Updated Watershed Implementation Plan for Core Creek/Lake Luxembourg

Bucks County, PA

Prepared for:

Bucks County Conservation District
Attn: Meghan Rogalus
1456 Ferry Road, Suite 704
Doylestown, Pennsylvania 18901
215.345.7577 x 107

Prepared by:

Princeton Hydro, LLC
203 Exton Commons
Exton, Pennsylvania 19341
(P) 610.524.4220
(F) 610.524.9434
www.princetonhydro.com
Offices in New Jersey, Pennsylvania and Connecticut

October 2016

Revised March 2017

Second Revision May 2017

Contents

Table of Contents

COMPANY INTRODUCTION **3**

Princeton Hydro, LLC 3

1.0 INTRODUCTION **4**

1.1 Non-319-Funded Projects 5

2.0 BMPS PROPOSED FOR FUTURE IMPLEMENTATION **11**

2.1 Shoreline Stabilization 11

2.2 Lake Restoration 12

2.3 Vegetated Buffers/Streambank Stabilization 14

2.4 Best Management Practice Retrofits 20

3.0 CONCLUSIONS **45**

Authors: Katie Walston and F. S. Lubnow, Ph.D.

Company Introduction

Princeton Hydro, LLC

Princeton Hydro, LLC is a full-service water resource firm founded in 1998 based on the principal of innovative design solutions for water, soil and wetland resource management. Princeton Hydro specializes in the restoration of impacted lakes, rivers and streams. Our award-winning, multidisciplinary team of ecologists, fluvial geomorphologists, fisheries biologists, environmental scientists and geotechnical and water resource engineers has a wealth of experience restoring degraded ecosystems. Our goal is to restore as many natural functions as possible while balancing the many essential societal uses of lakes. Our innovative restoration designs look to create resilient self-sustaining lake systems that measurably improve ecological health.

Balancing the needs of a community and the needs of lake ecosystems can be one of the greatest challenges for restoration projects. However, there are creative, yet still practical, solutions that can be found when all of a project's stakeholders are brought to the table and work to find common goals and interests. Princeton Hydro believes in working with local communities to promote a sound environmental stewardship ethic so that future generations can continue to benefit from healthy lakes.

1.0 Introduction

Lake Luxembourg, located in Bucks County, PA, serves as the focal point of Core Creek County Park. The lake, with a surface area of 174 acres, was formed through the impoundment of Core Creek in 1977. As a multi-use reservoir, Lake Luxembourg is important in the community for recreation and serves a vital ecological role as well. The Core Creek watershed has a surface area of 6,033 acres, of which almost 99% directly drains into Lake Luxembourg. The lake is located in Middletown Township, while the Core Creek watershed is located, with approximately equal portions, in Middletown, Lower Makefield and Newtown Townships.

Currently, Lake Luxembourg and Core Creek are on Sublist 4 of the State "Integrated Water Quality Monitoring and Assessment Report," indicating there are approved Total Maximum Daily Loads (TMDLs) for total phosphorus (Lake Luxembourg) and total suspended solids (Lake Luxembourg and Core Creek).

As a result of high rates of sedimentation and accelerated eutrophication a number of studies and projects have been conducted on Core Creek and Lake Luxembourg over the last 24 years. This Watershed Implementation Plan (WIP) update serves to build upon these studies and the associated best management practices (BMPs) that have been implemented in the past. In turn, the implementation of identified potential future projects will further the goal of reducing the sediment and phosphorus loads entering Lake Luxembourg, Core Creek and Neshaminy Creek. Thus, these proposed projects will continue to move the lake toward compliance with its TMDL for total phosphorus (TP) and total suspended solids (TSS) and Neshaminy Creek toward compliance with its TMDL for TSS.

When the original Phase I Diagnostic Feasibility Study was conducted (Coastal Environmental Services, 1993), the dominant land types in the Lake Luxembourg / Core Creek watershed were residential (36.2%) and agricultural (35.8%). These estimates are based on land use / land cover data from 1990. In contrast, using NLCD data from 2011 residential lands clearly dominated the watershed (50.4%) while agricultural lands slightly declined (29.3%).

While a variety of agricultural BMPs, residential BMPs, shoreline / streambank stabilization projects have been implemented in the Core Creek / Lake Luxembourg watershed since the late 1990's, the latest set included retrofitting four dry detention basins into naturalized dry basins and the stabilization of nearly 1,000 linear feet of lake shoreline. These projects were designed and implemented with funds through a 319-grant awarded to the Buck County Conservation District in SFY2012. This project was completed in June 2016, which included a supplemental planting of additional vegetation along the shoreline site, completed in May 2016.

The Bucks County Conservation District met with both PA DEP and US EPA in July 2015 to discuss moving the restoration of the Lake Luxembourg / Core Creek watershed forward. As part of this meeting Princeton Hydro provided a PowerPoint presentation, which included a summary of the

TP and TSS anticipated to be removed as a result of the five projects completed in 2016. A summary of the project activities relative to the TMDL is provided in Table 1.

As a result of the July 2015 meeting, this WIP update was conducted to identify potential BMP sites for design and implementation within the Core Creek Watershed that can contribute toward compliance with the TP and TSS TMDLs. In addition to identifying potential BMP sites for design and implementation, a brief description of non-319-funded is also provided below that have either been completed or will be completed by the end of 2017. Please note that the estimated amount of TP and TSS removed from many of these non-319-funded stormwater / watershed projects are also provided in Table 1.

1.1 Non-319 Funded Projects

Memorial Park Stormwater Basin (Lower Makefield Township)

In 2010, a one acre naturalized stormwater basin was implemented at Memorial Park in Lower Makefield Township (Figure 1.1.1). Naturalized basins provide temporary storage of stormwater runoff to help prevent flooding as well as improve water quality. These basins are planted with native vegetation to help reduce the nutrients being transported by the stormwater, as well as reduce flow. Overall, these basins help reduce flow, nutrients and sediments before the stormwater continues on through the watershed.

Figure 1.1.1: Memorial Park naturalized basin (Photo provided by Lower Makefield EAC).

Villas at Shady Brook (Newtown Township)

Two projects were implemented within the community at The Villas at Shady Brook located within Newtown Township. Two of the wet ponds on site underwent shoreline stabilizations (Figure 1.1.2). In 2008, the 0.37-acre wet pond shoreline was stabilized and a 20-foot riparian buffer was planted and established. In 2016, the 1.2-acre wet pond shoreline was stabilized and a 15-foot buffer was planted and established.

Restoration of shorelines prevents further erosion of the lake shore and aids in reducing the nutrient and sediment inputs. Riparian buffers also help provide ecological and water quality benefits to a waterbody through the planting of native vegetation. These buffers can help improve wildlife habitat, aesthetics, and help filter nutrients and sediments prior to runoff entering the lake.

Figure 1.1.2: Villas at Shady Brook shoreline stabilization and buffer.

