Continued Implementation of the Revised Restoration / Management Plan for Lake Luxembourg / Core Creek Watershed, Core Creek Park, Bucks County, Pennsylvania

Prepared for:
Bucks County Conservation District
Suite 704
1456 Ferry Road
Doylestown, PA 18901

Prepared by:
Princeton Hydro, LLC
1108 Old York Road, Suite 1
P.O. Box 720
Ringoes, NJ 08551

Project No: 121.012

May 2008

Section 1 - Introduction and Summary of Past Projects

Lake Luxembourg is a man-made impoundment located within Core Creek Park, part of the Bucks County Park System, Middletown Township, Bucks County, Pennsylvania (Figure 1). The Core Creek watershed has a surface area of 6,033 acres (9.43 square miles). The lake itself has a surface area of 174 acres. Approximately equal portions of the watershed are located in Middletown, Lower Makefield and Newtown Townships. Lake Luxembourg is an impoundment of Core Creek, a tributary of Neshaminy Creek. In turn, Neshaminy Creek enters the Delaware River approximately 13.5 miles downstream of where Core Creek discharges into the Neshaminy. Thus, Core Creek is part of the Delaware River Basin in Pennsylvania.

Lake Luxembourg was built in the 1970's with flood control as its primary function and recreation and local water supply its secondary functions. Core Creek Park is one of the most heavily attended parks within Bucks County, with the lake as the focal point of the park. Some of the most popular activities within the park are fishing and boating on Lake Luxembourg. Park attendance averaged 240,936 per year between 1980 and 1985 (Bucks County Planning Commission, 1986) and reached 355,275 per year by 1985 (Bucks County Department of Parks and Recreation, 1985). Park use increased by over 10 percent each year and reached 1,273,014 per year in 1992 (Pfanstiel, 1993). If this trend held through the 1990's and park attendance increased by approximately 10% each year, then current park attendance could be greater than 3 million.

Within a few years after Lake Luxembourg was created by impounding Core Creek, it began to experience water quality problems. The two primary water quality problems associated with the lake are excessively high rates of sedimentation and large and frequent algal blooms. The high rates of sedimentation have substantially reduced the depth of the lake and generally keep the surface waters highly turbid. The large and frequent algal blooms reduce the overall aesthetic appeal of the lake and increase the risk of undesirable conditions such as fish kills.

In response to these observed declines, a Phase I US Environmental Protection Agency (EPA) Clean Lakes (Section 314 of the Federal Clean Water Act) Grant was awarded in April 1991 to the Bucks Conservation District through the Pennsylvania Department of Environmental Protection.

The Phase I Diagnostic / Feasibility Study of Lake Luxembourg and its watershed had three major objectives. First, collect a variety of physical, chemical and biological data on the lake and watershed to quantitatively describe the system. Second, develop an annual “pollutant” budget for the lake. A large part of this pollutant budget involves quantifying the pollutant loads associated with each particular land use within the watershed. For the water quality problems experienced in Lake Luxembourg watershed the term pollutant specifically refers to phosphorus, nitrogen and suspended solids. It should be noted that the Phase I pollutant budget provided the foundation for the development of the State’s total phosphorus and total suspended solid TMDL (see below) for Lake Luxembourg. Third, all of the information complied for the Phase I Study is used to develop a holistic, long-term Management Plan for the lake and its watershed. A copy of the Executive Summary of the Phase I Diagnostic / Feasibility Study is provided in Appendix A.

In response to the long-term Management Plan, developed as part of the Phase I study, funding was provided by the PA Department of Environmental Protection (PADEP) for the implementation of a variety of implementation projects. In addition, a number of additional studies were conducted to better refine the pollutant load analysis of Lake Luxembourg, as well as an update the lake and watershed Management Plan. These projects and studies are summarized below:

1. A Section 319 (Non-Point Source) grant awarded to the Bucks County Conservation District in 1995 and completed in 1998. This grant focused on the implementation of Best Management Practices (BMPs) designed to reduce the pollutant loads associated with agricultural lands.

2. A second 319 grant was awarded to the Bucks County Conservation District in 1999 and completed in 2002. This grant focused on the implementation of shoreline and streambank BMP to reduce pollutant loads entering Lake Luxembourg. The grant also developed a proactive and successful educational program involving students from the FDR Middle School, Bristol PA. In addition, students from the Neshaminy Middle School, Langhorne, PA participated in planting the shoreline vegetation along approximately 800 feet of the northwest shoreline of Lake Luxembourg in spring of 2001.

