http://chesapeake.cbf.org/site/Calendar?id=100364&view=Detail)

In this six-week course, participants learn about the Chesapeake Bay watershed, its benefits, its issues, and what they can do to help restore it.

Attend

10 SEP 2017

Save the Bay Family Day (http://www.cbf.org/events/virginia/save-the-bay-family-day.html)

12:30-4:00 p.m.
Brock Environmental Center
Virginia Beach, Virginia

Attend

01 OCT 2017

Burgers and Brews for the Ba (http://www.cbf.org/events and-brews/)

Noon-4:00 p.m.
Clagett Farm
Upper Marlboro, Maryland

CHESAPEAKE BAY FOUNDATION
Saving a National Treasure
(http://www.cbf.org)

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Contact CBF's Pennsylvania Office

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Chesapeake Bay Foundation
1426 North 3rd Street
Suite 220
Harrisburg, PA 17102
717-234-5550 (phone)
717-234-9632 (fax)
Map (http://goo.gl/maps/uXpJQ)

Harry Campbell, Executive Director

Kelly Abbe, Office Manager
Bill Chain, Senior Agriculture Program Manager
Molly Cheatum, Restoration Manager
Elizabeth Fulton, Co-Manager, Susquehanna Watershed Environmental Education Program
Carla Johns, Grassroots Field Specialist
Jennifer Johns, Restoration Specialist
Kristen Hoke, Restoration Specialist
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Brent Nice, Conservation Planner
Kelly O'Neill, Agricultural Policy Analyst
Renee Reber, Staff Scientist
Frank Rohrer, Restoration Specialist
* **B.J. Small,** Communications & Media Coordinator
Heather Smith, Director of Major Giving
Steve Smith, Restoration Specialist
Ashley Spotts, Restoration Specialist
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  - What's Up in Pennsylvania (http://www.cbf.org/about-cbf/locations/pennsylvania/whats-up-in-pennsylvania/)
  - Contact CBF's Pennsylvania Office (http://www.cbf.org/about-cbf/locations/pennsylvania/contact-us.html)

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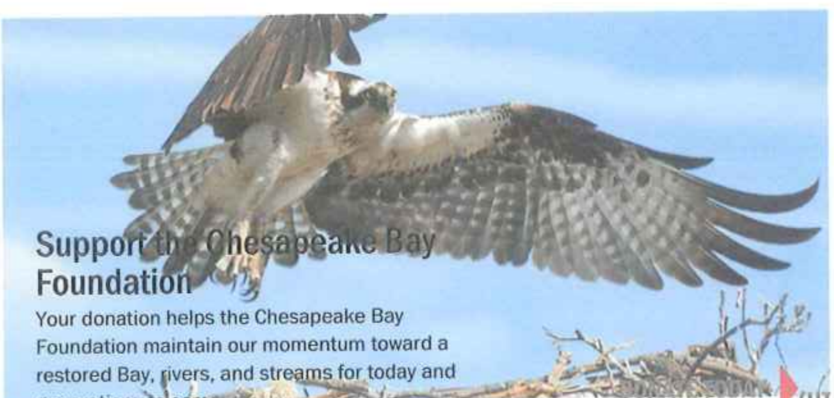

Support the Chesapeake Bay Foundation

Your donation helps the Chesapeake Bay Foundation maintain our momentum toward a restored Bay, rivers, and streams for today and generations to come.

(HT DF

Save the Bay

Founded in 1967, the Chesapeake Bay Foundation (CBF) is the largest independent conservation organization dedicated solely to saving the Bay.

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ACCREDITED CHARITY BBB (http://give.org/charity-reviews/national/environment/chesapeake-bay-foundation-in-annapolis-md-21487)

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6/30/2017 THE SENTINEL PA2

Funding to support stormwater projects

SENTINEL STAFF

Gov. Tom Wolf Thursday announced the approval of funding to support 17 municipal stormwater projects in Pennsylvania's portion of the Chesapeake Bay Watershed.

Three of the 17 projects are in Cumberland County. Carlisle Borough will receive $200,000 for its project involving native wetlands planting for an urban stormwater park.

Mechanicsburg Borough will receive $164,381 for a northside stormwater basin retrofit.

Lemoyne Borough will receive $176,700 for stream bank restoration at Harrisburg Academy.

The governor's offices said the state Department of Environmental Protection is ramping up implementation of the Environmental Protection Agency's Municipal Separate Storm Sewer System permit program.

Fundings:

Perhaps the Bay folks could spare a few of the $73 million in Federal dollars they get yearly to assist with the funding of the townships projects. Harrisburg Bay Office 717-234-5550

POC

Mr. Robert Small (from mechanicsburg)
(B. J. Small)

bjsmall@comcast.net

(Employed)(By)
Works for the Bay Foundation and was just sworn in as the PA Fish + Boat Commission's District 6 commissioner, which covers Adams, Cumberland, Dauphin, Franklin, Lancaster, Lebanon, Perry and York counties.

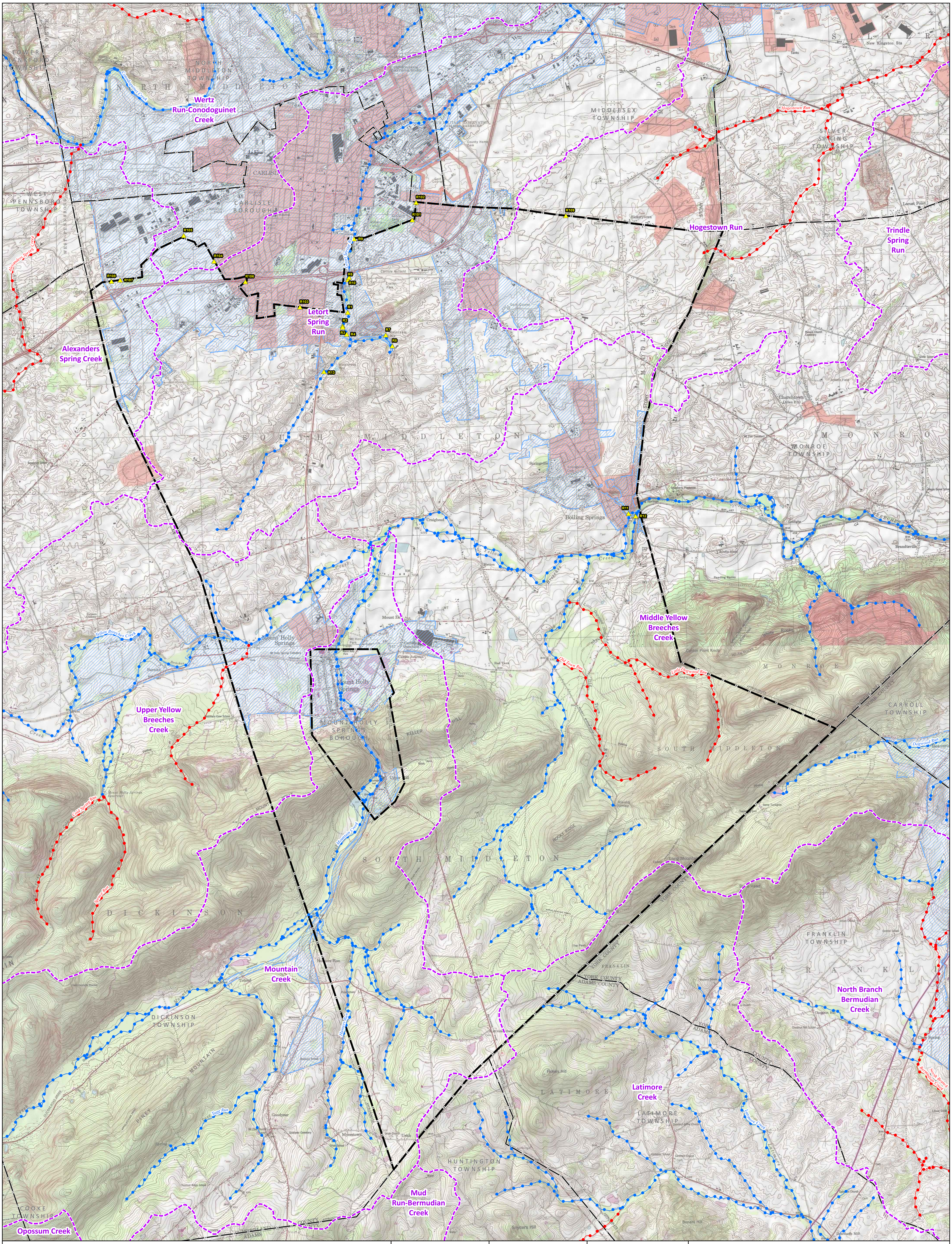
Section B

SECTION B - MAPS

South Middleton Township has completed a series of maps that show the location of the municipal boundary, streams, the 2010 urbanized area, stormwater system facilities, aerial imagery to identify land use and associated impervious and pervious areas, the storm sewershed area associated with each regulated MS4 outfall, and the location of proposed structural BMPs that will be implemented to achieve the required pollutant load reductions. Please note that some streams identified on the maps as impaired, may be impaired for reasons that do not need to be addressed by this PRP. This PRP addresses only those impairments that require Appendix D and/or Appendix E (See Section C for specific information on applicable impairments).

Attachments
B1: Hydrology Map
B2: Storm Sewershed Map
B3: Stormwater System Map
B4: Proposed Stormwater BMP Map

Attachment B1: Hydrology Map



Outfall

Non-Attaining Stream (for Aquatic Life)

Attaining Stream

National Hydrography Dataset HUC 12

South Middleton Township Boundary

Municipal Boundary

2010 Urban Area

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Project No: 016872003

Revised: 7/11/2017

RETTEW

N / W / E / S

0 2,000 4,000 Feet

1 inch = 2,000 feet

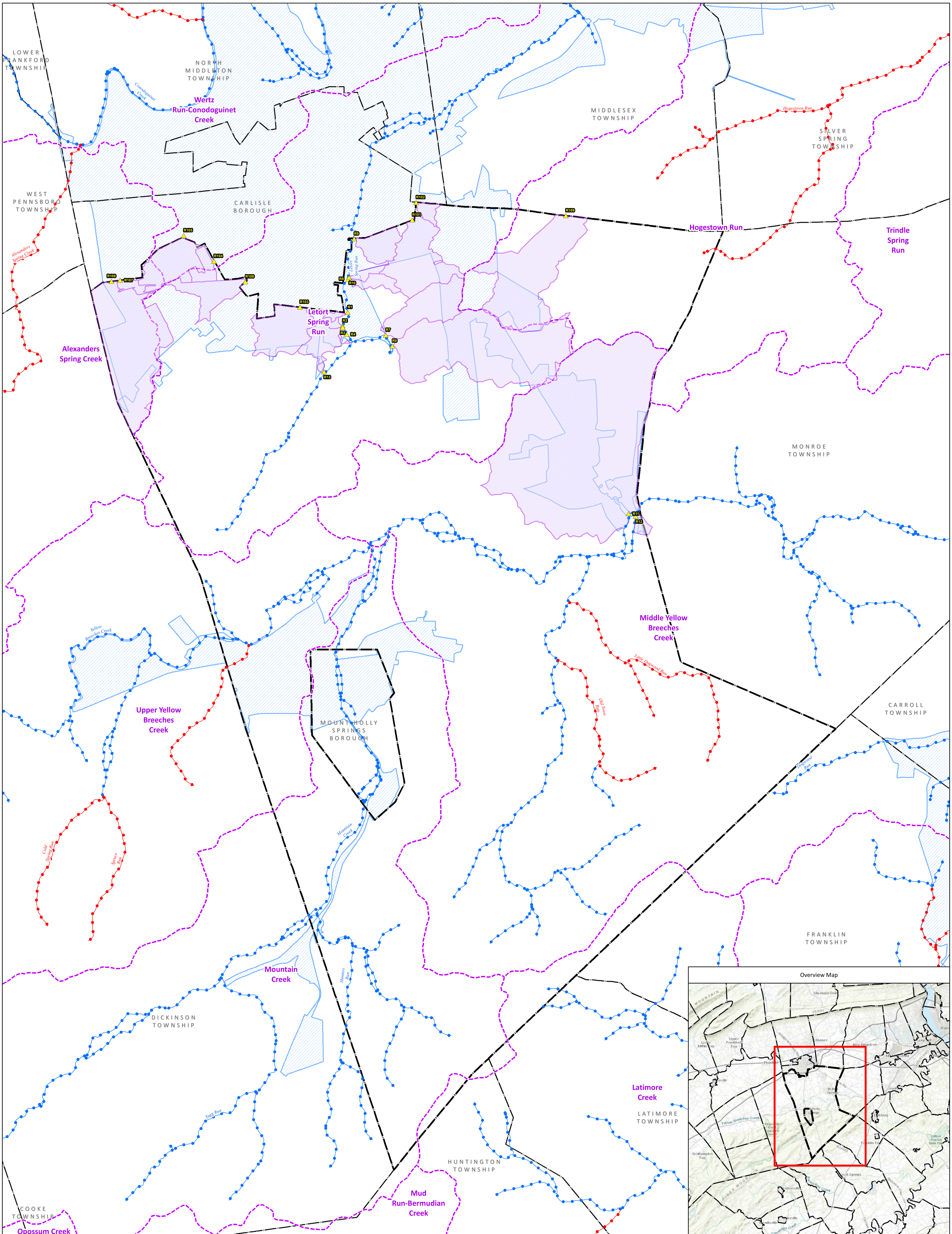
MAP 1

Hydrology Map

Pollutant Reduction Plan
Stormwater Management Program

South Middleton Township | Cumberland County, PA

Attachment B2: Storm Sewershed Map



Outfall

Non-Attaining Stream (for Aquatic Life)

Attaining Stream

Storm Sewershed

National Hydrography Dataset HUC 12

South Middleton Township Boundary

Municipal Boundary

2010 Urban Area

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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0 2,000 4,000 Feet

1 inch = 2,000 feet

MAP 2

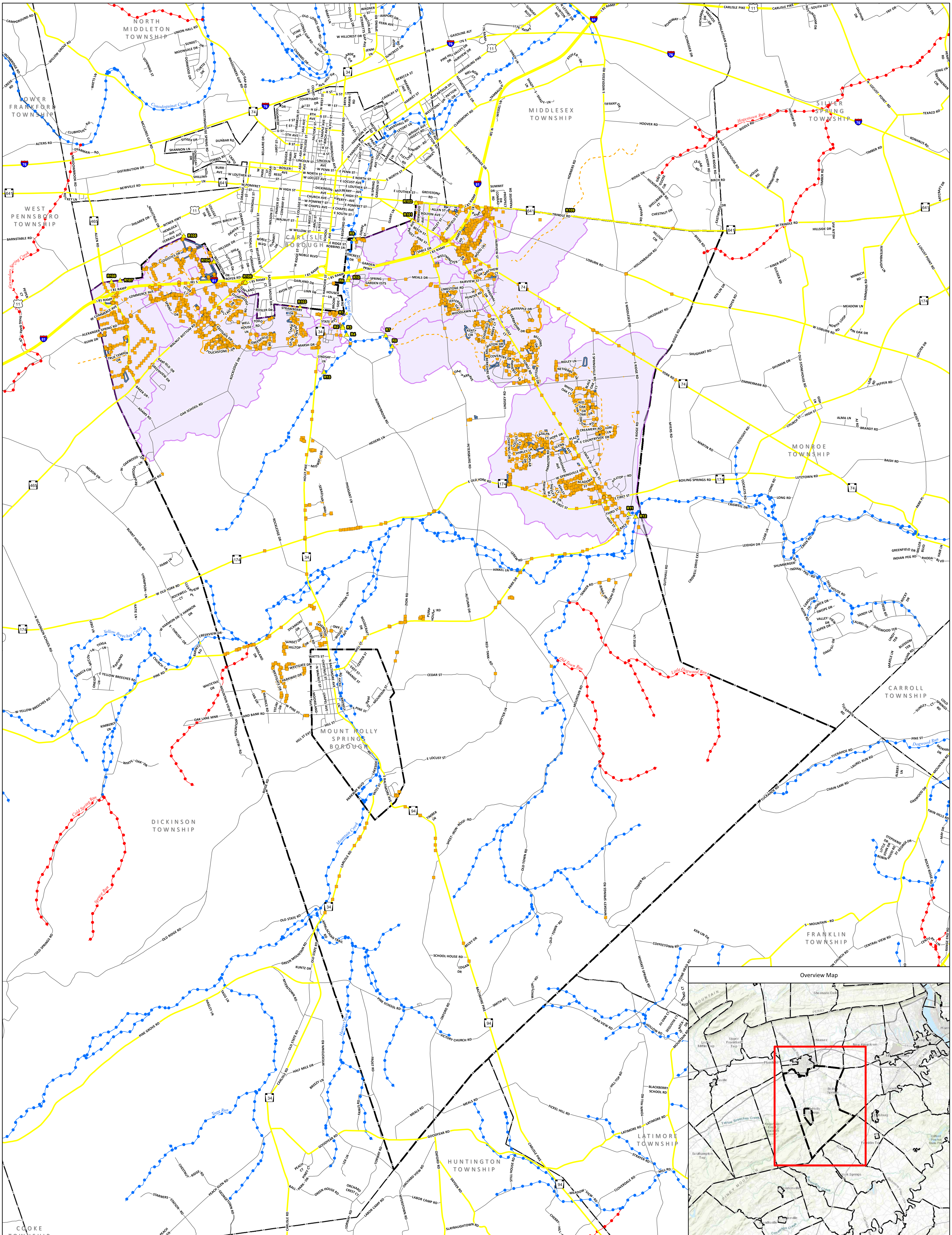
Municipal Storm Sewershed Map

Pollutant Reduction Plan
Stormwater Management Program

South Middleton Township

Cumberland County, PA

Attachment B3: Stormwater System Map



Outfall	Swale
Headwall-Endwall	State/US Highway
Inlet	Road
Manhole	Non-Attaining Stream (for Aquatic Life)
Pipe	Attaining Stream

Basin
Sewershed
South Middleton Township Boundary
Municipal Boundary

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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0 2,000 4,000 Feet

1 inch = 2,000 feet

MAP 3

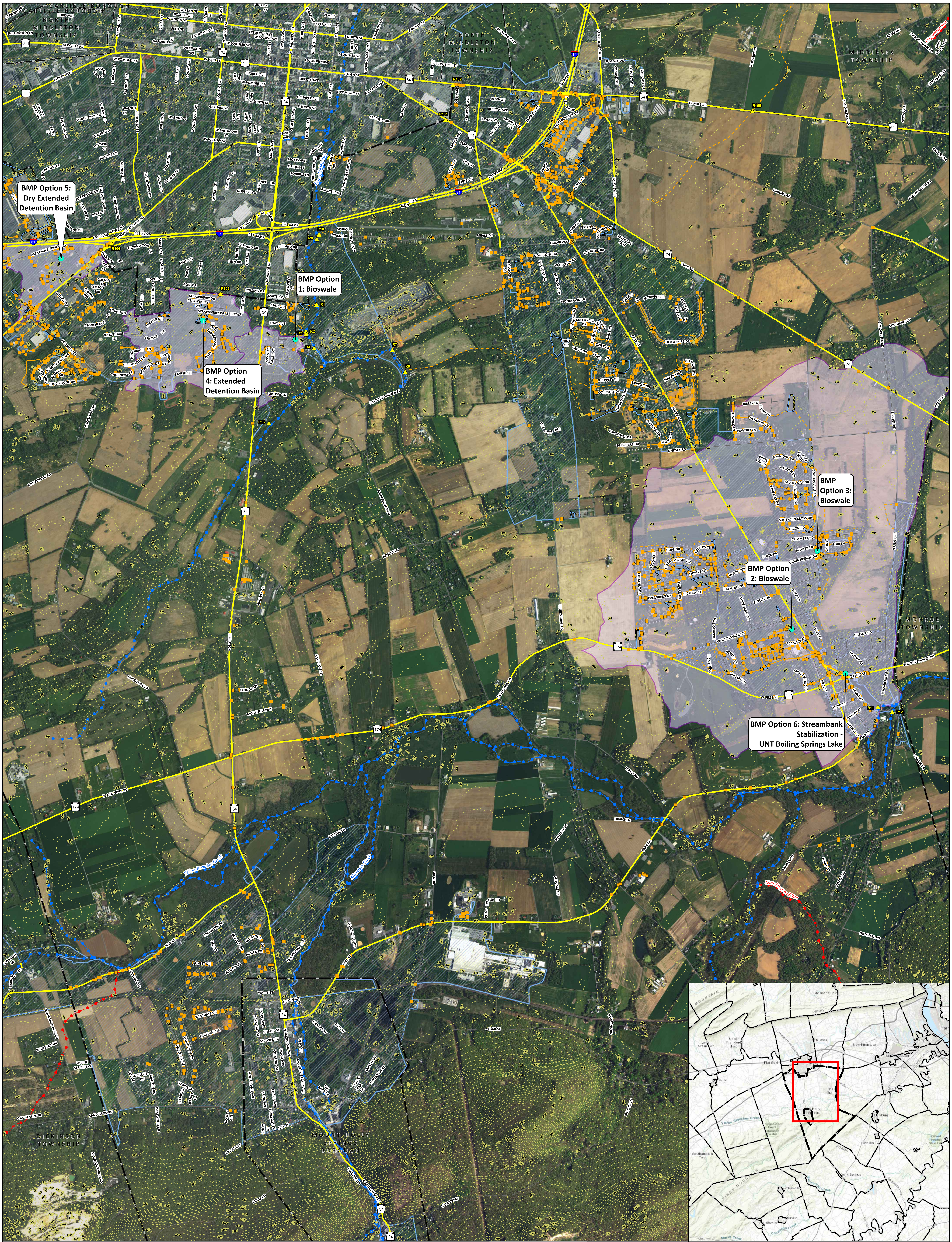
Stormwater System Map

Pollutant Reduction Plan
Stormwater Management Program

South Middleton Township

Cumberland County, PA

Attachment B4: Proposed Stormwater BMP Map



Proposed BMP
Outfall
Headwall-Endwall
Inlet
Manhole
Pipe
Swale
State/US Highway
Road
Contour (20' Interval)
Non-Attaining Stream (for Aquatic Life)
Attaining Stream
Basin
Storm Sewershed
South Middleton Township Boundary
Municipal Boundary
2010 Urban Area

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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Project No: 016872003

Revised: 7/11/2017

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0 1,000 2,000 Feet
1 inch = 1,000 feet

MAP 4

Proposed Stormwater BMPs

Pollutant Reduction Plan
Stormwater Management Program

South Middleton Township — Cumberland County, PA

N:\Shared\Projects\01687\016872003\GIS\MapDocs\Pollutant Reduction Plans\016872003_Map4_42x30.mxd

Section C

SECTION C - POLLUTANTS OF CONCERN

The following pollutants of concern are based on the impairment listing provided in the MS4 Requirements Table provided by PA DEP:

- Chesapeake Bay (Appendix D): Nutrients and Siltation

If the impairment listed above is based on siltation only, a minimum 10% sediment reduction is required. If the impairment is based on nutrients (including Excessive Algal Growth and Organic Enrichment/Low D.O.), a minimum 5% Total Phosphorus (TP) reduction is required. If the impairment is due to both siltation and nutrients, both a 10% sediment reduction and 5% TP reduction is required. PA DEP allows using a presumptive approach in which it is assumed that a 10% reduction in sediment will accomplish a 5% reduction in phosphorus and a 3% reduction in nitrogen.

South Middleton Township must achieve the required pollutant reductions over the 5-year period following PA DEP's approval of coverage.

Attachment
C1: MS4 Requirements Table for Cumberland County Municipalities

Attachment C1: MS4 Requirements Table for Cumberland County Municipalities

MS4 Name	NPDES ID	Individual Permit Required?	Reason	Impaired Downstream Waters or Applicable TMDL Name	Requirement(s)	Other Cause(s) of Impairment
Cumberland County						
CAMP HILL BORO	PAG133549	No		Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Susquehanna River	Appendix C-PCB (5)	
				Yellow Breeches Creek	Appendix B-Pathogens (5)	
				Cedar Run	Appendix B-Pathogens (5)	
				Unnamed Tributaries to Cedar Run		Cause Unknown (5)
CARLISLE BORO	PAI133517	Yes	SP, IP	Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
EAST PENNSBORO TWP	PAG133680	No		Holtz Run	Appendix B-Pathogens (5)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Unnamed Tributaries to Susquehanna River	Appendix E-Siltation (5)	Other Habitat Alterations (4c)
				Susquehanna River	Appendix C-PCB (5)	
				Unnamed Tributaries to Conodoguinet Creek		Cause Unknown (5)
HAMPDEN TWP	PAI133513	Yes	SP, IP	Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Susquehanna River	Appendix C-PCB (5)	
				Yellow Breeches Creek	Appendix B-Pathogens (5)	
				Sears Run	Appendix E-Siltation (5)	Cause Unknown (5)
				Trindle Spring Run	Appendix E-Siltation (4a), Appendix C-PCB, Priority Organics (5)	Cause Unknown (5)
				Cedar Run	Appendix B-Pathogens (5)	
				Pine Run	Appendix B-Pathogens (5)	
				Holtz Run	Appendix B-Pathogens (5)	
LEMOYNE BORO	PAG133552	No		Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Unnamed Tributaries to Susquehanna River	Appendix E-Siltation (5)	Other Habitat Alterations (4c)
				Susquehanna River	Appendix C-PCB (5)	
LOWER ALLEN TWP	PAG133711	No		Susquehanna River	Appendix C-PCB (5)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Yellow Breeches Creek	Appendix B-Pathogens (5)	
				Unnamed Tributaries to Yellow Breeches Creek	Appendix E-Organic Enrichment/Low D.O., Siltation (5)	
				Unnamed Tributaries to Cedar Run		Cause Unknown (5), Flow Alterations (4c)
				Cedar Run	Appendix B-Pathogens (5), Appendix E-Nutrients, Siltation (5)	Other Habitat Alterations (4c)

MS4 Name	NPDES ID	Individual Permit Required?	Reason	Impaired Downstream Waters or Applicable TMDL Name	Requirement(s)	Other Cause(s) of Impairment
Cumberland County						
MECHANICSBURG BORO	PAG133553	No		Trindle Spring Run	Appendix E-Siltation (4a), Appendix C-PCB, Priority Organics (5)	Cause Unknown (5)
				Unnamed Tributaries to Cedar Run		Flow Alterations, Other Habitat Alterations (4c)
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Cedar Run	Appendix B-Pathogens (5), Appendix E-Nutrients, Siltation (5)	
MIDDLESEX TWP		No		Wertz Run	Appendix E-Siltation (4a)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
MONROE TWP	PAG133573	No		Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Dogwood Run	Appendix B-Pathogens (5), Appendix E-Organic Enrichment/Low D.O., Suspended Solids (5)	
				Trindle Spring Run	Appendix E-Siltation (4a), Appendix C-PCB, Priority Organics (5)	Cause Unknown (5)
NEW CUMBERLAND BORO	PAG133677	No		Susquehanna River	Appendix C-PCB (5)	
				Yellow Breeches Creek	Appendix B-Pathogens (5)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
NORTH MIDDLETON TWP		Yes	SP	Alexanders Spring Creek	Appendix E-Siltation (4a)	
				Wertz Run	Appendix E-Siltation (4a)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
SHIREMANSTOWN BORO	PAG133660	No		Yellow Breeches Creek	Appendix B-Pathogens (5)	
				Unnamed Tributaries to Cedar Run		Flow Alterations, Other Habitat Alterations (4c)
				Susquehanna River	Appendix C-PCB (5)	
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Cedar Run	Appendix B-Pathogens (5), Appendix E-Nutrients, Siltation (5)	
SILVER SPRING TWP	PAI133514	Yes	SP, IP	Hogestown Run	Appendix E-Organic Enrichment/Low D.O., Siltation (4a), Appendix B-Pathogens (5)	Cause Unknown (5)
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Trindle Spring Run	Appendix E-Siltation (4a), Appendix C-PCB, Priority Organics (5)	Cause Unknown (5)
SOUTH MIDDLETON TWP		Yes	SP	Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	

MS4 Name	NPDES ID	Individual Permit Required?	Reason	Impaired Downstream Waters or Applicable TMDL Name	Requirement(s)	Other Cause(s) of Impairment
Cumberland County						
UPPER ALLEN TWP	PAG133708	No		Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	
				Cedar Run	Appendix B-Pathogens (5), Appendix E-Nutrients, Siltation (5)	Other Habitat Alterations (4c)
				Unnamed Tributaries to Yellow Breeches Creek	Appendix E-Organic Enrichment/Low D.O., Siltation (5)	Other Habitat Alterations (4c)
				Unnamed Tributaries to Cedar Run		Flow Alterations (4c)
				Yellow Breeches Creek	Appendix B-Pathogens (5)	
WORMLEYSBURG BORO	PAG133616	No		Susquehanna River	Appendix C-PCB (5)	
				Unnamed Tributaries to Susquehanna River	Appendix E-Siltation (5)	Other Habitat Alterations (4c)
				Chesapeake Bay Nutrients/Sediment	Appendix D-Nutrients, Siltation (4a)	

Section D

SECTION D - DETERMINE EXISTING LOADING FOR POLLUTANTS OF CONCERN

A. Base Pollutant Load Calculation

South Middleton Township calculated the existing pollutant loading rates (lbs/year) for sediment, phosphorus, and nitrogen generated within their regulated/planning area in the Spring of 2017. The process used to perform this task is as follows:

1. Analyze existing topographic and contour information on a GIS map to delineate the drainage area/sewershed to each regulated MS4 outfall.
2. Use the Stroud Water Research Center Wiki Watershed Tool (https://wikiwatershed.org) to digitize the sewershed area; the Wiki tool identifies the land use category breakdown within each storm sewershed.
3. Remove any non-Urban Area that is located downstream of the Urban Area and/or does not flow into the Urban Area of the sewershed area.
4. Remove any area located outside of the municipal boundary.
5. Calculate the impervious and pervious areas within each land use category by using data provided by the National Land Cover Database 2011 (www.mrlc.gov). This data identifies the percentage of impervious coverage in four land use categories as follows:
   a. Developed Open Space: 19% impervious
   b. Developed Low Intensity: 49% impervious
   c. Developed Medium Intensity: 79% impervious
   d. Developed High Intensity: 100% impervious
6. Add the total impervious and pervious areas within each sewershed. Multiply the total impervious and pervious areas by the applicable loading rate as identified in the Chesapeake Bay Derived Developed Land Loading Rates for PA Counties. The Cumberland County loading rates for sediment, phosphorus, and nitrogen are as follows:
   a. Developed impervious
      i. Sediment: 2,065.1 lbs/year
      ii. Phosphorus: 1.11 lbs/year
      iii. Nitrogen: 28.93 lbs/year
   b. Developed pervious
      i. Sediment: 306.95 lbs/year
      ii. Phosphorus: 0.34lbs/year
      iii. Nitrogen: 23.29 lbs/year
   c. Undeveloped Area outside the urbanized area
      i. Sediment: 234.6 lbs/acre/year
      ii. Phosphorus: 0.33 lbs/acre/year
      iii. Nitrogen: 10 lbs/acre/year
7. If applicable, reduce the existing baseline pollutant loads by assigning credit for structural BMPs in each sewershed area implemented prior to development of this PRP. The procedure for this task is described below.
8. Reduce the existing baseline pollutant loads by removing pollutant loads from parcels with NPDES MS4 permits and Rights-of-Way (R-O-W) areas of State Roads, Railroads, PA Turnpike,

airports, and any other parcel owned/operated by another MS4 permittee. The procedure for this task is described below.

9. Add the sediment, phosphorus, and nitrogen pollutant loads for each sewershed area by watershed area. Combine the total pollutant loads for each watershed to identify the total municipal baseline pollutant load.

B. Structural BMP Reduction Credits

Reduce the existing baseline pollutant loads by assigning credit for structural BMPs in each sewershed area implemented prior to development of this PRP. Each BMP identified in Attachment D7 includes the following information if applicable:

- Description of the BMP
- Latitude and longitude
- Location on the map
- The permit number, if any, that authorized installation of the BMP
- Calculations demonstrating the pollutant reductions achieved by the BMP (See Attachments D4-D6 for calculations)
- The date the BMP was installed and a statement that the BMP continues to serve the function it was designed for
- The O&M activities and frequencies associated with the BMP

1. Analyze existing topographic and contour information on a GIS map to identify existing structural BMPs within each regulated MS4 outfall sewershed area. Delineate the drainage area to each existing structural BMP.
2. Use the Stroud Water Research Center Wiki Watershed Tool (https://wikiwatershed.org) to digitize the drainage area; the Wiki tool identifies the land use category breakdown within each structural BMP drainage area.
3. Calculate the impervious and pervious areas within each land use category by using data provided by the National Land Cover Database 2011 (www.mrlc.gov), and as identified above (Part A.5).
4. Multiply the total impervious and pervious areas by the Chesapeake Bay Derived Developed Land Loading Rates for PA Counties as identified above (Part A.6).
5. Identify the percentage of pollutant reductions for each structural BMP by using PA DEP's BMP Effectiveness Values Table. Use the approved final subdivision, land development, and/or Post Construction Stormwater Management Plans to verify what type of stormwater BMP has been constructed. If no plans can be located, then existing detention basins are assumed to be dry detention basins. Multiply the BMP Effectiveness Value associated with the BMP by the calculated pollutant load for the same BMP to determine the appropriate pollutant reduction credit. Subtract the credit from the BMP pollutant load to determine the final pollutant load.
6. When one or more structural BMP(s) are located within the drainage area of another (sub-drainage area), the pollutant loads are calculated as follows: Subtract the impervious and pervious areas of the sub-drainage area from the overall drainage area. Determine the pollutant load that bypasses the sub-drainage area by multiplying the resultant impervious and pervious

areas by the County loading rates as identified above (Part A.6). Add the calculated bypass pollutant loading to the calculated upstream BMP(s) pollutant loading. Multiply the BMP Effectiveness Value associated with the BMP by the calculated pollutant load for the same BMP to determine the appropriate pollutant reduction credit. Subtract the credit from the BMP pollutant load to determine the final pollutant load.

C. Private MS4s/Right-of-Way (R-O-W) Reduction Credits

Reduce the existing baseline pollutant loads by removing pollutant loads from parcels with NPDES MS4 permits and Rights-of-Way (R-O-W) areas of State Roads, Railroads, PA Turnpike, airports, and any other parcel owned/operated by another MS4 permittee.

1. Analyze parcel information on a GIS map to identify any State Right-of-Way, Railroad Right-of-Way, or private MS4s. Mark the area within each sewershed area that falls under those categories. Calculate the area in each sewershed using GIS.
2. Calculate the impervious and pervious areas within each R-O-W. For this PRP, we have applied the medium density impervious area rate of 49% to these areas.
3. Multiply the total impervious and pervious areas by the Chesapeake Bay Derived Developed Land Loading Rates for PA Counties, as identified above (Part A.6).
4. Subtract the calculated Right-of-Way/private MS4 pollutant loads from the applicable sewershed area pollutant load.

Although the entire municipality is located within the Chesapeake Bay Watershed, we have summarized the pollutant load calculations and associated BMPs by local sub-watershed areas. In addition, South Middleton Township has large areas within the urbanized area where stormwater runoff drains to a closed depression and infiltrates into the ground. Because these areas do not discharge to surface water systems, the Township has excluded those areas from the baseline pollutant load calculations. Using the method described above, South Middleton Township has identified the baseline pollutant loads for each watershed as follows:

Watershed	Sediment (lbs/year)	Phosphorus (lbs/year)	Nitrogen (lbs/year)
Letort Spring Run	887,446	634	30,957
Yellow Breeches Creek	1,061,039	842	45,856
Hogestown Run	273,466	204	10,162
Alexanders Spring Creek	514,192	324	13,457
Conodoquinet Creek	107,742	86	4,878
Total	**2,843,885**	**2,090**	**105,310**

Attachments

D1: Watershed and Pollutant Loads Summary
D2: Outfall Information
D3: Outfall and Sewershed Spreadsheets
D4: Pollutant Load Calculations: Letort Spring Run
D5: Pollutant Load Calculations: Yellow Breeches Creek
D6: Pollutant Load Calculations: Hogestown Run
D7: Pollutant Load Calculations: Alexanders Spring Creek
D8: Pollutant Load Calculations: Conodoquinet Creek
D9: Existing BMP Summary
D10: PA DEP BMP Effectiveness Values
D11: Land Loading Rates for PA Counties

Attachment D1: Watershed Pollutant Loads Summary

WATERSHED POLLUTANT LOAD SUMMARY						
Watershed	**Baseline Pollutant Loads (lbs/year)**			**Required Reductions (lbs/year)**		
	Sediment	**Phosphorus**	**Nitrogen**	**Sediment (10%)**	**Phosphorus (5%)**	**Nitrogen (3%)**
Letort Spring Run	887,446	634	30,957	88,745	32	929
Yellow Breeches Creek	1,061,039	842	45,856	106,104	42	1,376
Hogestown Run	273,466	204	10,162	27,347	10	305
Alexanders Spring Creek	514,192	324	13,457	51,419	16	404
Conodoquinet Creek	107,742	86	4,878	10,774	4	146
Total	**2,843,885**	**2,090**	**105,310**	**284,389**	**104**	**3,160**

Attachment D2: Outfall Information

OUTFALL INFORMATION				
Outfall ID	**Watershed**	**Sediment Loading [lbs/year]**	**Phosphorus Loading [lbs/year]**	**Nitrogen Loading [lbs/year]**
R1	Letort Spring Run	8,248	5	227
R2	Letort Spring Run	10,887	7	349
R3	Letort Spring Run	71,212	48	2,082
R4	Letort Spring Run	1,599	1	30
R6	Letort Spring Run	38,304	26	1,097
R7	Letort Spring Run	50,108	35	1,623
R8	Letort Spring Run	194,694	158	8,972
R9	Letort Spring Run	44,336	36	2,025
R10	Letort Spring Run	17,959	12	504
R13	Letort Spring Run	3,451	2	115
R101	Letort Spring Run	169,258	122	6,157
R102	Letort Spring Run	28,852	18	668
R103	Letort Spring Run	134,191	93	4,563
R106	Letort Spring Run	114,348	70	2,544
	Totals for Letort Spring Run Watershed	**887,446**	**634**	**30,957**
R11	Yellow Breeches Creek	1,055,145	836	45,522
R12	Yellow Breeches Creek	5,894	5	333
	Totals for Yellow Breeches Creek	**1,061,039**	**842**	**45,856**
R109	Hogestown Run	273,466	204	10,162
	Totals for Hogestown Run	**273,466**	**204**	**10,162**
R107	Alexanders Spring Creek	14,949	10	457
R108	Alexanders Spring Creek	499,243	313	13,000
	Totals for Alexanders Spring Creek	**514,192**	**324**	**13,457**
R104	Conodoquinet Creek	24,780	19	1,005
R105	Conodoquinet Creek	82,962	68	3,873
	Totals for Conodoquinet Creek	**107,742**	**86**	**4,878**
	TOTAL BASELINE POLLUTANT LOADS	**2,843,885**	**2,090**	**105,310**

Attachment D3: Outfall and Sewershed Spreadsheets

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R1					Sewershed R2				
	Impaired Stream	Letort Spring Run					Letort Spring Run				
	Total Drainage Area (m2)	37,683.36					60,113.97				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	8,075.01	2.00	21.4	0.37	1.63	21,533.36	5.32	35.8	1.01	4.30
Developed, Low Intensity	49%	14,355.57	3.55	38.1	1.74	1.81	20,636.14	5.10	34.3	2.50	2.60
Developed, Medium Intensity	79%	6,280.56	1.55	16.7	1.23	0.33	4,486.12	1.11	7.5	0.88	0.23
Developed, High Intensity	100%	897.22	0.22	2.4	0.22	-	-	-	-	-	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	3,588.89	0.89	9.5	-	0.89	897.22	0.22	1.5	-	0.22
Evergreen Forest	0	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-	-	-	-	-	-
Pasture/Hay	0	3,588.89	0.89	9.5	-	0.89	12,561.13	3.10	20.9	-	3.10
Cultivated Crops	0	-	-	-	-	-	-	-	-	-	-
Woody Wetlands	0	-	-	-	-	-	-	-	-	-	-
Emergent Herbaceous Wetlands	0	897.22	0.22	2.4	-	0.22	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
				Total	**3.56**	**5.76**			**Total**	**4.39**	**10.46**

Land Use	Sewershed R3					Sewershed R4				
Impaired Stream	Letort Spring Run					Letort Spring Run				
Total Drainage Area (m2)	340,945.02					4,486.11				
	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	60,113.99	14.85	17.6	2.82	12.02	897.22	0.22	20.0	0.04	0.17
Developed, Low Intensity	87,927.93	21.73	25.8	10.65	11.08	897.22	0.22	20.0	0.11	0.11
Developed, Medium Intensity	46,655.63	11.53	13.7	9.11	2.42	1,794.45	0.44	40.0	0.35	0.09
Developed, High Intensity	16,150.03	3.99	4.7	3.99	-	897.22	0.22	20.0	0.22	-
Barren Land	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	49,347.31	12.19	14.5	-	12.19	-	-	-	-	-
Evergreen Forest	4,486.12	1.11	1.3	-	1.11	-	-	-	-	-
Mixed Forest	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	-	-	-	-	-	-	-	-	-	-
Pasture/Hay	58,319.54	14.41	17.1	-	14.41	-	-	-	-	-
Cultivated Crops	17,047.25	4.21	5.0	-	4.21	-	-	-	-	-
Woody Wetlands	-	-	-	-	-	-	-	-	-	-
Emergent Herbaceous Wetlands	897.22	0.22	0.3	-	0.22	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
			Total	**26.57**	**57.67**			**Total**	**0.72**	**0.38**

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R6					Sewershed R12					Sewershed R9					Sewershed R10				
	Impaired Stream	Letort Spring Run					Yellow Breeches					Letort Spring Run					Letort Spring Run				
	Total Drainage Area (m2)	176,752.81					64,600.40					357,991.42					83,441.66				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	33,197.23	8.20	18.8	1.56	6.64	10,766.73	2.66	16.7	0.51	2.16	75,366.62	18.62	21.1	3.54	15.09	36,786.11	9.09	44.1	1.73	7.36
Developed, Low Intensity	49%	78,058.35	19.29	44.2	9.45	9.84	10,766.73	2.66	16.7	1.30	1.36	62,805.51	15.52	17.5	7.60	7.91	42,169.44	10.42	50.5	5.11	5.31
Developed, Medium Intensity	79%	16,150.00	3.99	9.1	3.15	0.84	-	-	-	-	-	7,177.77	1.77	2.0	1.40	0.37	897.22	0.22	1.1	0.18	0.05
Developed, High Intensity	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	36,786.12	9.09	20.8	-	9.09	21,533.47	5.32	33.3	-	5.32	72,674.95	17.96	20.3	-	17.96	2,691.67	0.67	3.2	-	0.67
Evergreen Forest	0	4,486.11	1.11	2.5	-	1.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasture/Hay	0	7,177.78	1.77	4.1	-	1.77	21,533.47	5.32	33.3	-	5.32	13,458.32	3.33	3.8	-	3.33	897.22	0.22	1.1	-	0.22
Cultivated Crops	0	897.22	0.22	0.5	-	0.22	-	-	-	-	-	126,508.25	31.26	35.3	-	31.26	-	-	-	-	-
Woody Wetlands	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emergent Herbaceous Wetlands	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Total	**14.16**	**29.51**			**Total**	**1.81**	**14.15**			**Total**	**12.54**	**75.92**			**Total**	**7.01**	**13.61**

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R11					Sewershed R13					Sewershed R101					Sewershed R102				
	Impaired Stream	Yellow Breeches Creek					Letort Spring Run					Letort Spring Run					Letort Spring Run				
	Total Drainage Area (m2)	8,270,000.00					18,841.71					1,134,088.36					109,460.93				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	1,490,000.00	368.19	18.0	69.95	298.24	3,588.90	0.89	19.0	0.17	0.72	148,938.82	36.80	13.1	6.98	29.82	12,561.09	3.10	11.5	0.60	2.50
Developed, Low Intensity	49%	1,660,000.00	410.19	20.1	201.00	209.20	8,075.02	2.00	42.9	0.98	1.02	274,549.87	67.84	24.2	33.24	34.59	94,208.18	23.28	86.1	11.41	11.87
Developed, Medium Intensity	79%	200,000.00	49.42	2.4	39.04	10.38	-	-	-	-	-	112,152.73	27.71	9.9	21.89	5.81	2,691.66	0.67	2.5	0.53	0.14
Developed, High Intensity	100%	40,000.00	9.88	0.4	9.88	-	-	-	-	-	-	28,711.10	7.09	2.5	7.09	-	-	-	-	-	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	260,000.00	64.25	3.2	-	64.25	-	-	-	-	-	146,247.15	36.14	12.9	-	36.14	-	-	-	-	-
Evergreen Forest	0	20,000.00	4.94	0.2	-	4.94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasture/Hay	0	1,290,000.00	318.77	15.6	-	318.77	7,177.79	1.77	38.1	-	1.77	309,541.52	76.49	27.3	-	76.49	-	-	-	-	-
Cultivated Crops	0	3,310,000.00	817.92	40.0	-	817.92	-	-	-	-	-	102,283.29	25.27	9.0	-	25.27	-	-	-	-	-
Woody Wetlands	0	-	-	-	-	-	-	-	-	-	-	5,383.33	1.33	0.5	-	1.33	-	-	-	-	-
Emergent Herbaceous Wetlands	0	-	-	-	-	-	-	-	-	-	-	6,280.55	1.55	0.6	-	1.55	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Total	319.87	1,723.69			Total	1.15	3.51			Total	69.21	211.01			Total	12.53	14.52

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R103					Sewershed R104				
	Impaired Stream	Letort Spring Run					Conodoquinet Creek				
	Total Drainage Area (m2)	804,809.50					186,622.18				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	135,480.75	33.48	16.8	6.36	27.11	26,019.44	6.43	13.9	1.22	5.21
Developed, Low Intensity	49%	249,428.14	61.63	31.0	30.20	31.43	6,280.55	1.55	3.4	0.76	0.79
Developed, Medium Intensity	79%	100,489.03	24.83	12.5	19.62	5.21	7,177.78	1.77	3.8	1.40	0.37
Developed, High Intensity	100%	3,588.89	0.89	0.4	0.89	-	27,813.88	6.87	14.9	6.87	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	57,422.31	14.19	7.1	-	14.19	3,588.89	0.89	1.9	-	0.89
Evergreen Forest	0	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-	2,691.67	0.67	1.4	-	0.67
Pasture/Hay	0	170,472.47	42.12	21.2	-	42.12	39,477.77	9.76	21.2	-	9.76
Cultivated Crops	0	87,927.91	21.73	10.9	-	21.73	73,572.20	18.18	39.4	-	18.18
Woody Wetlands	0	-	-	-	-	-	-	-	-	-	-
Emergent Herbaceous Wetlands	0	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
				Total	57.07	141.80			Total	10.26	35.86

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R105					Sewershed R106				
	Impaired Stream	Conodoquinet Creek					Letort Spring Run				
	Total Drainage Area (m2)	708,805.48					479,116.90				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	74,469.44	18.40	10.5	3.50	14.91	80,750.04	19.95	16.9	3.79	16.16
Developed, Low Intensity	49%	43,066.66	10.64	6.1	5.21	5.43	175,855.64	43.45	36.7	21.29	22.16
Developed, Medium Intensity	79%	25,122.22	6.21	3.5	4.90	1.30	155,219.52	38.36	32.4	30.30	8.05
Developed, High Intensity	100%	53,833.33	13.30	7.6	13.30	-	16,150.01	3.99	3.4	3.99	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	85,236.10	21.06	12.0	-	21.06	-	-	-	-	-
Evergreen Forest	0	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	50,244.44	12.42	7.1	-	12.42	-	-	-	-	-
Pasture/Hay	0	64,599.99	15.96	9.1	-	15.96	51,141.69	12.64	10.7	-	12.64
Cultivated Crops	0	312,233.30	77.15	44.1	-	77.15	-	-	-	-	-
Woody Wetlands	0	-	-	-	-	-	-	-	-	-	-
Emergent Herbaceous Wetlands	0	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
				Total	26.92	148.23			Total	59.38	59.02

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R107					Sewershed R108				
	Impaired Stream	Alexanders Spring Creek					Alexanders Spring Creek				
	Total Drainage Area (m2)	100,488.92					2,378,539.70				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	21,533.34	5.32	21.4	1.01	4.31	415,414.52	102.65	17.5	19.50	83.15
Developed, Low Intensity	49%	28,711.12	7.09	28.6	3.48	3.62	425,283.98	105.09	17.9	51.49	53.60
Developed, Medium Intensity	79%	17,047.23	4.21	17.0	3.33	0.88	376,833.90	93.12	15.8	73.56	19.55
Developed, High Intensity	100%	2,691.67	0.67	2.7	0.67	-	459,378.47	113.51	19.3	113.51	-
Barren Land	0	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	0	30,505.56	7.54	30.4	-	7.54	82,544.57	20.40	3.5	-	20.40
Evergreen Forest	0	-	-	-	-	-	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-	33,197.27	8.20	1.4	-	8.20
Pasture/Hay	0	-	-	-	-	-	216,230.88	53.43	9.1	-	53.43
Cultivated Crops	0	-	-	-	-	-	364,272.77	90.01	15.3	-	90.01
Woody Wetlands	0	-	-	-	-	-	5,383.34	1.33	0.2	-	1.33
Emergent Herbaceous Wetlands	0	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
				Total	**8.48**	**16.35**			**Total**	**258.07**	**329.67**

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY	Sewershed R7-PA					Sewershed R8-PA				
Impaired Stream	Letort Spring Run					Letort Spring Run				
Total Drainage Area (m2)	279,036.28					1,600,647.39				
Land Use	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	48,450.03	11.97	-	2.27	9.70	316,720.03	78.26	-	14.87	63.39
Developed, Low Intensity	131,891.74	32.59	-	15.97	16.62	327,486.72	80.92	-	39.65	41.27
Developed, Medium Intensity	6,280.56	1.55	-	1.23	0.33	24,225.04	5.99	-	4.73	1.25
Developed, High Intensity	0.00	-	-	-	-	5,383.34	1.33	-	1.33	-
Barren Land	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	-	-	-	-	-	236,867.10	58.53	-	-	58.53
Evergreen Forest	-	-	-	-	-	-	-	-	-	-
Mixed Forest	-	-	-	-	-	-	-	-	-	-
Shrub/Scrub	-	-	-	-	-	-	-	-	-	-
Grassland/Herbaceous	-	-	-	-	-	-	-	-	-	-
Pasture/Hay	67,291.71	16.63	-	-	16.63	437,845.25	108.19	-	-	108.19
Cultivated Crops	25,122.24	6.21	-	-	6.21	236,867.10	58.53	-	-	58.53
Woody Wetlands	-	-	-	-	-	15,252.81	3.77		-	3.77
Emergent Herbaceous Wetlands	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
			Total	**19.47**	**49.48**			**Total**	**60.58**	**334.94**

Outfall and Sewershed Spreadsheet

SOUTH MIDDLETON TOWNSHIP CUMBERLAND COUNTY		Sewershed R109-PA				
	Impaired Stream	Hogestown Run				
	Total Drainage Area (m2)	1,727,154.55				
Land Use	% Impervious	Area (m2)	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	744,695.21	184.02	-	34.96	149.04
Developed, Low Intensity	49%	347,225.36	85.80	-	42.04	43.76
Developed, Medium Intensity	79%	49,347.27	12.19	-	9.63	2.56
Developed, High Intensity	100%	3,588.89	0.89	-	0.89	-
Barren Land	0	-	-	-	-	-
Deciduous Forest	0	12,561.12	3.10	-	-	3.10
Evergreen Forest	0	-	-	-	-	-
Mixed Forest	0	-	-	-	-	-
Shrub/Scrub	0	-	-	-	-	-
Grassland/Herbaceous	0	-	-	-	-	-
Pasture/Hay	0	132,789.03	32.81	-	-	32.81
Cultivated Crops	0	436,947.67	107.97	-	-	107.97
Woody Wetlands	0	-	-	-	-	-
Emergent Herbaceous Wetlands	0	-	-	-	-	-
		-	-	-	-	-
				Total	**87.53**	**339.25**

Attachment D4: Pollutant Load Calculations: Letort Spring Run

Municipal Storm Sewershed
R1

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2.00	0.0	0.38	1.62
Developed, Low Intensity	49%	3.55	0.0	1.74	1.81
Developed, Medium Intensity	79%	1.55	0.0	1.22	0.33
Developed, High Intensity	100%	0.22	0.0	0.22	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.89	0.0	0.00	0.89
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	0.89	0.0	0.00	0.89
Emergent Herbaceous Wetlands	0	0.22	0.0	0.00	0.22
Total		**9.32**	**0.7**	**3.56**	**5.76**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	3.56	2,065.10	7,360
Developed Pervious	5.76	306.95	1,767
Total	**9.32**		**9,127**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	3.56	1.11	4
Developed Pervious	5.76	0.34	2
Total	**9.32**		**6**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	3.56	28.93	103
Developed Pervious	5.76	23.29	134
Total	**9.32**		**237**

Municipal Storm Sewershed
R1

Drainage Area: Detention Basin Bypass					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Deciduous Forest	0	2,691.67	0.67	0.00	0.67
Emergent Herbaceous Wetlands	0	1,794.45	0.44	0.00	0.44
Total			**1.11**	**0.00**	**1.11**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.00	2,065.10	0
Developed Pervious	1.11	306.95	340
Total	**1.11**		**340**

Detention Basin 1: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.00	1.11	0
Developed Pervious	1.11	0.34	0
Total	**1.11**		**0**

Detention Basin 1 Bypass: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.00	28.93	0
Developed Pervious	1.11	23.29	26
Total	**1.11**		**26**

Drainage Areas		
Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Total Drainage	3.56	5.76
Detention Basin 1 Bypass	0.00	1.11
Detention Basin 1	**3.56**	**4.65**

Municipal Storm Sewershed
R1

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	3.56	2,065.10	7,360
Developed Pervious	4.65	306.95	1,427
Total	**8.21**		**8,787**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	3.56	1.11	4
Developed Pervious	4.65	0.34	2
Total	**8.21**		**6**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	3.56	28.93	103
Developed Pervious	4.65	23.29	108
Total	**8.21**		**211**

Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	8,787	10%	878.66	**7,908**
Phosphorus Load	6	10%	0.55	**5**
Nitrogen Load	211	5%	10.57	**201**

Municipal Storm Sewershed
R1

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin Bypass**			
Sediment Load	7,908	340			
Phosphorus Load	5	0			
Nitrogen Load	201	26			

Pollutant	**Total Post-BMP (Best Management Practice) Loading**
Sediment Load	**8,248**
Phosphorus Load	**5**
Nitrogen Load	**227**

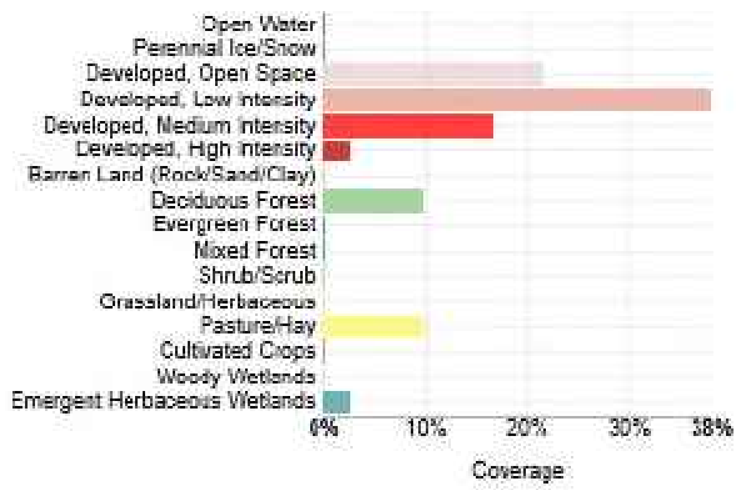
Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	9,127	879	0	**8,248**
Phosphorus Load	6	1	0	**5**
Nitrogen Load	237	11	0	**227**

Municipal Storm Sewershed R1
Letort Spring Run

Municipal Storm Sewershed R1
Letort Spring Run

Selected Area
Total Area 36,927 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	8,075.01	21.4
Developed, Low Intensity	14,355.57	38.1
Developed, Medium Intensity	6,280.56	16.7
Developed, High Intensity	897.22	2.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	3,588.89	9.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	3,588.89	9.5
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	897.22	2.4

Municipal Storm Sewershed
R2

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	5.32	0.0	1.01	4.31
Developed, Low Intensity	49%	5.10	0.0	2.50	2.60
Developed, Medium Intensity	79%	1.11	0.0	0.88	0.23
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.22	0.0	0.00	0.22
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	3.10	0.0	0.00	3.10
Cultivated Crops	0	0.00	0.0	0.00	0.00
Total		**14.85**	**0.7**	**4.39**	**10.46**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	4.39	2,065.10	9,059
Developed Pervious	10.46	306.95	3,212
Total	**14.85**		**12,271**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	4.39	1.11	5
Developed Pervious	10.46	0.34	4
Total	**14.85**		**8**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	4.39	28.93	127
Developed Pervious	10.46	23.29	244
Total	**14.85**		**371**

Municipal Storm Sewershed R2

Drainage Area: Detention Basin 1 Bypass					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Deciduous Forest	0	897.22	0.22	0.00	0.22
Total			**0.22**	**0.00**	**0.22**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.00	2,065.10	0
Developed Pervious	0.22	306.95	68
Total	**0.22**		**68**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.00	1.11	0
Developed Pervious	0.22	0.34	0
Total	**0.22**		**0**

Detention Basin 1 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.00	28.93	0
Developed Pervious	0.22	23.29	5
Total	**0.22**		**5**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total Drainage	4.39	10.46
Detention Basin 1 Bypass	0.00	0.22
Detention Basin 1	**4.39**	**10.24**

Municipal Storm Sewershed
R2

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	4.39	2,065.10	9,059
Developed Pervious	10.24	306.95	3,144
Total	**14.63**		**12,203**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	4.39	1.11	5
Developed Pervious	10.24	0.34	3
Total	**14.63**		**8**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	4.39	28.93	127
Developed Pervious	10.24	23.29	239
Total	**14.63**		**365**

Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	12,203	10%	1,220.26	**10,982**
Phosphorus Load	8	10%	0.84	**8**
Nitrogen Load	365	5%	18.27	**347**

Municipal Storm Sewershed
R2

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin Bypass**			
Sediment Load	10,982	68			
Phosphorus Load	8	0			
Nitrogen Load	347	5			

Pollutant	**Total Post-BMP (Best Management Practice) Loading**
Sediment Load	**11,050**
Phosphorus Load	**8**
Nitrogen Load	**352**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	0.14	49%	0.07	0.07
		Total	**0.07**	**0.07**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.07	2,065.10	142
Developed Pervious	0.07	306.95	22
Total	**0.14**		**164**

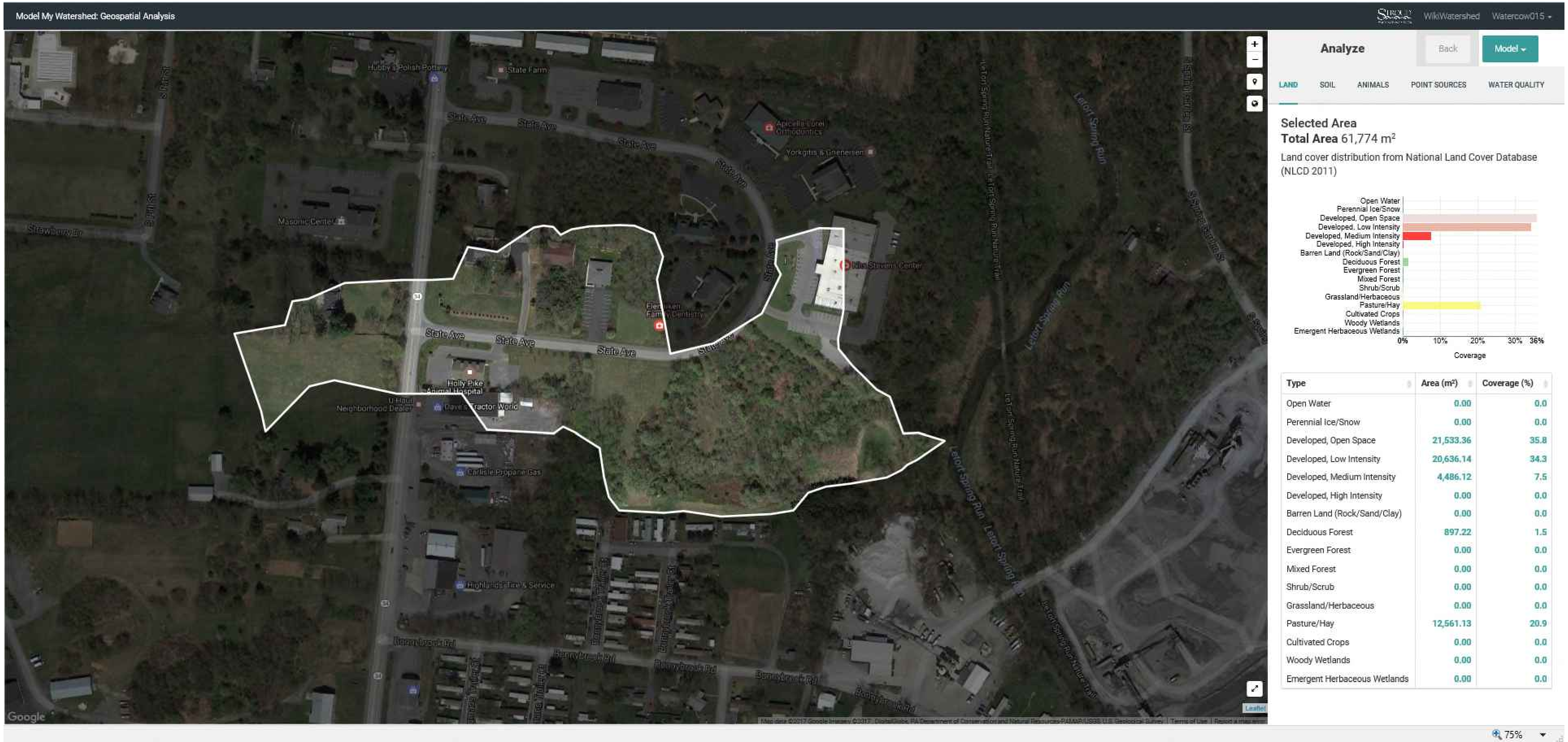
Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.07	1.11	0
Developed Pervious	0.07	0.34	0
Total	**0.14**		**0**