Moon Nursery Development (Lower Makefield Township)

A variety of projects are currently being implemented at Moon Nursery development, located along Quarry Rd in Lower Makefield Township. One water quality basin, two infiltration basins and a 13-acre conservation easement are currently being implemented. These three basins are effective in the reduction of flow, nutrients and sediment. The conservation easement aids in the preservation of riparian buffers within the watershed. This preservation helps reduce the impact of pollutant sources upstream, protect streambanks and shorelines, as well as provides wildlife with habitat and protection. This easement will also help bolster the native vegetative population. These projects should be completed by the end of 2017.

Village Road (Middletown Township)

An infiltration trench is planned to be implemented at Village Road in Middletown Township during the summer of 2017. The proposed trench will be 1,800 ft^3 (400 ft^2 x 4.5 ft deep). These trenches allow for greater infiltration of stormwater runoff, resulting in reductions in nutrient, sediment and hydrologic flow. Again, these stormwater projects will be completed by the end of 2017.

In addition to the projects listed above, provided below is a short list of observed sites that may be "naturalized" BMPs – that is, they may not have been intentionally designed to function as stormwater BMP may have been more passively created (e.g. establishing a no mow zone around a pond).

Steeple Chase Drive (Lower Makefield Township)

There is an approximately 1.8 acre area maintained in a wet meadow condition near the corner of Steeple Chase Drive and Lindenhurst Road. According to Buck County parcel data the property is privately owned. While the site does not appear to be an intentional stormwater BMP, the establishment of this non-mowed, meadow area does contribute toward reducing the pollutant loads (nutrients and suspended solids) as well as aid in facilitating infiltration of stormwater into the ground.

Powderhorn Drive (Lower Makefield Township)

These are two wet ponds, each approximately 0.5 acres in area, located on Lower Makefield Township property and have vegetative buffers of approximately 15 feet that may have been naturally established (Figures 1.1.3 and 1.1.4).

Figures 1.1.3 -1.1.4: Powderhorn Drive ponds.

Payten Drive (Lower Makefield Township)

Field investigations located a wetland basin that is owned by the Township of Lower Makefield. Wetland BMPs have some of the highest pollutant removal rates for both suspended solids and nutrients. In addition, they can be particularly effective at reducing dissolved forms of nutrients such as nitrogen and phosphorus.

Figure 1.1.5: Payten Drive naturalized stormwater basin.

Table 1

Comparison of Pollutants Removed as a Result of Implemented Projects to the Pollutants Targeted for Removal under the TMDL for Lake Luxembourg / Core Creek, Bucks County, PA

TMDL Loading Scenario	TP (lbs)	TSS (lbs)
Existing Pollutant Loads (pre-2008)	2,979	3,725,960
Targeted Pollutant Loads	2,254	2,866,127
Required Pollutant Load Reductions	**725**	**859,833**
BMPs Implemented in 319-grants (2008 - 2016)		
Stormwater BMPs, Shoreline Stabilization and Pocket Wetland (2008)	35	93,042
Village Farm BMPs	118.5	17,600
Heather Ridge Basin CC-E63	6.4	6,410
Heather Ridge Basin CC-F59	6.4	6,410
Yardley Run Basin	4.3	4,274
Nun Academy Basin	4.3	4,274
Shoreline Stabilization	0.4	792
Total	**175.3**	**132,802**
BMPs Implemented; non-319-grants		
Memorial Park naturalized Basin	8.0	8,013
Villas at Shady Brook shoreline stabilizations	0.5	792
Moon Nursery Development Basins	16	16,026
Village Road Infiltration Trench	8.5	7,122
Naturalized BMPs	15.4	420
Total	**48.4**	**32,373**
Total amount of Pollutant Removed (by 2018)	223	165,175
Amount of Pollutant Remaining to be Removed under the TMDL (by 2018)	**502**	**694,658**
Percent of Pollutant Load Removed under Targeted Reduction (by 2018)	31%	19%

2.0 BMPs Proposed for Future Implementation

2.1 Shoreline Stabilization

A large stretch of shoreline west of the Park boat launch could be better protected (Figure 2.1.1; noted as SS-1 on the watershed map in Appendix A). The area is currently mowed up to the water's edge and is the grazing area for a large population of geese and other birds. A vegetated buffer similar to those planted in the past along other sections of the Lake Luxembourg shoreline should be implemented to protect the shore from potential erosion as well as reduce nutrient inputs from surface runoff.

Please note the approximately 1,000 linear feet of shoreline in the southern "corner" of the lake was just re-graded, stabilized and planted with native vegetation in 2015-2016. This proposed project would potentially expand this vegetated shoreline by another 1,000 linear feet.

Recommendation: Major re-grading does not appear to be required, however, tilling of the soil may be necessary due to nearshore soil compaction. The proposed project should include multiple access points for fisherman or park visitors to avoid potential tampering that has occurred at other stabilization sites with only one access point.

Figure 2.1.1: Proposed shoreline stabilization and revegetation site at Lake Luxembourg.

2.2 Lake Restoration

Silver Lake (Newtown Township) is a small waterbody located north of Lake Luxembourg and adjacent to the Newtown Bypass. This waterbody drains directly into Core Creek, less than a mile and a half upstream of Lake Luxembourg. Silver Lake contains high nutrient concentrations year around, primarily as a result of hundreds of Canada geese that inhabit this area over the winter months (Figure 2.2.1; noted as SS-2 on the watershed map in Appendix A). The lake is directly adjacent to major roads and lacks a vegetated buffer; the installation of such buffers would contribute toward reducing some of the nutrient loads from nearby impervious surfaces. The lake is located in Silver Lake Park and is adjacent to a large manicured area where people often bring their dogs. Canada geese also frequent the large open areas in the park. Since Silver Lake is hydrologically connected to Lake Luxembourg reducing the nutrient loads, particularly phosphorus, that discharge from it will contribute toward reducing the loads that enter both Core Creek and Lake Luxembourg.

Recommendations: A vegetative buffer should be created for a substantial portion of the shoreline of this lake. Grasses and low lying herbaceous vegetation that do not obstruct the view of the lake to visitors, with strategically placed woody vegetation is recommended. The native vegetation would also deter some of the geese from entering the lake from the shore. In-lake practices should also be considered, such as an aeration / circulation system and / or Floating Wetland Islands (FWIs). Due to the amount of Canada geese at this site, an alternative to the FWIs would be a BioDi Aerobic Digester which is designed to reduce organic material, nitrogen and other pollutants in the waterbody. Controlling the Canada geese population should be a long-term, watershed goal for reducing the nutrient concentration both in Silver Lake and its discharge.

Figure 2.2.1: Conditions at Silver Lake over the winter season.

Timber Lakes Drive (Lower Makefield Township)

This site is located at Timber Lakes Dr and Lindenhurst Rd and includes a series of seven ponds (Figures 2.2.2 through 2.2.4; noted as SS-3 on the watershed map in Appendix A), likely owned by the community or individual residents. The ponds at the northern end of the neighborhood drain directly into Core Creek. Six of the ponds appear to be hydrologically connected. Large populations of Canada geese were present at all of the ponds and surrounding areas. Multiple ponds have no vegetated buffer with mowed lawns right to the ponds' edge and also exhibit some shoreline erosion. At least one of the ponds has an aeration system to address / improve water quality. The entrance pond has vegetation surrounding the entire lake, dominated by bamboo along the road side.