3. While the second 319 grant was underway, a total phosphorus (TP) and total suspended solid (TSS) Total Maximum Daily Load (TMDL) analysis was initiated by PADEP in 1999. The TMDL established existing and targeted (allocated) loads for TP and TSS and was reviewed and accepted for application to Lake Luxembourg by US EPA. This TMDL was revised / updated by US EPA in 2005.

4. In response to the established TP and TSS TMDLs for Lake Luxembourg, a revised Restoration / Management Plan was developed and completed in March 2005. This revised Plan developed a list of site-specific, proposed watershed projects, designed to attain the targeted TP and TSS pollutant endpoints as outlined in the TMDL.

This document summarizes the results of a third 319 grant awarded to the Bucks County Conservation District in 2005; the projects associated with this grant will be completed in spring of 2008. This third 319 grant implements some of the watershed projects described in the revised Restoration / Management Plan. Again, the ultimate goal of all of the current and future BMP projects is to reduce the existing TP and TSS pollutant loads to comply with Lake Luxembourg's TMDLs. In turn, complying with the TMDLs will result in improvements in water quality.

Section 2 - TMDL and Targeted Pollutant Loads

In 1999, PADEP conducted a TMDL analysis of Lake Luxembourg and the Core Creek watershed. This original TMDL analysis utilized the results of the Phase I Clean Lakes study in developing the TMDL model. Specifically, this involved using the Unit Aerial Loading (UAL) model to quantify annual pollutant loads based on empirically derived land use coefficients. Given the water quality impacts associated with phosphorus (i.e., large and frequent algal blooms, depletion of dissolved oxygen and associated loss of fishery habitat), this was the pollutant of concern for the TMDL analysis. The TMDL used the trophic state index (TSI) for total phosphorus as the endpoint for the annual loads, targeted under the established TMDL.

US EPA recently revised the existing land use and, in turn, the pollutant loads entering Lake Luxembourg and Core Creek. In contrast to the original Phase I Clean Lakes Study and the original phosphorus TMDL analysis for Lake Luxembourg, US EPA used the AVGWLF model to develop existing and targeted pollutant loads. This revised analysis addressed both total suspended solids (TSS) and total phosphorus (TP).

The AVGWLF model takes the same general approach of the UAL model in that empirically based loading coefficients are selected for appropriate land use types or conditions to quantify annual pollutant loads. However, the AVGWLF model takes into account more site-specific conditions (e.g., soil types, slopes, etc.) found in Pennsylvania watersheds and simulates other sources of pollutants. For example, the AVGWLF model can quantify and separate TSS pollutant loading by its source, whether from surface runoff or eroded streambanks. Such detailed levels of modeling are critical when determining the most cost-effective strategies for reducing NPS pollution.

Based on the AVGWLF model, the existing TP and TSS annual pollutant loads were 3,725,960 and 2,571 lbs / yr. US EPA's analysis of the Core Creek watershed proposes a 23% reduction in the annual TSS load and a 12% reduction in the annual TP load. Both seem to be reasonable targeted load reductions. However, for the sake of specifically addressing water quality issues of concern for Lake Luxembourg, US EPA's estimate of the annual TP load had to be adjusted. These site-specific adjustments resulted in an existing annual phosphorus load of 2,979 lbs / yr. Keeping the targeted phosphorus load at 2,254 lbs / yr, a 24% reduction in the annual phosphorus load is required in order to attain the targeted load. A comparison of the existing and targeted TMDL-based pollutant loads are provided in Table 1.

Finally, it should be noted that US EPA's revised analysis took the past watershed projects, excluding those documented in this report, into consideration. These past projects included the agricultural and streambank / shoreline BMPs previously described (see Section 1).

Table 1

Summary of the TMDL-Based Loading Scenarios for Lake Luxembourg / Core Creek, Bucks County, PA

TMDL Loading Scenario	TP (lbs)	TSS (lbs)
Existing Pollutant Loads	2,979	3,725,960
Targeted Pollutant Loads	2,254[A]	2,866,127[B]
Required Pollutant Load Reductions	**725**	**859,833**

A = Represents a 24% decline relative to the existing total phosphorus load.
B = Represents a 23% decline relative to the total suspended solid load.

Section 3 - Implementation of Watershed Projects to Reduce TP and TSS Pollutant Loads

PADEP awarded funds to the Bucks County Conservation District to implement a sub-set of the projects described in the revised Restoration / Management Plan for the Lake Luxembourg / Core Creek watershed. This current report documents the implementation of these latest set of BMP projects. The projects were initiated in 2006 and while the majority of them are complete, one BMP project will be completed in the spring of 2008 (see below). This report provides all of the information and data that were collected as part of this latest NPS 319 grant. Figure 2 identifies the location of the implemented BMPs, while Figure 3 identifies the stormwater sampling locations.