Municipal Storm Sewershed
R2

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.07	28.93	2
Developed Pervious	0.07	23.29	2
Total	**0.14**		**4**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	12,271	1,220	164	**10,887**
Phosphorus Load	8	1	0	**7**
Nitrogen Load	371	18	4	**349**

Municipal Storm Sewershed R2
Letort Spring Run

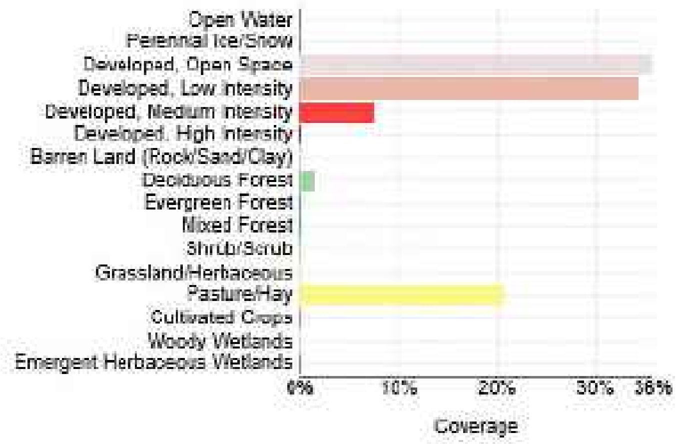


Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	21,533.36	35.8
Developed, Low Intensity	20,636.14	34.3
Developed, Medium Intensity	4,486.12	7.5
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	897.22	1.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	12,561.13	20.9
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R2
Letort Spring Run

Selected Area
Total Area 61,774 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	21,533.36	35.8
Developed, Low Intensity	20,636.14	34.3
Developed, Medium Intensity	4,486.12	7.5
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	897.22	1.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	12,561.13	20.9
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R3

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	14.85	0.0	2.82	12.03
Developed, Low Intensity	49%	21.73	0.0	10.65	11.08
Developed, Medium Intensity	79%	11.53	0.0	9.11	2.42
Developed, High Intensity	100%	3.99	0.0	3.99	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	12.19	0.0	0.00	12.19
Evergreen Forest	0	1.11	0.0	0.00	1.11
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	14.41	0.0	0.00	14.41
Cultivated Crops	0	4.21	0.0	0.00	4.21
Emergent Herbaceous Wetlands	0	0.22	0.0	0.00	0.22
Total		**84.24**	**0.7**	**26.57**	**57.67**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	26.57	2,065.10	54,865
Developed Pervious	57.67	306.95	17,702
Total	**84.24**		**72,568**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	26.57	1.11	29
Developed Pervious	57.67	0.34	20
Total	**84.24**		**49**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	26.57	28.93	769
Developed Pervious	57.67	23.29	1,343
Total	**84.24**		**2,112**

Municipal Storm Sewershed
R3

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions

	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	1.16	49%	0.57	0.59
		Total	**0.57**	**0.59**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.57	2,065.10	1,174
Developed Pervious	0.59	306.95	182
Total	**1.16**		**1,355**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.57	1.11	1
Developed Pervious	0.59	0.34	0
Total	**1.16**		**1**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.57	28.93	16
Developed Pervious	0.59	23.29	14
Total	**1.16**		**30**

Final Baseline Pollutant Loads (lbs/year)

Pollutant	Pollutant Load from Outfall	BMP Reductions	Right-of-Way (R-O-W) Reductions	Final Pollutant Loading from Outfall
Sediment Load	72,568	0	1,355	**71,212**
Phosphorus Load	49	0	1	**48**
Nitrogen Load	2,112	0	30	**2,082**

Municipal Storm Sewershed R3
Letort Spring Run

Model My Watershed: Geospatial Analysis

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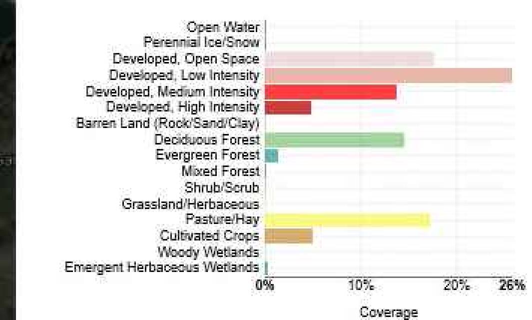
Selected Area
Total Area 338,391 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



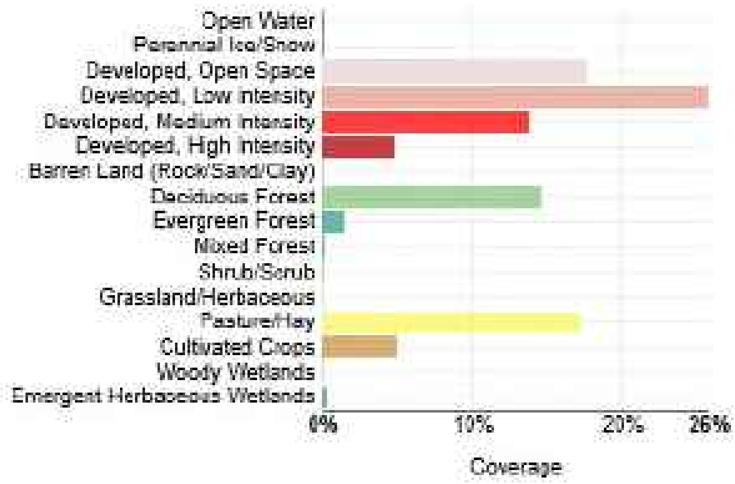
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	60,113.99	17.6
Developed, Low Intensity	87,927.93	25.8
Developed, Medium Intensity	46,655.63	13.7
Developed, High Intensity	16,150.03	4.7
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	49,347.31	14.5
Evergreen Forest	4,486.12	1.3
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	58,319.54	17.1
Cultivated Crops	17,047.25	5.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	897.22	0.3

Municipal Storm Sewershed R3
Letort Spring Run

Selected Area

Total Area 338,391 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	60,113.99	17.6
Developed, Low Intensity	87,927.93	25.8
Developed, Medium Intensity	46,655.63	13.7
Developed, High Intensity	16,150.03	4.7
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	49,347.31	14.5
Evergreen Forest	4,486.12	1.3
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	58,319.54	17.1
Cultivated Crops	17,047.25	5.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	897.22	0.3

Municipal Storm Sewershed
R4

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	0.22	0.0	0.04	0.18
Developed, Low Intensity	49%	0.22	0.0	0.11	0.11
Developed, Medium Intensity	79%	0.44	0.0	0.35	0.09
Developed, High Intensity	100%	0.22	0.0	0.22	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.00	0.0	0.00	0.00
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	0.00	0.0	0.00	0.00
Cultivated Crops	0	0.00	0.0	0.00	0.00
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**1.10**	**0.7**	**0.72**	**0.38**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.72	2,065.10	1,481
Developed Pervious	0.38	306.95	118
Total	**1.10**		**1,599**

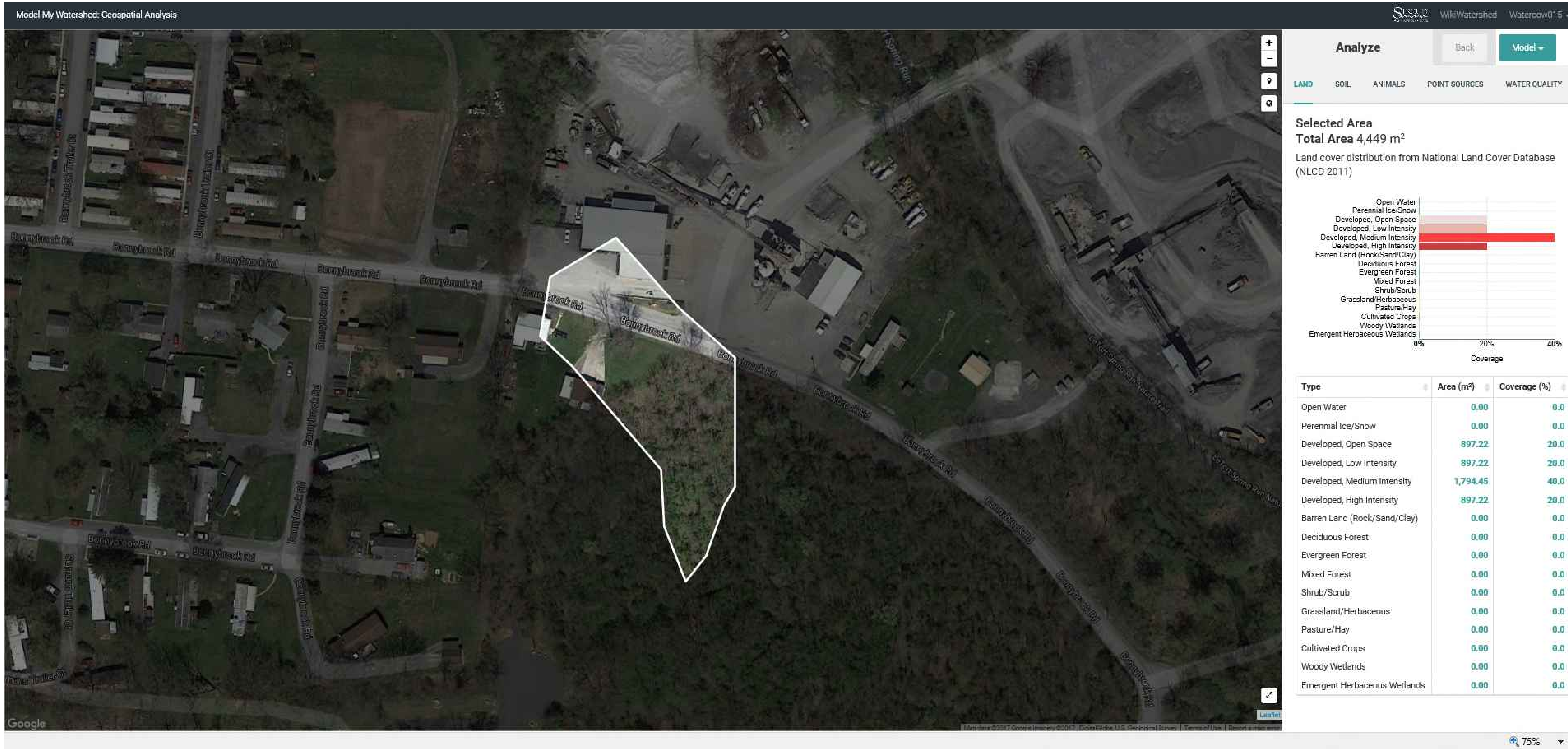
Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.72	1.11	1
Developed Pervious	0.38	0.34	0
Total	**1.10**		**1**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.72	28.93	21
Developed Pervious	0.38	23.29	9
Total	**1.10**		**30**

Municipal Storm Sewershed R4
Letort Spring Run

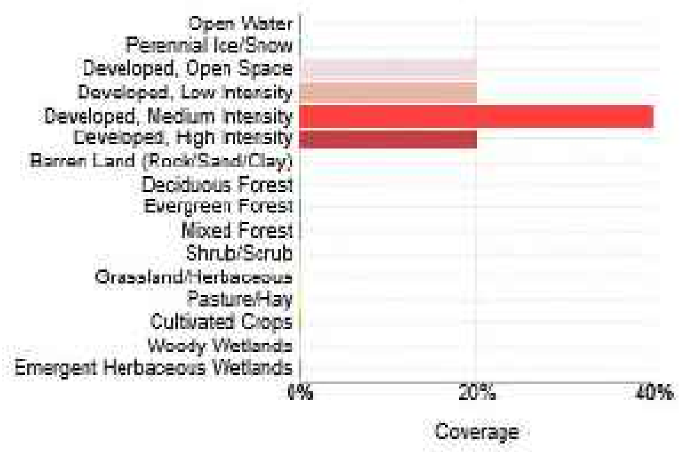


Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	897.22	20.0
Developed, Low Intensity	897.22	20.0
Developed, Medium Intensity	1,794.45	40.0
Developed, High Intensity	897.22	20.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R4
Letort Spring Run

Selected Area
Total Area 4,449 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	897.22	20.0
Developed, Low Intensity	897.22	20.0
Developed, Medium Intensity	1,794.45	40.0
Developed, High Intensity	897.22	20.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R6

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	8.20	0.0	1.56	6.64
Developed, Low Intensity	49%	19.29	0.0	9.45	9.84
Developed, Medium Intensity	79%	3.99	0.0	3.15	0.84
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	9.09	0.0	0.00	9.09
Evergreen Forest	0	1.11	0.0	0.00	1.11
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	1.77	0.0	0.00	1.77
Cultivated Crops	0	0.22	0.0	0.00	0.22
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**43.67**	**0.7**	**14.16**	**29.51**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	14.16	2,065.10	29,246
Developed Pervious	29.51	306.95	9,057
Total	**43.67**		**38,304**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	14.16	1.11	16
Developed Pervious	29.51	0.34	10
Total	**43.67**		**26**

Table 4: Nitrogen Loading

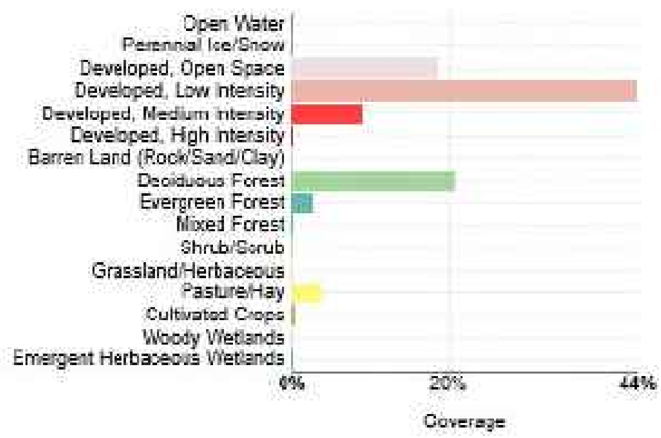
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	14.16	28.93	410
Developed Pervious	29.51	23.29	687
Total	**43.67**		**1,097**

Municipal Storm Sewershed R6
Letort Spring Run

Municipal Storm Sewershed R6
Letort Spring Run

Selected Area
Total Area 175,531 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	33,157.23	18.8
Developed, Low Intensity	78,058.35	44.2
Developed, Medium Intensity	16,150.00	9.1
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	36,766.12	20.8
Evergreen Forest	4,486.11	2.5
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	7,177.78	4.1
Cultivated Crops	897.22	0.5
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R7

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	11.97	0.0	2.27	9.70
Developed, Low Intensity	49%	32.59	0.0	15.97	16.62
Developed, Medium Intensity	79%	1.55	0.0	1.22	0.33
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.00	0.0	0.00	0.00
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	16.63	0.0	0.00	16.63
Cultivated Crops	0	6.21	0.0	0.00	6.21
Total		**68.95**	**0.7**	**19.47**	**49.48**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	19.47	2,065.10	40,203
Developed Pervious	49.48	306.95	15,189
Total	**68.95**		**55,392**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	19.47	1.11	22
Developed Pervious	49.48	0.34	17
Total	**68.95**		**38**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	19.47	28.93	563
Developed Pervious	49.48	23.29	1,152
Total	**68.95**		**1,716**

Municipal Storm Sewershed
R7

Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	6,280.56	1.55	0.29	1.26
Developed, Low Intensity	49%	60,113.91	14.85	7.28	7.58
Developed, Medium Intensity	79%	2,691.67	0.67	0.53	0.14
Pasture/Hay	0	39,477.79	9.76	0.00	9.76
Cultivated Crops	0	22,430.56	5.54	0.00	5.54
Total		**130,994.49**	**32.37**	**8.10**	**24.27**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	8.10	2,065.10	16,725
Developed Pervious	24.27	306.95	7,450
Total	**32.37**		**24,175**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	8.10	1.11	9
Developed Pervious	24.27	0.34	8
Total	**32.37**		**17**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	8.10	28.93	234
Developed Pervious	24.27	23.29	565
Total	**32.37**		**800**

Municipal Storm Sewershed
R7

Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	24,175	10%	2,417.50	**21,758**
Phosphorus Load	17	10%	1.72	**16**
Nitrogen Load	800	5%	39.98	**760**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	28,711.14	7.09	1.35	5.75
Developed, Low Intensity	49%	32,300.03	7.98	3.91	4.07
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Pasture/Hay	0	12,561.12	3.10	0.00	3.10
Total		**75,366.74**	**18.62**	**5.61**	**13.01**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	5.61	2,065.10	11,584
Developed Pervious	13.01	306.95	3,995
Total	**18.62**		**15,578**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.61	1.11	6
Developed Pervious	13.01	0.34	4
Total	**18.62**		**11**

Municipal Storm Sewershed
R7

Detention Basin 2: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	5.61	28.93	162
Developed Pervious	13.01	23.29	303
Total	**18.62**		**465**

Detention Basin 2: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 2 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 2 (lbs/year)
Sediment Load	15,578	10%	1,557.83	**14,021**
Phosphorus Load	11	10%	1.07	**10**
Nitrogen Load	465	5%	23.27	**442**

Drainage Areas

Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Total Drainage	19.47	49.48
Detention Basin 1	8.10	24.27
Detention Basin 2	5.61	13.01
Detention Basin Bypass	**5.76**	**12.20**

Detention Basin Bypass: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	5.76	2,065.10	11,894
Developed Pervious	12.20	306.95	3,744
Total	**17.96**		**15,638**

Municipal Storm Sewershed
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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.76	1.11	6
Developed Pervious	12.20	0.34	4
Total	**17.96**		**11**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.76	28.93	167
Developed Pervious	12.20	23.29	284
Total	**17.96**		**451**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 2**	**Detention Basin Bypass**		
Sediment Load	21,758	14,021	15,638		
Phosphorus Load	16	10	11		
Nitrogen Load	760	442	451		

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**51,416**
Phosphorus Load	**36**
Nitrogen Load	**1,652**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	1.12	49%	0.55	0.57
		Total	**0.55**	**0.57**

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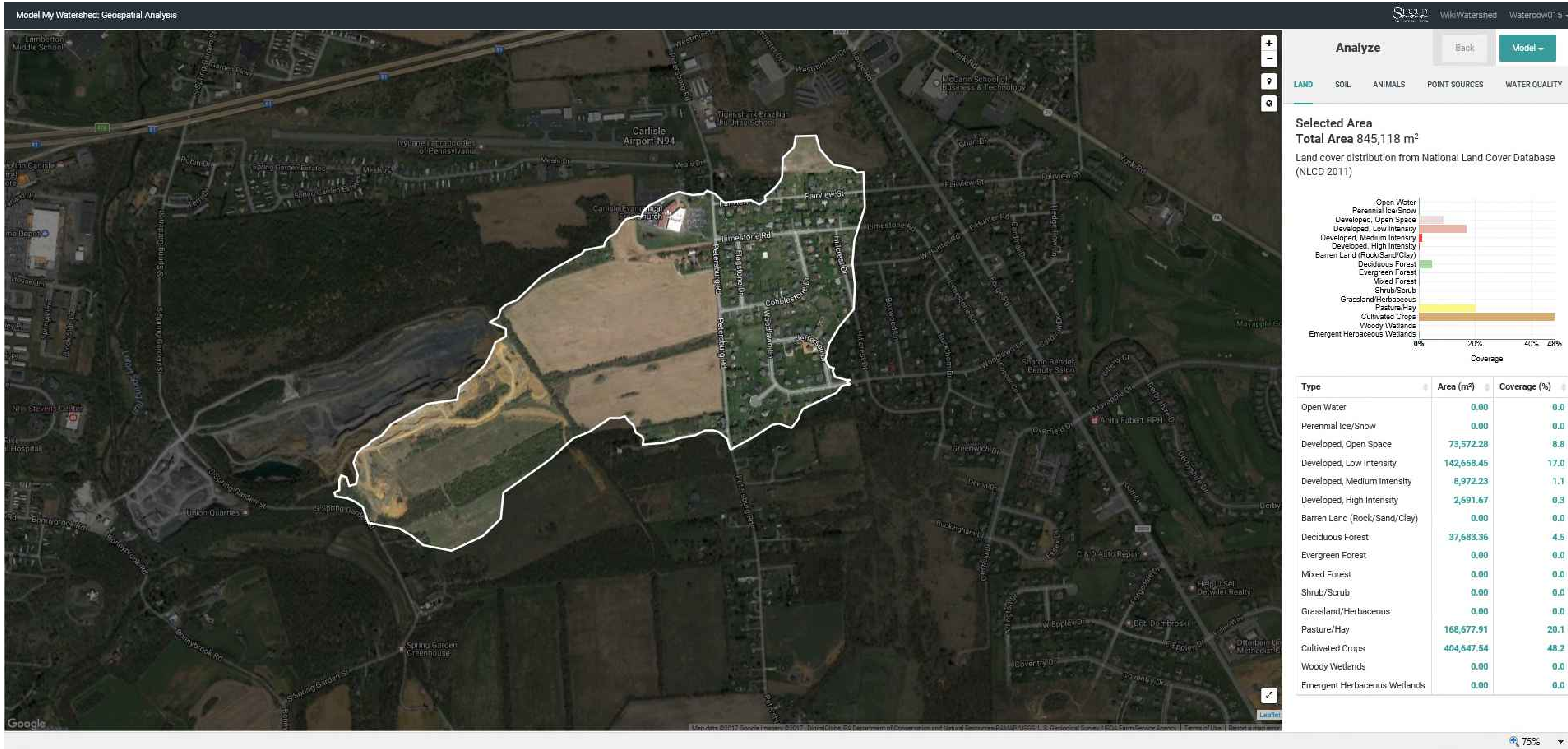
Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.55	2,065.10	1,133
Developed Pervious	0.57	306.95	175
Total	**1.12**		**1,309**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.55	1.11	1
Developed Pervious	0.57	0.34	0
Total	**1.12**		**1**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.55	28.93	16
Developed Pervious	0.57	23.29	13
Total	**1.12**		**29**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	55,392	3,975	1,309	**50,108**
Phosphorus Load	38	3	1	**35**
Nitrogen Load	1,716	63	29	**1,623**

Municipal Storm Sewershed R7
Letort Spring Run



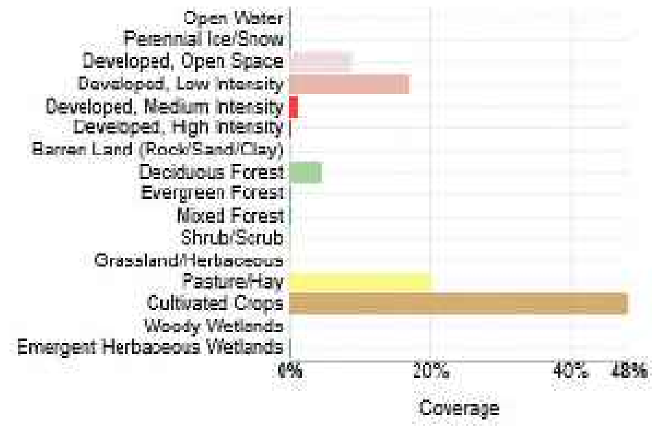
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	73,572.28	8.8
Developed, Low Intensity	142,658.45	17.0
Developed, Medium Intensity	8,972.23	1.1
Developed, High Intensity	2,691.67	0.3
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	37,683.36	4.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	168,677.91	20.1
Cultivated Crops	404,647.54	48.2
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R7
Letort Spring Run

Selected Area

Total Area 845,118 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
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Developed, Open Space	73,572.28	8.8
Developed, Low Intensity	142,658.45	17.0
Developed, Medium Intensity	8,972.23	1.1
Developed, High Intensity	2,691.67	0.3
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	37,683.36	4.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	168,677.91	20.1
Cultivated Crops	404,647.54	48.2
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
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Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	78.26	0.0	14.87	63.39
Developed, Low Intensity	49%	80.92	0.0	39.65	41.27
Developed, Medium Intensity	79%	5.99	0.0	4.73	1.26
Developed, High Intensity	100%	1.33	0.0	1.33	0.00
Deciduous Forest	0	58.53	0.0	0.00	58.53
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	108.19	0.0	0.00	108.19
Cultivated Crops	0	58.53	0.0	0.00	58.53
Woody Wetlands	0	3.77	0.0	0.00	3.77
Total		**395.52**	**0.0**	**60.58**	**334.94**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	60.58	2,065.10	125,109
Developed Pervious	334.94	306.95	102,809
Total	**395.52**		**227,918**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	60.58	1.11	67
Developed Pervious	334.94	0.34	114
Total	**395.52**		**181**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	60.58	28.93	1,753
Developed Pervious	334.94	23.29	7,801
Total	**395.52**		**9,553**

Municipal Storm Sewershed
R8

Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	13,458.36	3.33	0.63	2.69
Developed, Low Intensity	49%	58,319.55	14.41	7.06	7.35
Developed, Medium Intensity	79%	3,588.90	0.89	0.70	0.19
Pasture/Hay	0	29,608.39	7.32	0.00	7.32
Total		**104,975.20**	**25.94**	**8.39**	**17.55**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	8.39	2,065.10	17,334
Developed Pervious	17.55	306.95	5,386
Total	**25.94**		**22,720**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	8.39	1.11	9
Developed Pervious	17.55	0.34	6
Total	**25.94**		**15**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	8.39	28.93	243
Developed Pervious	17.55	23.29	409
Total	**25.94**		**651**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	22,720	10%	2,272.00	**20,448**
Phosphorus Load	15	10%	1.53	**14**
Nitrogen Load	651	5%	32.57	**619**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	66,394.55	16.41	3.12	13.29
Developed, Low Intensity	49%	97,797.38	24.17	11.84	12.32
Developed, Medium Intensity	79%	12,561.13	3.10	2.45	0.65
Developed, High Intensity	100%	5,383.34	1.33	1.33	0.00
Pasture/Hay	0	54,730.64	13.52	0.00	13.52
Cultivated Crops	0	14,355.58	3.55	0.00	3.55
Total		**251,222.62**	**62.08**	**18.74**	**43.34**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Drainage Basin 2	18.74	43.34
Drainage Basin 1	8.39	17.55
Detention Basin Bypass	**10.35**	**25.79**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	10.35	2,065.10	21,368
Developed Pervious	25.79	306.95	7,917
Total	**36.14**		**29,285**

Municipal Storm Sewershed
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Detention Basin 1 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	10.35	1.11	11
Developed Pervious	25.79	0.34	9
Total	**36.14**		**20**

Detention Basin 1 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	10.35	28.93	299
Developed Pervious	25.79	23.29	601
Total	**36.14**		**900**

Detention Basin 2 Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 1 Bypass**			
Sediment Load	20,448	29,285			
Phosphorus Load	14	20			
Nitrogen Load	619	900			

Pollutant	Detention Basin 2 Loading
Sediment Load	**49,732**
Phosphorus Load	**34**
Nitrogen Load	**1,519**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 2 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 2 (lbs/year)**
Sediment Load	49,732	10%	4,973.25	**44,759**
Phosphorus Load	34	10%	3.40	**31**
Nitrogen Load	1,519	5%	75.95	**1,443**

Municipal Storm Sewershed
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Drainage Area: Detention Basin 3

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	118,433.51	29.27	5.56	23.71
Developed, Low Intensity	49%	214,436.42	52.99	25.96	27.02
Developed, Medium Intensity	79%	17,047.25	4.21	3.33	0.88
Developed, High Intensity	100%	5,383.34	1.33	1.33	0.00
Deciduous Forest	0	18,841.69	4.66	0.00	4.66
Pasture/Hay	0	99,591.81	24.61	0.00	24.61
Cultivated Crops	0	53,833.41	13.30	0.00	13.30
Total		**527,567.43**	**130.36**	**36.18**	**94.18**

Drainage Areas

Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Drainage Basin 3	36.18	94.18
Drainage Basin 2	18.74	43.34
Detention Basin 2 Bypass	**17.44**	**50.84**

Detention Basin 2 Bypass: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	17.44	2,065.10	36,019
Developed Pervious	50.84	306.95	15,607
Total	**68.29**		**51,626**

Detention Basin 2 Bypass: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	17.44	1.11	19
Developed Pervious	50.84	0.34	17
Total	**68.29**		**37**

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Detention Basin 2 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	17.44	28.93	505
Developed Pervious	50.84	23.29	1,184
Total	**68.29**		**1,689**

Detention Basin 3 Loading (lbs/year)					
Pollutant	**Detention Basin 2**	**Detention Basin 2 Bypass**			
Sediment Load	44,759	51,626			
Phosphorus Load	31	37			
Nitrogen Load	1,443	1,689			

Pollutant	**Detention Basin 3 Loading**
Sediment Load	**96,385**
Phosphorus Load	**67**
Nitrogen Load	**3,132**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	96,385	10%	9,638.50	**86,746**
Phosphorus Load	67	10%	6.73	**61**
Nitrogen Load	3,132	5%	156.59	**2,975**

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Drainage Area: Detention Basin 4					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	18,841.70	4.66	0.88	3.77
Developed, Low Intensity	49%	28,711.17	7.09	3.48	3.62
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Deciduous Forest	0	1,794.45	0.44	0.00	0.44
Pasture/Hay	0	3,588.90	0.89	0.00	0.89
Cultivated Crops	0	4,486.12	1.11	0.00	1.11
Total		**59,216.79**	**14.63**	**4.71**	**9.92**

Detention Basin 4: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	4.71	2,065.10	9,729
Developed Pervious	9.92	306.95	3,045
Total	**14.63**		**12,775**

Detention Basin 4: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	4.71	1.11	5
Developed Pervious	9.92	0.34	3
Total	**14.63**		**9**

Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	4.71	28.93	136
Developed Pervious	9.92	23.29	231
Total	**14.63**		**367**

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Detention Basin 4: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 4 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 4 (lbs/year)
Sediment Load	12,775	10%	1,277.47	**11,497**
Phosphorus Load	9	10%	0.86	**8**
Nitrogen Load	367	5%	18.37	**349**

Drainage Area: Detention Basin 5					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	69,983.51	17.29	3.29	14.01
Developed, Low Intensity	49%	41,272.33	10.20	5.00	5.20
Developed, Medium Intensity	79%	897.22	0.22	0.18	0.05
Pasture/Hay	0	10,766.69	2.66	0.00	2.66
Cultivated Crops	0	8,075.02	2.00	0.00	2.00
Total		**130,994.77**	**32.37**	**8.46**	**23.91**

Detention Basin 5: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	8.46	2,065.10	17,467
Developed Pervious	23.91	306.95	7,340
Total	**32.37**		**24,807**

Detention Basin 5: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	8.46	1.11	9
Developed Pervious	23.91	0.34	8
Total	**32.37**		**18**

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Detention Basin 5: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	8.46	28.93	245
Developed Pervious	23.91	23.29	557
Total	**32.37**		**802**

Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	24,807	10%	2,480.66	**22,326**
Phosphorus Load	18	10%	1.75	**16**
Nitrogen Load	802	5%	40.08	**762**

Drainage Area: Detention Basin 6					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	98,694.69	24.39	4.63	19.75
Developed, Low Intensity	49%	52,039.02	12.86	6.30	6.56
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Pasture/Hay	0	10,766.69	2.66	0.00	2.66
Cultivated Crops	0	11,663.92	2.88	0.00	2.88
Total		**174,958.77**	**43.23**	**11.28**	**31.95**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 6	11.28	31.95
Detention Basin 5	8.46	23.91
Detention Basin 5 Bypass	**2.83**	**8.04**

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Detention Basin 5 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	2.83	2,065.10	5,838
Developed Pervious	8.04	306.95	2,467
Total	**10.86**		**8,305**

Detention Basin 5 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	2.83	1.11	3
Developed Pervious	8.04	0.34	3
Total	**10.86**		**6**

Detention Basin 5 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	2.83	28.93	82
Developed Pervious	8.04	23.29	187
Total	**10.86**		**269**

Detention Basin 6 Loading (lbs/year)					
Pollutant	**Detention Basin 5**	**Detention Basin 5 Bypass**			
Sediment Load	22,326	8,305			
Phosphorus Load	16	6			
Nitrogen Load	762	269			

Pollutant	Detention Basin 6 Loading
Sediment Load	**30,630**
Phosphorus Load	**22**
Nitrogen Load	**1,030**

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Detention Basin 6: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 6 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 6 (lbs/year)**
Sediment Load	30,630	10%	3,063.04	**27,567**
Phosphorus Load	22	10%	2.16	**19**
Nitrogen Load	1,030	5%	51.52	**979**

Drainage Area: Detention Basin 7					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	129,200.32	31.93	6.07	25.86
Developed, Low Intensity	49%	80,750.20	19.95	9.78	10.18
Developed, Medium Intensity	79%	5,383.35	1.33	1.05	0.28
Deciduous Forest	0	10,766.69	2.66	0.00	2.66
Pasture/Hay	0	39,477.87	9.76	0.00	9.76
Cultivated Crops	0	136,378.11	33.70	0.00	33.70
Total		**401,956.54**	**99.33**	**16.89**	**82.43**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 7	16.89	82.43
Detention Basin 6	11.28	31.95
Detention Basin 6 Bypass	**5.61**	**50.48**

Detention Basin 6 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	5.61	2,065.10	11,584
Developed Pervious	50.48	306.95	15,496
Total	**56.09**		**27,079**

Municipal Storm Sewershed
R8

Detention Basin 6 Bypass: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	5.61	1.11	6
Developed Pervious	50.48	0.34	17
Total	**56.09**		**23**

Detention Basin 6 Bypass: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	5.61	28.93	162
Developed Pervious	50.48	23.29	1,176
Total	**56.09**		**1,338**

Detention Basin 7 Loading (lbs/year)					
Pollutant	Detention Basin 6	Detention Basin 6 Bypass			
Sediment Load	27,567	27,079			
Phosphorus Load	19	23			
Nitrogen Load	979	1,338			

Pollutant	Detention Basin 7 Loading
Sediment Load	**54,647**
Phosphorus Load	**43**
Nitrogen Load	**2,317**

Detention Basin 7: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 7 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 7 (lbs/year)
Sediment Load	54,647	10%	5,464.68	**49,182**
Phosphorus Load	43	10%	4.29	**39**
Nitrogen Load	2,317	5%	115.85	**2,201**

Municipal Storm Sewershed
R8

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	60.58	334.94
Detention Basin 3	36.18	94.18
Detention Basin 4	4.71	9.92
Detention Basin 7	16.89	82.43
Detention Basin Bypass	**2.79**	**148.40**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	2.79	2,065.10	5,770
Developed Pervious	148.40	306.95	45,552
Total	**151.20**		**51,322**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	2.79	1.11	3
Developed Pervious	148.40	0.34	50
Total	**151.20**		**54**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	2.79	28.93	81
Developed Pervious	148.40	23.29	3,456
Total	**151.20**		**3,537**

Municipal Storm Sewershed R8

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 3**	**Detention Basin 4**	**Detention Basin 7**	**Detention Basin Bypass**	
Sediment Load	86,746	11,497	49,182	51,322	
Phosphorus Load	61	8	39	54	
Nitrogen Load	2,975	349	2,201	3,537	

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**198,748**
Phosphorus Load	**160**
Nitrogen Load	**9,062**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	3.47	49%	1.70	1.77
		Total	**1.70**	**1.77**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.70	2,065.10	3,511
Developed Pervious	1.77	306.95	543
Total	**3.47**		**4,054**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.70	1.11	2
Developed Pervious	1.77	0.34	1
Total	**3.47**		**2**

Municipal Storm Sewershed
R8

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.70	28.93	49
Developed Pervious	1.77	23.29	41
Total	**3.47**		**90**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	227,918	29,170	4,054	**194,694**
Phosphorus Load	181	21	2	**158**
Nitrogen Load	9,553	491	90	**8,972**

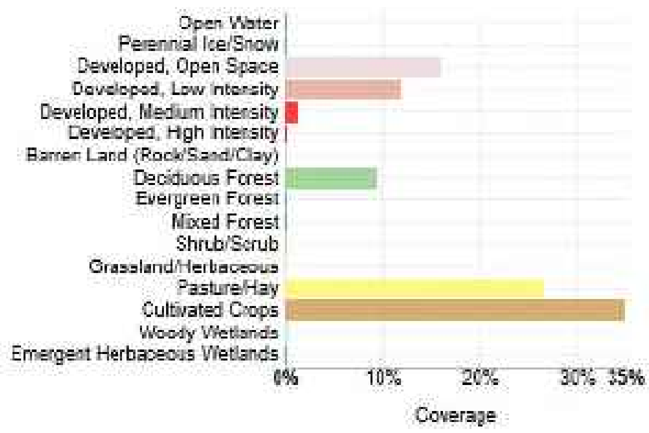
Municipal Storm Sewershed R8
Letort Spring Run

Type	Area (km²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	0.52	15.7
Developed, Low Intensity	0.39	11.8
Developed, Medium Intensity	0.04	1.1
Developed, High Intensity	0.01	0.2
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.31	9.2
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.87	26.5
Cultivated Crops	1.15	34.9
Woody Wetlands	0.02	0.5
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R8
Letort Spring Run

Selected Area
Total Area 3 km²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (km^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	0.52	15.7
Developed, Low Intensity	0.39	11.8
Developed, Medium Intensity	0.04	1.1
Developed, High Intensity	0.01	0.2
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.31	9.2
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.87	26.5
Cultivated Crops	1.15	34.9
Woody Wetlands	0.02	0.5
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R9

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	18.62	0.0	3.54	15.08
Developed, Low Intensity	49%	15.52	0.0	7.60	7.92
Developed, Medium Intensity	79%	1.77	0.0	1.40	0.37
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	17.96	0.0	0.00	17.96
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	3.33	0.0	0.00	3.33
Cultivated Crops	0	31.26	0.0	0.00	31.26
Total		**88.46**	**0.7**	**12.54**	**75.92**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	12.54	2,065.10	25,898
Developed Pervious	75.92	306.95	23,303
Total	**88.46**		**49,202**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	12.54	1.11	14
Developed Pervious	75.92	0.34	26
Total	**88.46**		**40**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	12.54	28.93	363
Developed Pervious	75.92	23.29	1,768
Total	**88.46**		**2,131**

Municipal Storm Sewershed
R9

Drainage Area: Detention Basin 1 Bypass					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	1,794.44	0.44	0.08	0.36
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Total		**2,691.66**	**0.22**	**0.19**	**0.47**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.19	2,065.10	397
Developed Pervious	0.47	306.95	144
Total	**0.66**		**541**

Detention Basin 1 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.19	1.11	0
Developed Pervious	0.47	0.34	0
Total	**0.66**		**0**

Detention Basin 1 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.19	28.93	6
Developed Pervious	0.47	23.29	11
Total	**0.66**		**16**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total Drainage	12.54	75.92
Detention Basin 1 Bypass	0.19	0.47
Detention Basin 1	**12.35**	**75.45**

Municipal Storm Sewershed
R9

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	12.35	2,065.10	25,501
Developed Pervious	75.45	306.95	23,159
Total	**87.80**		**48,660**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	12.35	1.11	14
Developed Pervious	75.45	0.34	26
Total	**87.80**		**39**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	12.35	28.93	357
Developed Pervious	75.45	23.29	1,757
Total	**87.80**		**2,114**

Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	48,660	10%	4,866.05	**43,794**
Phosphorus Load	39	10%	3.94	**35**
Nitrogen Load	2,114	5%	105.72	**2,009**

Municipal Storm Sewershed
R9

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin Bypass**			
Sediment Load	43,794	541			
Phosphorus Load	35	0			
Nitrogen Load	2,009	16			

Pollutant	**Total Post-BMP (Best Management Practice) Loading**
Sediment Load	**44,336**
Phosphorus Load	**36**
Nitrogen Load	**2,025**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	49,202	4,866	0	**44,336**
Phosphorus Load	40	4	0	**36**
Nitrogen Load	2,131	106	0	**2,025**

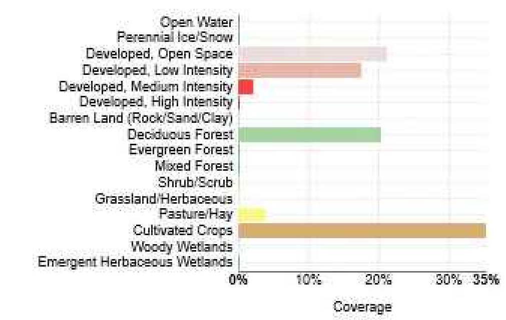
Municipal Storm Sewershed R9
Letort Spring Run

Model My Watershed: Geospatial Analysis

Analyze

LAND | SOIL | ANIMALS | POINT SOURCES | WATER QUALITY

Selected Area
Total Area 357,743 m²
Land cover distribution from National Land Cover Database (NLCD 2011)



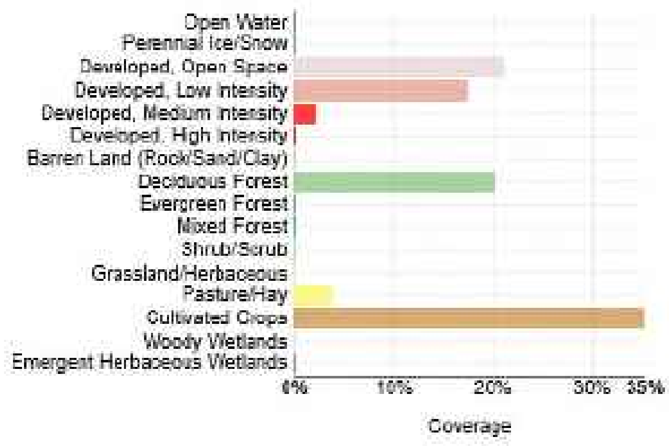
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	75,366.62	21.1
Developed, Low Intensity	62,805.51	17.5
Developed, Medium Intensity	7,177.77	2.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	72,674.95	20.3
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	13,458.32	3.8
Cultivated Crops	126,508.25	35.3
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R9
Letort Spring Run

Selected Area

Total Area 357,743 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	75,366.62	21.1
Developed, Low Intensity	62,605.51	17.5
Developed, Medium Intensity	7,177.77	2.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	72,674.95	20.3
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	13,458.32	3.8
Cultivated Crops	126,508.25	35.3
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R10

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	9.09	0.0	1.73	7.36
Developed, Low Intensity	49%	10.42	0.0	5.11	5.31
Developed, Medium Intensity	79%	0.22	0.0	0.17	0.05
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Deciduous Forest	0	0.67	0.0	0.00	0.67
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	0.22	0.0	0.00	0.22
Cultivated Crops	0	0.00	0.0	0.00	0.00
Woody Wetlands	0	0.00	0.0	0.00	0.00
Total		**20.62**	**0.0**	**7.01**	**13.61**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	7.01	2,065.10	14,470
Developed Pervious	13.61	306.95	4,179
Total	**20.62**		**18,648**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	7.01	1.11	8
Developed Pervious	13.61	0.34	5
Total	**20.62**		**12**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	7.01	28.93	203
Developed Pervious	13.61	23.29	317
Total	**20.62**		**520**

Municipal Storm Sewershed
R10

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	0.59	49%	0.29	0.30
		Total	**0.29**	**0.30**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading**
Developed Impervious	0.29	2,065.10	597
Developed Pervious	0.30	306.95	92
Total	**0.59**		**689**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading**
Developed Impervious	0.29	1.11	0
Developed Pervious	0.30	0.34	0
Total	**0.59**		**0**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading**
Developed Impervious	0.29	28.93	8
Developed Pervious	0.30	23.29	7
Total	**0.59**		**15**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	18,648	0	689	**17,959**
Phosphorus Load	12	0	0	**12**
Nitrogen Load	520	0	15	**504**

Municipal Storm Sewershed R10
Letort Spring Run

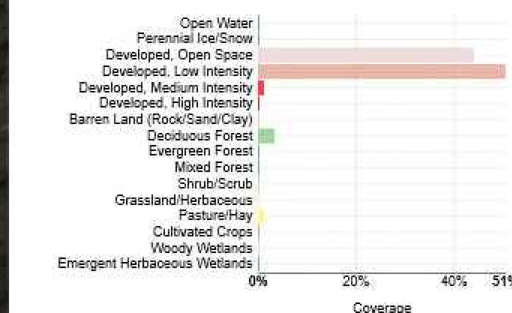
Model My Watershed: Geospatial Analysis

Analyze

LAND SOIL ANIMALS POINT SOURCES WATER QUALITY

Selected Area
Total Area 85,862 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



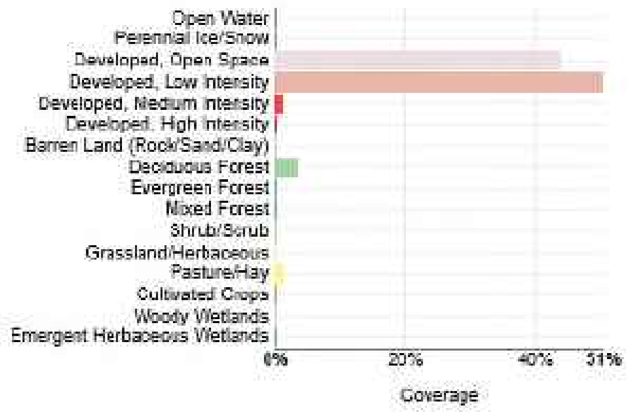
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	36,786.11	44.1
Developed, Low Intensity	42,169.44	50.5
Developed, Medium Intensity	897.22	1.1
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	2,691.67	3.2
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	897.22	1.1
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R10
Letort Spring Run

Selected Area

Total Area 85,862 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	36,786.11	44.1
Developed, Low Intensity	42,169.44	50.5
Developed, Medium Intensity	897.22	1.1
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	2,691.67	3.2
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	897.22	1.1
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R13

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	0.89	0.0	0.17	0.72
Developed, Low Intensity	49%	2.00	0.0	0.98	1.02
Developed, Medium Intensity	79%	0.00	0.0	0.00	0.00
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.00	0.0	0.00	0.00
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	1.77	0.0	0.00	1.77
Cultivated Crops	0	0.00	0.0	0.00	0.00
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**4.66**	**0.7**	**1.15**	**3.51**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.15	2,065.10	2,373
Developed Pervious	3.51	306.95	1,078
Total	**4.66**		**3,451**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.15	1.11	1
Developed Pervious	3.51	0.34	1
Total	**4.66**		**2**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.15	28.93	33
Developed Pervious	3.51	23.29	82
Total	**4.66**		**115**

Municipal Storm Sewershed R13
Letort Spring Run

Model My Watershed: Geospatial Analysis   WikiWatershed   Watercow015

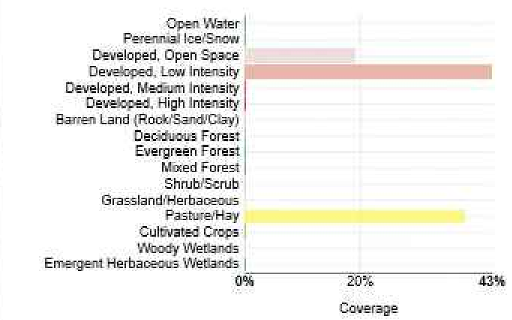
Analyze   Back   Model

LAND   SOIL   ANIMALS   POINT SOURCES   WATER QUALITY

Selected Area

Total Area 18,075 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	3,588.90	19.0
Developed, Low Intensity	8,075.02	42.9
Developed, Medium Intensity	0.00	0.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	7,177.79	38.1
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

75%

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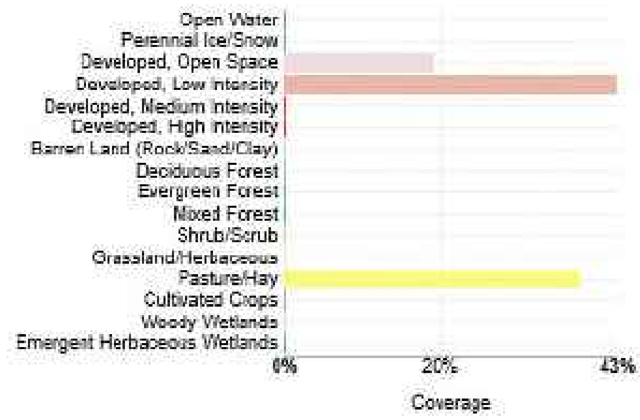
Selected Area

Total Area 18,075 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	3,588.90	19.0
Developed, Low Intensity	8,075.02	42.9
Developed, Medium Intensity	0.00	0.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	7,177.79	38.1
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

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Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	36.80	0.0	6.99	29.81
Developed, Low Intensity	49%	67.84	0.0	33.24	34.60
Developed, Medium Intensity	79%	27.71	0.0	21.89	5.82
Developed, High Intensity	100%	7.09	0.0	7.09	0.00
Deciduous Forest	0	36.14	0.0	0.00	36.14
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	76.49	0.0	0.00	76.49
Cultivated Crops	0	25.27	0.0	0.00	25.27
Woody Wetlands	0	1.33	0.0	0.00	1.33
Emergent Herbaceous Wetlands	0	1.55	0.0	0.00	1.55
Total		**280.22**	**0.0**	**69.21**	**211.01**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	69.21	2,065.10	142,935
Developed Pervious	211.01	306.95	64,768
Total	**280.22**		**207,703**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	69.21	1.11	77
Developed Pervious	211.01	0.34	72
Total	**280.22**		**149**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	69.21	28.93	2,002
Developed Pervious	211.01	23.29	4,914
Total	**280.22**		**6,917**

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Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2,691.67	0.67	0.13	0.54
Developed, Low Intensity	49%	1,794.44	0.44	0.22	0.23
Cultivated Crops	0	7,177.78	1.77	0.00	1.77
Total		**11,663.89**	**2.88**	**0.34**	**2.54**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.34	2,065.10	710
Developed Pervious	2.54	306.95	779
Total	**2.88**		**1,489**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.34	1.11	0
Developed Pervious	2.54	0.34	1
Total	**2.88**		**1**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.34	28.93	10
Developed Pervious	2.54	23.29	59
Total	**2.88**		**69**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	1,489	10%	148.89	**1,340**
Phosphorus Load	1	10%	0.12	**1**
Nitrogen Load	69	5%	3.45	**66**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	3,588.89	0.89	0.17	0.72
Developed, Low Intensity	49%	1,794.44	0.44	0.22	0.23
Cultivated Crops	0	6,280.56	1.55	0.00	1.55
Total		**11,663.89**	**2.88**	**0.39**	**2.50**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Drainage Basin 2	0.39	2.54
Drainage Basin 1	0.34	2.54
Detention Basin 1 Bypass	**0.04**	**0.00**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.04	2,065.10	87
Developed Pervious	0.00	306.95	0
Total	**0.04**		**87**

Detention Basin 1 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.04	1.11	0
Developed Pervious	0.00	0.34	0
Total	**0.04**		**0**

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Detention Basin 1 Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.04	28.93	1
Developed Pervious	0.00	23.29	0
Total	**0.04**		**1**

Detention Basin 2 Loading (lbs/year)

Pollutant	Detention Basin 1	Detention Basin 1 Bypass			
Sediment Load	1,340	87			
Phosphorus Load	1	0			
Nitrogen Load	66	1			

Pollutant	Detention Basin 2 Loading
Sediment Load	**1,427**
Phosphorus Load	**1**
Nitrogen Load	**67**

Detention Basin 2: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 2 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 2 (lbs/year)
Sediment Load	1,427	10%	142.74	**1,285**
Phosphorus Load	1	10%	0.12	**1**
Nitrogen Load	67	5%	3.34	**64**

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Drainage Area: Detention Basin 3					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	1,794.44	0.44	0.08	0.36
Developed, Low Intensity	49%	3,588.89	0.89	0.43	0.45
Developed, Medium Intensity	79%	1,794.44	0.44	0.35	0.09
Developed, High Intensity	100%	1,794.44	0.44	0.44	0.00
Pasture/Hay	0	1,794.44	0.44	0.00	0.44
Cultivated Crops	0	897.22	0.22	0.00	0.22
Total		**11,663.87**	**2.88**	**1.31**	**1.57**

Detention Basin 3: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.31	2,065.10	2,710
Developed Pervious	1.57	306.95	482
Total	**2.88**		**3,192**

Detention Basin 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.31	1.11	1
Developed Pervious	1.57	0.34	1
Total	**2.88**		**2**

Detention Basin 3: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.31	28.93	38
Developed Pervious	1.57	23.29	37
Total	**2.88**		**75**

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Detention Basin 3: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 3 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 3 (lbs/year)
Sediment Load	3,192	10%	319.23	**2,873**
Phosphorus Load	2	10%	0.20	**2**
Nitrogen Load	75	5%	3.73	**71**

Drainage Area: Detention Basin 4					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Developed, Medium Intensity	79%	2,691.67	0.67	0.53	0.14
Developed, High Intensity	100%	897.22	0.22	0.22	0.00
Pasture/Hay	0	3,588.89	0.89	0.00	0.89
Total		**8,075.00**	**2.00**	**0.86**	**1.14**

Detention Basin 4: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.86	2,065.10	1,767
Developed Pervious	1.14	306.95	350
Total	**2.00**		**2,117**

Detention Basin 4: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.86	1.11	1
Developed Pervious	1.14	0.34	0
Total	**2.00**		**1**

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Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.86	28.93	25
Developed Pervious	1.14	23.29	27
Total	**2.00**		**51**

Detention Basin 4: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 4 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 4 (lbs/year)**
Sediment Load	2,117	10%	211.71	**1,905**
Phosphorus Load	1	10%	0.13	**1**
Nitrogen Load	51	5%	2.56	**49**

Drainage Area: Detention Basin 5					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	90,619.44	22.39	4.25	18.14
Developed, Low Intensity	49%	142,658.32	35.25	17.27	17.98
Developed, Medium Intensity	79%	71,777.77	17.74	14.01	3.72
Developed, High Intensity	100%	16,150.00	3.99	3.99	0.00
Deciduous Forest	0	61,908.33	15.30	0.00	15.30
Pasture/Hay	0	254,811.09	62.97	0.00	62.97
Cultivated Crops	0	105,872.21	26.16	0.00	26.16
Total		**743,797.16**	**183.80**	**39.53**	**144.27**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Drainage Basin 5	39.53	144.27
Drainage Basin 2	0.39	2.54
Drainage Basin 3	1.31	1.57
Drainage Basin 4	0.86	1.14
Detention Basin Bypass	**36.98**	**139.02**

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Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	36.98	2,065.10	76,360
Developed Pervious	139.02	306.95	42,671
Total	**175.99**		**119,031**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	36.98	1.11	41
Developed Pervious	139.02	0.34	47
Total	**175.99**		**88**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	36.98	28.93	1,070
Developed Pervious	139.02	23.29	3,238
Total	**175.99**		**4,307**

Detention Basin 5 Loading (lbs/year)					
Pollutant	**Detention Basin 2**	**Detention Basin 3**	**Detention Basin 4**	**Detention Basin Bypass**	
Sediment Load	1,285	2,873	1,905	119,031	
Phosphorus Load	1	2	1	88	
Nitrogen Load	64	71	49	4,307	

Pollutant	Detention Basin 5 Loading
Sediment Load	**125,094**
Phosphorus Load	**92**
Nitrogen Load	**4,490**

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Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	125,094	10%	12,509.43	**112,585**
Phosphorus Load	92	10%	9.24	**83**
Nitrogen Load	4,490	5%	224.52	**4,266**

Detention Basin 5 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.19	2,065.10	2,457
Developed Pervious	12.34	306.95	3,788
Total	**13.53**		**6,245**

Detention Basin 5 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.19	1.11	1
Developed Pervious	12.34	0.34	4
Total	**13.53**		**6**

Detention Basin 5 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.19	28.93	34
Developed Pervious	12.34	23.29	287
Total	**13.53**		**322**

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Detention Basin 6 Loading (lbs/year)					
Pollutant	**Detention Basin 5**	**Detention Basin 5 Bypass**			
Sediment Load	112,585	6,245			
Phosphorus Load	83	6			
Nitrogen Load	4,266	322			

Pollutant	Detention Basin 6 Loading
Sediment Load	**118,830**
Phosphorus Load	**89**
Nitrogen Load	**4,588**

Detention Basin 6: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 6 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 6 (lbs/year)**
Sediment Load	118,830	10%	11,883.01	**106,947**
Phosphorus Load	89	10%	8.86	**80**
Nitrogen Load	4,588	5%	229.39	**4,358**

Drainage Area: Detention Basin 7					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	4,486.11	1.11	0.21	0.90
Developed, Low Intensity	49%	11,663.88	2.88	1.41	1.47
Developed, Medium Intensity	79%	1,794.44	0.44	0.35	0.09
Deciduous Forest	0	8,074.99	2.00	0.00	2.00
Cultivated Crops	0	13,458.32	3.33	0.00	3.33
Total		**39,477.74**	**9.76**	**1.97**	**7.78**

Detention Basin 7: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.97	2,065.10	4,075
Developed Pervious	7.78	306.95	2,389
Total	**9.76**		**6,464**

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Detention Basin 7: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	1.97	1.11	2
Developed Pervious	7.78	0.34	3
Total	**9.76**		**5**

Detention Basin 7: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	1.97	28.93	57
Developed Pervious	7.78	23.29	181
Total	**9.76**		**238**

Detention Basin 7: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 7 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 7 (lbs/year)
Sediment Load	6,464	10%	646.35	**5,817**
Phosphorus Load	5	10%	0.48	**4**
Nitrogen Load	238	5%	11.92	**226**

Drainage Areas		
Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Total	69.21	211.01
Detention Basin 5	39.53	144.27
Detention Basin 5 Byass	1.19	12.34
Detention Basin 7	1.97	7.78
Detention Basin Bypass	**26.52**	**46.62**

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Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	26.52	2,065.10	54,768
Developed Pervious	46.62	306.95	14,309
Total	**73.14**		**69,077**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	26.52	1.11	29
Developed Pervious	46.62	0.34	16
Total	**73.14**		**45**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	26.52	28.93	767
Developed Pervious	46.62	23.29	1,086
Total	**73.14**		**1,853**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 6**	**Detention Basin 7**	**Detention Basin Bypass**		
Sediment Load	106,947	5,817	69,077		
Phosphorus Load	80	4	45		
Nitrogen Load	4,358	226	1,853		

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**181,842**
Phosphorus Load	**129**
Nitrogen Load	**6,438**

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Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	10.77	49%	5.28	5.49
		Total	**5.28**	**5.49**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	5.28	2,065.10	10,898
Developed Pervious	5.49	306.95	1,686
Total	**10.77**		**12,584**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.28	1.11	6
Developed Pervious	5.49	0.34	2
Total	**10.77**		**8**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.28	28.93	153
Developed Pervious	5.49	23.29	128
Total	**10.77**		**281**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	207,703	25,861	12,584	**169,258**
Phosphorus Load	149	19	8	**122**
Nitrogen Load	6,917	479	281	**6,157**

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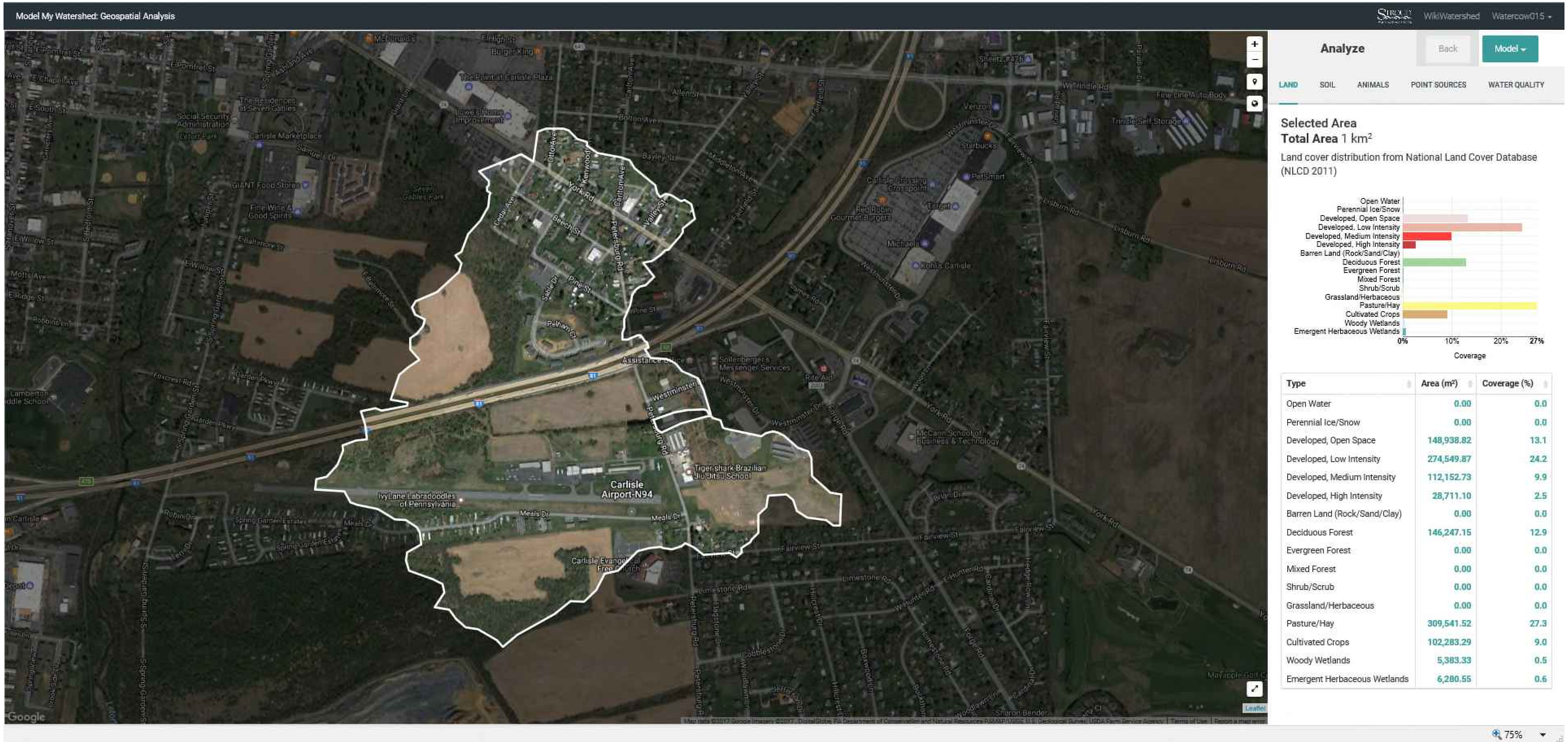

Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	148,938.82	13.1
Developed, Low Intensity	274,549.87	24.2
Developed, Medium Intensity	112,152.73	9.9
Developed, High Intensity	28,711.10	2.5
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	146,247.15	12.9
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	309,541.52	27.3
Cultivated Crops	102,283.29	9.0
Woody Wetlands	5,383.33	0.5
Emergent Herbaceous Wetlands	6,280.55	0.6