Recommendations: Vegetated buffers should be considered for the pond shorelines; at a minimum, a no-mow zone should be established between 5 and 25 feet. Planted shoreline vegetation and/or a no-mow zone would reduce nutrient loads from surface runoff and also deter some of the geese from entering the ponds. In-lake practices should also be considered, such as aeration / circulation system and / or Floating Wetland Islands (FWIs). Due to the amount of Canada geese at this site, like Silver Lake, an alternative to the FWIs could be a BioDi Aerobic Digester. Geese control is absolutely necessary.

Figures 2.2.2, 2.2.3 and 2.2.4: Conditions at multiple ponds at Timber Lakes Dr.

2.3 Vegetated Buffers/Streambank Stabilization

While site assessments conducted in September 2004 indicated that a large portion of the Core Creek system has sufficient vegetative buffers, many areas along the creek could be improved by increasing the width of these buffers. Vegetated buffers allow for uptake of nutrients from the surrounding areas before entering the waterbody. Possible site locations are described below.

Broad Meadows Farm (Lower Makefield Township)

This length of exposed Core Creek is located on Lindenhurst Road in the middle of the Broad Meadows Farm property. This section of the creek lacks a vegetated buffer has some steep cuts (Figure 2.3.1; noted as SS-4 on the watershed map in Appendix A) and is surrounded by horse pastures. Along with nutrient input from the farm animals and farmland, large amounts of Canada geese also frequent the areas around the creek. The stream channel is eroded and often trampled by the large farm animals. Stormwater also enters the site from Lindenhurst Road. This long-exposed reach is directly upstream of Silver Lake, and is a source of NPS pollution for both it and Lake Luxembourg.

Recommendations: The streambanks should be re-graded and stabilized. A buffer of trees and fencing should be implemented to prevent horses from entering the stream. Various stabilized crossings should be implemented along the stream to allow for farm animals to cross safely and without harming the condition of the channel.

Figure 2.3.1: Stretch of Core Creek located at Broad Meadows Farm.

Tributary 1

Located immediately upgradient of the most southeastern cove of Lake Luxembourg, this tributary is completely surrounded by forested lands, making it very difficult to access. A large buffer exists around this stream; however, significant erosion has been observed in some of the upstream sections (Figure 2.3.2; noted as SS-5 on the watershed map in Appendix A).

Recommendations: If access allows, possibly create bankfull benches with rock and rip-rap in areas with highly eroded sides. Drawing back banks is likely difficult due to existing woody vegetation. Possible understory plantings (e.g. ferns) or plantings along the streambank to stabilize is also an option.

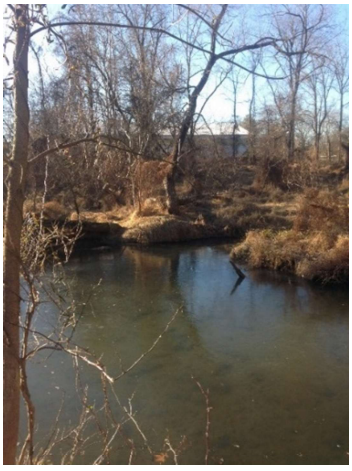
Figure 2.3.2: Eroded banks at Tributary 1.

Tributary 3 (Core Creek)

Core Creek flows directly into the Conservation pool located at the northern end of Lake Luxembourg. This creek runs adjacent to the Village Farm, which contains horse stables and pastures, with some limited riparian buffers. Access for an expansion of these buffers is limited and therefore such a project would be difficult to implement (Figures 2.3.3 and 2.3.4; noted as SS-6 on the watershed map in Appendix A). Some erosion of the shoreline can be observed in portions of this reach, contributing toward a decline in downstream water quality. *Phragmites* also dominates the farm side of the streambank. Again, due to the forested nature of the area and limited space between the streambank and farm, access is likely difficult for large equipment.

Recommendations: If access allows, eliminate the P*hragmites* and stabilize shoreline with native vegetation. If possible, expand the width of the riparian buffer or thicken understory. More vegetation could be added to the meadow areas present; however, in general this project should be ranked as low due to accessibility issues.

Figures 2.3.3 and 2.3.4: Streambank conditions along Core Creek immediately upstream of the Lake Luxembourg Conservation Pool.

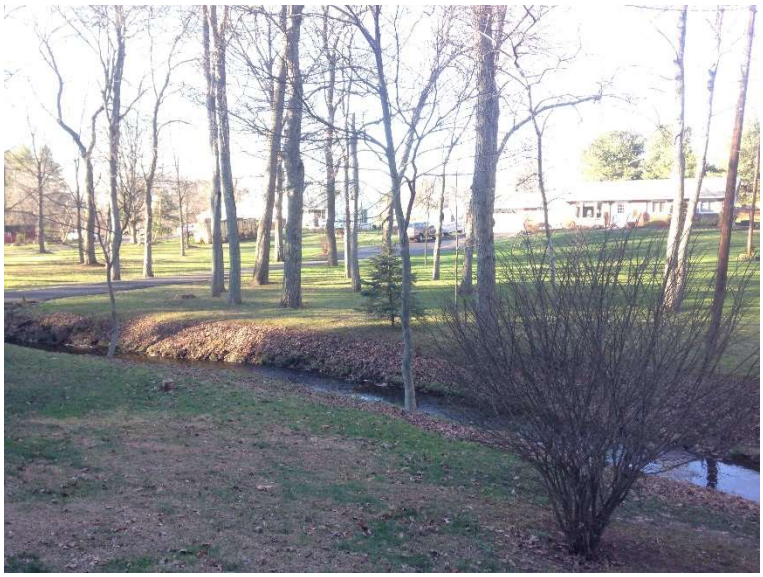


Tributary 2

Located along Village Rd at Basil Rd, this tributary flows parallel to a road and through private properties. This section of tributary contains little to no buffer to the road (Figure 2.3.5; noted as SS-7 on the watershed map in Appendix A). The land area on the neighborhood side of the stream has scattered trees but the grass is mowed up to the streambank, where patches of slight erosion are evident. This stream passes under a road from a meadow/forested area which provides some buffering and stabilization.

Recommendations: Expand / improve upon a vegetated buffer between the stream and both the road and the houses. At the forested section of the stream, add to the existing buffer. Along the exposed stretch of stream, any eroded areas should be stabilized through tree plantings. Do not mow up to the stream's edge; create a no mow zone.

Figure 2.3.5: Conditions seen at Tributary 2.



Tributary 5

Located near the main entrance of Core Creek Park, this tributary is surrounded by farmland, which is leased by the park. The stream is located in a forested area that provides some buffers (Figure 2.3.6; noted as SS-8 on the watershed map in Appendix A). Adjacent to the road, the forested area provides a larger buffer, but farther upstream, there is minimal riparian buffer adjacent to the farmland. There is little to no erosion in the forested area near the park entrance.