Task 1 – Installation of Two Innovative Stormwater Treatment Devices

Since the original Phase I study there has been a substantial decrease in agricultural lands and an increase in residential lands within the Core Creek watershed. Many residential properties have some type of stormwater infrastructure to prevent / minimize flooding of local property. However, most of this infrastructure, particularly those located on older properties, have no means of removing pollutants, specifically total phosphorus (TP) and total suspended solids (TSS).

A number of small-scale Manufacture Treatment Devices (MTDs) were considered for a demonstration project to retrofit existing stormwater infrastructure. Aqua-Guardians, manufactured by AquaShield, Inc were used. Unlike other small-scale retrofit MTDs, Aqua-Guardians can remove dissolved forms of phosphorus as well as those adsorbed onto sediment particles. Enhanced phosphorus removal capacities are important since dissolved forms of phosphorus are most readily available for assimilation by the cyanobacteria (also known as blue-green algae), which is the primary algal group responsible for the nuisance blooms in Lake Luxembourg.

Two catch basins were retrofitted with Aqua-Guardians units in January 2007 (Figure 1). The two sites were existing catch basins that conveyed water directly to Lake Luxembourg (Figure 2). For site photographs, a manual on the Aqua-Guardian, which includes general schematics and how the units were sized, based on the existing catch basins, and a maintenance manual on their long-term care and operation, please refer to Appendix E.

Similar to many MTDs, the Aqua-Guardian has a sump or area that allows for the collection and trapping of gross pollutants such as sediment, trash and debris. However, unlike other stormwater retrofit devices, the Aqua-Guardian includes a filter media that the stormwater flows through before leaving the structure. This filter media, composed primarily of medium grain perlite and reclaimed hydrophobic cellulose, removes a large portion of the dissolved pollutants such as orthophosphorus, dissolved heavy metals and petroleum hydrocarbons. Again this added level of treatment will increase the removal efficiency of the stormwater-based phosphorus

entering Lake Luxembourg. These efficiencies were documented through the stormwater monitoring program (for details see Task 4 and Appendix H).

Task 2 – Stabilization of an additional 1,000 linear feet of shoreline along Lake Luxembourg

Approximately 800 linear feet of shoreline along the north central portion of Lake Luxembourg was stabilized in 2001 through re-grading the shoreline and planting with a variety of wetland and upland vegetation. This stabilization project was highly successful. The vegetation was planted in 2001 and has stabilized the shoreline (see photos in Appendix H). However, recently a few invasive species have been identified at the stabilization site and will require removal and/or control. For the current grant, an additional 1,000 linear feet of shoreline, adjacent to and to the north of the first stabilization site, was stabilized using similar techniques.

Collection of topographic data and plan development was implemented in 2005. The design plan for the 1,000 shoreline site is provided in Appendix F. A State General Permit for Bank Rehabilitation, Bank Protection and Gravel Bar Removal (BDWW-GP-3) was obtained for this shoreline stabilization project. In addition, Princeton Hydro worked under the guidance of the Bucks County Conservation District to ensure that each project was conducted in a manner as to minimize potential environmental impacts such as soil loss and/or erosion.

The eroded shoreline was re-graded and geotextile fabric was placed for stabilization. In May of 2006 approximately 2 weeks after the re-grading of the shoreline and students from the Neshaminy Middle School planted a variety of wetland and upland vegetation at the stabilized site. Princeton Hydro and the Conservation District conducted the supplemental plantings a few days later. The surveying, re-grading and installing the vegetation along the 1,000 linear feet of shoreline at Lake Luxembourg, with the aid of the students of Neshaminy Middle School, was photo-documented and provided in Appendix F.

Task 3 – Design, Engineering and Creation of a Pocket Wetland

In an effort to reduce the conveyance of NPS pollution over County Park property and into Lake Luxembourg, a pocket wetland was proposed for an approximately 1/3 acre grassed area within Core Creek Park (Figure 4). Stormwater from the stormwater conveyance system at nearby St. Mary Medical Center travels onto Core Creek County Park property through a pipe under Park Road and enters a small swale. In turn, flow from the swale enters a tributary that discharges into Lake Luxembourg.

The original design for the pocket wetland was completed in the winter of 2006, however, the County's Department of Parks and Recreation was not satisfied with the design. Thus, the pocket wetland was re-designed to allow water to flow into small "wetland cells" before it flows back into the stabilized swale and out of the project area. This second design was accepted and Princeton Hydro worked with the Conservation District and the selected contractor to re-grade the site and plant small grasses and herbaceous plant species. The second design was re-submitted to the Department of Parks and Recreation in the spring of 2007, approval was

obtained in the summer of 2007 and the project was initiated in the fall of 2007. Photo-documentation of the project and the approved design are provided in Appendix G.