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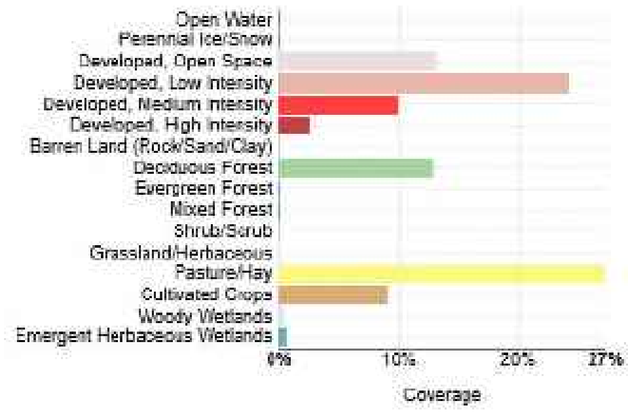
Selected Area
Total Area 1 km²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	148,938.82	13.1
Developed, Low Intensity	274,549.87	24.2
Developed, Medium Intensity	112,152.73	9.9
Developed, High Intensity	28,711.10	2.5
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	146,247.15	12.9
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	309,541.52	27.3
Cultivated Crops	102,283.29	9.0
Woody Wetlands	5,383.33	0.5
Emergent Herbaceous Wetlands	6,280.55	0.6

Municipal Storm Sewershed R102

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	3.10	0.0	0.59	2.51
Developed, Low Intensity	49%	23.28	0.0	11.41	11.87
Developed, Medium Intensity	79%	0.67	0.0	0.53	0.14
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	0.00	0.0	0.00	0.00
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	0.00	0.0	0.00	0.00
Cultivated Crops	0	0.00	0.0	0.00	0.00
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**27.05**	**0.7**	**12.53**	**14.52**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	12.53	2,065.10	25,866
Developed Pervious	14.52	306.95	4,458
Total	**27.05**		**30,325**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	12.53	1.11	14
Developed Pervious	14.52	0.34	5
Total	**27.05**		**19**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	12.53	28.93	362
Developed Pervious	14.52	23.29	338
Total	**27.05**		**701**

Municipal Storm Sewershed
R102

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	1.26	49%	0.62	0.64
		Total	**0.62**	**0.64**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.62	2,065.10	1,275
Developed Pervious	0.64	306.95	197
Total	**1.26**		**1,472**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.62	1.11	1
Developed Pervious	0.64	0.34	0
Total	**1.26**		**1**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.62	28.93	18
Developed Pervious	0.64	23.29	15
Total	**1.26**		**33**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	30,325	0	1,472	**28,852**
Phosphorus Load	19	0	1	**18**
Nitrogen Load	701	0	33	**668**

Municipal Storm Sewershed R102
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Model My Watershed: Geospatial Analysis   WikiWatershed   Watercow015

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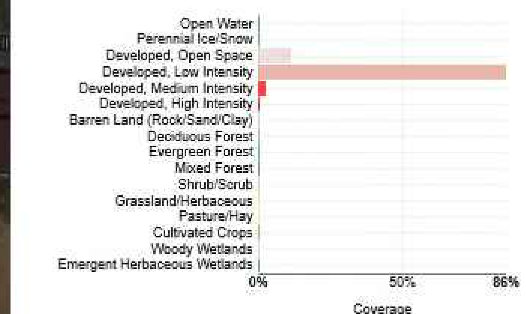
LAND   SOIL   ANIMALS   POINT SOURCES   WATER QUALITY

Selected Area
Total Area 111,101 m²
Land cover distribution from National Land Cover Database (NLCD 2011)



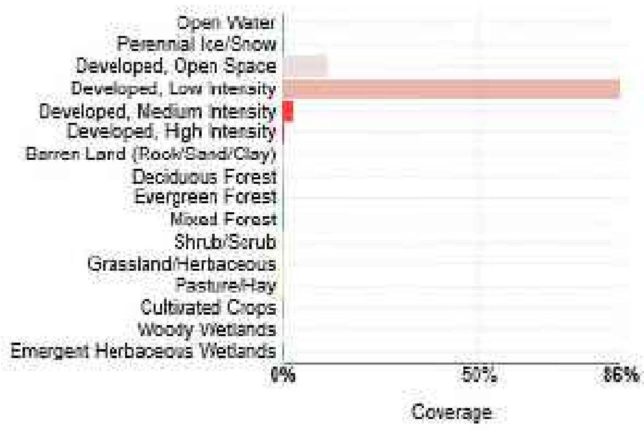
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	12,561.09	11.5
Developed, Low Intensity	94,208.18	86.1
Developed, Medium Intensity	2,691.66	2.5
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

75%

Municipal Storm Sewershed R102
Letort Spring Run

Selected Area
Total Area 111,101 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	12,561.09	11.5
Developed, Low Intensity	94,208.18	86.1
Developed, Medium Intensity	2,691.66	2.5
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R103

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	33.48	0.0	6.36	27.12
Developed, Low Intensity	49%	61.63	0.0	30.20	31.43
Developed, Medium Intensity	79%	24.83	0.0	19.62	5.21
Developed, High Intensity	100%	0.89	0.0	0.89	0.00
Barren Land	0	0.00	0.0	0.00	0.00
Deciduous Forest	0	14.19	0.0	0.00	14.19
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	42.12	0.0	0.00	42.12
Cultivated Crops	0	21.73	0.0	0.00	21.73
Woody Wetlands	0	0.00	0.0	0.00	0.00
Total		**198.87**	**0.0**	**57.07**	**141.80**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	57.07	2,065.10	117,846
Developed Pervious	141.80	306.95	43,527
Total	**198.87**		**161,373**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	57.07	1.11	63
Developed Pervious	141.80	0.34	48
Total	**198.87**		**112**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	57.07	28.93	1,651
Developed Pervious	141.80	23.29	3,303
Total	**198.87**		**4,954**

Municipal Storm Sewershed
R103

Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	26,916.70	6.65	1.26	5.39
Developed, Low Intensity	49%	51,141.73	12.64	6.19	6.45
Developed, Medium Intensity	79%	3,588.89	0.89	0.70	0.19
Deciduous Forest	0	897.22	0.22	0.00	0.22
Total		**82,544.54**	**20.40**	**8.16**	**12.24**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	8.16	2,065.10	16,844
Developed Pervious	12.24	306.95	3,757
Total	**20.40**		**20,602**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	8.16	1.11	9
Developed Pervious	12.24	0.34	4
Total	**20.40**		**13**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	8.16	28.93	236
Developed Pervious	12.24	23.29	285
Total	**20.40**		**521**

Municipal Storm Sewershed
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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	20,602	10%	2,060.15	**18,541**
Phosphorus Load	13	10%	1.32	**12**
Nitrogen Load	521	5%	26.05	**495**

Detention Basin 1 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.91	2,065.10	3,944
Developed Pervious	3.63	306.95	1,114
Total	**5.54**		**5,059**

Detention Basin 1 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.91	1.11	2
Developed Pervious	3.63	0.34	1
Total	**5.54**		**3**

Detention Basin 1 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.91	28.93	55
Developed Pervious	3.63	23.29	85
Total	**5.54**		**140**

Municipal Storm Sewershed
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Detention Basin 2 Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 1 Bypass**			
Sediment Load	18,541	5,059			
Phosphorus Load	12	3			
Nitrogen Load	495	140			

Pollutant	**Detention Basin 2 Loading**
Sediment Load	**23,600**
Phosphorus Load	**15**
Nitrogen Load	**635**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 2 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 2 (lbs/year)**
Sediment Load	23,600	10%	2,359.99	**21,240**
Phosphorus Load	15	10%	1.52	**14**
Nitrogen Load	635	5%	31.74	**603**

Drainage Area: Detention Basin 3					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	9,869.46	2.44	0.46	1.98
Developed, Low Intensity	49%	63,702.89	15.74	7.71	8.03
Developed, Medium Intensity	79%	58,319.54	14.41	11.38	3.03
Developed, High Intensity	100%	1,794.45	0.44	0.44	0.00
Pasture/Hay	0	9,869.46	2.44	0.00	2.44
Cultivated Crops	0	8,972.24	2.22	0.00	2.22
Total		**152,528.04**	**37.69**	**20.00**	**17.69**

Municipal Storm Sewershed
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Detention Basin 3: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	20.00	2,065.10	41,312
Developed Pervious	17.69	306.95	5,429
Total	**37.69**		**46,740**

Detention Basin 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	20.00	1.11	22
Developed Pervious	17.69	0.34	6
Total	**37.69**		**28**

Detention Basin 3: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	20.00	28.93	579
Developed Pervious	17.69	23.29	412
Total	**37.69**		**991**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	46,740	10%	4,674.04	**42,066**
Phosphorus Load	28	10%	2.82	**25**
Nitrogen Load	991	5%	49.53	**941**

Municipal Storm Sewershed
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Drainage Area: Detention Basin 4					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	52,936.19	13.08	2.49	10.60
Developed, Low Intensity	49%	67,291.77	16.63	8.15	8.48
Developed, Medium Intensity	79%	20,636.14	5.10	4.03	1.07
Pasture/Hay	0	29,608.38	7.32	0.00	7.32
Cultivated Crops	0	47,552.85	11.75	0.00	11.75
Total		**218,025.33**	**53.88**	**14.66**	**39.21**

Detention Basin 4: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	14.66	2,065.10	30,278
Developed Pervious	39.21	306.95	12,037
Total	**53.88**		**42,314**

Detention Basin 4: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	14.66	1.11	16
Developed Pervious	39.21	0.34	13
Total	**53.88**		**30**

Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	14.66	28.93	424
Developed Pervious	39.21	23.29	913
Total	**53.88**		**1,337**

Municipal Storm Sewershed
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Detention Basin 4: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 4 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 4 (lbs/year)**
Sediment Load	42,314	10%	4,231.42	**38,083**
Phosphorus Load	30	10%	2.96	**27**
Nitrogen Load	1,337	5%	66.87	**1,271**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	10.31	2,065.10	21,291
Developed Pervious	51.76	306.95	15,888
Total	**62.07**		**37,179**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	10.31	1.11	11
Developed Pervious	51.76	0.34	18
Total	**62.07**		**29**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	10.31	28.93	298
Developed Pervious	51.76	23.29	1,205
Total	**62.07**		**1,504**

Municipal Storm Sewershed
R103

Detention Basin 5 Loading (lbs/year)					
Pollutant	**Detention Basin 2**	**Detention Basin 3**	**Detention Basin 4**	**Detention Basin Bypass**	
Sediment Load	21,240	42,066	38,083	37,179	
Phosphorus Load	14	25	27	29	
Nitrogen Load	603	941	1,271	1,504	

Pollutant	Detention Basin 5 Loading
Sediment Load	**138,568**
Phosphorus Load	**95**
Nitrogen Load	**4,318**

Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	138,568	10%	13,856.81	**124,711**
Phosphorus Load	95	10%	9.48	**85**
Nitrogen Load	4,318	5%	215.92	**4,103**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	57.07	141.80
Detention Basin 1	8.16	12.24
Detention Basin 1 Bypass	1.91	3.63
Detention Basin 3	20.00	17.69
Detention Basin 4	14.66	39.21
Detention Basin Bypass	10.31	51.76
Detention Basin Bypass	**2.02**	**17.27**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	2.02	2,065.10	4,177
Developed Pervious	17.27	306.95	5,302
Total	**19.30**		**9,479**

Municipal Storm Sewershed
R103

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	2.02	1.11	2
Developed Pervious	17.27	0.34	6
Total	**19.30**		**8**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	2.02	28.93	59
Developed Pervious	17.27	23.29	402
Total	**19.30**		**461**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 5**	**Detention Basin Bypass**			
Sediment Load	124,711	9,479			
Phosphorus Load	85	8			
Nitrogen Load	4,103	461			

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**134,191**
Phosphorus Load	**93**
Nitrogen Load	**4,563**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	161,373	27,182	0	**134,191**
Phosphorus Load	112	18	0	**93**
Nitrogen Load	4,954	390	0	**4,563**

Municipal Storm Sewershed R103
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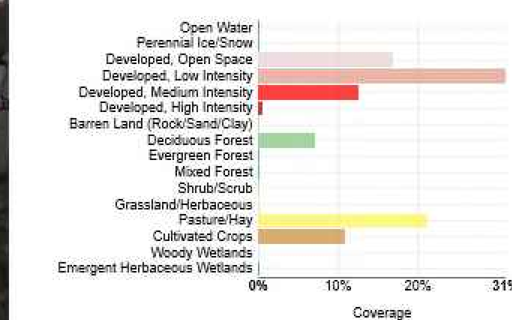
Model My Watershed: Geospatial Analysis   WikiWatershed   Watercow015

Analyze   Back   Model

LAND   SOIL   ANIMALS   POINT SOURCES   WATER QUALITY

Selected Area
Total Area 809,881 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	135,480.75	16.8
Developed, Low Intensity	249,428.14	31.0
Developed, Medium Intensity	100,489.03	12.5
Developed, High Intensity	3,588.89	0.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	57,422.31	7.1
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	170,472.47	21.2
Cultivated Crops	87,927.91	10.9
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

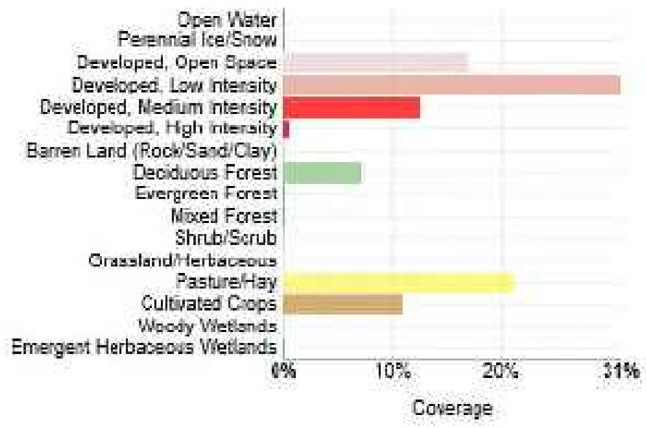
75%

Municipal Storm Sewershed R103
Letort Spring Run

Selected Area

Total Area 809,881 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	135,480.75	16.8
Developed, Low Intensity	249,428.14	31.0
Developed, Medium Intensity	100,489.03	12.5
Developed, High Intensity	3,588.89	0.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	57,422.31	7.1
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	170,472.47	21.2
Cultivated Crops	87,927.91	10.9
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R106

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	19.95	0.0	3.79	16.16
Developed, Low Intensity	49%	43.45	0.0	21.29	22.16
Developed, Medium Intensity	79%	38.36	0.0	30.30	8.06
Developed, High Intensity	100%	3.99	0.0	3.99	0.00
Deciduous Forest	0	0.00	0.0	0.00	0.00
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	12.64	0.0	0.00	12.64
Cultivated Crops	0	0.00	0.0	0.00	0.00
Woody Wetlands	0	0.00	0.0	0.00	0.00
Total		**118.39**	**0.0**	**59.38**	**59.01**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	59.38	2,065.10	122,616
Developed Pervious	59.01	306.95	18,115
Total	**118.39**		**140,731**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	59.38	1.11	66
Developed Pervious	59.01	0.34	20
Total	**118.39**		**86**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	59.38	28.93	1,718
Developed Pervious	59.01	23.29	1,374
Total	**118.39**		**3,092**

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Drainage Area: Detention Basin 1

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	2,691.67	0.67	0.13	0.54
Developed, Low Intensity	49%	5,383.34	1.33	0.65	0.68
Developed, Medium Intensity	79%	7,177.79	1.77	1.40	0.37
Developed, High Intensity	100%	897.22	0.22	0.22	0.00
Pasture/Hay	0	8,075.01	2.00	0.00	2.00
Total		**24,225.03**	**5.99**	**2.40**	**3.59**

Detention Basin 1: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	2.40	2,065.10	4,959
Developed Pervious	3.59	306.95	1,100
Total	**5.99**		**6,059**

Detention Basin 1: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	2.40	1.11	3
Developed Pervious	3.59	0.34	1
Total	**5.99**		**4**

Detention Basin 1: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	2.40	28.93	69
Developed Pervious	3.59	23.29	83
Total	**5.99**		**153**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	6,059	10%	605.89	**5,453**
Phosphorus Load	4	10%	0.39	**3**
Nitrogen Load	153	5%	7.65	**145**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Total		**2,691.67**	**0.67**	**0.46**	**0.21**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.46	2,065.10	948
Developed Pervious	0.21	306.95	63
Total	**0.67**		**1,011**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.46	1.11	1
Developed Pervious	0.21	0.34	0
Total	**0.67**		**1**

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Detention Basin 2: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.46	28.93	13
Developed Pervious	0.21	23.29	5
Total	**0.67**		**18**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 2 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 2 (lbs/year)**
Sediment Load	1,011	10%	101.10	**910**
Phosphorus Load	1	10%	0.06	**1**
Nitrogen Load	18	5%	0.90	**17**

Drainage Area: Detention Basin 3					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	897.22	0.22	0.04	0.18
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Total		**1,794.44**	**0.44**	**0.15**	**0.29**

Detention Basin 3: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.15	2,065.10	311
Developed Pervious	0.29	306.95	90
Total	**0.44**		**401**

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Detention Basin 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.15	1.11	0
Developed Pervious	0.29	0.34	0
Total	**0.44**		**0**

Detention Basin 3: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.15	28.93	4
Developed Pervious	0.29	23.29	7
Total	**0.44**		**11**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	401	10%	40.12	**361**
Phosphorus Load	0	10%	0.03	**0**
Nitrogen Load	11	5%	0.56	**11**

Drainage Area: Detention Basin 4					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Total		**2,691.67**	**0.67**	**0.46**	**0.21**

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Detention Basin 4: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.46	2,065.10	948
Developed Pervious	0.21	306.95	63
Total	**0.67**		**1,011**

Detention Basin 4: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.46	1.11	1
Developed Pervious	0.21	0.34	0
Total	**0.67**		**1**

Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.46	28.93	13
Developed Pervious	0.21	23.29	5
Total	**0.67**		**18**

Detention Basin 4: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 4 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 4 (lbs/year)**
Sediment Load	1,011	10%	101.10	**910**
Phosphorus Load	1	10%	0.06	**1**
Nitrogen Load	18	5%	0.90	**17**

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Drainage Area: Detention Basin 5					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	1,794.45	0.44	0.08	0.36
Developed, Low Intensity	49%	30,505.57	7.54	3.69	3.84
Developed, Medium Intensity	79%	35,888.91	8.87	7.01	1.86
Developed, High Intensity	100%	1,794.45	0.44	0.44	0.00
Pasture/Hay	0	8,972.23	2.22	0.00	2.22
Total		**78,955.61**	**19.51**	**11.23**	**8.28**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Drainage Basin 5	11.23	8.28
Drainage Basin 4	0.46	0.21
Detention Basin 4 Bypass	**10.77**	**8.08**

Detention Basin 4 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	10.77	2,065.10	22,238
Developed Pervious	8.08	306.95	2,479
Total	**18.85**		**24,717**

Detention Basin 4 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	10.77	1.11	12
Developed Pervious	8.08	0.34	3
Total	**18.85**		**15**

Detention Basin 4 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	10.77	28.93	312
Developed Pervious	8.08	23.29	188
Total	**18.85**		**500**

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Detention Basin 5 Loading (lbs/year)					
Pollutant	**Detention Basin 4**	**Detention Basin 4 Bypass**			
Sediment Load	910	24,717			
Phosphorus Load	1	15			
Nitrogen Load	17	500			

Pollutant	Detention Basin 5 Loading
Sediment Load	**25,627**
Phosphorus Load	**15**
Nitrogen Load	**517**

Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	25,627	10%	2,562.69	**23,064**
Phosphorus Load	15	10%	1.52	**14**
Nitrogen Load	517	5%	25.84	**491**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	59.38	59.01
Drainage Basin 1	2.40	3.59
Drainage Basin 2	0.46	0.21
Drainage Basin 3	0.15	0.29
Drainage Basin 5	11.23	8.28
Detention Basin Bypass	**45.14**	**46.65**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	45.14	2,065.10	93,213
Developed Pervious	46.65	306.95	14,319
Total	**91.79**		**107,532**

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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	45.14	1.11	50
Developed Pervious	46.65	0.34	16
Total	**91.79**		**66**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	45.14	28.93	1,306
Developed Pervious	46.65	23.29	1,086
Total	**91.79**		**2,392**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 2**	**Detention Basin 3**	**Detention Basin 5**	**Detention Basin Bypass**
Sediment Load	5,453	910	361	23,064	107,532
Phosphorus Load	3	1	0	14	66
Nitrogen Load	145	17	11	491	2,392

Pollutant	**Total Post-BMP (Best Management Practice) Loading**
Sediment Load	**137,320**
Phosphorus Load	**84**
Nitrogen Load	**3,056**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	19.66	49%	9.63	10.03
		Total	**9.63**	**10.03**

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Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	9.63	2,065.10	19,894
Developed Pervious	10.03	306.95	3,078
Total	**19.66**		**22,972**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	9.63	1.11	11
Developed Pervious	10.03	0.34	3
Total	**19.66**		**14**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	9.63	28.93	279
Developed Pervious	10.03	23.29	234
Total	**19.66**		**512**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	140,731	3,411	22,972	**114,348**
Phosphorus Load	86	2	14	**70**
Nitrogen Load	3,092	36	512	**2,544**

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Letort Spring Run

Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	80,750.04	16.9
Developed, Low Intensity	175,855.64	36.7
Developed, Medium Intensity	155,219.52	32.4
Developed, High Intensity	16,150.01	3.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	51,141.69	10.7
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

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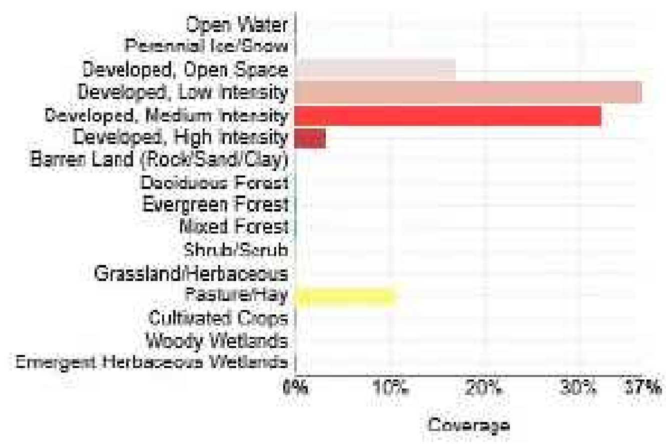
Selected Area
Total Area 482,247 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	80,750.04	16.9
Developed, Low Intensity	175,855.64	36.7
Developed, Medium Intensity	155,219.52	32.4
Developed, High Intensity	16,150.01	3.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.00	0.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	51,141.69	10.7
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Attachment D5: Pollutant Load Calculations: Yellow Breeches Creek

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Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	368.19	0.0	69.96	298.23
Developed, Low Intensity	49%	410.19	0.0	200.99	209.20
Developed, Medium Intensity	79%	49.42	0.0	39.04	10.38
Developed, High Intensity	100%	9.88	0.0	9.88	0.00
Deciduous Forest	0	64.25	0.0	0.00	64.25
Evergreen Forest	0	4.94	0.0	0.00	4.94
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	318.77	0.0	0.00	318.77
Cultivated Crops	0	817.92	0.0	0.00	817.92
Total		**2,043.56**	**0.0**	**319.87**	**1,723.69**

Drainage Areas

Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Total	319.87	1,723.69
Closed Depression 14	2.96	14.33
Closed Depression 15	1.16	33.20
Closed Depression 16	3.90	7.18
Outfall R11	**311.85**	**1,668.98**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	319.87	2,065.10	660,566
Developed Pervious	1,723.69	306.95	529,086
Total	**2,043.56**		**1,189,652**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	319.87	1.11	355
Developed Pervious	1,723.69	0.34	586
Total	**2,043.56**		**941**

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Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	319.87	28.93	9,254
Developed Pervious	1,723.69	23.29	40,145
Total	**2,043.56**		**49,399**

Drainage Area: Detention Basin 1

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	109,461.39	27.05	5.14	21.91
Developed, Low Intensity	49%	10,766.69	2.66	1.30	1.36
Pasture/Hay	0	16,150.04	3.99	0.00	3.99
Cultivated Crops	0	97,797.47	24.17	0.00	24.17
Total		**234,175.59**	**57.87**	**6.44**	**51.42**

Detention Basin 1: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	6.44	2,065.10	13,305
Developed Pervious	51.42	306.95	15,784
Total	**57.87**		**29,089**

Detention Basin 1: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	6.44	1.11	7
Developed Pervious	51.42	0.34	17
Total	**57.87**		**25**

Detention Basin 1: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	6.44	28.93	186
Developed Pervious	51.42	23.29	1,198
Total	**57.87**		**1,384**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	29,089	10%	2,908.95	**26,181**
Phosphorus Load	25	10%	2.46	**22**
Nitrogen Load	1,384	5%	69.20	**1,315**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	28,711.20	7.09	1.35	5.75
Developed, Low Intensity	49%	52,936.27	13.08	6.41	6.67
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Cultivated Crops	0	13,458.37	3.33	0.00	3.33
Total		**96,900.29**	**23.94**	**8.11**	**15.84**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	8.11	2,065.10	16,744
Developed Pervious	15.84	306.95	4,861
Total	**23.94**		**21,605**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	8.11	1.11	9
Developed Pervious	15.84	0.34	5
Total	**23.94**		**14**

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Detention Basin 2: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	8.11	28.93	235
Developed Pervious	15.84	23.29	369
Total	**23.94**		**603**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 2 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 2 (lbs/year)
Sediment Load	21,605	10%	2,160.47	**19,444**
Phosphorus Load	14	10%	1.44	**13**
Nitrogen Load	603	5%	30.17	**573**

Drainage Area: Detention Basin 3					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	95,105.87	23.50	4.47	19.04
Developed, Low Intensity	49%	96,900.32	23.94	11.73	12.21
Developed, Medium Intensity	79%	4,486.13	1.11	0.88	0.23
Pasture/Hay	0	1,794.45	0.44	0.00	0.44
Cultivated Crops	0	91,516.97	22.61	0.00	22.61
Total		**289,803.74**	**71.61**	**17.07**	**54.54**

Detention Basin 2 Bypass: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	17.07	2,065.10	35,259
Developed Pervious	54.54	306.95	16,740
Total	**71.61**		**52,000**

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Detention Basin 2 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	17.07	1.11	19
Developed Pervious	54.54	0.34	19
Total	**71.61**		**37**

Detention Basin 2 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	17.07	28.93	494
Developed Pervious	54.54	23.29	1,270
Total	**71.61**		**1,764**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	52,000	10%	5,199.96	**46,800**
Phosphorus Load	37	10%	3.75	**34**
Nitrogen Load	1,764	5%	88.21	**1,676**

Drainage Area: Detention Basin 3 Bypass					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	5,383.35	1.33	0.25	1.08
Developed, Low Intensity	49%	11,663.93	2.88	1.41	1.47
Developed, Medium Intensity	79%	897.23	0.22	0.18	0.05
Total		**17,944.51**	**4.43**	**1.84**	**2.59**

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Detention Basin 3 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.84	2,065.10	3,800
Developed Pervious	2.59	306.95	796
Total	**4.43**		**4,596**

Detention Basin 3 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.84	1.11	2
Developed Pervious	2.59	0.34	1
Total	**4.43**		**3**

Detention Basin 3 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.84	28.93	53
Developed Pervious	2.59	23.29	60
Total	**4.43**		**114**

Detention Basin 4 Loading (lbs/year)					
Pollutant	**Detention Basin 3**	**Detention Basin 3 Bypass**			
Sediment Load	46,800	4,596			
Phosphorus Load	34	3			
Nitrogen Load	1,676	114			

Pollutant	Detention Basin 4 Loading
Sediment Load	**51,396**
Phosphorus Load	**37**
Nitrogen Load	**1,790**

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Detention Basin 4: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 4 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 4 (lbs/year)
Sediment Load	51,396	10%	5,139.60	**46,256**
Phosphorus Load	37	10%	3.67	**33**
Nitrogen Load	1,790	5%	89.48	**1,700**

Drainage Area: Detention Basin 5					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	22,430.64	5.54	1.05	4.49
Developed, Low Intensity	49%	37,683.48	9.31	4.56	4.75
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Total		**61,908.57**	**15.30**	**5.97**	**9.33**

Detention Basin 5: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	5.97	2,065.10	12,321
Developed Pervious	9.33	306.95	2,864
Total	**15.30**		**15,185**

Detention Basin 5: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	5.97	1.11	7
Developed Pervious	9.33	0.34	3
Total	**15.30**		**10**

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Detention Basin 5: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.97	28.93	173
Developed Pervious	9.33	23.29	217
Total	**15.30**		**390**

Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	15,185	10%	1,518.51	**13,667**
Phosphorus Load	10	10%	0.98	**9**
Nitrogen Load	390	5%	19.50	**370**

Drainage Area: Detention Basin 6					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	31,402.91	7.76	1.47	6.29
Developed, Low Intensity	49%	52,039.10	12.86	6.30	6.56
Developed, Medium Intensity	79%	6,280.58	1.55	1.23	0.33
Cultivated Crops	0	8,075.03	2.00	0.00	2.00
Total		**97,797.62**	**24.17**	**9.00**	**15.16**

Detention Basin 6: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	9.00	2,065.10	18,589
Developed Pervious	15.16	306.95	4,655
Total	**24.17**		**23,244**

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Detention Basin 6: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	9.00	1.11	10
Developed Pervious	15.16	0.34	5
Total	**24.17**		**15**

Detention Basin 6: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	9.00	28.93	260
Developed Pervious	15.16	23.29	353
Total	**24.17**		**614**

Detention Basin 6: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 6 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 6 (lbs/year)
Sediment Load	23,244	10%	2,324.36	**20,919**
Phosphorus Load	15	10%	1.51	**14**
Nitrogen Load	614	5%	30.68	**583**

Drainage Area: Detention Basin 7					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Medium Intensity	79%	3,588.90	0.89	0.70	0.19
Developed, High Intensity	100%	897.23	0.22	0.22	0.00
Total		**4,486.13**	**1.11**	**0.92**	**0.19**

Detention Basin 7: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.92	2,065.10	1,905
Developed Pervious	0.19	306.95	57
Total	**1.11**		**1,962**

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Detention Basin 7: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.92	1.11	1
Developed Pervious	0.19	0.34	0
Total	**1.11**		**1**

Detention Basin 7: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.92	28.93	27
Developed Pervious	0.19	23.29	4
Total	**1.11**		**31**

Detention Basin 7: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 7 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 7 (lbs/year)**
Sediment Load	1,962	10%	196.18	**1,766**
Phosphorus Load	1	10%	0.11	**1**
Nitrogen Load	31	5%	1.55	**29**

Drainage Area: Detention Basin 8					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	81,647.58	20.18	3.83	16.34
Developed, Low Intensity	49%	16,150.07	3.99	1.96	2.04
Cultivated Crops	0	32,300.14	7.98	0.00	7.98
Total		**130,097.79**	**32.15**	**5.79**	**26.36**

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Detention Basin 8: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	5.79	2,065.10	11,954
Developed Pervious	26.36	306.95	8,091
Total	**32.15**		**20,045**

Detention Basin 8: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.79	1.11	6
Developed Pervious	26.36	0.34	9
Total	**32.15**		**15**

Detention Basin 8: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.79	28.93	167
Developed Pervious	26.36	23.29	614
Total	**32.15**		**781**

Detention Basin 8: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 8 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 8 (lbs/year)**
Sediment Load	20,045	10%	2,004.54	**18,041**
Phosphorus Load	15	10%	1.54	**14**
Nitrogen Load	781	5%	39.07	**742**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 8	5.79	26.36
Detention Basin 8 Bypass	9.29	39.71
Total	**0.00**	**1.02**

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Detention Basin 8 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	9.29	2,065.10	19,185
Developed Pervious	39.71	306.95	12,189
Total	**49.00**		**31,374**

Detention Basin 8 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	9.29	1.11	10
Developed Pervious	39.71	0.34	14
Total	**49.00**		**24**

Detention Basin 8 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	9.29	28.93	269
Developed Pervious	39.71	23.29	925
Total	**49.00**		**1,194**

Detention Basin 9 Loading (lbs/year)					
Pollutant	**Detention Basin 8**	**Detention Basin 8 Bypass**			
Sediment Load	18,041	31,374			
Phosphorus Load	14	24			
Nitrogen Load	742	1,194			

Pollutant	**Detention Basin 9 Loading**
Sediment Load	**49,415**
Phosphorus Load	**38**
Nitrogen Load	**1,936**

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Detention Basin 9: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 9 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 9 (lbs/year)**
Sediment Load	49,415	10%	4,941.46	**44,473**
Phosphorus Load	38	10%	3.77	**34**
Nitrogen Load	1,936	5%	96.80	**1,839**

Drainage Area: Detention Basin 10					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	8,972.27	2.22	0.42	1.80
Developed, Low Intensity	49%	897.23	0.22	0.11	0.11
Deciduous Forest	0	15,252.85	3.77	0.00	3.77
Cultivated Crops	0	69,086.45	17.07	0.00	17.07
Total		**94,208.80**	**23.28**	**0.53**	**22.75**

Detention Basin 10: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.53	2,065.10	1,094
Developed Pervious	22.75	306.95	6,983
Total	**23.28**		**8,077**

Detention Basin 10: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.53	1.11	1
Developed Pervious	22.75	0.34	8
Total	**23.28**		**8**

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Detention Basin 10: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.53	28.93	15
Developed Pervious	22.75	23.29	530
Total	**23.28**		**545**

Detention Basin 10: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 10 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 10 (lbs/year)**
Sediment Load	8,077	10%	807.73	**7,270**
Phosphorus Load	8	10%	0.83	**7**
Nitrogen Load	545	5%	27.26	**518**

Drainage Area: Detention Basin 11					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	203,670.34	50.33	9.56	40.77
Developed, Low Intensity	49%	122,919.99	30.37	14.88	15.49
Developed, Medium Intensity	79%	7,177.81	1.77	1.40	0.37
Deciduous Forest	0	52,039.12	12.86	0.00	12.86
Pasture/Hay	0	47,552.99	11.75	0.00	11.75
Cultivated Crops	0	160,603.49	39.69	0.00	39.69
Total		**593,963.74**	**146.77**	**25.85**	**120.92**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 11	25.85	120.92
Detention Basin 8	5.79	26.36
Detention Basin 8 Bypass	9.29	39.71
Detention Basin 10	0.53	22.75
Detention Basin Bypass	**10.24**	**32.11**

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Detention Basin Bypass: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	10.24	2,065.10	21,143
Developed Pervious	32.11	306.95	9,855
Total	**42.34**		**30,998**

Detention Basin Bypass: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	10.24	1.11	11
Developed Pervious	32.11	0.34	11
Total	**42.34**		**22**

Detention Basin Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	10.24	28.93	296
Developed Pervious	32.11	23.29	748
Total	**42.34**		**1,044**

Detention Basin 11 Loading (lbs/year)

Pollutant	Detention Basin 9	Detention Basin 10	Detention Basin Bypass		
Sediment Load	44,473	7,270	30,998		
Phosphorus Load	34	7	22		
Nitrogen Load	1,839	518	1,044		

Pollutant	Detention Basin 11 Loading
Sediment Load	**82,740**
Phosphorus Load	**64**
Nitrogen Load	**3,401**

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Detention Basin 11: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 11 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 11 (lbs/year)**
Sediment Load	82,740	10%	8,274.04	**74,466**
Phosphorus Load	64	10%	6.37	**57**
Nitrogen Load	3,401	5%	170.05	**3,231**

Drainage Area: Detention Basin 12					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	3,588.90	0.89	0.17	0.72
Developed, Low Intensity	49%	12,561.16	3.10	1.52	1.58
Developed, Medium Intensity	79%	897.23	0.22	0.18	0.05
Pasture/Hay	0	14,355.61	3.55	0.00	3.55
Cultivated Crops	0	9,869.48	2.44	0.00	2.44
Total		**41,272.38**	**10.20**	**1.86**	**8.33**

Detention Basin 12: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.86	2,065.10	3,851
Developed Pervious	8.33	306.95	2,558
Total	**10.20**		**6,409**

Detention Basin 12: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.86	1.11	2
Developed Pervious	8.33	0.34	3
Total	**10.20**		**5**

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Detention Basin 12: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.86	28.93	54
Developed Pervious	8.33	23.29	194
Total	**10.20**		**248**

Detention Basin 12: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 12 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 12 (lbs/year)**
Sediment Load	6,409	10%	640.87	**5,768**
Phosphorus Load	5	10%	0.49	**4**
Nitrogen Load	248	5%	12.40	**236**

Drainage Area: Closed Depression 23					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	13,458.37	3.33	0.63	2.69
Developed, Low Intensity	49%	1,794.45	0.44	0.22	0.23
Developed, Medium Intensity	79%	897.22	0.22	0.18	0.05
Pasture/Hay	0	7,177.80	1.77	0.00	1.77
Cultivated Crops	0	41,272.34	10.20	0.00	10.20
Total		**64,600.18**	**15.96**	**1.02**	**14.94**

Closed Depression, no water discharges to the surface waters of the Commonwealth

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Drainage Area: Detention Basin 13					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	340,945.82	84.25	16.01	68.24
Developed, Low Intensity	49%	302,365.11	74.72	36.61	38.11
Developed, Medium Intensity	79%	24,255.10	5.99	4.73	1.26
Developed, High Intensity	100%	4,486.13	1.11	1.11	0.00
Deciduous Forest	0	68,189.16	16.85	0.00	16.85
Pasture/Hay	0	266,476.07	65.85	0.00	65.85
Cultivated Crops	0	624,469.18	154.31	0.00	154.31
Total		**1,631,186.57**	**403.07**	**58.46**	**344.61**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 13	58.46	344.61
Closed Depression 23	1.02	14.94
Detention Basin 11	25.85	120.92
Detention Basin 12	1.86	8.33
Detention Basin Bypass	**29.73**	**200.42**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	29.73	2,065.10	61,387
Developed Pervious	200.42	306.95	61,517
Total	**230.14**		**122,905**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	29.73	1.11	33
Developed Pervious	200.42	0.34	68
Total	**230.14**		**101**

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Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	29.73	28.93	860
Developed Pervious	200.42	23.29	4,668
Total	**230.14**		**5,528**

Detention Basin 13 Loading (lbs/year)					
Pollutant	**Detention Basin 11**	**Detention Basin 12**	**Closed Depression 23**	**Detention Basin Bypass**	
Sediment Load	74,466	5,768	0	122,905	
Phosphorus Load	57	4	0	101	
Nitrogen Load	3,231	236	0	5,528	

Pollutant	Detention Basin 13 Loading
Sediment Load	**203,139**
Phosphorus Load	**163**
Nitrogen Load	**8,994**

Detention Basin 13: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 13 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 13 (lbs/year)**
Sediment Load	203,139	10%	20,313.87	**182,825**
Phosphorus Load	163	10%	16.29	**147**
Nitrogen Load	8,994	5%	449.71	**8,544**

Drainage Area: Detention Basin 14					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	1,794.45	0.44	0.08	0.36
Developed, Medium Intensity	79%	897.23	0.22	0.18	0.05
Total		**2,691.68**	**0.67**	**0.26**	**0.41**

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Detention Basin 14: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.26	2,065.10	536
Developed Pervious	0.41	306.95	125
Total	**0.67**		**660**

Detention Basin 14: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.26	1.11	0
Developed Pervious	0.41	0.34	0
Total	**0.67**		**0**

Detention Basin 14: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.26	28.93	8
Developed Pervious	0.41	23.29	9
Total	**0.67**		**17**

Detention Basin 14: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 14 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 14 (lbs/year)**
Sediment Load	660	10%	66.02	**594**
Phosphorus Load	0	10%	0.04	**0**
Nitrogen Load	17	5%	0.85	**16**

Municipal Storm Sewershed
R11

Drainage Area: Detention Basin 15					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	3,588.91	0.89	0.17	0.72
Developed, Low Intensity	49%	3,588.91	0.89	0.43	0.45
Developed, Medium Intensity	79%	1,794.45	0.44	0.35	0.09
Pasture/Hay	0	897.23	0.22	0.00	0.22
Total		**9,869.50**	**2.44**	**0.95**	**1.49**

Detention Basin 15: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.95	2,065.10	1,969
Developed Pervious	1.49	306.95	456
Total	**2.44**		**2,425**

Detention Basin 15: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.95	1.11	1
Developed Pervious	1.49	0.34	1
Total	**2.44**		**2**

Detention Basin 15: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.95	28.93	28
Developed Pervious	1.49	23.29	35
Total	**2.44**		**62**

Municipal Storm Sewershed
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Detention Basin 15: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 15 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 15 (lbs/year)**
Sediment Load	2,425	10%	242.47	**2,182**
Phosphorus Load	2	10%	0.16	**1**
Nitrogen Load	62	5%	3.11	**59**

Drainage Area: Detention Basin 20					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2,691.68	0.67	0.13	0.54
Cultivated Crops	0	119,331.17	29.49	0.00	29.49
Total		**122,022.85**	**30.15**	**0.13**	**30.03**

Detention Basin 20: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.13	2,065.10	261
Developed Pervious	30.03	306.95	9,217
Total	**30.15**		**9,477**

Detention Basin 20: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.13	1.11	0
Developed Pervious	30.03	0.34	10
Total	**30.15**		**10**

Detention Basin 20: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.13	28.93	4
Developed Pervious	30.03	23.29	699
Total	**30.15**		**703**

Municipal Storm Sewershed
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Detention Basin 20: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 20 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 20 (lbs/year)**
Sediment Load	9,477	10%	947.75	**8,530**
Phosphorus Load	10	10%	1.03	**9**
Nitrogen Load	703	5%	35.15	**668**

Drainage Area: Detention Basin 16					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	112,153.39	27.71	5.27	22.45
Developed, Low Intensity	49%	187,520.47	46.34	22.71	23.63
Developed, Medium Intensity	79%	8,972.27	2.22	1.75	0.47
Deciduous Forest	0	15,252.86	3.77	0.00	3.77
Pasture/Hay	0	72,675.40	17.96	0.00	17.96
Cultivated Crops	0	480,016.53	118.61	0.00	118.61
Total		**876,590.92**	**216.61**	**29.72**	**186.89**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 16	29.72	186.89
Detention Basin 20	0.13	30.03
Detention Basin Bypass	**29.60**	**156.86**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	29.60	2,065.10	61,119
Developed Pervious	156.86	306.95	48,149
Total	**186.46**		**109,267**

Municipal Storm Sewershed
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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	29.60	1.11	33
Developed Pervious	156.86	0.34	53
Total	**186.46**		**86**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	29.60	28.93	856
Developed Pervious	156.86	23.29	3,653
Total	**186.46**		**4,510**

Detention Basin 16 Loading (lbs/year)					
Pollutant	**Detention Basin 20**	**Detention Basin Bypass**			
Sediment Load	8,530	109,267			
Phosphorus Load	9	86			
Nitrogen Load	668	4,510			

Pollutant	Detention Basin 16 Loading
Sediment Load	**117,797**
Phosphorus Load	**95**
Nitrogen Load	**5,177**

Detention Basin 16: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 16 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 16 (lbs/year)**
Sediment Load	117,797	10%	11,779.70	**106,017**
Phosphorus Load	95	10%	9.55	**86**
Nitrogen Load	5,177	5%	258.87	**4,918**

Municipal Storm Sewershed
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Detention Basin 16 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.26	2,065.10	537
Developed Pervious	15.70	306.95	4,819
Total	**15.96**		**5,356**

Detention Basin 16 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.26	1.11	0
Developed Pervious	15.70	0.34	5
Total	**15.96**		**6**

Detention Basin 16 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.26	28.93	8
Developed Pervious	15.70	23.29	366
Total	**15.96**		**373**

Detention Basin 17 Loading (lbs/year)					
Pollutant	**Detention Basin 16**	**Detention Basin 16 Bypass**			
Sediment Load	106,017	5,356			
Phosphorus Load	86	6			
Nitrogen Load	4,918	373			

Pollutant	Detention Basin 17 Loading
Sediment Load	**111,373**
Phosphorus Load	**92**
Nitrogen Load	**5,292**

Municipal Storm Sewershed
R11

Detention Basin 17: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 17 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 17 (lbs/year)**
Sediment Load	111,373	10%	11,137.34	**100,236**
Phosphorus Load	92	10%	9.16	**82**
Nitrogen Load	5,292	5%	264.58	**5,027**

Drainage Area: Detention Basin 18					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	9,869.50	2.44	0.46	1.98
Developed, Low Intensity	49%	8,075.05	2.00	0.98	1.02
Pasture/Hay	0	2,691.68	0.67	0.00	0.67
Total		**20,636.23**	**5.10**	**1.44**	**3.66**

Detention Basin 18: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.44	2,065.10	2,976
Developed Pervious	3.66	306.95	1,123
Total	**5.10**		**4,099**

Detention Basin 18: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.44	1.11	2
Developed Pervious	3.66	0.34	1
Total	**5.10**		**3**

Municipal Storm Sewershed
R11

Detention Basin 18: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.44	28.93	42
Developed Pervious	3.66	23.29	85
Total	**5.10**		**127**

Detention Basin 18: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 18 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 18 (lbs/year)**
Sediment Load	4,099	10%	409.89	**3,689**
Phosphorus Load	3	10%	0.28	**3**
Nitrogen Load	127	5%	6.34	**121**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	311.85	1,668.98
Detention Basin 1	6.44	51.42
Detention Basin 2	8.11	15.84
Detention Basin 3	17.07	54.54
Detention Basin 3 Bypass	1.84	2.59
Detention Basin 5	5.97	9.33
Detention Basin 6	9.00	15.16
Detention Basin 7	0.92	0.19
Detention Basin 13	58.46	344.61
Detention Basin 14	0.26	0.41
Detention Basin 15	0.95	1.49
Detention Basin 16	29.72	186.89
Detention Basin 16 Bypass	0.26	15.70
Detention Basin 18	1.44	3.66
Detention Basin Bypass	**171.40**	**967.15**

Municipal Storm Sewershed
R11

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	171.40	2,065.10	353,955
Developed Pervious	967.15	306.95	296,868
Total	**1,138.55**		**650,823**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	171.40	1.11	190
Developed Pervious	967.15	0.34	329
Total	**1,138.55**		**519**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	171.40	28.93	4,959
Developed Pervious	967.15	23.29	22,525
Total	**1,138.55**		**27,484**

Municipal Storm Sewershed
R11

Outfall Loading (lbs/year)

Pollutant	Detention Basin 1	Detention Basin 2	Detention Basin 4	Detention Basin 5	Detention Basin 6
Sediment Load	26,181	19,444	46,256	13,667	20,919
Phosphorus Load	22	13	33	9	14
Nitrogen Load	1,315	573	1,700	370	583

Pollutant	Detention Basin 7	Detention Basin 13	Detention Basin 14	Detention Basin 15	Detention Basin 17
Sediment Load	1,766	182,825	594	2,182	100,236
Phosphorus Load	1	147	0	1	82
Nitrogen Load	29	8,544	16	59	5,027

Pollutant	Detention Basin 18	Detention Basin Bypass			
Sediment Load	3,689	650,823			
Phosphorus Load	3	519			
Nitrogen Load	121	27,484			

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**1,068,582**
Phosphorus Load	**844**
Nitrogen Load	**45,822**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions

	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	11.50	49%	5.64	5.87
		Total	**5.64**	**5.87**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	5.64	2,065.10	11,637
Developed Pervious	5.87	306.95	1,800
Total	**11.50**		**13,437**

Municipal Storm Sewershed
R11

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.64	1.11	6
Developed Pervious	5.87	0.34	2
Total	**11.50**		**8**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.64	28.93	163
Developed Pervious	5.87	23.29	137
Total	**11.50**		**300**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	1,189,652	121,070	13,437	**1,055,145**
Phosphorus Load	941	97	8	**836**
Nitrogen Load	49,399	3,577	300	**45,522**

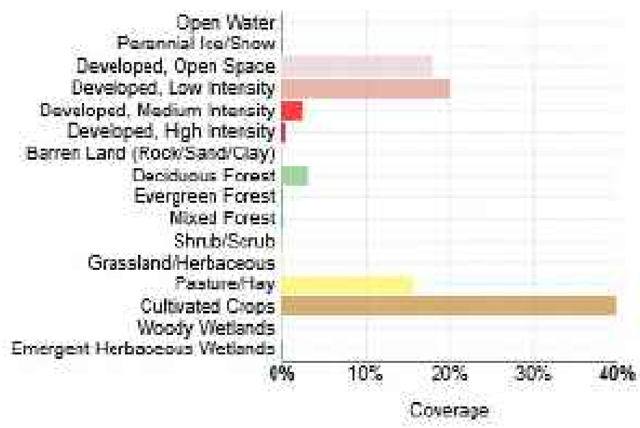
Municipal Storm Sewershed R11
Yellow Breeches Creek

Type	Area (km²)	Coverage (%)
Open Water	0.02	0.2
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	1.49	18.0
Developed, Low Intensity	1.66	20.1
Developed, Medium Intensity	0.20	2.4
Developed, High Intensity	0.04	0.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.26	3.2
Evergreen Forest	0.02	0.2
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	1.29	15.6
Cultivated Crops	3.31	40.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R11
Yellow Breeches Creek

Selected Area
Total Area 8 km²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (km²)	Coverage (%)
Open Water	0.02	0.2
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	1.49	18.0
Developed, Low Intensity	1.66	20.1
Developed, Medium Intensity	0.20	2.4
Developed, High Intensity	0.04	0.4
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.26	3.2
Evergreen Forest	0.02	0.2
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	1.29	15.6
Cultivated Crops	3.31	40.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed
R12

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2.66	0.0	0.51	2.15
Developed, Low Intensity	49%	2.66	0.0	1.30	1.36
Developed, Medium Intensity	79%	0.00	0.0	0.00	0.00
Developed, High Intensity	100%	0.00	0.0	0.00	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	5.32	0.0	0.00	5.32
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	5.32	0.0	0.00	5.32
Cultivated Crops	0	0.00	0.0	0.00	0.00
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**15.96**	**0.7**	**1.81**	**14.15**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.81	2,065.10	3,735
Developed Pervious	14.15	306.95	4,344
Total	**15.96**		**8,079**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.81	1.11	2
Developed Pervious	14.15	0.34	5
Total	**15.96**		**7**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.81	28.93	52
Developed Pervious	14.15	23.29	330
Total	**15.96**		**382**

Municipal Storm Sewershed
R12

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	1.87	49%	0.92	0.95
PennDOT	0.00	49%	0.00	0.00
		Total	**0.92**	**0.95**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.92	2,065.10	1,892
Developed Pervious	0.95	306.95	293
Total	**1.87**		**2,185**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.92	1.11	1
Developed Pervious	0.95	0.34	0
Total	**1.87**		**1**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.92	28.93	27
Developed Pervious	0.95	23.29	22
Total	**1.87**		**49**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	8,079	0	2,185	**5,894**
Phosphorus Load	7	0	1	**5**
Nitrogen Load	382	0	49	**333**

Municipal Storm Sewershed R12
Yellow Breeches Creek

Model My Watershed: Geospatial Analysis

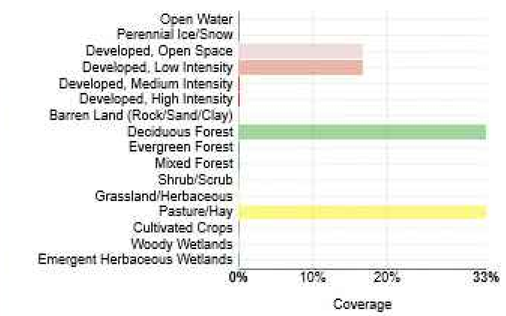
Analyze

LAND SOIL ANIMALS POINT SOURCES WATER QUALITY

Selected Area

Total Area 61,312 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



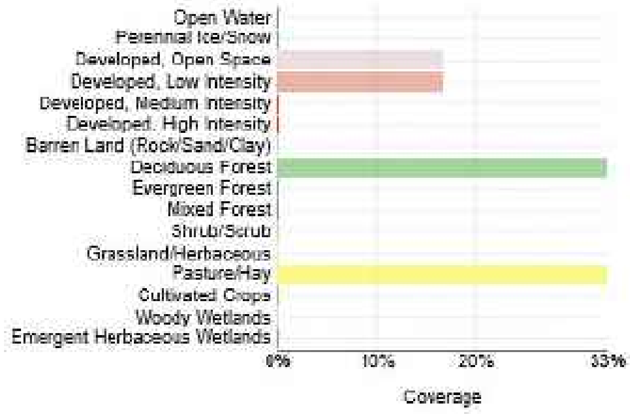
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	10,766.73	16.7
Developed, Low Intensity	10,766.73	16.7
Developed, Medium Intensity	0.00	0.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	21,533.47	33.3
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	21,533.47	33.3
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R12
Yellow Breeches Creek

Selected Area

Total Area 61,312 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	10,766.73	16.7
Developed, Low Intensity	10,766.73	16.7
Developed, Medium Intensity	0.00	0.0
Developed, High Intensity	0.00	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	21,533.47	33.3
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	21,533.47	33.3
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Attachment D6: Pollutant Load Calculations: Hogestown Run

Municipal Storm Sewershed
R109

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	184.02	0.0	34.96	149.06
Developed, Low Intensity	49%	85.80	0.0	42.04	43.76
Developed, Medium Intensity	79%	12.19	0.0	9.63	2.56
Developed, High Intensity	100%	0.89	0.0	0.89	0.00
Barren Lands	0	0.00	0.0	0.00	0.00
Deciduous Forest	0	3.10	0.0	0.00	3.10
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	32.81	0.0	0.00	32.81
Cultivated Crops	0	107.97	0.0	0.00	107.97
Total		**426.78**	**0.0**	**87.53**	**339.25**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	87.53	2,065.10	180,750
Developed Pervious	339.25	306.95	104,134
Total	**426.78**		**284,884**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	87.53	1.11	97
Developed Pervious	339.25	0.34	115
Total	**426.78**		**213**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	87.53	28.93	2,532
Developed Pervious	339.25	23.29	7,901
Total	**426.78**		**10,433**

Municipal Storm Sewershed
R109

Drainage Area: Detention Basin 1

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	9,869.47	2.44	0.46	1.98
Developed, Low Intensity	49%	14,355.59	3.55	1.74	1.81
Developed, Medium Intensity	79%	2,691.67	0.67	0.53	0.14
Pasture/Hay	0	14,355.59	3.55	0.00	3.55
Cultivated Crops	0	21,533.39	5.32	0.00	5.32
Total		**62,805.71**	**15.52**	**2.73**	**12.79**

Detention Basin 1: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	2.73	2,065.10	5,632
Developed Pervious	12.79	306.95	3,927
Total	**15.52**		**9,558**

Detention Basin 1: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	2.73	1.11	3
Developed Pervious	12.79	0.34	4
Total	**15.52**		**7**

Detention Basin 1: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	2.73	28.93	79
Developed Pervious	12.79	23.29	298
Total	**15.52**		**377**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	9,558	10%	955.82	**8,602**
Phosphorus Load	7	10%	0.74	**7**
Nitrogen Load	377	5%	18.84	**358**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	897.22	0.22	0.04	0.18
Developed, Low Intensity	49%	7,177.79	1.77	0.87	0.90
Developed, Medium Intensity	79%	8,075.02	2.00	1.58	0.42
Developed, High Intensity	100%	1,794.45	0.44	0.44	0.00
Pasture/Hay	0	8,972.24	2.22	0.00	2.22
Cultivated Crops	0	897.22	0.22	0.00	0.22
Total		**27,813.94**	**6.87**	**2.93**	**3.94**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	2.93	2,065.10	6,053
Developed Pervious	3.94	306.95	1,210
Total	**6.87**		**7,263**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	2.93	1.11	3
Developed Pervious	3.94	0.34	1
Total	**6.87**		**5**

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Detention Basin 2: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	2.93	28.93	85
Developed Pervious	3.94	23.29	92
Total	**6.87**		**177**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 2 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 2 (lbs/year)**
Sediment Load	7,263	10%	726.28	**6,536**
Phosphorus Load	5	10%	0.46	**4**
Nitrogen Load	177	5%	8.83	**168**

Drainage Area: Detention Basin 3					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	78,058.49	19.29	3.66	15.62
Developed, Low Intensity	49%	26,916.72	6.65	3.26	3.39
Developed, Medium Intensity	79%	10,766.69	2.66	2.10	0.56
Developed, High Intensity	100%	1,794.45	0.44	0.44	0.00
Pasture/Hay	0	122,022.47	30.15	0.00	30.15
Cultivated Crops	0	245,839.40	60.75	0.00	60.75
Total		**485,398.22**	**119.94**	**9.47**	**110.48**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Drainage Basin 3	9.47	110.48
Drainage Basin 1	2.73	12.79
Drainage Basin 2	2.93	3.94
Detention Basin Bypass	**3.81**	**93.74**

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Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	3.81	2,065.10	7,870
Developed Pervious	93.74	306.95	28,774
Total	**97.55**		**36,644**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	3.81	1.11	4
Developed Pervious	93.74	0.34	32
Total	**97.55**		**36**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	3.81	28.93	110
Developed Pervious	93.74	23.29	2,183
Total	**97.55**		**2,293**

Detention Basin 3 Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 2**	**Detention Basin Bypass**		
Sediment Load	8,602	6,536	36,644		
Phosphorus Load	7	4	36		
Nitrogen Load	358	168	2,293		

Pollutant	**Detention Basin 3 Loading**
Sediment Load	**51,783**
Phosphorus Load	**47**
Nitrogen Load	**2,819**

Municipal Storm Sewershed
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Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	51,783	10%	5,178.30	**46,605**
Phosphorus Load	47	10%	4.69	**42**
Nitrogen Load	2,819	5%	140.96	**2,678**

Drainage Area: Detention Basin 4					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Low Intensity	49%	1,794.45	0.44	0.22	0.23
Deciduous Forest	0	1,794.45	0.44	0.00	0.44
Pasture/Hay	0	2,691.67	0.67	0.00	0.67
Cultivated Crops	0	7,177.79	1.77	0.00	1.77
Total		**13,458.36**	**3.33**	**0.22**	**3.11**

Detention Basin 4: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.22	2,065.10	449
Developed Pervious	3.11	306.95	954
Total	**3.33**		**1,403**

Detention Basin 4: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.22	1.11	0
Developed Pervious	3.11	0.34	1
Total	**3.33**		**1**

Municipal Storm Sewershed
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Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.22	28.93	6
Developed Pervious	3.11	23.29	72
Total	**3.33**		**79**

Detention Basin 4: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 4 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 4 (lbs/year)**
Sediment Load	1,403	10%	140.28	**1,263**
Phosphorus Load	1	10%	0.13	**1**
Nitrogen Load	79	5%	3.93	**75**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	87.53	339.25
Drainage Basin 3	9.47	110.48
Drainage Basin 4	0.22	3.11
Detention Basin Bypass	**77.84**	**225.67**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	77.84	2,065.10	160,746
Developed Pervious	225.67	306.95	69,270
Total	**303.51**		**230,016**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	77.84	1.11	86
Developed Pervious	225.67	0.34	77
Total	**303.51**		**163**

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Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	77.84	28.93	2,252
Developed Pervious	225.67	23.29	5,256
Total	**303.51**		**7,508**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 3**	**Detention Basin 4**	**Detention Basin Bypass**		
Sediment Load	46,605	1,263	230,016		
Phosphorus Load	42	1	163		
Nitrogen Load	2,678	75	7,508		

Pollutant	**Total Post-BMP (Best Management Practice) Loading**
Sediment Load	**277,883**
Phosphorus Load	**206**
Nitrogen Load	**10,261**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	3.78	49%	1.85	1.93
		Total	**1.85**	**1.93**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.85	2,065.10	3,825
Developed Pervious	1.93	306.95	592
Total	**3.78**		**4,417**

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Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.85	1.11	2
Developed Pervious	1.93	0.34	1
Total	**3.78**		**3**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.85	28.93	54
Developed Pervious	1.93	23.29	45
Total	**3.78**		**98**

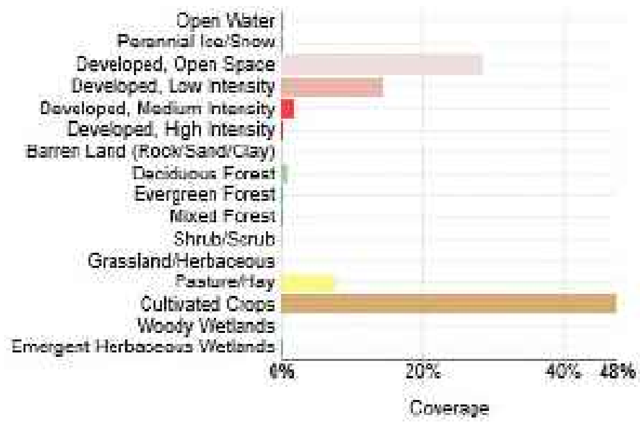
Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	284,884	7,001	4,417	**273,466**
Phosphorus Load	213	6	3	**204**
Nitrogen Load	10,433	173	98	**10,162**

Municipal Storm Sewershed R109
Hogestown Run

Municipal Storm Sewershed R109
Hogestown Run

Selected Area
Total Area 2 km²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (km²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	0.62	28.3
Developed, Low Intensity	0.31	14.3
Developed, Medium Intensity	0.04	1.7
Developed, High Intensity	0.00	0.1
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	0.02	0.7
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.16	7.3
Cultivated Crops	1.04	47.6
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Attachment D7: Pollutant Load Calculations: Alexanders Spring Creek

Municipal Storm Sewershed
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Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	5.32	0.0	1.01	4.31
Developed, Low Intensity	49%	7.09	0.0	3.47	3.62
Developed, Medium Intensity	79%	4.21	0.0	3.33	0.88
Developed, High Intensity	100%	0.67	0.0	0.67	0.00
Barren Land	0	0.00	0.7	0.00	0.00
Deciduous Forest	0	7.54	0.0	0.00	7.54
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Pasture/Hay	0	0.00	0.0	0.00	0.00
Cultivated Crops	0	0.00	0.0	0.00	0.00
Emergent Herbaceous Wetlands	0	0.00	0.0	0.00	0.00
Total		**24.83**	**0.7**	**8.48**	**16.35**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	8.48	2,065.10	17,514
Developed Pervious	16.35	306.95	5,018
Total	**24.83**		**22,532**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	8.48	1.11	9
Developed Pervious	16.35	0.34	6
Total	**24.83**		**15**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	8.48	28.93	245
Developed Pervious	16.35	23.29	381
Total	**24.83**		**626**