Recommendations: Increase the width of the riparian buffer along the stream to reduce the magnitude of the surface runoff pollutant load that originates from the farmland. Also, eliminate any invasive species found on site, such as multiflora rose. Since the land is probably owned by the Park, this project should be ranked high since issues associated with property ownership, easements and/or right-of-ways should be minimal.

Figure 2.3.6: Buffer conditions found at Tributary 5.

Tributary 4

This tributary is located on Ellis Road in between two neighborhoods and adjacent to a farm, possibly leased by the Park. Some erosion is present along the streambank. The vegetation / riparian buffer along the farm (Figure 2.3.7; noted as SS-9 on the watershed map in Appendix A) could be expanded and patches of multiflora rose should be eradicated and replaced with native vegetation. However, access with large equipment to the streambank project sites may be difficult due to forested nature of the site.

Recommendations: Increase the riparian buffer width and/or increase the density of existing vegetation. Also eliminate the invasive species found, possibly with a forest mower, and revegetate the understory. If access allows, possibly create bankfull benches to combat erosion.

Figure 2.3.7: Buffer conditions found at Tributary 4.

2.4 Best Management Practice Retrofits

For additional measures to reduce the NPS pollutant loads within the Core Creek / Lake Luxembourg watershed, various existing detention basins and swales could be retrofitted as naturalized dry basins and vegetated swales, respectively, to function as BMPs. Such upgrades can serve as a very cost effective approach in converting existing stormwater infrastructure that functions primarily for flood control, into structures that have the capacity to reduce NPS pollutant loads. Aspects of this project could be vegetating, regrading, and altering or replacing current stormwater practices. Potential locations for such stormwater retrofits are listed below. It should be noted that some of these potential projects may be on private property and would require consent and cooperation from the landowners.

Ellis Road (Middletown Township)

This site is located at the northeastern corner at Ellis Road and Woodbourne Road. This large mowed lawn is on Today Inc.'s property and contains an eroded, turbid channel draining directly to Lake Luxembourg (Figure 2.4.1; noted as BMP-1 on the watershed map in Appendix A). The site is also adjacent to the Village Farm, a horse farm, and a highly-developed neighborhood. The site is also frequented by Canada geese. The area is the outlet for stormwater from a large neighborhood just north. The area also lacks a buffer to the road.

Recommendations: A vegetated, meandering swale stretching from the forested inlet to the outlet by the road should be implemented. Another option would be to create a riprap or another stabilized channel with some buffer from forested inlet to outlet, where a vegetated basin would be located.

Figure 2.4.1: Channel condition at Ellis Road.

Dolington (Newtown Township)

This basin is located at the northeastern corner of Lower Dolington Road and Newtown Yardley Road. It contains a large basin with eroded channels located between two busy roads and associated neighborhood. The large basin is mowed and lacks any other vegetation (Figure 2.4.2; noted as BMP-2 on the watershed map in Appendix A). There is a thin buffer to the road at the top of the sloped sides. One inlet has strategically placed rock to function as energy dissipaters.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. This would be done by improving on the current channels, vegetating the area, and creating a no mow area surrounding the basin.

Figure 2.4.2: Basin condition at Dolington site.

Wellington (Newtown Township)

This basin is located in the northeast corner of Penns Trail N and Newtown Yardley Rd. It is adjacent to multiple roads, a neighborhood and a powerline. The basin contains three concrete channels, with a significant buildup of sediment, organic material, and gravel in front of outlet (Figure 2.4.3; noted as BMP-3 on the watershed map in Appendix A). The site is also kept mowed preventing the establishment of any other vegetation. There is no vegetated buffer adjacent the road.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. It should be vegetated and the channel buildup debris should be removed. The low flow channels should be replaced with a more efficient system. A no mow line should also be established.

Figure 2.4.3: Conditions at Wellington site.

Hartfield (Newtown Township)

This basin is located in the southeastern corner of Penns Trail N and Hartfield Road. The site is adjacent to a small road and a neighborhood. The basin contains concrete channels with a buildup of sediments, leaves and gravel at one inlet and the outlet (Figure 2.4.4; noted as BMP-4 on the watershed map in Appendix A). The presence of Canada geese droppings in channels and adjacent areas was noted and indicates an added nutrient input. The area was kept mowed and lacks a buffer. There are energy dissipaters in the form of rocks at the inlets at this site.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. It should be vegetated and the accumulated material / debris should be removed from the channel. The low flow channels should be replaced with a more efficient system or preferably eliminated and replaced with a meandering, non-impervious structure. A no mow line should also be established.

Figure 2.4.4: Site conditions at the Hartfield basin.

Teletronics (Newtown Township)

This site is located at Penn Street and Pheasant Run, across the street from the Law School Admissions Council and behind Teletronics Technology Corporation. It is adjacent to a large manicured lawn and parking lots. The current swale contains eroded channels with a buildup of leaves and a concrete channel originating from one lot (Figure 2.4.5; noted as BMP-5 on the watershed map in Appendix A). The current inlet has a riprap energy dissipater and is vegetated with cattails and some other vegetation.

Recommendations: A vegetated, meandering swale should replace the existing structure. In addition, trees and vegetation should be planted between the parking lots as a slight buffer for runoff. A no mow area should also be established.

Figure 2.4.5: Swale conditions at Teletronics site.

The Atrium Sites

Newtown-Yardley Road and Terry Drive (Newtown Township):

This site is located along Newtown Yardley Road at the front of the complex. The site lacks a significant buffer to the road (Figure 2.4.6) and has eroded channels and sides (Figure 2.4.7; noted as BMP-6 on the watershed map in Appendix A). The eroded channel in the basin hugs one side. The main swale channel exhibits additional erosion. Grass is mowed up to channel sides. The inlet from the road has an energy dissipater.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. The basin should be vegetated and possibly re-graded. A vegetated swale or stabilized channel should flow into the basin in the form of a stormwater treatment train. A no mow line should also be established.

Figure 2.4.6 and 2.4.7: Conditions at the Newtown-Yardley Road and Terry Drive site.

Terry Drive (Newtown Township):

This site is located along Terry Drive behind a complex building. It is a small mowed basin with a couple of trees next to the parking lot (Figure 2.4.8; noted as BMP-7 on the watershed map in Appendix A). The basin flows into a creek that has a small forested buffer. The basin contains pre-existing BMP structures including curb cuts, inlets and an outlet with stone energy dissipaters / infiltrations. However, multiple areas contained standing water.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. It should be vegetated and possibly re-graded to eliminate some of the standing water issues. Vegetation could be added to create a buffer adjacent to the parking lot.

Figure 2.4.8: Conditions at the Terry Drive site.

Just Play (Newtown Township):

This site is located next to the Terry Drive site, behind the Just Play building. The site contains just an outlet structure with thin rock buffer between parking lot and basin. It is essentially a small mowed basin that has no plant buffer to the parking lot (Figure 2.4.9; noted as BMP-8 on the watershed map in Appendix A). The outlet discharges directly to stream with no potential treatment for stormwater / surface runoff.