Many of the wetland plants that were ordered for the pocket wetland were not available in the fall of 2007. These will be planted in the pocket wetland in the spring of 2008. Subsequent to the installation of the wetland plants, stormwater samples will be collected above and below the pocket wetland during three stormwater events so the pollutant removal efficiency of this BMP can be quantified. Similar to the other BMPs implemented, the pollutants of concern are TP and TSS. The spring planting of the wetland plants and an analysis of the pocket wetland's pollutant removal efficiencies will be submitted as an addendum to this report.

Task 4 - Stormwater Quality Monitoring Program

Similar to the past Implementation projects, some stormwater monitoring was conducted during this project to aid in quantifying existing stormwater pollutant concentrations entering Lake Luxembourg, as well as assesses the pollutant removal efficiency of the installed BMPs. The pollutants of concern for Lake Luxembourg / Core Creek are TP and TSS, so the stormwater monitoring focused on these parameters.

During each storm event, composited samples were collected at each sampling site (Figure 3). The samples were composited from three discrete sub-samples collected in 5 to 10 minute intervals as per the original Quality Assurance Protection Plan. Additionally, samples were collected only during storm events that produced more than 0.1" of rain within 24 hours. The raw stormwater data are provided in Appendix H.

Pre-installation stormwater samples were collected on 25 October 2005, 3 February 2006 and 22 April 2006, while the post-installation monitoring, which focused exclusively on the two Aqua-Guardians, were collected on 5 January 2007, 23 March 2007 and 23 July 2007.

Prior to the installation of the two Aqua-Guardians, the TP concentrations varied between 0.11 and 0.21 mg/L at Station 6 and 0.08 and 0.16 mg/L at Station 7. In contrast, after the two Aqua-Guardians were installed, TP concentrations in the outlets varied between 0.04 and 0.09 mg/L at Station 6 and 0.04 and 0.06 mg/L at Station 7 (Appendix I). Comparing post-installation inlet and outlet TP concentrations for Station 6, the percent reductions for the 5 January, 23 March and 23 July storm events were 72%, 93% and 44%, respectively. For Station 7, these inlet / outlet percent reductions were 91%, 91% and 58%, respectively.

Under post-installation conditions, inlet TSS concentrations at Station 6 varied between 22 and 322 mg/L, while inlet TSS concentrations at Station 7 varied from 5 to 504 mg/L. Comparing post-installation inlet and outlet TSS concentrations for Station 6, the percent reductions for the 5 January, 23 March and 23 July storm events were 89%, 99% and 82%, respectively. For Station 7, these inlet / outlet percent reductions were 94%, 99% and 70%, respectively.

Based on these percent reductions relative to concentration, the Aqua-Guardian is extremely effective at removing both TP and TSS from stormwater. The lower percent reductions

associated with the third post-installation sampling event (23 July 2007), particularly with TP, was attributed to the units filling in with material and/or seasonal variability. Based on visual observations of the units, they appear to require clean outs approximately twice a year; however, depending on the size of the fall leaf litter it is possible that the frequency of clean outs may be higher.

Task 5 – Public Education / Presentation to the Neshaminy Middle School Student Body

As part of this Implementation project, Princeton Hydro developed a Power Point presentation for the study body of Neshaminy Middle School. The presentation was conducted in late January of 2006 and introduced the concepts of non-point source pollution and stormwater management to the student body. It also summarized the projects that have been conducted in the Lake Luxembourg / Core Creek watershed to reduce the TP and TSS loads entering the lake. A copy of the Power Point presentation is provided in Appendix I.

Section 4 - Estimated Pollutant Load Reduction Associated with Projects

Using a combination of site specific stormwater data and pollutant removal rates established in the *Pennsylvania Stormwater Best Management Practices Manual* (PA DEP, 2006), an estimate of the annual amount of pollutants removed as a result of the watershed projects described in this report was calculated and compared to TP and TSS TMDLs.

Based on the inlet and outlet stormwater data collected from the Aqua-Guardian treatment devices in 2007, each unit removes approximately 4 lbs of TP per year. However, it should be emphasized that based on the stormwater data, the TP removal efficiency of the Aqua-Guardians decline after about 6 months. Thus, in order to maintain the desired 4 lbs removal per year, these units should be cleaned at a minimum of twice a year.