Municipal Storm Sewershed
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Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	6.49	49%	3.18	3.31
		Total	**3.18**	**3.31**

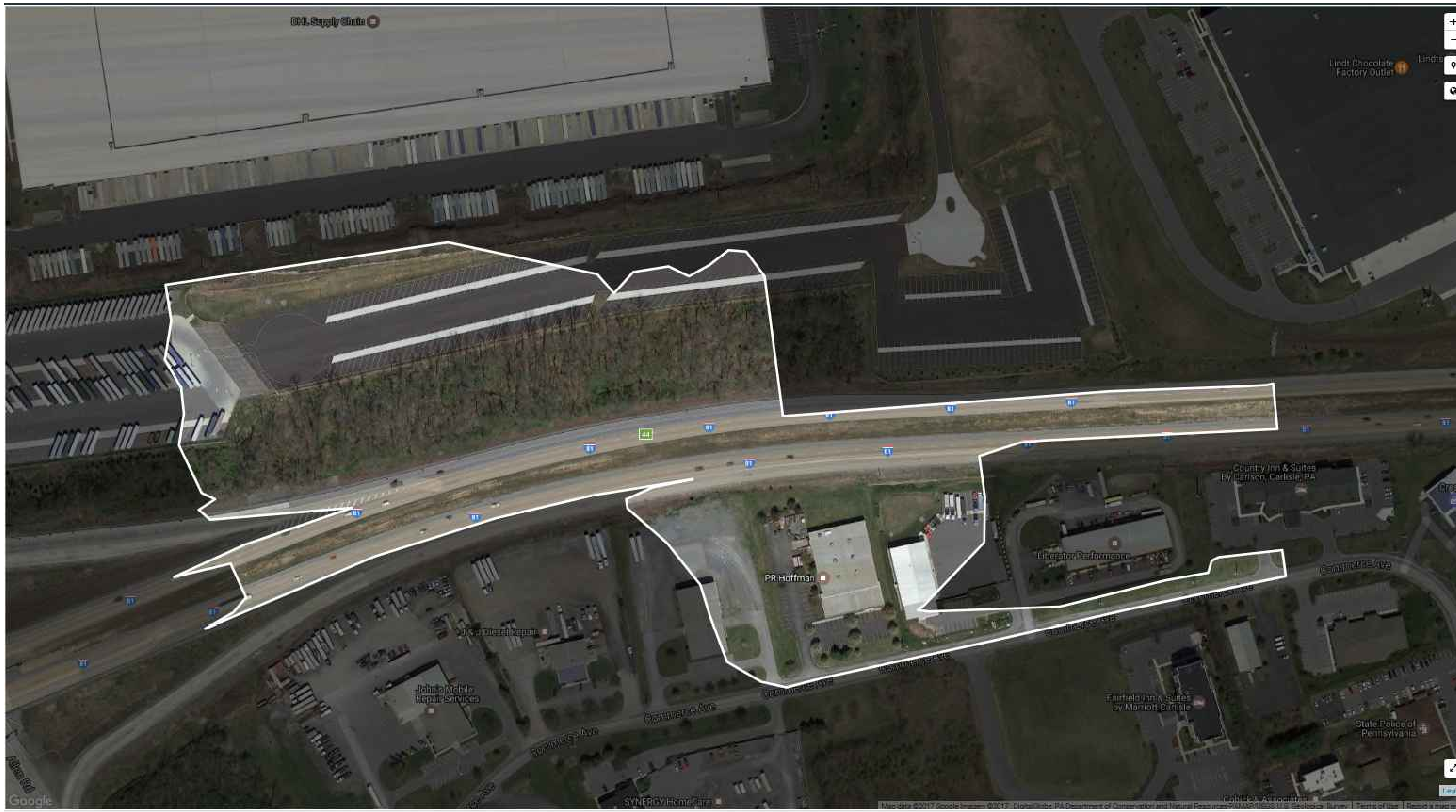
Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	3.18	2,065.10	6,567
Developed Pervious	3.31	306.95	1,016
Total	**6.49**		**7,583**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	3.18	1.11	4
Developed Pervious	3.31	0.34	1
Total	**6.49**		**5**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	3.18	28.93	92
Developed Pervious	3.31	23.29	77
Total	**6.49**		**169**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	22,532	0	7,583	**14,949**
Phosphorus Load	15	0	5	**10**
Nitrogen Load	626	0	169	**457**

Municipal Storm Sewershed R107
Alexanders Spring Creek



Analyze

Back

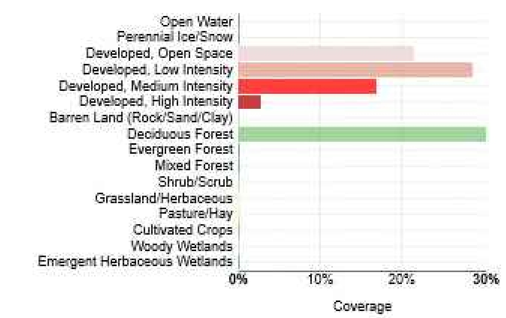
Model

LAND SOIL ANIMALS POINT SOURCES WATER QUALITY

Selected Area

Total Area 101,644 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	21,533.34	21.4
Developed, Low Intensity	28,711.12	28.6
Developed, Medium Intensity	17,047.23	17.0
Developed, High Intensity	2,691.67	2.7
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	30,505.56	30.4
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

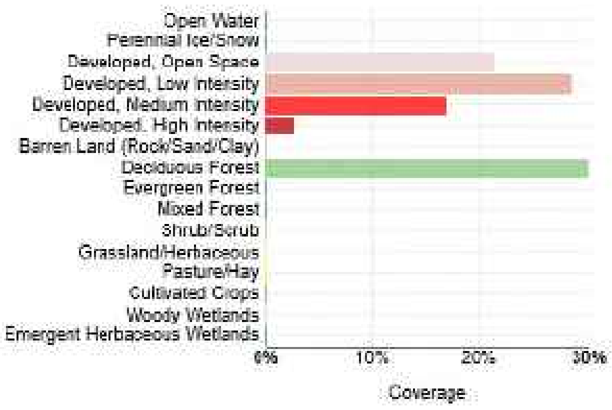
75%

Municipal Storm Sewershed R107
Alexanders Spring Creek

Selected Area

Total Area 101,644 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	21,533.34	21.4
Developed, Low Intensity	28,711.12	28.6
Developed, Medium Intensity	17,047.23	17.0
Developed, High Intensity	2,691.67	2.7
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	30,505.56	30.4
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	0.00	0.0
Pasture/Hay	0.00	0.0
Cultivated Crops	0.00	0.0
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R108

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	102.65	0.0	19.50	83.15
Developed, Low Intensity	49%	105.09	0.0	51.49	53.60
Developed, Medium Intensity	79%	93.12	0.0	73.56	19.56
Developed, High Intensity	100%	113.51	0.0	113.51	0.00
Deciduous Forest	0	20.40	0.0	0.00	20.40
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	8.20	0.0	0.00	8.20
Pasture/Hay	0	53.43	0.0	0.00	53.43
Cultivated Crops	0	90.01	0.0	0.00	90.01
Woody Wetlands	0	1.33	0.0	0.00	1.33
Total		**587.74**	**0.0**	**258.07**	**329.67**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	258.07	2,065.10	532,945
Developed Pervious	329.67	306.95	101,191
Total	**587.74**		**634,137**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	258.07	1.11	286
Developed Pervious	329.67	0.34	112
Total	**587.74**		**399**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	258.07	28.93	7,466
Developed Pervious	329.67	23.29	7,678
Total	**587.74**		**15,144**

Municipal Storm Sewershed
R108

Drainage Area: Detention Basin 1					
Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	13,458.37	3.33	0.63	2.69
Developed, Low Intensity	49%	6,280.57	1.55	0.76	0.79
Pasture/Hay	0	36,786.21	9.09	0.00	9.09
Cultivated Crops	0	88,825.24	21.95	0.00	21.95
Total		**145,350.39**	**35.92**	**1.39**	**34.52**

Detention Basin 1: Sediment Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	1.39	2,065.10	2,875
Developed Pervious	34.52	306.95	10,597
Total	**35.92**		**13,473**

Detention Basin 1: Phosphorus Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	1.39	1.11	2
Developed Pervious	34.52	0.34	12
Total	**35.92**		**13**

Detention Basin 1: Nitrogen Loading			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	1.39	28.93	40
Developed Pervious	34.52	23.29	804
Total	**35.92**		**844**

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Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	13,473	10%	1,347.26	**12,125**
Phosphorus Load	13	10%	1.33	**12**
Nitrogen Load	844	5%	42.22	**802**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	3,588.90	0.89	0.17	0.72
Developed, Low Intensity	49%	2,691.67	0.67	0.33	0.34
Total		**6,280.57**	**1.55**	**0.49**	**1.06**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.49	2,065.10	1,021
Developed Pervious	1.06	306.95	325
Total	**1.55**		**1,346**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.49	1.11	1
Developed Pervious	1.06	0.34	0
Total	**1.55**		**1**

Detention Basin 2: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.49	28.93	14
Developed Pervious	1.06	23.29	25
Total	**1.55**		**39**

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Detention Basin 2: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 2 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 2 (lbs/year)**
Sediment Load	1,346	10%	134.56	**1,211**
Phosphorus Load	1	10%	0.09	**1**
Nitrogen Load	39	5%	1.95	**37**

Drainage Area: Detention Basin 3					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	174,958.77	43.23	8.21	35.02
Developed, Low Intensity	49%	140,864.24	34.81	17.06	17.75
Developed, Medium Intensity	79%	63,702.94	15.74	12.44	3.31
Developed, High Intensity	100%	75,366.86	18.62	18.62	0.00
Deciduous Forest	0	57,422.37	14.19	0.00	14.19
Pasture/Hay	0	183,033.79	45.23	0.00	45.23
Cultivated Crops	0	299,672.97	74.05	0.00	74.05
Total		**995,021.94**	**245.87**	**56.33**	**189.55**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 3	56.33	189.55
Detention Basin 1	1.39	34.52
Detention Basin 2	0.49	1.06
Detention Basin Bypass	**54.44**	**153.96**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	54.44	2,065.10	112,430
Developed Pervious	153.96	306.95	47,259
Total	**208.41**		**159,689**

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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	54.44	1.11	60
Developed Pervious	153.96	0.34	52
Total	**208.41**		**113**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	54.44	28.93	1,575
Developed Pervious	153.96	23.29	3,586
Total	**208.41**		**5,161**

Detention Basin 3 Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 2**	**Detention Basin Bypass**		
Sediment Load	12,125	1,211	159,689		
Phosphorus Load	12	1	113		
Nitrogen Load	802	37	5,161		

Pollutant	**Detention Basin 3 Loading**
Sediment Load	**173,025**
Phosphorus Load	**126**
Nitrogen Load	**6,000**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	173,025	10%	17,302.52	**155,723**
Phosphorus Load	126	10%	12.56	**113**
Nitrogen Load	6,000	5%	300.00	**5,700**

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Drainage Area: Detention Basin 4					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	1,794.45	0.44	0.08	0.36
Developed, Low Intensity	49%	5,383.34	1.33	0.65	0.68
Developed, Medium Intensity	79%	897.22	0.22	0.18	0.05
Developed, High Intensity	100%	8,075.02	2.00	2.00	0.00
Total		**16,150.03**	**3.99**	**2.91**	**1.08**

Detention Basin 4: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	2.91	2,065.10	6,002
Developed Pervious	1.08	306.95	333
Total	**3.99**		**6,335**

Detention Basin 4: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	2.91	1.11	3
Developed Pervious	1.08	0.34	0
Total	**3.99**		**4**

Detention Basin 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	2.91	28.93	84
Developed Pervious	1.08	23.29	25
Total	**3.99**		**109**

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Detention Basin 4: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 4 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 4 (lbs/year)**
Sediment Load	6,335	10%	633.52	**5,702**
Phosphorus Load	4	10%	0.36	**3**
Nitrogen Load	109	5%	5.47	**104**

Drainage Area: Detention Basin 5					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	8,972.24	2.22	0.42	1.80
Developed, Low Intensity	49%	28,711.17	7.09	3.48	3.62
Developed, Medium Intensity	79%	26,916.72	6.65	5.25	1.40
Developed, High Intensity	100%	28,711.17	7.09	7.09	0.00
Cultivated Crops	0	2,691.67	0.67	0.00	0.67
Total		**96,002.97**	**23.72**	**16.25**	**7.48**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 5	16.25	7.48
Detention Basin 4	2.91	1.08
Detention Basin 4 Bypass	**13.34**	**6.39**

Detention Basin 4 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	13.34	2,065.10	27,549
Developed Pervious	6.39	306.95	1,962
Total	**19.73**		**29,511**

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Detention Basin 4 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	13.34	1.11	15
Developed Pervious	6.39	0.34	2
Total	**19.73**		**17**

Detention Basin 4 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	13.34	28.93	386
Developed Pervious	6.39	23.29	149
Total	**19.73**		**535**

Detention Basin 5 Loading (lbs/year)					
Pollutant	**Detention Basin 4**	**Detention Basin 4 Bypass**			
Sediment Load	5,702	29,511			
Phosphorus Load	3	17			
Nitrogen Load	104	535			

Pollutant	Detention Basin 5 Loading
Sediment Load	**35,213**
Phosphorus Load	**20**
Nitrogen Load	**639**

Detention Basin 5: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 5 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 5 (lbs/year)**
Sediment Load	35,213	10%	3,521.25	**31,691**
Phosphorus Load	20	10%	2.02	**18**
Nitrogen Load	639	5%	31.93	**607**

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Drainage Area: Detention Basin 6					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	4,486.12	1.11	0.21	0.90
Developed, Low Intensity	49%	12,561.13	3.10	1.52	1.58
Developed, Medium Intensity	79%	897.22	0.22	0.18	0.05
Total		**17,944.47**	**4.43**	**1.91**	**2.53**

Detention Basin 6: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	1.91	2,065.10	3,938
Developed Pervious	2.53	306.95	776
Total	**4.43**		**4,713**

Detention Basin 6: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	1.91	1.11	2
Developed Pervious	2.53	0.34	1
Total	**4.43**		**3**

Detention Basin 6: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	1.91	28.93	55
Developed Pervious	2.53	23.29	59
Total	**4.43**		**114**

Detention Basin 6: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 6 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 6 (lbs/year)**
Sediment Load	4,713	10%	471.33	**4,242**
Phosphorus Load	3	10%	0.30	**3**
Nitrogen Load	114	5%	5.70	**108**

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Drainage Area: Detention Basin 7					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	32,300.06	7.98	1.52	6.47
Developed, Low Intensity	49%	70,880.69	17.51	8.58	8.93
Developed, Medium Intensity	79%	90,619.61	22.39	17.69	4.70
Developed, High Intensity	100%	52,936.21	13.08	13.08	0.00
Cultivated Crops	0	8,075.02	2.00	0.00	2.00
Total		**254,811.59**	**62.97**	**40.87**	**22.10**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 7	40.87	22.10
Detention Basin 5	16.25	7.48
Detention Basin 6	1.91	2.53
Detention Basins 5 & 6 Bypass	**22.72**	**12.09**

Detention Basins 5 & 6 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	22.72	2,065.10	46,911
Developed Pervious	12.09	306.95	3,712
Total	**34.81**		**50,623**

Detention Basins 5 & 6 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	22.72	1.11	25
Developed Pervious	12.09	0.34	4
Total	**34.81**		**29**

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Detention Basins 5 & 6 Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	22.72	28.93	657
Developed Pervious	12.09	23.29	282
Total	**34.81**		**939**

Detention Basin 7 Loading (lbs/year)

Pollutant	Detention Basin 5	Detention Basin 6	Detention Basins 5 & 6 Bypass		
Sediment Load	31,691	4,242	50,623		
Phosphorus Load	18	3	29		
Nitrogen Load	607	108	939		

Pollutant	Detention Basin 7 Loading
Sediment Load	**86,556**
Phosphorus Load	**50**
Nitrogen Load	**1,654**

Detention Basin 7: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 7 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 7 (lbs/year)
Sediment Load	86,556	10%	8,655.62	**77,901**
Phosphorus Load	50	10%	5.02	**45**
Nitrogen Load	1,654	5%	82.69	**1,571**

Drainage Area: Detention Basin 8

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, High Intensity	100%	897.22	0.22	0.22	0.00
Grassland/Herbaceous	0	5,383.34	1.33	0.00	1.33
Cultivated Crops	0	8,075.01	2.00	0.00	2.00
Total		**14,355.57**	**3.55**	**0.22**	**3.33**

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Detention Basin 8: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.22	2,065.10	458
Developed Pervious	3.33	306.95	1,021
Total	**3.55**		**1,479**

Detention Basin 8: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.22	1.11	0
Developed Pervious	3.33	0.34	1
Total	**3.55**		**1**

Detention Basin 8: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.22	28.93	6
Developed Pervious	3.33	23.29	77
Total	**3.55**		**84**

Detention Basin 8: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 8 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 8 (lbs/year)**
Sediment Load	1,479	10%	147.86	**1,331**
Phosphorus Load	1	10%	0.14	**1**
Nitrogen Load	84	5%	4.19	**80**

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Drainage Area: Detention Basin 9					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	17,047.25	4.21	0.80	3.41
Developed, Low Intensity	49%	17,944.47	4.43	2.17	2.26
Developed, Medium Intensity	79%	16,150.02	3.99	3.15	0.84
Developed, High Intensity	100%	13,458.35	3.33	3.33	0.00
Grassland/Herbaceous	0	13,458.35	3.33	0.00	3.33
Cultivated Crops	0	9,869.46	2.44	0.00	2.44
Total		**87,927.90**	**21.73**	**9.45**	**12.28**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 9	9.45	12.28
Detention Basin 8	0.22	3.33
Detention Basin 8 Bypass	**9.23**	**8.95**

Detention Basin 8 Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	9.23	2,065.10	19,060
Developed Pervious	8.95	306.95	2,747
Total	**18.18**		**21,808**

Detention Basin 8 Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	9.23	1.11	10
Developed Pervious	8.95	0.34	3
Total	**18.18**		**13**

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Detention Basin 8 Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	9.23	28.93	267
Developed Pervious	8.95	23.29	208
Total	**18.18**		**475**

Detention Basin 9 Loading (lbs/year)					
Pollutant	**Detention Basin 8**	**Detention Basin 8 Bypass**			
Sediment Load	1,331	21,808			
Phosphorus Load	1	13			
Nitrogen Load	80	475			

Pollutant	Detention Basin 9 Loading
Sediment Load	**23,138**
Phosphorus Load	**15**
Nitrogen Load	**555**

Detention Basin 9: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 9 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 9 (lbs/year)**
Sediment Load	23,138	10%	2,313.84	**20,825**
Phosphorus Load	15	10%	1.45	**13**
Nitrogen Load	555	5%	27.76	**527**

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Drainage Area: Detention Basin 10					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2,691.67	0.67	0.13	0.54
Developed, Low Intensity	49%	2,691.67	0.67	0.33	0.34
Developed, Medium Intensity	79%	6,280.56	1.55	1.23	0.33
Developed, High Intensity	100%	17,047.24	4.21	4.21	0.00
Deciduous Forest	0	897.22	0.22	0.00	0.22
Grassland/Herbaceous	0	2,691.67	0.67	0.00	0.67
Total		**32,300.03**	**7.98**	**5.89**	**2.09**

Detention Basin 10: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	5.89	2,065.10	12,165
Developed Pervious	2.09	306.95	642
Total	**7.98**		**12,807**

Detention Basin 10: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	5.89	1.11	7
Developed Pervious	2.09	0.34	1
Total	**7.98**		**7**

Detention Basin 10: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	5.89	28.93	170
Developed Pervious	2.09	23.29	49
Total	**7.98**		**219**

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Detention Basin 10: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 10 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 10 (lbs/year)**
Sediment Load	12,807	10%	1,280.68	**11,526**
Phosphorus Load	7	10%	0.72	**7**
Nitrogen Load	219	5%	10.96	**208**

Drainage Area: Detention Basin 11					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	241,353.29	59.64	11.33	48.31
Developed, Low Intensity	49%	244,044.96	60.30	29.55	30.76
Developed, Medium Intensity	79%	185,725.40	45.89	36.26	9.64
Developed, High Intensity	100%	168,678.14	41.68	41.68	0.00
Deciduous Forest	0	61,908.47	15.30	0.00	15.30
Grassland/Herbaceous	0	17,944.48	4.43	0.00	4.43
Pasture/Hay	0	190,211.52	47.00	0.00	47.00
Cultivated Crops	0	322,103.46	79.59	0.00	79.59
Total		**1,431,969.72**	**353.85**	**118.82**	**235.03**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 11	118.82	235.03
Detention Basin 3	56.33	189.55
Detention Basin 7	40.87	22.10
Detention Basin 9	9.45	12.28
Detention Basin 10	5.89	2.09
Detention Basin Bypass	**6.28**	**9.02**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	6.28	2,065.10	12,962
Developed Pervious	9.02	306.95	2,769
Total	**15.30**		**15,731**

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Detention Basin Bypass: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	6.28	1.11	7
Developed Pervious	9.02	0.34	3
Total	**15.30**		**10**

Detention Basin Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	6.28	28.93	182
Developed Pervious	9.02	23.29	210
Total	**15.30**		**392**

Detention Basin 11 Loading (lbs/year)

Pollutant	Detention Basin 3	Detention Basin 7	Detention Basin 9	Detention Basin 10	Detention Basin Bypass
Sediment Load	155,723	77,901	20,825	11,526	15,731
Phosphorus Load	113	45	13	7	10
Nitrogen Load	5,700	1,571	527	208	392

Pollutant	Detention Basin 11 Loading
Sediment Load	**281,705**
Phosphorus Load	**188**
Nitrogen Load	**8,398**

Detention Basin 11: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 11 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 11 (lbs/year)
Sediment Load	281,705	10%	28,170.48	**253,534**
Phosphorus Load	188	10%	18.78	**169**
Nitrogen Load	8,398	5%	419.92	**7,978**

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Drainage Area: Detention Basin 12					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	897.22	0.22	0.04	0.18
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Developed, Medium Intensity	79%	21,533.36	5.32	4.20	1.12
Pasture/Hay	0	897.22	0.22	0.00	0.22
Cultivated Crops	0	18,841.69	4.66	0.00	4.66
Total		**43,066.71**	**10.64**	**4.35**	**6.29**

Detention Basin 12: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	4.35	2,065.10	8,992
Developed Pervious	6.29	306.95	1,930
Total	**10.64**		**10,922**

Detention Basin 12: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	4.35	1.11	5
Developed Pervious	6.29	0.34	2
Total	**10.64**		**7**

Detention Basin 12: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	4.35	28.93	126
Developed Pervious	6.29	23.29	146
Total	**10.64**		**272**

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Detention Basin 12: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 12 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 12 (lbs/year)
Sediment Load	10,922	10%	1,092.22	**9,830**
Phosphorus Load	7	10%	0.70	**6**
Nitrogen Load	272	5%	13.62	**259**

Drainage Area: Detention Basin 13

Land Use	% Impervious	Area (m2)	Acres	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	3,588.89	0.89	0.17	0.72
Developed, Low Intensity	49%	2,691.67	0.67	0.33	0.34
Developed, Medium Intensity	79%	5,383.34	1.33	1.05	0.28
Developed, High Intensity	100%	49,347.30	12.19	12.19	0.00
Cultivated Crops	0	15,252.80	3.77	0.00	3.77
Total		**76,264.00**	**18.85**	**13.74**	**5.11**

Detention Basin 13: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	13.74	2,065.10	28,373
Developed Pervious	5.11	306.95	1,567
Total	**18.85**		**29,940**

Detention Basin 13: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	13.74	1.11	15
Developed Pervious	5.11	0.34	2
Total	**18.85**		**17**

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Detention Basin 13: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	13.74	28.93	397
Developed Pervious	5.11	23.29	119
Total	**18.85**		**516**

Detention Basin 13: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 13 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 13 (lbs/year)**
Sediment Load	29,940	10%	2,994.02	**26,946**
Phosphorus Load	17	10%	1.70	**15**
Nitrogen Load	516	5%	25.82	**491**

Drainage Area: Detention Basin 14					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	5,383.34	1.33	0.25	1.08
Developed, Low Intensity	49%	3,588.89	0.89	0.43	0.45
Developed, Medium Intensity	79%	11,663.90	2.88	2.28	0.61
Developed, High Intensity	100%	60,113.97	14.85	14.85	0.00
Cultivated Crops	0	16,150.02	3.99	0.00	3.99
Total		**96,900.12**	**23.94**	**17.82**	**6.13**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 14	17.82	6.13
Detention Basin 13	13.74	5.11
Detention Basin Bypass	**4.08**	**1.02**

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Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	4.08	2,065.10	8,424
Developed Pervious	1.02	306.95	313
Total	**5.10**		**8,737**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	4.08	1.11	5
Developed Pervious	1.02	0.34	0
Total	**5.10**		**5**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	4.08	28.93	118
Developed Pervious	1.02	23.29	24
Total	**5.10**		**142**

Detention Basin 14 Loading (lbs/year)					
Pollutant	**Detention Basin 13**	**Detention Basin Bypass**			
Sediment Load	26,946	8,737			
Phosphorus Load	15	5			
Nitrogen Load	491	142			

Pollutant	**Detention Basin 14 Loading**
Sediment Load	**35,684**
Phosphorus Load	**20**
Nitrogen Load	**632**

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Detention Basin 14: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 14 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 14 (lbs/year)**
Sediment Load	35,684	10%	3,568.37	**32,115**
Phosphorus Load	20	10%	2.02	**18**
Nitrogen Load	632	5%	31.62	**601**

Drainage Area: Detention Basin 15					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	33,197.26	8.20	1.56	6.64
Developed, Low Intensity	49%	15,252.80	3.77	1.85	1.92
Developed, Medium Intensity	79%	35,888.93	8.87	7.01	1.86
Developed, High Intensity	100%	159,705.75	39.46	39.46	0.00
Cultivated Crops	0	15,252.80	3.77	0.00	3.77
Total		**259,297.54**	**64.07**	**49.88**	**14.20**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Detention Basin 15	49.88	14.20
Detention Basin 14	17.82	6.13
Detention Basin Bypass	**32.06**	**8.07**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	32.06	2,065.10	66,201
Developed Pervious	8.07	306.95	2,478
Total	**40.13**		**68,678**

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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	32.06	1.11	36
Developed Pervious	8.07	0.34	3
Total	**40.13**		**38**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	32.06	28.93	927
Developed Pervious	8.07	23.29	188
Total	**40.13**		**1,115**

Detention Basin 15 Loading (lbs/year)					
Pollutant	**Detention Basin 14**	**Detention Basin Bypass**			
Sediment Load	32,115	68,678			
Phosphorus Load	18	38			
Nitrogen Load	601	1,115			

Pollutant	**Detention Basin 15 Loading**
Sediment Load	**100,794**
Phosphorus Load	**56**
Nitrogen Load	**1,716**

Detention Basin 15: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 15 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 15 (lbs/year)**
Sediment Load	100,794	10%	10,079.37	**90,714**
Phosphorus Load	56	10%	5.65	**51**
Nitrogen Load	1,716	5%	85.81	**1,630**

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Drainage Area: Detention Basin 16					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	8,075.01	2.00	0.38	1.62
Developed, Low Intensity	49%	7,177.79	1.77	0.87	0.90
Developed, Medium Intensity	79%	17,047.24	4.21	3.33	0.88
Developed, High Intensity	100%	41,272.27	10.20	10.20	0.00
Cultivated Crops	0	897.22	0.22	0.00	0.22
Total		**74,469.53**	**18.40**	**14.77**	**3.63**

Detention Basin 16: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	14.77	2,065.10	30,511
Developed Pervious	3.63	306.95	1,113
Total	**18.40**		**31,624**

Detention Basin 16: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	14.77	1.11	16
Developed Pervious	3.63	0.34	1
Total	**18.40**		**18**

Detention Basin 16: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	14.77	28.93	427
Developed Pervious	3.63	23.29	84
Total	**18.40**		**512**

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Detention Basin 16: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 16 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 16 (lbs/year)**
Sediment Load	31,624	10%	3,162.45	**28,462**
Phosphorus Load	18	10%	1.76	**16**
Nitrogen Load	512	5%	25.60	**486**

Drainage Area: Detention Basin 17					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Low Intensity	49%	2,691.67	0.67	0.33	0.34
Developed, Medium Intensity	79%	8,075.00	2.00	1.58	0.42
Developed, High Intensity	100%	5,383.34	1.33	1.33	0.00
Total		**16,150.01**	**3.99**	**3.23**	**0.76**

Detention Basin 17: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	3.23	2,065.10	6,675
Developed Pervious	0.76	306.95	233
Total	**3.99**		**6,908**

Detention Basin 17: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	3.23	1.11	4
Developed Pervious	0.76	0.34	0
Total	**3.99**		**4**

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Detention Basin 17: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	3.23	28.93	94
Developed Pervious	0.76	23.29	18
Total	**3.99**		**111**

Detention Basin 17: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 17 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 17 (lbs/year)**
Sediment Load	6,908	10%	690.82	**6,217**
Phosphorus Load	4	10%	0.38	**3**
Nitrogen Load	111	5%	5.56	**106**

Drainage Area: Detention Basin 18					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Low Intensity	49%	897.22	0.22	0.11	0.11
Developed, Medium Intensity	79%	10,766.67	2.66	2.10	0.56
Developed, High Intensity	100%	17,047.23	4.21	4.21	0.00
Total		**28,711.12**	**7.09**	**6.42**	**0.67**

Detention Basin 18: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	6.42	2,065.10	13,264
Developed Pervious	0.67	306.95	206
Total	**7.09**		**13,470**

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Detention Basin 18: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	6.42	1.11	7
Developed Pervious	0.67	0.34	0
Total	**7.09**		**7**

Detention Basin 18: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	6.42	28.93	186
Developed Pervious	0.67	23.29	16
Total	**7.09**		**201**

Detention Basin 18: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 18 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 18 (lbs/year)**
Sediment Load	13,470	10%	1,347.01	**12,123**
Phosphorus Load	7	10%	0.74	**7**
Nitrogen Load	201	5%	10.07	**191**

Drainage Area: Detention Basin 19					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	3,588.89	0.89	0.17	0.72
Developed, Low Intensity	49%	13,458.35	3.33	1.63	1.70
Developed, Medium Intensity	79%	19,738.91	4.88	3.85	1.02
Developed, High Intensity	100%	30,505.58	7.54	7.54	0.00
Deciduous Forest	0	2,691.67	0.67	0.00	0.67
Total		**69,983.40**	**17.29**	**13.19**	**4.10**

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Detention Basin 19: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	13.19	2,065.10	27,237
Developed Pervious	4.10	306.95	1,260
Total	**17.29**		**28,497**

Detention Basin 19: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	13.19	1.11	15
Developed Pervious	4.10	0.34	1
Total	**17.29**		**16**

Detention Basin 19: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	13.19	28.93	382
Developed Pervious	4.10	23.29	96
Total	**17.29**		**477**

Detention Basin 19: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 19 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 19 (lbs/year)**
Sediment Load	28,497	10%	2,849.72	**25,647**
Phosphorus Load	16	10%	1.60	**14**
Nitrogen Load	477	5%	23.86	**453**

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Drainage Area: Detention Basin 20					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	32,300.02	7.98	1.52	6.47
Developed, Low Intensity	49%	22,430.57	5.54	2.72	2.83
Developed, Medium Intensity	79%	7,177.78	1.77	1.40	0.37
Developed, High Intensity	100%	5,383.34	1.33	1.33	0.00
Total		**67,291.71**	**16.63**	**6.96**	**9.66**

Detention Basin 20: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	6.96	2,065.10	14,381
Developed Pervious	9.66	306.95	2,966
Total	**16.63**		**17,348**

Detention Basin 20: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	6.96	1.11	8
Developed Pervious	9.66	0.34	3
Total	**16.63**		**11**

Detention Basin 20: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	6.96	28.93	201
Developed Pervious	9.66	23.29	225
Total	**16.63**		**427**

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Detention Basin 20: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 20 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 20 (lbs/year)**
Sediment Load	17,348	10%	1,734.75	**15,613**
Phosphorus Load	11	10%	1.10	**10**
Nitrogen Load	427	5%	21.33	**405**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	258.07	329.67
Detention Basin 11	118.82	235.03
Detention Basin 12	4.35	6.29
Detention Basin 15	49.88	14.20
Detention Basin 16	14.77	3.63
Detention Basin 17	3.23	0.76
Detention Basin 18	6.42	0.67
Detention Basin 19	13.19	4.10
Detention Basin 20	6.96	9.66
Detention Basin Bypass	**40.44**	**55.33**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	40.44	2,065.10	83,515
Developed Pervious	55.33	306.95	16,983
Total	**95.77**		**100,498**

Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	40.44	1.11	45
Developed Pervious	55.33	0.34	19
Total	**95.77**		**64**

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Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	40.44	28.93	1,170
Developed Pervious	55.33	23.29	1,289
Total	**95.77**		**2,459**

Outfall Loading (lbs/year)

Pollutant	Detention Basin 11	Detention Basin 12	Detention Basin 15	Detention Basin 16	Detention Basin 17
Sediment Load	253,534	9,830	90,714	28,462	6,217
Phosphorus Load	169	6	51	16	3
Nitrogen Load	7,978	259	1,630	486	106

Pollutant	Detention Basin 18	Detention Basin 19	Detention Basin 20	Detention Basin Bypass	
Sediment Load	12,123	25,647	15,613	100,498	
Phosphorus Load	7	14	10	64	
Nitrogen Load	191	453	405	2,459	

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**542,639**
Phosphorus Load	**340**
Nitrogen Load	**13,968**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	37.14	49%	18.20	18.94
		Total	**18.20**	**18.94**

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Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	18.20	2,065.10	37,582
Developed Pervious	18.94	306.95	5,814
Total	**37.14**		**43,396**

Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	18.20	1.11	20
Developed Pervious	18.94	0.34	6
Total	**37.14**		**27**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	18.20	28.93	526
Developed Pervious	18.94	23.29	441
Total	**37.14**		**968**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	634,137	91,498	43,396	**499,243**
Phosphorus Load	399	58	27	**313**
Nitrogen Load	15,144	1,176	968	**13,000**

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Alexanders Spring Creek

Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	415,414.52	17.5
Developed, Low Intensity	425,283.98	17.9
Developed, Medium Intensity	376,833.90	15.8
Developed, High Intensity	459,378.47	19.3
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	82,544.57	3.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	33,197.27	1.4
Pasture/Hay	216,230.88	9.1
Cultivated Crops	364,272.77	15.3
Woody Wetlands	5,383.34	0.2
Emergent Herbaceous Wetlands	0.00	0.0

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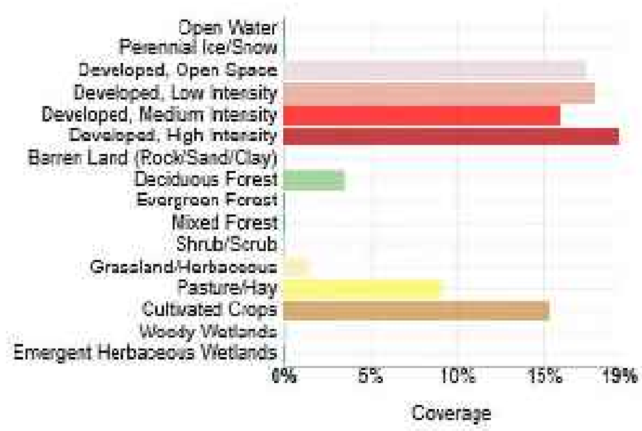
Alexanders Spring Creek

Selected Area

Total Area 2 km^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	415,414.52	17.5
Developed, Low Intensity	425,283.98	17.9
Developed, Medium Intensity	376,833.90	15.8
Developed, High Intensity	459,378.47	19.3
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	82,544.57	3.5
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	33,197.27	1.4
Pasture/Hay	216,230.88	9.1
Cultivated Crops	364,272.77	15.3
Woody Wetlands	5,383.34	0.2
Emergent Herbaceous Wetlands	0.00	0.0

Attachment D8: Pollutant Load Calculations: Conodoquinet Creek

Municipal Storm Sewershed
R104

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	6.43	0.0	1.22	5.21
Developed, Low Intensity	49%	1.55	0.0	0.76	0.79
Developed, Medium Intensity	79%	1.77	0.0	1.40	0.37
Developed, High Intensity	100%	6.87	0.0	6.87	0.00
Barren Land	0	0.00	0.0	0.00	0.00
Deciduous Forest	0	0.89	0.0	0.00	0.89
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	0.67	0.0	0.00	0.67
Pasture/Hay	0	9.76	0.0	0.00	9.76
Cultivated Crops	0	18.18	0.0	0.00	18.18
Total		**46.12**	**0.0**	**10.25**	**35.87**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	10.25	2,065.10	21,166
Developed Pervious	35.87	306.95	11,010
Total	**46.12**		**32,177**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	10.25	1.11	11
Developed Pervious	35.87	0.34	12
Total	**46.12**		**24**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	10.25	28.93	297
Developed Pervious	35.87	23.29	835
Total	**46.12**		**1,132**

Municipal Storm Sewershed
R104

Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	14,355.55	3.55	0.67	2.87
Developed, Low Intensity	49%	4,486.11	1.11	0.54	0.57
Developed, Medium Intensity	79%	7,177.78	1.77	1.40	0.37
Developed, High Intensity	100%	29,608.33	7.32	7.32	0.00
Cultivated Crops	0	21,533.33	5.32	0.00	5.32
Total		**77,161.10**	**19.07**	**9.93**	**9.13**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	9.93	2,065.10	20,516
Developed Pervious	9.13	306.95	2,803
Total	**19.07**		**23,319**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	9.93	1.11	11
Developed Pervious	9.13	0.34	3
Total	**19.07**		**14**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	9.93	28.93	287
Developed Pervious	9.13	23.29	213
Total	**19.07**		**500**

Municipal Storm Sewershed
R104

Detention Basin 1: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 1 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 1 (lbs/year)
Sediment Load	23,319	10%	2,331.93	**20,987**
Phosphorus Load	14	10%	1.41	**13**
Nitrogen Load	500	5%	25.00	**475**

Drainage Areas

Drainage Area	Developed Impervious (Acres)	Developed Pervious (Acres)
Total	10.25	35.87
Drainage Basin 1	9.93	9.13
Detention Basin Bypass	**0.31**	**26.74**

Detention Basin Bypass: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.31	2,065.10	650
Developed Pervious	26.74	306.95	8,207
Total	**27.05**		**8,857**

Detention Basin Bypass: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.31	1.11	0
Developed Pervious	26.74	0.34	9
Total	**27.05**		**9**

Detention Basin Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.31	28.93	9
Developed Pervious	26.74	23.29	623
Total	**27.05**		**632**

Municipal Storm Sewershed
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Detention Basin 2 Loading (lbs/year)					
Pollutant	Detention Basin 1	Detention Basin 1 Bypass			
Sediment Load	20,987	8,857			
Phosphorus Load	13	9			
Nitrogen Load	475	632			

Pollutant	Detention Basin 2 Loading
Sediment Load	**29,845**
Phosphorus Load	**22**
Nitrogen Load	**1,107**

Detention Basin 2: Detention Basin Effectiveness				
Pollutant	Pollutant Loads from Detention Basin 2 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 2 (lbs/year)
Sediment Load	29,845	10%	2,984.48	**26,860**
Phosphorus Load	22	10%	2.22	**20**
Nitrogen Load	1,107	5%	55.35	**1,052**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	% Impervious	Impervious Acres	Pervious Acres
Railroad	0.00	49%	0.00	0.00
PennDOT	1.78	49%	0.87	0.91
		Total	**0.87**	**0.91**

Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.87	2,065.10	1,801
Developed Pervious	0.91	306.95	279
Total	**1.78**		**2,080**

Municipal Storm Sewershed
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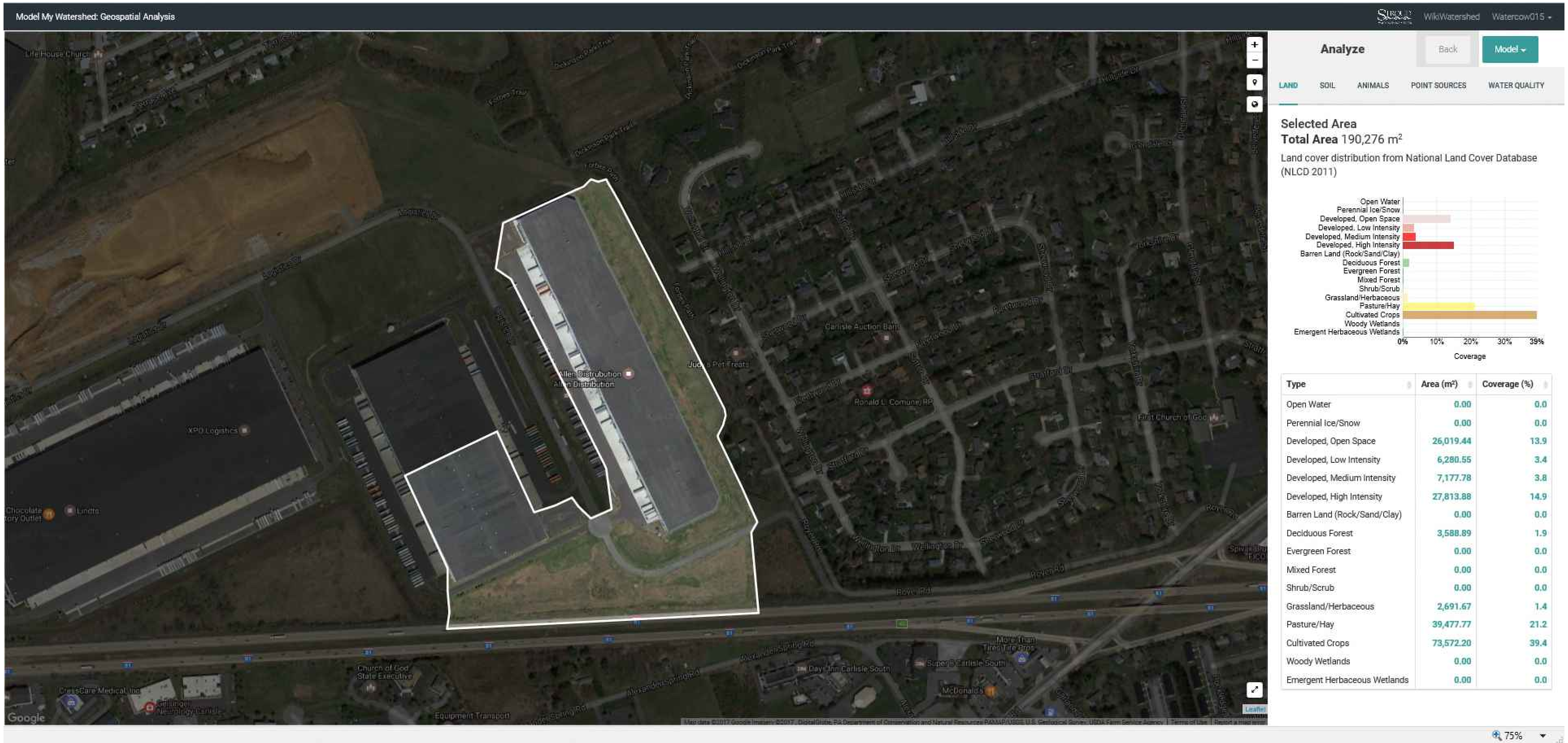
Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.87	1.11	1
Developed Pervious	0.91	0.34	0
Total	**1.78**		**1**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.87	28.93	25
Developed Pervious	0.91	23.29	21
Total	**1.78**		**46**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading from Outfall**
Sediment Load	32,177	5,316	2,080	**24,780**
Phosphorus Load	24	4	1	**19**
Nitrogen Load	1,132	80	46	**1,005**

Municipal Storm Sewershed R104
Conodoquinet Creek

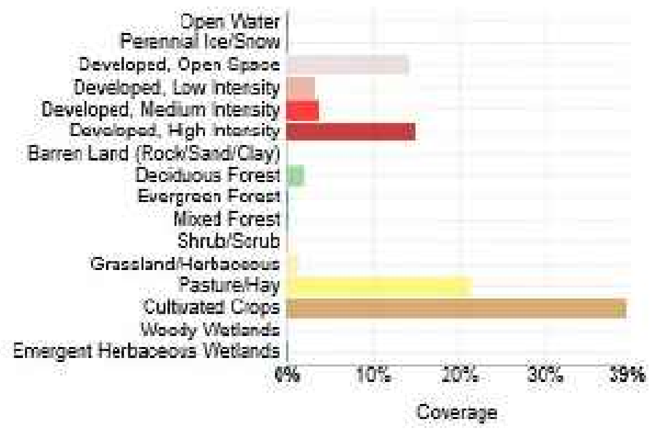


Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	26,019.44	13.9
Developed, Low Intensity	6,280.55	3.4
Developed, Medium Intensity	7,177.78	3.8
Developed, High Intensity	27,813.88	14.9
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	3,588.89	1.9
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	2,691.67	1.4
Pasture/Hay	39,477.77	21.2
Cultivated Crops	73,572.20	39.4
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R104
Conodoquinet Creek

Selected Area
Total Area 190,276 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	26,019.44	13.9
Developed, Low Intensity	6,280.55	3.4
Developed, Medium Intensity	7,177.78	3.8
Developed, High Intensity	27,813.88	14.9
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	3,568.89	1.9
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	2,691.67	1.4
Pasture/Hay	39,477.77	21.2
Cultivated Crops	73,572.20	39.4
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R105

Table 1: Land Use

Land Use	% Impervious	Acres	Coverage (%)	Developed Impervious (Acres)	Developed Pervious (Acres)
Developed, Open Space	19%	18.40	0.0	3.50	14.90
Developed, Low Intensity	49%	10.64	0.0	5.21	5.43
Developed, Medium Intensity	79%	6.21	0.0	4.91	1.30
Developed, High Intensity	100%	13.30	0.0	13.30	0.00
Barren Land	0	0.00	0.0	0.00	0.00
Deciduous Forest	0	21.06	0.0	0.00	21.06
Evergreen Forest	0	0.00	0.0	0.00	0.00
Mixed Forest	0	0.00	0.0	0.00	0.00
Shrub/Scrub	0	0.00	0.0	0.00	0.00
Grassland/Herbaceous	0	12.42	0.0	0.00	12.42
Pasture/Hay	0	15.96	0.0	0.00	15.96
Cultivated Crops	0	77.15	0.0	0.00	77.15
Total		**175.14**	**0.0**	**26.92**	**148.22**

Table 2: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	26.92	2,065.10	55,583
Developed Pervious	148.22	306.95	45,498
Total	**175.14**		**101,081**

Table 3: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	26.92	1.11	30
Developed Pervious	148.22	0.34	50
Total	**175.14**		**80**

Table 4: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	26.92	28.93	779
Developed Pervious	148.22	23.29	3,452
Total	**175.14**		**4,231**

Municipal Storm Sewershed
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Drainage Area: Detention Basin 1					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	2,691.67	0.67	0.13	0.54
Developed, Low Intensity	49%	1,794.44	0.44	0.22	0.23
Developed, Medium Intensity	79%	1,794.44	0.44	0.35	0.09
Developed, High Intensity	100%	897.22	0.22	0.22	0.00
Total		**7,177.77**	**1.77**	**0.92**	**0.86**

Detention Basin 1: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	0.92	2,065.10	1,891
Developed Pervious	0.86	306.95	263
Total	**1.77**		**2,154**

Detention Basin 1: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	0.92	1.11	1
Developed Pervious	0.86	0.34	0
Total	**1.77**		**1**

Detention Basin 1: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	0.92	28.93	26
Developed Pervious	0.86	23.29	20
Total	**1.77**		**46**

Municipal Storm Sewershed R105

Detention Basin 1: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 1 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 1 (lbs/year)**
Sediment Load	2,154	10%	215.43	**1,939**
Phosphorus Load	1	10%	0.13	**1**
Nitrogen Load	46	5%	2.32	**44**

Drainage Area: Detention Basin 2					
Land Use	**% Impervious**	**Area (m2)**	**Acres**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Developed, Open Space	19%	34,991.65	8.65	1.64	7.00
Developed, Low Intensity	49%	15,252.77	3.77	1.85	1.92
Developed, Medium Intensity	79%	18,841.66	4.66	3.68	0.98
Developed, High Intensity	100%	49,347.21	12.19	12.19	0.00
Deciduous Forest	0	57,422.20	14.19	0.00	14.19
Grassland/Herbaceous	0	38,580.54	9.53	0.00	9.53
Pasture/Hay	0	40,374.99	9.98	0.00	9.98
Cultivated Crops	0	56,524.98	13.97	0.00	13.97
Total		**311,336.00**	**76.93**	**19.36**	**57.57**

Detention Basin 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	19.36	2,065.10	39,984
Developed Pervious	57.57	306.95	17,671
Total	**76.93**		**57,655**

Detention Basin 2: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	19.36	1.11	21
Developed Pervious	57.57	0.34	20
Total	**76.93**		**41**

Municipal Storm Sewershed
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Detention Basin 2: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	19.36	28.93	560
Developed Pervious	57.57	23.29	1,341
Total	**76.93**		**1,901**

Detention Basin 2: Detention Basin Effectiveness

Pollutant	Pollutant Loads from Detention Basin 2 (lbs/year)	Effectiveness Value	Pollutant Removal (lbs/year)	Total Pollutant Loading from Detention Basin 2 (lbs/year)
Sediment Load	57,655	10%	5,765.54	**51,890**
Phosphorus Load	41	10%	4.11	**37**
Nitrogen Load	1,901	5%	95.05	**1,806**

Detention Basin 2 Bypass: Sediment Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	0.00	2,065.10	0
Developed Pervious	31.48	306.95	9,663
Total	**31.48**		**9,663**

Detention Basin 2 Bypass: Phosphorus Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	0.00	1.11	0
Developed Pervious	31.48	0.34	11
Total	**31.48**		**11**

Detention Basin 2 Bypass: Nitrogen Loading

Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	0.00	28.93	0
Developed Pervious	31.48	23.29	733
Total	**31.48**		**733**

Municipal Storm Sewershed
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Detention Basin 3 Loading (lbs/year)					
Pollutant	**Detention Basin 2**	**Detention Basin 2 Bypass**			
Sediment Load	51,890	9,663			
Phosphorus Load	37	11			
Nitrogen Load	1,806	733			

Pollutant	Detention Basin 3 Loading
Sediment Load	**61,553**
Phosphorus Load	**48**
Nitrogen Load	**2,539**

Detention Basin 3: Detention Basin Effectiveness				
Pollutant	**Pollutant Loads from Detention Basin 3 (lbs/year)**	**Effectiveness Value**	**Pollutant Removal (lbs/year)**	**Total Pollutant Loading from Detention Basin 3 (lbs/year)**
Sediment Load	61,553	10%	6,155.26	**55,397**
Phosphorus Load	48	10%	4.77	**43**
Nitrogen Load	2,539	5%	126.95	**2,412**

Drainage Areas		
Drainage Area	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Total	26.92	148.22
Drainage Basin 1	0.92	0.86
Drainage Basin 2	19.36	57.57
Drainage Basin 2 Bypass	0.00	31.48
Detention Basin Bypass	**6.64**	**58.32**

Detention Basin Bypass: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	6.64	2,065.10	13,708
Developed Pervious	58.32	306.95	17,900
Total	**64.95**		**31,608**

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Detention Basin Bypass: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	6.64	1.11	7
Developed Pervious	58.32	0.34	20
Total	**64.95**		**27**

Detention Basin Bypass: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Cumberland County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	6.64	28.93	192
Developed Pervious	58.32	23.29	1,358
Total	**64.95**		**1,550**

Outfall Loading (lbs/year)					
Pollutant	**Detention Basin 1**	**Detention Basin 3**	**Detention Basin Bypass**		
Sediment Load	1,939	55,397	31,608		
Phosphorus Load	1	43	27		
Nitrogen Load	44	2,412	1,550		

Pollutant	Total Post-BMP (Best Management Practice) Loading
Sediment Load	**88,944**
Phosphorus Load	**71**
Nitrogen Load	**4,006**

Railroad and PennDOT Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
Railroad	0.00	49%	0.00	0.00
PennDOT	5.12	49%	2.51	2.61
		Total	**2.51**	**2.61**

Municipal Storm Sewershed
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Right-of-Way (R-O-W) Loading: Sediment Loading Reduction			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Sediment Loading (lbs/year)
Developed Impervious	2.51	2,065.10	5,181
Developed Pervious	2.61	306.95	802
Total	**5.12**		**5,982**

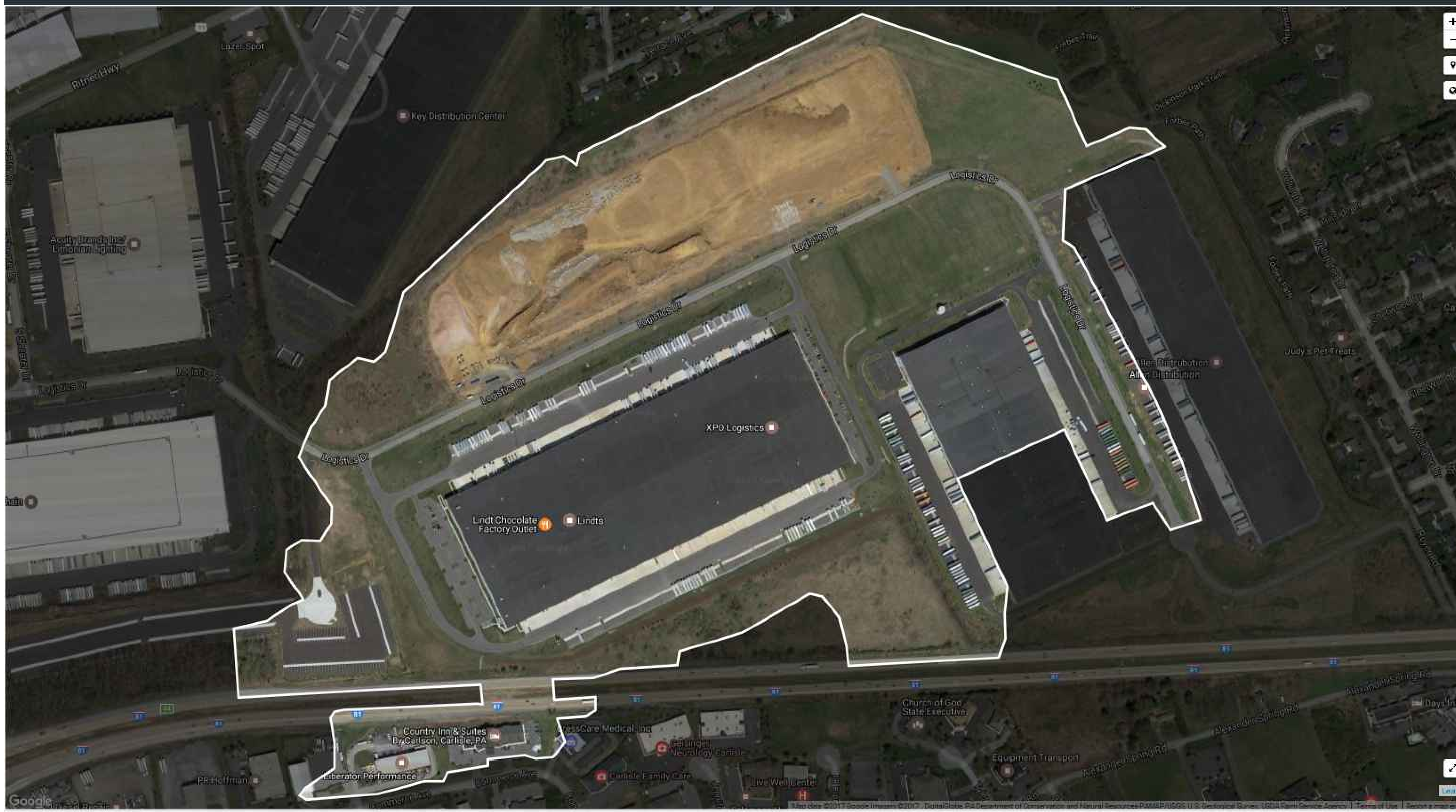
Right-of-Way (R-O-W) Loading: Phosphorus Loading Reduction			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Phosphorus Loading (lbs/year)
Developed Impervious	2.51	1.11	3
Developed Pervious	2.61	0.34	1
Total	**5.12**		**4**

Right-of-Way (R-O-W) Loading: Nitrogen Loading Reduction			
Land Use	Acres	Loading Rate - Cumberland County (lbs per acre per year)	Nitrogen Loading (lbs/year)
Developed Impervious	2.51	28.93	73
Developed Pervious	2.61	23.29	61
Total	**5.12**		**133**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	Pollutant Load from Outfall	BMP Reductions	Right-of-Way (R-O-W) Reductions	Final Pollutant Loading from Outfall
Sediment Load	101,081	12,136	5,982	**82,962**
Phosphorus Load	80	9	4	**68**
Nitrogen Load	4,231	224	133	**3,873**

Municipal Storm Sewershed R105
Conodoquinet Creek

Model My Watershed: Geospatial Analysis — WikiWatershed — Watercow015



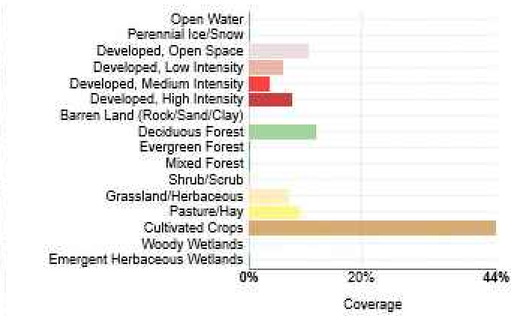
Analyze — Back — Model

LAND | SOIL | ANIMALS | POINT SOURCES | WATER QUALITY

Selected Area

Total Area 712,165 m²

Land cover distribution from National Land Cover Database (NLCD 2011)



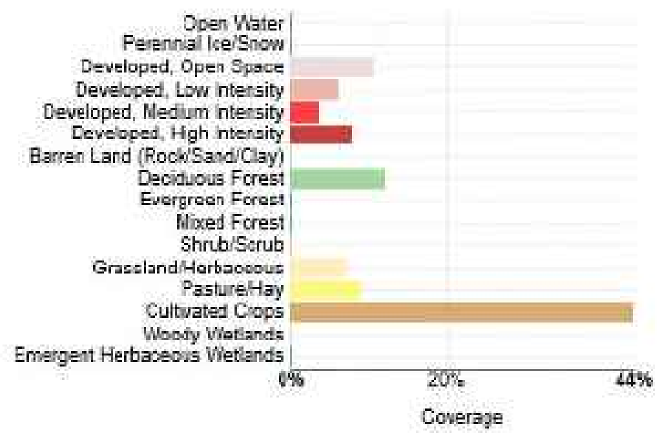
Type	Area (m²)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	74,469.44	10.5
Developed, Low Intensity	43,066.66	6.1
Developed, Medium Intensity	25,122.22	3.5
Developed, High Intensity	53,833.33	7.6
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	85,236.10	12.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	50,244.44	7.1
Pasture/Hay	64,599.99	9.1
Cultivated Crops	312,233.30	44.1
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Municipal Storm Sewershed R105
Conodoquinet Creek

Selected Area

Total Area 712,165 m^2

Land cover distribution from National Land Cover Database (NLCD 2011)



Type	Area (m^2)	Coverage (%)
Open Water	0.00	0.0
Perennial Ice/Snow	0.00	0.0
Developed, Open Space	74,469.44	10.5
Developed, Low Intensity	43,066.66	6.1
Developed, Medium Intensity	25,122.22	3.5
Developed, High Intensity	53,833.33	7.6
Barren Land (Rock/Sand/Clay)	0.00	0.0
Deciduous Forest	85,236.10	12.0
Evergreen Forest	0.00	0.0
Mixed Forest	0.00	0.0
Shrub/Scrub	0.00	0.0
Grassland/Herbaceous	50,244.44	7.1
Pasture/Hay	64,599.99	9.1
Cultivated Crops	312,233.30	44.1
Woody Wetlands	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.0

Attachment D9: Existing BMP Summary

South Middleton Township
Pollutant Reduction Plan
6/19/2017

EXISTING BMP SUMMARY

BMP Name	NPDES Permit No.	Latitude	Longitude	Type of BMP	Year of Installation
R1-1		40°10'53.21"N	77°11'15.72"W	Detention Basin	
R2-1		40°10'45.53"N	77°11'16.88"W	Detention Basin	
R7-1		40°11'4.50"N	77° 9'50.76"W	Detention Basin	
R7-2		40°10'57.59"N	77° 9'52.87"W	Detention Basin	
R8-1		40°10'33.79"N	77° 9'10.27"W	Detention Basin	
R8-2		40°10'45.66"N	77° 9'20.02"W	Detention Basin	
R8-3		40°10'41.04"N	77° 9'35.80"W	Detention Basin	
R8-4		40°10'26.43"N	77° 9'21.87"W	Detention Basin	
R8-5		40°10'19.71"N	77° 8'57.26"W	Detention Basin	
R8-6		40°10'20.83"N	77° 9'3.68"W	Detention Basin	
R8-7		40°10'20.17"N	77° 9'19.35"W	Detention Basin	
R9-1		40°11'38.06"N	77°11'1.60"W	Detention Basin	
R11-1		40°10'22.15"N	77° 8'3.88"W	Detention Basin	
R11-2		40°10'4.15"N	77° 7'56.67"W	Detention Basin	
R11-3		40° 9'55.28"N	77° 7'59.76"W	Detention Basin	
R11-4		40° 9'54.96"N	77° 7'56.03"W	Detention Basin	
R11-5		40° 9'44.60"N	77° 7'56.70"W	Detention Basin	
R11-6		40° 9'39.02"N	77° 7'52.80"W	Detention Basin	
R11-7		40° 9'36.34"N	77° 8'9.61"W	Detention Basin	
R11-8		40° 9'32.79"N	77° 8'57.40"W	Detention Basin	
R11-9		40° 9'32.38"N	77° 8'45.20"W	Detention Basin	
R11-10		40° 9'22.22"N	77° 8'49.78"W	Detention Basin	
R11-11		40° 9'28.97"N	77° 8'36.95"W	Detention Basin	
R11-12		40° 9'38.83"N	77° 8'34.69"W	Detention Basin	
R11-13		40° 9'29.79"N	77° 8'21.06"W	Detention Basin	
R11-14		40° 9'20.57"N	77° 8'9.08"W	Detention Basin	
R11-15		40° 9'14.70"N	77° 8'5.93"W	Detention Basin	
R11-16		40° 9'1.60"N	77° 8'20.85"W	Detention Basin	
R11-17		40° 9'3.14"N	77° 8'14.06"W	Detention Basin	
R11-18		40° 8'58.22"N	77° 7'56.44"W	Detention Basin	
R11-20		40° 9'10.55"N	77° 9'4.53"W	Detention Basin	
R101-1		40°11'12.47"N	77°10'3.93"W	Detention Basin	
R101-2		40°11'13.49"N	77°10'2.38"W	Detention Basin	
R101-3		40°11'19.48"N	77° 9'47.52"W	Detention Basin	
R101-4		40°11'19.78"N	77° 9'50.09"W	Detention Basin	
R101-5		40°11'29.00"N	77°10'18.76"W	Detention Basin	
R101-6		40°11'31.84"N	77°10'19.05"W	Detention Basin	
R101-7		40°11'32.25"N	77°10'15.32"W	Detention Basin	
R103-1		40°10'50.53"N	77°12'11.86"W	Detention Basin	
R103-2		40°10'50.85"N	77°12'9.36"W	Detention Basin	
R103-3		40°10'41.22"N	77°12'8.84"W	Detention Basin	
R103-4		40°10'49.37"N	77°11'54.75"W	Detention Basin	
R103-5		40°10'53.58"N	77°11'54.34"W	Detention Basin	
R104-1		40°11'14.74"N	77°12'57.14"W	Detention Basin	
R104-2		40°11'24.10"N	77°12'58.72"W	Detention Basin	
R105-1		40°11'9.48"N	77°13'46.25"W	Detention Basin	
R105-2		40°11'29.81"N	77°13'17.95"W	Detention Basin	
R105-3		40°11'34.81"N	77°13'13.25"W	Detention Basin	
R106-1		40°10'53.11"N	77°13'3.88"W	Detention Basin	
R106-2		40°11'6.24"N	77°13'15.14"W	Detention Basin	
R106-3		40°11'8.51"N	77°13'14.54"W	Detention Basin	
R106-4		40°11'3.03"N	77°12'58.78"W	Detention Basin	
R106-5		40°11'8.20"N	77°12'51.34"W	Detention Basin	
R108-1		40°10'17.08"N	77°14'6.31"W	Detention Basin	
R108-2		40°10'21.30"N	77°14'5.65"W	Detention Basin	
R108-3		40°10'40.29"N	77°13'58.58"W	Detention Basin	
R108-4		40°10'28.23"N	77°14'5.01"W	Detention Basin	
R108-5		40°10'26.62"N	77°14'13.43"W	Detention Basin	
R108-6		40°10'31.39"N	77°14'21.38"W	Detention Basin	
R108-7		40°10'38.04"N	77°14'5.87"W	Detention Basin	
R108-8		40°10'39.87"N	77°14'23.20"W	Detention Basin	
R108-9		40°10'44.08"N	77°14'15.43"W	Detention Basin	

R108-10		40°10'47.40"N	77°14'14.89"W	Detention Basin	
R108-11		40°10'47.15"N	77°14'6.97"W	Detention Basin	
R108-12		40°10'45.65"N	77°13'59.45"W	Detention Basin	
R108-13		40°10'40.68"N	77°13'45.11"W	Detention Basin	
R108-14		40°10'52.74"N	77°13'51.46"W	Detention Basin	
R108-15		40°10'57.63"N	77°13'46.51"W	Detention Basin	
R108-16		40°10'53.53"N	77°13'57.66"W	Detention Basin	
R108-17		40°11'2.45"N	77°14'0.89"W	Detention Basin	
R108-18		40°11'2.67"N	77°14'8.52"W	Detention Basin	
R108-19		40°10'54.69"N	77°14'17.92"W	Detention Basin	
R108-20		40°11'1.38"N	77°14'18.15"W	Detention Basin	
R109-1		40°10'19.51"N	77° 8'41.90"W	Detention Basin	
R109-2		40°10'29.48"N	77° 8'46.86"W	Detention Basin	
R109-3		40°10'32.50"N	77° 8'45.93"W	Detention Basin	
R109-4		40°10'32.77"N	77° 8'47.99"W	Detention Basin	

O&M Activities Associated with BMP Types

Detention Basins	Property owners and/or responsible parties for O&M conduct the following activities: mowing grass as needed; removing accumulated debris from all pipes and outlet structures; re-seeding to cover bare spots as needed; inspecting the basin after significant storm events; removing accumulated sediment as needed to maintain positive drainage; and inspecting the basin berm to ensure structural stability.
Extended Detention Basins	In addition to those activities described above for detention basins, property owners and/or responsible parties for O&M conduct the following activities: trimming vegetation as needed to sustain the system; removing all plant detritus to prevent clogging as needed; reestablish vegetation if vegetative cover falls below 10%.
Constructed Wetlands	Property owners and/or responsible parties for O&M conduct the following activities: remove unwanted vegetation as needed including weeds and invasive species as needed; inspect the outlet structure, flow channel, bank stability and sediment/debris accumulation at least twice per year and after significant storms; maintain vegetative cover at 85%; remove accumulated sediment from the forebay when it occupies 50% of the forebay.