Recommendations: A potential rain garden or vegetated filter strip could be placed within the existing site to treat runoff and improve water quality before entering the creek.

Figure 2.4.9: Conditions at the Just Play site.

Park Road (Middletown Township)

This site is located within Core Creek Park along Park road, adjacent to a hospital access road. The site contains pooling water and a pipe under the access road (Figure 2.4.10; noted as BMP-9 on the watershed map in Appendix A). There is a vegetated buffer between the site and the hospital that is overrun with feral cats. The site includes a long strip of mowed grass.

Recommendations: A vegetated swale could be created to eliminate erosion and the pooling of water. The Park should initiate a discussion on the large population of feral cats in the watershed, their impact on the health / water quality of the park and lake and what could be done to address this issue.

Figure 2.4.10: Channel conditions at the Park Rd site.

Foxhall (Newtown Township)

This basin is located at Foxhall Rd and Washington Crossing Rd. This mowed basin contains one concrete channel with four inlets (Figure 2.4.11; noted as BMP-10 on the watershed map in Appendix A). The channel had a buildup of sediment, gravel and leaves, which ultimately blocked the outlet. Some pooling of water was present as a result of the blockage and a fill line made of grass clippings indicated that the basin may fill up to 1-2 ft high, likely due to the blocked outlet. Existing conditions pose a potential breeding area for mosquitos.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. It should be vegetated and the channel buildup and outlet should be cleared. The low flow channels should be replaced with a meandering, non-impervious channel to allow for infiltration and / or evapotranspiration. A no mow line should also be established.

Figure 2.4.11: Site conditions at the Foxhall basin.

Dorothy Drive (Lower Makefield Township)

This basin is located in the southwest corner of Dorothy Dr and Brentwood Rd. It is a mowed basin containing concrete channels (Figure 2.4.12; noted as BMP-11 on the watershed map in Appendix A). There was a buildup of sediment and leaves within the channels. The western side of the basin is vegetated and buffered to the houses behind it. The eastern side has some trees lining the road, while a farm is located on the southern side of the basin.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. It should be vegetated with the establishment of a no mow area. The low flow channels should be replaced with a meandering, non-impervious channel to allow for infiltration and / or evapotranspiration.

Figure 2.4.12: Site conditions at the Dorothy basin.

Bridle Estates (Lower Makefield Township)

This basin is located in the southwestern corner of Bridle Estates Dr. and is mowed with concrete channels leading to the outlet. At the time of the site visit, in which it had not rained in the last few days, a large pooling of water was present, resembling a shallow pond (Figure 2.4.13; noted as BMP-12 on the watershed map in Appendix A). The low flow channels contained a buildup of sediment, leaves and grass clippings. The "pond" was iced over and the outlet appeared to be blocked at this time.

Recommendations. Depending on the amount of water that remains in the basin, it may be more appropriate to convert this existing detention basin into a wet pond / retention BMP. If this is not feasible, the existing basin should be retrofitted into a naturalized extended detention basin. The basin should be vegetated and the accumulated debris within the channel and outlet should be cleared. The low flow concrete channels should be replaced with meandering, non-impervious structures. A no mow line should also be established. Again, depending on the amount of water that tends to pool here, the wet pond / retention BMP may be more appropriate.

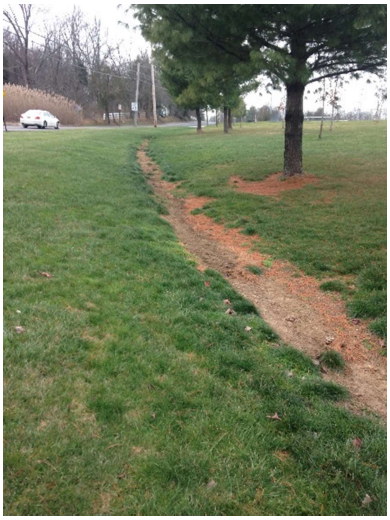
Figure 2.4.13: Site conditions at the Bridle Estates basin.

Middletown Community Park (Middletown Township)

This site is located at a park along Langhorne Yardley Rd mainly used for its athletic fields. There are a number of locations within the park that could be selected for watershed improvements (Figures 2.4.14 through 2.4.17; noted as BMP-13 on the watershed map in Appendix A). First, the park contains a naturalized basin on the western edge which could potentially be expanded, and the swale leading to it could be enhanced. There is a small rock channel behind the baseball fields adjacent to the parking lot that is currently mowed. Also, there are multiple mowed areas within the parking lot that currently serve no purpose. A somewhat vegetated J hook riprap channel is located between a soccer and baseball field that leads to an overgrown eroded pit at the bottom of the hill. There is a swale adjacent to Langhorne Yardley Rd that drains into the creek that has experienced some erosion. This swale receives stormwater directly from the road as well as the park.

Recommendations: The current naturalized basin on the western edge could be expanded. A vegetated swale could replace the current swale leading to that basin. A vegetated swale could be installed behind the first set of baseball fields. The grassed areas in the parking lot could be retrofitted into rain gardens. The J hook riprap should have a vegetated buffer and the eroded pit at the bottom should be stabilized and vegetated. The roadside swale should be retrofitted to a vegetated swale to combat excess nutrients and sediments from directly entering the creek. A vegetated buffer can also be placed between the swale and the road / fields. There may be a possibility for a baffle box somewhere in the area to help reduce inputs to the creek.

Figures 2.4.14 through 2.4.17: Site conditions at Middletown Community Park.



Holy Family at Newtown (Newtown Township)

This site is located at the Newtown campus of Holy Family University. This area is also adjacent to an old Lockheed Martin facility as well as Shady Brook Farm. There were various BMPs that could be improved at this site (Figures 2.4.18 through 2.4.21; noted as BMP-14 on the watershed map in Appendix A). North of the Holy Family parking lot, there is a long stretch of concrete channel leading from the farm area. There was a buildup of sediment within the channel which leads to an outlet surrounded by riprap sides. Evidence of Canada geese was noted at this site. This outlet leads to the other side of the berm, where a large bed of rock allows for filtration. The area had large quantities of sediment, leaves and standing water. A swale runs the length of Campus Dr to the basin at the southeastern end of the property. This swale is generally acceptable with a few muddied areas and a partially blocked exit under one of the access roads. There is also a swale with a riprap bed at the end before a forested area connects with the roadside swale. The swale leads to a large, mowed basin with steep side slopes that contains eroded channels. There is a constructed spillway on the opposite side of the channel inlet which is reinforced with rock or cement blocks that leads to the forest. There was evidence of standing water in the center of the spillway.

Recommendations: The basin in the southern portion of the site should be retrofitted into a naturalized detention basin. The channel should be enhanced and the area vegetated. A no mow area should be enforced. The spillway may be able to be enhanced. The roadside and connecting swale should be vegetated with native species and the adjacent forest could be expanded. The low flow channel in the area north of the parking lot should be replaced with a more efficient system. The bed of rock in front of the outlet could be enhanced or expanded as well as buffered with vegetation to help settle the large amount of sediment entering the area.