As per the State BMP Manual, a TP removal rate of 30% was ascribed to the additional 1,000 ft of stabilized shoreline along the northwestern shore of Lake Luxembourg. Using this removal rate along with the TP loading coefficient used in the original Phase I study, it is estimated that the additional 1,000 ft of stabilized shoreline removes approximately 9 lbs of phosphorus per year.

A TP removal rate of 50% was ascribed to the pocket wetland BMP. Using a TP loading coefficient that reflects the upstream land use, it is estimated that approximately 18 lbs of TP would be removed by the pocket wetland per year. Thus, in total, the BMPs projects implemented are estimated to remove approximately 35 lbs of TP per year. Since one pound of phosphorus has the potential to generate up to 1,100 lbs of wet algae biomass, preventing 35 lbs of phosphorus from entering Lake Luxembourg essentially removes approximately 38,500 lbs of wet algal biomass.

Again, based on the stormwater data, it was estimated that the Aqua-Guardians each remove approximately 3,589 lbs of TSS per year.

As per the State BMP Manual, a TSS removal rate of 60% was ascribed to the additional 1,000 ft of stabilized shoreline along the northwestern shore of Lake Luxembourg. Using this removal rate along with the TSS loading coefficient used in the original Phase I study, it is estimated that the additional 1,000 ft of stabilized shoreline removes approximately 44,317 lbs of TSS per year.

For the pocket wetland, a TSS removal rate of 75% was ascribed. The State Manual recommends a removal rate of 90%, however, given the size of the pocket wetland a more conservative value of 75% is being used. Using a TSS loading coefficient that reflects the upstream land use, it is estimated that approximately 41,547 lbs of TSS would be removed by the pocket wetland per year. Thus, in total, the BMP projects implemented are estimated to remove approximately 93,042 lbs per year.

These estimated pollutant removals were compared to the existing TP and TSS TMDLs for Lake Luxembourg (Table 2). As previously mentioned, to attain the targeted TMDL-based pollutant loads, 725 lbs and 859,833 lbs of TP and TSS need to be removed, respectively. The BMPs implemented under this project are estimated to address approximately 5% and 11% of the TP and TSS loads targeted for reduction, respectively (Table 2). However, it must be emphasized that these estimates assume that the BMPs will be well maintained.

Table 2

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	2,979	3,725,960
Targeted Pollutant Loads	2,254	2,866,127
Required Pollutant Load Reductions	**725**	**859,833**
Estimated Pollutants Removed per Year as a Result of Implemented Projects	35	93,042
Percent of Pollutant Load Removed under Targeted Reduction	**5%**	**11%**

Section 5 – Conclusions

A set of watershed-based Best Management Practices were designed and implemented to reduce the TP and TSS loads entering Lake Luxembourg and Core Creek, Bucks County, Pennsylvania. These BMPs included:

- Two Manufactured Treatment Devices (Aqua-Guardians)
- The stabilization of approximately 1,000 ft of lake shoreline
- The installation of a 0.3 pocket wetland

In addition, an education program was implemented where presentations were given the students of the Neshaminy Middle School on non-point source pollutant and the projects at Lake Luxembourg. Some of these same students assisted in the planting of the vegetation along the lake's shoreline. While most of the work associated with the BMPs is complete, the pocket wetland requires some additional planting of vegetation which will occur in May or June of 2008. Some additional, but minor, re-grading will also occur to maximize its pollutant removal efficiency.

Through the collection of stormwater samples and the use of pollutant removal efficiencies identified in the State's stormwater BMP manual, it was estimated that approximately 35 lbs of TP and 93,042 lbs of TSS was removed per year through the implementation of these projects. Relative to the TMDL, this accounts for approximately 5% of the TP targeted for removal and 11% of the TSS targeted for removal. Putting the amount of TP removed into perspective, the 35 lbs removed on an annual basis is equivalent to approximately 38,500 lbs of wet algal biomass.

It should be stated that in order to keep these annual removal rates consistent, the installed BMPs need to be maintained and cleaned out on a regular basis. The two Aqua-Guardians will be maintained by Middletown Township, while the two vegetative BMPs will be maintained by the Core Creek County Park. As previously mentioned some additional plantings of the pocket wetland will be conducted in May or June of 2008.

Finally, it should be mentioned that future projects within the Lake Luxembourg / Core Creek watershed should focus on streambank vegetative plantings and stabilization, additional plantings in the Park, retrofitting existing detention basins to increase their pollutant removal efficiencies, and developing a design to convert the conservation pool into a regional wetland treatment facility. The large wetland treatment facility alone has the potential to remove more than half of the TP load targeted for removal under the TMDL.