Attachment D10: PA DEP BMP Effectiveness Values

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF CLEAN WATER

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) STORMWATER DISCHARGES FROM SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEMS BMP EFFECTIVENESS VALUES

This table of BMP effectiveness values (i.e., pollutant removal efficiencies) is intended for use by MS4s that are developing and implementing Pollutant Reduction Plans and TMDL Plans to comply with NPDES permit requirements. The values used in this table generally consider pollutant reductions from both overland flow and reduced downstream erosion, and are based primarily on average values within the Chesapeake Assessment Scenario Tool (CAST) (www.casttool.org). Design considerations, operation and maintenance, and construction sequences should be as outlined in the Pennsylvania Stormwater BMP Manual, Chesapeake Bay Program guidance, or other technical sources. The Department of Environmental Protection (DEP) will update the information contained in this table as new information becomes available. Interested parties may submit information to DEP for consideration in updating this table to DEP's MS4 resource account, RA-EPPAMS4@pa.gov. Where an MS4 proposes a BMP not identified in this document or in Chesapeake Bay Program expert panel reports, other technical resources may be consulted for BMP effectiveness values. Note – TN = Total Nitrogen and TP = Total Phosphorus.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Wet Ponds and Wetlands	20%	45%	60%	A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Until recently, these practices were designed specifically to meet water quantity, not water quality objectives. There is little or no vegetation living within the pooled area nor are outfalls directed through vegetated areas prior to open water release. Nitrogen reduction is minimal.
Dry Detention Basins and Hydrodynamic Structures	5%	10%	10%	Dry Detention Ponds are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Hydrodynamic Structures are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff.
Dry Extended Detention Basins	20%	20%	60%	Dry extended detention (ED) basins are depressions created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry ED basins are designed to dry out between storm events, in contrast with wet ponds, which contain standing water permanently. As such, they are similar in construction and function to dry detention basins, except that the duration of detention of stormwater is designed to be longer, theoretically improving treatment effectiveness.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Infiltration Practices w/ Sand, Veg.	85%	85%	95%	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration. Design specifications require infiltration basins and trenches to be built in good soil, they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approval to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff.
Filtering Practices	40%	60%	80%	Practices that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media. There are various sand filter designs, such as above ground, below ground, perimeter, etc. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds due to the increased cation exchange capacity achieved by increasing the organic matter. These systems require yearly inspection and maintenance to receive pollutant reduction credit.
Filter Strip Runoff Reduction	20%	54%	56%	Urban filter strips are stable areas with vegetated cover on flat or gently sloping land. Runoff entering the filter strip must be in the form of sheet-flow and must enter at a non-erosive rate for the site-specific soil conditions. A 0.4 design ratio of filter strip length to impervious flow length is recommended for runoff reduction urban filter strips.
Filter Strip Stormwater Treatment	0%	0%	22%	Urban filter strips are stable areas with vegetated cover on flat or gently sloping land. Runoff entering the filter strip must be in the form of sheet-flow and must enter at a non-erosive rate for the site-specific soil conditions. A 0.2 design ratio of filter strip length to impervious flow length is recommended for stormwater treatment urban filter strips.
Bioretention – Raingarden (C/D soils w/ underdrain)	25%	45%	55%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in C or D soil.
Bioretention / Raingarden (A/B soils w/ underdrain)	70%	75%	80%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in A or B soil.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Bioretention / Raingarden (A/B soils w/o underdrain)	80%	85%	90%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has no underdrain and is in A or B soil.
Vegetated Open Channels (C/D Soils)	10%	10%	50%	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed, includes bioswales. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils. This BMP has no underdrain and is in C or D soil.
Vegetated Open Channels (A/B Soils)	45%	45%	70%	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed, includes bioswales. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils. This BMP has no underdrain and is in A or B soil.
Bioswale	70%	75%	80%	With a bioswale, the load is reduced because, unlike other open channel designs, there is now treatment through the soil. A bioswale is designed to function as a bioretention area.
Permeable Pavement w/o Sand or Veg. (C/D Soils w/ underdrain)	10%	20%	55%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, no sand or vegetation and is in C or D soil.
Permeable Pavement w/o Sand or Veg. (A/B Soils w/ underdrain)	45%	50%	70%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, no sand or vegetation and is in A or B soil.
Permeable Pavement w/o Sand or Veg. (A/B Soils w/o underdrain)	75%	80%	85%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has no underdrain, no sand or vegetation and is in A or B soil.
Permeable Pavement w/ Sand or Veg. (A/B Soils w/ underdrain)	50%	50%	70%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, has sand and/or vegetation and is in A or B soil.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Permeable Pavement w/ Sand or Veg. (A/B Soils w/o underdrain)	80%	80%	85%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has no underdrain, has sand and/or vegetation and is in A or B soil.
Permeable Pavement w/ Sand or Veg. (C/D Soils w/ underdrain)	20%	20%	55%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, has sand and/or vegetation and is in C or D soil.
Stream Restoration	0.075 lbs/ft/yr	0.068 lbs/ft/yr	44.88 lbs/ft/yr	An annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that otherwise would be delivered downstream from an actively enlarging or incising urban stream. Applies to 0 to 3rd order streams that are not tidally influenced. If one of the protocols is cited and pounds are reported, then the mass reduction is received for the protocol.
Forest Buffers	25%	50%	50%	An area of trees at least 35 feet wide on one side of a stream, usually accompanied by trees, shrubs and other vegetation that is adjacent to a body of water. The riparian area is managed to maintain the integrity of stream channels and shorelines, to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals. (Note – the values represent pollutant load reductions from stormwater draining through buffers).
Tree Planting	10%	15%	20%	The BMP effectiveness values for tree planting are estimated by DEP. DEP estimates that 100 fully mature trees of mixed species (both deciduous and non-deciduous) provide pollutant load reductions for the equivalent of one acre (i.e., one mature tree = 0.01 acre). The BMP effectiveness values given are based on immature trees (seedlings or saplings); the effectiveness values are expected to increase as the trees mature. To determine the amount of pollutant load reduction that can credited for tree planting efforts: 1) multiply the number of trees planted by 0.01; 2) multiply the acreage determined in step 1 by the pollutant loading rate for the land prior to planting the trees (in lbs/acre/year); and 3) multiply the result of step 2 by the BMP effectiveness values given.
Street Sweeping	3%	3%	9%	Street sweeping must be conducted 25 times annually. Only count those streets that have been swept at least 25 times in a year. The acres associated with all streets that have been swept at least 25 times in a year would be eligible for pollutant reductions consistent with the given BMP effectiveness values.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Storm Sewer System Solids Removal	0.0027 for sediment, 0.0111 for organic matter	0.0006 for sediment, 0.0012 for organic matter	1 – TN and TP concentrations	This BMP (also referred to as "Storm Drain Cleaning") involves the collection or capture and proper disposal of solid material within the storm system to prevent discharge to surface waters. Examples include catch basins, stormwater inlet filter bags, end of pipe or outlet solids removal systems and related practices. Credit is authorized for this BMP only when proper maintenance practices are observed (i.e., inspection and removal of solids as recommended by the system manufacturer or other available guidelines). The entity using this BMP for pollutant removal credits must demonstrate that they have developed and are implementing a standard operating procedure for tracking the material removed from the sewer system. Locating such BMPs should consider the potential for backups onto roadways or other areas that can produce safety hazards. To determine pollutant reductions for this BMP, these steps must be taken: 1) Measure the weight of solid/organic material collected (lbs). Sum the total weight of material collected for an annual period. Note – do not include refuse, debris and floatables in the determination of total mass collected. 2) Convert the annual wet weight captured into annual dry weight (lbs) by using site-specific measurements (i.e., dry a sample of the wet material to find its weight) or by using default factors of 0.7 (material that is predominantly wet sediment) or 0.2 (material that is predominantly wet organic matter, e.g., leaf litter). 3) Multiply the annual dry weight of material collected by default or site-specific pollutant concentration factors. The default concentrations are shown in the BMP Effectiveness Values columns. Alternatively, the material may be sampled (at least annually) to determine site-specific pollutant concentrations. DEP will allow up to 50% of total pollutant reduction requirements to be met through this BMP. The drainage area treated by this BMP may be no greater than 0.5 acre unless it can be demonstrated that the specific system proposed is capable of treating stormwater from larger drainage areas. For planning purposes, the sediment removal efficiency specified by the manufacturer may be assumed, but no higher than 80%.

D11: Land Loading Rates for PA Counties

ATTACHMENT B

DEVELOPED LAND LOADING RATES FOR PA COUNTIES[1,2,3]

County	Category	Acres	TN lbs/acre/yr	TP lbs/acre/yr	TSS (Sediment) lbs/acre/yr
Adams	impervious developed	10,373.2	33.43	2.1	1,398.77
	pervious developed	44,028.6	22.99	0.8	207.67
Bedford	impervious developed	9,815.2	19.42	1.9	2,034.34
	pervious developed	19,425	17.97	0.68	301.22
Berks	impervious developed	1,292.4	36.81	2.26	1,925.79
	pervious developed	5,178.8	34.02	0.98	264.29
Blair	impervious developed	3,587.9	20.88	1.73	1,813.55
	pervious developed	9,177.5	18.9	0.62	267.34
Bradford	impervious developed	10,423	14.82	2.37	1,880.87
	pervious developed	23,709.7	13.05	0.85	272.25
Cambria	impervious developed	3,237.9	20.91	2.9	2,155.29
	pervious developed	8,455.4	19.86	1.12	325.3
Cameron	impervious developed	1,743.2	18.46	2.98	2,574.49
	pervious developed	1,334.5	19.41	1.21	379.36
Carbon	impervious developed	25.1	28.61	3.97	2,177.04
	pervious developed	54.2	30.37	2.04	323.36
Centre	impervious developed	7,828.2	19.21	2.32	1,771.63
	pervious developed	15,037.1	18.52	0.61	215.84
Chester	impervious developed	1,838.4	21.15	1.46	1,504.78
	pervious developed	10,439.8	14.09	0.36	185.12
Clearfield	impervious developed	9,638.5	17.54	2.78	1,902.9
	pervious developed	17,444.3	18.89	1.05	266.62
Clinton	impervious developed	7,238.5	18.02	2.80	1,856.91
	pervious developed	11,153.8	16.88	0.92	275.81
Columbia	impervious developed	7,343.1	21.21	3.08	1,929.18
	pervious developed	21,848.2	22.15	1.22	280.39
Cumberland	impervious developed	8,774.8	28.93	1.11	2,065.1
	pervious developed	26,908.6	23.29	0.34	306.95
Dauphin	impervious developed	3,482.4	28.59	1.07	1,999.14
	pervious developed	9,405.8	21.24	0.34	299.62
Elks	impervious developed	1,317.7	18.91	2.91	1,556.93
	pervious developed	1,250.1	19.32	1.19	239.85
Franklin	impervious developed	13,832.3	31.6	2.72	1,944.85
	pervious developed	49,908.6	24.37	0.76	308.31
Fulton	impervious developed	3,712.9	22.28	2.41	1,586.75
	pervious developed	4,462.3	18.75	0.91	236.54
Huntington	impervious developed	7,321.9	18.58	1.63	1,647.53
	pervious developed	11,375.4	17.8	0.61	260.15
Indiana	impervious developed	589	19.29	2.79	1,621.25
	pervious developed	972	20.1	1.16	220.68
Jefferson	impervious developed	21.4	18.07	2.76	1,369.63
	pervious developed	20.4	19.96	1.24	198.60
Juniata	impervious developed	3,770.2	22.58	1.69	1,903.96
	pervious developed	8,928.3	17.84	0.55	260.68
Lackawana	impervious developed	2,969.7	19.89	2.84	1,305.05
	pervious developed	7,783.9	17.51	0.76	132.98
Lancaster	impervious developed	4,918.7	38.53	1.55	1,480.43
	pervious developed	21,649.7	22.24	0.36	190.93
Lebanon	impervious developed	1,192.1	40.58	1.85	1,948.53
	pervious developed	5,150	27.11	0.4	269.81
Luzerne	impervious developed	5,857	20.43	3	1,648.22
	pervious developed	13,482.9	19.46	0.98	221.19
Lycoming	impervious developed	10,031.7	16.48	2.57	1,989.64
	pervious developed	19,995.5	16	0.84	277.38

County	Category	Acres	TN lbs/acre/yr	TP lbs/acre/yr	TSS (Sediment) lbs/acre/yr
McKean	impervious developed	38.7	20.93	3.21	1,843.27
	pervious developed	5.3	22.58	1.45	249.26
Mifflin	impervious developed	5,560.2	21.83	1.79	1,979.13
	pervious developed	16,405.5	21.13	0.71	296.07
Montour	impervious developed	5,560.2	21.83	1.79	1,979.13
	pervious developed	16,405.5	21.13	0.71	296.07
Northumberland	impervious developed	8,687.3	25.73	1.54	2,197.08
	pervious developed	25,168.3	24.63	0.54	367.84
Perry	impervious developed	5,041.1	26.77	1.32	2,314.7
	pervious developed	9,977	23.94	0.51	343.16
Potter	impervious developed	2,936.3	16.95	2.75	1,728.34
	pervious developed	2,699.3	17.11	1.09	265.2
Schuylkill	impervious developed	5,638.7	30.49	1.56	1,921.08
	pervious developed	14,797.2	29.41	0.57	264.04
Snyder	impervious developed	4,934.2	28.6	1.11	2,068.16
	pervious developed	14,718.1	24.35	0.4	301.5
Somerset	impervious developed	1,013.6	25.13	2.79	1,845.7
	pervious developed	851.2	25.71	1.14	293.42
Sullivan	impervious developed	3,031.7	19.08	2.85	2,013.9
	pervious developed	3,943.4	21.55	1.31	301.58
Susquehanna	impervious developed	7,042.1	19.29	2.86	1,405.73
	pervious developed	14,749.7	20.77	1.21	203.85
Tioga	impervious developed	7,966.9	12.37	2.09	1,767.75
	pervious developed	18,090.3	12.22	0.76	261.94
Union	impervious developed	4,382.6	22.98	2.04	2,393.55
	pervious developed	14,065.3	20.88	0.69	343.81
Wayne	impervious developed	320.5	18.69	2.89	1,002.58
	pervious developed	509	21.14	1.31	158.48
Wyoming	impervious developed	3,634.4	16.03	2.53	2,022.32
	pervious developed	10,792.9	13.75	0.7	238.26
York	impervious developed	10,330.7	29.69	1.18	1,614.15
	pervious developed	40,374.8	18.73	0.29	220.4
All Other Counties	impervious developed	-	23.06	2.28	1,839
	pervious developed	-	20.72	0.84	264.96

Notes:

1 These land loading rate values may be used to derive existing pollutant loading estimates under DEP's simplified method for PRP development. MS4s may choose to develop estimates using other scientifically sound methods.

2 Acres and land loading rate values for named counties in the Chesapeake Bay watershed are derived from CAST. (The column for Acres represents acres within the Chesapeake Bay watershed). For MS4s located outside of the Chesapeake Bay watershed, the land loading rates for "All Other Counties" may be used to develop PRPs under Appendix E; these values are average values across the Chesapeake Bay watershed.

3 For land area outside of the urbanized area, undeveloped land loading rates may be used where appropriate. When using the simplified method, DEP recommends the following loading rates (for any county) for undeveloped land:

- TN – 10 lbs/acre/yr
- TP – 0.33 lbs/acre/yr
- TSS (Sediment) – 234.6 lbs/acre/yr

These values were derived by using the existing loads for each pollutant, according to the 2014 Chesapeake Bay Progress Run, and dividing by the number of acres for the unregulated stormwater subsector.

Section E

SECTION E - SELECT BMPs TO ACHIEVE THE MINIMUM REQUIRED REDUCTIONS IN POLLUTANT LOADING

South Middleton Township has identified the minimum required reductions in pollutant loading for each watershed:

Watershed	Required 10% Sediment Reduction (lbs/year)	Required 5% Phosphorus Reduction (lbs/year)	Required 3% Nitrogen Reduction (lbs/year)
Letort Spring Run	88,745	32	929
Yellow Breeches Creek	106,104	42	1,376
Hogestown Run	27,347	10	305
Alexanders Spring Creek	51,419	16	404
Conodoquinet Creek	10,774	4	146
Total	**284,389**	**104**	**3,160**

South Middleton Township has identified five stormwater BMPs described below that may be implemented to achieve the minimum required pollutant reductions over the next 5-year permit term.

BMP Option 1: Bioswale - Letort Spring Run Watershed

An existing grass-lined swale located north of Bonny Brook Road conveys stormwater flows from upland areas into Letort Spring Run. This swale is in the storm sewershed of Outfall R3 and has a contributing drainage area of 84.3 acres which includes 26.57 acres of impervious area and 57.68 acres of pervious area. The Township plans to work with the property owner to retro-fit this grass-lined swale into a bioswale. The calculated pollutant reduction loads for this BMP are as follows:

Sediment: 58,060 lbs/year
Phosphorus: 37 lbs/year
Nitrogen: 1,478 lbs/year

BMP Option 2: Bioswale - Yellow Breeches Creek Watershed

An existing grass-lined swale located on school district property west of Forge Road conveys stormwater flows from upland areas toward the Yellow Breeches Creek. This swale is in the storm sewershed of Outfall R11 and has a contributing drainage area of 465.6 acres which includes 82.62 acres of impervious area and 382.97 acres of pervious area. The Township plans to work with the property owner to retro-fit this grass-lined swale into a bioswale. The calculated pollutant reduction loads for this BMP are as follows:

Sediment: 165,111 lbs/year
Phosphorus: 133 lbs/year
Nitrogen: 6,707 lbs/year

BMP Option 3: Bioswale - Yellow Breeches Creek Watershed

An existing grass-lined swale located east of East Springville Road conveys stormwater flows from upland areas toward the Yellow Breeches Creek. This swale is in the storm sewershed of Outfall R11 and has a contributing drainage area of 753.7 acres which includes 87.85 acres of impervious area and 665.82 acres of pervious area. The Township plans to work with the property owner to retro-fit this grass-lined swale into a bioswale. The calculated pollutant reduction loads for this BMP are as follows:

Sediment:	293,102 lbs/year
Phosphorus:	232 lbs/year
Nitrogen:	12,026 lbs/year

BMP Option 4: Dry Extended Detention Basin - Letort Spring Run Watershed

An existing dry detention basin provides stormwater management control for Cumberland Crossings, a residential development in the Letort Spring Run Watershed. This detention basin is in the storm sewershed of Outfall R103 which has a contributing drainage area of 53.9 acres. Approximately 14.66 acres of this area is developed impervious area and approximately 39.21 acres is developed pervious area. South Middleton Township plans to work with the property owner to retro-fit this dry detention basin into a dry extended detention basin. The calculated pollutant load reductions for this BMP are as follows:

Sediment:	22,847 lbs/year
Phosphorus:	5 lbs/year
Nitrogen:	254 lbs/year

BMP Option 5: Dry Extended Detention Basin - Letort Spring Run Watershed

An existing dry detention basin provides stormwater management control for a commercial property in the Letort Spring Run Watershed. This detention basin is in the storm sewershed of Outfall R106 which has a contributing drainage area of 19.51 acres. Approximately 11.23 acres of this area is developed impervious area and approximately 8.28 acres is developed pervious area. South Middleton Township plans to work with the property owner to retro-fit this dry detention basin into a dry extended detention basin. The calculated pollutant load reductions for this BMP are as follows:

Sediment:	13,841 lbs/year
Phosphorus:	3 lbs/year
Nitrogen:	98 lbs/year

BMP Option 6: Streambank Stabilization - UNT Boiling Springs Lake

South Middleton Township plans to stabilize approximately 500 LF of the north streambank along an UNT Boiling Springs Lake. This small stream conveys spring water and stormwater discharge from an upland drainage area of approximately 2,000 acres. The proposed reductions are calculated based on the effectiveness values identified in the PA DEP BMP Effectiveness Table as follows:

Sediment: 44.88 lbs/ft/yr
Phosphorus: 0.068 lbs/ft/yr
Nitrogen: 0.075 lbs/ft/yr

Proposed BMP	Watershed	Calculated Sediment Reduction (lbs/year)	Calculated Phosphorus Reduction (lbs/year)	Calculated Nitrogen Reduction (lbs/year)
500 LF Urban Stream Restoration - Boiling Springs Lake	Chesapeake Bay	22,440	34	37

In summary, South Middleton Township will implement a combination of the following BMPs to meet the required pollutant load reductions for the PAG Individual Permit:

Proposed BMP	Watershed	Calculated Sediment Reduction (lbs/year)	Calculated Phosphorus Reduction (lbs/year)	Calculated Nitrogen Reduction (lbs/year)
BMP Option 1: Bioswale	Chesapeake Bay / Letort Spring Run	58,060	37	1,478
BMP Option 2: Bioswale	Chesapeake Bay / Yellow Breeches Creek	165,111	133	6,707
BMP Option 3: Bioswale	Chesapeake Bay / Yellow Breeches Creek	293,102	232	12,026
BMP Option 4: Dry Extended Detention Basin	Chesapeake Bay / Letort Spring Run	22,847	5	254
BMP Option 5: Dry Extended Detention Basin	Chesapeake Bay / Letort Spring Run	13,841	3	98
BMP Option 6: Streambank Stabilization - UNT Boiling Springs Lake	Chesapeake Bay / Boiling Springs Lake	22,440	34	37
	Total	**575,401**	**444**	**20,600**

South Middleton Township has identified six BMPs that, once implemented, would achieve sediment reductions of 575,401 lbs/year which exceeds the required 284,389 lbs/year by 291,012 lbs/year. The Township plans to work with individual property owners over the next five-year permit term to implement only those stormwater BMPs that will achieve the minimum required pollutant reductions as required by the Chesapeake Bay PRP Appendix D. Over the next 5-year permit term, the Township will provide updates in the MS4 annual report on the status of BMP implementation.

Attachments

E1: BMP Option 1 Calculations
E2: BMP Option 2 Calculations
E3: BMP Option 3 Calculations
E4: BMP Option 4 Calculations
E5: BMP Option 5 Calculations
E6: BMP 6.4.5 Rain Garden and Bioretention
E7: BMP 6.4.8 Vegetated Swale
E8: BMP 6.6.3 Dry Extended Detention Basin
E9: Expert Panel - Stream Restoration
E10: Urban Stream Restoration Fact Sheet

Attachment E1: BMP Option 1 Calculations

South Middleton Township
Pollutant Reduction Plan
6/15/2017

BMP Option 1
Bioswale

WORKSHEET: POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

* FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.

BMP TYPE: Swale Retrofit- Grass Swale to Bioswale

BMP LOCATION (MS4 OUTFALL NUMBER)	R3
STORM SEWERSHED AREA TRIBUTARY TO THIS BMP (AC)	84.3

AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT RATES				POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)	AREA (Acres)	TN (LBS)	TP (LBS)	TSS (LBS)
Loading Rates for Cumberland County	Impervious Developed	28.93	1.11	2065.1	26.57	768.6701	29.4927	54869.707
	Pervious Developed	23.29	0.34	306.95	57.68	1343.367	19.6112	17704.876
	Undeveloped	10	0.33	234.6	0.00	0	0	0
				Total	84.250			
					TOTAL LOAD TO THIS BMP TYPE	2112.037	49.1039	72574.583
					PROPOSED POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	70%	75%	80%
					POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	1478.426	36.8279	58059.6664

POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	1478.426	36.8279	58059.6664

Attachment E2: BMP Option 2 Calculations

South Middleton Township
Pollutant Reduction Plan
6/15/2017

BMP Option 2
Bioswale

WORKSHEET: POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

* FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.

BMP TYPE: Swale Retrofit- Grass Swale to Bioswale

BMP LOCATION (MS4 OUTFALL NUMBER)	R11
STORM SEWERSHED AREA TRIBUTARY TO THIS BMP (AC)	465.6

AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT RATES				POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)	AREA (Acres)	TN (LBS)	TP (LBS)	TSS (LBS)
Loading Rates for Cumberland County	Impervious Developed	28.93	1.11	2065.1	82.62	2390.197	91.7082	170618.6
	Pervious Developed	23.29	0.34	306.95	382.97	8919.371	130.21	117552.6
	Undeveloped	10	0.33	234.6	0.00	0	0	0
				Total	465.590			
	Reductions					1728.55	44.45	81782.08
					TOTAL LOAD TO THIS BMP TYPE	9581.018	177.468	206389.1
					PROPOSED POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	70%	75%	80%
					POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	6706.713	133.101	165111.3

POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	6706.713	133.101	165111.3

Attachment E3: BMP Option 3 Calculations

South Middleton Township
Pollutant Reduction Plan
6/15/2017

BMP Option 3
Bioswale

WORKSHEET: POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

* FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.

BMP TYPE: Swale Retrofit- Grass Swale to Bioswale

BMP LOCATION (MS4 OUTFALL NUMBER)	R11
STORM SEWERSHED AREA TRIBUTARY TO THIS BMP (AC)	753.7

AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT RATES				POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)	AREA (Acres)	TN (LBS)	TP (LBS)	TSS (LBS)
Loading Rates for Cumberland County	Impervious Developed	28.93	1.11	2065.1	87.85	2541.38	97.5089	181410.42
	Pervious Developed	23.29	0.34	306.95	665.82	15507.05	226.38	204374.81
	Undeveloped	10	0.33	234.6	0.00	0	0	0
				Total	753.670			
	Upstream BMP Reductions					869	14	19408
	TOTAL LOAD TO THIS BMP TYPE					17179.43	309.889	366377.22
	PROPOSED POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)					70%	75%	80%
	POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)					12025.6	232.417	293101.78

POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	12025.6	232.417	293101.78

Attachment E4: BMP Option 4 Calculations

South Middleton Township
Pollutant Reduction Plan
6/15/2017

BMP Option 4
Dry Extended Detention Basin

WORKSHEET: POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

* FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.

BMP TYPE: BMP Retrofit - Dry Detention to Dry Extended Detention

BMP LOCATION (MS4 OUTFALL NUMBER)	R103
AREA CONTROLLED BY THIS BMP TYPE (AC)	53.9

AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT RATES				POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)	AREA (Acres)	TN (LBS)	TP (LBS)	TSS (LBS)
Loading Rates for Cumberland County	Impervious Developed	28.93	1.11	2065.1	14.66	424.1138	16.2726	30274.366
	Pervious Developed	23.29	0.34	306.95	39.21	913.2009	13.3314	12035.51
	Undeveloped	10	0.33	234.6	0.00	0	0	0
				Total	53.870			
					TOTAL LOAD TO THIS BMP TYPE	1337.315	29.604	42,310
					EXISTING POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	5%	10%	10%
					EXISTING POLLUTANT REDUCTION ACHIEVED BY DETENTION BASIN (LBS)	66.86574	2.9604	4230.9876
					TOTAL ADJUSTED EXISTING LOAD TO BMP (LBS)	1270.449	26.6436	38078.888
					PROPOPSED POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	20%	20%	60%
					POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	254.0898	5.32872	22847.333

POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	254.0898	5.32872	22847.333

Attachment E5: BMP Option 5 Calculations

South Middleton Township
Pollutant Reduction Plan
6/15/2017

BMP Option 5
Dry Extended Detention Basin

WORKSHEET: POLLUTANT REDUCTION THROUGH BMP APPLICATIONS*

* FILL THIS WORKSHEET OUT FOR EACH BMP TYPE WITH DIFFERENT POLLUTANT REMOVAL EFFICIENCIES. SUM POLLUTANT REDUCTION ACHIEVED FOR ALL BMP TYPES ON FINAL SHEET.

BMP TYPE: BMP Retrofit - Dry Detention to Dry Extended Detention

BMP Location (MS4 Outfall Number)	R106
AREA CONTROLLED BY THIS BMP TYPE (AC)	19.5

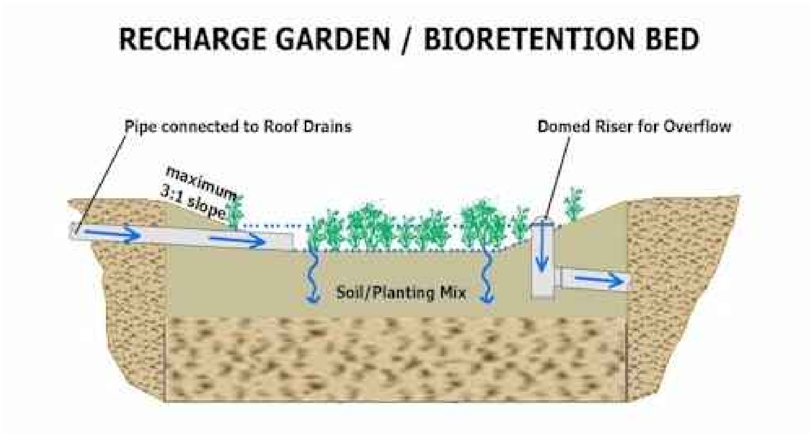
AREAS CONTROLLED BY THIS BMP TYPE:

		POLLUTANT RATES				POLLUTANT LOAD		
	LAND COVER CLASSIFICATION	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (lbs/ac/yr)	AREA (Acres)	TN (LBS)	TP (LBS)	TSS (LBS)
Loading Rates for Cumberland County	Impervious Developed	28.93	1.11	2065.1	11.23	324.8839	12.4653	23191.073
	Pervious Developed	23.29	0.34	306.95	8.28	192.8412	2.8152	2541.546
	Undeveloped	10	0.33	234.6	0.00	0	0	0
				Total	19.51			
	Upstream BMP Reductions					1	0	101
					TOTAL LOAD TO THIS BMP TYPE	517	15	25,632
					EXISTING POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	5%	10%	10%
					EXISTING POLLUTANT REDUCTION ACHIEVED BY DETENTION BASIN (LBS)	25.84106	1.52205	2563.1519
					TOTAL ADJUSTED EXISTING LOAD TO BMP (LBS)	490.9801	13.6985	23068.367
					PROPOSED POLLUTANT REMOVAL EFFICIENCIES FROM PADEP MS4 BMP EFFECTIVENESS TABLE (%)	20%	20%	60%
					POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	98.19602	2.73969	13841.02

POLLUTANT REDUCTION ACHIEVED BY PROPOSED BMP TYPE (LBS)	98.19602	2.73969	13841.02

Attachment E6: BMP 6.4.5 Rain Garden and Bioretention

BMP 6.4.5: Rain Garden/Bioretention



A Rain Garden (also called Bioretention) is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff.

Key Design Elements

- Flexible in terms of size and infiltration
- Ponding depths generally limited to 12 inches or less for aesthetics, safety, and rapid draw down. Certain situations may allow deeper ponding depths.
- Deep rooted perennials and trees encouraged
- Native vegetation that is tolerant of hydrologic variability, salts and environmental stress
- Modify soil with compost.
- Stable inflow/outflow conditions
- Provide positive overflow
- Maintenance to ensure long-term functionality

Potential Applications

Residential: Commercial: Ultra Urban: Industrial: Retrofit: Highway/Road:
Yes Yes Yes Yes Yes Yes

Stormwater Functions

Volume Reduction: Medium
Recharge: Med./High
Peak Rate Control: Low/Med.
Water Quality: Med./High

Water Quality Functions

TSS: TP: 85% 85%
NO3: 30%

Other Considerations

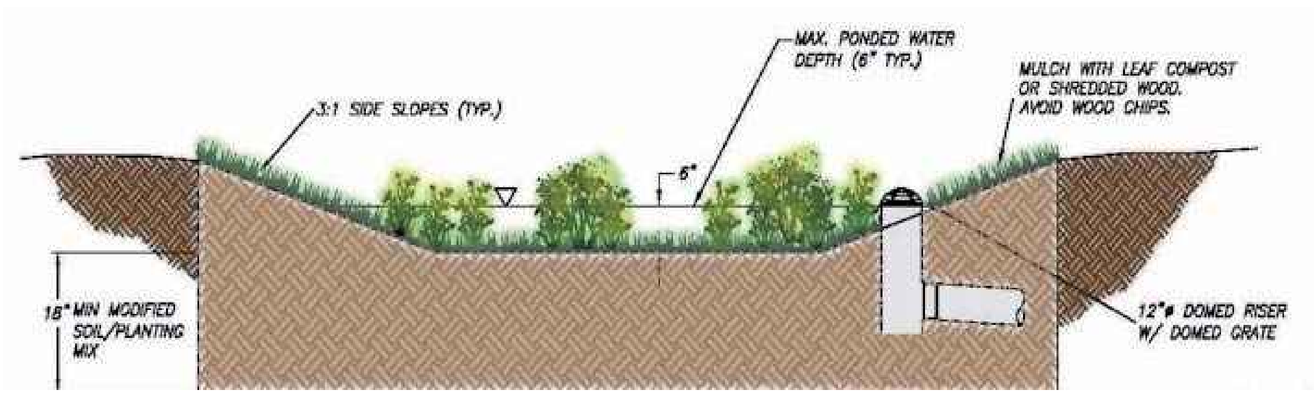
- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

Description

Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Bioretention techniques are used to accomplish water quality improvement and water quantity reduction. Prince George's County, Maryland, and Alexandria, Virginia have used this BMP since 1992 with success in many urban and suburban settings.

Bioretention can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMPs described in Chapter 5.

The vegetation serves to filter (water quality) and transpire (water quantity) runoff, and the root systems can enhance infiltration. The plants take up pollutants; the soil medium filters out pollutants and allows storage and infiltration of stormwater runoff; and the bed provides additional volume control. Properly designed bioretention techniques mimic natural ecosystems through species diversity, density and distribution of vegetation, and the use of native species, resulting in a system that is resistant to insects, disease, pollution, and climatic stresses.



Rain Gardens / Bioretention function to:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Recharge groundwater by infiltration
- Reduce stormwater temperature impacts
- Enhance evapotranspiration
- Enhance aesthetics
- Provide habitat

Primary Components of a Rain Garden/Bioretention System

The primary components (and subcomponents) of a rain garden/bioretention system are:

Pretreatment (optional)

- Sheet flow through a vegetated buffer strip, cleanout, water quality inlet, etc. prior to entry into the Rain Garden

Flow entrance

- Varies with site use (e.g., parking island versus residential lot applications)
- Water may enter via an inlet (e.g., flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection
- Trench drain
- Entering velocities should be non-erosive.

Ponding area

- Provides temporary surface storage of runoff
- Provides evaporation for a portion of runoff
- Design depths allow sediment to settle
- Limited in depth for aesthetics and safety

Plant material

- Evapotranspiration of stormwater
- Root development and rhizome community create pathways for infiltration
- Bacteria community resides within the root system creating healthy soil structure with water quality benefits
- Improves aesthetics for site
- Provides habitat for animals and insects
- Reinforces long-term performance of subsurface infiltration
- Should be tolerant of salts if in a location that would receive snow melt chemicals

Organic layer or mulch

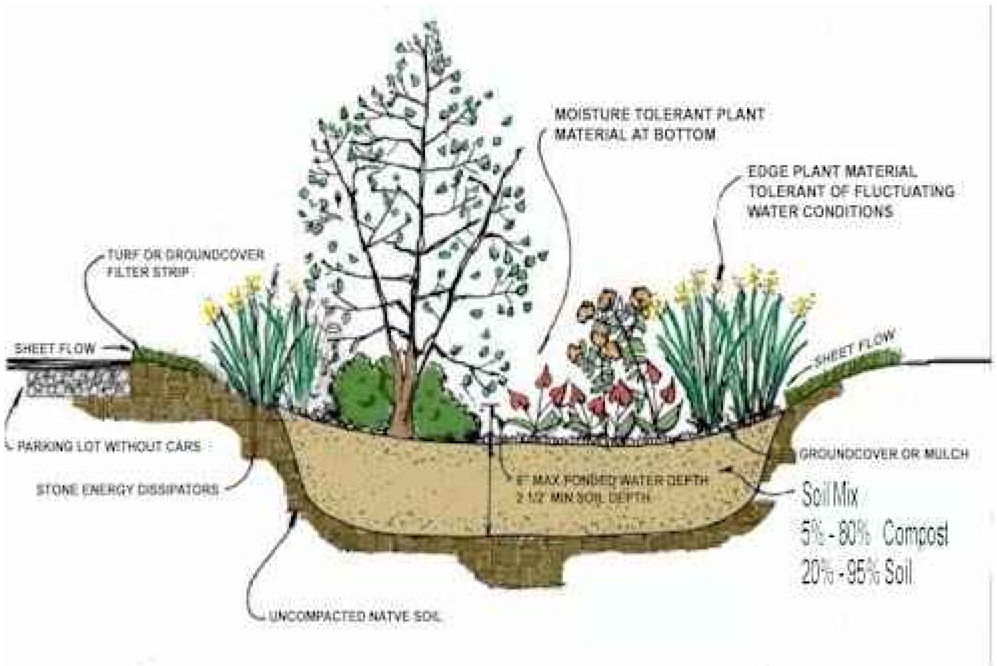
- Acts as a filter for pollutants in runoff
- Protects underlying soil from drying and eroding
- Simulates leaf litter by providing environment for microorganisms to degrade organic material
- Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals
- Wood mulch should be shredded - compost or leaf mulch is preferred.

Planting soil/volume storage bed

- Provides water/nutrients to plants
- Enhances biological activity and encourages root growth
- Provides storage of stormwater by the voids within the soil particles

Positive overflow

- Will discharge runoff during large storm events when the storage capacity is exceeded. Examples include domed riser, inlet, weir structure, etc.
- An underdrain can be included in areas where infiltration is not possible or appropriate.



Variations

Generally, a Rain Garden/Bioretention system is a vegetated surface depression that provides for the infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis (versus the total development site). If greater volumes of runoff need to be managed or stored, the system can be designed with an expanded subsurface infiltration bed or the Bioretention area can be increased in size.

The design of a Rain Garden can vary in complexity depending on the quantity of runoff volume to be managed, as well as the pollutant reduction objectives for the entire site. Variations exist both in the components of the systems, which are a function of the land use surrounding the Bioretention system.

The most common variation includes a gravel or sand bed underneath the planting bed. The original intent of this design, however, was to perform as a filter BMP utilizing an under drain and subsequent discharge. When a designer decides to use a gravel or sand bed for volume storage under the planting bed, then additional design elements and changes in the vegetation plantings should be provided.

Flow Entrance: Curbs and Curb Cuts

Flow Entrance: Trench Drain

Positive Overflow: Domed Riser

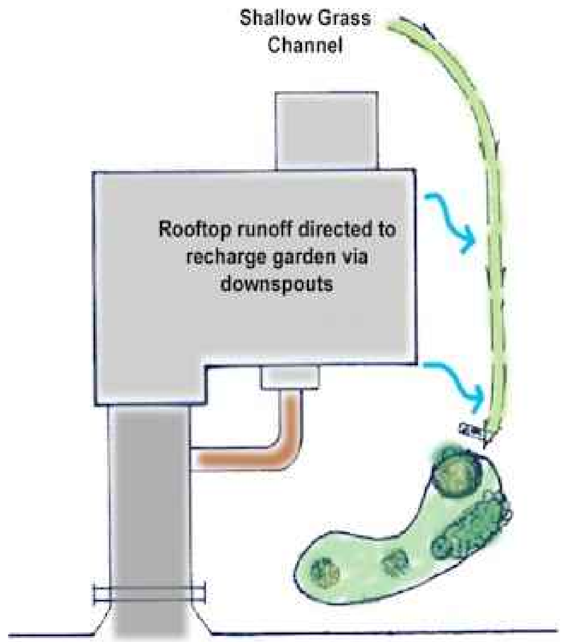
Positive Overflow: Inlet

Applications

Bioretention areas can be used in a variety of applications: from small areas in residential lawns to extensive systems in large parking lots (incorporated into parking islands and/or perimeter areas).

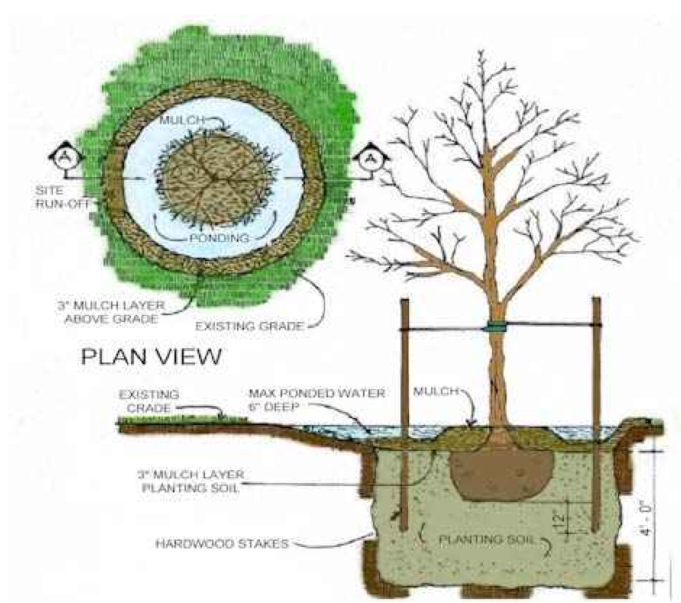
- **Residential On-lot**

  Rain Garden (Prince George's County)
  Simple design that incorporates a planting bed in the low portion of the site

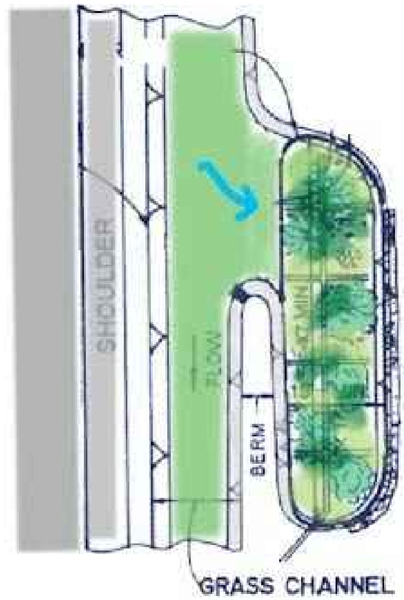


- **Tree and Shrub Pits**
  Stormwater management technique that intercepts runoff and provides shallow ponding in a dished mulched area around the tree or shrub.

  Extend the mulched area to the tree dripline



- **Roads and highways**



- **Parking Lots**
- **Parking Lot Island Bioretention**

- **Commercial/Industrial/Institutional**

In commercial, industrial, and institutional situations, stormwater management and greenspace areas are limited, and in these situations, Rain Gardens for stormwater management and landscaping provide multifunctional options.

- **Curbless (Curb cuts) Parking Lot Perimeter Bioretention**
  The Rain Garden is located adjacent to a parking area with no curb or curb cuts , allowing stormwater to sheet flow over the parking lot directly into the Rain Garden. Shallow grades should direct runoff at reasonable velocities; this design can be used in conjunction with depression storage for stormwater quantity control.

- **Curbed Parking Lot Perimeter Bioretention**

- **Roof leader connection from adjacent building**

Design Considerations

Rain Gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. Though Rain Gardens are a structural BMP, the initial siting of bioretention areas should respect the Integrating Site Design Procedures described in Chapter 4 and integrated with the preventive non-structural BMPs.

It is important to note that bioretention areas are not to be confused with constructed wetlands or wet ponds which permanently pond water. Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.1 inches per hour). In extreme situations where permeability is less than 0.1 inches per hour, special variants may apply, including under drains, or even constructed wetlands.

Rain Gardens are often very useful in retrofit projects and can be integrated into already developed lots and sites. An important concern for all Rain Garden applications is their long-term protection and maintenance, especially if undertaken in multiple residential lots where individual homeowners provide maintenance. In such situations, it is important to provide some sort of management that insures their long-term functioning (deed restrictions, covenants, and so forth).

1. **Sizing criteria**

    a. **Surface area** is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 5:1 (impervious drainage area to infiltration area; see Protocol 2. Infiltration Systems Guidelines (Appendix C) for additional guidance on loading rates.)

    b. **Surface Side slopes** should be gradual. For most areas, maximum 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.

    c. **Surface Ponding depth** should not exceed 6 inches in most cases and should empty within 72 hours.

    d. **Ponding area** should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface storage/infiltration bed is used to supplement surface storage where feasible.

    e. **Planting soil depth** should generally be at least 18" where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased, depending on plant species.

2. **Planting Soil** should be a loam soil capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A typical organic amended soil is combined with 20-30% organic material (compost), and 70-80% soil base (preferably topsoil). Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.

3. **Volume Storage Soils** should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10% (a small amount of clay is beneficial to adsorb pollutants and retain water), be free of toxic substances and unwanted plant material and have a 5 –10% organic matter content. Additional organic matter can be added to the soil to increase water holding capacity (tests should be conducted to determine volume storage capacity of amended soils).

4. Proper **plant selection** is essential for bioretention areas to be effective. Typically, native floodplain plant species are best suited to the variable environmental conditions encountered. If shrubs and trees are included in a bioretention area (which is recommended), at least three species of shrub and tree should be planted at a rate of approximately 700 shrubs and 300 trees per acre (shrub to tree ratio should be 2:1 to 3:1). An experienced landscape architect is recommended to design native planting layout.

5. **Planting periods** will vary, but in general trees and shrubs should be planted from mid-March through the end of June, or mid-September through mid-November

6. A maximum of 2 to 3 inches of shredded **mulch** or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. Mulch / compost layer should not exceed 3" in depth so as not to restrict oxygen flow to roots.

7. Must be designed carefully in areas with **steeper slopes** and should be aligned parallel to contours to minimize earthwork.

8. Under drains should not be used except where in-situ soils fail to drain surface water to meet the criteria in Chapter 3.

Detailed Stormwater Functions

Infiltration Area

Volume Reduction Calculations

The storage volume of a Bioretention area is defined as the sum total of 1. and the smaller of 2a or 2b below. The surface storage volume should account for at least 50% of the total storage. Inter-media void volumes may vary considerably based on design variations.

1. Surface Storage Volume (CF) = Bed Area (ft^2) x Average Design Water Depth

2a. Infiltration Volume = Bed Bottom area (sq ft) x infiltration design rate (in/hr) x infiltration period (hr) x 1/12.
2b. Volume = Bed Bottom area (sq ft) x soil mix bed depth x void space.

Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence; however, alterations might be necessary depending on design variations.

1. Install temporary sediment control BMPs as shown on the plans.

2. Complete site grading. If applicable, construct curb cuts or other inflow entrance but provide protection so that drainage is prohibited from entering construction area.

3. Stabilize grading within the limit of disturbance except within the Rain Garden area. Rain garden bed areas may be used as temporary sediment traps provided that the proposed finish elevation of the bed is 12 inches lower than the bottom elevation of the sediment trap.

4. Excavate Rain Garden to proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.

5. Backfill Rain Garden with amended soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light hand tamping is acceptable if necessary.

6. Presoak the planting soil prior to planting vegetation to aid in settlement.

7. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans.

8. Plant vegetation according to planting plan.

9. Mulch and install erosion protection at surface flow entrances where necessary.

Maintenance Issues

Properly designed and installed Bioretention areas require some regular maintenance.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may also need to be removed every year. Perennial plantings may be cut down at the end of the growing season.
- Mulch should be re-spread when erosion is evident and be replenished as needed. Once every 2 to 3 years the entire area may require mulch replacement.
- Bioretention areas should be inspected at least two times per year for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, Bioretention areas may require watering.
-
- Trees and shrubs should be inspected twice per year to evaluate health.

Cost Issues

Rain Gardens often replace areas that would have been landscaped and are maintenance-intensive so that the net cost can be considerably less than the actual construction cost. In addition, the use of Rain Gardens can decrease the cost for stormwater conveyance systems at a site. Rain Gardens cost approximately $5 to $7 (2005) per cubic foot of storage to construct.

Specifications

The following specifications are provided for informational purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1Vegetation - See Appendix B

2 Execution

a. Subgrade preparation

1. Existing sub-grade in Bioretention areas shall NOT be compacted or subject to excessive construction equipment traffic.
2. Initial excavation can be performed during rough site grading but shall not be carried to within one feet of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
3. Where erosion of sub-grade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material shall be removed with light

equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent by light tractor.

4. Bring sub-grade of bioretention area to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
5. Halt excavation and notify engineer immediately if evidence of sinkhole activity or pinnacles of carbonate bedrock are encountered in the bioretention area.

b. Rain Garden Installation

1. Upon completion of sub-grade work, the Engineer shall be notified and shall inspect at his/her discretion before proceeding with bioretention installation.
2. For the subsurface storage/infiltration bed installation, amended soils should be placed on the bottom to the specified depth.
3. Planting soil shall be placed immediately after approval of sub-grade preparation/bed installation. Any accumulation of debris or sediment that takes place after approval of sub-grade shall be removed prior to installation of planting soil at no extra cost to the Owner.
4. Install planting soil (exceeding all criteria) in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket or by hand). Keep equipment movement over planting soil to a minimum – **do not over compact**. Install planting soil to grades indicated on the drawings.
5. Plant trees and shrubs according to supplier's recommendations and only from mid-March through the end of June or from mid-September through mid-November.
6. Install 2-3" shredded hardwood mulch (minimum age 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
7. Protect Rain Gardens from sediment at all times during construction. Hay bales, diversion berms and/or other appropriate measures shall be used at the toe of slopes that are adjacent to Rain Gardens to prevent sediment from washing into these areas during site development.
8. When the site is <u>fully vegetated</u> and the soil mantle stabilized the plan designer shall be notified and shall inspect the Rain Garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.
9. Water vegetation at the end of each day for two weeks after planting is completed.

Contractor should provide a one-year 80% care and replacement warranty for all planting beginning after installation and inspection of all plants.

Attachment E7: BMP 6.4.8 Vegetated Swale

BMP 6.4.8: Vegetated Swale

Hawthorne Ridge Subdivision (SE 162nd, South of Foster)

A Vegetated Swale is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. In steeper slope situations, check dams may be used to further enhance attenuation and infiltration opportunities.

- Plant dense, low-growing native vegetation that is water-resistant, drought and salt tolerant, providing substantial pollutant removal capabilities
- Longitudinal slopes range from 1 to 6%
- Side slopes range from 3:1 to 5:1
- Bottom width of 2 to 8 feet
- Check-dams can provide limited detention storage, as well as enhanced volume control through infiltration. Care must be taken to prevent erosion around the dam
- Convey the 10-year storm event with a minimum of 6 inches of freeboard
- Designed for non-erosive velocities up to the 10-year storm event
- Design to aesthetically fit into the landscape, where possible
- Significantly slow the rate of runoff conveyance compared to pipes

Potential Applications

Residential:
Commercial: Yes Yes
Ultra Urban: Limited
Industrial: Yes Yes
Retrofit: Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med.
Peak Rate Control: Med./High
Water Quality: Med./High

Water Quality Functions

TSS: 50%
TP: 50%
NO3: 20%

Other Considerations

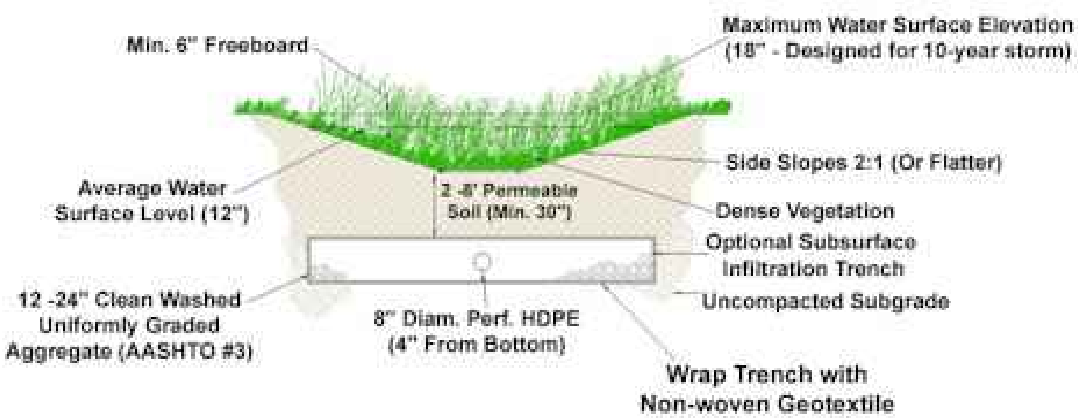
- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed whenever infiltration of runoff is desired, see Appendix C

Description

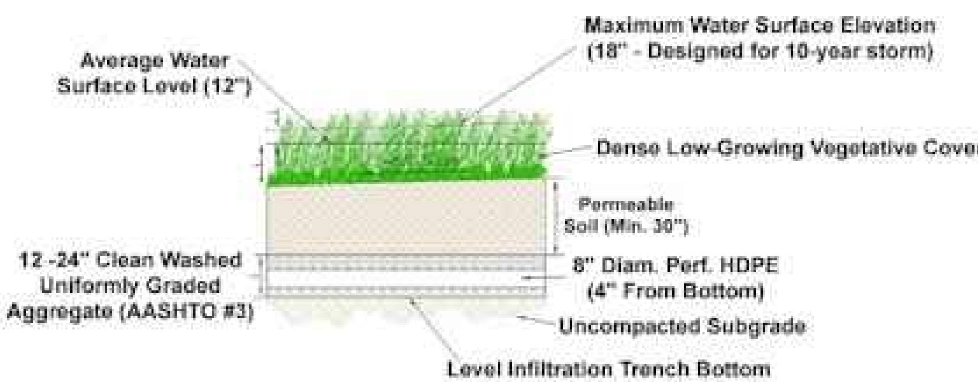
Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated Swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems, while providing partially treated (pretreatment) and partially distributed stormwater flows to subsequent BMPs. Swales are often heavily vegetated with a dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential. The various pollutant removal mechanisms of a swale include: sedimentary filtering by the swale vegetation (both on side slopes and on bottom), filtering through a subsoil matrix, and/or infiltration into the underlying soils with the full array of infiltration-oriented pollutant removal mechanisms.

A Vegetated Swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (See BMP 6.4.4 Infiltration Trench for further design guidelines).

CROSS-SECTION



PROFILE



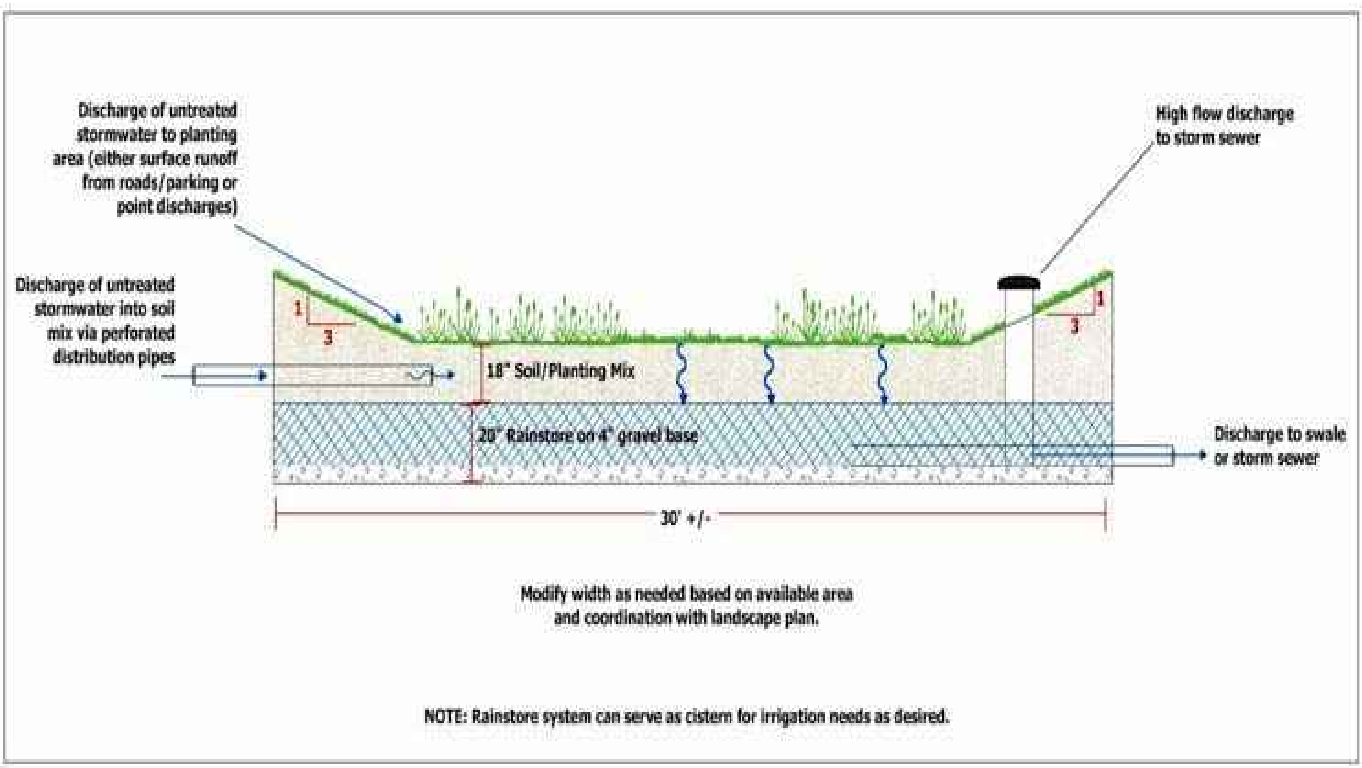
A major concern when designing Vegetated Swales is to make certain that excessive stormwater flows, slope, and other factors do not combine to produce erosive flows, which exceed the Vegetated Swale capabilities. Use of check dams or turf reinforcement matting (TRM) can enhance swale performance in some situations.