Figures 2.4.18 through 2.4.21: Site conditions at Holy Family University at Newtown.

Teal Drive (Middletown Township)

Middletown Township applied for Growing Greener 2016 funding to retrofit this basin (Figure 2.4.22; noted as BMP-15 on the watershed map in Appendix A) and several others in township. This basin has very steep sides and has been naturalized by with a mixture of native and invasive species.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. The invasive vegetation should be removed and the basin should be revegetated with native plants.

Figure 2.4.22: Site conditions at Teal Drive stormwater basin.

Swan Pointe (Middletown Township)

Middletown Township applied for 2016 Growing Greener funding to retrofit this basin and several others in the municipality (Figure 2.4.23; noted as BMP-16 on the watershed map in Appendix A). This is a standard large mowed basin buffered to most of the adjacent houses by a large hedgerow.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. The basin should be vegetated and possibly re-graded. A no mow line should also be established around the basin perimeter.

Figure 2.4.23: Site conditions at Swan Pointe stormwater basin.

Adeline Place and Barnsbury Road (Middletown Township)

Large regional basin for this neighborhood (Figures 2.4.24 and 2.4.25; noted as BMP-17 on the watershed map in Appendix A). Does not appear to be well maintained and/or functioning as was intended. Per Bucks County parcel data, this basin is owned by Middletown Township.

Recommendations: Given the wet ground and the potential for hydric soils, this site may be an excellent candidate for a pocket wetland BMP. However, its close proximity to residential homes means the design for such a BMP would have to have a high aesthetic value, as well as a very pro-active, local educational program to provide information to residents on the value of such a BMP. Additionally, since this site is not an obvious stormwater structure, it is not known if permitting would be more complicated. However, if recommended the project would actually enhance the wetland values (e.g. establishment of wetland vegetation, pollutant loading reductions and mitigation of stormwater) associated with the site.

Figure 2.4.24 – 2.4.25: Site conditions at Adeline Place and Barnsbury Road stormwater basin.

Argyle Rd (Middletown Township)

At the end of this road is a shallow basin receiving curb cuts from 2 dead end streets: Argyle Road and Barley Court (Figure 2.4.26; noted as BMP-18 on the watershed map in Appendix A). Stormwater runoff from the streets is eroding the area at the curb cuts that appear to serve as the only basin inlets.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. The basin should be vegetated and possibly re-graded. An energy dissipater and vegetated swale or stabilized channel should flow into the basin in the form of a stormwater treatment train. A no mow line should also be established around the basin perimeter.

Figure 2.4.26: Site conditions at Argyle Road stormwater basin.

Chilton Place (Middletown Township)

Tributary crossing at this location. Corner captured in photos is owned by Middletown Twp. (Figure 2.4.27; noted as BMP-19 on the watershed map in Appendix A). This site may be appropriate for a bioretention feature here and expansion of a limited riparian buffer. The site contains an outlet structure that captures drainage from the adjacent residential streets. The outlet discharges directly to a small tributary with no potential treatment for stormwater / surface runoff currently.

Recommendations: A potential rain garden or vegetated filter strip could be placed within the existing site to treat runoff and improve water quality before it enters the creek. A vegetated buffer could be planted along the tributary to provide additional water quality and habitat benefits.

Figure 2.4.27: Site conditions at Chilton Place discharge area.

Stonebridge Court (Middletown Township)

This site contains a small basin that is mowed (Figure 2.4.28; noted as BMP-20 on the watershed map in Appendix A). Unlike most of the other sites listed in this report, the Bucks County parcel info basin indicates that this basin is owned by the Home Owners Association.

Recommendations: The existing basin should be retrofitted into a naturalized extended detention basin. The basin should be vegetated and possibly re-graded. A no mow line should also be established around the basin perimeter.

Figure 2.4.28: Site conditions at Stonebridge Court basin.

Table 2a - Summary of the Watershed BMPs Proposed for Lake Luxembourg / Core Creek Watershed (September 2016)

Proposed Watershed / BMP Project	TP (lbs)	TSS (lbs)
Conservation Pool regional wetland BMP*	1,719	332,122
Another Shoreline Stabilization Project	0.4	792
Silver Lake (wet pond)	7.7	7,479
Timber Lakes Drive (wet pond / buffers)	8.1	8,271
Broad Meadows Farm buffers	0.4	792
Tributary 1; vegetated buffer	0.2	396
Tributary 3; vegetated buffer	0.4	792
Tributary 4; vegetated buffer	0.2	396
Tributary 5; vegetated buffer	0.4	792
Tributary 6; vegetated buffer	0.4	792
Ellis Road; vegetated swale	0.4	792
Dolington; retrofitted basin	5.3	5,342
Wellington; retrofitted basin	5.3	5,342
Hartfield; retrofitted basin	5.3	5,342
Teletronics; vegetated buffer	0.4	792
Newtown Yardley Rd; retrofitted basin and buffer	5.7	6,134
Terry Drive; retrofitted basin	5.3	5,342
Just Play; rain garden	9.1	7,568
Foxhall; retrofitted basin	5.3	5,342
Dorothy Drive; retrofitted basin	5.3	5,342
Bridle Estates; retrofitted basin	5.3	5,342
Ellis Road; vegetated swale	0.8	1,584
Middletown Comm Pk; retrofitted basin and buffer	5.7	6,134
Holy Family / Newtown; retrofitted basin and buffer	5.7	6,134
Teal Drive; retrofitted basin	5.3	5,342
Swan Pointe; retrofitted basin	5.3	5,342
Adeline Pl and Barnsbury Rd; retrofitted basin and swale	5.3	5,342
Argyle Road; retrofitted basin	5.7	6,134
Chilton Place; rain garden and buffer	9.1	7,568
Stonebridge Court; retrofitted basin	5.3	5,342
Summary of Pollutants Removed	**1,838**	**454,226**
Remaining Pollutant Load Reductions (as of 2018)	**502**	**694,658**
Percentage of Pollutant Load Removed by all Proposed BMPs	**366%**	**65%**

Note: For the wetland conservation pool BMP used baseline TP and TSS concentrations from conservation pool / Station #2 from 2013, 2014 and 2016, coupled with the stormwater hydrologic load calculated as

part of original Phase I study to estimate pollutant loads. The selected percent removal rates were lower than what is identified in the State's Stormwater BMP Manual for wetland BMPs (55% TP and 75% TSS). Also, Table 2b focuses solely on the TSS being removed as part of the draft plan for the *Neshaminy Creek Sediment Reduction Plan* (Bucks County Planning Commission, 2014)

Table 2b - Summary of the Watershed BMPs Proposed for Lake Luxembourg / Core Creek Watershed (May 2017) (TSS removal through Neshaminy Creek Sediment Reduction Plan)