A key feature of vegetated swale design is that swales can be well integrated into the landscape character of the surrounding area. A vegetated swale can often enhance the aesthetic value of a site through the selection of appropriate native vegetation. Swales may also discreetly blend in with landscaping features, especially when adjacent to roads.

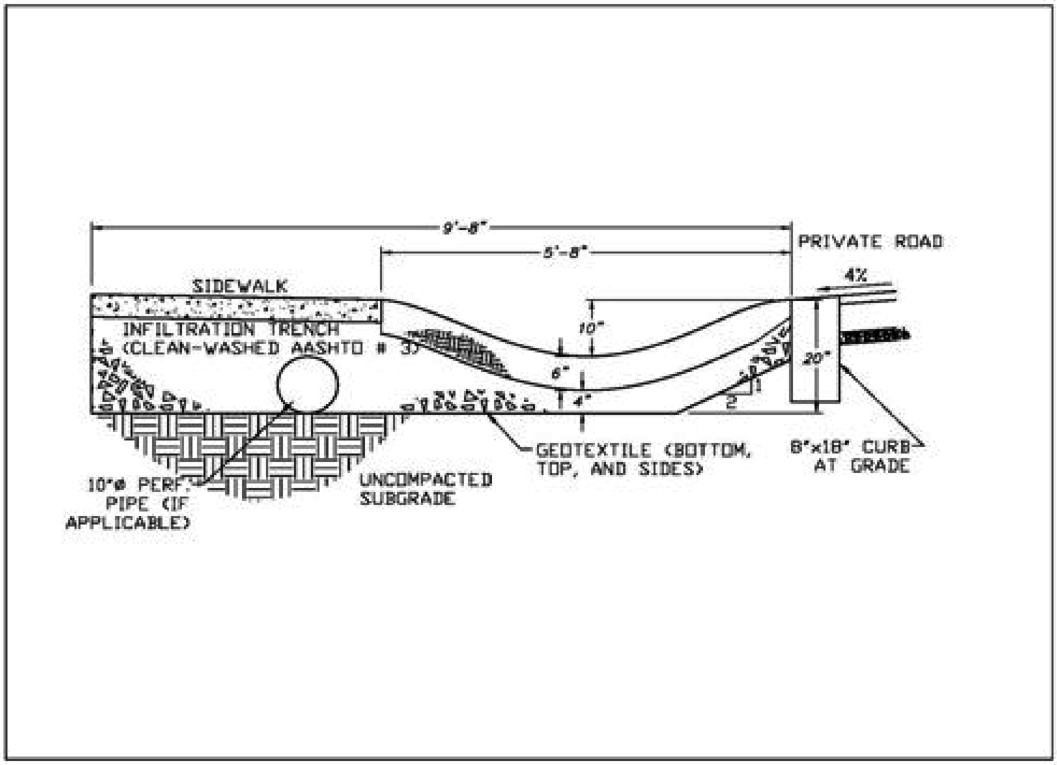
Variations

Vegetated Swale with Infiltration Trench

This option includes a 12 to 24 inch aggregate bed or trench, wrapped in a nonwoven geotextile (See BMP 6.4.4 Infiltration Trench for further design guidelines). This addition of an aggregate bed or trench substantially increases volume control and water quality performance although costs also are increased. Soil Testing and Infiltration Protocols in Appendix C should be followed.



Vegetated Swales with Infiltration Trenches are best fitted for milder sloped swales where the addition of the aggregate bed system is recommended to make sure that the maximum allowable ponding time of 72 hours is not exceeded. This aggregate bed system should consist of at least 12 inches of uniformly graded aggregate. Ideally, the underdrain system shall be designed like an infiltration trench. The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the required storage of the 1-inch storm event.

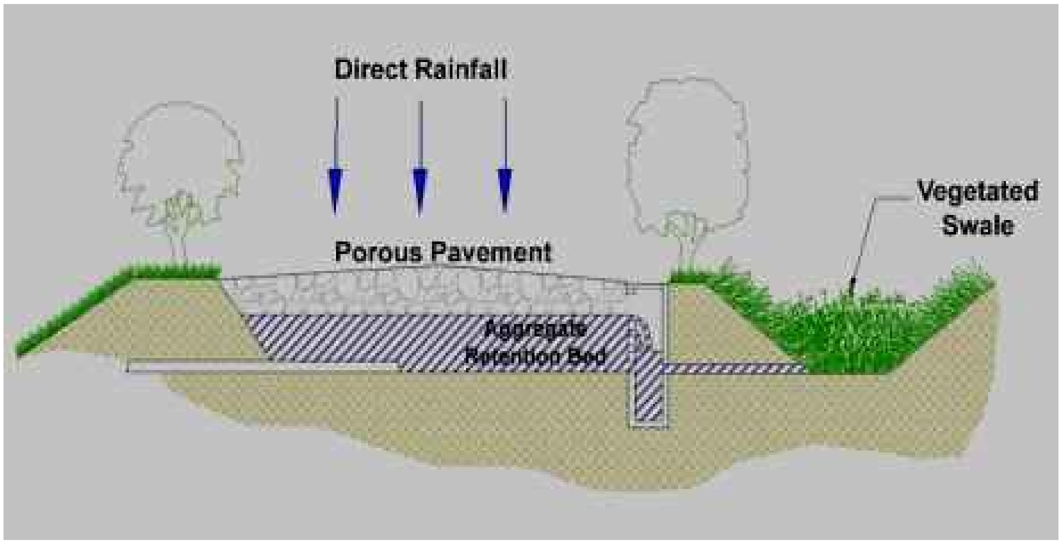


Grass Swale
Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than swales with longer and denser vegetation. However, they provide far less infiltration and pollutant removal opportunities. Grass swales are to be used only as pretreatment for other structural BMPs. Design of grass swales is often rate-based. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to reduce the rate of flow across a site.

Wet Swales
Wet swales are essentially linear wetland cells. Their design often incorporates shallow, permanent pools or marshy conditions that can sustain wetland vegetation, which in turn provides potentially high pollutant removal. A high water table or poorly drained soils are a prerequisite for wet swales. The drawback with wet swales, at least in

residential or commercial settings, is that they may promote mosquito breeding in the shallow standing water (follow additional guidance under Constructed Wetland for reducing mosquito population). Infiltration is minimal if water remains for extended periods.

Applications



- **Parking**
- **Commercial and light industrial facilities**
- **Roads and highways**
- **Residential developments**
- **Pretreatment for volume-based BMPs**
- **Alternative to curb/gutter and storm sewer**

Design Considerations

1. Vegetated Swales are sized to temporarily store and infiltrate the 1-inch storm event, while providing conveyance for up to the 10-year storm with freeboard; flows for up to the 10-year storm are to be accommodated without causing erosion. Swales should maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout. Six inches of freeboard is recommended for the 10-year storm. Residence times between 5 and 9 minutes are acceptable for swales without check-dams. The maximum ponding time is 48 hours, though 24 hours is more desirable (minimum of 30 minutes). Studies have shown that the maximum amount of swale filtering occurs for water depths below 6 inches. It is critical that swale vegetation not be submerged, as it could cause the vegetation to bend over with the flow. This would naturally lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

2. Longitudinal slopes between 1% and 3% are generally recommended for swales. If the topography necessitates steeper slopes, check dams or TRM's are options to reduce the energy gradient and erosion potential.

3. Check dams are recommended for vegetated swales with longitudinal slopes greater than 3%. They are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity, and promote additional filtering and settling of nutrients and other pollutants. In effect, check-dams create a series of small, temporary pools along the length of the swale, which shall drain down within a maximum of 72 hours. Swales with check-dams are much more effective at mitigating runoff quantity and quality than those without. The frequency and design of check-dams in a swale will depend on the swale length and slope, as well as the desired amount of storage/treatment volume. Care must be taken to avoid erosion around the ends of the check dams.

   Check-dams shall be constructed to a height of 6 to 12 in and be regularly spaced. The following materials have been employed for check-dams: natural wood, concrete, stone, and earth. Earthen check-dams however, are typically not recommended due to their potential to erode. A weep hole(s) may be added to a check-dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep hole(s) is not subject to clogging. In the case of a stone check-dam, a better approach might be to allow low flows (2-year storm) to drain through the stone, while allowing higher flows (10-year storm) drain through a weir in the center of the dam. Flows through a stone check-dam are a function of stone size, flow depth, flow width, and flow path length through the dam. The following equation can be used to estimate the flow through a stone check dam up to 6 feet long:

$$q = h^{1.5} / (L/D + 2.5 + L^2)^{0.5}$$

   where:

   q = flow rate exiting check dam (cfs/ft)
   h = flow depth (ft)
   L = length of flow (ft)
   D = average stone diameter (ft) (more uniform gradations are preferred)

   For low flows, check-dam geometry and swale width are actually more influential on flow than stone size. The average flow length through a check-dam as a function of flow depth can be determined by the following equation:

$$L = (ss) \times (2d - h)$$

where:
ss = check dam side slope (maximum 2:1)
d = height of dam (ft)
h = flow depth (ft)

When swale flows overwhelm the flow-through capacity of a stone check-dam, the top of the dam shall act as a standard weir (use standard weir equation). (Though a principal spillway, 6 inches below the height of the dam, may also be required depending on flow conditions.) If the check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

4. The effectiveness of a vegetated swale is directly related to the contributing land use, the size of the drainage area, the soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. Use of natural low points in the topography may be suited for swale location, as are natural drainage courses although infiltration capability may also be reduced in these situations. The topography of a site should allow for the design of a swale with sufficiently mild slope and flow capacity. Swales are impractical in areas of extreme (very flat or steep) slopes. Of course, adequate space is needed for vegetated swales. Swales are ideal as an alternative to curbs and gutters along parking lots and along small roads in gently sloping terrain.

   Siting of vegetated swales should take into account the location and function of other site features (buffers, undisturbed natural areas, etc.). Siting should also attempt to aesthetically fit the swale into the landscape as much as possible. Sharp bends in swales should be avoided.

   Implementing vegetated swales is challenging when development density exceeds four dwelling units per acre, in which case the number of driveway culverts often increases to the point where swales essentially become broken-pipe systems.

   Where possible, construct swales in areas of uncompacted cut. Avoid constructing side slopes in fill material. Fill slopes can be prone to erosion and/or structural damage by burrowing animals.

5. Soil Testing is required when infiltration is planned (see Appendix C).

6. Guidelines for Infiltration Systems should be met as necessary (see Appendix C).

7. Swales are typically most effective, when treating an area of 1 to 2 acres although vegetated swales can be used to treat and convey runoff from an area of 5 to 10 acres in size. Swales serving greater than 10-acre drainage areas will provide a lesser degree water quality treatment, unless special provisions are made to manage the increased flows.

8. Runoff can be directed into Vegetated Swales either as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is

included (see #6). If flow is to be directed into a swale via curb cuts, provide a 2 to 3 inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately.

9. Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially roadway runoff. However, when swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the heavier sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Pretreatment options include a vegetated filter strip, a sediment forebay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a 6-inch drop where parking lot sheet flow is directed into a swale.

10. The soil base for a vegetated swale must provide stability and adequate support for proposed vegetation. When the existing site soil is deemed unsuitable (clayey, rocky, coarse sands, etc.) to support dense vegetation, replacing with approximately 12 inches of loamy or sandy soils is recommended. In general, alkaline soils should be used to further reduce and retain metals. Swale soils should also be well-drained. If the infiltration capacity is compromised during construction, the first several feet should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth.

11. Swales are most efficient when their cross-sections are parabolic or trapezoidal in nature. Swale side slopes are best within a range of 3:1 to 5:1 and should not be greater than 2:1 for ease of maintenance and side inflow from sheet flow.

12. To ensure the filtration capacity and proper performance of swales, the bottom widths typically range from 2 to 8 feet. Wider channels are feasible only when obstructions such as berms or walls are employed to prohibit braiding or uncontrolled sub-channel formation. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.

13. Ideal swale vegetation should consist of a dense and diverse selection of close-growing, water-resistant plants whose growing season preferably corresponds to the wet season. For swales that are not part of a regularly irrigated landscaped area, drought tolerant vegetation should be considered as well. Vegetation should be selected at an early stage in the design process, with well-defined pollution control goals in mind. Selected vegetation must be able to thrive at the specific site and therefore should be chosen carefully (See Appendix B). Use of native plant species is strongly advised, as is avoidance of invasive plant species. Swale vegetation must also be salt tolerant, if winter road maintenance activities are expected to contribute salt/chlorides.

Table 6.8.1

Commonly used vegetation in swale (New Jersey BMP Manual, 2004)		
Common Name	Scientific Name	Notes
Alkai Saltgrass	Puccinellia distans	Cool, good for wet, saline swales
Fowl Bluegrass	Poa palustris	Cool, good for wet swales
Canada Bluejoint	Calamagrostis canadensis	Cool, good for wet swales
Creeping Bentgrass	Agrostis palustris	Cool, good for wet swales, salt tolerant
Red Fescue	Festuca rubra	Cool, not for wet swales
Redtop	Agrostis gigantea	Cool, good for wet swales
Rough Bluegrass	Poa trivialis	Cool, good for wet, shady swales
Switchgrass	Panicum virgatum	Warm, good for wet swales, somwe salt tolerance
Wildrye	Elymus virginicus/rigarius	Cool, good for wet, shady swales

Notes: These grasses are sod forming and can withstand frequent inundation, and are idela for the swale or grass channel environment. A few are also salt tolerant. Cool refers to cool season grasses that grow during the colder temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot , mid summer months.

By landscaping with trees along side slopes, swales can be easily and aesthetically integrated into the overall site design without unnecessary loss of usable space. An important consideration however, is that tree plantings allow enough light to pass and sustain a dense ground cover. When the trees have reached maturity, they should provide enough shade to markedly reduce high temperatures in swale runoff.

14. Check the temporary and permanent stability of the swale using the standards outlined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual. Swales should convey either 2.75 cfs/acre or the calculated peak discharge from a 10-year storm event. The permissible velocity design method may be used for design of channel linings for bed slopes <0.10 ft/ft; use of the maximum permissible shear stress is acceptable for all bed slopes. Flow capacity, velocity, and design depth in swales are generally calculated by Manning's equation.

    Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, compost blankets, or curled wood blankets. Most vendors will provide information about the Manning's 'n' value and will specify the maximum permissible velocity or allowable shear stress for the lining material.

    The post-vegetation establishment capacity of the swale should also be confirmed. Permanent turf reinforcement may supersede temporary reinforcement on sites where not exceeding the maximum permissible velocity is problematic. If driveways or roads cross a swale, culvert capacity may supersede Manning's equation for determination of design flow depth. In these cases, the culvert should be checked to establish that the backwater elevation would not exceed the banks of the swale. If the culverts are to discharge to a minimum tailwater condition, the exit velocity for the culvert should be evaluated for design conditions. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures should be implemented. The following tables list the maximum permissible shear stresses (for various channel liners) and velocities (for channels lined with vegetation) from the Pennsylvania Erosion and Sediment Pollution Control Program Manual.

Maximum Permissible Shear Stresses for Various Channel Liners

Lining Category	Lining Type	lb/ft2
Unlined - Erodible Soils*	Silts, Fine - Medium Sands	0.03
	Coarse Sands	0.04
	Very Coarse Sands	0.05
	Fine Gravel	0.10
Erosion Resistant Soils**	Clay loam	0.25
	Silty Clay loam	0.18
	Sandy Clay Loam	0.10
	Loam	0.07
	Silt Loam	0.12
	Sandy Loam	0.02
	Gravely, Stony, Channery Loam	0.05
	Stony or Channery Silt Loam	0.07
Temporary Liners	Jute	0.45
	Straw with Net	1.45
	Coir - Double Net	2.25
	Coconut Fiber - Double Net	2.25
	Curled Wood Mat	1.55
	Curled Wood - Double Net	1.75
	Curled Wood - Hi Velocity	2.00
	Synthetic Mat	2.00
Vegetative Liners	Class B	2.10
	Class C	1.00
	Class D	0.60
Riprap***	R-1	0.25
	R-2	0.50
	R-3	1.00
	R-4	2.00
	R-5	3.00
	R-6	4.00
	R-7	5.00
	R-8	8.00

* Soils having an erodibility "K" factor greater than 0.37

** Soils having an erodibility "K" factor less than or equal to 0.37

*** Permissible shear stresses based on rock at 165 lb/cuft. Adjust velocities for other rock weights used. See Table 12.

Manufacturer's shear stress values based on independent tests may be used.

xture Reed Canarygrass	<5 5-10	5 4	4 3
Serecea Lespedeza Weeping Lovegrass Redtop Red Fescue	<5	3.5	2.5
Annuals Temporary cover only Sudangrass	<5	3.5	2.5

[1]Cohesive (clayey) fine grain soils and coarse grain soils with a plasticity index OF 10 TO 40 (CL, CH, SC and GC). Soils with K values less than 0.37.

[2]Soils with K values greater than 0.37.

[3]Use velocities exceeding 5 ft/sec only where good cover and proper maintenance can be obtained.

15. Manning's roughness coefficient, or 'n' value, varies with type of vegetative cover and design flow depth. Two common methods are based on design depth (see adjacent graph) and based on vegetative cover (as defined in the Pennsylvania Erosion and Sediment Pollution Control Program Manual). Either of these can be used in design.

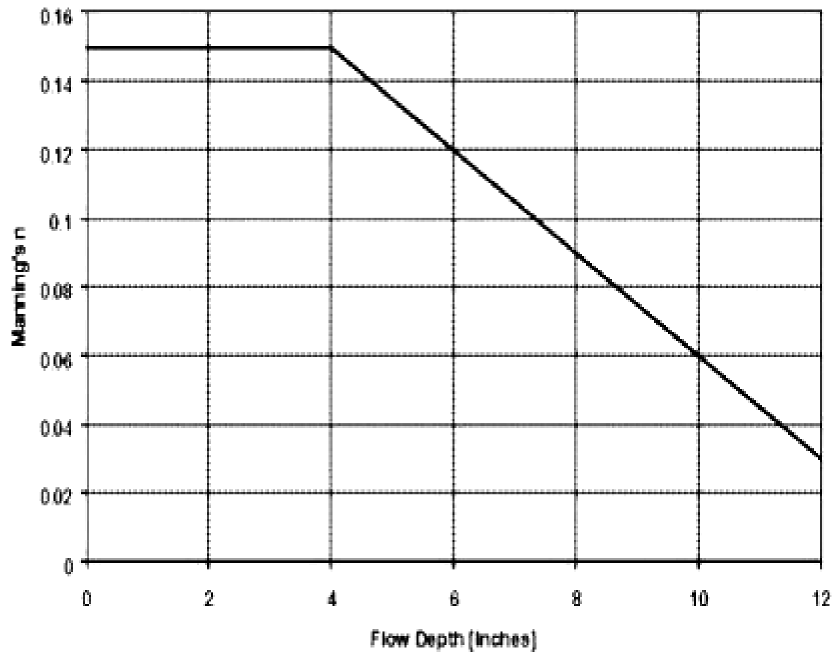


Figure D9.1 Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

16. If swales are designed according to the guidelines discussed in this section, significant levels of pollutant reduction can be expected through filtration and infiltration. In a particular swale reach, runoff should be well filtered by the time it flows over a check-dam. Thus, the stabilizing stone apron on the downhill side of the check-dam may be designed as an extension of an infiltration trench. In this way, only filtered runoff will enter a subsurface infiltration trench, thereby reducing the threat of groundwater contamination by metals.

17. Culverts are typically used in a vegetated swale at driveway or road crossings. By oversizing culverts and their flow capacity, cold weather concerns (e.g. clogging with snow) are lessened.

18. Where grades limit swale slope and culvert size, trench drains may be used to cross driveways.

19. Swales should discharge to another structural BMP (bioretention, infiltration basin, constructed wetlands, etc.), existing stormwater infrastructure, or a stable outfall.

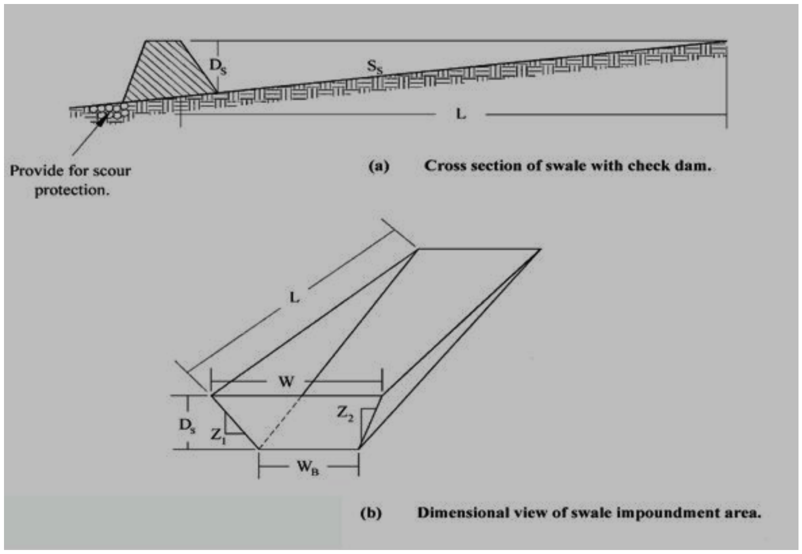
Detailed Stormwater Functions

Infiltration Area (if needed)

Volume Reduction Calculations

The volume retained behind each check-dam can be approximated from the following equation:

Storage Volume = 0.5 x Length of Swale Impoundment Area Per Check Dam x Depth of Check Dam x (Top Width of Check Dam + Bottom Width of Check Dam) / 2



Peak Rate Mitigation

See Chapter 8 for Peak Rate Mitigation methodology, which addresses link between volume reduction and peak rate control.

Water Quality Improvement

See Chapter 8 for Water Quality Improvement methodology, which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Begin vegetated swale construction only when the upgradient temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the Pennsylvania Department of Environmental Protection's *Erosion and Sediment Pollution Control Program Manual,* March 2000 or latest edition.)

2. Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

3. Construct check dams, if required.

4. Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

5. Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

6. Once all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving upland stormwater flow.

7. Follow maintenance guidelines, as discussed below.

   Note: If a vegetated swale is used for runoff conveyance during construction, it should be regraded and reseeded immediately after construction and stabilization has occurred. Any damaged areas should be fully restored to ensure future functionality of the swale.

Maintenance Issues

Compared to other stormwater management measures, the required upkeep of vegetated swales is relatively low. In general, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a dense vegetative cover. Experience has proven that proper maintenance activities ensure the functionality of vegetated swales for many years. The following schedule of inspection and maintenance activities is recommended:

Maintenance activities to be done annually and within 48 hours after every major storm event (> 1 inch rainfall depth):

- Inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when > 3 inches at any spot or covering vegetation)
- Inspect vegetation on side slopes for erosion and formation of rills or gullies, correct as needed
- Inspect for pools of standing water; dewater and discharge to an approved location and restore to design grade
- Mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation; dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting
- Inspect for litter; remove prior to mowing
- Inspect for uniformity in cross-section and longitudinal slope, correct as needed
- Inspect swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage, correct as needed

Maintenance activities to be done as needed:

- Plant alternative grass species in the event of unsuccessful establishment

- Reseed bare areas; install appropriate erosion control measures when native soil is exposed or erosion channels are forming

- Rototill and replant swale if draw down time is more than 48 hours

- Inspect and correct check dams when signs of altered water flow (channelization, obstructions, erosion, etc.) are identified

- Water during dry periods, fertilize, and apply pesticide **only when absolutely necessary**

Most of the above maintenance activities are reasonably within the ability of individual homeowners. More intensive swales (i.e. more substantial vegetation, check dams, etc.) may warrant more intensive maintenance duties and should be vested with a responsible agency. A legally binding and enforceable maintenance agreement between the facility owner and the local review authority might be warranted to ensure sustained maintenance execution. Winter conditions also necessitate additional maintenance concerns, which include the following:

- Inspect swale immediately after the spring melt, remove residuals (e.g. sand) and replace damaged vegetation without disturbing remaining vegetation.

- If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of deicing agents.

- Use nontoxic, organic deicing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.

- Use salt-tolerant vegetation in swales.

Cost Issues

As with all other BMPs, the cost of installing and maintaining Vegetated Swales varies widely with design variability, local labor/material rates, real estate value, and contingencies. In general, Vegetated Swales are considered relatively low cost control measures. Moreover, experience has shown that Vegetated Swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers. The following table compares the cost of a typical vegetated swale (15 ft top width) with the cost of traditional conveyance elements.

ot)			
Total Annual Cost (per linear foot)	$1 (from seed) $2 (from sod)	No data	No data
Lifetime (years	50		20

It is important to note that the costs listed above are strictly estimates and shall be used for design purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding (if required). The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) reported that actual costs, which do include these activities, may range from $8.50 to $50.00 per linear foot depending on swale depth and bottom width. When all pertinent construction activities are considered, it is still likely that the cost of vegetated swale installation is less than that of traditional conveyance elements. When annual operation and maintenance costs are considered however, swales may prove the more expensive option, though they typically have a much longer lifespan.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Swale Soil** shall be USCS class ML (Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity), SM (Silty sands, poorly graded sand-silt mixtures), SW (Well-graded sands, gravelly sands, little or no fines) or SC (Clayey sands, poorly graded sand-clay mixtures). The first three of these designations are preferred for swales in cold climates. In general, soil with a higher percent organic content is preferred.

2. **Swale Sand** shall be ASTM C-33 fine aggregate concrete sand (0.02 in to 0.04 in).

3. **Check dams** constructed of natural wood shall be 6 in to 12 in diameter and notched as necessary. The following species are acceptable: Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut. The following species are not acceptable, as they can rot over time: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, and Willow. An earthen **check dam** shall be constructed of sand, gravel, and sandy loam to encourage grass cover (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone **check dam** shall be constructed of R-4 rip rap, or equivalent.

4. Develop a native **planting mix**. (see Appendix B)

5. If infiltration trench is proposed, see BMP 6.4.4 Infiltration Trench for specifications.

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Attachment E8: BMP 6.6.3 Dry Extended Detention Basin

BMP 6.6.3: Dry Extended Detention Basin

A dry extended detention basin is an earthen structure constructed either by impoundment of a natural depression or excavation of existing soil, that provides temporary storage of runoff and functions hydraulically to attenuate stormwater runoff peaks. The dry detention basin, as constructed in countless locations since the mid-1970's and representing the primary BMP measure until now, has served to control the peak rate of runoff, although some water quality benefit accrued by settlement of the larger particulate fraction of suspended solids. This extended version is intended to enhance this mechanism in order to maximize water quality benefits.

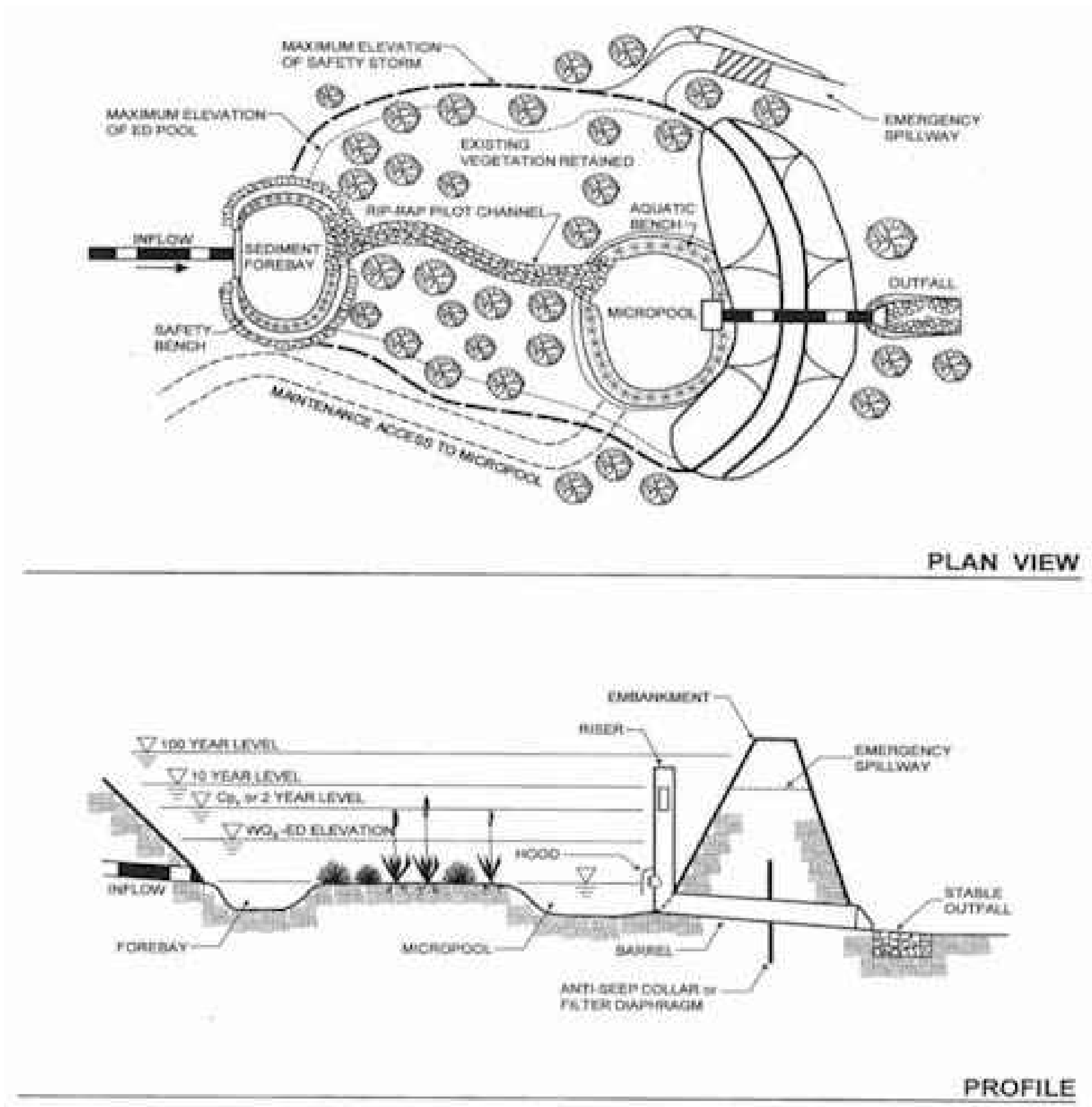
The basin outlet structure must be designed to detain runoff from the stormwater quality design storm for extended periods. Some volume reduction is also achieved in a dry basin through initial saturation of the soil mantle (even when compacted) and some evaporation takes place during detention. The net volume reduction for design storms is minimal, especially if the precedent soil moisture is assumed as in other volume reduction BMPs.

Key Design Elements	Potential Applications
▪ Evaluation of the device chosen should be balanced with cost ▪ Hydraulic capacity controls effectiveness ▪ Ideal in combination with other BMPs ▪ Regular maintenance is necessary including periodic sediment removal	Residential: Yes Commercial: Yes Ultra Urban: Yes Industrial: Yes Retrofit: Yes Highway/Road: Yes
	Stormwater Functions Volume Reduction: Low Recharge: None Peak Rate Control: High Water Quality: Low
	Water Quality Functions TSS: 60% TP: 40% NO3: 20%

Description

Dry extended detention basins are surface stormwater structures which provide for the temporary storage of stormwater runoff to prevent downstream flooding impacts. Water quality benefits may be achieved with extended detention of the runoff volume from the water quality design storm.

- The primary purpose of the detention basin is the attenuation of stormwater runoff peaks.
  - Detention basins should be designed to control runoff peak flow rates of discharge for the 1 year through 100 year events.
  - Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event.



- Basins should be designed to provide water quality treatment storage to capture the computed runoff volume of the water quality design storm.
  - Detention basins should have a sediment forebay or equivalent upstream pretreatment. The forebay should consist of a separate cell that is offline (so as to not resuspend sediment, formed by an acceptable barrier and will need periodic sediment removal.

- A micropool storage area should be designed where feasible for the extended detention of runoff volume from the water quality design storm.
- Flow paths from inflow points to outlets should be maximized.

Variations

Sub-surface extended detention

Extended detention storage can also be provided in a variety of sub-surface structural elements, such as underground vaults, tanks, large pipes or other structural media placed in an aggregate filled bed in the soil mantle. All such systems are designed to provide runoff peak rate mitigation as their primary function, but some pollutant removal may be included. Regular maintenance is needed, since the structure must be drained within a design period and cleaned to assure detention capacity for subsequent rainfall events. These facilities are usually intended for space-limited applications and are not intended to provide significant water quality treatment.

- Underground vaults are typically box shaped underground stormwater storage facilities constructed of reinforced concrete, while tanks are usually constructed of large diameter metal or plastic pipe. They may be situated within a building, but the use of internal space is frequently not cost beneficial.
  - Storage design and routing methods are the same as for surface detention basins.
  - Underground vaults and tanks do not provide water quality treatment and should be used in combination with a pretreatment BMP.

- Underground detention beds can be constructed by excavating a subsurface area and filling with uniformly graded aggregate for support of overlying land uses.
  - This approach may be used where space is limited but subsurface infiltration is not feasible due to high water table conditions or shallow soil mantle.
  - As with detention vaults and tanks, this facility provides minimal water quality treatment and should be used in combination with a pretreatment BMP.
  - It is recommended that underground detention facilities not be lined to allow for even minimal infiltration, except in the case where toxic contamination is possible.

Applications

- **Low Density Residential Development**
- **Industrial Development**
- **Commercial Development**
- **Urban Areas**

Design Considerations

1. **Storage Volume, Depth and Duration**

   a. Extended detention basins should be designed to mitigate runoff peak flow .rates.b. An emergency outlet or spillway which is capable of conveying the spillway design flood (SDF) should be included in the design. The SDF is usually equal to the 100-year design flood
   c. Extended detention basins should be designed to treat the runoff volume produced by the water quality design storm.

d. Extended Detention Basins are designed to achieve a specified detention time. Details on the detention time are outlined in Chapter 3.
e. The lowest elevation within an extended dry detention basin should be at least 2 feet above the seasonal high water table. If high water table conditions are anticipated, then the design of a wet pond, constructed wetland or bioretention facility should be considered.

2. **Dry Extended Detention Basin Location**

a. Extended detention basins should be located down gradient of disturbed or developed areas on the site. The basin should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.).
b. Extended detention basins should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
c. Extended detention basins should not worsen the runoff potential of the existing site by removal of trees for the purpose of installing a basin.
d. Extended detention basins should not be constructed in areas with high quality and/or well draining soils, which are adequate for the installation of BMPs capable of achieving stormwater infiltration.
e. Extended detention basins should not be constructed within jurisdictional waters, including wetlands.

3. **Basin Sizing and Configuration**

a. Basins should be shaped to maximize the length of stormwater flow pathways and minimize short-circuited inlet-outlet systems. Basins should have a minimum width of 10 feet. A minimum length-to-width ratio of 2:1 is recommended to maximize sedimentation.
b. Irregularly shaped basins are encouraged and appear more natural.
c. If site conditions inhibit construction of a long, narrow basin, baffles constructed from earthen berms or other materials can be incorporated into the pond design to "lengthen" the stormwater flow path. Care should be taken to ensure the design storage capacity is provided after baffle installation.
d. Low flow channels, if required, should always be vegetated with a maximum slope of 3 percent to encourage sedimentation. Alternatively, other BMPs may be considered such as wet ponds, constructed wetlands or bioretention.

4. **Embankments**

a. Embankments should be less than 15 feet in height and should have side slopes no steeper than 3:1 (H:V).
b. The basin should have a minimum freeboard of 1 foot above the SDF elevation.

5. **Inlet Structures**

a. Inlet structures to basin should not be submerged at the normal pool depth.
b. Erosion protection measures should be utilized to stabilize inflow structures and channels.

6. **Outlet Design**

   a. In order to meet designs storm requirements, dry extended detention basins should have a multistage outlet structure. Three elements are typically included in this design:
      1. A low-flow outlet that controls the extended detention and functions to slowly release the water quality design storm.
      2. A primary outlet that functions to attenuate the peak of larger design storms.
      3. An emergency overflow outlet/spillway
   b. The primary outlet structure should incorporate weirs, orifices, pipes or a combination of these to control runoff peak rates for required design storms. Water quality storage should be provided below the invert of the primary outlet. When routing basins, the low-flow outlet should be included in the depth-discharge relationship.
   c. Energy dissipaters are to be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.
   d. The orifice should typically be no smaller than 2.5 inches in diameter. However, the orifice diameter may be reduced to 1 inch if adequate protection from clogging is provided.
   e. The hydraulic design of all outlet structures should consider any tailwater effects of downstream waterways.
   f. The primary and low flow outlet should be protected from clogging by an external trash rack.

7. **Sediment Forebay**

   a. Forebays should be incorporated into the extended detention design. The forebay storage volume is included for the water quality volume requirement.
   b. Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays are typically constructed as shallow marsh areas and should adhere to the following design criteria:
      1. It is recommended that forebays have a minimum length of 10 feet.
      2. Storage should be provided to trap the anticipated sediment volume produced over a period of 2 years.
      3. Forebays should be protected from the erosive force of the inflow to prevent resuspension of previously collected sediment during large storms (typically constructed offline).

8. **Vegetation and Soils Protection**
    a. Care should be taken to prevent compaction of in situ soils in the bottom of the extended detention basin in order to promote healthy plant growth and to encourage infiltration. If soils compaction is not prevented during construction, soils should be restored as discussed in BMP 6.7.3 – Soils Amendment & Restoration.
    b. It is recommended that basin bottoms be vegetated in a diverse native planting mix to reduce maintenance needs, promote natural landscapes, and increase infiltration potential. Vegetation may include trees, woody shrubs and meadow/wetland herbaceous plants.
    c. Woody vegetation should not be planted on the embankments or within 25 feet of the emergency overflow spillway.
    d. Meadow grasses or other deeply rooted herbaceous vegetation is recommended on the interior slope of embankments.
    e. Fertilizers and pesticides should not be used.

9. **Special Design Considerations**
    a. Ponds that have embankments higher than 15 feet, have a drainage of more than 100 acres or will impound more that 50 acre-feet of runoff during the high-water condition will be regulated as dams by PADEP. The designer shall consult Pennsylvania Chapter 105 to determine which provisions may apply to the specific project in question.
    b. Extended detention ponds should not be utilized as recreation areas due to health and safety issues. Design features that discourage access are recommended.

Detailed Stormwater Functions

Peak Rate Mitigation

Inflow and discharge hydrographs should be calculated and routed for each design storm. Hydrographs should be based on a 24-hour rainfall event.

Water Quality Improvement

Water quality mitigation is partially achieved by retaining the runoff volume from the water quality design storm for a minimum prescribed period as specified in Chapter 3. Sediment forebays should be incorporated into the design to improve sediment removal. The storage volume of the forebay may be included in the calculated storage of the water quality design volume.

Construction Sequence

1. Install all temporary erosion and sedimentation controls.
    a. The area immediately adjacent to the basin must be stabilized in accordance with the PADEP's *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to basin construction.
2. Prepare site for excavation and/or embankment construction.
    a. All existing vegetation should remain if feasible and should only be removed if necessary for construction.
    b. Care should be taken to prevent compaction of the basin bottom.
    c. If excavation is required, clear the area to be excavated of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area
3. Excavate bottom of basin to desired elevation (if necessary).
4. Install surrounding embankments and inlet and outlet control structures.
5. Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.
6. Apply and grade planting soil.
7. Apply geo-textiles and other erosion-control measures.
8. Seed, plant and mulch according to Planting Plan
9. Install any anti-grazing measures, if necessary.

Maintenance Issues

Maintenance is necessary to ensure proper functionality of the extended detention basin and should take place on a quarterly basis. A basin maintenance plan should be developed which includes the following measures:

- All basin structures expected to receive and/or trap debris and sediment should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than 1 inch.
    - Structures include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment removal should be conducted when the basin is completely dry. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and revegetated.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus should be removed from the basin.
    - Vegetated areas should be inspected annually for erosion.
    - Vegetated areas should be inspected annually for unwanted growth of exotic/invasive species.
    - Vegetative cover should be maintained at a minimum of 95 percent. If vegetative cover has been reduced by 10%, vegetation should be reestablished.

Cost Issues

The construction costs associated with dry extended detention basins can range considerably. One recent study evaluated the cost of all pond systems (Brown and Schueler, 1997). Before adjusting for inflation from 1997, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

Where:

C = Construction, Design and Permitting Cost
V = Volume needed to control the 10-year storm (cubic feet)
Using this equation, a typical construction costs (1997) are:
$ 41,600 for a 1 acre-foot pond
$ 239,000 for a 10 acre-foot pond
$ 1,380,000 for a 100 acre-foot pond

Dry extended detention basins utilizing highly structural design features (rip-rap for erosion control, etc.) are more costly than naturalized basins. There is an installation cost savings associated with a natural vegetated slope treatment which is magnified by the additional environmental benefits provided. Long-term maintenance costs are reduced when more naturalized approaches are utilized due to the ability of native vegetation to adapt to local weather conditions and a reduced need for maintenance, such as mowing and fertilization.

Normal maintenance costs can be expected to range form 3 to 5 percent of the construction costs on an annual basis.

These costs don't include the cost or value of the property.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Site Preparation**
   a. All excavation areas, embankments, and where structures are to be installed shall be cleared and grubbed as necessary, but trees and existing vegetation should be retained and incorporated within the dry detention basin area where possible.
   b. Where feasible, trees and other native vegetation should be protected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow construction.
   c. Any cleared material should be used as mulch for erosion control or soil stabilization.
   d. Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

2. **Earth Fill Material & Placement**
   a. The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, or other

objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.

b. Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum 8-inch lifts. The principal spillway should be installed concurrently with fill placement and not excavated into the embankment.
c. The movement of the hauling and spreading equipment over the site should be controlled. For the embankment, each lift should be compacted to 95% of the standard proctor. Fill material should contain sufficient moisture so that if formed in to a ball it will not crumble, yet not be so wet that water can be squeezed out.

3. **Embankment Core**
   a. The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1 to 1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
4. **Structure Backfill**
   a. Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
   b. Structure backfill may be flowable fill meeting the requirements of the PADOT Standard Specifications for Construction. Material should be placed so that a minimum of 6 inches of flowable fill should be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill material should be 7 inches to assure flowability of the mixture. Adequate measures should be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill all metal pipe should be bituminous coated. Adjoining soil fill should be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment.
   c. Refer to Chapter 220 0f PennDot Pub. 408 (2000).

5. **Rock Riprap**
   a. Rock riprap should meet the requirements of Pennsylvania Department of Transportation Standard Specifications.

6. **Stabilization**
   a. All borrow areas should be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms should be stabilized by seeding, planting and mulching.

7. **Operation and Maintenance**
   a. An operation and maintenance plan in accordance with Local or State Regulations will be prepared for all basins. As a minimum, a dam and inspection checklist should be included as part of the operation and maintenance plan and performed at least annually.

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Attachment E9: Expert Panel - Stream Restoration

Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects

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Dave Goerman, Natalie Hardman, Sujay Kaushal, Dan Medina, Matt Meyers, Bob Kerr,
Steve Stewart, Bettina Sullivan, Robert Walter and Julie Winters

Accepted by Urban Stormwater Work Group (USWG): **February 19, 2013**
Approved by Watershed Technical Work Group (WTWG): **April 5, 2013**
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Test-Drive Revisions Approved by the USWG : **January 17, 2014**
Test-Drive Revisions Approved by the WTWG: August 28, 2014
Test-Drive Revisions Approved by the WQGIT: September 8, 2014

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Table of Contents

List of common acronyms used throughout the text:

BANCS	Bank Assessment for Nonpoint Source Consequences of Sediment
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CBWM	Chesapeake Bay Watershed Model
GIS	Geographic Information Systems
IBI	Index of Biotic Integrity
lf	Linear feet
LSR	Legacy Sediment Removal
MS4	Municipal Separate Storm Sewer System
NBS	Near Bank Stress
NCD	Natural Channel Design
RR	Runoff Reduction
RTVM	Reporting, Tracking, Verification and Monitoring
RSC	Regenerative Stormwater Conveyance
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WIP	Watershed Implementation Plan
WQGIT	Water Quality Group Implementation Team

WTWG	Watershed Technical Work Group

Summary of Panel Recommendations

Over the last few decades, the Chesapeake Bay states have pioneered new techniques to restore urban streams using diverse approaches such as natural channel design, regenerative stormwater conveyance, and removal of legacy sediments. In the future, several Bay states are considering greater use of stream restoration as part of an overall watershed strategy to meet nutrient and sediment load reduction targets for existing urban development under the Chesapeake Bay TMDL.

The Panel conducted an extensive review of recent research on the impact of stream restoration projects in reducing the delivery of sediments and nutrients to the Bay. A majority of the Panel decided that the past practice of assigning a single removal rate for stream restoration was not practical or scientifically defensible, as every project is unique with respect to its design, stream order, landscape position and function.

Instead, the Panel elected to craft four general protocols to define the pollutant load reductions associated with individual stream restoration projects.

> *Protocol 1: Credit for Prevented Sediment during Storm Flow* -- This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.
>
> *Protocol 2: Credit for Instream and Riparian Nutrient Processing during Base Flow* -- This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow within the stream channel through hyporheic exchange within the riparian corridor.
>
> *Protocol 3: Credit for Floodplain Reconnection Volume*-- This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events.
>
> *Protocol 4: Credit for Dry Channel Regenerative Stormwater Conveyance (RSC) as an Upland Stormwater Retrofit*-- This protocol provides an annual nutrient and sediment reduction *rate* for the contributing drainage area to a qualifying dry channel RSC project. The rate is determined by the degree of stormwater treatment provided in the upland area using the retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel.

The protocols are additive, and an individual stream restoration project may qualify for credit under one or more of the protocols, depending on its design and overall restoration approach however the WTWG recommends that the aggregate load reductions from a practice should not exceed estimated loads in the Watershed Model for any given land-river segment. These approaches are based on the best available data as of November 2013.

Summary of Stream Restoration Credits for Individual Restoration Projects [1, 2]					
Protocol	*Name*	*Units*	*Pollutants*	*Method*	*Reduction Rate*
1	Prevented Sediment (S)	Pounds per year	Sediment TN, TP	Define bank retreat using BANCS or other method	Measured N/P content in streambed and bank sediment
2	Instream Denitrification (B)	Pounds per year	TN	Define hyporheic box for reach	Measured unit stream denitrification rate
3	Floodplain Reconnection (S/B)	Pounds per year	Sediment TN, TP	Use curves to define volume for reconnection storm event	Measured removal rates for floodplain wetland restoration projects
4	Dry Channel RSC as a Retrofit (S/B)	Removal rate	Sediment TN, TP	Determine stormwater treatment volume	Use adjustor curves from retrofit expert panel

[1] Depending on project design, more than one protocol may be applied to each project, and the load reductions are additive.
[2] Sediment load reductions are further reduced by a sediment delivery ratio in the CBWM (which is not used in local sediment TMDLs)
S: applies to stormflow conditions, B: applies to base flow or dry weather conditions

The report also includes examples to show users how to apply each protocol in the appropriate manner. In addition, the Panel recommended several important qualifying conditions and environmental considerations for stream restoration projects to ensure they produce functional uplift for local streams. *Historic projects and new projects that cannot conform to recommended reporting requirements as described in Section 7.1 may be able to receive credit through a revised interim rate which will be referred to as the default rate (Table 3, Row 3). Refer to Section 2.4 for additional details.*

The Panel recognizes that the data available at this time does not allow a perfect understanding or prediction of stream restoration performance. As a result, the Panel also stressed that verification of the initial and long term performance of stream restoration projects is critical to ensure that projects are functioning as designed. To this end, the Panel recommends that the stream restoration credits be limited to 5 years, although the credits can be renewed based on a field inspection that verifies the project still exists, is adequately maintained and is operating as designed and the critical assumptions (e.g., upstream hydrology) used in the protocols haven't changed.

Important Disclaimer: The Panel recognizes that stream restoration projects as defined in this report may be subject to authorization and associated requirements from federal, State, and local agencies. The recommendations in this report are not intended to supersede any other requirements or standards mandated by other government authorities. Consequently, some stream restoration projects may conflict with other regulatory requirements and may not be suitable or authorized in certain locations.

Section 1: Charge and Membership of the Expert Panel

Expert BMP Review Panel for Urban Stream Restoration	
Panelist	***Affiliation***
Deb Cappuccitti	Maryland Department of Environment
Bob Kerr	Kerr Environmental Services (VA)
Matthew Meyers, PE	Fairfax County (VA) Department of Public Works and Environmental Services
Daniel E. Medina,Ph.D, PE	Atkins (MD)
Joe Berg	Biohabitats (MD)
Lisa Fraley-McNeal	Center for Watershed Protection (MD)
Steve Stewart	Baltimore County Dept of Environmental Protection and Sustainability (MD)
Dave Goerman	Pennsylvania Department of Environmental Protection
Natalie Hardman	West Virginia Department of Environmental Protection
Josh Burch	District Department of Environment
Dr. Robert C. Walter	Franklin and Marshall College
Dr. Sujay Kaushal	University of Maryland
Dr. Solange Filoso	University of Maryland
Julie Winters	US Environmental Protection Agency CBPO
Bettina Sullivan	Virginia Department of Environmental Quality
Panel Support	
Tom Schueler Bill Stack	Chesapeake Stormwater Network (facilitator) Center for Watershed Protection (co-facilitator)
Other Panel Support: Russ Dudley – Tetra Tech, Debra Hopkins – Fish and Wildlife Service, Molly Harrington, CBP CRC, Norm Goulet, Chair Urban Stormwater Work Group, Gary Shenk, EPA CBPO, Jeff Sweeney, EPA CBPO, Paul Mayer, EPA ORD	

The initial charge of the Panel was to review all of the available science on the nutrient and sediment removal performance associated with qualifying urban stream restoration projects in relation to those generated by degraded urban stream channels.

The Panel was specifically requested to:

- Provide a specific definition of what constitutes effective stream restoration in the context of any nutrient or sediment reduction credit, and define the qualifying conditions under which a local stream restoration project may be eligible to receive the credit.

- Assess whether the existing Chesapeake Bay Program-approved removal rate is suitable for qualifying stream restoration projects, or whether a new protocol needs to be developed to define improved rates. In doing so, the Panel was asked to consider project specific factors such as physiographic region, landscape position, stream order, type of stream restoration practices employed and upstream or subwatershed conditions.

- Define the proper units that local governments will use to report retrofit implementation to the states to incorporate into the Chesapeake Bay Watershed Model (CBWM).

Beyond this specific charge, the Panel was asked to;

- Determine whether to recommend that an interim removal rate be established for one or more classes of stream restoration practices prior to the conclusion of the research for Watershed Implementation Plan (WIP) planning purposes.

- Recommend procedures for reporting, tracking, and verifying any recommended stream restoration credits over time.

- Critically analyze possible unintended consequences associated with the credit and the potential for over-counting of the credit, with a specific reference to any upstream BMPs installed.

While conducting its review, the Panel followed the procedures and process outlined in the Water Quality Goal Implementation Team (WQGIT) BMP review protocol (WQGIT, 2012). The process begins with BMP Expert Panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup (USWG), the Watershed Technical Workgroup (WTWG) and the WQGIT to ensure they are accurate and consistent with the CBWM framework. Given the implications for stream habitat and wetland permitting, the panel recommendations will also be forwarded to both the Restoration and Habitat GITs for their independent review.

Appendix D documents the process by which the Expert Panel reached consensus, in the form of five meeting minutes that summarize their deliberations. Appendix E documents how the Panel satisfied the requirements of the BMP review protocol. Although not reflected in the minutes, there were several conversations, email exchanges, and edits to the drafts from Panel members that are not reflected in the minutes.

Section 2: Stream Restoration in the Chesapeake Bay

Section 2.1
Urbanization, Stream Quality and Restoration

Declining stream quality in the Chesapeake Bay watershed is a function of historic land use and present day urbanization. Historic land use included land clearing for agricultural development, subsequent reforestation in the 20th century, low-head dam construction, and widespread stream channel straightening/relocation (Knox, 1972; Pizzuto et al., 2000; Merritts et al., 2011). A significant amount of sediment is stored in Piedmont floodplains that was delivered from accelerated erosion during historical land clearing and subsequent upland erosion (Trimble, 1974; Costa, 1975; Jacobson and Coleman, 1986). In addition, present day urbanization has led to stream quality decline, as documented by considerable research over the last two decades in the Chesapeake Bay watershed. Declines in hydrologic, morphologic, water quality and biological indicators have been associated with increased watershed impervious cover (Paul and Mayer, 2001; Schueler et al., 2009). For example, Cianfrani et al. (2006) documented the relationship between impervious cover and degraded channel morphology in 46 urbanizing streams in southeast Pennsylvania.

Further research has shown increased rates of channel erosion and sediment yield in urbanizing streams (Trimble, 1997; Booth and Henshaw, 2001; Langland and Cronin, 2003; Allmendinger et al., 2007; Fraley et al., 2009). Other common impacts associated with urbanization are the hydrologic and hydraulic disconnection of the stream from its floodplain (Groffman et al., 2003), simplification of instream habitat, loss of riparian cover, and loss of diversity in aquatic life indicators.

The effect of urbanization on stream health also diminishes the functional capacity of streams to retain both sediments and nutrients. For example, sediment yields are more than an order of magnitude higher in urban streams compared to rural ones (Langland and Cronin, 2003). Floodplain and channel soils largely derived from historic land clearing practices are highly enriched with respect to nutrients as a result of past soil erosion and subsequent alluvial and colluvial deposition in the stream valley (Merritts et al., 2011). Similarly, stream nitrate levels rise sharply at low levels of urbanization and remain high across greater levels of urbanization (Morgan and Kline, 2010). Other research has shown that degraded streams and disconnected floodplains have less capacity for internal nutrient uptake and processing, particularly with respect to denitrification (Lautz and Fannelli, 2008; Kaushal et al., 2008; Klocker et al., 2009).

In 2008, the Chesapeake Bay Program's Sediment Work Group organized an information exchange workshop entitled "*Fine Sediment and the Chesapeake Bay Watershed" (*Smith et al., 2008) to identify the key knowledge gaps in watershed sediment modeling, monitoring and assessment and to identify the most effective BMPs for reducing fine sediment loads to the Chesapeake Bay. The workshop participants were comprised of watershed managers, scientists, regulators, engineers, and environmental restoration professionals. The conclusions from the workshop are that while much progress has been made in understanding the origins, transport, and fate of sediment, there is no consensus for immediate tools to make quantifiable progress towards improving Chesapeake Bay goals.

Despite this lack of consensus, watershed managers are continuing the widespread implementation of stream restoration to meet local water quality goals and will rely heavily on stream restoration as an important tool in meeting the water quality goals of the WIPs. It is therefore critical to develop a consistent set of protocols that managers can use throughout the Chesapeake Bay watershed that can be adapted as better information becomes available. Stream restoration projects that reduce bank erosion and create in-stream habitat features are a useful strategy as part of a comprehensive watershed approach to reduce sediment and nutrient export from urban and non-urban watersheds. In Section 3, the Panel analyzed the available evidence to define the functional benefits of restored versus non-restored streams.

It is important to note that watersheds can only be comprehensively restored by installing practices in upland areas, the stream corridor, and in appropriate settings, within the stream itself. The CBP currently has completed or launched a half dozen expert panels on urban BMPs, most of which are applied to upland areas, with the goal of providing a wide range of watershed tools to meet restoration goals.

Section 2.2
Stream Restoration Definitions

The discipline of stream restoration has spawned many different terms and nomenclature; therefore, the Panel wanted to precisely define the terms that are employed within this report.

Floodplain – For flood hazard management purposes, floodplains have traditionally been defined as the extent of inundation associated with the 100-year flood, which is a flooding event that has a one-percent probability of being equaled or exceeded in any one year[1]. However, in the context of this document, floodplains are defined as relatively flat areas of land between the stream channel and the valley wall that will receive excess storm flows when the channel capacity is exceeded. Therefore, water accesses the floodplain thus defined much more frequently than what is typically considered a flooding event.

[1] Floodplain management agencies use the term one-percent-annual chance to define this event, in part to dispel the misconception that the 100-year flood occurs once every 100 years. In this report, return periods instead of probabilities are used for convenience.

Floodplain Reconnection Volume - This term quantifies the benefit that a given project may provide in terms of bringing streamflow in contact with the floodplain. The Floodplain Reconnection Volume is the additional annual volume of stream runoff and base flow from an upstream subwatershed that is effectively diverted onto the available floodplain, riparian zone, or wetland complex, over the pre-project volume. The volume is usually calculated using a series of curves provided in this report to convert unit rainfall depth thresholds in the contributing watershed to an effective annual volume expressed in watershed-inches.

Functional Uplift - A general term for the ability of a restoration project in a degraded stream to recover hydrologic, hydraulic, geomorphic, physiochemical, or biological indicators of healthy stream function.

Hyporheic Zone - The hyporheic zone is defined as the region below and alongside a stream, occupied by a porous medium where there is an exchange and mixing of shallow groundwater and the surface water in the channel. The dimensions of the hyporheic zone are defined by the hydrology of the stream, substrate material, its surrounding environment, and local groundwater sources. This zone has a strong influence on stream ecology, biogeochemical cycling, and stream water temperatures.

Legacy Sediment - Sediment that (1) was eroded from uplands during several centuries of land clearing, agriculture and other intensive uses; (2) accumulated behind ubiquitous dams in slackwater environments, resulting in thick accumulations of cohesive clay, silt and sand, which distinguishes "legacy sediment" from fluvial deposits associated with meandering streams; (3) collected along stream corridors and within valley bottoms, effectively burying natural floodplains, streams and wetlands; (4)altered and continues to impair the morphologic, hydrologic biologic, riparian and other ecological services and functions of aquatic resources; (5) can also accumulate as coarser grained more poorly sorted colluvial deposits, usually at valley margins; (6) can contain varying amounts of nutrients that can generate nutrient export via bank erosion processes. Widespread indicators of legacy sediment impairment include a history of damming, high banks and degree of channel incision, rapid bank erosion rates and high sediment loads. Other indicators include low channel pattern development, infrequent inundation of the riparian zone, diminished sediment storage capacity, habitat degradation, and lack of groundwater connection near the surface of the floodplain and/or riparian areas.

Legacy Sediment Removal (LSR) - A class of aquatic resource restoration that seeks to remove legacy sediments and restore the natural potential of aquatic resources including a combination of streams, floodplains, and palustrine wetlands. Although several LSR projects have been completed, the major experimental site was constructed in 2011 at Big Spring Run near Lancaster, PA. For additional information on the research project, consult Hartranft (2011).

Natural Channel Design (NCD) - Application of fluvial geomorphology to create stable channels that maintain a state of dynamic equilibrium among water, sediment, and vegetation such that the channel does not aggrade or degrade over time. This class of stream restoration utilizes data on current channel morphology, including stream cross section, plan form, pattern, profile, and sediment characteristics for a stream classified according to the Rosgen (1996) classification scheme, but which may be modified to meet the unique constraints of urban streams as described in Doll et al. (2003).

Non-Urban - A subwatershed with less than 5% impervious cover, and is primarily composed of forest, agricultural or pasture land uses. Individual states may have alternative definitions.

Prevented Sediment - The annual mass of sediment and associated nutrients that are retained by a stable, restored stream bank or channel that would otherwise be eroded and delivered downstream in an actively enlarging or incising urban stream. The mass of prevented sediment is estimated using the field methods and desktop protocols presented later in this document.

Project Reach - the length of an individual stream restoration project as measured by the valley length (expressed in units of feet). The project reach is defined as the specific work areas where stream restoration practices are installed.

Regenerative Stormwater Conveyance (RSC) - Refers to two specific classes of stream restoration as defined in the technical guidance developed by Flores (2011) in Anne Arundel County, Maryland. The RSC approach has also been referred to as coastal plain outfalls, regenerative step pool storm conveyance, base flow channel design, and other biofiltration conveyance. For purposes of this report, there are two classes of RSC: dry channel and wet channel.

> *Dry channel RSC* involves restoration of ephemeral streams or eroding gullies using a combination of step pools, sand seepage wetlands, and native plants. These applications are often located at the end of storm drain outfalls or channels. The receiving channels are dry in that they are located above the water table and carry water only during and immediately after a storm event. The Panel concluded that dry channel RSC should be classified as a stormwater retrofit practice rather than a stream restoration practice.
>
> *Wet channel RSCs* can be located in intermittent streams, but are more typically located farther down the perennial stream network and use instream weirs to spread storm flows across the floodplain at minor increases in the stream stage for events much smaller than the 1.5-year storm event, which has been traditionally been assumed to govern stream geomorphology and channel capacity. Wet channel RSC may also include sand seepage wetlands or other wetland types in the floodplain that increase floodplain connection, reconnection, or interactions with the stream.

Stream Restoration - Refers to any NCD, RSC, LSR or other restoration project that meets the qualifying conditions for credits, including environmental limitations and stream functional improvements. The Panel did not have a basis to suggest that any single design approach was superior, as any project can fail if it is inappropriately located, assessed, designed, constructed, or maintained.

Upland Restoration - The implementation of best management practices outside the stream corridor to reduce runoff volumes and pollutant loads in order to restore the quality of streams and estuaries.

Urban - Generally a subwatershed with more than 5% impervious cover, although individual states may have their own definition.

Section 2.3
Derivation of the Original Chesapeake Bay Program-Approved Rate for Urban Stream Restoration

The original nutrient removal rate for stream restoration projects was approved by CBP in 2003, and was based on a single monitoring study conducted in Baltimore County, Maryland (Stewart, 2008). The Spring Branch study reach involved 10,000 linear feet of stream restoration located in a 481-acre subwatershed that primarily consisted of medium density residential development. The project applied natural channel design techniques as well as 9.7 acres of riparian reforestation.

The original monitoring effort encompassed two years prior to the project and three years after it was constructed. The preliminary results were expressed in terms of pounds reduced per linear foot and these values were subsequently used to establish the initial CBP-approved rate, as shown in Table 1 and documented in Simpson and Weammert (2009).

Table 1. Edge-of-Stream CBP-Approved Removal Rates per Linear foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS
Spring Branch N=1	0.02	0.0035	2.55
See also: Simpson and Weammert (2009)			

Baltimore County continued to monitor the Spring Branch site for seven years following restoration and recomputed the sediment and nutrient removal rates for the project reach (Stewart, 2008). Both the nutrient and sediment removal rates increased when the longer term monitoring data were analyzed, regardless of whether they were expressed per linear foot or as a percent reduction through the project reach (see Table 2).

Table 2. Revised Removal Rates per Linear foot for Spring Branch, Based on Four Additional Years of Sampling and Data Re-Analysis (lb/ft/yr)

Source	TN	TP	TSS

Spring Branch N=1	0.227	0.0090	3.69
% Removal in Reach	42%	43%	83%
Source: Stewart (2008) and Steve Stewart presentation to Expert Panel 1/25/2012			

In the last few years, the rates shown in Table 1 have been applied to non-urban stream restoration projects, presumably because of a lack of research on nutrient uptake and sediment removal for restoration projects located in rural or agricultural areas. As a result, the CBWM, Scenario Builder, and CAST all now include non-urban stream restoration rates equal to the urban values in Table 1. The Panel was not able to document when the informal decision was made by the CBP to apply the interim urban stream restoration rate to non-urban stream restoration projects. The Panel recommendations for addressing non-urban stream restoration projects are provided in Section 4.5 of this document.

Section 2.4
Derivation of the New Default CBP-Approved Rate

Since the first stream restoration estimate was approved in 2003, more research has been completed on the nutrient and sediment dynamics associated with urban stream restoration. These studies indicated that the original credit for stream restoration was too conservative.

Chesapeake Stormwater Network (CSN) (2011) proposed a revised interim credit that was originally developed by the Baltimore Department of Public Works (BDPW, 2006). This credit included five additional unpublished studies on urban stream erosion rates located in Maryland and southeastern Pennsylvania. These additional studies were found to have substantially higher erosion rates than those originally measured at Spring Branch (Table 3).

The rationale of using the Baltimore City data review as the interim rate is based on the assumption that the higher sediment and nutrient export rates are more typical of urban streams undergoing restoration. The Commonwealth of Virginia requested that the higher rate in Table 3 be accepted as a new interim rate in December of 2011, and EPA Chesapeake Bay Program Office (CBPO) approved the rate in January 2012, pending the outcome of this Expert Panel. The Watershed Technical Work Group decided in their April 1, 2013 meeting as part of their review of this report that the interim rate will be used as a default rate and will apply to historic projects and new projects that cannot conform to recommended reporting requirements as described in Section 7.1. As a result of the 6-month Test Drive, several projects resulted in excessively high removal rates when using the default rate, in some cases exceeding the watershed loading estimates. Further review of the studies used to develop the interim rate revealed that a 50% restoration efficiency was applied to the rate for TP, but not to the TN and TSS rates. The Expert Panel met to discuss this and the other observations from the 6-month test drive and determined the default rate should be adjusted for TN and TSS to make it consistent with TP. The only known study with TN and TSS removal efficiencies associated with stream restoration is Spring Branch (Stewart, 2008) in Baltimore County. The Panel felt the efficiencies from this study should be applied to the default rate (37.5% for TN and 80% for TSS; Table 3, Row 3). Additional information about the revised default rate is provided in Appendix G.

Table 3. Edge-of-Stream 2011 Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS*
Interim CBP Rate	0.20	0.068	56.11
Revised Default Rate	**0.075**	**0.068**	**44.88 non-coastal plain** **15.13 coastal plain**

Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania
*To convert edge of field values to edge of stream values a sediment delivery ratio (SDR) was applied to TSS. The SDR was revised to distinguish between coastal plain and non-coastal plain streams. The SDR is 0.181 for non-coastal plain streams and 0.061 for coastal plain streams. Additional information about the sediment delivery ratio is provided in Section 2.5 and Appendix B.

At its January 25, 2012 research workshop, the Panel concluded that there was no scientific support to justify the use of a single rate for all stream restoration projects (i.e., the lb/ft/yr rates shown in Tables 2 and 3). Sediment and nutrient load reductions will always differ, given the inherent differences in stream order, channel geometry, landscape position, sediment dynamics, restoration objectives, design philosophy, and quality of installation among individual stream restoration projects. Instead, the Panel focused on predictive methods to account for these factors, using various watershed, reach, cross-section, and restoration design metrics.

The Panel acknowledges that the new stream restoration removal rate protocols may not be easily integrated into existing CBP BMP assessment and scenario builder tools used by states and localities to evaluate options for watershed implementation plans (i.e., MAST, CAST, VAST and Scenario Builder). This limitation stems from the fact that each recommended protocol has its own removal rate, whereas the CBP tools apply a universal rate to all stream restoration projects.

Local watershed planners will often need to compare many different BMP options within their community. In the short term, the Panel recommends that CBP watershed assessment tools use the revised default rate (Table 3, Row 3) for general watershed planning purposes. It should be noted that sediment removals will be reduced due to the sediment delivery ratio employed by the CBWM (see Section 2.5).

Over the long term, the Panel recommends that the WTWG develop a more robust average removal rate for planning purposes, based on the load reductions achieved by stream restoration projects reported to the states using the new reporting protocols.

Section 2.5
How Sediment and Nutrients are Simulated in the Chesapeake Bay Watershed Model

It is important to understand how sediment and nutrients are simulated in the context of the CBWM to derive representative stream restoration removal rates that are consistent with the scale and technical assumptions of the model. The technical documentation for how sediment loads are simulated and calibrated for urban pervious and impervious lands in the CBWM can be found in Section 9 and the documentation for nutrients can be found in Section 10 of U.S. EPA (2010). The following paragraphs summarize the key model assumptions that the Panel reviewed.

The scale at which the CBWM simulates sediment dynamics corresponds to basins that average about 60 to 100 square miles in area. The model does not explicitly simulate the contribution of channel erosion to enhanced sediment/nutrient loadings for smaller 1st, 2nd, and 3rd order streams not included as part of the CBWM reach network (i.e., between the edge-of-field and edge-of-stream), that is, scour and deposition with the urban stream channel network with these basins are not modeled.

Due to the scale issue, the CBWM indirectly estimates edge-of-stream sediment loads as a direct function of the impervious cover in the contributing watershed. The empirical relationships between impervious cover and sediment delivery for urban watersheds in the Chesapeake Bay were established from data reported by Langland and Cronin (2003), which included SWMM Model estimated sediment loads for different developed land use categories. A percent impervious was assigned to the land use categories to form a relationship between the degree of imperviousness and an associated sediment load (Figure 1).

The CBWM operates on the assumption that all sediment loads are edge-of-field and that transport and associated losses in overland flow and in low-order streams decrement the sediment load to an edge-of-stream input. The sediment loss between the edge-of-field and edge-of-stream is incorporated into the CBWM as a sediment delivery ratio. The SDF for each land use in a river segment is determined by the average distance that land use is away from the main river simulated in the river reach..
The ratio is multiplied by the predicted edge-of-field erosion rate to estimate the eroded sediments actually delivered to a specific reach.

Riverine transport processes are then simulated by HSPF as a completely mixed reactor at each time step of an hour to obtain the delivered load. Sediment can be deposited in a reach, or additional sediment can be scoured from the bed, banks, or other sources of stored sediment throughout the watershed segment. Depending on the location of the river-basin segment in the watershed and the effect of reservoirs, as much as 70 to 85%

of the edge-of-field sediment load is deposited before it reaches the tidal waters of the Bay (U.S. EPA, 2010).

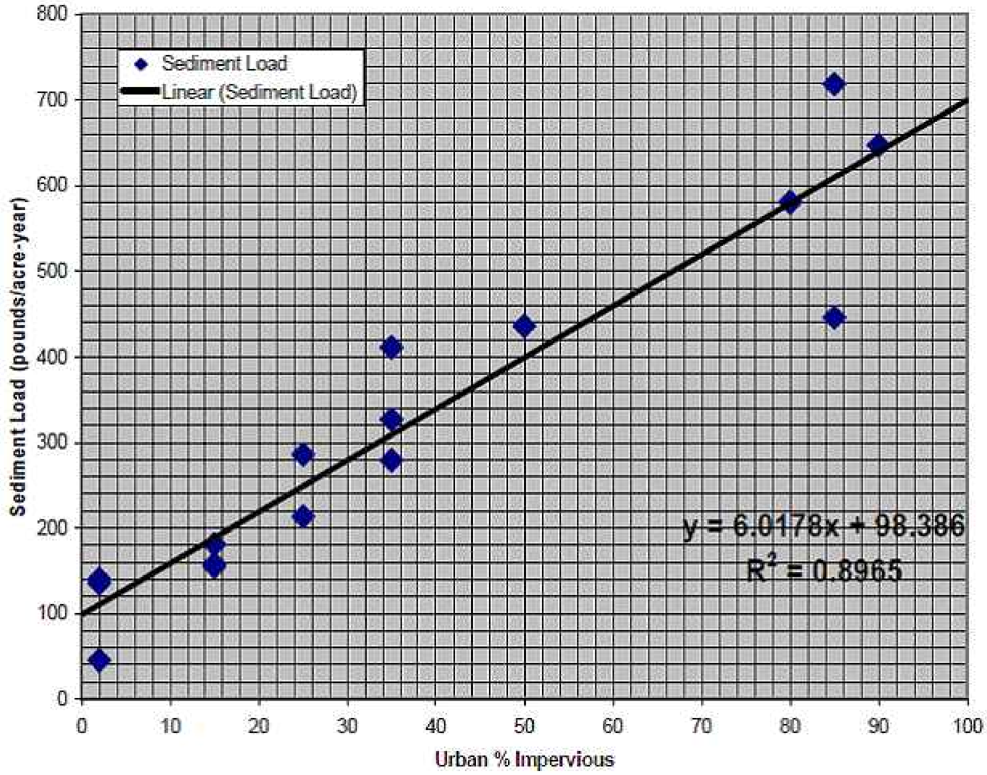


Figure 1. Relationship between Edge-of-Stream Urban Sediment Loads and Watershed Impervious Cover (Source: Langland and Cronin, 2003).

This means there will be a strong scale effect associated with any estimate of urban stream restoration removal rates, that is, a higher rate that occurs locally at the project reach compared with a lower rate for the sediment that actually reaches the Bay. Therefore, stream restoration projects may be much more effective in addressing local sediment impairments (i.e. TMDLs) than at the Chesapeake Bay scale.

Urban nutrient loads are modeled by build-up and wash-off from impervious areas and export in surface runoff, interflow, and groundwater flow from pervious land (see Section 10 in U.S. EPA, 2010). The unit area loading rates from both types of urban land are then checked to see if they correspond to loading targets derived from the literature. The resulting edge of stream nutrient loads for both urban and impervious areas are calibrated to monitoring data at the river-basin segment scale, and may be subject to regional adjustment factors and reductions due to presence of urban BMPs.

Unlike sediment, nutrients are simulated as being directly delivered to the edge of stream. Losses due to denitrification are not explicitly simulated for the smaller 1st, 2nd, and 3rd order streams not included as part of the CBWM reach network (i.e., between the edge-of-field and edge-of-stream). The edge-of-field nutrient loads and the delivery to the edge-of-stream are not specified in the model.

The fact that nutrients and sediment loads are simulated independently in the CBWM somewhat complicates the assessment of the effect of urban stream restoration on reducing them for several reasons. As previously noted, there are currently no mechanisms in the CBWM to adjust model parameters to account for enhanced instream nutrient uptake and/or denitrification associated with stream restoration. Additionally, there are no mechanisms in the model to account for the delivery of nutrients attached to sediments from eroding stream banks of small order streams. Lastly, the CBWM does not account for the interaction of the stream network with its floodplain, particularly with respect to nutrient and sediment dynamics in groundwater or during flood events.

Due to the preceding CBWM model limitations, the Panel decided that the effect of stream restoration could only be modeled as a mass load reduction for each individual restoration project at the river basin segment scale. The Panel also recommended several important model refinements for the 2017 CBWM revisions that could improve the simulation of urban streams and their unique sediment and nutrient dynamics. These recommendations can be found in Section 8.4. Furthermore, the WTWG recommended that nutrient attenuation within the stream network be characterized, if adequate literature supports such an effort, prior to the Phase 6 Model.

Section 2.6
Stream Restoration in Phase 2 Watershed Implementation Plans

Stream restoration appears to be a significant strategy for many Bay states to achieve their load reduction targets over the next 15 years, according to a review of individual state WIPs submitted to EPA in 2012 (Table 4). As can be seen, 655 stream miles of urban and non-urban stream restoration are anticipated by the year 2025, with most of the mileage projected for Maryland.

It should be noted that state WIPs are general planning estimates of the type and nature of BMPs being considered for implementation. The actual construction of stream restoration projects in the future, however, will largely depend on the watershed implementation plans being developed by local governments, and their ability to secure funding and environmental permits. Consequently, the mileage of future stream restoration is difficult to forecast.

Given that the proposed level of future stream restoration represents about 0.7% of the estimated 100,000 miles of perennial streams in the Bay watershed, the Panel was extremely mindful of the potential environmental consequences of poorly designed practices on existing stream health. Section 4 presents a series of environmental requirements and qualifying conditions the Panel developed to ensure projects create functional uplift in various indicators of stream health.

Table 4. Total Urban Stream Restoration Expected by 2025 in Bay State Phase 2 Watershed Implementation Plans[1]

State	Urban Stream Restoration	Non-Urban Stream Restoration
	Linear Feet (Miles)	
Delaware	200 (0.02)	63,202 (12)
District of Columbia	42,240 (8)	0
Maryland	2,092,325 (396)	73,975 (14)
New York	26,500 (5)	337,999 (64)
Pennsylvania	55,000 (10)	529,435 (100)
Virginia	116,399 (22)	104,528 (20)
West Virginia	0	19,618 (3.7)
TOTAL	441 miles	214 miles

[1] Total miles under urban and non-urban stream restoration (including historical projects) in each state by 2025 as reported in the Phase 2 Watershed Implementation Plan submissions to EPA in 2012, as summarized in May and July 2012 spreadsheets provided by Jeff Sweeney, EPA CBPO.

Section 3: Review of the Available Science

The Panel reviewed more than 100 papers to establish the state of the practice and determine the key components related to nutrient and sediment dynamics within streams. These papers were compiled mainly from research conducted within the Chesapeake Bay watershed or the eastern U.S. and included experimental studies of erosion and denitrification as well as case studies involving restored reaches. Papers and studies were obtained from a literature search as well as from academics, regulators, and consultants on the Panel involved with stream restoration research and application. An annotated summary of the key research papers is provided in Appendix A of this report.

Differences in measurement techniques and monitored parameters often made it difficult to directly compare individual stream restoration studies. In addition, the research varied greatly with respect to stream types, watershed characteristics, restoration objectives, and restoration design and construction techniques.

Consequently, the Panel organized its review by looking at four major research areas to define the probable influence of stream restoration on the different nutrient and sediment pathways by measuring:

- Nutrient flux at the stream reach
- Physical and chemical (nutrients) properties of stream sediments
- Internal nitrogen processing in streams
- Nutrient dynamics in palustrine and floodplain wetlands

Section 3.1
Measurements of Nutrient Flux at the Stream Reach Level

This group of studies measures the change in flow weighted nutrient and sediment concentrations above and below (and sometimes before and after) a stream restoration reach, and are often compared to an un-restored condition. Reach studies require frequent sampling during both storm and base flow conditions, and need to be conducted over multiple years to derive adequate estimates of nutrient and sediment fluxes. A good example of this approach was the nine year monitoring effort conducted on Spring Branch in Maryland by Stewart (2008).

Filoso and Palmer (2011) and Filoso (2012) recently completed sediment and nitrogen mass balance for eight low-order stream reaches located in Anne Arundel County, Maryland, based on a three-year base flow and storm flow sampling effort. The study reaches included four NCD restored streams, two RSC restored streams, and two un-restored control reaches. In terms of landscape position, the study reaches were situated in both upland and lowland areas, and were located in subwatersheds ranging from 90 to 345 acres in size. Individual stream reaches ranged from 500 to 1,500 feet in length.

Filoso noted that there was significant inter-annual variation in N and TSS loads and retention. The results suggest that two out of six restored reaches were clearly effective at reducing the export of TN to downstream waters. The capacity of stream restoration projects to reduce fluxes during periods of elevated flows was essential since most of the observed TSS and N export occurred during high water conditions.

Lowland channels were found to be more effective than upland channels, and projects that restored wetland-stream complexes were observed to be the most effective. Filoso also noted that the capacity of restoration practices to moderate discharge and reduce peak flows during high flow conditions seemed to be crucial to restoration effectiveness. Stream restoration of upland channels may have been effective at preventing sediment export and, therefore, might have reduced export downstream. However, without pre- and post- restoration data, they could not conclude that the upland streams were effective.

Filoso also noted that there appears to be a contrast between the length of a stream restoration project and the cumulative length of the upstream drainage network to the project reach. Short restoration projects in large catchments do not have enough retention time or bank protection to allow nutrient and sediment removal mechanisms to operate, especially during storm events.

Richardson et al. (2011) evaluated the effect of a stream restoration project in the North Carolina Piedmont that involved stream restoration, floodplain reconnection, and wetland creation. The project treated base flow and storm flow generated from a subwatershed with 30% impervious cover. Richardson reported significant sediment retention within the project, as well as a 64% and 28% reduction nitrate-N and TP loads, respectively. The study emphasized the need to integrate stream, wetland, and floodplain restoration together within the stream corridor to maximize functional benefits.

Other reach studies have focused on monitoring nitrogen dynamics under base flow conditions only (e.g., Sivirichi et al., 2011, Bukaveckas 2007, Ensign and Doyle 2005), and these are described in Section 3.3.

Section 3.2
Physical and Chemical (Nutrients) Properties of Stream Sediments

This group of studies evaluates the impact of stream restoration projects to prevent channel enlargement within a project reach, and retain bank and floodplain sediments (and attached nutrients) that would otherwise be lost from the reach. Stream restoration practices that increase the resistance of the stream bed and banks to erosion or reduce channel and/or floodplain energy to greatly limit the ability for erosive conditions can be expected to reduce the sediment and nutrient load delivered to the stream. The magnitude of this reduction is a function of the pre-project sediment supply from channel degradation in direct proportion to the length of erosion-prone stream bed and banks that are effectively treated.

Sediment reduction due to stream restoration is largely attributed to the stabilization of the bed and banks within the channel. Sediment correlation studies indicate that upland erosion and channel enlargement are significant components of the sediment budget (Allmendinger et al., 2007) and erosion and deposition values are higher in unstable reaches (Bergmann and Clauser, 2011). In a study monitoring sediment transport and storage in a tributary of the Schuylkill River in Pennsylvania, Fraley et al. (2009) found that bank erosion contributed an estimated 43% of the suspended sediment load, with bed sediment storage and remobilization an important component of the entire sediment budget.

Most studies define the rate of bank retreat and estimate the mass of prevented sediment using bank pins and cross-sectional measurements within the restored stream reach. The studies may also sample the soil nutrient content in bank and floodplain sediments to determine the mass of nutrients lost via channel erosion. This measurement approach provides robust long-term estimates for urban streams that are actively incising or enlarging. The "prevented" sediment effect can be masked in other reach studies unless they capture the range of storms events that induce bank erosion.

Five of the six studies that were used to derive the new default rate (see Table 3 in Section 2.4) used the prevented sediment approach to estimate nutrient and sediment export for urban streams in Maryland and Pennsylvania (BDPW, 2006; Land Studies, 2005). The loading rates attributed to stream channel erosion were found to be in the range of 300 to 1500 lb/ft/yr of sediment.

Nutrient content in stream bank and floodplain sediments is therefore a major consideration. Table 5 compares the TP and TN content measured in various parts of the urban landscape, including upland soils, street solids, and sediments trapped in catch basins and BMPs. As can be seen in Table 5, the four Pennsylvania and Maryland studies that measured the nutrient content of stream sediments consistently showed higher nutrient content than upland soils, and were roughly comparable to the more enriched street solids and BMP sediments.

Nutrient levels in stream sediments were variable. The Panel elected to use a value of 2.28 pounds of TN per ton of sediment and 1.05 pounds of TP per ton of sediment, as documented by Walter et al. (2007). These numbers align with recent findings from Baltimore County Department of Environmental Protection and Sustainability in comments to an earlier draft from Panelist Steve Stewart.

Table 5. TN and TP Concentrations in Sediments in Different Parts of the Urban Landscape[1]

Location	Mean TP	TP Range	Mean TN	TN Range	Location	Reference
Upland Soils	0.18	0.01-2.31	3.2	0.2-13.2	MD	Pouyat et al., 2007
Street Solids	2.07	0.76-2.87	4.33	1.30-10.83	MD	Diblasi, 2008
Catch Basin [3]	1.96	0.23-3.86	6.96	0.23-25.08	MD	Law et al., 2008
BMP Sediments	1.17	0.06-5.51	5.86	0.44-22.4	National	Schueler, 1994
Streambank Sediments	0.439	0.19-0.90	--	--	MD	BDPW, 2006
	1.78		5.41		MD	Stewart, 2012
	1.43	0.93-1.87	4.4	2.8-6.8	PA	Land Studies, 2005 [2]
	1.05	0.68-1.92	2.28	0.83-4.32	PA	Walter et al., 2007 [2,4]

[1] all units are lb/ton
[2] the Pennsylvania data on streambank sediments were in rural/agricultural subwatersheds
[3] catch basin values are for sediment only, excluding leaves
[4] median TN and TP values are reported

Several empirical tools exist to estimate the expected rate of bank retreat, using field indicators of the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS). Section 5 provides detailed guidance on how to properly apply these tools to estimate the mass of prevented sediments at restoration projects.

Section 3.3
Internal Nitrogen Processing in Streams and Floodplains

This group of research studies evaluates nitrogen dynamics in restored streams and floodplains using N mass balances, stream N tracer injections, N isotope additions, denitrification assays, and other methods, usually under base flow conditions. Most of the research studies have occurred in restored and non-restored streams, and floodplain wetlands in the Baltimore metropolitan area (Kaushal et al., 2008; Lautz and Fanelli, 2008; Klocker et al., 2009; Mayer et al., 2010; Harrison et al., 2011).

Mayer et al. (2010) examined N dynamics at groundwater-surface water interface in Minebank Run in Baltimore County, Maryland, and found the groundwater–surface water interface to be a zone of active nitrogen transformation. Increased groundwater residence time creates denitrification hot spots in the hyporheic zone, particularly when sufficient organic carbon is available to the system. Increased groundwater and stream flow interaction can alter dissolved oxygen concentrations and transport N and organic matter to microbes in subsurface sediments, fostering denitrification hot spots and hot moments (Mayer et al., 2010; Klocker et al., 2009).

Lautz and Fanelli (2008) found that anoxic zones were located upstream of a stream restoration structure in a low velocity pool and oxic zones were located downstream of the structure in a riffle, regardless of the season. They also found the restored streambed can act as a sink for nitrate and other redox-sensitive solutes, and that water residence time in the subsurface hyporheic zone plays a strong role in determining the spatial patterns of these practices. They suggest that the installation of small dams in restoration projects may be a mechanism to create denitrification hotspots.

Kaushal et al. (2008) analyzed denitrification rates in restored and un-restored streams in Baltimore, and found higher denitrification rates in restored streams that were connected to the floodplain as compared to high bank restoration projects that were not. Kaushal also noted that longer hydrologic residence times are important to remove N. Additional research by Klocker et al. (2009) reinforces the notion that "restoration approaches that increase hydrologic connectivity with hyporheic sediments and increasing hydrologic residence time may be useful in stimulating denitrification".

Sivirichi et al. (2011) compared dissolved nitrogen and carbon dynamics in two restored stream reaches (Minebank Run and Spring Branch) and two un-restored reaches (Dead Run and Powder Mill) in Baltimore. They concluded that restored stream reaches were a net sink for TDN and a net source for DOC. By contrast, the un-restored urban reaches had a net release of TDN and net uptake for DOC.

High denitrification rates were observed in both summer and winter in urban riparian wetlands in Maryland (Harrison et al., 2011). Restored streams in NC had higher rates of nitrate uptake in the summer, but this can be explained by increased stream temperature and reduced forest canopy cover (Sudduth et al., 2011).

The maximum amount of internal stream and floodplain nitrogen reduction appears to be limited or bounded by the dominant flow regime that is delivering N to the stream reach. Internal N processing is greatest during base flow conditions, and is masked due to the short residence times of high flow events that quickly transit the stream reach. Stewart et al. (2005) measured the relative proportion of annual nutrient loads delivered during storm flow and base flow conditions for five urban watersheds in Maryland that had 25 to 50% imperviousness. Stewart found that base flow nitrate loads were 20 to 30% of total annual nitrogen load, with one outlier of 54% that appeared to be influenced by sewage sources of nitrogen.

The Panel identified a series of factors that could promote greater dry weather N reduction:

- Increase retention time in flood plain wetlands;
- Add dissolved organic carbon via riparian vegetation, debris jams, instream woody debris, and where applicable, re-expose hydric soils in the pre-settlement floodplain;
- Reconnect the stream to floodplain and wetlands during both dry weather flow and storm flows through low floodplain benches, sand seepage wetlands, legacy sediment removal, or other techniques;
- Focus on streams with high dry-weather nitrate concentrations that are often delivered by sewage exfiltration;
- Ensure the restored reach is sufficiently long in relationship to the contributing channel network to achieve maximum hydrologic residence time;
- Install instream and floodplain wetland practices with a high surface area to depth ratio and in some cases add channel length or create multi-channel systems;
- Attenuate flows and reduce pollutants through upstream or lateral stormwater retrofits.

Section 3.4
Nutrient Dynamics in Restored Palustrine and Floodplain Wetlands

The Panel reviewed another line of evidence by looking at research that measured the input and output of nutrients from restored and created wetlands located in palustrine and floodplain areas. In this respect, the Panel relied on a previous CBP Expert Panel that comprehensively reviewed nutrient reduction rates associated with wetland restoration projects most of which were located in rural areas (Jordan, 2007). The majority of the research reviewed focused on restored wetlands that received stormflow (and, in some cases, groundwater), as opposed to engineered or created wetlands.

Jordan (2007) noted that restored wetlands had significant potential to remove nutrients and sediments, although the rates were variable. For example, Jordan notes the average TN removal for restored wetlands was 20%, with a standard error of 3.7 % and a range of -12% to 52% (N=29 annual measurements). Similarly, Jordan found that the average TP removal rate for restored wetlands was 30%, with a standard error of 5%, and a range of -54% to 88%.

Jordan (2007) also explored how the removal rates were influenced by the size of the watershed contributing nutrients and sediments to the restored wetlands. He found that removal rates tended to increase as restored wetland area increased (expressed as a percent of watershed area), although the relationship was statistically weak. Most of the low performing wetland restoration projects had wetland areas less than 1% of their contributing watershed area. It should be noted that there were negative removal recorded but these data points were not included in the analysis.

More recently, Harrison et al. (2011) measured denitrification rates in alluvial wetlands in Baltimore and found that urban wetlands are potential nitrate sinks. The highest rates of denitrification were observed in wetlands with the highest nitrate concentrations, as long as a carbon source was available. The study supports the notion that stream restoration associated with floodplain reconnection and wetland creation may produce additional N reduction.

The Panel considered the previous research and concluded that the impact of restoration projects in reconnecting streams with their floodplains during baseflow and stormflow conditions could have a strong influence on sediment and nutrient reduction, depending on the characteristics of the floodplain connection project.

Section 3.5
Classification of Regenerative Stormwater Conveyance (RSC) Systems

The Panel classified dry channel RSC systems as an upland stormwater retrofit rather than a stream restoration practice. They rely on a combination of a sand filter, micro-bioretention, and wetland micro-pools. Therefore, when dry channel RSC systems are sized to a given runoff volume from their contributing drainage area, their removal rates are calculated using retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel. In addition, RSC practices need to be designed to provide safe on-line passage for larger storm events without the need for flow splitters.

The Panel concluded that wet channel RSC systems were a stream restoration practice, and their pollutant removal rate can be estimated based on the appropriate protocols outlined in this document.

Section 3.6
Effect of Riparian Cover on Stream Restoration Effectiveness and Functional Lift

Several recent studies have documented the critical importance of riparian cover in enhancing nutrient removal associated with individual restoration practices. Weller et al. (2011) evaluated the effect of 321 riparian buffers of the Chesapeake Bay watershed, and found forest buffers were a good predictor of stream nitrate concentrations in agricultural streams. Their watershed analysis integrated the prevalence of source areas, their nitrate source strength, the spatial pattern of buffers relative to sources, and buffer nitrate removal potential. In general, the effectiveness of forest buffers was maximized when they were located downhill from nutrient sources and were sufficiently wide.

Orzetti et al. (2010) explored the effect of forest buffers on 30 streams in the Bay watershed that ranged in age from zero to 50 years. They found that habitat, water quality, and benthic macroinvertebrate indicators improved with buffer age. Noticeable improvements were detected within 5 to 10 years after buffer restoration and significant improvements were observed 10 to 15 years after buffer restoration.

Others (Schnabel et al., 1995; Klapproth et al., 2009) have noted that non-forested riparian areas perform as well as forested riparian areas, and the data suggest other features, such as soils, surface and subsurface flow portioning, and other factors may be more important than vegetation type when it comes to nutrient and sediment retention. In addition, several studies have found that natural aquatic resources buried beneath legacy sediment are not exclusively forested and may provide substantial habitat and water quality benefits (Voli et al., 2009; Hilgartner et al., 2010; Merrits et al., 2011; Hartranft et al., 2011).

Three recent studies have documented that the construction of stream restoration projects can lead to local destruction of riparian cover within the project reach. The loss of riparian cover can adversely impact functional responses within the stream, including nutrient reduction. For example, Sudduth et al. (2011) and Violin et al. (2011) compared the functional services provided by four forest reference streams, four NCD-restored streams, and four non-restored urban streams in the North Carolina Piedmont. The studies concluded that the heavy machinery used to reconfigure channels and banks led to significant loss of riparian canopy cover (and corresponding increase in stream temperatures), and these were a major factor in the lack of functional uplift observed in restored streams, compared to non-restored streams.

Selvakumar et al. (2010) studied various functional metrics above and below, and before and after a NCD stream restoration was installed on a 1,800 foot reach in the North Fork of Accotink Creek in Fairfax County, Virginia. The conclusion from the two year study was that the restoration project had reduced stream bank degradation and slightly increased benthic IBI scores, but made no statistical difference in water quality parameters, including nutrients and bacteria. Once again, the loss of riparian cover associated with project construction was thought to be a factor in the low functional uplift observed.

By contrast, other studies have documented greater functional uplift associated with stream restoration practices (see Northington and Hershey, 2006; Baldigo et al., 2010; and Tullos et al., 2006).

It was outside the Panel's charge to resolve the scientific debate over the prospects of functional uplift associated with urban and non-urban stream restoration (i.e., beyond nutrient and sediment reduction). The research does, however, have three important implications directly related to the Panel's final recommendations:

- First, the maintenance of riparian cover is a critical element in the ultimate success of any stream restoration project. Projects that involve extensive channel reconfiguration or remove existing riparian cover are likely to see less functional uplift, including nutrient removal, at least until the replanted areas achieve maturity (Orzetti et al., 2010). Consequently, the Panel included a key qualifying condition related to the reestablishment of riparian cover in its recommendations. An urban filter strips/stream buffer CBP Expert Panel was recently formed and held its first meeting in February 2013 to define stream buffer upgrades and how they can be applied in the CBWM. The results from this Panel will help determine the appropriate buffer conditions for stream restoration projects.

- Second, the research reinforces the notion that stream restoration should not be a stand-alone strategy for watersheds, and that coupling restoration projects with upland retrofits and other practices can help manage the multiple stressors that impact urban streams (Palmer et al., 2007).

- Lastly, the Panel concluded that some type of stream functional assessment needs to be an important part of both project design and post-project monitoring of individual restoration projects to provide better scientific understanding of the prospects for functional uplift over time.

Section 3.7
Success of Stream Restoration Practices

An important part of the Panel charge was to define the success rate of stream restoration projects. Until recently, post-project monitoring has been rarely conducted to assess how well stream restoration projects meet their intended design objectives over time. For example, Bernhardt et al. (2005) compiled a national database of river restoration projects, and found that fewer than 6% of projects in the Chesapeake Bay watershed incorporated a post-construction monitoring or assessment plan. On a national basis, less than 10% of all restoration projects had clearly defined restoration objectives against which project success could be compared.

Brown (2000) investigated 450 individual stream restoration practices installed at 20 different stream reaches in Maryland, and found that 90% were still intact after four years, although only 78% were still fully achieving the intended design objective. Johnson et al. (2002) analyzed the manner and modes of failure at four Maryland stream restoration projects. Although the study did not quantify the rate of failure of individual practices, it did recommend changes in design guidelines for individual restoration practices.

Hill et al. (2011) conducted an extensive permit analysis of the success of 129 stream restoration projects constructed in North Carolina from 2007 to 2009. They reported that 75% of the stream restoration projects could be deemed "successful", as defined by whether the mitigation site met the regulatory requirements for the project at the time of construction (however, the actual degree of functional uplift or ecological improvement was not measured in the study). The authors noted that the success rate for stream restoration mitigation was less than 42% in the mid-1990s, and attributed the marked improvement to better hydrologic modeling during design, better soils analysis, and more practitioner experience.

Miller and Kochel (2010) evaluated post-construction changes in stream channel capacity for 26 stream restoration projects in North Carolina. While stream responses to restoration were variable at each project, the authors found that 60% of the NCD projects underwent at least a 20% change in channel capacity. The greatest post-construction changes were observed for channels with high sediment transport capacity, large sediment supply or easily eroded banks.

The Panel discussed whether to assign a discount rate to the removal credits to reflect project failure due to poorly conceived applications, inadequate design, poor installation, or a lack of maintenance. In the end, the Panel decided to utilize a stringent approach to verify the performance of individual projects over time, as outlined in Section 7.

The verification approach establishes measurable restoration objectives, project monitoring plans, and a limited five-year credit duration that can only be renewed based on verification that the project is still working as designed. The agency that installs the restoration practice will be responsible for verification. This approach should be sufficient to eliminate projects that fail or no longer meet their restoration objectives, and remove their sediment and nutrient reduction credit.

The Panel agreed that the verification approach could generate useful data on real world projects that would have great adaptive management value to further refine restoration methods and practices that could ultimately ensure greater project success.

The monitoring data reviewed does not provide a perfect understanding of the benefits of stream restoration, but the results do conclusively demonstrate that stream restoration, when properly implemented, does have sediment and nutrient reduction benefits. The Panel felt there is sufficient monitoring information to develop the protocols in this document with the recognition of the need for refinement as better monitoring data becomes available.

Section 4: Basic Qualifying Conditions for Individual Projects

Section 4.1
Watershed-Based Approach for Screening and Prioritizing

A watershed-based approach for screening and prioritizing stream restoration projects is recommended to focus restoration efforts at locations that will provide the most benefit in terms of sediment and nutrient reduction, as well as improvement to stream function. Application of a model, such as the BANCS method described in Section 5 for Protocol 1, or other screening tools, at a watershed scale enables better reconciliation of the total sediment loadings from stream bank erosion at the watershed level to edge of field loadings predicted by the Chesapeake Bay Watershed Model. This can be a useful check to assure that the BANCS method is appropriately applied and that no single project will have disproportionate load reduction.

Section 4.2
Basic Qualifying Conditions

Not all stream restoration projects will qualify for sediment or nutrient reduction credits. The Panel recommended the following qualifying conditions for acceptable stream restoration credit:

- Stream restoration projects that are primarily designed to protect public infrastructure by bank armoring or rip rap do not qualify for a credit.

- The stream reach must be greater than 100 feet in length and be still actively enlarging or degrading in response to upstream development or adjustment to previous disturbances in the watershed (e.g., a road crossing and failing dams). Most projects will be located on first- to third-order streams, but if larger fourth and fifth order streams are found to contribute significant and uncontrolled amounts of sediment and nutrients to downstream waters, consideration for this BMP would be appropriate, recognizing that multiple and/or larger scale projects may be needed or warranted to achieve desired watershed treatment goals.

- The project must utilize a comprehensive approach to stream restoration design, addressing long-term stability of the channel, banks, and floodplain.

- Special consideration is given to projects that are explicitly designed to reconnect the stream with its floodplain or create wetlands and instream habitat features known to promote nutrient uptake or denitrification.

- In addition, there may be certain project design conditions that must be satisfied in order to be eligible for credit under one or more of the specific protocols described in Section 5.

Section 4.3
Environmental Considerations and 404/401 Permits

- Each project must comply with all state and federal permitting requirements, including 404 and 401 permits, which may contain conditions for pre-project assessment and data collection, as well as post construction monitoring.

- Stream restoration is a carefully designed intervention to improve the hydrologic, hydraulic, geomorphic, water quality, and biological condition of degraded urban streams, and must not be implemented for the sole purpose of nutrient or sediment reduction.

- There may be instances where limited bank stabilization is needed to protect critical public infrastructure, which may need to be mitigated and does not qualify for any sediment or reduction credits.

- A qualifying project must meet certain presumptive criteria to ensure that high-functioning portions of the urban stream corridor are not used for in-stream stormwater treatment (i.e., where existing stream quality is still good). These may include one or more of the following:

    - Geomorphic evidence of active stream degradation (i.e., BEHI score)
    - An IBI of fair or worse
    - Hydrologic evidence of floodplain disconnection
    - Evidence of significant depth of legacy sediment in the project reach

- Stream restoration should be directed to areas of severe stream impairment, and the use and design of a proposed project should also consider the level of degradation, the restoration needs of the stream, and the potential functional uplift.

- In general, the effect of stream restoration on stream quality can be amplified when effective upstream BMPs are implemented in the catchment to reduce runoff and stormwater pollutants and improve low flow hydrology.

- Before credits are granted, stream restoration projects will need to meet post-construction monitoring requirements, exhibit successful vegetative establishment, and have undergone initial project maintenance.

- A qualifying project must demonstrate that it will maintain or expand existing riparian vegetation in the stream corridor, and compensate for any project-related riparian losses in project work areas as determined by regulatory agencies.

- All qualifying projects must have a designated authority responsible for development of a project maintenance program that includes routine maintenance and long-term repairs. The stream restoration maintenance protocols being developed by Starr (2012) may serve as a useful guide to define maintenance triggers for stream restoration projects.

Section 4.4
Stream Functional Assessment

The Panel noted that it is critical for project designers to understand the underlying functions that support biological, chemical, and physical stream health to ensure successful stream restoration efforts. In particular, it is important to know how these different functions work together and which restoration techniques influence a given function. Harman et al. (2011) note that stream functions are interrelated and build on each other in a specific order, a functional hierarchy they have termed the stream functions pyramid. Once the function pyramid is understood, it is easier to establish clear restoration objectives for individual projects and measure project success.

Consequently, the Panel recommends that proposed stream restoration projects be developed through a functional assessment process, such as the stream functions pyramid (Harman et al., 2011) or functional equivalent. It is important to note that stream evolution theory is still evolving with widely divergent opinions and views, which should be considered in any functional assessment. In addition, most current assessment methods have not yet been calibrated to LSR and RSC projects. State approved methodologies should be considered when available. Regardless of the particular functional assessment method utilized, the basic steps should include:

- Set programmatic goals and objectives
- Site selection and watershed assessment
- Conduct site-level function-based assessment
- Determine restoration potential
- Establish specific restoration design objectives
- Select restoration design approach and alternative analysis
- Project design review
- Implement post-construction monitoring

In general, the level of detail needed to perform a function-based assessment will be based on the size, complexity and landscape position of the proposed project.

Section 4.5
Applicability to Non-Urban Stream Restoration Projects

As noted in Section 2.3, the CBP-approved removal rate for urban stream restoration projects has been extended to non-urban stream restoration projects. Limited research exists to document the response of non-urban streams to stream restoration projects in comparison to the still limited, but more extensive literature on urban streams. However, many of the papers reviewed were from rural streams (Bukaveckas, 2007; Ensign and Doyle, 2005; Mulholland et al., 2009; and Merritts et al., 2010).

The Panel was cognizant of the fact that urban and non-urban streams differ with respect to their hydrologic stressors, nutrient loadings and geomorphic response. At the same time, urban streams also are subject to the pervasive impact of legacy sediments observed in rural and agricultural watersheds (Merritts et al., 2011). The Panel further reasoned that the prevented sediment and floodplain reconnection protocols developed for urban streams would work reasonably well in rural situations, depending on the local severity of bank erosion and the degree of floodplain disconnection.

Consequently, the Panel recommends that the urban protocols can be applied to non-urban stream restoration projects, if they are designed using the NCD, LSR, RSC or other approaches, and also meet the relevant qualifying conditions, environmental considerations and verification requirements.

At the same time, the Panel agreed that certain classes of non-urban stream restoration projects would not qualify for the removal credit. These include:

- Enhancement projects where the stream is in fair to good condition, but habitat features are added to increase fish production (e.g., trout stream habitat, brook trout restoration, removal of fish barriers, etc.)
- Projects that seek to restore streams damaged by acid mine drainage
- Riparian fencing projects to keep livestock out of streams

Section 5: Recommended Protocols for Defining Pollutant Reductions Achieved by Individual Stream Restoration Projects

Based on its research review, the Panel crafted four general protocols that can be used to define the pollutant load reductions associated with individual stream restoration projects. The following protocols apply for smaller 0 – 3rd order stream reaches not simulated in the Chesapeake Bay Watershed Model (CBWM). These protocols do not apply to sections of streams that are tidally influenced, which will be included in either the Shoreline Erosion Control Expert Panel or a pending future Expert Panel for tidal wetlands.

Protocol 1: Credit for Prevented Sediment during Storm Flow -- This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.

Protocol 2: Credit for Instream and Riparian Nutrient Processing during Base Flow -- This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow. Qualifying projects receive credit under Protocol 1 and use this protocol to determine enhanced nitrogen removal through denitrification within the stream channel during base flow conditions. The credit is applied to a "theoretical" box where denitrification occurs through increased hyporheic exchange for that portion of the channel with hydrologic connectivity to the adjacent riparian floodplain.

Protocol 3: Credit for Floodplain Reconnection Volume-- This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events. Qualifying projects receive credit for sediment and nutrient removal under Protocols 1 and 2 and use this protocol to determine enhanced sediment and nutrient removal through floodplain wetland connection. A wetland-like treatment is used to compute the load reduction attributable to floodplain deposition, plant uptake, denitrification and other biological and physical processes.

Protocol 4: Credit for Dry Channel RSC as an Upland Stormwater Retrofit-- This protocol computes an annual nutrient and sediment reduction *rate* for the contributing drainage area to a qualifying dry channel RSC project. The rate is determined by the volume of stormwater treatment provided in the upland area using the retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel (WQGIT, 2012).

The protocols are additive, and an individual stream restoration project may qualify for credit under one or more of the protocols, depending on its design and overall restoration approach however the WTWG recommended that the aggregate load reductions from a practice should not exceed estimated loads in the Watershed Model for any given land-river segment. The next four sections describe how each protocol is applied to individual stream restoration projects.

Protocol 1
Credit for Prevented Sediment during Storm Flow

This protocol follows a three step process to compute a mass reduction credit for prevented sediment:

1. Estimate stream sediment erosion rates and annual sediment loadings,
2. Convert erosion rates to nitrogen and phosphorus loadings, and
3. Estimate reduction attributed to restoration.

Estimates of sediment loss are required as a basis to this protocol. The options to estimate stream sediment erosion rates and annual sediment loadings in Step 1 of this protocol are included below. States are encouraged to select an approach to estimate stream bank erosion rates that best fits their unique conditions and capabilities. In addition, they are encouraged to pursue their own more robust methods to yield the most accurate estimates possible.

- Monitoring

- BANCS method
- Alternative modeling approach

Monitoring through methods such as cross section surveys and bank pins is the preferred approach, however can be prohibitive due to cost and staffing constraints. The extrapolation of monitoring data to unmeasured banks should be done with care and the monitored cross sections should be representative of those within the project reach. Based on these factors, the use of a method that can be applied to unmonitored stream banks and calibrated to monitoring data, such as the BANCS method described below, is a useful tool.

When monitoring is not feasible, the Panel recommends a modeling approach called the "Bank Assessment for Non-point Source Consequences of Sediment" or BANCS method (Rosgen, 2001; U.S. EPA, 2012; Doll et al., 2003) to estimate sediment and nutrient load reductions. The BANCS method was developed by Rosgen (2001) and utilizes two commonly used bank erodibility estimation tools to predict stream bank erosion; the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) methods. *Alternative modeling approaches, such as the Bank Stability and Toe Erosion Model (BSTEM) developed by the USDA-ARS National Sedimentation Laboratory, may also be used provided they are calibrated to measured stream bank erosion rates.*

The BANCS method has been used by others for the purpose of estimating stream erosion rates. For example, MDEQ (2009) used the BANCS method to develop sediment TMDLs. U.S. EPA has also recommended the BANCS method in its TMDL Guidance (U.S. EPA, 2012). The Philadelphia Water Department has used the BANCS method to prioritize streams for restoration (Haniman, 2012), although they did note some accuracy issues attributed to misuse of the BEHI and NBS methods.

Altland (2012) and Beisch (2012) have used a modified BANCS method with reasonable success and the general approach has been used in Anne Arundel County to prioritize their stream restoration projects (Flores, 2012) and in Fairfax County to evaluate cost-effectiveness of restoration projects (Medina and Curtis, 2011). More information on the technical derivation of Protocol 1 can be found in Appendix B.

The Panel identified a series of potential limitations to the BANCS method, including:

- The method is based on the NCD stream restoration approach, which uses assumptions regarding bank full storm frequency that are not shared in other design approaches (e.g., LGS, RSC).
- Some studies have found that frost heaving may be a better predictor of stream bank erosion than NBS.
- Estimates of BEHI and NBS can vary significantly among practitioners.
- Extrapolation of BEHI and NBS data to unmeasured banks may not be justifiable.
- The BANCS method is not effective in predicting future channel incision and bank erodibility in reaches upstream of active head cuts. These zones upstream of active head cuts, failing dams, or recently lowered culverts/utility crossings often

yield the greatest potential for long-term sediment degradation and downstream sediment/nutrient pollution.
- This method estimates sediment supply and not transport or delivery. Refer to Appendix B for additional information about this method and sediment delivery.

Despite these concerns, the Panel felt that the use of a method that allows the estimation of stream bank erosion from an empirical relationship between standard assessment tools (BEHI and NBS) and in-stream measurements justified its use for the purposes of crediting stream restoration. Furthermore, a literature review of the BANCS Method in Appendix B indicates further refinements to this method that can improve the accuracy. States are encouraged to add parameters or stratify data for the BANCS Method to account for local conditions. The Panel recommended several steps to improve the consistency and repeatability of field scoring of BEHI and NBS, as follows:

- The development of a standardized photo glossary to improve standardization in selecting BEHI and NBS scores.

- Continued support for the development of regional stream bank erosion curves for the BANCS method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results. Ideally, measured bank erosion rates within each subwatershed or County would be used to validate the BANCS method specific to that location. Given that these data may not be readily available, additional methodologies for adjusting the BEHI and NBS scores to accommodate local subwatershed characteristics may be useful. For example, adjustments to the BEHI to account for areas with predominantly sandy soils, agricultural channels, or legacy sediment.

- Using other methods to validate the BANCS method such as aerial photographs that can be used to estimate historical erosion rates, dendro-geomorphic studies of exposed roots and new shoots, time series channel surveys, and/or bank pins.

- The BANCS method should only be performed by a qualified professional, as determined by each permitting authority.

- Extrapolation of BEHI and NBS to unmeasured banks should not be allowed unless photo documentation is used to provide the basis of extrapolation.

- If BEHI and NBS data are not available for *existing* stream restoration projects, the current CBP approved rate will apply.

Step 1. *Estimate stream sediment erosion rate*

Studies have shown that when the BANCS method is properly applied it can be an excellent predictor of the stream bank erosion rate (e.g., Rosgen, 2001; Starr, 2012, Doll et al., 2003). An estimate of the pre-project erosion rate is made by performing BEHI and NBS assessments for each stream bank within the restoration reach. BEHI and NBS scores are then used to estimate erosion rates as determined from a regional bank erosion curve. An example of a regional curve is shown in Appendix B, which shows the USFWS curve for Hickey Run in Washington, DC.

The pre-project erosion rate, is then multiplied by the bank height, qualifying stream bank length and a bulk density factor to estimate the annual sediment loading rate (in tons/year) using Equation 1 below.

$$S = \frac{\sum(cAR)}{2{,}000} \qquad \text{(Eq. 1)}$$

where: S = sediment load (ton/year) for reach or stream
c = bulk density of soil (lbs/ft^3)
R = bank erosion rate (ft/year) (from regional curve)
A = eroding bank area (ft^2)
2,000 = conversion from pounds to tons

The summation is conducted over all stream reaches being evaluated. Bulk density measurements, although fairly simple, can be highly variable and each project site should have samples collected throughout the reach to develop site-specific bulk density estimates. Van Eps et al. (2004) describes how bulk density is applied using this approach. Note that if monitoring data or other models similar to the BANCS method are used, loading rates will also have to be adjusted for bulk density.

Step 2. *Convert stream bank erosion to nutrient loading*

To estimate nutrient loading rates, the prevented sediment loading rates are multiplied by the median TP and TN concentrations in stream sediments. The default values for TP and TN are from Walter et al. (2007) and are based on bank samples in Pennsylvania (Table 5):

- 1.05 pounds P/ton sediment
- 2.28 pounds N/ton sediment

Localities are encouraged to use their own values for stream bank and stream bed nutrient concentrations, if they can be justified through local sampling data.

Step 3. *Estimate stream restoration efficiency*

Stream bank erosion is estimated in Step 1, but not the efficiency of stream restoration practices in preventing bank erosion. The Panel concluded that the mass load reductions should be discounted to account for the fact that projects will not be 100% effective in preventing stream bank erosion and that some sediment transport occurs naturally in a stable stream channel.

Consequently, the Panel took a conservative approach and assumed that projects would be 50% effective in reducing sediment and nutrients from the stream reach. The technical basis for this assumption is supported by the long term Spring Branch Study mentioned in Section 2.3 and the sediment and nutrient removal rates reported in Table 2. The Panel felt that efficiencies greater than 50% should be allowed for projects that have shown through monitoring that the higher rates can be justified subject to approval by the states. This will hopefully promote monitoring (e.g., Big Spring Run in Pennsylvania) of stream restoration projects.

The reduction efficiency is applied at the "edge of field." Additional losses between the edge of field and Chesapeake Bay are accounted for in the Chesapeake Bay Watershed Model, as referenced below. An alternative approach is to use the erosion estimates from banks with low BEHI and NBS scores to represent "natural" conditions which is the approach taken by Van Eps et al. (2004) and to use the difference between the predicted erosion rate and the "natural" erosion rate as the stream restoration credit. The Philadelphia Water Department has also suggested using this approach (Haniman, 2012). While the Panel felt the "natural background" approach had merit, it agreed that the recommended removal efficiency would provide a more conservative estimate, and would be less susceptible to manipulation.

For CBWM purposes, the calculated sediment mass reductions would be taken at the edge of field, and would be subject to a sediment delivery ratio which should be applied to account for loss due to depositional processes between the edge-of-field and edge-of-stream. Sediment delivery ratios have been averaged for coastal plain (0.061) and non-coastal plain (0.181) streams and should be multiplied by the erosion rate to determine the sediment load reduction that is reported. Riverine transport processes are then simulated by HSPF to determine the delivered load. See design example in section 6.1 to see how the sediment delivery ratio is applied. Additional information on the sediment delivery ratio can be found in Appendix B. The calculated nutrient mass reductions are not subject to a delivery ratio and would be deducted from the annual load delivered to the river basin segment (edge-of-stream) in the CBWM.

Protocol 2
Credit for In-Stream and Riparian Nutrient Processing within the Hyporheic Zone during Base Flow

This protocol applies to stream restoration projects where in-stream design features are incorporated to promote biological nutrient processing, with a special emphasis on denitrification. Qualifying projects receive credit under Protocol 1 and use this protocol to determine enhanced nitrogen removal through denitrification within the stream channel during base flow conditions. Hyporheic exchange between the stream channel and the floodplain rooting zone is improved, however is confined by the dimensions in Figure 3. Situations where the restored channel is connected to a floodplain wetland are also eligible for additional credit under Protocol 3. Protocol 2 only provides a nitrogen removal credit; no credit is given for sediment or phosphorus removal. More detail on the technical derivation of Protocol 2 can be found in Appendix C.

This protocol relies heavily on in-situ denitrification studies in restored streams within the Baltimore metropolitan area (Kaushal et al., 2008; Striz and Mayer, 2008). After communication with two of the principal researchers of these studies, Dr. Sujay Kaushal and Dr. Paul Mayer, the Panel assumed that credit from denitrification can be conservatively estimated as a result of increased hyporheic exchange between the floodplain rooting zone and the stream channel.

The credit is determined only for the length of stream reach that has improved connectivity to the floodplain as indicated by a bank height ratio of 1.0 (bank full storm) or less for projects that use the natural channel design approach. The bank height ratio is an indicator of floodplain connectivity and is a common measurement used by stream restoration professionals. It is defined as the lowest bank height of the channel cross section divided by the maximum bank full depth. Care must be taken by design professionals on how to increase the dimensions of the hyporheic box in the restoration design. Raising the stream bed or overly widening the stream channel to qualify for this credit may not be appropriate because of other design considerations.

The above studies also demonstrated the importance of "carbon" availability in denitrification. To assure that sites have adequate carbon, localities should require extensive plant establishment along the riparian corridor of the stream reach. Additional design and construction guidelines that promote in-stream nutrient removal should be followed and are available in Appendix G.

It is assumed that the denitrification occurs in a "box" that extends the length of the restored reach. The cross sectional area of the box extends to a maximum depth of 5 feet beneath the stream invert with a width that includes the median base flow channel and 5 feet added on either side of the stream bank (see Figure 2). The dimensions of the box apply only to sections of the reach where hyporheic exchange can be documented. Areas of bedrock outcroppings or confining clay layers should be excluded and the dimensions of the box adjusted accordingly. Geotechnical testing may be required to confirm the depth of hyporheic exchange.

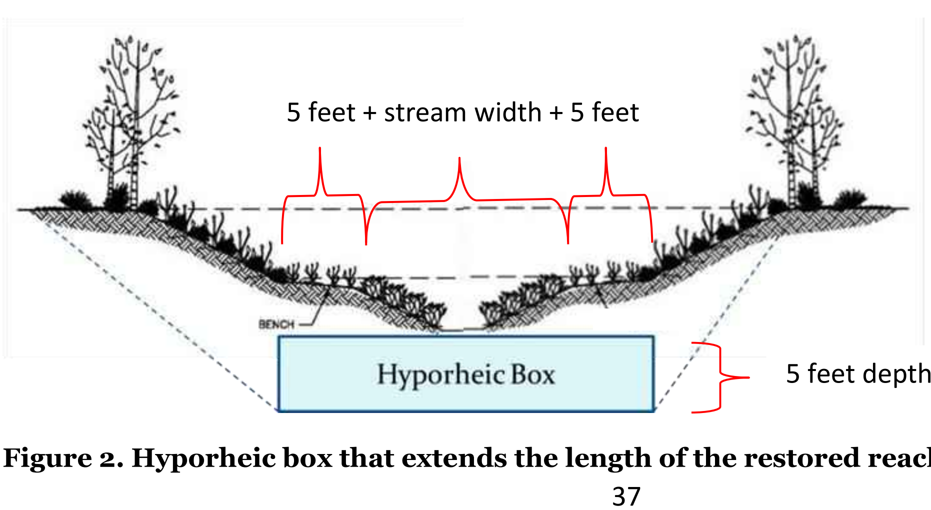


Figure 2. Hyporheic box that extends the length of the restored reach

The cross sectional area of the hyporheic box is multiplied by the length of the restored connected channel. In actuality, because not all of the restored channel will meet the qualifying conditions described above, there may be several smaller disconnected hyporheic boxes that are averaged across the reach. The result is then multiplied by an average denitrification rate that represents the additional dentrification provided from restored sites versus unrestored sites from Kaushal et al. (2008) of 48.2 μg N/kg/day of soil (1.06 x 10^{-4} pounds/ton/day of soil). This is the denitrification rate within the mass of stream sediment within the hyporheic box.

The Expert Panel felt that a cap was necessary given the excessively high nitrogen reductions in some of the test drive results. An initial cap was suggested based on a study by Klocker et al. (2009), who found that 40% of the daily load of nitrate in Minebank Run could be removed through denitrification. However, the WTWG recommended the 40% cap be placed on total nitrate loads entering the stream for any given land-river segment rather than total nitrogen loads as denitrification only impacts nitrate.

Step 1. *Determine the total post construction stream length that has been reconnected using the bank height ratio of 1.0 or less.*

Step 2. *Determine the dimensions of the hyporheic box.*

The cross sectional area is determined by adding 10 ft (2 times 5 ft) to the width of the channel at median base flow depth (as determined by gage station data) and multiplying the result by 5 ft. This assumes that the stream channel is connected on both sides, which is not always the case. The design example in Section 6 shows how this condition is addressed. Next, multiply the cross sectional area by the length of the restored connected channel from Step 1 to obtain the hyporheic box volume.

Step 3. *Multiply the hyporheic box mass by the unit denitrification rate (1.06 x 10^{-4} pounds/ton/day of soil).*

Note that this also requires the estimation of the bulk density of the soil within the hyporheic box.

Step 4: *Check to make sure the watershed cap is not exceeded.*

Since nitrate loadings are highly variable spatially, the Chesapeake Bay Program Modeling Team should be contacted for the total nitrate loading to assure that the load reductions from this and other projects do not exceed the 40% cap for any given land-river segment.

Protocol 3
Credit for Floodplain Reconnection Volume

This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events, from the small, high frequency events to the larger, less frequent events. Credit for base flow is also given. Qualifying projects receive credit for sediment and nutrient removal under Protocol 1 and denitrification in Protocol 2 (if applicable) and use this protocol to determine enhanced sediment and nutrient removal through floodplain wetland connection. This method assumes that sediment, nitrogen and phosphorus removal occurs only for that volume of annual flow that is effectively in contact with the floodplain. For planning purposes, a series of conceptual curves were developed that relate the floodplain reconnection volume to the effective depth of rainfall treated in the floodplain, which in turn are used to define the nutrient removal rate that is applied to subwatershed loads delivered to the project. The results of Protocol 3 will vary depending on which hydrologic model is used for estimating floodplain connection volume. Appendix G provides further explanation and an alternative curve example. Project-specific calculations should be used when design details are available.

The extent of the credit depends on the elevation of the stream invert relative to the stage elevation at which the floodplain is effectively accessed. Designs that divert more stream runoff onto the floodplain during smaller storm events (e.g., 0.25 or 0.5 inches) receive greater nutrient credit than designs that only interact with the floodplain during infrequent events, for example the 1.5 year storm event. Wet channel RSC and LSR and specially designed NCD restoration projects may qualify for the credit.

The floodplain connection volume afforded by a project is equated to a wetland volume so that a wetland removal efficiency can be applied. The Panel reasoned that the function of the increased floodplain connection volume would behave in the same fashion as a restored floodplain wetland, for which there is robust literature to define long term nitrogen and phosphorus removal rates (Jordan, 2007). However, it will be critical for stream restoration designers to consult with a wetland specialist in designing or enhancing the floodplain wetlands to assure there is sufficient groundwater-surface water interaction to qualify for this benefit. The Panel decided that the maximum ponded volume in the flood plain that receives credit should be 1.0 foot to ensure interaction between runoff and wetland plants. A key factor in determining the wetland effectiveness is the hydraulic detention time. The TN, TP and TSS efficiencies used in this protocol are from Jordan (2007), who assumes that detention time is proportional to the fraction of watershed occupied by wetlands. To ensure that there is adequate hydraulic detention time for flows in the floodplain, there should be a minimum watershed to floodplain surface area ratio of one percent. The credit is discounted proportionally for projects that cannot meet this criterion. For instance, if the wetland to surface area ratio is 0.75% rather than the 1% minimum then the credit would be 75% of the full credit.

The recommended protocol is similar to the methods utilized by Altland (2012) for crediting stream restoration projects that reconnect to the floodplain. More detail on the technical derivation of the curves that are used in Protocol 3 can be found in Appendix C. Two examples are provided to illustrate how this approach can be applied using hydrologic and hydraulic modeling. The examples are using discrete storm modeling and continuous simulation.

Step 1: *Estimate the floodplain connection volume in the available floodplain area.*

The first step involves a survey of the potential additional runoff volume that can be diverted from the stream to the floodplain during storm events. Credit for this protocol applies only to the additional runoff volume diverted to the floodplain beyond what existed prior to restoration. Designers will need to conduct detailed hydrologic and hydraulic modeling (or post restoration monitoring) of the subwatershed, stream and floodplain to estimate the potential floodplain connection volume. In addition, designers will need to show that 100-year regulatory floodplain elevations are maintained. As a guide for project planning, the Center for Watershed Protection has developed a series of curves that define the fraction of annual rainfall that is treated under various depths of floodplain connection treatment (Appendix C, Figure 3).

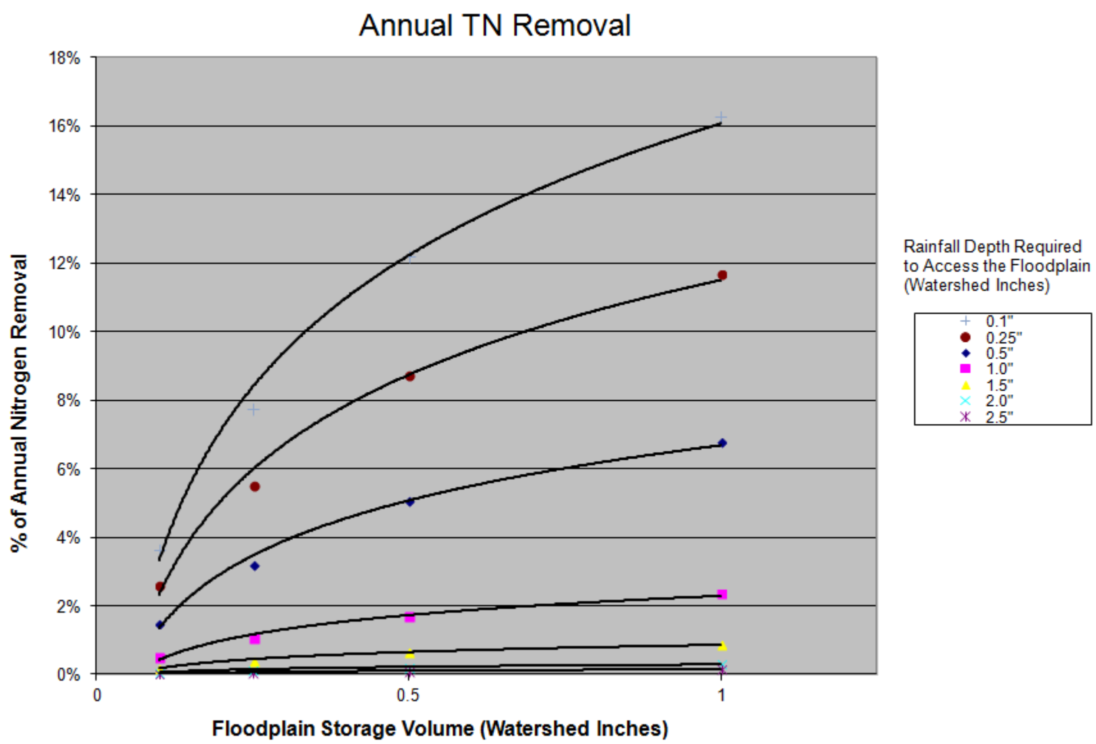
Step 2: *Estimate the nitrogen and phosphorus removal rate attributable to floodplain reconnection for the floodplain connection volume achieved.*

The curves in Figures 3 -5 can be used to calculate an approximate removal rate for each project. When project-specific data are available, the loads can be estimated using the results of hydrologic and hydraulic modeling to calculate the volume of runoff that accesses the floodplain.