Proposed Watershed / BMP Project	TSS (lbs)
Streambank restoration - Agricultural Lands (focus on 7.0 miles of the 15.8 miles of impaired waterways; takes into account the projects identified in the WIP; TSS removal rate of 40%)	130,188
Streambank restoration - Developed Lands (focus on 4.5 miles of the 15.8 miles of impaired waterways; takes into account the projects identified in the WIP; TSS removal rate of 40%)	66,658
Streambank restoration - Transitional Lands (focus on 2.1 miles of the 15.8 miles of impaired waterways; TSS removal rate of 40%)	31,768
Riparian Buffers (focus on 0.14 miles of the 15.8 miles of impaired waterways; excluding agr. and developed streambank restoration projects; TSS removal rate of 65%)	2,402
Riparian Buffers (focus on 0.14 miles of the 15.8 miles of impaired waterways; excluding agr. and developed streambank restoration projects; TSS removal rate of 65%)	2,402
Manufactured Treatment Devices (Approximately 28 MTDs in low intensity development and 8 MTDs in high intensity development TSS removal rate of 70%)	5,37 1,178
Sub-Total for Projects under Neshaminy Sediment Plan Sub-Total for Projects under Luxembourg WIP (Table 2a)	234,596 454,226
Grand Total of TSS Removed	**688,822**
Percent of TSS Load Removed by all BMPs in both Tables 2a and 2b	**99%**
TSS left to remove (lbs)	**5,836**

3.0 Conclusions

The targeted TMDL, for the Lake Luxembourg / Core Creek watershed, as per the AVGWLF/PRedICT model analysis, for TP and TSS are 2,254 lbs per year and 2,866,127 lbs per year, respectively. Per the TMDL, a 23% and 24% reduction was needed to reach those targeted annual loads of TSS and TP, respectively. In turn, the TP and TSS load reductions required to attain these targeted TMDLs are 725 lbs and 859,833 lbs, respectively.

Various shoreline stabilization projects and watershed BMPs have been implemented over the years to reduce the annual pollutant loads entering the lake and creek. However, in order to obtain full compliance with the TMDLs it was necessary to identify additional, watershed-based projects and this is the goal of this Watershed Implementation Plan (WIP) update.

From 2008, when the model analysis was completed and established the targeted TMDLs, to 2013, a series of 319-grant funded projects were implemented throughout the Lake Luxembourg / Core Creek watershed. These 319-grant projects removed a total of 175 lbs of TP and 132,802 lbs of TSS (Table 1). Additionally, a series of other, non-319-funded stormwater projects were or soon will be implemented, account for 48 lbs of TP removal and 32,373 lbs of TSS removal.

Thus, by the end of 2017, a total of 208 lbs of TP will have been removed from the watershed, which accounts for approximately 31% of the TP load targeted for reduction, leaving 502 lbs of TP to be removed. Additionally, by the end of 2017, a total of 164,755 lbs of TSS will have been removed from the watershed, which accounts for approximately 19% of the TSS load targeted for reduction, leaving 695,078 lbs of TSS to be removed (Table 1).

Currently, the Bucks County Conservation District is working on the designs and permitting to convert the existing conservation pool, immediately upstream of the main body of Lake Luxembourg, into a regional wetland BMP. The estimated amount of TP and TSS removal associated with this large, regional BMP as well as the suggested watershed projects described in this plan are listed in Table 2. If all of these projects were implemented the amount of TP and TSS removed per year would be 1,838 lbs and 454,226 lbs, respectively. The anticipated TP load reduction would exceed the remaining amount targeted under the TMDL, resulting in full compliance with the TP portion of the TMDL. In contrast, the proposed reductions in TSS would result in 65% compliance for that portion of the TMDL (Table 2a). However, it should be noted that the actual percent compliance for the conservation pool may be substantially higher since baseline TSS concentrations, not stormwater concentrations, were used to estimate the TSS load reductions. Thus, additional monitoring and modeling is required in order to obtain an accurate representation of the TSS load reductions.

Table 3a is a summary of the estimated costs associated with the recommended watershed-based implementation measures. Estimates included a range in costs for both implementation as well as long-term, annual maintenance.

While the proposed WIP reaches full compliance with the TP portion of the TMDL it does not reach full compliance with the portion associated with TSS. However, some of the projects identified in the *Neshaminy Creek Sediment Reduction Plan* (Bucks County Planning Commission, 2014) are listed in Table 2b and move the TSS portion of the TMDL closer to full compliance. Specifically, the Neshaminy Creek Sediment Reduction Plan identifies a series of streambank buffers / stormwater BMPs within the sub-watersheds of the Neshaminy Creek watershed, which includes the Core Creek / Lake Luxembourg watershed. That portion of the plan is provided in Table 2b and the costs associated with their implementation are provided in Table 3b. Note that if all of the BMPs listed in Tables 2a and 2b were implemented, the TSS portion of the TMDL would be 99% in compliance, leaving 5,836 lbs of TSS to be removed. Additional measures associated with the township's MS4 (e.g. street sweeping) could make up the difference to remove the last 5,836 lbs for full compliance of TSS.

It is anticipated that the conservation pool project will be completely by the end of 2020 and that all of the projects listed in Table 2a are completed within a span of 10 years so the TP portion of the TMDL should be in complete compliance by 2027. In contrast, a large portion of the additional projects listed in Table 2b focus on the establishment of streambank buffers and may take more time from a land use planning perspective. Thus, those projects are expected to take a little longer to implement, say 12 years for complete TSS compliance by 2029. However, the actual dates of implementation and completion are highly dependent upon available sources of funds and landowner cooperation.

Finally, it should be emphasized that this Implementation Plan is a planning document and more site-specific information is required in order to conduct a more complete assessment of project-specific feasibility. This information should include, but is not limited to, topographic and property boundaries, existing easements and right-of-ways, and existing soil and groundwater characteristics. The overall goal of this plan was to provide guidance in the selection, design, and implementation of cost-effective projects that will reduce the phosphorus and sediment loads entering Lake Luxembourg and Core Creek.