Step 3: *Compute the annual N, P and TSS load delivered to the project.*

For urban watersheds, these loads are estimated by using the unit area TN, TP and TSS loading rates for pervious and impervious land derived for the river basin segment in which the project is located (i.e., CBWM version 5.3.2). These unit loads are readily available from CBP tools such as CAST, MAST and VAST. Similarly, unit loads for non-urban watersheds are available from the same CBP tools, but the delivered load is calculated from the total agricultural land use upon which the stream restoration is being applied.

1. BMPs installed within the drainage area to the project will reduce the delivered loads by serving as a treatment train. The hydrologic models/methods used for this protocol are specific to a watershed and should already account for load reductions associated with runoff reduction practices. If the assumptions that were used in the models used for this protocol have changed substantially within the 5 yr verification period because of the implementation of upstream BMPs, then the protocol should be updated accordingly.
2. However, jurisdictions should account for any appreciable load reductions attributed to non-run-off reduction practices. Appendix F provides an explanation of treatment train effects and how they are accounted for in Scenario Builder.



3.
Figure 3. Annual TN removal as a function of floodplain storage volume for several rainfall thresholds that allow runoff to access the floodplain.

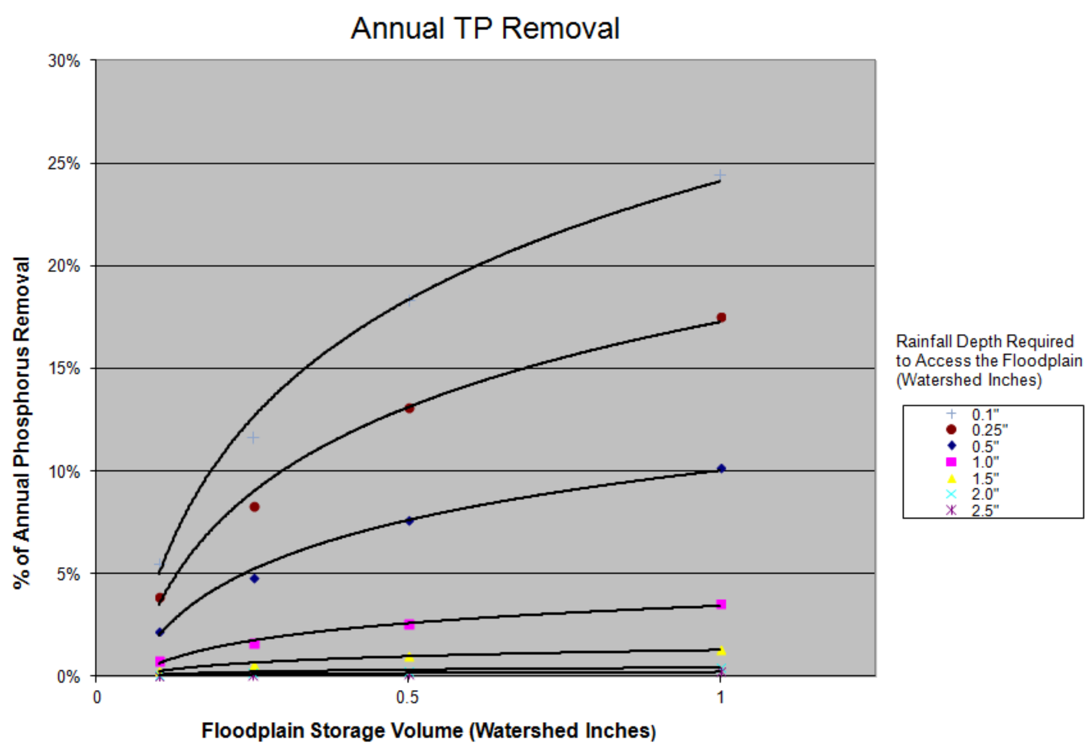


Figure 4. Annual TP removal as a function of floodplain storage volume for several rainfall thresholds that allow runoff to access the floodplain.

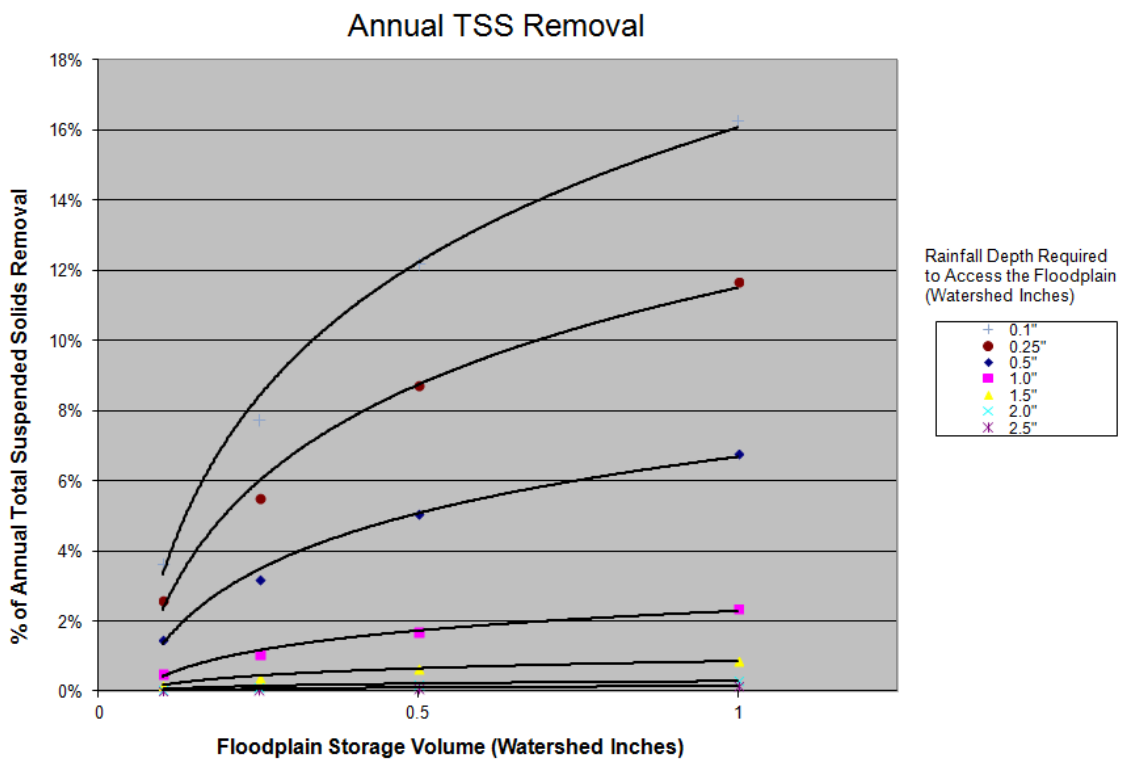


Figure 5. Annual TSS removal as a function of floodplain storage volume for several rainfall thresholds that allow runoff to access the floodplain.

Step 4: *Multiply the pollutant load by the project removal rate to define the reduction credit.*

If the wetland to watershed ratio is less than 1.0% the removal rates should be adjusted as described above. For instance a ratio of 0.5% would receive half the efficiency that a project with a 1.0% or larger efficiency.

Protocol 4
Dry Channel RSC as a Stormwater Retrofit

Because the Panel decided to classify dry channel RSC systems as an upland stormwater retrofit, designers should use the protocols developed by the Urban Stormwater Retrofit Expert Panel to derive their specific nutrient and sediment removal rates (WQGIT, 2012).

That Panel developed adjustor curves to determine TP, TN and TSS removal rates based on the depth of rainfall captured over the contributing impervious area treated by an individual retrofit. In general, dry channel RSCs should be considered retrofit facilities, and the runoff reduction (RR) credit from the appropriate retrofit removal adjustor curve may be used to determine project removal rates. The final removal rate is then applied to the entire drainage area to the dry channel RSC project.

Localities will need to check with their state stormwater agency on the specific data to report individual retrofit projects, and must meet the BMP reporting, tracking and verification procedures established by the Retrofit Expert Panel (WQGIT, 2012). In general, the following information will be reported:

a. Retrofit class (i.e., new retrofit facility)
b. Location coordinates
c. Year of installation (and ten year credit duration)
d. 12 digit watershed in which it is located
e. Total drainage area and impervious cover area treated
f. Runoff volume treated
g. Projected sediment, nitrogen, and phosphorus removal rates

Section 6: Credit Calculation Examples

The following examples are based on typical projects one might encounter in urban areas and have been created to show the proper application of the four protocols to determine the nutrient and sediment reductions associated with individual stream restoration projects. Depending on the project design, more than one protocol may apply to be used to determine the total load removed by the stream restoration project.

Section 6.1
Design Example for Protocol 1
Credit for Prevented Sediment during Storm Flow

Bay City, VA is planning on restoring 7,759 feet of Hickey Run[2]

Step 1. *Estimating stream sediment erosion rate*

Five reaches were subdivided into a total of 28 banks for BEHI and NBS assessment (Figure 1, Appendix B). The BEHI and NBS scores were taken for each bank and an estimated stream erosion rate was made using the curve developed by the USFWS. The bank height and length were used to convert the erosion rate from feet per year to pounds per year using Equation 1 from the description of Protocol 1 in Section 5. The data used in this calculation is provided in Appendix B.

The bank erosion estimates in feet per year were multiplied by the bulk density and the total eroding area (bank length in feet x bank height in feet) to convert the sediment loading to tons per year. The loading rates for each of the 5 reaches were totaled to give an estimated erosion rate for the entire 7,759 feet project length. The predicted erosion rate for the entire project length is 1,349 tons per year (348 pounds per linear foot per year).

[2] The data used for this example are taken from Hickey Run collected by the USFWS, except for bulk density, which was taken from Van Eps et al. (2004).

Step 2. *Convert erosion rate to nutrient loading rates*

From Walter et al. (2007), the phosphorus and nitrogen concentrations measured in streambank sediments are:

- 1.05 pounds TP/ton sediment
- 2.28 pounds TN/ton sediment

A sediment delivery ratio of 0.181 is applied only to the sediment load to account for the loss that occurs because of depositional processes between the edge-of-field and edge-of-stream loads and it was determined that the stream is outside of the coastal plain. Refer to Appendix B for additional information about the sediment delivery ratio. Therefore, the total predicted sediment, phosphorus and nitrogen loading rates from the restoration area is:

Sediment =	244 tons per year
Total Phosphorus =	1,416 pounds per year
Total Nitrogen =	3,076 pounds per year

Step 3. *Estimate stream restoration efficiency*

Assume the efficiency of the restoration practice to be 50% (from Baltimore County DEP Spring Branch Study). Therefore, the sediment and nutrient credits are:

Sediment =	122 tons per year
Total Phosphorus =	708 pounds per year
Total Nitrogen =	1,538 pounds per year

Section 6.2
Design Example for Protocol 2
Credit for In-Stream and Riparian Nutrient Processing within the Hyporheic Zone during Base Flow

Bay City would like to also determine the nutrient reduction enhancement credits that would be earned through in-stream and riparian nutrient processing within the hyporheic zone during base flow if parts of the restoration design for Hickey Run resulted in improved connectivity of the stream channel to the floodplain as indicated by a post construction bank height ratio of 1.0. The watershed area is 1,102 acres with an impervious cover of 41%.

Step 1. *Determine the total post construction stream length that has a bank height ratio of 1.0 or less.*

It was determined that the stream restoration could improve the floodplain connectivity by reducing the bank height ratio to 1.0 for 500 feet of stream channel. Only one side of the stream meets the reconnection criterion because of an adjoining road embankment on the other side. In the study by Striz and Mayer (2008), the groundwater flow is split into left and right bank compartments allowing the hyporheic box to be split into a left and a right bank compartment on either side of the stream thalweg divide. In step 2, only half of the stream width is used to size the hyporheic box dimensions.

Step 2. *Determine the dimensions of the hyporheic box.*

This is done by adding 5 feet to the width of the stream channel taken from the thalweg to the edge of the connected side of the stream at median base flow depth. Multiply the result by the 5 foot depth of the hyporheic box. This is the cross sectional area of the hyporheic box. Multiply the cross sectional area by the length of the restored connected channel from Step 1. The post construction stream width from the 500 foot channel segment at base flow will be on average 14 feet. To determine the width of the hyporheic box, 5 feet is added to width of half of the total stream width (7 feet) for a total width of 12 feet. The depth of the box is 5 feet. The total volume of the hyporheic box is $500(12 \times 5) = 30{,}000$ cubic feet.

Step 3. *Multiply the hyporheic box mass by the unit denitrification rate*

This step requires the estimation of the bulk density of the soil within the hyporheic box. Assume that the bulk density of the soil under a stream is 125 pounds per cubic foot. The total mass of the soil is calculated in Equation 2 below.

$$\frac{(30{,}000\ ft^3)(125\ lb/ft^3)}{2{,}000} = 1{,}875\ tons \qquad \text{(Eq. 2)}$$

Where: 2,000 = conversion from pounds to tons

The hyporheic exchange rate is 1.06×10^{-4} lb/ton/day of soil (conversion from 48.2 μg TN/kg/day of soil); therefore, the estimated TN credit is:

$$(1.06\ x\ 10^{-4}\ \ lb/ton/day)(1{,}875\ tons) = 0.20\ \ lb/day\ or\ 73\ \ lb/yr \qquad \text{(Eq. 3)}$$

Step 4: *Check to make sure the watershed cap is not exceeded.*

Since nitrate loadings are highly variable spatially, the Chesapeake Bay Program Modeling Team should be contacted for the total nitrate loading to assure that the load reductions from this and other projects do not exceed the 40% cap for any given land-river segment.

Section 6.3
Design Example for Protocol 3
Credit for Floodplain Reconnection Volume

The stream currently accesses its floodplain only during extreme storm events (> 2 year). Bay City would like to determine the amount of additional sediment and nutrient credit they would receive by connecting the stream to the floodplain, as opposed to only receiving credit for denitrification during baseflow that is provided by Protocol 2.

Step 1: *Estimate the floodplain connection volume in the available floodplain area.*

Bay City determined that by establishing a floodplain bench and performing minor excavation the stream would spill into the floodplain at storm flows exceeding 0.5 inches of rainfall (from a hydraulic model such as HEC-RAS) and the volume of storage available in the floodplain for the storm being analyzed is 23 acre feet, which corresponds to 0.25 inches of rainfall.

Step 2: *Estimate the nitrogen and phosphorus removal rate attributable to floodplain reconnection for the floodplain connection volume achieved.*

The curves in Figures 7-9 are used to estimate a removal rate for the project. The TN reduction efficiency is 3.5%, The TP efficiency is 5.0% and the TSS efficiency is 3.5%. (Note that Figures 6 – 8 should not be used for actual designs. Appendix G explains how to use more robust hydrological methods with this protocol).

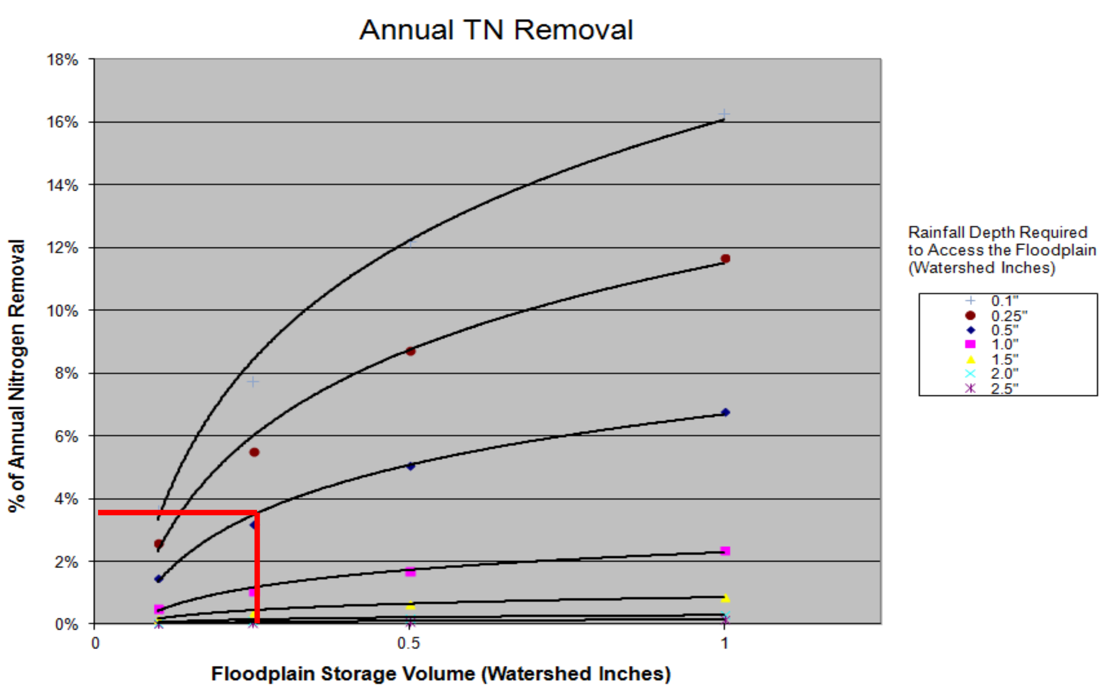


Figure 6. Annual TN removal as a function of 0.25 watershed inch[3] floodplain storage volume and 0.5 inch rainfall depth required to access the floodplain.

[3] 1 watershed inch = the volume of the watershed area to 1" of depth.

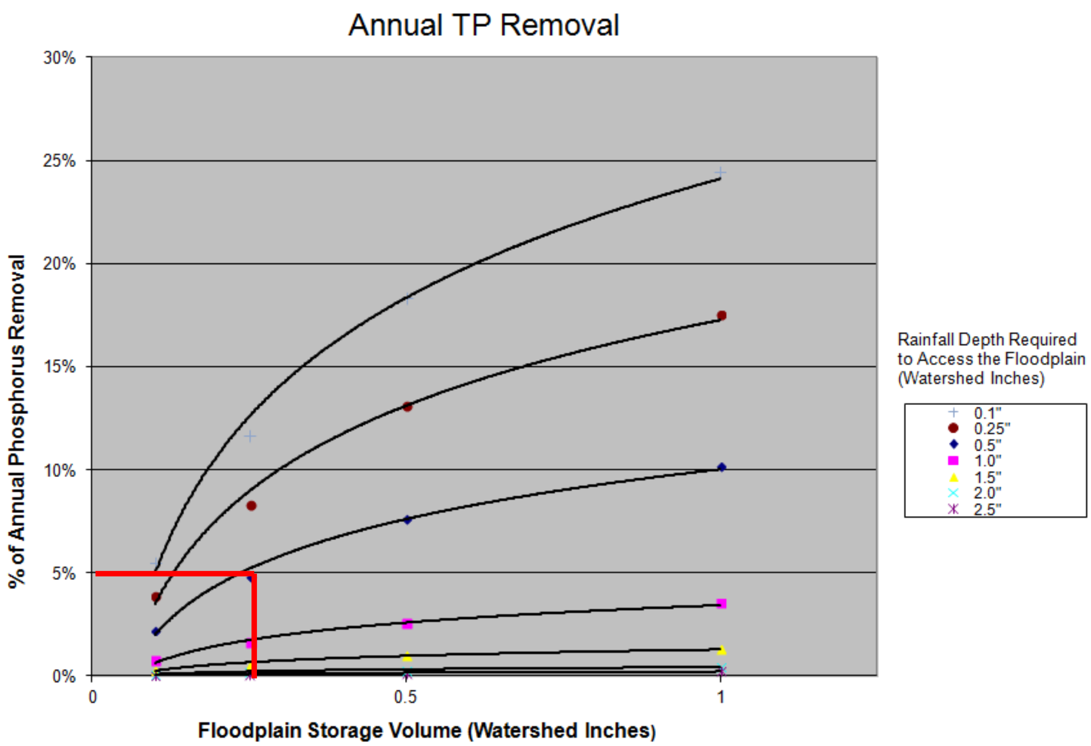


Figure 7. Annual TP removal as a function of 0.25 watershed inch floodplain storage volume and 0.5 inch rainfall depth required to access the floodplain.

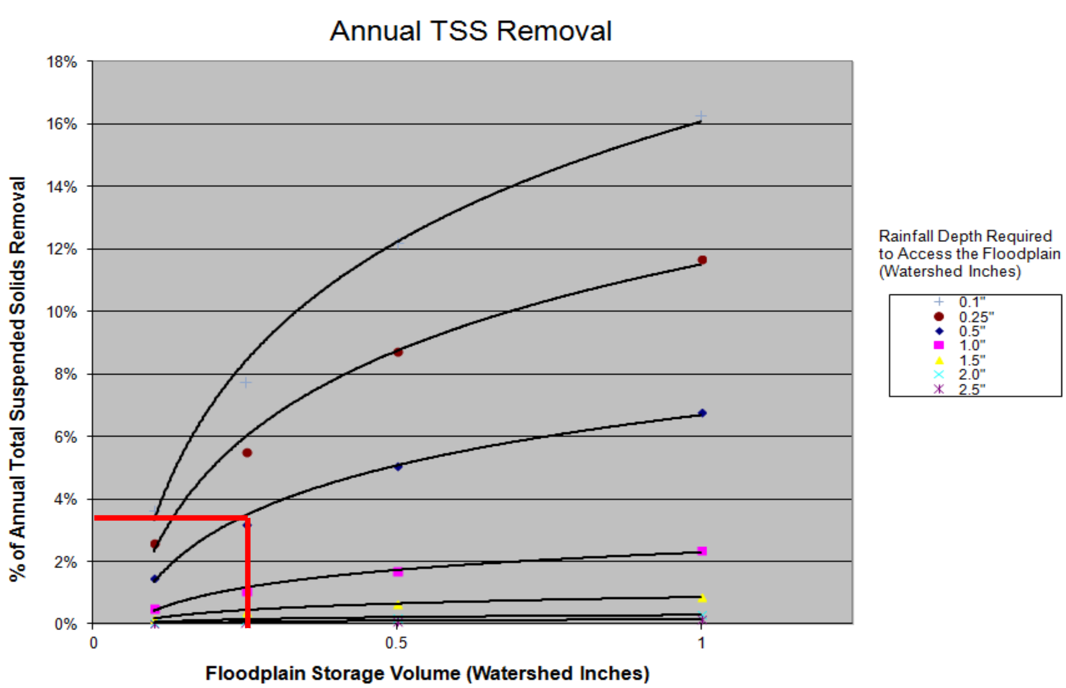


Figure 8. Annual TSS removal as a function of 0.25 watershed inch floodplain storage volume and 0.5 inch rainfall depth required to access the floodplain.

Step 3: *Compute the annual N, P and TSS load delivered to the project during storms.*

With the watershed area of 1,102 acres and impervious cover of 41%, the loading attributed to urban pervious and impervious land from Table 6 is:

TN= 12,912 pounds per year
TP= 1,389 pounds per year
TSS= 6.5×10^5 pounds per year

The efficiencies from Step 2 are multiplied by this result to yield the reduction credits.

TN= 452 pounds per year
TP= 70 pounds per year
TSS= 22.6×10^3 pounds per year

Section 6.4
Design Example for Protocol 4
Dry Channel RSC as a Stormwater Retrofit

Bay County plans to install a Regenerative Stormwater Conveyance (RSC) on an eroding hill slope near a stream valley park. Because the project is located outside of waters of the US, it is classified as a dry channel RSC and the retrofit adjustor curves are used to define its sediment and nutrient removal rate (WQGIT, 2012).

The upland drainage area to the RSC project is an 8-acre residential neighborhood that has 25% impervious cover. The engineer has estimated that the retrofit storage (*RS*) associated with the RSC is 0.167 acre-feet. The engineer determines the number of inches that the retrofit will treat using the standard retrofit Equation 4:

$$\frac{(RS)(12)}{IA} = x\ in \qquad \text{(Eq. 4)}$$

Where: RS = retrofit storage in acre-feet
12 = conversion from feet to inches
I = impervious cover percent expressed as a decimal
A = drainage area in acres

Equation 5 below incorporates the specifications for the Bay County RSC into the standard retrofit equation:

$$\frac{(0.167\ ac-ft)(12\ in/ft)}{(0.25)(8\ ac)} = 1.0\ in \qquad \text{(Eq. 5)}$$

The equation indicates that RSC will capture and treat 1.0 inch of rainfall. By definition, RSC is classified as a runoff reduction (RR) practice, so the RR retrofit removal curves in WQGIT are used. Consequently, the proposed RSC retrofit will have the following pollutant removal rates applied to the load generated from its upland contributing area:

TP	TN	TSS
52%	33%	66%

Section 6.5
Cumulative Load Reduction Comparison

The results from the design examples for Protocol 1-3 have been summarized in Table 7 so they can be compared to the reductions achieved using the revised default rate (Table 3, Row 3). These results represent the edge-of-stream load reductions and were calculated based on an average 0.181 delivery ratio for TSS.

The comparison in Table 7 shows that total sediment and nutrient reductions are additive when project design allows for more than one protocol to be used. In general, Protocol 1 yields the greatest load reduction. It should be noted that the magnitude of load reductions for Protocols 2 and 3 is extremely sensitive to project design factors, such as the degree of floodplain interaction and the floodplain reconnection.

The comparison in Table 6 also shows that load reductions achieved under the protocols for TP and TN are higher than that for the revised interim rate and the load reductions using the revised interim rate are higher for TSS. It is difficult to say whether this pattern will hold for other projects using these protocols. The Panel recommends the use of the protocols because they use site data and are believed to provide more accurate load reductions. The interim rate has value when this is not possible. Also, the interim rate is a useful planning tool within the context of CAST, VAST, or MAST and can be used to assess stream restoration strategies at the local level. The protocols can then be applied to define the specific removal rates for individual projects.

Because the Chesapeake Bay model "lumps" stream bank erosion from small order streams into the urban impervious sediment load, a portion of the sediment load delivered to the floodplain from the watershed in Protocol 3 may be accounted for in the stream bank loading from Protocol 1. Improvements to how the watershed model models sediments from stream banks are one of the major research recommendations made in Section 8.

Table 6. Edge-of-Stream Load Reductions for Various Treatment Options (lb/year)

	Protocol 1 (BANCS)[1]	Protocol 2 (Hyporehic Box)[2]	Protocol 3 (Floodplain Reconnection)[3]	Total Load Reduction from Protocols 1-3	Revised Default Rate[4]
TN	1,538	73	452	2,063	582
TP	708	--	70	778	528
TSS[5]	244,000	--	22,600	258,600	348,224

[1] For the design conditions as outlined in protocol 1 example
[2] For the design conditions as outlined in protocol 2 example
[3] For the design conditions as outlined in protocol 3 example
[4] Applying the revised unit rate to 7,759 linear feet of the project
[5] For Protocol 1 and default rate for TSS reductions, a sediment delivery ratio of 0.181 was applied.

Section 7: Accountability Mechanisms

The Panel concurs with the conclusion of the National Research Council (NRC, 2011) that verification of the initial and long term performance of stream restoration projects is a critical element to ensure that pollutant reductions are actually achieved and sustained across the watershed. The Panel also concurred with the broad principles for urban BMP reporting, tracking, and verification contained in the 2012 memo produced by the Urban Stormwater Workgroup.

Section 7.1
Basic Reporting, Tracking and Verification Requirements

The Panel recommends the following specific reporting and verification protocols for stream restoration projects:

4. *Duration of Stream Restoration Removal Credit*. The maximum duration for the removal credits is 5 years, although the credit can be renewed indefinitely based on a field performance inspection that verifies the project still exists, is adequately maintained and is operating as designed. The duration of the credit is shorter than other urban BMPs, and is justified since these projects are subject to catastrophic damage from extreme flood events, and typically have requirements for 3 to 5 years of post-construction monitoring to satisfy permit conditions. If the assumptions that were used in the protocols have changed substantially within the 5 yr verification period because of the implementation of upstream BMPs, then the protocols should be reapplied.

5. *Initial Verification of Performance*. The installing agency will need to provide a post-construction certification that the stream restoration project was installed properly, meets or exceeds its functional restoration objectives and is hydraulically and vegetatively stable, prior to submitting the load reduction to the

state tracking database. This initial verification is provided either by the designer, local inspector, or state permit authority as a condition of project acceptance or final permit approval.

6. *Restoration Reporting to the State*. The installing agency must submit basic documentation to the appropriate state agency to document the nutrient and sediment reduction claimed for each individual stream restoration project installed. Localities should check with their state agency on the specific data to report for individual projects. The Watershed Technical Work Group recommended at their April 1, 2013 meeting the following general reporting requirements.
    a. General
        i. Type and length of stream restoration project[4]
        ii. Location coordinates
        iii. Year of installation and maximum duration of credit
        iv. 12 digit watershed in which it is located
        v. Land uses and acres treated
        vi. Protocol(s) used
    b. Protocol 1
        i. Length
        ii. TSS, TP, TN load reduction (pounds per year)
    c. Protocol 2
        i. Information for right and left bank (pre and post restoration)
            1. Stream length connected to floodplain where bank height ratio is 1.0 or less
            2. Width of the stream channel taken from the thalweg to the edge of connected side of stream, as indicated by a bank height ratio of 1.0 or less
            3. TN load reduction (pounds per year)
            4. Watershed area
    d. Protocol 3
        i. Floodplain wetland area
        ii. Upstream watershed area
        iii. TSS, TP, TN loading rate reduction efficiencies (percent)
        iv. TSS, TP, TN load reduction (pounds per year)

7. *Recordkeeping*. The installing agency should maintain an extensive project file for each stream restoration project installed (i.e., construction drawings, as-built survey, credit calculations, digital photos, post construction monitoring, inspection records, and maintenance agreement). The file should be maintained for the lifetime for which the load reduction will be claimed.

8. *Ongoing Field Verification of Project Performance*. The installing agency needs to conduct inspections once every 5 years to ensure that individual projects are

[4] The length of the stream restoration project is defined as the linear feet of actual project work area and not the entire study reach. The stream valley length is the proper baseline to measure stream length.

still capable of removing nutrients and sediments. The protocols being developed by Starr (2012) may be helpful in defining performance indicators to assess project performance.

9. *Down-grading*. If a field inspection indicates that a project is not performing to its original specifications, the locality would have up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, the pollutant reduction for the project would be eliminated, and the locality would report this to the state in its annual MS4 report. Non-permitted municipalities would be expected to submit annual progress reports. The load reduction can be renewed, however, if evidence is provided that corrective maintenance actions have restored its performance.

10. *Pre and Post Construction Monitoring Requirements*. Stream restoration projects are different compared to urban BMPs, in that permit authorities often subject them to more extensive pre-project assessment and post-construction monitoring. The Panel feels that such data are important to define project success and continuously refine how projects are designed, installed and maintained.

11. *Credit for Previously Installed Projects and non-conforming projects*. Past projects and projects that do not conform to these reporting requirements can receive credit using the *"revised interim rate" a*s described in Section 2.4. The new protocols can be applied to projects that have been installed less than 5 years to receive credit. However, the credit determined from the new protocols must then be used, regardless of whether it is higher or lower than the credit provided by the interim rate.

The specific elements of the project monitoring requirements will always be established by state and federal permit authorities, and the Panel is encouraged by the knowledge that a new EPA/CBP/Corps of Engineers workgroup was launched in November, 2012 to provide more consistent project permitting and monitoring guidance for stream restoration projects. This workgroup consists of local, state and federal resource protection professionals who have recently drafted a series of principles and protocols for verification of stream restoration projects that expand in considerable detail upon the Panel recommendations with respect to project verification and assessment of functional uplift. Upon approval by the Habitat GIT, these principles will be a useful resource to guide and inform deliberations of state/federal permitting agencies.

The only specific recommendation that the Panel has to offer to the new work group is to maximize the adaptive management value of any project monitoring data collected. Specifically, the Panel encourages a more regional, comprehensive and systematic analysis of the individual project data, with an emphasis on how innovative and experimental restoration design approaches are working and the degree of functional uplift achieved (or not achieved). Such an effort could provide watershed managers with an improved understanding of not only how stream restoration can influence urban nutrient dynamics but also the degree of biological uplift (see Section 8).

Section 7.2
Issues Related to Mitigation and Trading

The Panel was clear that a stream restoration project must provide a net watershed removal benefit to be eligible for either a sediment or nutrient credit. The issues surrounding the potential for "credit stacking," as commonly referred, must be left to the agencies that are responsible for the regulatory program development and oversight and not this Panel. This is a separate policy issue that the Panel was not asked to evaluate.

The Panel also recommends a more frequent and stringent inspection and verification process for any stream restoration project built for the purpose of nutrient trading or banking, in order to assure that the project is meeting its nutrient or sediment reduction design objectives.

Section 8: Future Research and Management Needs

Section 8.1
Panel's Confidence in its Recommendations

One of the key requirements of the BMP Review Protocol is for the Expert Panel to assign its degree of confidence in the removal rates that it ultimately recommends (WQGIT, 2010). While the Panel considers its current recommendations to be much superior to the previously approved CBP removal rates, it also clearly acknowledges that major scientific gaps still exist to our understanding of urban and non-urban stream restoration. For example:

- The majority of the available stream research has occurred in the Piedmont portion of the Bay watershed and western coastal plan, and virtually none for the ridge and valley province or the Appalachian plateau. The dearth of data from these important physiographic regions of the watershed reduces the Panel's confidence in applications in these areas. In addition, there are no calibration stations within the coastal plain, and therefore, assumptions about sediment transport in this region are less accurate.

- Several parameters involved in Protocol 1 are based on intensive sampling in the Baltimore and Washington, DC metropolitan areas (e.g., nutrient content of bank and bed sediments, regional stream bank erosion curves). Given the sensitivity of the BANCS methods to these parameters, the Panel would be much more confident if more data were available from other regions of the watershed.

- The denitrification rate in Protocol 2 is based on a single study and may not be representative of all streams in the Bay watershed. However, the Panel feels that the protocol was developed based on the best science available, and recognizing the Chesapeake Bay Program's adaptive management process can be updated based on the results of continued research.

- While the floodplain connection protocol has a strong engineering foundation, the Panel would be more confident if more measurements of urban floodplain wetland nutrient dynamics were available, as well as more data on denitrification rates within the hyporheic zone.

- The Panel remains concerned about how urban sediment delivery is simulated at the river-basin segment scale of the CBWM and how this ultimately impacts the fate of the reach-based sediment and nutrient load reductions calculated by its recommended protocols.

- Limited literature exists to document the response of non-urban streams to stream restoration projects in comparison to the still limited, but more extensive literature on urban streams in the Bay watershed. The Panel would be more confident to the application of the protocols to non-urban streams if more research was available.

Given these gaps, the Panel agreed that the recommended rates should be considered interim and provisional, and that a new Panel be reconvened by 2017 when more stream restoration research, better practitioner experience, and an improved CBWM model all become available to Bay managers.

Section 8.2
Research and Management Needs to Improve Accuracy of Protocols

The Panel acknowledges that the protocols it has recommended are new, somewhat complex and will require project-based interpretation on the part of practitioners and regulators alike. Consequently, a six month "test-drive" period was allowed for practitioners and regulators to test the protocols on real world projects. Findings from the test-drive are included in Appendix G and reflect revisions to this report since initial approval by the WQGIT in May 2013. Once the protocols are finalized, the Panel recommends that a series of webcasts or workshops be conducted to deliver a clear and consistent message to the Bay stream restoration community on how to apply the protocols.

In the meantime, the Panel recommended several additional steps to increase the usefulness of the protocols that should be taken in the next 2 to 5 years:

- Provide support for the development of regional stream bank erosion curves for the BANCS method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results. Ideally, measured bank erosion rates within each subwatershed or County would be used to validate the BANCS Method specific to that location. Given that these data may not be readily available, additional methodologies for adjusting the BEHI and NBS scores to accommodate local subwatershed characteristics may be useful. For example, adjustments to the BEHI to account for areas with predominantly sandy soils, agricultural channels, or legacy sediment.

- Form a workgroup comprised of managers, practicing geomorphologists, and scientists to develop more robust guidelines for estimating rates of bank retreat.

- Continued support for more performance research on legacy sediment removal projects, such as the ongoing research at Big Spring Run in Pennsylvania, as well as broader dissemination of the results to the practitioner community.

- Further work to increase the use of stream functional assessment methods at proposed stream restoration project sites to determine the degree of functional uplift that is attained.

- Establishment of an ongoing stream restoration monitoring consortium and data clearinghouse within the CBPO to share project data, train the practitioner and permitting community, and provide ongoing technical support.

- Ongoing coordination with state and federal wetland permitting authorities to ensure that stream restoration projects used for credit in the Bay TMDL are consistently applied and meet or exceed permitting requirements established to protect waters of the US.

- Additional research to test the protocols' ability to adequately estimate load reductions in coastal plain, ridge and valley, and Appalachian plateau locations, and to investigate sediment and nutrient dynamics associated with non-urban stream restoration projects in all physiographic regions of the Bay watershed.

Section 8.3
Other Research Priorities

The Panel also discussed other research priorities that could generally improve the practice of stream restoration. A good review of key stream restoration research priorities can be found in Wenger et al. (2009). Some key priorities that emerged from the Panel included:

- Subwatershed monitoring studies that could explore how much upland retrofit implementation is needed to optimize functional uplift when stream restoration and stormwater retrofits are installed as part of an integrated restoration plan.

- Development of a database of the different stream restoration projects that are submitted for credit under each protocol, and case studies that profile both failure and success stories and on-going maintenance needs that may be required to preserve the credits (see Section 7.1).

- Further economic, sociologic, and ecological research to define the value and benefits of local stream restoration projects, beyond nutrient or sediment reduction.

- Rapid field assessment methods to assess project performance, identify maintenance problems, develop specific rehabilitation regimes, or down-grade nutrient credits where projects fail.

- Proper use and application of engineering hydrology, hydraulic, and sediment transport models to assess channel morphology.

- Development of improved design guidelines for individual in-stream restoration structures.

- Further refinement in stream restoration design methods that are habitat-based and watershed process-oriented.

- Continued research on the performance of palustrine and wetland efficiencies over time to inform Protocol 3.

Section 8.4
Recommended CBWM Model Refinements

The Center for Watershed Protection is now serving in the capacity of the Sediment Reduction and Stream Corridor Restoration Coordinator for the Chesapeake Bay Program. This work includes providing support to the key Panels related to sediment reduction such as the Stream Panel and also assisting the Watershed Technical Committee in helping to incorporate new and refined sediment reduction BMPs as they directly factor into the continued development and enhancement of Scenario Builder, the CBWM, and CAST.

Given that the sediment reduction credit of stream restoration could be greater than the existing approved rate by an order of magnitude, it is critical that the effect of this on the Watershed Model be clearly understood. Currently the model includes sediment loading from the smaller 0-3rd order streams as a part of either pervious or impervious urban and agricultural land classifications. However, the assumption from Langland and Cronin (2003) is that the majority of this sediment originates from small upland stream channels. The Center for Watershed Protection is working with the Modeling Team to determine how to better represent the smaller order streams, as well as modeling sediment transport in the next phase of model development. One possible model refinement involves modeling stream channel erosion from the smaller order streams separately from the urban and agricultural land use classifications. Whether this will result in adjustments to the total amount of sediment being delivered to the Bay or a simpler reallocation remains to be determined.

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Attachment E10: Urban Stream Restoration Fact Sheet

U-4 URBAN STREAM RESTORATION

PRACTICE AT A GLANCE

- New techniques have been pioneered in the Chesapeake Bay watershed to restore urban streams using diverse approaches such as natural channel design, regenerative stream channel, and removal of legacy sediments.
- Stream restoration improves the health of aquatic resources, and, when combined with upland restoration practices, is one of the more cost-effective practices to remove sediment and nutrients from urban watersheds.
- Credit is only given when stream restoration projects meet stringent qualifying conditions and can produce functional uplift for local streams so they provide a net environmental benefit in the watershed.
- Thus, not every stream restoration project will qualify for credit. For example, no credit can be granted for any project built to offset, compensate, or otherwise mitigate for an impact elsewhere in the watershed. The same is true for stream bank stabilization projects that are primarily designed to protect public infrastructure by bank armoring or rip rap.
- Stream restoration projects undergo extensive regulatory review and require state and federal permits.

PRACTICE DESCRIPTION

Stream restoration projects work to remove pollutants in several ways. First, the projects retain the sediment and attached nutrients in a stable, restored stream bank or channel that would otherwise be delivered downstream by an actively eroding stream. Some projects can also increase the interaction of the stream baseflow with groundwater, and promote conditions that lead to nitrogen removal. Lastly, projects that reconnect a stream to its floodplain help trap and retain sediment and nutrients carried in smaller floods.

Three different approaches can be used to restore streams:

- *Natural Channel Design* applies the principles of stream geomorphology to maintain a state of dynamic equilibrium among water, sediment, and vegetation that creates a stable channel.

- *Legacy Sediment Removal* seeks to remove legacy sediments from the stream and its floodplain and thereby restore the natural potential of aquatic resources including a combination of streams, floodplains, and wetlands.

- *Regenerative Stream Channel* uses in-stream weirs in perennial streams to increase the interaction with the floodplain during smaller storm events. These projects may also include sand seepage wetlands and other habitats to increase the stream's connection with its floodplain.

Many projects use a combination of these three techniques. Each approach is eligible for pollutant removal credits, as long it meets qualifying conditions, environmental permitting requirements and improves stream health.

WHERE TO FIND THE BEST OPPORTUNITIES IN YOUR COMMUNITY

Stream restoration projects can occur almost anywhere where streams are badly eroding including urbanized areas. They are best implemented when:

- As part of a comprehensive watershed approach
- Geomorphic evidence shows active stream degradation
- The index of biological diversity for the stream scores as fair or worse
- Hydrologic evidence shows the floodplain is disconnected from the stream
- Evidence shows that legacy sediments are prevalent in the project reach
- Evidence that stream functions can be improved
- Adjacent land becomes available through eminent domain due to flooding and offers opportunities for flood-plain reconnection
- Some of the best locations are streams that run through public parks and municipal land

The best opportunities are in areas with severely incised streams that have adjacent flood plain areas to which the stream can be reconnected. Property ownership is a key issue so it is critical to involve adjoining property owners from the get-go.

STREAM RESTORATION APPROACHES

Natural Channel Design

Legacy Sediment Removal

Regenerative Stream Channel

Likewise, the best projects are part of a comprehensive watershed restoration plan to assure better outcomes of the project goals. This plan should identify key upland practices in the watershed as well as priority areas for stream restoration.

GENERAL COST INFORMATION

Despite the fact that they are cost-effective in terms of pollutants removed per dollar expended, stream restoration projects are not cheap. Their cost can range from $150 to $400 per linear foot restored, which means most projects will cost several hundred thousand dollars or more to construct. Therefore, it is critical to assess multiple candidate stream restoration projects to find the most cost-effective ones.

Most communities finance the construction of their stream restoration projects through their long term capital improvement budgets and may require grant funding to implement the project.

TIPS FOR GETTING STARTED IN YOUR COMMUNITY

It can typically take anywhere between one and three years to go from project concept to construction of stream restoration projects, and even longer if there are contentious permit issues. In addition, the design of most stream restoration projects requires a lot of upfront monitoring and survey work, and there may also be additional post-construction monitoring, as well.

Most streams and floodplains are classified as wetlands, and any activity within them is regulated under state and federal wetland permits. Getting a permit to proceed with construction can be a very lengthy process, and is not automatic. Consequently, it is essential to consult with the Corps of Engineers, U.S. EPA and other wetland regulators very early in the process to get feedback on permitting.

Another key tip is to involve the public during the stream restoration design process; particularly if there will be significant construction impacts, such as the removal of large trees.

WHAT DEGREE OF TECHNICAL SUPPORT IS NEEDED

Stream restoration design, permitting and construction can be very complex, and requires a lot of skill in engineering, project management and construction oversight. Most communities will need to hire experienced consultants to do most of the work, but will need good in-house talent to effectively manage the projects.

Stream restoration requires a multidiscipline team including the following:

- Stream restoration should be part of a comprehensive watershed restoration strategy requiring the skills of a watershed planner and those skilled in monitoring and assessment.
- A stream restoration project should be designed by a professional engineer with appropriate training in geomorpholgy. The design team should also consult with a professional biologist to consider what stream functions can be improved or what stream functions might be lost as a result of the project.
- The construction of a stream restoration project also requires an experienced contractor that specializes in stream restoration installation.
- To receive credits, all qualifying projects must have a designated authority responsible for project maintenance that includes both routine maintenance and long-term repairs.

COMPUTING THE POLLUTANT REMOVAL CREDIT

There are three general protocols to define the pollutant load reductions associated with individual stream restoration projects. The protocols are additive, and an individual stream restoration project may qualify for credit under one or more of the protocols, depending on its design and overall restoration approach. A general description is provided below. Jurisdictions may find it beneficial to perform the calculations as part of their design contracting to optimize the project's pollutant load reductions.

Default Rate. Historic projects and new projects that cannot conform to recommended reporting requirements of the Chesapeake Bay Program may be able to receive credit through a default rate (**Table 1**).

Table 1. Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS*
Revised Default Rate	**0.075**	**0.068**	**44.88 non-coastal plain** **15.13 coastal plain**

Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania

*To convert edge of field values to edge of stream values a sediment delivery ratio (SDR) was applied to TSS. The SDR was revised to distinguish between coastal plain and non-coastal plain streams. The SDR is 0.181 for non-coastal plain streams and 0.061 for coastal plain streams.

Protocol 1. Credit for Prevented Sediment During Storm Flow

This protocol provides a nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.

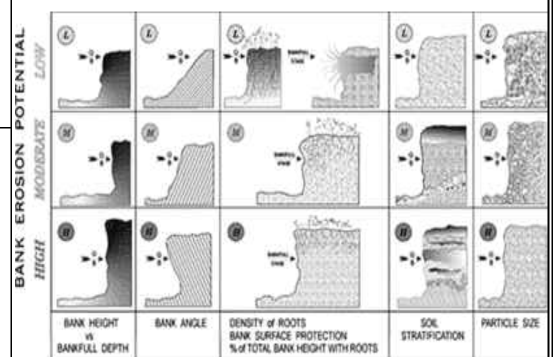
This protocol follows a three step process to compute a mass reduction credit for prevented sediment:

1. Estimate stream sediment erosion rates and annual sediment loadings,
2. Convert erosion rates to nitrogen and phosphorus loadings, and
3. Estimate reduction attributed to restoration (50% default rate) or use monitoring data.

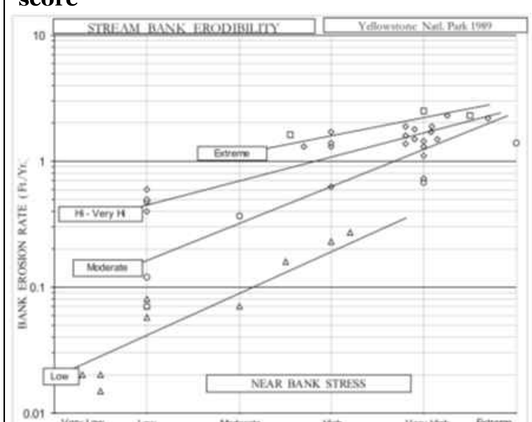
- Monitoring using methods such as cross section surveys and bank pins is the preferred approach.
- When monitoring is not feasible, use the “Bank Assessment for Non-point Source Consequences of Sediment” or BANCS method to estimate sediment and nutrient load reductions.
- The BANCS method utilizes two commonly used bank erodibility estimation tools to predict stream bank erosion: the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) methods.

BANCS METHOD

1. Assess BEHI score based on criteria below



2. Use field measurements to determine BEHI score



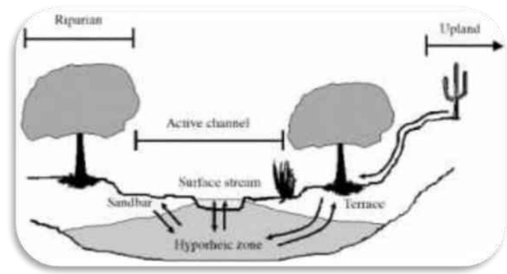
3. Estimate erosion rate using BEHI and near bank stress.

Protocol 2. Credit for In-stream Nitrogen Processing During Base Flow

This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow within the stream channel through enhanced surface water/groundwater exchange (hyporheic zone) within the riparian corridor. This protocol relies heavily on denitrification research in restored streams within the Baltimore metropolitan area.

- This protocol applies to stream restoration projects where in-stream design features are incorporated to enhance nutrient processing, such as denitrification.
- Qualifying projects receive credit for enhanced nitrogen removal within the stream channel during base flow conditions.
- Protocol 2 only provides a nitrogen removal credit; no credit is given for sediment or phosphorus removal.

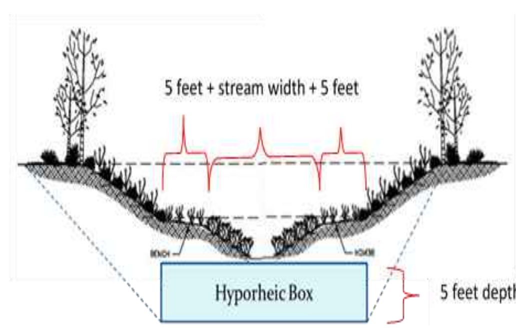
- It is assumed that the denitrification occurs in a "box" that extends the length of the restored reach. The cross sectional area of the box extends to a maximum depth of 5 feet beneath the stream bottom with a width that includes the median base flow channel and 5 feet added on either side of the stream bank (see Figure 3 to the right). The dimensions of the box apply only to sections of the stream where hyporheic exchange can be documented.
- The volume of the "box" is multiplied by a denitrification rate.



Functional ecomorphology: Feedbacks between form and function in fluvial landscape ecosystems. Stuart G. Fisher, , James B. Heffernan, Ryan A. Sponseller, Jill R. Welter

1. Surface and groundwater interaction described as "hyporheic exchange" between the stream channel and the floodplain

2. Restored stream with improved hyporheic connection

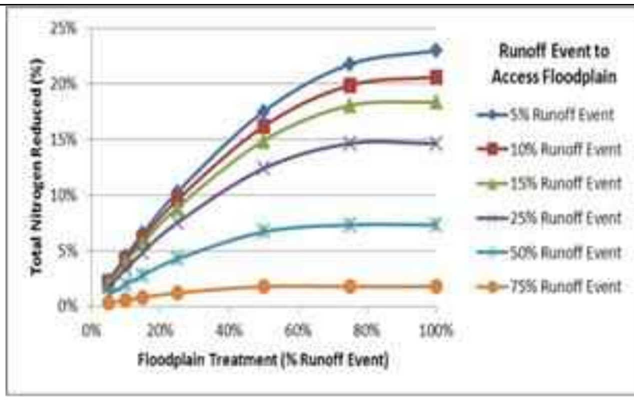


3. Volume used to compute enhance denitrification The credit is determined only for the length of stream reach that has improved connectivity to the floodplain as indicated by a bank height ratio of 1.0 (bank full storm) or less for projects that use the natural channel design approach.

Protocol 3. Credit for Reconnection to the Floodplain

This protocol provides a sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events, from the small, high frequency events to the larger, less frequent events.

- Qualifying projects receive credit for sediment and nutrient removal under Protocol 1 and denitrification in Protocol 2 (if applicable) and use this protocol to determine enhanced sediment and nutrient removal through floodplain wetland connection.
- This method assumes that sediment, nitrogen and phosphorus removal occurs only for that volume of annual flow that is effectively in contact with the floodplain.
- A series of curves were developed that relate the floodplain reconnection volume to the effective depth of rainfall treated in the floodplain, which in turn are used to define the nutrient removal rate that is applied to subwatershed loads delivered to the project.



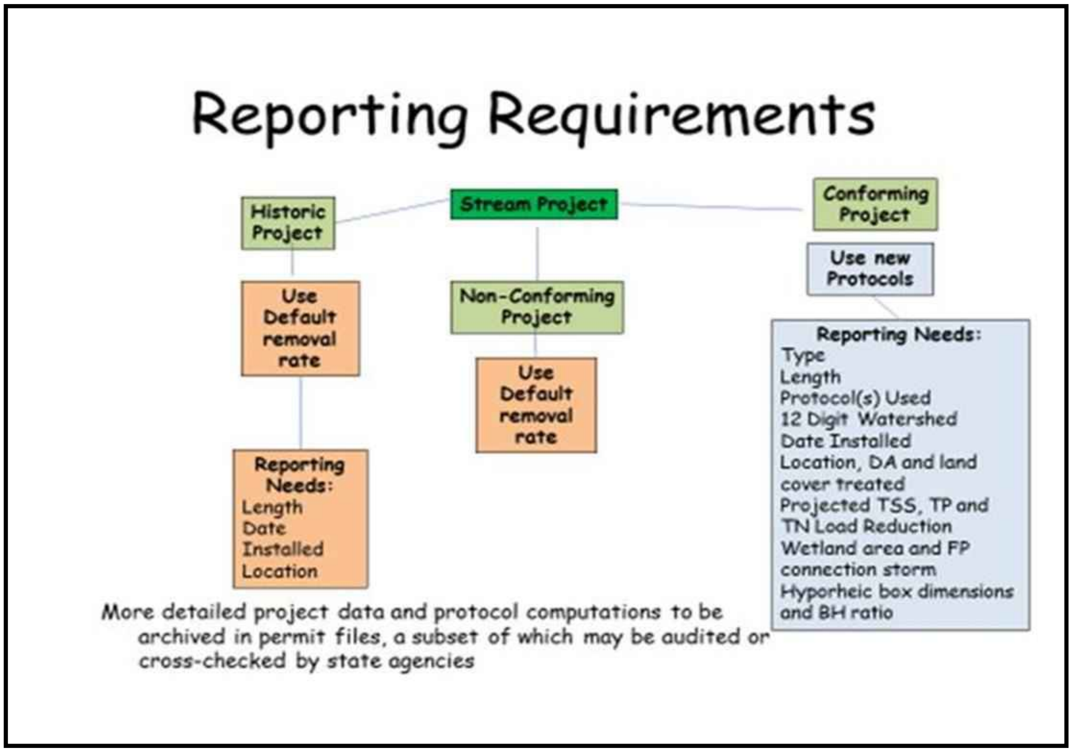
Higher bank in lower picture translates to lower frequency of floodplain access than upper photo and consequently lower reduction efficiencies.

The extent of the credit depends on the elevation of the stream invert relative to the stage elevation at which the floodplain is effectively accessed. Designs that divert more stream runoff onto the floodplain during smaller storm events (e.g., 0.25 or 0.5 inches) receive greater nutrient credit than designs that only interact with the floodplain during infrequent events, for example the 1.5 year storm event.

The floodplain connection volume afforded by a project is equated to a wetland volume so that a wetland removal efficiency for TN, TP and TSS can be applied.

HOW TO REPORT THE PRACTICE TO THE STATE

Basic reporting requirements are presented in the figure below. The maximum duration for the removal credits is 5 years, although the credit can be renewed indefinitely based on a field performance inspection that verifies the project still exists, is adequately maintained and is operating as designed.



WHAT IS REQUIRED TO VERIFY THE PRACTICE OVER TIME

- The installing agency needs to certify that the stream restoration project was installed properly, meets or exceeds its functional restoration objectives and is hydraulically and vegetatively stable, prior to submitting it for credit to the state tracking database. This initial verification is provided either by the designer, local inspector, or state permit authority as a condition of project acceptance or final permit approval.

- The installing agency inspects the project once every 5 years to ensure that it is still capable of removing nutrients and sediments.

- If the field inspection indicates the project is not performing to its original specifications, the locality has one year to take corrective maintenance or rehabilitation actions to bring it back into compliance.

RESOURCES

The following resources are available for help with all aspects of this practice:

Type of Resource	Title of Resource	Web link
Expert Panel Report	Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects (2014) – Short Version	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2013/10/stream-restoration-short-version.pdf
	Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects (2014) – Long Version	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2013/05/stream-restoration-merged.pdf
Archived webcast(s)	Urban Stream Restoration Protocols and Frequently Asked Questions Webcast (2014)	http://chesapeakestormwater.net/events/webcast-urban-stream-restoration/
Expert Panel Appendix A	Appendix A: Annotated Literature Review	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2015/03/Appendix-A.-Annotated-Literature-Review.pdf
Expert Panel Appendix B	Appendix B: Protocol 1 Supplemental Details	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2015/03/Appendix-B.-Protocol-1-Supplemental-Details.pdf
Expert Panel Appendix C	Appendix C: Protocol 2 and 3 Supplemental Details	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2015/03/Appendix-B.-Protocol-1-Supplemental-Details.pdf
Paper	Harman, W., et al. "A Function-Based Framework for Stream Assessment and Restoration Projects." (2012).	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2015/03/A_Function-Based_Framework-2.pdf
Stream Restoration Manual	Urban Subwatershed Restoration Manual Series Manual 10: Unified Stream Assessment: A User's Manual	http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2014/09/Manual-10.pdf
More Tools & Resources		http://chesapeakestormwater.net/training-library/urban-restoration-techniques/stream-restoration/

Section F

SECTION F - IDENTIFY FUNDING MECHANISM

South Middleton Township plans to consider many sources of funding to implement the proposed stormwater BMPs identified in this Plan. The anticipated funding source to implement the stormwater BMPs may include any of the following:

South Middleton Township General Fund: The Township may plan to budget sufficient funds each year of the five-year permit term (2018-2023) to fully fund the implementation of all stormwater BMPs to meet the required pollutant reductions.

PENNVEST: The Pennsylvania Infrastructure Investment Authority (PENNVEST) provides funding for urban stormwater and agricultural BMPs.

Growing Greener Grants: Growing Greener provides state funds to address environmental concerns, including the negative effects of stormwater pollution on water quality. These grants vary in availability and total funding dollars.

PA DEP's Urban Stormwater BMP Grants: As part of the Local Stormwater BMP Implementation Program, PA DEP has provided grants to communities located in the Chesapeake Bay Watershed to reduce stormwater runoff to local waterways. These grants vary in availability and total funding dollars.

Collaboration: South Middleton Township will continue to look for other funding opportunities to implement stormwater BMPs by collaborating with municipalities, watershed organizations, and the Cumberland County Conservation District.

Section G

SECTION G - IDENTIFY RESPONSIBLE PARTIES FOR OPERATION AND MAINTENANCE (O&M) OF BMPs

All the identified stormwater BMPs must be maintained on a regular basis, after fully implemented, to ensure they continue to provide water quality benefits as designed.

Parties Responsible for ongoing O&M: South Middleton Township will work with property owners to develop a mutually agreed upon Operation & Maintenance Agreement to ensure that the implemented BMPs function as designed to minimize the sediment and nutrient loading rates to local surface streams.

Activity involved with O&M for each BMP and the frequency at which O&M activities occur:

Bioswales: A bioswale is an excavated shallow surface depression planted with native vegetation to treat stormwater runoff. This BMP functions to reduce stormwater volumes and stormwater pollutants that may otherwise discharge to local surface waters. Additional benefits of constructing a bioswale include recharging groundwater supplies, reducing stormwater temperature impacts, enhancing evapotranspiration, providing habitat, and expanding bio-diversity. However, to ensure that bioswales continue to function as designed, regular O&M activities must occur as follows:

- Inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation. Remove sediment when >3 inches accumulates at any spot or is covering the vegetation.
- Inspect vegetation on side slopes for erosion and formation of rill or gullies; correct as needed.
- Inspect for pools of standing water; dewater and discharge to an approved location and restore to design grade.
- Mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation; dispose of cuttings properly; if vegetation requires mowing, mow only when the swale is dry to prevent rutting.
- Inspect for uniformity in cross-section and longitudinal slope; correct as needed.
- Inspect associated stormwater facilities such as inlets, pipes, and curb cuts, for signs of erosion or blockage; correct as needed.

O&M activities to be performed as needed:

- Plant alternative grass species in the event of unsuccessful establishment.
- Reseed bare areas; install appropriate erosion control measures when native soil is exposed or erosion channels are forming.
- Rototill and replant swale if draw down time is more than 72 hours.
- Inspect and correct check dams, if applicable, when signs of altered water flow are identified.
- Water during dry periods, fertilize, and apply pesticide only when necessary.

Dry Extended Detention Basin: A dry extended detention basin provides temporary storage of stormwater runoff so that suspended solids have time to settle out into the basin instead of being carried downstream. To ensure this stormwater BMP continues to function as designed, regular O&M activities must occur as follows:

- All basin structures should be inspected at least four times per year and after all storm events greater than 1 inch in 24 hours. Structures may include basin bottoms, trash racks, outlet structures, riprap or gabion structures, and inlets. Check for clogging, excessive debris and sediment accumulation.
- Remove accumulated sediment as needed when the basin is completely dry and dispose of properly. Seed and stabilize the disturbed areas immediately.
- Mow and trim all vegetation as needed. Remove all plant detritus and dispose of properly.
- Inspect vegetated areas as follows:
  - Inspect annually for erosion.
  - Inspect annually for unwanted growth of exotic/invasive species.
  - Maintain vegetative cover at 95% minimum cover. If bare spots exist, replant or seed and stabilize as needed.

Streambank stabilization: Once the streambank project has been completed, regular inspection and maintenance activities will occur as follows:

- Since vegetation establishment is a critical component of the long-term stability of the streambank, monthly inspections should occur for the first year after the project is complete. A minimum 85% plant survival rate should be achieved and documented.
- Weeds and invasive plants threaten the survival of native plants, and should be aggressively controlled by herbicides, mowing, and/or weed mats for the first four years after implementation.
  - Applying herbicides for the first two to three years may be necessary to control weeds. This activity is regulated by the PA Department of Agriculture and proper care should be taken in a streamside setting.
  - Mowing grasses should occur twice each growing season with a mower height set to eight to twelve inches.
  - Weed mats suppress weed growth around newly planted vegetation and should be removed once trees have developed a canopy sufficient to shade out the weeds.
- Once the vegetation has been established, regular maintenance should be minimal.