Table 3a - Summary of Implementation and Maintenance Costs for Lake Luxembourg / Core Creek Watershed (May 2017)

Proposed Watershed / BMP Project	Implementation Estimates		Annual Maintenance Estimates*	
	Low	High	Low	High
Conservation Pool regional wetland BMP	$510,000	$850,000	$7,650	$12,750
Another Shoreline Stabilization Project	$5,370	$21,070	$790	$2,900
Silver Lake (wet pond)	$87,500	$175,000	$5,800	$11,600
Timber Lakes Drive (wet pond / buffers)	$9,500	$37,700	$1,400	$5,180
Broad Meadows Farm buffers	$5,280	$36,960	$1,320	$4,488
Tributary 1; vegetated buffer	$5,280	$21,120	$792	$2,904
Tributary 3; vegetated buffer	$5,280	$36,960	$1,320	$4,488
Tributary 4; vegetated buffer	$5,280	$21,120	$792	$2,904
Tributary 5; vegetated buffer	$5,280	$36,960	$1,320	$4,488
Tributary 6; vegetated buffer	$5,280	$36,960	$1,320	$4,488
Ellis Road; vegetated swale	$5,000	$20,000	$750	$5,000
Dolington; retrofitted basin	$1,500	$50,000	$225	$2,500
Wellington; retrofitted basin	$1,500	$50,000	$225	$2,500
Hartfield; retrofitted basin	$1,500	$50,000	$225	$2,500
Teletronics; vegetated swale/buffer	$5,280	$21,120	$792	$2,904
Newtown; retrofitted basin and buffer	$1,500	$64,840	$573	$4,084
Terry; retrofitted basin	$1,500	$50,000	$225	$2,500
Just Play; rain garden	$1,500	$50,000	$225	$2,500
Foxhall; retrofitted basin	$1,500	$50,000	$225	$2,500
Dorothy Drive; retrofitted basin	$1,500	$50,000	$225	$2,500
Bridle Estates; retrofitted basin	$1,500	$50,000	$225	$2,500
Ellis Road; vegetated swale	$5,000	$20,000	$750	$5,000
Middletown Comm Pk; retrofitted basin and buffer	$1,500	$65,840	$573	$4,084
Holy Family / Newtown; retrofitted basin and buffer	$1,500	$65,840	$573	$4,084
Teal Drive; retrofitted / naturalized basin	$0	$50,000	$225	$2,500
Swan Pointe retrofitted / naturalized basin	$0	$50,000	$225	$2,500
Adeline Place and Barnsbury Rd pocket wetland	$25,000	$75,000	$1,500	$5,000
Argyle Road retrofitted basin	$1,500	$50,000	$225	$2,500
Chilton Place rain garden and/or veg. filter strip	$2,000	$50,000	$225	$2,500
Stonebridge Court retrofitted / naturalized basin	$0	$50,000	$225	$2,500

*the estimated maintenance costs include labor associated with monitoring / observing the site as well as maintenance operations.

Table 3b – Summary of Implementation and Maintenance Costs for Lake Luxembourg / Core Creek Watershed, based on revisions of the Neshaminy Creek Sediment Reduction Plan

Proposed Watershed / BMP Project	Implementation Estimates		Annual Maintenance Estimates*	
	Low	High	Low	High
Streambank restoration Agricultural lands (7 miles)	$184,800	$739,200	$19,800	$72,600
Streambank restoration Developed lands (4.5 miles)	$118,800	$475,200	$14,256	$52,272
Streambank restoration Transitional lands (2.1 miles)	$55,440	$221,760	$1,888	$4,356
Riparian buffers Forested lands (0.14 miles)	$0	$11,088	$1,400	$5,180
Manufactured Treatment Devices (total of 35 units)	$1,225,000	$1,925,000	$0	$0

Appendix A

Site Map

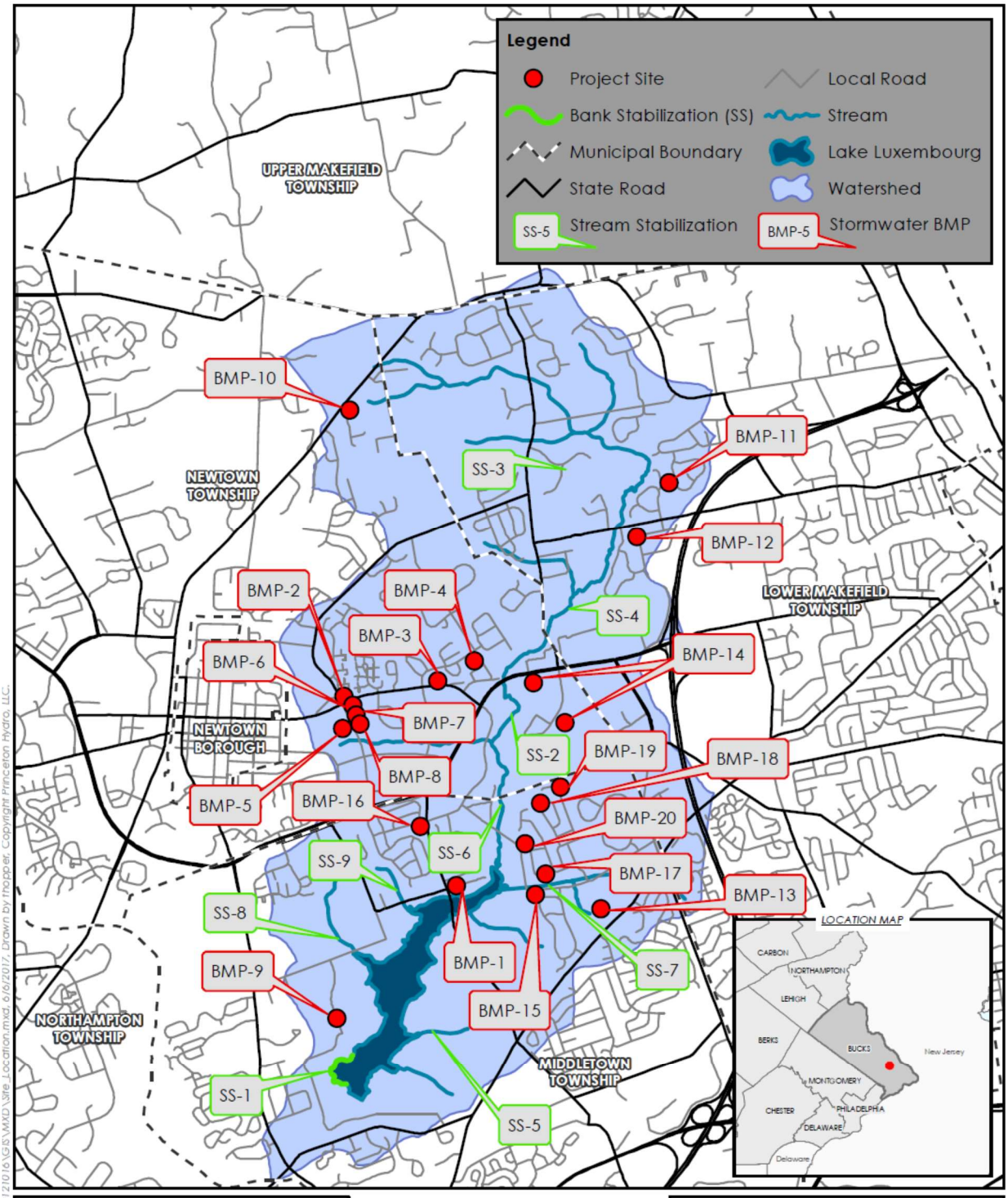


FIGURE 1: SITE LOCATION MAP

WATERSHED IMPLEMENTATION PLAN FOR
CORE CREEK/LAKE LUXEMBOURG
MIDDLETON TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. Stormwater BMP and bank stabilization locations are approximate.
2. Municipal boundaries, roads, streams, lakes, and watersheds obtained from the Pennsylvania Spatial Data Access (PASDA).

0 2,000 4,000 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet