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1.0 Introduction

Core Creek is located in Bucks County, Pennsylvania and enters Neshaminy Creek approximately 13.5 miles upstream of the Delaware River (Figure 1 in Appendix A). Thus, Core Creek is part of the Delaware River Basin in Pennsylvania. Under Public Law 566 funding, a dam was constructed across Core Creek (PA Dam 620) to provide local communities with a multi-purpose reservoir. Construction work and the dam were completed in June 1976 and the reservoir, which was officially named Lake Luxembourg, was filled in the summer of 1977.

The Core Creek watershed has a surface area of 6,033 acres, of which almost 99% directly drains into Lake Luxembourg, which has a surface area of 174 acres. 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. Core Creek is the main inlet and outlet of Lake Luxembourg and the approximate coordinates of the dam are 40 11' 45" north latitude and 74 55' 12" west longitude (Figure 1 in Appendix A).

In 2004, Pennsylvania placed both Lake Luxembourg and Core Creek on Sublist 4 of the State “Integrated Water Quality Monitoring and Assessment Report,” indicating that both waterbodies have approved Total Maximum Daily Loads (TMDLs) for nutrients (Lake Luxembourg) and suspended solids (Lake Luxembourg and Core Creek).

Core Creek has two State-designed sampling sites, the first located upstream of Dam 620 (Lake Luxembourg) and the second located downstream of the lake between Dam 620 and the mouth, where Core Creek enters Neshaminy Creek (PADEP 2001). Recently, the State-identified protected water use designations have been modified by the Environmental Quality Board. As adopted in February 2004, Lake Luxembourg is designated as a Trout Stocking (TSF) and Migratory Fishes (MF) waterbody. Specifically, Lake Luxembourg does not have the year-round or “carry over” habitat and water quality conditions conducive for the support of cold water species (i.e., trout). However, Lake Luxembourg is an extremely popular spot for trout fishing in the spring and fall. Therefore, the lake is regularly stocked as a put-and-take trout fishery. These conditions have resulted in re-designating Lake Luxembourg as a TSF, MF fishery.

The lake’s main inlet, Core Creek, and the unnamed tributaries that enter Lake Luxembourg all remain designated as cold-water fishery (CWF) and MF waterways. In addition, the section of Core Creek immediately downstream of Lake Luxembourg’s dam to where it enters Neshaminy Creek remains designated as a warm-water fishery (WWF) and MF waterway.

From 1991 to 1992, a Clean Lakes (314) Diagnostic / Feasibility Phase I Study was conducted on Lake Luxembourg and the surrounding Core Creek watershed. One of the major tasks of this study was to develop a nonpoint source (NPS) pollutant budget for the Core Creek watershed. For the purposes of the Phase I study, the term “pollutant”
referred to the nutrients nitrogen and phosphorus, as well as total suspended solids. Unit Areal Loading (UAL) methodology was used to calculate the annual pollutant loads generated from each land category within the Core Creek watershed (Coastal 1993).

The results of the Phase I Study were used to develop a site-specific Restoration and Management Plan for Lake Luxembourg. The executive summary, results of the UAL pollutant budget analysis and the original Restoration and Management Plan for Lake Luxembourg are provided in Appendix B.

The Core Creek watershed is almost 35 times larger than the surface area of Lake Luxembourg. The large watershed area relative to the lake indicates that land use is the predominant factor dictating the water quality of Lake Luxembourg and Core Creek. This statement was confirmed by the quantification of all of the major sources of pollutants within the watershed (i.e., surface runoff, internal regeneration, waterfowl, atmospheric) (Coastal 1993). Thus, based on the findings of the Phase I study at that time, overall water quality problems in the Core Creek watershed were primarily the result of a large surface runoff NPS pollutant load originating from stormwater.

Of the major pollutant sources, surface runoff was the largest contributor of nutrients and suspended solids, which indicates that land use was important in determining the water quality of the lake. Quantification of the land categories within the Core Creek watershed determined that agricultural land (i.e., row crops, pasture/grass) was the dominant land type. In turn, agricultural land was the dominant source of nitrogen, phosphorus and suspended solids for Lake Luxembourg and Core Creek (Coastal 1993).

In response to large contributions to the annual NPS pollutant loads from agricultural land, an NPS (“319”) Phase II Grant was awarded to the Bucks County Conservation District by PADEP through US EPA funding. This grant funded the installation and monitoring of a number of agricultural Best Management Practices (BMPs) in an effort to reduce the watershed-based NPS pollutant loads. The project also developed and distributed educational newsletters, and continued, in a very limited scope, the in-lake and watershed monitoring program. A summary of this 319 project is provided in Appendix C.

With the completion of the agricultural 319 pollutant project, the installation of the agricultural BMPs appeared to have reduced a portion of the watershed’s total annual pollutant load (Princeton Hydro, 1998). However, due to the relatively small size of the in-lake water quality database, it was not apparent whether the improvements documented during the Phase II monitoring program were the result of the recently installed agricultural BMPs or a function of natural inter-annual variability. Therefore, additional funding was provided to continue the in-lake monitoring program in 1999 and 2000. Funding for this extension of the in-lake monitoring program was provided through a second 319 Phase II Grant. Unlike the first 319 Phase II Grant which focused on NPS pollutants originating from agricultural runoff, the second 319 grant focused on
NPS pollutants originating from residential sources, with an emphasis placed on streambank / shoreline stabilization. A summary of the second 319 grant is provided in Appendix D.

In addition to implementing a number of streambank / shoreline stabilization projects within the Core Creek watershed and extending the long-term monitoring program over an additional two years, an interactive and holistic educational program was developed as part of the second NPS 319 grant. Specifically, the Bucks County Conservation District and Princeton Hydro worked with the advanced ecology class at FDR Middle School, Bristol Township, Bucks County, PA throughout the 1999-2000 school year. The students of this class are taught by Ms. Kathleen Horwatt of the Bristol Township School District and are known as the “Flood Kids.” The Flood Kids have designed and developed educational brochures on the impacts and solutions to local and regional flooding and have given several public presentations on these subjects. Given the proactive interests of these students, the Bucks County Conservation District and Princeton Hydro worked with the Flood Kids to develop a curriculum and produce an educational brochure. More details on the second NPS 319 grant are provided in Appendix D.

1.1 Purpose and Objectives of this Study

The purpose of this study is to revise the Restoration and Management Plan for Lake Luxembourg and Core Creek. The original Restoration and Management Plan, which was conducted as part of the Phase I Clean Lake Diagnostic / Feasibility Study, was developed in the early 1990s. Since that time substantial changes in land use occurred through the Core Creek watershed. In addition, two Implementation programs have been completed to improve the water quality conditions of both the lake and creek. Finally, a phosphorus TMDL was developed for Lake Luxembourg in the late 1990s by the Pennsylvania Department of Environmental Protection (PADEP). Given all the changes and projects that have occurred in the Core Creek watershed over the last decade, an assessment of the original Restoration and Management Plan was required. In order to accomplish this, the following objectives are addressed in this document:

1. Review and document the positive impacts exerted by the two previously completed implementation projects.
2. Incorporate recently collected water quality data into the long-term database of Lake Luxembourg / Core Creek.
3. Evaluate the relative feasibility and quantify the percent pollutant removal rates of the BMPs that will be implemented in the upcoming Implementation Project.
4. Evaluate the relative feasibility and quantify the percent pollutant removal rates of the BMPs that will be recommended as part of the long-term Implementation Plan.
In addition to these objectives, the estimated percent pollutant removal capacities of the BMPs will be compared to the existing and targeted annual pollutant loads, as estimated in a revised TMDL analysis conducted by US EPA. US EPA recently finalized the TMDL analysis with the use of the ArcView Generalized Watershed Loading Functions (AVGWLF) model. In addition, US EPA used the Pollution Reduction Impact Tool (PRedICT) software to quantify the effectiveness of different pollution strategies, such as agricultural and urban Best Management Practices (BMPs).

2.0 Results of Completed Implementation Projects

At the completion of the second 319 Implementation project, a detailed, long-term analysis of the semi-continuous water quality database was conducted (Princeton Hydro, 2002). For the sake of this revised Restoration and Management Plan, this long-term data analysis will be briefly summarized. In addition, data collected during the 2004 growing season were added onto the long-term database and analyzed (for details see Section 3.0).

For the Lake Luxembourg TMDL, total phosphorus was identified as the primary pollutant of concern. High phosphorus concentrations stimulate excessive algal growth, which impacts the water quality and recreational use of the lake. Phosphorus concentrations also serve as an endpoint for measuring how the lake will respond to the TMDL loading scenarios and the various watershed-based measures. Specifically, this endpoint was the trophic state index (TSI) for phosphorus, a relative expression of a lake’s biological productivity. The most commonly used method of assessing or quantifying the trophic state is Carlson’s (1977) TSI.

TSI values are on a logarithmic scale, ranging from 1 to 100. Increasing values for the TSI are indicative of increasing trophic state, with indices of 40, 50 and 60 representing mesotrophic, meso-eutrophic and eutrophic conditions, respectively. Index values above 70 are usually indicative of hypereutrophic, or extremely productive, conditions. In contrast, index values below 40 are usually indicative of low levels of biological productivity, termed oligotrophic. Higher TSI numbers are associated with increased probabilities of encountering nuisance conditions such as aesthetic problems and algal scums.

Based on the original TMDL, conducted in 1999, the phosphorus TSI for Lake Luxembourg during the Phase I Study (1991-92) was 79, indicating high levels of productivity. Using the TSI for the in-lake data that were collected during the subsequent two NPS Implementation Projects, resulted in a general decline in the TSI (Table 1). By 2000, the phosphorus TSI was 68, which indicates a long-term decline in total phosphorus concentrations in the lake.

In sharp contrast to the phosphorus TSI, the chlorophyll a TSI declined from the Phase I study to the first Phase II project and then increased through the second Phase II
As corroborated by the raw water quality data, the chlorophyll a TSI increased from 1997-98 to 1999-2000 in spite of the fact that the phosphorus TSI declined. The ecological mechanisms behind these seemingly contradictorily results were revealed by examining the Secchi TSIs.

Essentially, by increasing water clarity in Lake Luxembourg through the implementation of BMPs that reduce total suspended solid (TSS) loads, light limitation for algal growth was reduced. While phosphorus concentrations and their associated TSIs were lower, they were not low enough to exert a high degree of nutrient limitation in terms of algal growth. Thus, with the resident algae receiving more light, and with enough phosphorus to fuel high rates of algal growth, the chlorophyll a TSI increased.

In spite of these observed conditions, it should be emphasized that the watershed-based efforts are considered a success. Shifting a waterbody’s trophic state from hypereutrophic toward a more eutrophic state takes a considerable amount of time and effort. To date, the projects over the last ten years have contributed toward shifting Lake Luxembourg toward a more eutrophic level of biological productivity. If a reduction in the size, duration and frequency of algal blooms in Lake Luxembourg is ultimately to be achieved, long-term, watershed-based planning and implementation efforts must continue in the Core Creek watershed.

Based on the State’s TMDL, the targeted goal for Lake Luxembourg should be a phosphorus TSI of 62, which translates to an average in-lake TP concentration of 0.057 mg/L (Table 2). This conclusion is consistent with what Princeton Hydro has observed in the field. Based on Princeton Hydro’s in-house database of Mid-Atlantic waterbodies, in-lake TP concentrations greater than 0.060 mg/L generally result in nuisance conditions (i.e., algal blooms / scums). While the phosphorus TSI has declined in Lake Luxembourg through the 1990s, the targeted TMDL endpoint of 62 has yet to be achieved (Table 1). Algal blooms documented in the later portion of the 1990s support this conclusion.

Evaluating both the annual pollutant loads and the water quality conditions of Lake Luxembourg will assist in determining what needs to be done in order to ensure that the long-term restoration and management efforts continue to make progress toward the targeted TMDL phosphorus endpoint. As provided in the subsequent section of this report, water quality data collected in 2004 were added to the long-term database of Lake Luxembourg in order to identify changes since 2000.
### Table 1 - Summary of the TSI Results for the Long-term Database of Lake Luxembourg

<table>
<thead>
<tr>
<th>Monitoring Year</th>
<th>Phosphorus TSI</th>
<th>Chlorophyll a TSI</th>
<th>Secchi TSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I Study (1991-92)</td>
<td>79</td>
<td>71</td>
<td>75</td>
</tr>
<tr>
<td>1996</td>
<td>77</td>
<td>77</td>
<td>75</td>
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<td>1997</td>
<td>78</td>
<td>67</td>
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<td>1999</td>
<td>70</td>
<td>72</td>
<td>78</td>
</tr>
<tr>
<td>2000</td>
<td>68</td>
<td>73</td>
<td>72</td>
</tr>
<tr>
<td>2004</td>
<td>65</td>
<td>74</td>
<td>70</td>
</tr>
</tbody>
</table>

### Table 2 - Summary of Selected Data from the Original Lake Luxembourg TMDL

<table>
<thead>
<tr>
<th>TMDL Model Scenario</th>
<th>Phosphorus TSI</th>
<th>Anticipated TP concentration</th>
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</thead>
<tbody>
<tr>
<td>Existing Conditions (as of 1991-92)</td>
<td>79</td>
<td>0.18 mg/L</td>
</tr>
<tr>
<td>Baseline Conditions (Completely forested, with no human impact)</td>
<td>60</td>
<td>0.047 mg/L</td>
</tr>
<tr>
<td>Targeted Conditions (Based on 1.2 times the baseline condition)</td>
<td>62</td>
<td>0.057 mg/L</td>
</tr>
</tbody>
</table>
3.0 An Assessment of Water Quality Conditions of Lake Luxembourg

Since the completion of the second Phase II Implementation project in 2000, no water quality monitoring of Lake Luxembourg was conducted until the lake’s monitoring program was resumed in 2004. Three monitoring events were conducted this year: 29 April, 21 July and 17 August 2004. In order to assess existing water quality conditions, the 2004 data were added to Lake Luxembourg’s long-term database.

For convenience, specific parameters of the long-term water quality database for Lake Luxembourg are graphically illustrated (Appendix A). Surface and bottom water total phosphorus (TP) concentrations were generally lower in 2004 than in previous monitoring years (Figure 2 in Appendix A). For example, surface water TP concentrations among the three 2004 sampling events did not exceed 0.090 mg/L, while during previous sampling events surface water TP concentrations commonly exceeded 0.100 mg/L. Similar results were observed with the bottom water TP data. In 2004, bottom water TP concentrations varied between 0.072 and 0.104 mg/L, while bottom water TP concentrations were equal to or greater than 0.100 mg/L for ten of the twelve previous sampling events.

As described above, 2004 TP concentrations were typically lower than what was measured during previous sampling years. This decline in TP concentrations was also evident in the 2004 TSI calculation. The 2000 phosphorus TSI was 68, while the 2004 phosphorus TSI was 65 (Table 1), demonstrating that progress was made toward compliance with the 1999 TMDL endpoint of 62 (Table 2). A comparison of the 2000 and 2004 Secchi depth data also supports this finding.

Water clarity, as measured with a Secchi disk, in 2004 varied between 0.4 and 0.6 meters. While Secchi depths in 2004 did not exceed 0.6 meters as has been recorded in previous years, they remained at or above 0.4 meters (Figure 5 in Appendix A). During past monitoring years, Secchi depths as low as 0.2 meters have been recorded. The mean Secchi depths in 1999 and 2000 were both 0.4 meters, while the mean Secchi depth in 2004 was 0.5 meters.

The 2000 Secchi TSI was 72, while 2004 Secchi TSI was 70. In addition, the 2004 Secchi TSI was lowest value since the 1998 Secchi TSI value (Table 1). Both the raw and the TSI Secchi data indicate that water clarity in 2004 was slightly above what has been previously recorded for Lake Luxembourg.

From a long-term perspective (1992-2004), total nitrogen (TN) concentrations in Lake Luxembourg during the 2004 sampling program were relatively low. However, a significant decline in 2004 TN concentrations relative to the previous monitoring data was not as readily apparent as it was for TP (Figure 3 in Appendix A).
Concentrations of total suspended solids (TSS) in 2004 were similar to those measured during previous monitoring programs (Figure 4 in Appendix A). The 29 April 2004 TSS concentrations were moderately high, with the surface water TSS concentration being slightly above the State-accepted concentration of 25 mg/L for baseline (non-storm) conditions. In contrast, the July and August TSS samples were below 15 mg/L. The elevated TSS concentrations in late April were more than likely the result of spring storms.

In contrast to TP concentrations and Secchi depth, the TSI for chlorophyll $a$ concentrations, a measure of algal biomass, increased from 2000 to 2004 rather than decreased. The 2000 chlorophyll $a$ TSI for Lake Luxembourg was 73, while the 2004 value was 74 (Table 1). Similar observations were made upon the completion of the second NPS Implementation project. The implemented BMPs to date have contributed toward a long-term reduction in the TP and TSS loads, which in turn has produced an increase in the seasonal water clarity. This increase in water clarity was attributed to a reduction in the TSS loads entering Lake Luxembourg, since a correlating reduction in algal biomass was not observed.

It is more than likely that the increase in water clarity has reduced light limitation with regard to algal growth. Although TP concentrations have generally been on the decline, in-lake TP concentrations were still sufficient to produce large amounts of algal biomass. As will be described in Section 4.0, average in-lake TP concentrations need to fall below a threshold value of 0.060 mg/L in order to produce average in-lake chlorophyll $a$ concentrations that reflect more acceptable water quality conditions from a recreational perspective. To conclude, watershed efforts implemented to date have exhibited water quality improvements in Lake Luxembourg. However, additional restoration measures need to be conducted in order to reduce pollutant loads to a level that will produce observable improvements from a recreational perspective.

Over the last decade, the water quality of Lake Luxembourg and Core Creek has been monitored through a relatively consistent water quality monitoring program. This same monitoring program was implemented during the 2004 growing season. And has been described in detail in previous project reports. Future monitoring efforts should continue to use this growing season monitoring program to collect in-lake, tributary and stormwater data within the Core Creek watershed. Such consistency provides a means of assessing long-term trends in water quality.
4.0 Reviewing the TMDL Analysis and the NPS 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. Details on the 1999 TMDL analysis are provided in Appendix E.

Based on the long-term water quality database (1992-2000), the watershed-based projects that were implemented through the 1990s exerted a positive impact on Lake Luxembourg. However, the targeted phosphorus endpoint established under the TMDL has yet to be achieved. Therefore, in order to attain the desired water quality conditions, additional reductions in the annual phosphorus load must be implemented.

Through the 1990s, there were substantial changes within the Lake Luxembourg / Core Creek watershed. For example, since the completion of the Phase I Diagnostic / Feasibility Study, dramatic shifts in land use patterns have been observed and predicted within the Core Creek watershed. Substantial areas of agricultural land within the watershed have been converted to residential land. This shift in land use increases the relative contribution of certain NPS pollutants (e.g., phosphorous and petroleum hydrocarbons) and increases the magnitude of the “first flush” of a storm event (i.e., increased flooding of private and commercial property).

As more people move into both Bucks County and the Core Creek watershed, the recreational, economic and ecological value of the Core Creek County Park and its associated lake will increase. At the same time, the impacts of NPS pollution will also increase. As compared to the rest of the state, Bucks County experienced a higher rate of growth throughout the 1990s. For example, while the county population increased by over 10% from 1990 to 2000, the overall increase in population for the entire State of Pennsylvania during the same time period was only approximately 3.4% (Census Bureau 2000). On a municipal level, the population of Middletown Township, where Core Creek is located, only increased by 2.5% from 1990 to 2000. However, during this same time period, the population of both Lower Makefield Township and Newtown Township, the other two watershed municipalities, increased by over 30%. Such a significant increase in the number of people living within the Core Creek watershed is highly likely to produce water quality impacts associated with increased development.

Given these population and land use changes, it was necessary to assess the annual pollutant loads for Lake Luxembourg and Core Creek. Such an assessment was
certainly required for Lake Luxembourg, since the land use data used to develop the pollutant loads for the Phase I study were based on aerial photographs and field reconnaissance conducted in 1990 (Coastal Environmental Services, Inc. 1993). Thus, the land use data is over 14 years old. If the recommended restoration measures are to address the site specific and current NPS loads and impacts, the land use data needed to be re-assessed.

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.

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.

In addition to utilizing the most up-to-date existing land use and employing a different model, the revised TMDL for the Lake Luxembourg / Core Creek ecosystem includes an analysis of both total phosphorus (TP) and total suspended solids (TSS) (Appendix F). This is being done since TSS negatively impacts Lake Luxembourg, Core Creek and the associated downstream ecosystems through increased turbidity, excessive sedimentation, and the destruction of aquatic habitat for a variety of organisms, including fish and wildlife.

One of the final goals of this work was to re-establish the phosphorus targeted TMDL load and establish a TSS targeted TMDL load for the Lake Luxembourg / Core Creek ecosystem. In turn, these targeted loads were used to develop an Restoration and Management Plan for Lake Luxembourg and Core Creek. The pollutant removal capacities of the recommended measures were used to quantify compliance with the TMDL, using the PRedICT modeling tool.

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 AVGWLF/PRedICT model analysis of the Core Creek watershed have proposed 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.

From the provided information, the AVGWLF/PRedICT model analysis did not take into account several known sources of phosphorus that impact the water quality of
Lake Luxembourg. These sources are internal phosphorus loading and the resident population of waterfowl. These two phosphorus sources were quantified as part of PADEP’s earlier TMDL analysis of Lake Luxembourg. Therefore, these two calculated loads were incorporated into US EPA’s annual phosphorus load, to account for these sources of phosphorus. With this adjustment, the existing annual phosphorus load was estimated to be 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.

To determine if a targeted phosphorus load of 2,254 lbs / yr will result in a measurable and observable improvement in the water quality of Lake Luxembourg, some additional modeling analyses were conducted. The in-lake modeling approach was similar to same methodology that was employed in the original Phase I Diagnostic / Feasibility Clean Lakes Study of Lake Luxembourg and Core Creek watershed. One notable addition is that this set of analyses includes TMDL components such as existing, targeted and baseline loads. A summary of these results of these analyses is provided in Table 3.

With an existing annual phosphorus load of 2,979 lbs / yr, the areal phosphorus load for Lake Luxembourg is 1.92 g/m²/yr and the resulting mean in-lake phosphorus concentration is 0.061 mg/L. In contrast, with the proposed 24% reduction to the targeted annual phosphorus load of 2,254 lbs, the resulting areal phosphorus load for Lake Luxembourg would be 1.71 g/m²/yr. Attaining the targeted phosphorus load would produce a mean in-lake phosphorus concentration is 0.054 mg/L (Table 3).

In order to better assess how this reduction in the mean in-lake phosphorus concentration of Lake Luxembourg would translate into recreational and ecological impacts, a robust and generalized water quality model was used to convert the predicted phosphorus concentrations into algal biomass. The model, based on a large, worldwide empirical database (Schindler, 1978), used a linear regression model to predict mean chlorophyll \( a \) concentrations based on in-lake phosphorus concentrations. Under existing conditions, the predicted phosphorus concentration of 0.061 mg/L would result in a mean chlorophyll \( a \) concentration of 20.6 mg/m³, while the targeted phosphorus concentration of 0.054 mg/L would result in a mean chlorophyll \( a \) concentration of 17.9 mg/m³.

Under both existing and targeted phosphorus loads, Lake Luxembourg will be an eutrophic waterbody. Based on a detailed study of global lakes (Nurnberg, 1996), eutrophic (highly productivity) waterbodies tend to have total phosphorus (TP) concentrations ranging between 0.030 and 0.100 mg/L and chlorophyll \( a \) concentrations between 9 and 25 mg/m³. Thus, under both existing and targeted conditions, Lake Luxembourg will be an eutrophic waterbody and should be managed as one.

In order to obtain a better perspective on the water quality benefits of shifting from the existing to targeted phosphorus loading, TP and chlorophyll \( a \) concentrations were further assessed. Based on Princeton Hydro’s in-house experience of lakes and
reservoirs throughout the Mid-Atlantic States, TP concentrations greater than 0.060 mg/L typically result nuisance algal blooms. While the existing condition had a mean in-lake TP concentration slightly above the 0.060 mg/L threshold, the targeted condition mean in-lake TP concentration was below the threshold (Table 3).

Although shifting from a mean chlorophyll $a$ concentration of 20.6 mg/m$^3$ to 17.9 mg/m$^3$ does not appear to be a large reduction from a numerical perspective, from a recreational perspective this is a substantial reduction. Walmsley and Butty (1979) proposed some typical relationships between chlorophyll $a$ concentrations and recreational impacts relative to water quality (Table 4). Based on this relationship between chlorophyll $a$ concentrations and perceived water quality conditions, attaining the targeted phosphorus loads for Lake Luxembourg will downgrade general conditions from nuisance conditions to the presence of algae (Table 4). Such a targeted result is a reasonable and attainable goal for an impounded and eutrophic waterbody.
Table 3

Summary of the Phosphorus TMDL-based Water Quality Analysis for Lake Luxembourg

<table>
<thead>
<tr>
<th>Modeled Parameter</th>
<th>Existing Conditions</th>
<th>Targeted Conditions</th>
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</thead>
<tbody>
<tr>
<td>Annual Phosphorus Load</td>
<td>2,979 lbs</td>
<td>2,254 lbs</td>
</tr>
<tr>
<td></td>
<td>(1,351 kg)</td>
<td>(1,207 kg)</td>
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<tr>
<td>Areal Phosphorus Load</td>
<td>1.92 g/m²/yr</td>
<td>1.71 g/m²/yr</td>
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<td>Predicted Mean Phosphorus Concentration</td>
<td>0.061 mg/L</td>
<td>0.054 mg/L</td>
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<td>(as per Reckhow)</td>
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<tr>
<td>Predicted Mean Chlorophyll a Concentration</td>
<td>20.6 mg/m³</td>
<td>17.9 mg/m³</td>
</tr>
<tr>
<td>(as per Schindler)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted Maximum Chlorophyll a Concentration</td>
<td>39.5 mg/m³</td>
<td>35.4 mg/m³</td>
</tr>
<tr>
<td>(as per existing database)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reckhow, 1980
Schindler, 1978
Table 4

Impact of Chlorophyll a Concentrations on Perceived Water Quality

<table>
<thead>
<tr>
<th>Chlorophyll a Concentration</th>
<th>Nuisance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10 mg/m³</td>
<td>No problems evident</td>
</tr>
<tr>
<td>10 to 20 mg/m³</td>
<td>Algal scums evident</td>
</tr>
<tr>
<td>20 to 30 mg/m³</td>
<td>Nuisance conditions encountered</td>
</tr>
<tr>
<td>Greater than 30 mg/m³</td>
<td>Severe nuisance conditions encountered</td>
</tr>
</tbody>
</table>
5.0 Restoration and Management Plan for Lake Luxembourg and the Core Creek Watershed

The goal of the Restoration and Management Plan is to utilize the most readily available up-to-date land use, pollutant loading (i.e., total phosphorus and total suspended solids) and limnological data on the Lake Luxembourg / Core Creek watershed to develop restoration recommendations based on the best available information. These recommendations will function in two capacities. First, they are designed to reduce the pollutant loads entering the Lake Luxembourg / Core Creek ecosystem. Second, they are designed to make progress toward attaining the targeted, TMDL-established pollutant loads for TP and TSS. Both of these objectives will result in an improvement in the water quality and natural resource value of the Lake Luxembourg / Core Creek ecosystem.

As previously mentioned, the pollutants removed through both the BMPs to be immediately implemented and those proposed for the future were quantified in order to develop a specific plan toward attaining the targeted TMDL pollutant loads. This quantification will be accomplished through the use of pollutant removal efficiencies for each BMP identified in the scientific literature and the implementation of a stormwater monitoring program. Since the analysis of collected stormwater data will not be conducted until the recommendations are implemented, literature-based pollutant removal efficiencies will be used to estimate the expected removal rates for the proposed BMPs.

Details on each proposed BMP are provided in Appendix G. A data sheet was developed for the BMPs including a description of the BMP, its advantages and disadvantages, estimated costs, maintenance requirements and ascribed pollutant removal efficiencies. This information was used to assist in the evaluation of the management alternatives for Lake Luxembourg and Core Creek.

Given the size of the watershed and the magnitude of the pollutant sources, the emphasis of the original Restoration and Management Plan for Lake Luxembourg focused primarily on watershed-based control techniques (Appendix B). A similar strategy was used in the development of the Restoration and Management Plan. Such an approach is particularly relevant in striving toward long-term compliance with the established TP and TSS TMDLs.

5.1 Evaluation of Management Alternatives

In order to objectively evaluate the applicability of various watershed management methods, a feasibility matrix was developed by Princeton Hydro, LLC. An ordinal ranking, based on a score of 1 to 5, was generated for each alternative. Those alternatives scoring the highest were given priority consideration. A similar approach
was used to evaluate the management alternatives proposed for the original Restoration and Management Plan (Appendix B) and has been frequently used in US EPA’S Clean Lakes Program (US EPA, 1980). For this revised Restoration and Management Plan for the Core Creek watershed, the feasibility matrix factors were slightly modified and included:

1. Pollutant reduction - How substantial a decrease in nutrient and/or sediment loading can be expected from the implementation of this technique?

2. Practicality - Can the technique be realistically implemented for Lake Luxembourg and/or the Core Creek watershed?

3. Effectiveness - Based on the scientific literature, how effective is this technique in meeting desired management objectives?

4. Environmental Impacts - Are there any adverse environmental impacts associated with implementation of the technique?

5. Initial Costs - How much will it cost to design and initially implement the technique compared to the expected returns?

6. Operations and Maintenance (O/M) Costs - How much will it cost to operate and/or maintain the technique on a long-term, annual basis?

For the sake of this Feasibility Study, the BMPs identified for immediate implementation under the existing grant were evaluated separately (Table 5) from the other BMPs proposed for long-term implementation under the guidance of the TP and TSS TMDLs for the Lake Luxembourg / Core Creek ecosystem (Table 6).
Table 5 - Management Alternatives Feasibility Matrix (Proposed for Immediate Implementation)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Pollutant Reduction</th>
<th>Practicality</th>
<th>Effectiveness</th>
<th>Environmental Impacts</th>
<th>Initial Cost</th>
<th>Operation and Maintenance Costs</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrofit BMPs (Catch Basins with SNOUTs)</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Retrofit BMPs (Grate Inlet Skimmer Box)</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Retrofit BMPs (Hydro-Cartridges)</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Stabilization of Shoreline (1,000 ft)</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Stabilization of Shoreline (400 ft)</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Pocket Wetland BMP</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Public Education</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>
### Table 6 - Management Alternatives Feasibility Matrix (Proposed for Future Implementation)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Pollutant Reduction</th>
<th>Practicality</th>
<th>Effectiveness</th>
<th>Environmental Impacts</th>
<th>Initial Cost</th>
<th>Operation and Maintenance Costs</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Wetland / Pool Complex BMP</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Vegetated Buffer (Agricultural)</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Vegetated Buffer (Urban)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Streambank Stabilization</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Retrofit BMPs (Extended Detention Basins)</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>Construction of Extended Detention Basins</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Development of a Meadow Habitat</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Public Education</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>
5.2 BMPs Proposed for Immediate Implementation

Funding was awarded to the BCCD to conduct a third implementation project for Lake Luxembourg and the Core Creek watershed. This grant was awarded by the Pennsylvania Department of Environmental Protection (PADEP) through the United States Environmental Protection Agency’s (US EPA’s) Non-Point Source Pollutant Program (Section 319(h) of the Clean Water Act). BMPs that will be implemented as part of this grant are shown in Figure 7 (Appendix A) and described below.

**Installation of Seventeen Retrofit Stormwater BMPs (Sites 1a and 1b)**

Many of the standard structural stormwater BMPs (i.e., wet ponds, retention basins, infiltration basins) tend to have large land requirements and are most effective when included in the planning phase of development. Consequently, all future development within the Core Creek watershed should incorporate Low Impact Development (LID) strategies to minimize impacts associated with both flooding and NPS pollution. Such LID strategies include, but are not limited to, vegetation and landscaping, minimizing site disturbance, time of concentration modifications, maximizing infiltration capacity and impervious area management. Once the potential and feasibility for LID has been exhausted in development planning, then the larger, structural BMPs should be considered, particularly in minimizing post-development NPS pollution. Under such a strategy, all efforts should be made to keep post-development pollutant loads and recharge capacities as close to pre-development conditions as possible.

While the LID / structural BMP strategy is appropriate for future development, it is more difficult to implement in sections of the watershed that have already been developed. As previously cited, under post-development conditions, the installation of large, structural BMPs can be costly and difficult. However, an alternative approach for developed land is to incorporate manufactured stormwater treatment devices and retrofits into the existing stormwater infrastructure.

The advantages to incorporating stormwater retrofits into the existing infrastructure include the relatively low cost, both in materials and installation; the relatively small requirements for space or land; the relative ease of installation of such devices; and the minimum or negligible amount of permitting required. The disadvantages of stormwater retrofits include their need for frequent routine maintenance and clean-outs and the limited amount of pollutants they can remove. However, when integrated into a community’s routine maintenance of their existing stormwater infrastructure, retrofits can be an extremely cost-effective means of reducing the NPS pollutant loads originating from developed land.

Three specific types of retrofit devices are being proposed for the third Implementation Project for Lake Luxembourg / Core Creek. These retrofits include:
• Water quality drop (sumped) inlet with attached SNOUT device,
• Grate Inlet Skimmer Box, and
• Hydro-cartridge.

Detailed information on each of these retrofits is provided in Appendix G. The goal of this task will be to install a total of 17 of these retrofits within the Lake Luxembourg / Core Creek watershed and quantify the pollutant removal to be achieved by their installation.

Based on input provided by the local municipalities within the Core Creek watershed, as well as several site visits conducted by the BCCD, US EPA and Princeton Hydro, several sites were identified for the installation of the 17 proposed retrofit BMPs. One of these sites is Lakeview Estates, a community located in Middletown Township (Site 1a, Figure 7). This community is located on very steep slopes and the township has noted some sedimentation along the roadways. In addition, surface runoff from this community enters a small tributary which, in turn, enters Core Creek. Given the identified non-point source (NPS) pollution problems and the close proximity of the community to Lake Luxembourg, the majority of the seventeen retrofit BMPs will be installed in Lakeview Estates, Middletown Township.

The second site identified for the installation of a series of retrofits BMPs is located along Upper Silver Lake Road in Newtown Township (Site 1b, Figure 7). The stormwater flowing into the stormsewer basins along Upper Silver Lake Road has been observed to be particularly turbid. Given these turbid stormwater conditions and the fact that the road runs directly into Core Creek from the west, this site was identified for the installation of retrofitted BMPs into the existing stormwater infrastructure.

To date, no verified water quality data are available on the pollutant removal effectiveness of the Grate Inlet Skimmer Box and Hydro-cartridge retrofits. However, one case study exists in Luzerne County, PA, where several Grate Inlet Skimmer Boxes were installed in the existing stormwater infrastructure surrounding Harveys Lake. Harveys Lake is another Pennsylvania TMDL watershed targeting reductions in TP and TSS loads. This installation of these retrofits was just completed in the summer of 2004, so a limited amount of stormwater data have been collected this year to quantify the pollutant load reductions associated with the Skimmer Box retrofits. A similar stormwater monitoring program will be conducted as part of the immediate Restoration Plan for Lake Luxembourg.

Some data are available for the drop inlet / SNOUT retrofit. According to information provided by the manufacturer of the SNOUT device, Best Management Practices, Inc., removal rates of 50% have been measured for TSS (Appendix G). In addition, Princeton Hydro worked with Putnam Valley and the community of Lake Peekskill, Putnam County, New York in the installation of two drop inlet / SNOUT retrofits adjacent to the lake. This small demonstration project was funded through the
County’s Lake Grant Program and included the design, sizing, installation and monitoring of the retrofits. After installing the devices, Princeton Hydro instructed local volunteers on the proper collection of stormwater samples to quantify the pollutant removal capacities of these BMPs.

After some field training, the volunteers collected stormwater flowing into and out of the drop inlet structures with SNOUTS over five storm events from August through December 2003. TSS removal rates, based on concentration, varied from 0 to 76% with a mean of 53%. This mean removal rate is similar to the manufacturer’s removal rate of 50%. TP removal rates, again based on concentration, varied from 0 to 77%, with a mean of 36%.

In addition to quantifying pollutant removal rates, it was estimated that during one of the basin clean-outs, the community’s Public Works staff removed approximately 520 lbs of material (gravel, sand, rock, soil) from each upgraded basin. This material was removed seven months after the upgraded basins with SNOUTS were installed. Based on these conditions, it was estimated that approximately 74 lbs of material are removed from each upgraded basin per month—material that would otherwise enter Lake Peekskill. The study also concluded that, barring any unusually large storm events, the upgraded basins must be cleaned out at least twice each year. It is anticipated that similar conditions will be observed when such upgraded basins are installed in the Lake Luxembourg / Core Creek watershed and the stormwater monitoring plan is implemented. The data collected can be used by the local municipalities to determine if similar structures should be installed on a broader, watershed-wide basis.

**Stabilization of 1,000 Feet of Shoreline (Site 2)**

As part of the second Implementation project, approximately 800 linear feet of shoreline at Lake Luxembourg was stabilized through re-grading and subsequent planting of vegetation. On 25 April 2001, students from the Neshaminy Middle School assisted the Bucks County Department of Parks and Recreation and Princeton Hydro in the installation of shoreline vegetation at this site (see Appendix D). This stabilization project was conducted along the shoreline, immediately northeast of the County Park Boat Launch.

The proposed project for immediate implementation involves extending the stabilization of this section of the lake shoreline another 1,000 linear feet toward the northeast (Site 2, Figure 7). Since shoreline conditions are similar to those experienced along the first site that was stabilized, a similar restoration approach will be employed. Specifically, a contractor will be hired to re-grade the shoreline with machinery and install geotextile and biologs. Students from the Neshaminy Middle School will assist the Bucks County Department of Parks and Recreation and Princeton Hydro in the installation of the shoreline vegetation. The entire site will be protected from grazing.
(i.e., Canada geese, deer) with a combination of silt fence and mylar wire through the first growing season.

Both the lake shoreline project that was conducted in 2001, as well as the one proposed for immediate implementation, will be categorized as vegetative filter BMPs (Appendix G). Such BMPs have been documented to have nitrogen and TP removal rates of 30% and TSS removal rates between 60 and 80%, depending on the type of vegetation used (Appendix G).

**Stabilization of 400 Feet of Shoreline  (Site 3)**

As part of the second Implementation project, which was conducted from 1999 to 2001, 300 linear feet of shoreline between the dam and the fishing pier was stabilized through the installation of a vegetative filter and placement of rip-rap within an eroded gully. This combination of structural and bioengineering techniques was used to stabilize a portion of the southern shoreline of Lake Luxembourg.

This proposed project for immediate implementation (Site 3, Figure 7) would stabilize an additional 400 linear feet of shoreline in this area, again with a combination of structural and bio-engineering techniques. Along most of the 400 feet of shoreline, re-grading with mechanical equipment and the subsequent placement of geotextile and biologs will be conducted. These areas will then be planted with a mix of native grasses, meadow and woody plants. A contractor will be hired to conduct the re-grading, and both the contractor and Princeton Hydro will place the geotextile and biologs. Once again, students from the Neshaminy Middle School will assist the Bucks County Department of Parks and Recreation and Princeton Hydro in the installation of the shoreline vegetation.

While most of the shoreline within this proposed project site will be stabilized with vegetation, a small section (approximately 50 – 75 linear feet) will be stabilized with carefully placed rip-rap stone. This structural technique will be better suited to preserve and protect some trees at risk of falling into the lake.

Again, this shoreline stabilization project is categorized as a vegetative filter strip BMP. Thus, the pollutant removal rates of 60% for TSS and 30% for phosphorus will be used to predict associated pollutant reductions.

**Design, Engineering and Installation of a “Pocket” Wetland BMP (Site 4)**

One of the tributaries that directly enter Lake Luxembourg continues to experience severe streambank erosion (Site 4, Figure 7). In an effort to minimize these impacts, a 200-linear-foot section of streambank was stabilized with geotextile and rip-rap materials during the 1999 – 2001 implementation project. While the rip-rap did aid in
reducing the streambank erosion and protecting some of the larger trees, the project was only marginally effective. As of August 2004, a portion of the placed rip-rap was in the streambed. To re-engineer a significant portion of the tributary would be extremely difficult. Mature trees surround either side of the tributary, so re-grading and engineering the site can only be accomplished if a substantial amount of the existing vegetative is removed. In order to avoid this scenario, but also improve the condition of the stream, a small “pocket” wetland BMP is being proposed for an approximately 0.3 acre site just upstream of the forested area.

Currently, this 0.3 acre site is covered by turfgrass. In order to convert this site into a pocket wetland system (Appendix G), the site will be surveyed and the pocket wetland will be designed for construction. The system will include a forebay and/or pool, marsh and a semi-wet zone. The pocket wetland BMP will temporarily store stormwater runoff and provide pollutant removal through the assimilation of nutrients and the settling of particulates. Depending on site-specific conditions, the capacity to infiltrate some of the stormwater will be incorporated into the design. In addition, the installation of this BMP will contribute toward reducing the streambank erosion along the tributary that enters Lake Luxembourg.

The pollutant removal capacities of a pocket wetland BMP are typically identified at 57% for both TSS and TP. After the wetland BMP is designed and installed, a stormwater monitoring program will be conducted to verify these pollutant removal rates. Princeton Hydro will work with a hired contractor in the earth moving and re-grading of the site. In turn, Princeton Hydro and the Bucks County Department of Parks and Recreation will work together to select and install wetland vegetation. Princeton Hydro will also submit a maintenance document to the Bucks County Department of Parks and Recreation that outlines both short-term and long-term maintenance requirements for the pocket wetland BMP.

Public Education

The BCCD and Princeton Hydro will work with the students of Neshaminy Middle School to develop two public outreach brochures. The first brochure will describe their participation in the shoreline stabilization projects, while the second will summarize the rest of the restoration projects targeted for immediate implementation.

5.3 Evaluation of the BMPs Proposed for Immediate Implementation

As previously described, a matrix analysis was conducted by Princeton Hydro to objectively rank the BMPs proposed for immediate implementation (Table 5). Each recommended BMP was assessed, based on a number of important matrix facts (see Section 5.1). An ordinal ranking, based on a score of 1 to 5 (with 1 being the lowest and...
5 being the highest), was generated for each alternative. Thus, the highest summed value is identified as the highest ranked BMP.

The BMPs identified in Table 5 have all been identified and approved for implementation by the Bucks County Conservation District, PADEP and US EPA. These BMPs were approved due to their high feasibility and potential for cost-effective reduction of existing pollutant loads. Thus, these BMPs received relatively high matrix ratings. Due to its low associated costs and positive impacts, public education was ranked as the highest of the BMPs. However, the highest ratings out of the structural BMPs were received by the two lake shoreline stabilization projects, each with a recorded value of 23 (Table 5). These high ratings are due to the fact that similar projects were already successfully implemented at Lake Luxembourg in 2001.

The second highest ranked structural BMP for immediate implementation was the pocket wetland BMP. While the initial cost for such a BMP is high, operation and maintenance costs are relatively low. In addition, the pollutant reduction and environmental impact categories received high matrix rankings.

Of the three proposed retrofits, upgrading catch basins (with a sumped bottom) with SNOT’s was ranked slightly higher than the Grate Inlet Skimmer Box and the Hydro-Cartridges. The slightly higher ranking value was primarily due to the SNOT’s documented pollutant removal capacity and relatively low initial cost. While the other two BMP retrofits ranked the lowest of all of the alternatives recommended for immediate implementation, they still received relatively high values at 19 each.

As previously cited, public education was ranked the highest of the BMPs to be immediately implemented. Again, this was primarily due to the low costs associated with conducting public education, the minimal amount of maintenance activities and its positive impacts on both the environment and user perception. As with any implementation project, public education needs to be included as a vital component for its successful completion.

5.4 BMPs Proposed for Future Implementation

US EPA calculated the existing pollutant loads entering the Lake Luxembourg / Core Creek system (see Section 4.0 and Appendix F). In turn, this information was used to assess the TP and TSS TMDL for Lake Luxembourg / Core Creek. As a result of the US EPA’s modeling efforts another set of proposed BMPs is being considered for implementation. However, unlike the first set of alternatives, which is recommended for immediate implementation under the existing grant, this next set of alternatives is being recommended for future implementation. Therefore, since funds have not yet been secured for this additional work, a particularly high amount of emphasis will be placed on each alternative BMP’s ranking matrix values. The BMPs that receive the highest matrix values should be prioritized over the remaining alternatives.
Based on US EPA’s analysis of changing land use and associated changes in NPS pollutant loading, a set of general strategies is being recommended to achieve the load reductions identified in the TMDL. These modeled results have been integrated with the water quality and implementation database developed for Lake Luxembourg and Core Creek over the last twelve years to generate the “future implementation” Restoration Plan described in this document.

**Regional Wetland/Pool Complex (Constructed Treatment Wetland)**

When Lake Luxembourg was designed and constructed in the mid-1970s, a 17-acre conservation pool was created in the upper northeastern section of the lake, just above the Woodbourne Road Bridge (Figure 1 in Appendix A). The conservation pool was designed to function as a large settling basin for the suspended solids load that would flow through Core Creek and into Lake Luxembourg.

Based on calculations made prior to the construction of the dam, it was estimated that it would take approximately 100 years for the conservation pool to fill in with sediment. In reality, it took only 9 years (Coastal Environmental Services, Inc. 1993). This accelerated sedimentation rate was due to the extremely high rates of development that occurred in the Core Creek watershed from the 1980s to the present. Currently, the conservation pool does not function as a pollutant-reducing (sediments or nutrients) BMP for Lake Luxembourg and downstream ecosystems. In fact, instead of being a sink for TSS and associated pollutants, the conservation pool is now a source of NPS pollution.

During particularly heavy storm events, accumulated sediments within the conservation pool are re-suspended into the water column and flushed into the main body of Lake Luxembourg and subsequently downstream into Core Creek. Therefore, in order to eliminate this internal source of NPS pollution, contribute toward reducing upstream-generated NPS pollution and enhance the ecological and wildlife value, the existing conservation pool should be converted into a functional regional wetland pool complex or constructed treatment wetland system (Site 1, Figure 8).

Similar to the “pocket” wetland proposed for immediate implementation (Section 5.2), the regional wetland BMP would include a variety of habitats, including a pool or series of pools, marshes dominated by emergent wetland vegetation, and a semi-wet zone that would support both wetland and upland plants (for details see Appendix G). Obviously, the regional wetland BMP would be designed and constructed on a larger scale, to accommodate its larger pollutant loads.

Depending on the specific wetland BMP design, the phosphorus removal efficiency for such regional systems typically varies between 25% and 60%, while the suspended solid removal efficiency typically varies between 60% and 85% (The Center for Watershed Protection 1996). Using conservative estimates of 38% for phosphorus...
and 57% for suspended solids, it is possible that the wetland / pool complex would account for the largest amount of TP and TSS reductions of all of the identified BMPs (for details see Section 6.0). A series of pools or a large pool would function as settling basins, prior to the water moving through the wetland portion of the BMP (see Appendix G). It should be emphasized that these are very preliminary estimates and some detailed stormwater monitoring would be required to confirm these predicted reductions.

**Vegetated Buffers**

US EPA’S AVGWLF/PRedICT model analysis identified that vegetated buffers would provide benefits toward preserving and protecting the Lake Luxembourg / Core Creek ecosystem. While site assessments conducted in September 2004 indicated that a large portion of the Core Creek system has sufficient vegetative buffers, it was estimated that approximately 1.5 miles of urban land and 0.5 miles of agricultural land would benefit from larger vegetated buffers.

For the development of the Restoration and Management Plan, it was estimated that approximately half of the targeted 1.5 miles of urban land would be readily available for the installation of vegetated buffers. In contrast, it is more than likely that 0.5 miles of agricultural land will be identified for vegetated buffers within the Core Creek watershed. The estimated pollutant removal rates for vegetated buffers is strongly dependent upon the width of the buffer and for the sake of this Plan, selected pollutant removal rates reflect a small width associated with the urban buffers, relative to the agricultural buffers.

**Streambank Stabilization Plan**

The pollutant budget analysis conducted by US EPA indicated that the majority of the restoration efforts within the Lake Luxembourg / Core Creek system should focus on streambank stabilization. A limited number of shoreline and streambank stabilization projects have been completed within the Core Creek watershed over the past four years. For the most part, these projects have been successful in stabilizing eroding shorelines and streambanks and have contributed toward measurable reductions in the in-lake TP and TSS concentrations. Thus, both the modeling and past implementation efforts suggest that streambank stabilization will have a substantially positive impact by reducing the TP and TSS pollutant loads entering Lake Luxembourg and Core Creek.

Based on the results of the US EPA AVGWLF/PRedICT model analysis, approximately five miles of streambank within the Core Creek watershed should be targeted for stabilization efforts (Site 2, Figure 8). In the development of this Restoration and Management Plan, it was estimated that approximately half of the five miles of targeted streambank will be available and/or accessible for stabilization efforts.
Actual pollutant removal rates vary widely for streambank stabilization, depending upon the specific restoration techniques that are implemented.

**Best Management Practice Retrofits (Extended Detention Basins)**

As described in Section 5.2, seventeen stormwater retrofits will be installed in selected areas within the Core Creek watershed as part of the immediate Implementation project. The advantages of such retrofits are that they can be easily installed into existing stormwater infrastructure and their relatively low materials and installation costs. However, the effectiveness of such retrofits is strongly based on frequent and regular clean-outs. Therefore, as long as the commitment exists to maintain the retrofits, these structures can be effective in reducing the pollutant load entering receiving waterways.

For future implementation work within the Core Creek / Lake Luxembourg watershed, field surveys conducted by US EPA identified fourteen existing detention basins that could be upgraded / retrofitted to function as water quality BMPs, in the form of extended detention basins (Appendix F). Such upgrades can serve as a very cost effective approach in converting existing stormwater infrastructure that functions primarily for flood control, into a structure that has the capacity to reducing NPS pollutant loads (Appendix G).

The estimated costs of retrofitting each of the identified detention basins will vary widely, depending on what type of retrofits are required. Some of the more common retrofits include modifying the outfall to create a two-stage release to better control small storms, inverting the orifice plate to raise invert elevation and in turn creating a shallow pool, eliminating low-flow bypasses, incorporating berms, forebays, micropools and/or wetland micro-habitats within the basin, and allow for infiltration of water within the basin.

The actual cost of implementing one or a combination of these retrofits is based on site specific conditions, however, Princeton Hydro’s in-house cost estimates vary from $5,000.00 to $30,000.00 for the labor and materials associated with the various retrofit scenarios described above. Other studies and provided retrofit cost ranges of $2,000.00 to $13,000.00 (Stack and Belt, 1989). Using these cost ranges as guidance, an estimated average budget of $10,000.00 per basin retrofitted as identified for the Restoration and Management Plan. Obviously, depending on site specific conditions and the identified retrofits, the actual cost per basin may be higher or lower than the average budget. However, $10,000.00 per basin retrofitted was determined to be a reasonable average for fourteen basins identified for the Restoration and Management Plan.

In addition to retrofitting fourteen detention basins, the US EPA fall surveys identified three sub-divisions that would benefit from the installation of an extended detention basin. Using the identified drainage areas of these three sub-divisions, a cost estimate of $1,000.00 per acre of drainage area (Center for Watershed Protection, 1999).
More details on the location of all of the sub-divisions identified for either retrofit of existing basins or the installation of basins can be found in Appendix F.

**Development of a Meadow Habitat Adjacent to Lake Luxembourg**

The majority of the land immediately adjacent to the northwestern shoreline of Lake Luxembourg is primarily open lawn. While some of the more upland sections of lawn are used for various parkland recreational activities, some of it could be converted into meadowland habitat. For example, the grassed area just upland of the section of shoreline targeted for stabilization (see Section 5.2) and just downslope of a line of trees would benefit from being converted into meadowland. This area is not heavily utilized for recreation, and a small walking path that begins north of the targeted area could be extended through the proposed meadow. This area targeted for the meadowland habitat is approximately 0.5 acres in size.

The development of meadowland habitat would contribute toward reducing the NPS pollutant load that enters the lake from this portion of the watershed, increase the ecological and wildlife value of the park, and serve as a means of educating local and visiting stakeholders as to the value of meadowland habitat. A walking path through the meadowland would be a very inexpensive and interactive means of educating residents and visitors.

As cited above, the creation of a meadowland habitat contributes toward a reduction in the amount of NPS pollution that enters a receiving waterbody. For example, the annual TP load generated from a meadow typically varies between 0.2 to 0.5 lbs of TP per acre. In contrast, lawned areas, especially those at Core Creek Park that are highly compacted, can generate more than 0.8 lbs of TP per acre annually (The Center for Watershed Protection, 1996). Based on these conservative pollutant loading coefficients, a meadowland can reduce the annual TP load by approximately 38% to 75% per acre. Other studies have cited that in general, vegetative BMPs typically reduce phosphorus loads by 40% to 60% (Schueler, 1994). However, a conservative removal rate of 30% for total phosphorus has been selected for the proposed meadowland habitat (see BMP summary sheet for permanent vegetative stabilization in Appendix G).

**Public Education**

To date, the public education programs that have been conducted for the Core Creek / Lake Luxembourg projects have been extremely successful. This is particularly true for the curriculum that was developed by students from the FDR Middle School and the vegetative planting of Lake Luxembourg’s shoreline by students from the Neshaminy Middle School.
One of the extremely successful components of the student-developed curriculum is that once it was complete, the students of FDR Middle School gave a series of public presentations to various groups and organizations on the impacts that both flooding and non-point source pollution have on the ecology and economics of the local communities. A similar approach is proposed for the students of the Neshaminy Middle School.

Since a student-based, social curriculum was already developed on Core Creek and Lake Luxembourg, the proposed public education program for the Neshaminy Middle School students will focus on the implementation of the TMDL (i.e. the Restoration and Management Plan). Similar to the original social curriculum, a number of subjects will be covered under this proposed curriculum, which will include science, math, social studies and art. The proposed outline for the curriculum includes:

1. A review of the environmental and economic impacts associated with declines in water quality, specific to the Lake Luxembourg / Core Creek watershed.

2. A brief, layperson’s description of the Total Maximum Daily Load (TMDL) process, how it works, why it is being used for Lake Luxembourg / Core Creek and how it will benefit the local communities.

3. A presentation of the Restoration and Management Plan for Lake Luxembourg and the benefits associated with its implementation.

4. Achievement of an understanding of the value and purpose of streambank stabilization and why it is an important component of the Lake Luxembourg TMDL.

5. Participation in a variety of educational exercises to develop cost estimates for restoration projects to obtain a sense of the costs and values associated with maintaining “good” or favorable water quality conditions.

6. Involvement with the actual hands-on implementation of some of the recommended restoration techniques (i.e., planting of shoreline and/or streambank vegetation, creation of the meadowland habitat).

7. Participation in developing and conducting public presentations to the three municipalities within the Core Creek watershed. The presentations will be used by the students to present their findings.

The implementation of such a proactive educational program will obviously require a high level of participation from the faculty and students of the Neshaminy Middle School. However, the teachers of Neshaminy Middle School have already demonstrated a strong desire to participate in such a project. For example, the students of Neshaminy Middle School assisted in the planting of shoreline vegetation in the spring of
2001. The close proximity of the school, and the fact that it is located within the Lake Luxembourg / Core Creek watershed, makes the project particularly attractive. Finally, based on the results of the public presentations given by the FDR Middle School (Bristol Township, Bucks County, PA) students as part of one of the earlier 319 projects, such presentations are extremely well received and very effective at educating and influencing the adult stakeholders. Therefore, a minimum of two such public presentations are recommended for this education program.

The proposed educational program would also include the development of an outline for the student-based curriculum, professional guidance for the program, associated field trips and the printing of the resulting student-based curriculum. A critical component of the student-based curriculum will include a strategy devised by the students to provide local stakeholders with information on the restoration projects underway within the watershed, as well as what they can do to contribute toward reducing the existing pollutant loads entering Lake Luxembourg and Core Creek.

5.5 Evaluation of the BMPs Proposed for Future Implementation

Similar to the BMPs identified for immediate implementation, a matrix analysis was conducted to objectively assess the BMPs proposed for future implementation. These BMP alternatives and their associated matrix scores are provided in Table 6. Based on the matrix analysis, the highest-rated alternatives for future implementation are the vegetative buffers installed on agricultural land and the Public Education Program with students from the Neshaminy Middle School. Issues of practicality, environmental impacts and costs are the primary reasons for the high ranking of these two alternatives.

The development of meadowland habitat within Core Creek Park received the second highest ranking of 23 (Table 6). Conversion of a section of lawned area into meadow habitat was highly rated due to the practicability, effectiveness and positive environmental impacts.

Retrofitting fourteen existing detention basins to provide some pollutant reducing capacity of these structures was ranked third with a 22. The practicability and potentially low costs to retrofit these existing basins, resulted in a relatively high rating for this BMP.

After retrofitting the fourteen existing detention basins, the fourth highest ranked BMP was the Regional Wetland / Pool Complex BMP with a ranking of 21 (Table 6). Pollutant reduction capacity, effectiveness and positive environmental impacts all received high scores for the Regional Wetland BMP. However, practicality and initial costs were scored relatively low, at least in terms of the actual construction of the project.

The urban vegetated buffers received a ranking of 20, which is lower than what is ascribed to the agricultural vegetated buffers (Table 6). The lower ranking of the urban
vegetated buffer was due to the anticipated land and space limitations associated with installing such buffers in urban areas. Such limitation will more than likely reduce the size of urban buffers relative to the agricultural buffers, in turn, lowering the pollutant removal capacity for the urban buffers.

Of all of the BMPs recommended for the Restoration and Management Plan for Lake Luxembourg and Core Creek, streambank stabilization and the construction of extended detention basins received the lowest ranked values of 19 (Table 6). While these two BMPs did receive the lowest ranked values, they are still considered applicable and effective measures in complying with the targeted pollutant TMDL loads for Lake Luxembourg and Core Creek. The main purpose of this ranking exercise is to prioritize the projects for future planning efforts relative to available funds. Those projects that are ranked the highest should be implemented first as funding becomes available.

The relatively low ranked values for streambank stabilization and the construction of extended detention basins were due to the low scores for pollutant removal capacity, initial costs and the operation and maintenance costs (Table 6).
6.0 Pollutant Removal Efficiencies, Projected Load Reductions and Associated Costs for Identified Restoration Measures.

In order to attain the targeted annual TP load of 2,254 lbs and TSS load of 2,866,127 lbs, as per the AVGWLF/PRedICT model analysis, a set of watershed-based restoration measures have been outlined and discussed in Section 5.0. To connect the recommended restoration measures to the targeted TMDL loads, widely accepted pollutant removal efficiencies were used to estimate the expected pollutant load reductions associated with each restoration measure. These expected load reductions were totaled and compared to the TMDL targeted loads. In turn, cost estimates and a proposed schedule for implementation were developed for striving toward compliance with the Lake Luxembourg / Core Creek TMDL.

A series of structural BMPs are identified in Pennsylvania’s Handbook of Best Management Practices for Developing Areas (Pennsylvania Association of Conservation Districts, Inc., et al, 1998), however, no pollutant removal efficiencies have been formally ascribed within the manual. Therefore, the pollutant removal efficiencies listed for the Lake Luxembourg / Core Creek TMDL in Table 7 have been obtained from a number of widely accepted sources that include:

1. The Center for Watershed Protection
2. US Environmental Protection Agency
3. US Federal Highway Administration
4. New Jersey Department of Environmental Protection
5. Manufacture’s Claims (for select retrofits)

The pollutant removal efficiencies identified in Table 7 are conservative; that is, when a range or set of removal efficiencies was identified for specific type of BMP, the lower removal efficiencies were selected in quantifying the predicted load reductions. Using the identified pollutant removal efficiencies, the TP and TSS load reductions associated with both the immediate and future BMPs were calculated (Table 8).

For the immediate BMPs, the two lake shore projects include 1,000 linear feet of lake shore just northwest of the boat launch and 400 linear feet in the southern end of the lake, near the floating dock fishing pier. For the sake of selecting the pollutant removal coefficients and calculating the amount of pollutant removed, the width of these lake shore projects were estimated to be 50 feet, similar to the lake shore stabilization projects that were conducted as part of the 1999 – 2001 NPS Implementation grant project.
**Table 7 - Selected Pollutant Removal Rates for the Lake Luxembourg / Core Creek Implementation Plan**

<table>
<thead>
<tr>
<th>Structural BMPs</th>
<th>TSS</th>
<th>TP</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMPs Identified for Immediate Implementation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakeshore Stabilization</td>
<td>60%</td>
<td>30%</td>
<td>New Jersey Department of Environmental Protection</td>
</tr>
<tr>
<td>Retrofit Structures</td>
<td>50%</td>
<td>20%</td>
<td>TSS value manufacturer's claims and Princeton Hydro's in-house database (modified)</td>
</tr>
<tr>
<td>Pocket Wetlands</td>
<td>57%</td>
<td>57%</td>
<td>Center for Watershed Protection</td>
</tr>
<tr>
<td><strong>BMPs Identified for Future Implementation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streambank Stabilization*</td>
<td>60%</td>
<td>30%</td>
<td>New Jersey Department of Environmental Protection</td>
</tr>
<tr>
<td>Vegetated Buffer (agricultural)</td>
<td>67%</td>
<td>22%</td>
<td>US Federal Highway Administration</td>
</tr>
<tr>
<td>Vegetated Buffer (urban)</td>
<td>27%</td>
<td>22%</td>
<td>US Federal Highway Administration</td>
</tr>
<tr>
<td>Retrofitting Existing Detention Basin</td>
<td>40%</td>
<td>20%</td>
<td>New Jersey Department of Environmental Protection</td>
</tr>
<tr>
<td>Meadow Field Habitat</td>
<td>70%</td>
<td>30%</td>
<td>New Jersey Department of Environmental Protection</td>
</tr>
<tr>
<td>Conservation Pool Wetland**</td>
<td>57%</td>
<td>38%</td>
<td>US EPA (modified)</td>
</tr>
<tr>
<td>Grassed / Meadow Swale***</td>
<td>81%</td>
<td>9%</td>
<td>US EPA</td>
</tr>
</tbody>
</table>

* Actual removal rates strongly dependent on site specific conditions and implemented technique of restoration.

** Actual removal rates strongly dependent on the general hydraulics of stormwater moving through the Core Creek watershed.

*** This BMP was implemented as part of the 1999 - 2001 Non-Point Source (319) Implementation Grant
Table 8

Estimated Pollutant Removals Treatments Drainage Areas Associated with the Implemented and Future BMPs

<table>
<thead>
<tr>
<th>Identified BMP</th>
<th>TP lbs removed per year</th>
<th>TSS lbs removed per year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implemented BMPs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two lake shore Stabilization projects</td>
<td>0.3</td>
<td>581</td>
</tr>
<tr>
<td>(1,400 ft / 1.6 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two retrofit Installation projects</td>
<td>7.2</td>
<td>22,609</td>
</tr>
<tr>
<td>(approximately 75 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pocket Wetland (50 acres)</td>
<td>13.7</td>
<td>17,183</td>
</tr>
<tr>
<td><strong>Future BMPs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streambank Stabilization Projects</td>
<td>2.2</td>
<td>5,482</td>
</tr>
<tr>
<td>throughout watershed (13,200 ft / 15.1 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban Vegetative Buffer</td>
<td>0.2</td>
<td>296</td>
</tr>
<tr>
<td>(3,960 ft / 1.8 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Vegetative Buffer</td>
<td>0.3</td>
<td>1,224</td>
</tr>
<tr>
<td>(2,640 ft / 3.0 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrofitted Detention Basins</td>
<td>55.3</td>
<td>138,333</td>
</tr>
<tr>
<td>(approximately 574 acres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Created Meadow (0.5 acres)</td>
<td>0.1</td>
<td>211</td>
</tr>
<tr>
<td>Conservation Pool – Wetland Complex*</td>
<td>652</td>
<td>1,142,228</td>
</tr>
<tr>
<td>(approximately 3,600 acres)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The estimated pollutant load reduction associated with the pool – wetland BMP was adjusted to account for the immediate and future BMPs that would be located upstream of the conservation pool.

The calculations used to quantify the amount of pollutants removed as a result of the Implemented and Future BMPs are provided in Appendix H.
Three types of small-scale retrofit projects were identified for installation in the Core Creek watershed (see Section 5.2). Based on both manufacture claims and similar projects implemented and monitored by Princeton Hydro in other watersheds, a conservative TSS removal efficiency of 50% was ascribed to all three retrofit projects. Such small-scale retrofits are generally not considered to remove a substantial amount of phosphorus from incoming stormwater. Thus, most manufactures do not provide phosphorus removal rates.

Particulate material transported through stormwater can account for a significant fraction of phosphorus entering a receiving waterway. Depending on the type of particulate material, between 80 to 90% of the total phosphorus in stormwater can be adsorbed onto particulates. Therefore, even small retrofits have the potential to remove a measurable proportion of the phosphorus in stormwater. Based on a two year monitoring program of a series of upgraded drop inlets with SNOUT structures, these retrofits removed an average of 53% of the stormwater TSS and 36% of the stormwater TP, based on measured concentrations. Since no such data were available for the other two retrofits, Grate Inlet Skimmer Box and Hydro-cartridge, the conservative removal rates of 50% for TSS and 20% for TP were selected for all three types. As part of the current Implementation Project, a stormwater monitoring program will be conducted to quantify the removal rates associated with these retrofit BMPs.

The pollutant removal efficiencies for the pocket wetland were selected from the Center of Watershed Protection (2000) and estimated that the wetland would be approximately 0.5 acres in size.

The US EPA’s AVGWLF/PRedICT analysis quantified that approximately 5 miles of streambank within the Core Creek watershed requires stabilization. For the sake of the Restoration and Management Plan, it was estimated 2.5 miles of the targeted 5 miles would be readily available for streambank stabilization and/or simply require non-biological, structural stabilization measures (i.e. imbricated rip-rap, boulder revetment). Additionally, the selection of the pollutant removal efficiencies for streambank stabilization was based on an average stabilization width of 50 feet.

In addition to the streambank stabilization efforts, vegetative buffers were also identified as viable and applicable BMPs for the Lake Luxembourg / Core Creek watershed. Two types of vegetative buffers, agricultural and urban, were identified by the US EPA’s AVGWLF/PRedICT analysis. Based on US EPA’s analysis, 1.5 miles of urban land and 0.5 miles of agricultural land would benefit from vegetative plantings. For the sake of the pollutant removal efficiency analysis, it was estimated that approximately half, or 0.75 miles, of the urban vegetative buffers would be available due to limitations associated with property ownership and easement issues. In contrast, it is estimated that the entire 0.5 miles of the targeted agricultural land would be stabilized with vegetative planting. An average width of 50 feet was used to quantify the potential removal efficiency associated with both the urban and agricultural vegetative buffers.
As part of US EPA’s work associated with the Core Creek / Lake Luxembourg project, a series of site surveys were conducted in September 2004 of several areas of residential development. These surveys were specifically conducted to assess the potential to upgrade or retrofit existing stormwater infrastructure, particularly detention basins, to better facilitate collecting and retaining TP and TSS.

Three subdivisions were identified as having no detention basins, while a set of six sub-divisions was identified as utilizing standard detention basin drainage to convey stormwater flows. Thus, the recommended management action for this portion of the Plan is to install extended detention basins in the first three subdivisions and retrofit the basins in the other six sub-divisions to function as extended detention basins. As shown in Table 7, retrofitted detention basins, do not result in the high TP and TSS removal rates. However, retrofitting existing stormwater infrastructure eliminates the need of locating substantial areas of land for the installation of large structural BMPs. In addition, the costs associated with retrofitting existing infrastructure such as detention basins is substantially lower than constructing and installing new structural BMPs. Therefore, retrofitting existing detention basins was integrated into the Restoration and Management Plan.

Based on the sub-division survey results, it is proposed to install three extended detention basins and retrofit fourteen existing detention basins, to contribute toward reducing the existing stormwater TP and TSS loads of Core Creek. Both the installed and the retrofitted basins were ascribed the same pollutant removal rates (Table 7) for compliance toward the Lake Luxembourg / Core Creek TMDL.

The created meadowland habitat, proposed for along the northwestern shore of Lake Luxembourg, will function as a permanent vegetative BMP (see Appendix G). The meadowland BMP will have moderate pollutant removal rates (Table 7), in addition to providing valuable wildlife habitat for the Core Creek Park.

Modifying the existing conservation pool into a pool wetland complex BMP would contribute toward removing a substantial amount of TP and TSS for Lake Luxembourg and the downstream Core Creek ecosystem. The exact design proposed for this regional wetland BMP would be based on an analysis of the hydrologic flow entering the conservation pool from the Core Creek watershed. In turn, the specific pollutant removal efficiencies would be better determined once such an analysis is complete. However, for sake of the Restoration and Management Plan, relatively conservative TP and TSS loading rates were selected for the proposed conservation pool wetland (Table 7). In addition, the estimated amount of pollutants removed (Table 8) takes into account the structural BMPs that are proposed for installation upstream of the conservation pool.

Finally, while a grassed / meadow swale is not recommended at this time, one was installed within the Core Creek Park as part of the 1999 – 2000 NPS Implementation Project. Therefore, the selected pollutant loading rates were ascribed to this BMP, in
order to obtain pollutant removal “credit” toward the TMDL. The other implemented BMPs were included in the TMDL analysis (see Table 9 for details).

The selected BMP pollutant reducing coefficients (Table 7) were used to calculate the pollutant removed for each identified BMP (Table 8). In turn, the pollutant removal data were complied, totaled and then compared to the TMDL-based required reductions (Table 9). Based on the estimated pollutant reductions for all of the recommended BMPs, as well as those installed in 1999 – 2000, the implementation of these combined BMPs will result in compliance with the targeted TMDL loads for TP and TSS. The TMDL load reduction for TP is 725 lbs, while the proposed Restoration and Management Plan will result in a TP reduction of 732 lbs. For TSS, the identified TMDL load reduction for TSS is 859,833 lbs, while the proposed Restoration and Management Plan will result in a TSS reduction of 1,338,497 lbs (Table 9).

Table 10 provides a cost analysis for the structural BMPs proposed for future implementation in the Lake Luxembourg / Core Creek watershed. These are BMPs that are not being implemented as part of the NPS project that will be initiated in 2005. The estimated costs were derived primarily from the Center of Watershed Protection, the US EPA, and Princeton Hydro’s in-house experience on implementing watershed-based projects in the Core Creek watershed.

It is estimated that 2.5 miles of the 5 miles of streambank within the Core Creek watershed would be targeted for stabilization practices. At an estimated cost of $22.50 per linear foot stabilized, the construction and materials cost associated with the proposed streambank stabilization is $297,000.00. Based on past lakeshore and streambank stabilization projects at Lake Luxembourg / Core Creek, the estimated cost per linear foot varied between $20.00 and $25.00 per linear foot. This estimate is substantially lower than those provided by the Center of Watershed Protection, which varied between $40.00 and $50.00 per linear foot (Center of Watershed Protection, 1999). However, the $20.00 to $25.00 range is based on previous work conducted by Princeton Hydro within the Core Creek watershed and therefore was used for the Restoration / Management Plan.

Combined, the agricultural and urban vegetative buffers would cost less than $45,000.00. As with most BMPs, the actual cost is strongly dependent upon the amount of required earth moving activities and the ease of access to the site. In addition, this estimated cost does not include the potential need to purchase land and associated engineering / design work / permitting that would be required.

The BMP category extended detention basins includes the installation of three new basins, designed to accommodate 250 acres of land for water quality control measures over three sub-divisions. This category also includes retrofitting fourteen basins throughout the Core Creek watershed.
In installation of a 0.5 acre meadowland habitat along the northwestern shoreline of Lake Luxembourg is estimated to cost $11,500.00. Again, the majority of the cost is associated with the necessary earth moving activities.

The actual cost of converting the conservation pool into a pool / wetland BMP is very difficult to estimate in the absence of more site specific information, it was estimated that this proposed watershed measure would cost approximately $425,000.00. The cost of creating a wetland BMP widely varies. For example, based on the Center for Watershed Protection, the creation of a wetland BMP costs approximately $15,000 per acre no including design, permitting and land acquisition. In contrast, US EPA estimates that a constructed wetland costs approximately $57,000.00 per acre-ft; this estimate includes labor and materials, as well as design work, engineering and permitting.

Since it is anticipated that the proposed pool / wetland BMP will be dominated by shallow (mean depth 1-2 ft) wetland habitat, it was decided to use a per acre estimate. In addition, no acquisition of land is required for the BMP, which aids in lowering the project costs. Typically, the acquisition of land is the most costly component of installing a large, regional BMP. However, since a pool or series of pools will more than likely be incorporated into the design, the estimated cost per acre was increased to $25,000.00 per acre for a cost of $425,000.00. Again, this estimate does not include design work, engineering and permitting. Thus, the estimated construction costs for this BMP include earth moving activities, installation of hydraulic structures, and vegetative plantings.

As shown in Table 10, the implementation of the watershed BMPs recommended for the future would cost approximately $1,166,700.00. However, it should again be emphasized that this cost estimate is for labor, the use of earth moving equipment and materials (both structural and biological). The estimated cost does not include design work, engineering analyses, permitting, project management and water quality / stormwater monitoring. These non-construction tasks frequently account for 15 to 25% of the construction costs; the actual percent depends on the level of detail associated with the necessary watershed analyses and investigations required to develop acceptable plans for implementation.

Based on US EPA’s AVGWLF/PRedICT analysis, the cost of implementing the proposed watershed measures, in order to attain a 23.1% reduction in the total sediment load, was estimated to cost $1,520,939.45 (Appendix G). The implementation of the Restoration and Management Plan, including both construction and non-construction costs, has an estimated budget of $1,341,705.00 to $1,458,375.00. This cost range for the Restoration and Management Plan is slightly less than the estimated cost provided by US EPA.
Table 9

Summary of the Predicted Pollutant Reductions Associated With the Implementation of the Restoration / Management Plan And the TMDL Loading Scenarios for Lake Luxembourg / Core Creek

<table>
<thead>
<tr>
<th>Proposed BMP</th>
<th>TP Removed (lbs) per year</th>
<th>TSS Removed (lbs) per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural BMPs upstream of Conservation Pool / Wetland BMP</td>
<td>65.2</td>
<td>167,944</td>
</tr>
<tr>
<td>Conservation Pool / Wetland BMP</td>
<td>651.8</td>
<td>1,142,228</td>
</tr>
<tr>
<td>Structural BMPs immediately adjacent to Lake Luxembourg</td>
<td>14.1</td>
<td>17,976</td>
</tr>
<tr>
<td>Structural BMPs completed as part of the 1999 – 2000 NPS Implementation Project</td>
<td>1.1</td>
<td>10,349</td>
</tr>
<tr>
<td>Total Amount of Removed Pollutants</td>
<td>732</td>
<td>1,338,497</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TMDL Loading Scenarios</th>
<th>TP (lbs)</th>
<th>TSS (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Pollutant Loads</td>
<td>2,979</td>
<td>3,725,960</td>
</tr>
<tr>
<td>Targeted Pollutant Loads</td>
<td>2,254</td>
<td>2,866,127</td>
</tr>
<tr>
<td>Required Pollutant Load Reductions</td>
<td>725</td>
<td>859,833</td>
</tr>
</tbody>
</table>
Table 10

Estimated Costs for the Implementation of the Watershed BMPs
For Lake Luxembourg / Core Creek, Bucks County, PA

<table>
<thead>
<tr>
<th>Recommended Watershed Technique</th>
<th>Estimated Cost*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streambank Stabilization</td>
<td>$297,000.00</td>
</tr>
<tr>
<td>Vegetated Buffer (Agricultural)</td>
<td>$27,000.00</td>
</tr>
<tr>
<td>Vegetated Buffer (Urban)</td>
<td>$16,200.00</td>
</tr>
<tr>
<td>Retrofitting and Installation</td>
<td>$390,000.00</td>
</tr>
<tr>
<td>Extended Detention Basins</td>
<td></td>
</tr>
<tr>
<td>Meadowland Habitat</td>
<td>$11,500.00</td>
</tr>
<tr>
<td>Pool / Wetland BMP Complex</td>
<td>$425,000.00</td>
</tr>
<tr>
<td>Public Education Program</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>Total</td>
<td>$1,166,700.00</td>
</tr>
</tbody>
</table>

The estimated costs do not include design work, engineering, permitting, project management and water quality / stormwater monitoring. Including these non-construction costs would result in total implementation costs varying between $1,341,705.00 and $1,458,375.00.
7.0 Concluding Recommendations

This report summarizes the Restoration work that has been completed to date in moving toward compliance with the TMDL for Lake Luxembourg / Core Creek. The report also assesses the long-term water quality database and the annual pollutant model that was originally developed as part of the Phase I Diagnostic / Feasibility Study. In addition, the report provides recommendations on the implementation of watershed-based alternatives to strive toward compliance with the US EPA targeted TP and TSS TMDL goals for Lake Luxembourg / Core Creek.

The identified restoration measures were divided into measures that will be implemented immediately and those that should be considered for future implementation. The restoration measures recommended for immediate implementation are scheduled to be conducted as part of an existing grant that was recently awarded to the Bucks County Conservation District. In contrast, additional funding would be required to implement those recommended measures identified for the future. For the sake of providing long-term guidance in compliance with the targeted pollutant loads of the TMDL, the following restoration strategy is proposed for the future.

Based on US EPA’s AVGWLF/PRedICT analysis, TMDL-based targeted loads were established for TP and TSS. The targeted TP loads were used to predict in-lake water quality conditions and justify the value of implementing the TMDL-based Plan in layperson’s terms.

Specific watershed-based BMPs were then reviewed and proposed for implementation as part of the Restoration and Management Plan for Lake Luxembourg / Core Creek. The recommended BMPs were prioritized based on a number of factors, their pollutant removal capacities were calculated and then compared to the TMDL targeted pollutant loads. It was demonstrated that if implemented, the proposed BMPs would attain compliance with the TMDL established for Lake Luxembourg and Core Creek.

A cost analysis of the implementation of the proposed BMPs was also conducted and compared to the cost estimated provided by US EPA’s AVGWLF/PRedICT analysis. The cost of implementing the Restoration and Management Plan was slightly less than the cost estimated by the AVGWLF/PRedICT analysis.

As with the Phase I study, the two completed Phase II Implementation projects, as well as the project that will be implemented in 2005, a variety of stakeholders will continue to participate in the Restoration and Management of Lake Luxembourg / Core Creek. These stakeholders include the Bucks County Conservation District, the Bucks County Department of Parks and Recreation, several local Middle Schools, the three municipalities with the Core Creek watershed, and the farms and other residents who live in the watershed. The successes that have been documented to date are the direct result of the high degree of interaction and cooperation among the stakeholders. A similar
approach will be used for both the watershed project that will be initiated in 2005, as well as other projects that will be conducted in the future once funds are available.

The Bucks County Conservation District will continue to serve as the lead agency in designing and implementing watershed projects within the Lake Luxembourg / Core Creek watershed. The Bucks County Department of Parks and Recreation will be a “co-lead” agency for any projects that are conducted within the County’s Core Creek Park. Beyond the boundaries Core Creek Park, the municipalities will work with the Conservation District in design and implementation any identified watershed projects. Informing the public on the projects conducted within the Core Creek watershed will include newspaper and television coverage of certain projects, as well as public meetings. Middle School students will also participate in a number of planting and stabilization projects at Core Creek Park and these projects will be highly publicized. Additionally, watershed tours will be conducted approximately once a year to demonstrate to varying agencies and stakeholders progress on the long-term implementation of the TMDL-based Restoration / Management Plan.

To summarize, Bucks County Conservation District and the Bucks County Department of Parks and Recreation, will continue to work with the municipalities and other stakeholders in the implementation of the Restoration and Management Plan for Lake Luxembourg and the Core Creek watershed. The long-term goal of the Plan is to comply with the TMDL by reducing existing TP and TSS loads to the targeted levels. In contrast, the short-term goal is to implement the restoration measures identified under the existing grant, educate and work with all stakeholders in striving toward reducing NPS pollution, and seek funds to implement the additional restoration measures identified for the future.

In terms of the project scheduling, the Conservation District and associated stakeholders will initiate the existing grant in 2005 and complete it by the end of 2007. The stakeholders will also seek additional funds in 2005 to implement at least some of the highest prioritized projects identified in the Restoration and Management Plan.

As shown in Tables 3 and 4, the goal of the phosphorus TMDL for Lake Luxembourg is to reduce the existing TP load to a level where the mean growing season chlorophyll $a$ concentration falls below 20 mg/m$^3$. Such a response would result in a reduction in the magnitude, frequency and duration of algal blooms, which in turn would result in a reduction in observed nuisance conditions (Table 4). Substantial reductions in the in-lake TP concentrations were detected approximately 1-2 years after the agricultural BMPs were completed and in operation in the Core Creek watershed (Figure 2). Based on these observations, if all of the recommended watershed implementation projects were completed by 2007, sustained improvements in the in-lake conditions of Lake Luxembourg would be measured and observed by the end of the decade (2010).

It should be emphasized that this generalized prediction holds only if other sources of phosphorus loading, which are not being addressed in the TMDL, do not
proportionally increase to a level that stimulates additional algal growth. For example, it is common and well documented that subsequent to the implementation of a large-scale watershed-based nutrient reduction program, the relative contribution of the internal phosphorus load is sufficient to sustain algal blooms through the summer months. Under such conditions, an internal phosphorus control program (i.e. aeration, hypolimnetic withdrawal, the application of alum) would be warranted. However, at this time, the watershed-based phosphorus load is clearly the dominant source of phosphorus that needs to be address in the Core Creek watershed.

The Bucks County Conservation District will continue to serve as the lead agency in implementing the watershed projects and monitoring the status of the TMDL in Lake Luxembourg. This includes monitoring in-lake, stormwater and BMP water quality conditions. Princeton Hydro has assisted the Conservation District and the Park in the Lake Luxembourg / Core Creek project since the Phase I study was initiated in 1991, and will continue to do so in the future. Thus, the 12-year long-term water quality database that has been developed from the Phase I study to the present will be extremely valuable in gauging or assessing the status of the overall project.

Milestones variables that will be used to assess the relative success or effectiveness of the long-term Restoration / Management Plan can be divided into in-lake and watershed-based. The in-lake milestone variables will include, but not be limited to:

1. Areal phosphorus load
2. Predicted and measured in-lake TP concentrations
3. Predicted and measured chlorophyll \( a \) concentrations
4. Mean seasonal chlorophyll \( a \) concentrations
5. Maximum chlorophyll \( a \) concentrations
6. Measured in-lake TSS concentrations
7. Measured Secchi depth values

The watershed-based milestone variables will include, but not be limited to:

1. Stormwater TP concentrations entering Lake Luxembourg
2. Stormwater TSS concentrations entering Lake Luxembourg
3. Measured efficiency of installed BMPs in removing TP
4. Measured efficiency of installed BMPs in removing TSS
5. Calculated TP and TSS pollutant load removals associated with the installed BMPs

The quantitative values, thresholds or criteria for most the in-lake milestone variables have already been identified (see the targeted values in Table 3). For the watershed-based milestone variables, the pollutant removal efficiencies will be measured through BMP monitoring during storm events and then compared to removal efficiencies found within the scientific literature. The calculated pollutant load removals will be compared to the predicted load removals provided in Tables 8 and 9.
As with any large-scale, watershed-based project, it is possible that through the years the measured progress is not reaching the expected or predicted progress goals. The most pro-active means of avoiding, or at least minimizing, this condition is to periodically re-calculate the annual phosphorus load based on the most recently available data. Thus, any future shifts or changes in land use that have not been identified in the TMDL can be addressed. Increasing pollutant loads associated with future development should be addressed at the municipality level through the MS4 program and the use of LID measures. However, other unexpected pollutant increases may include an increase in the resident waterfowl population or a proportional increase in the internal phosphorus load. To identify and address such potential load increases, the annual pollutant load entering Lake Luxembourg should be periodically re-calculated.

Approximately 12 years elapsed between the completion of the Phase I annual pollutant load budget and the US EPA AVGWLF/PRedICT pollutant model analysis. Given the high rates of population growth within Bucks County, as well as the major land use shifts from agricultural to residential land within the Core Creek watershed, a period of 12 years to re-calculate the lake’s annual pollutant loads is insufficient to properly track the status of the TMDL. Based on rates of development in southeast Pennsylvania and associated changes in water quality, the recommendation is to re-calculate the annual pollutant loads once every 5 years. Thus, the Lake Luxembourg / Core Creek watershed annual pollutant budget should be re-calculated sometime in 2010. The primary goal of re-assessing the annual pollutant loads is to determine if the Restoration / Management program is attaining its goals and expectations. If these expectations are not being met, then the goal is to use the revised annual pollutant loads to identify the cause for these sub-optimal conditions.
Appendix A

Figures
FIGURE 1: SITE LOCATION MAP
BUCKS COUNTY CONSERVATION DISTRICT
WATERSHED ASSESSMENT
CORE CREEK
BUCKS CO., PENNSYLVANIA

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

SOURCES:
1. USGS 7.5 Minute Quadrangle of Langhorne, PA
2. Project areas outlined by Princeton Hydro, LLC

1 inch equals 4,000 feet
FIGURE 2: SUB-WATERSHEDS

BUCKS COUNTY CONSERVATION DISTRICT
WATERSHED ASSESSMENT
CORE CREEK
BUCKS CO., PENNSYLVANIA

Legend
- Roads
- Streams
- Municipal Boundaries
- Watershed Boundary
- Sub-Watersheds
- Lake Luxembourg

SOURCES:
1. Watershed and Sub-Watersheds delineated by Princeton Hydro. Areas delineated thru 3-D Modeling (ESRI) with 10 meter DEMs
2. Road data obtained from PA DOT

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

1 inch equals 3,000 feet
Figure 2 - Total phosphorus concentrations in Lake Luxembourg, Bucks County, PA through the course of the Phase I Diagnostic / Feasibility Study and the two Phase II Implementation Projects and four years after the completion of the second Phase II project.
Figure 3 - Total nitrogen concentrations in Lake Luxembourg, Bucks County, PA through the course of the Phase I Diagnostic / Feasibility Study and the two Phase II Implementation Projects and four years after the completion of the second Phase II project.
Figure 4 - Total suspended solid concentrations in Lake Luxembourg, Bucks County, PA through the course of the Phase I Diagnostic / Feasibility Study and the two Phase II Implementation Projects and four years after the completion of the second Phase II project.
Figure 5 - Water clarity, as measured by Secchi depth in meters, in Lake Luxembourg, Bucks County, PA through the course of the Phase I Diagnostic / Feasibility Study and two Phase II Implementation Projects and four years after the completion of the second Phase II project.
Figure 6 - Chlorophyll \(a\) concentrations in the sub-surface waters of Lake Luxembourg, Bucks County, PA through the course of the Phase I Diagnostic / Feasibility Study and the two Phase II Implementation Projects and four years after the completion of the second Phase II project.
FIGURE 7: PROJECTS FOR IMMEDIATE IMPLEMENTATION
BUCKS COUNTY CONSERVATION DISTRICT WATERSHED ASSESSMENT
CORE CREEK
BUCKS CO., PENNSYLVANIA

Legend

- Watershed Projects
- Lake Luxembourg
- Watershed

SOURCES:
1. USGS 7.5 Minute Quadrangle of Langhorne, PA
2. Project areas outlined by Princeton Hydro, LLC
Appendix B

Original Restoration and Management Plan for Lake Luxembourg
(from the Phase I Diagnostic / Feasibility Study on Lake Luxembourg and Core Creek, funded under the US EPA Clean Lakes – 314 Program)
6.0 Lake Luxembourg Restoration and Management Plan

The recommended management plan for Lake Luxembourg will need to be implemented over a period of several years to minimize impacts on County finances and to allow time for the implementation of the agricultural BMP's that are the key to the proposed restoration program. The proposed Phase II program will provide some immediate benefits to park users, while the suggested watershed management techniques will lead to long-term improvements in water quality. Funding to implement the proposed restoration project will be sought from the EPA Clean Lakes Program, as well as other federal, state and county sources.

6.1 Proposed Restoration Activities

The Lake Luxembourg restoration program is based on the alternatives discussed in Section 6. The initial stages of the Phase II project can be implemented as soon as funding is available. The major activities planned as part of the initial restoration efforts include the implementation of agricultural BMP's in the Lake Luxembourg watershed and the use of buffer strips to reduce shoreline erosion and to reduce access for ducks and geese around the lake perimeter. Locations of some of the proposed restoration activities are shown in Figure 6.1.

Additional restoration activities are recommended in future years. The activities include the implementation of more agricultural BMP's, a dredging project to remove existing silt accumulations, shoreline stabilization and the installation of fish habitat improvement devices and a restructuring of the lake fishery. The dredging program, shoreline stabilization and fishery improvement activities would take place following a complete drawdown of the lake.

Several of the recommended management activities will increase public access to the lake and improve the lake fishery. The completion of a bicycle path around the lake will make the entire lake readily accessible for cyclists and pedestrians. The construction of an additional fishing pier will increase direct lake access, and the installation of fish attractant devices will provide fish habitat and promote the congregation of fish in areas accessible to shoreline anglers.

The proposed restoration activities will result in reductions in annual soil loss of an estimated 25,200 tons/year (22,900 metric tons/year) at an average cost of only $1.01/ton. Phosphorus loadings to the lake would also be significantly reduced.

Associated activities, including a monitoring program to document the effects of the proposed restoration activities, a public education program to keep the public informed of project progress and the preparation of project reports are also included in the suggested Phase II implementation program to meet the requirements of the Clean Lakes Program. The proposed tasks for the Lake Luxembourg Phase II project are summarized in Table 6.1. Tasks 1 to 7 were discussed in the preceding chapter; the remaining tasks are discussed below. Figure 6.1. Locations of proposed restoration measures.
Table 6.1 - Proposed Tasks for the Lake Luxembourg Phase II Project

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Implementation of Agricultural BMP's</td>
</tr>
<tr>
<td>2</td>
<td>Establishment of Buffer Areas for Waterfowl Control</td>
</tr>
<tr>
<td>3</td>
<td>Dredging</td>
</tr>
<tr>
<td>4</td>
<td>Lake Drawdown</td>
</tr>
<tr>
<td>5</td>
<td>Environmental Landscaping and Shoreline Stabilization</td>
</tr>
<tr>
<td>6</td>
<td>Fishery Enhancement</td>
</tr>
<tr>
<td>7</td>
<td>Completion of Bicycle/Jogging Path</td>
</tr>
<tr>
<td>8</td>
<td>Public Education Program</td>
</tr>
<tr>
<td>9</td>
<td>Phase II Monitoring</td>
</tr>
<tr>
<td>10</td>
<td>Project Documentation</td>
</tr>
</tbody>
</table>

6.2 Public Education Program

A comprehensive public education program will be conducted as part of the Lake Luxembourg restoration project. The public education program will be coordinated through the Bucks County Conservation District and the Bucks County Department of Parks and Recreation. At least one public meeting will be held during each year of the project to inform interested citizens of project progress and to permit public input on possible new directions for improving public access the implementation of agricultural BMP's. The public education program will also include the development of educational materials for use at Core Creek Park. The annual cost of the public education program would be about $3,500.

6.3 Phase II Monitoring

A monitoring program is required for Phase II projects by the U.S. EPA to document changes in water quality occurring as a result of implementation of the lake restoration program. The Phase II monitoring program will be conducted throughout the restoration project and for at least one additional year following the implementation of all recommended management activities.

A limited lake and watershed monitoring program will be conducted during the implementation phase of the Lake Luxembourg Phase II project to evaluate the effectiveness of the lake and watershed management measures that are implemented and to document any changes in lake water quality.

Lake samples should be collected from the surface, middle and bottom of the water column from a single station near the dam. Samples should be collected once per month in June, July and August, and again in December or January of each year and analyzed for all of the parameters
included in the Phase I study, including Secchi depth, profiles for temperature, dissolved oxygen, pH and conductivity, nutrients (soluble orthophosphate, total phosphorus, nitrate + nitrite-N, ammonia-N and total Kjeldahl nitrogen), total solids, total suspended solids, alkalinity, chlorophyll \( a \), phytoplankton and zooplankton.

Additional samples should be collected from the watershed to monitor the progress of the restoration project and to help identify new potential problem areas. Watershed samples should be analyzed for total phosphorus, total nitrogen and total suspended solids. The annual cost of the monitoring program is estimated to be $5,200.

6.4 Project Documentation

A detailed work plan for the Lake Luxembourg Phase II project will be completed prior to the initiation of any project activities. The detailed work plan will include a Quality Assurance Project Plan (QAPjP) designed to meet all EPA requirements if funding is obtained from the U.S. EPA Clean Lakes Program. Regardless of the funding source, the work plan should meet all current EPA requirements for Phase II projects.

Quarterly progress reports will be prepared and submitted to the Bucks County Conservation District and all appropriate funding agencies to document project results. Each progress report will contain a description of project activities and copies of all data collected. A final report will be prepared at the conclusion of the Phase II project containing all information required by the EPA Clean Lakes Program.

Semi-annual reports will contain all information from the progress reports, a description of project expenditures, and a description of proposed activities and expenditures for the following six month period. A final report will be prepared at the conclusion of the Phase II project containing all information required by the EPA Clean Lakes Program. The total cost for project documentation is estimated at $12,500 over a three year period.

6.5 Proposed Phase II Budget

The proposed cost for the Lake Luxembourg Phase II project is approximately $828,900 over a three year period. Funding for 50 percent of the project costs will be sought from the U.S. EPA Clean Lakes Program. Part of the required local funding match can be met by the Bucks County Conservation District and cooperating agencies through the performance of in-kind services. The proposed project budget is shown in Table 6.2.
Table 6.2 - Lake Luxembourg Phase II Budget

<table>
<thead>
<tr>
<th>Phase II Program Element</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>Implementation of Agricultural BMP’s</td>
<td>$818,440</td>
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<tr>
<td>Establishment of a Buffer Area for Waterfowl Control</td>
<td>$5,000</td>
</tr>
<tr>
<td>Dredging</td>
<td>$286,800</td>
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<tr>
<td>Lake Drawdown</td>
<td>$0</td>
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<tr>
<td>Environmental Landscaping and Shoreline Stabilization</td>
<td>$92,000</td>
</tr>
<tr>
<td>Fishery Enhancement</td>
<td>$15,000</td>
</tr>
<tr>
<td>Completion of Bicycle/Jogging Path</td>
<td>$236,680</td>
</tr>
<tr>
<td>Public Education</td>
<td>$10,500</td>
</tr>
<tr>
<td>Phase II Monitoring</td>
<td>$15,600</td>
</tr>
<tr>
<td>Project Documentation</td>
<td>$12,500</td>
</tr>
<tr>
<td><strong>Total Project Cost</strong></td>
<td><strong>$1,492,520</strong></td>
</tr>
</tbody>
</table>

6.6 Implementation Schedule

The proposed implementation schedule for the Lake Luxembourg Phase II project is presented in Table 6.3. The project would begin as soon as funding was available and would continue for a three-year period. The implementation of agricultural BMP's and the establishment of buffer areas for waterfowl control could begin as soon as funding was available. Lake drawdown, dredging, shoreline stabilization and the implementation of fishery enhancement measures would be conducted during the second year of the project, and the bicycle path would be completed during the third year. Public education, monitoring and documentation would be conducted throughout the project period. Specific program elements could be implemented over a more extended period, if necessary, depending upon the availability of funding.

6.6 Lake and Watershed Improvements

The proposed restoration activities will result in significant reductions in pollutant loadings to Lake Luxembourg. Implementation of the recommended agricultural BMP's would reduce the average soil loss from cropland from 15 tons/acre/year to about 3 tons/acre/year. This would result in a total reduction in annual soil loss of about 25,300 tons for the Lake Luxembourg watershed. Although it is difficult to quantify the impact that this reduction will have on the annual suspended solids load to Lake Luxembourg, estimated reductions of about 25 percent
Table 6.3 - Proposed Implementation Schedule

<table>
<thead>
<tr>
<th>Program Element</th>
<th>Months from Project Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of Agricultural BMP's</td>
<td>0 to 36</td>
</tr>
<tr>
<td>Establishment of a Buffer Area for Waterfowl Control</td>
<td>0 to 6</td>
</tr>
<tr>
<td>Dredging</td>
<td>12 to 24</td>
</tr>
<tr>
<td>Lake Drawdown</td>
<td>12 to 24</td>
</tr>
<tr>
<td>Environmental Landscaping and Shoreline Stabilization</td>
<td>12 to 24</td>
</tr>
<tr>
<td>Fishery Enhancement</td>
<td>12 to 24</td>
</tr>
<tr>
<td>Completion of Bicycle/Jogging Path</td>
<td>25 to 36</td>
</tr>
<tr>
<td>Public Education</td>
<td>0 to 36</td>
</tr>
<tr>
<td>Phase II Monitoring</td>
<td>0 to 36</td>
</tr>
<tr>
<td>Project Documentation</td>
<td>0 to 36</td>
</tr>
</tbody>
</table>
of the suspended solids and total phosphorus loads would result if a delivery ratio of 5 percent is used for the eroding soil. Monitoring information gathered as part of the Phase II monitoring program will be used to further quantify the actual reductions achieved by the proposed management measures.

Significant reductions in nutrient loading to Lake Luxembourg would also occur. Total phosphorus concentrations are closely related to concentrations of suspended solids entering the lake. As a result, reductions in soil loss will reduce the concentrations of phosphorus entering the lake.

The limited groundwater monitoring conducted during the Phase I Study indicated that very high nitrate concentrations are found in shallow groundwater as a result of the current high fertilization rates and cropping practices. Improved fertilizer management practices and the recirculation of will help alleviate this problem and will also reduce the current nutrient load to Lake Luxembourg.

Fishing is one of the most popular activities in Lake Luxembourg. The revitalization of the lake fishery, improved access, installation of an additional fishing pier and the installation of fish attractant devices will all help increase fishing success.

As a final consideration, shoreline access to the lake will be significantly improved by the completion of a bicycle trail completely encircling the lake. The proposed extension of the existing mile trail will provide direct access to all areas of the lake to pedestrian traffic.

6.8 Technical and Financial Feasibility

Proposed restoration activities for the Lake Luxembourg Phase II project are technically and financially feasible. The implementation of agricultural BMP's has been shown to be an effective long-term lake management technique. Dredging, lake drawdown and shoreline stabilization are also proven management techniques.

Proposed restoration activities for the Lake Luxembourg Phase II project are technically and financially feasible. The implementation of agricultural BMP's and dredging programs have been shown to be effective long-term lake management techniques. The proposed measures to increase public access to the lake and enhance the lake fishery will help gain support for the project and maintain public interest while the less visible watershed management measures are being implemented.

While the proposed restoration project is expensive, the high use and visibility of Core Creek Park merit local funding for the project. Funds will also be sought from additional federal, state and local sources to implement the proposed management plan. In-kind services can be provided by County personnel in several areas of the restoration plan, and a grant from the FishAmerica Foundation will also help defray some of the necessary local match for the proposed project. The long-term benefits expected from the proposed project justify the expected costs of the proposed restoration program.
In-lake restoration measures

1. Partial lake drawdown for sediment consolidation and fishery rehabilitation,
2. And a limited dredging project to remove a portion of the accumulated material just north of Woodborne Road (i.e. the conservation pool), thus increasing its sediment trapping efficiency.

Watershed-based restoration measures

1. Concentrate on the implementation of agricultural BMPs to reduce pollutant loadings,
2. Implement a number of shoreline and streambank stabilization projects,
3. And generate a series of newsletters that address specific issues concerning the water quality of Lake Luxembourg and Core Creek (i.e. non-point source pollution, waterfowl and water conservation).

Lake and park enhancement measures

1. Environmental landscaping for avian (i.e. geese and ducks) population control,
2. Completion of the bicycle path around the lake,
3. Installation of an additional fishing pier,
4. And the installation of fish attractant devices to provide cover and increase the success rate for shoreline anglers.
Appendix C

Summary of the first Non-Point Source Implementation Project – 1996 - 1998
(funded under the US EPA NPS (319) Program)
Conclusions – Report for First 319 Phase II Project

This report documents the response of the Core Creek - Lake Luxemburg ecosystem to the Non-point Source 319, Phase II project. This project focused specifically on the design and implementation of a number of agricultural best management practices (BMPs) in an effort to reduce the magnitude of the nitrogen, phosphorus and suspended solid loads entering Lake Luxembourg.

Based on the Phase II water quality data, the lake is still a highly eutrophic (productive) waterbody that is thermally stratified through the growing season and its typically anoxic (no dissolved oxygen) at depths greater than 3 m (approximately 10 feet).

Although high nutrient concentrations were periodically measured in Lake Luxemburg, a comparison of the Phase I and II data sets, revealed that Phase II mean concentrations had a tendency to be lower than the Phase I means. Similar results were observed with Secchi depth, TSS and chlorophyll a concentrations. Notable exceptions to this general trend were observed in 1996, which had an unusually wet growing season. The extremely heavy rain through the spring and summer seasons in 1996 generated a larger NPS pollutant load which had a direct impact on the water quality of Lake Luxembourg.

Baseline sampling of Core Creek indicated that Lake Luxembourg tends to function as a retention basin for NPS pollutants. While this benefits Core Creek in the short term, a continued decline in the water quality of Lake Luxembourg in the long term will result in a direct decline in the water quality of the creek. This and future watershed-based management projects are designed to reduce the NPS pollutant load to avoid such declines in the future.

Stormwater sampling of the grass waterway, water quality terrace and pollutant and sediment water quality basin, three agricultural BMPs, revealed that the waterway and the terrace were fairly effective in reducing the storm-generated, NPS pollutant loads. In contrast, the frequency of effectiveness was lower in the water quality basin relative to the other two BMPs. The marginal effectiveness of the water quality basin indicates that the design and maintenance of this basin should be re-evaluated to determine ways of maximizing its effectiveness.

Based on the findings of this study, in conjunction with the Phase I Clean Lakes study, a number of recommendations have been made in regard to what steps should be implemented to continue to minimize the generation of NPS pollutants within the Lake Luxembourg watershed:

1. Both the in-lake and watershed-based monitoring should be continued. The generation of a long-term, in-lake data set is the only direct and effective way of measuring the relative effectiveness of the BMPs in improving water quality conditions in Lake Luxembourg. Watershed-based monitoring should continue to focus on the installed BMPs to ensure they are operating at maximum efficiency. Any problems associated with the BMPs will be identified early on, with a water quality monitoring program.

2. The recently installed agricultural BMPs need to be well maintained in order for them to remain or increase to peak efficiency. Well maintained BMPs will maximize the amount of NPS pollutants removed from the runoff before they enter the lake.
3. The NPS 319 project of Core Creek focused on agricultural land within the watershed, however, large portions of this farmland are being converted into residential and suburban development. Thus, the source of NPS pollutants will shift from agricultural fertilizers and animal waste, to lawn fertilizers and runoff over impervious surfaces. This shift in the land use within the watershed should be taken into consideration for the next stage of the Management and Restoration Plan for the Core Creek - Lake Luxembourg ecosystem. Such a shift will rely heavily on coordination with local townships and an aggressive public education campaign.

4. Besides focusing on land use changes within the watershed, future management options should consider shoreline aquascaping and stabilization. Implementation of these management techniques will aid in controlling the resident waterfowl population, reduce the shoreline generated NPS pollutant loads, reduce shoreline erosion and increase the aesthetic appeal of the lake. Such improvements will directly translate to improvements in the water quality of both Lake Luxembourg and Core Creek.
Appendix D

Summary of the second Non-Point Source Implementation Project – 1999 - 2001
(funded under the US EPA NPS (319) Program)
4.0 Identified Scope of Work for the Second Phase II Implementation Project

As originally identified in the proposal submitted to PADEP, there were three primary objectives of the second Phase II Implementation Project for Core Creek. Each objective is outlined below. The three objectives included:
• Begin to address the increasing contribution residential land will have on the NPS pollutant load of Core Creek,

• Implement several shoreline buffer / streambank stabilization projects within the Core Creek watershed and

• Continue the in-lake and watershed water quality monitoring program.

As will be provided in detail below, each of these three objective were attained with the NPS (319) funds provided to the Bucks County Conservation District from PA DEP and US EPA.

Conclusions

This report documents the response of the Core Creek - Lake Luxemburg ecosystem to the Non-point Source 319, Phase II project. This project focused specifically on the design and implementation of a number of agricultural best management practices (BMPs) in an effort to reduce the magnitude of the nitrogen, phosphorus and suspended solid loads entering Lake Luxembourg.

Based on the Phase II water quality data, the lake is still a highly eutrophic (productive) waterbody that is thermally stratified through the growing season and its typically anoxic (no dissolved oxygen) at depths greater than 3 m (approximately 10 feet).

Although high nutrient concentrations were periodically measured in Lake Luxemburg, a comparison of the Phase I and II data sets, revealed that Phase II mean concentrations had a tendency to be lower than the Phase I means. Similar results were observed with Secchi depth, TSS and chlorophyll $a$ concentrations. Notable exceptions to this general trend were observed in 1996, which had an unusually wet growing season. The extremely heavy rain through the spring and summer seasons in 1996 generated a larger NPS pollutant load which had a direct impact on the water quality of Lake Luxembourg.

Baseline sampling of Core Creek indicated that Lake Luxembourg tends to function as a retention basin for NPS pollutants. While this benefits Core Creek in the short term, a continued decline in the water quality of Lake Luxembourg in the long term will result in a direct decline in the water quality of the creek. This and future watershed-based management projects are designed to reduce the NPS pollutant load to avoid such declines in the future.

Stormwater sampling of the grass waterway, water quality terrace and pollutant and sediment water quality basin, three agricultural BMPs, revealed that the waterway and the terrace were fairly effective in reducing the storm-generated, NPS pollutant loads. In contrast, the frequency of effectiveness was lower in the water quality basin relative to the other two BMPs. The marginal effectiveness of the water quality basin indicates that the design and maintenance of this basin should be re-evaluated to determine ways of maximizing its effectiveness.

Based on the findings of this study, in conjunction with the Phase I Clean Lakes study, a number of recommendations have been made in regard to what steps should be implemented to continue to minimize the generation of NPS pollutants within the Lake Luxembourg watershed:
1. Both the in-lake and watershed-based monitoring should be continued. The generation of a long-term, in-lake data set is the only direct and effective way of measuring the relative effectiveness of the BMPs in improving water quality conditions in Lake Luxembourg. Watershed-based monitoring should continue to focus on the installed BMPs to ensure they are operating at maximum efficiency. Any problems associated with the BMPs will be identified early on, with a water quality monitoring program.

2. The recently installed agricultural BMPs need to be well maintained in order for them to remain or increase to peak efficiency. Well maintained BMPs will maximize the amount of NPS pollutants removed from the runoff before they enter the lake.

3. The NPS 319 project of Core Creek focused on agricultural land within the watershed, however, large portions of this farmland are being converted into residential and suburban development. Thus, the source of NPS pollutants will shift from agricultural fertilizers and animal waste, to lawn fertilizers and runoff over impervious surfaces. This shift in the land use within the watershed should be taken into consideration for the next stage of the Management and Restoration Plan for the Core Creek - Lake Luxembourg ecosystem. Such a shift will rely heavily on coordination with local townships and an aggressive public education campaign.

4. Besides focusing on land use changes within the watershed, future management options should consider shoreline aquascaping and stabilization. Implementation of these management techniques will aid in controlling the resident waterfowl population, reduce the shoreline generated NPS pollutant loads, reduce shoreline erosion and increase the aesthetic appeal of the lake. Such improvements will directly translate to improvements in the water quality of both Lake Luxembourg and Core Creek.
Appendix E

The 1999 Phosphorus-Based TMDL for Lake Luxembourg / Core Creek, Conducted by the Pennsylvania Department of Environmental Protection
Lake Luxembourg TMDL

Prepared by the Pennsylvania Department of Environmental Protection
Bureau of Watershed Conservation

March 01, 1999
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Acknowledgements

The preparer of this document would like to thank the following individuals for their contributions.

Ken Bartal
Barb Lathrop

Technical Consultant
Data Acquisition and Preparation

Prepared by Lee A. McDonnell, Bureau of Watershed Conservation
TMDL for Lake Luxembourg

Introduction

This TMDL document for Lake Luxembourg was completed to address the impairments noted on the PA 1996 303(d) list. The impairments were caused by sedimentation, and excess nutrient loads to the lake. PA does not currently have water quality criteria for nutrients or sediment. For this reason Carlson's Trophic Status Index (TSI) is used as the indicator of lake water quality. TSI analysis is used to determine the necessary phosphorus reduction targets for this TMDL. Since Lake Luxembourg is a phosphorus limited lake (see Attachment A), the established relationship between in-lake phosphorus concentration and TSI to estimate the load reductions that will meet the water quality objectives have been used. Suspended Solids reduction targets are set based on the life design of the lake and its sediment filling rate.

All information used for the TMDL computations is taken from the Phase One Clean Lakes Study conducted by Coastal Environmental Services, and was completed in 1994.

The Lake Luxembourg TMDL Information sheet that is attached to the front of this document provides a primer for TMDLs (What are they and why are we doing them?) and water quality standards. (What makes up a water quality standard?)

Background

Lake Luxembourg is located in Middletown Township, Bucks County, PA, and is the recreational and aesthetic focal point of the popular multi-use Core Creek Park. Water quality problems arose in the lake within just a few years after its impoundment in the 1970's. Reduced depth, turbid water, and excessive algae growth have interfered with the quality of aquatic and lakeside recreation, water supply and flood control uses of the lake. The reservoir reached its 100-year sediment capacity in just nine years. Agricultural practices and rapid urbanization combined with a highly erodible soil type contribute to high sediment loads to the lake during storm events.

The Lake Luxembourg watershed is a unique and valuable asset to lower Bucks County. The watershed contains some of the last actively farmed agricultural land in lower Bucks County and the Core Creek Park provides a valuable open space amid a rapidly expanding residential area.

TMDL Endpoints

All pollutant contributions to Lake Luxembourg are from non-point sources. Based on land use and accepted land use runoff coefficients, estimated loadings for each land use category have been computed. Load reductions for phosphorus were based on the necessary reduction of the in-lake phosphorus concentration needed to achieve the target TSI. Load reductions for suspended solids were based on the lake's design sediment filling rate.

Water quality objectives for phosphorus are set using PA Title 25 Chapter 93.5(c) which governs the use of ambient or natural conditions as water quality criteria. The natural or ambient TSI and in-lake phosphorus concentration was based on the forest runoff coefficient used in the Clean
Lakes Study. This value, 0.176 lb/ac-yr, was developed for use during the preparation of the Clean Lakes Study. This value is appropriate for use as representing the ambient condition. This value was verified in the sources used for the Clean Lake Study. This value represents the uncontrollable load (the load that would always be present), and does not account for any anthropogenic activity. To account for anthropogenic activity the allowable loading was increased by twenty percent. This quantity is the controllable load. A portion of the controllable load is reserved as the margin of safety for the TMDL computation. This is further explained in the section on page five.

The water quality objective for sediment was based on the lake's original design sediment storage capacity. The lake's original design sediment storage capacity was set at 261 ac-ft of sediment over a life span of 100 years. This allowed for a sediment filling rate of 2.6 ac-ft per year. Lake Luxembourg accumulated sediment at the rate 19.6 ac-ft per year during its first ten years of existence, and the accumulation rate has dropped to approximately 9.8 ac-ft per year since 1987. For Lake Luxembourg the objective is to reduce the present sedimentation rate to 2.6 ac-ft per year (this is the original sediment filling rate anticipated by the designers of the lake). This is further explained in the section on page seven.

Data Compilation

This section is separated into lake information and pollutant source information.

Lake samples were taken each month for a full year during 1991 and 1992. Samples were collected bimonthly from June to August 1991. Lake samples were collected from the surface, middle and bottom depths at two stations. Watershed samples were taken during both wet and dry conditions. All Clean Lakes projects follow the Clean Lakes Program requirements for temporal and spatial sampling, and parameters to be sampled (40 CFR Part 35 Subpart H and 40 CFR Part 31 attached as attachment C). The diagnostic/feasibility study done in this watershed was a Clean Lakes Phase I study funded under Section 314 of the Federal Clean Water Act.

The following table shows lake data used for TSI computations.

<table>
<thead>
<tr>
<th>Data</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Type</td>
<td>Anoxic</td>
<td>Attached excerpt from Lake Guidance</td>
</tr>
<tr>
<td>Lake Status</td>
<td>Regular</td>
<td>There is no special protection designation for this lake</td>
</tr>
<tr>
<td>Existing P Conc.</td>
<td>.1846 mg/l</td>
<td>This was computed by plugging load into the anoxic lake equation (phosphorus load from Unit Areal Loading method/lake surface area) and solving for concentration</td>
</tr>
<tr>
<td>Hydraulic Residence Time</td>
<td>45.5 days</td>
<td>Info from Phase 1 Lake study (average value)</td>
</tr>
<tr>
<td>Surface Area</td>
<td>174 acres</td>
<td>Info from Phase 1 Lake study (average value)</td>
</tr>
<tr>
<td>Mean Depth</td>
<td>2.1 meters</td>
<td>Info from Phase 1 Lake study (average value)</td>
</tr>
</tbody>
</table>

The existing phosphorus concentration above represents the average annual concentration in the lake based on the unit area loadings shown in Table 2. This value is consistent with the
measured values recorded in the Phase I Clean Lakes Study showing a range between 0.16 and 0.20 mg/l of phosphorus. The value accounts for background loads such as waterfowl. This value also accounts for seasonal variation because the measured values were collected monthly for a one year period.

Biomonitoring was completed on Lake Luxembourg and included chlorophyll a, phyto- and zooplankton densities, and an assessment of the fisheries.

Phosphorus was found to be the limiting nutrient in the lake (Attachment A). The lake is hypereutrophic at present; high phosphorus levels and sedimentation are major sources of impairment to the lake.

Pollutant Source Information

The pollutant loadings were developed for each type of land use in the watershed, and by monitoring some of the lake inlets during dry and storm events (p.31). Inlets monitored routinely included Core Creek (the major tributary), Park drain tile, two wells, and the lake outlet. For storm samples, the following were sampled: Core Creek (lake inlet), a Park storm sewer, and a storm sewer draining agricultural land. Monitoring was also done at two stations on the lake. The chart on the following page depicts the unit area loading values for the land use categories considered in this evaluation.
<table>
<thead>
<tr>
<th>Land Use</th>
<th>Area (Acres)</th>
<th>% of Total Land</th>
<th>Parameter</th>
<th>lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Crops</td>
<td>2,019.05</td>
<td>33.5</td>
<td>Total P</td>
<td>2,881.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>72,068.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>517,665.6</td>
</tr>
<tr>
<td>Pasture/Grass</td>
<td>206.08</td>
<td>3.4</td>
<td>Total P</td>
<td>110.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>2,575.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>152,634.5</td>
</tr>
<tr>
<td>Nurseries</td>
<td>306.40</td>
<td>5.1</td>
<td>Total P</td>
<td>436.6</td>
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<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>10,936.8</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>747,803.7</td>
</tr>
<tr>
<td>Park</td>
<td>315.79</td>
<td>5.2</td>
<td>Total P</td>
<td>83.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>1,409.0</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>233,893.2</td>
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<tr>
<td>Institutional</td>
<td>148.26</td>
<td>2.5</td>
<td>Total P</td>
<td>66.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>926.1</td>
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<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>109,809.0</td>
</tr>
<tr>
<td>Residential</td>
<td>1,794.69</td>
<td>27.9</td>
<td>Total P</td>
<td>800.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>6,405.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>1,329,237.9</td>
</tr>
<tr>
<td>Commercial</td>
<td>455.65</td>
<td>7.5</td>
<td>Total P</td>
<td>650.5</td>
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<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>4,066.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>337,479.7</td>
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<tr>
<td>Forested</td>
<td>635.29</td>
<td>10.5</td>
<td>Total P</td>
<td>112.5</td>
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<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>1,417.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>25,511.9</td>
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<tr>
<td>Barren</td>
<td>35.34</td>
<td>0.6</td>
<td>Total P</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>630.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>86,239.8</td>
</tr>
<tr>
<td>Wetland</td>
<td>102.30</td>
<td>1.7</td>
<td>Total P</td>
<td>-22.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>-18,257.4</td>
</tr>
<tr>
<td>Open Water</td>
<td>17.05</td>
<td>0.3</td>
<td>Total P</td>
<td>-4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>-3,042.9</td>
</tr>
<tr>
<td>Ducks &amp; Geese</td>
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<td></td>
<td>Total P</td>
<td>44.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>165.4</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>Totals</td>
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<td></td>
<td>Total P</td>
<td>5,561</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total N</td>
<td>102,418</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSS</td>
<td>3,518,975</td>
</tr>
</tbody>
</table>
Consideration of Critical Conditions

It is not practical with existing data and resources to explicitly consider critical conditions in terms of both pollutant loading and in-lake conditions. Such an explicit approach would require continuous model simulation of the watershed and lake. Further, by expressing the TMDLs for sediment and nutrients as annual loads, both the storm loads and the dry weather loads have been implicitly included. Given that there is generally a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective.

Explanation of TMDL Computations for Phosphorus

The TMDL was computed by the following methods.

1. An existing TSI and Phosphorus loading were computed using the equations contained in the Lake for Windows program "TSI Only " option (see attachment D, excerpt from the Implementation Guidance for Section 95.6 Management of Point Source Phosphorus Discharges to Lakes Ponds and Impoundments (Section shows the Reckhow Models and the TSI equation). Refer to page 10 to the TSI analysis titled, "Existing conditions".

<table>
<thead>
<tr>
<th>Scenario</th>
<th>In-Lake P concentration</th>
<th>TSI</th>
<th>Load(lb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions</td>
<td>0.1846</td>
<td>79.40</td>
<td>5561</td>
</tr>
<tr>
<td>All Forest</td>
<td>0.0474</td>
<td>59.79</td>
<td>1429</td>
</tr>
<tr>
<td>Target TMDL</td>
<td>0.0569</td>
<td>62.43</td>
<td>1714 **</td>
</tr>
</tbody>
</table>

** - The target TMDL represents the uncontrollable load + the controllable load + margin of safety (mos)
uncontrollable load = 1429 lb/yr
controllable load = (1714 - 1429)*(1-0.1) = 257 lb/yr
mos = 10% of the controllable load (1714 - 1429)* 0.1 = 28 lb/yr

2. To establish the controllable and non-controllable contributions of phosphorus to the lake, a TSI and loading was computed based on all of the land in the lake watershed being forested. The all forest scenario is an estimate of natural conditions, with no influence from man. This all forest scenario also represents the best possible condition for lake water quality. This represents the non-controllable load.

Refer to page 11 to the TSI Analysis titled "All Forest Scenario".

3. To determine the target TMDL loading for the lake, the in-lake concentration from the all forest scenario was multiplied by a factor of 1.2. This allows for a 20 % increase in the in-lake phosphorus concentration.

The scientific justification for the 20% change in the allowable in-lake phosphorus concentration is based on relationships observed from Vollenweider-OECD eutrophication
results by Lee and Jones (1982). These results indicated that a 20% change in the normalized phosphorus loading to a waterbody must occur before a change in the plankton algal chlorophyll concentrations due to a change in the phosphorus load would be discerned. These studies also indicated that the percent change that must occur in phosphorus load to produce a detectable change in water quality is independent of the trophic state of the waterbody. The 20% change in phosphorus concentration equates to an approximate 5% change in the lake Trophic Status Index (TSI).

The preceding paragraph states that a 20% change in phosphorus loading must occur before there is a discernable change in lake water quality. This is an aesthetic criteria defined by sight, using plankton algal chlorophyll as the indicator. The paragraph also states that this premise holds true at any given trophic state.

Pennsylvania is using the 20% change in load above the estimated natural condition, to allow for man induced activity. We feel this establishes a reasonable target for setting phosphorus controls. Our estimates show that it would be much more difficult to reduce the phosphorus loading rate to the baseline, all forest condition.

Research to verify these relationships was conducted in September, 1998. Original documentation, and literature citations from the rationale documents were reviewed along with M.W. Marsden 1989.

4. The load from the all forest scenario is subtracted from the target TMDL load. This is quantity of phosphorus that is allocated among the land use categories. The categories of forest, wetland, open water, waterfowl, and internal loading were held constant from the all forest scenario. The other land use categories are allocated 90% of the available load. This applies a 10% margin of safety. The category of barren land is also held constant because there is no BMP implementation planned for that land use.

This resets the controllable phosphorus load to the following

<table>
<thead>
<tr>
<th>Controllable load (from 1 above)</th>
<th>257 lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>P load adjustment for barren land</td>
<td>31 lb/yr (37 lb/yr existing load - 6 lb/yr accounted for in forest load)</td>
</tr>
<tr>
<td>Controllable load</td>
<td>257 lb/yr - 31 lb/yr = 226 lb/yr</td>
</tr>
</tbody>
</table>

5. The TMDL load for phosphorus is divided by the existing phosphorus load to determine the percent reduction. Table 4 shows individual land use phosphorus reductions and Table 5 shows the cumulative phosphorus loading and percent reduction.

%reduction = 1 - (TMDL load/ existing load)

The EMPR allocation method was used (see attachment E).

---

Explanation of TMDL Computations for Sediment

Previously mentioned in the background section, Lake Luxembourg’s design sediment storage capacity was exceeded in less than 10 years. The storage capacity of 261 ac-ft of sediment was expected to last 100 years. This would allow for the entrapment of 2.6 ac-ft per year of sediment. From bathymetric analysis it was determined that the sediment fill rate from 1987 to 1992 was 9.6 ac-ft per year. From 1977, when the lake was filled, to 1987 the fill rate was more than double the 1992 rate. Management activities have helped to cut the sedimentation rate. Plans have been made to complete selective dredging operations and other alternative measures to combat this problem. For purposes of setting a target for a reduction in sedimentation the original design of 2.6 ac-ft per year is used.

The TMDL for sediment is based on yearly accumulation. The required reduction is to drop from the current sedimentation rate to 2.6 ac-ft per year. It will be assumed that the current sedimentation rate is 9.6 ac-ft per year as was measured from 1987 to 1992. The required reduction is as follows:

\[
(1 - \frac{\text{actual rate}}{\text{current rate}}) \times 100 = \text{percent reduction}
\]

\[
(1 - \frac{2.6}{9.6}) \times 100 = 73\%
\]

The 73% reduction is assigned to the following land use categories: Row Crops, Pasture/Grass, Nurseries, Parks, Institutional, Residential, Commercial.

The total reduction necessary, in pounds, is equal to 73% of the current suspended solids runoff load.

\[
(1 - .73) \times \text{current TSS load} = \text{TMDL}
\]

\[
(1 - .73) \times 3,518,975 \text{ lb/yr} = 950,123 \text{ lb/yr}
\]

The margin of safety is set at 10%. This requires that an additional 10% of the load be targeted for removal to account for uncertainty in the calculation of this TMDL.

\[
\text{MOS} = 0.10 \times 950,123
\]

\[
\text{MOS} = 95,012 \text{ lb/yr}
\]

\[
\text{TMDL} = \text{LA} + \text{WLA} + \text{MOS}
\]

\[
\text{TMDL} = 855,111 + 0 + 95,012
\]

\[
\text{TMDL} = 950,123
\]

\[
\% \ \text{Reduction} = (1 - \frac{\text{LA}}{\text{TSS current}}) \times 100
\]

\[
\% \ \text{Reduction} = (1 - \frac{855,111}{3,518,975}) \times 100
\]

\[
\% \ \text{Reduction} = 76\%
\]

Percent Reductions for the appropriate land use categories are shown in Table 4. The EMPR allocation method was used (see attachment E).
Negative numbers shown in this table represent pollution sinks that account for removal of nutrients and sediment.

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Area (ac)</th>
<th>current load (lb/yr)</th>
<th>forest load (lb/yr)</th>
<th>TMDL Target</th>
<th>% Reduction of Annual P Load</th>
<th>current load (lb/yr)</th>
<th>TMDL Target</th>
<th>% Reduction of Annual TSS Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Crops</td>
<td>2,019</td>
<td>2,882</td>
<td>357</td>
<td>401</td>
<td>86</td>
<td>517,666</td>
<td>138,214</td>
<td>73</td>
</tr>
<tr>
<td>Pasture/Grass</td>
<td>206</td>
<td>110</td>
<td>36</td>
<td>58</td>
<td>47</td>
<td>152,635</td>
<td>40,753</td>
<td>73</td>
</tr>
<tr>
<td>Nurseries</td>
<td>306</td>
<td>437</td>
<td>54</td>
<td>98</td>
<td>78</td>
<td>747,804</td>
<td>199,660</td>
<td>73</td>
</tr>
<tr>
<td>Park</td>
<td>316</td>
<td>84</td>
<td>56</td>
<td>72</td>
<td>14</td>
<td>233,893</td>
<td>62,448</td>
<td>73</td>
</tr>
<tr>
<td>Institutional</td>
<td>148</td>
<td>66</td>
<td>26</td>
<td>39</td>
<td>41</td>
<td>109,809</td>
<td>29,318</td>
<td>73</td>
</tr>
<tr>
<td>Residential</td>
<td>1,795</td>
<td>800</td>
<td>318</td>
<td>362</td>
<td>55</td>
<td>1,329,238</td>
<td>204,160</td>
<td>85</td>
</tr>
<tr>
<td>Commercial</td>
<td>456</td>
<td>650</td>
<td>81</td>
<td>125</td>
<td>81</td>
<td>337,480</td>
<td>90,105</td>
<td>73</td>
</tr>
<tr>
<td>Forested</td>
<td>635</td>
<td>112</td>
<td>112</td>
<td>112</td>
<td>0</td>
<td>25,512</td>
<td>25,513</td>
<td>0</td>
</tr>
<tr>
<td>Barren</td>
<td>35</td>
<td>37</td>
<td>6</td>
<td>37</td>
<td>0</td>
<td>86,240</td>
<td>86,240</td>
<td>0</td>
</tr>
<tr>
<td>Wetland</td>
<td>102</td>
<td>-22</td>
<td>-22</td>
<td>-22</td>
<td>0</td>
<td>-18,257</td>
<td>-18,257</td>
<td>0</td>
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<tr>
<td>Open Water</td>
<td>17</td>
<td>-4</td>
<td>-4</td>
<td>-4</td>
<td>0</td>
<td>-3,043</td>
<td>-3,043</td>
<td>0</td>
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<tr>
<td>Waterfowl</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Internal Loading</td>
<td>364</td>
<td>364</td>
<td>364</td>
<td>364</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>6,036</td>
<td>5,561</td>
<td>1,429</td>
<td>1,686</td>
<td>70</td>
<td>3,518,975</td>
<td>855,111</td>
<td>76</td>
</tr>
</tbody>
</table>
Table 5. Summary of Load Reductions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Load (lb/yr)</th>
<th>TMDL Load (lb/yr)</th>
<th>% reduction to meet TMDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus</td>
<td>5,561</td>
<td>1686</td>
<td>70</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>3,518,975</td>
<td>855,111</td>
<td>76</td>
</tr>
</tbody>
</table>

Table 6. TMDL Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WLA (lb/yr)</th>
<th>LA</th>
<th>MOS</th>
<th>TMDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus</td>
<td>1,686²</td>
<td>28³</td>
<td>1714</td>
<td></td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>855,111</td>
<td>95,012</td>
<td>950,123</td>
<td></td>
</tr>
</tbody>
</table>

These TMDLs implicitly consider seasonal variation by expressing the loads as annual averages. The annual loads encompass both storm flow and dry weather loads associated with the different seasons.

² The load allocation for Phosphorus can be broken down into the Uncontrollable Load (UL), which is the load resulting from an all-forested watershed absent of anthropogenic sources, and the Controllable Load (CL), which is the result of anthropogenic impacts. The UL is equal to 1429 lbs. And the CL is equal to 257 lbs.

³ The explicit margin of safety is calculated as 10% of the difference between the computed TMDL loading and the loading computed from the all-forested watershed scenario, which is referred to as the controllable load.
Assessment of Measures and Follow-up Monitoring

The recommendations contained in the Phase I Clean Lakes Study completed by Coastal Environmental Services in 1994, are currently being implemented. The Phase I Clean Lakes study will be the basis for remediation in Lake Luxembourg. Remediation activities to reduce nutrient and sediment contributions to the lake have already begun. The following is a list of practices that have or will be installed through the FY95 workplan. Table 7 shows projects that have been completed to date.

<table>
<thead>
<tr>
<th>Practice Installed/Task Completed</th>
<th>Number Installed</th>
<th>Approximate Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Waste Facility</td>
<td>1</td>
<td>$2,790</td>
</tr>
<tr>
<td>Barnyard Runoff Control</td>
<td>1</td>
<td>$11,240</td>
</tr>
<tr>
<td>Diversion</td>
<td>7,875 Ft.</td>
<td>$12,980</td>
</tr>
<tr>
<td>Other Practices</td>
<td>5</td>
<td>$12,450</td>
</tr>
<tr>
<td>Sediment Basin</td>
<td>9</td>
<td>$112,705</td>
</tr>
<tr>
<td>Terrace</td>
<td>22,935 Ft.</td>
<td>$31,990</td>
</tr>
<tr>
<td>Underground Outlet</td>
<td>3</td>
<td>$8,000</td>
</tr>
<tr>
<td>Waterway</td>
<td>40,190 Ft.</td>
<td>$103,150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$297,000</strong></td>
</tr>
</tbody>
</table>

All of the projects listed in Table 7 are agricultural best management practices (BMPs). All of these BMPs are designed to reduce sediment runoff, and address a significant portion of the work toward meeting the TDML objectives for agricultural land uses. However, there is much more work to be done.

The Clean Lakes Study has identified other sources of nutrient and sediment runoff that need to be addressed. Runoff from residential and commercial land use areas need to be addressed along with the other land use categories targeted for load reductions. To support this effort, education of the public concerning nutrient and sediment runoff needs to occur.

There are funding sources available to support the development of site-specific implementation plans and remediation projects that address sources of water quality impairment. One of the primary sources is the Section 319 grant program that is specifically designated for addressing non-point source pollution. Pennsylvania has placed more emphasis on funding projects slated for implementation on waterbodies where TMDLs have been completed.

There is currently a funding request that plans for the completion of more agricultural BMPs, water quality sampling, public education, and documentation. The water quality sampling will help determine if the assumptions for phosphorus loading are correct and also measure performance efficiency of various BMPs.
Public Participation

The Lake Luxembourg study documented several meetings held during the course of the Phase I project to obtain information from the Bucks County Conservation District, the Bucks County Parks Dept., the USDA, the Soil Conservation Service and the ASCS. Recommendations from those meetings were included in the proposed management plan. A public meeting to discuss the findings and recommendations of the Lake Luxembourg Phase I study was held on April 14, 1994 at Core Creek Park (the Bucks County Parks Department Office). Comments received at the meeting concerning the Phase I study and the proposed Phase II projects were incorporated into the final report.

Public notice of the draft TMDL was published in the Bucks County Courier Times on January 20, 1999 and January 27, 1999 and in the Pennsylvania Bulletin on January 23, 1999 to foster public comment on the allowable loads calculated, which were not part of the original Phase I study. A public meeting was held on February 3, 1999 at the Middletown Township Building in Levittown, PA to discuss the proposed TMDL. Notice of final plan approval will be published in the PA Bulletin.
Existing Conditions

*LAKE for Windows: Lake TSI Evaluation*

- **Lake Name:** Lake Luxembourg Exist
- **Type:** Anoxic
- **Status:** Regular

**Existing Phosphorous**
- **Concentration (mg/l):** 0.1846

**Residence Time (days):** 45.5
**Surface Area (acres):** 174
**Mean Depth (meters):** 2.1

**Comment:** Lake is currently Hyper-Eutrophic

**Expected TSI:** 79.40

**Expected Load (lb/ac/yr):** 31.96

The existing TSI was computed by using the total load value for Phosphorus that was calculated using the Unit Area Loading method in the Phase I Clean Lakes Study and dividing it by the surface area of the lake.

\[
\frac{5561 \text{ lbs./yr.}}{174 \text{ ac}} = 31.96 \text{ lb/ac/yr}
\]

The Lake for Windows model uses the units of lb/ac/yr to describe the expected Phosphorus load. The concentration associated with this load using the equation for an anoxic lake is 0.1846 mg/l. This concentration value falls within the range of measured in-lake P values of 0.16 to 0.20 mg/l.

The load from waterfowl is included, and the load reductions for wetlands and open water are taken (See table 4).
All Forest Scenario

LAKE for Windows: Lake TSI Evaluation

Lake Name: Lake Luxembourg Forrest
Type: Anoxic
Status: Regular

Existing Phosphorous
Concentration (mg/l): 0.0474

Residence Time (days): 45.5
Surface Area (acres): 174
Mean Depth (meters): 2.1

Comment: Lake is currently Eutrophic.

Expected TSI: 59.79
Expected Load (lb/ac/yr): 8.21

The all forest Load is computed for use as a baseline condition. This is accomplished by taking all of the land use categories with the exception of wetlands, open water and the background loading for waterfowl and converting it to forest.

This represents the expected TSI and loading for the lake if it had no influence from man. All wetlands and open water are assumed to exist at their current state in the all forest scenario. The load from waterfowl is also included at its current rate.

The All Forest TSI was computed by using the acreage for each land use and multiplying it times the run off coefficient for the forest land use. These loads were summed and divided by lake surface area to obtain the loading in lb/ac/yr (See table 4).

1429 lbs./yr. / 174 ac = 8.21 lb/ac/yr
TMDL Target

LAKE for Windows: Lake TSI Evaluation

Lake Name: Lake Luxembourg TMDL
Type: Anoxic
Status: Regular

Existing Phosphorus
Concentration (mg/l): 0.0569

Residence Time (days): 45.5
Surface Area (acres): 174
Mean Depth (meters): 2.1

Comment: Lake is currently Eutrophic.

Expected TSI: 62.43
Expected Load (lb/ac/yr): 9.85

The TMDL Target was computed using 1.2 times the all forest in-lake Phosphorus concentration. The scientific justification for using the multiplier of 1.2 is explained on page 4 of the written documentation.

The expected load for the existing condition will be divided into the expected load of the TMDL target scenario to determine the percent reduction of Phosphorus needed to attain the TMDL target TSI.

The allowable load for Phosphorus to meet the TMDL TSI for Phosphorus is as follows:

\[ 1714 \text{ lbs./yr.} / 174 \text{ ac} = 9.85 \text{ lb/ac/yr} \]

The body of this paper explains how the margin of safety and the loads that will remain constant (waterfowl, barren land, internal loading) are accounted for.
Comment and Response
Comment
Residential development represents the largest source of suspended solids, and second largest source of phosphorus. A more aggressive reduction target for phosphorus is warranted because residential land use is a significant source of phosphorus.

Response
The reduction of phosphorus specified for the residential land use is significant. A significant portion of the land in the watershed falls in the residential land use category. For this reason the uncontrollable load from the residential land use is large. Specifying a greater reduction for this land use category would not make a significant difference in the TMDL.

Comment
Nutrient Management is missing from the list of proposed management techniques. This applies to agricultural activities as well as residences.

Response
All of the large farms in the watershed have recently completed nutrient management plans. It is in the best interest of the farmer to use the minimal amount of fertilizer to achieve the desired effect. Over fertilizing will cost the farmer money. The start of a source reduction program for the other land uses will come through education of the public. A Section 319 Non-point source grant proposal has been submitted to address this need by the Bucks County Conservation District.

Comment
PADEP does have a responsibility to take action to actually implement the Lake Luxembourg TMDL once issued. What is your position on this?

Response
PADEP has a responsibility to oversee the implementation of the TMDL, however, the effort to develop and implement restoration plans and apply pollution prevention measures must be locally driven and sponsored. PADEP, along with other agencies and organizations, can assist in this effort by providing funding through grant programs and by providing technical assistance, facilitation, and guidance to local residents.

Comment
Public education should focus on how citizens and communities can diminish non-point source pollution and stormwater runoff.
Response
We agree. To initiate this public education focus the Bucks County Conservation district has applied for a Section 319 Non-point source grant for the upcoming fiscal year that includes a major educational component.

Comment
The TMDL should include enforcement of the Neshaminy Creek watershed stormwater management plan.

Response
The three municipalities located within the boundaries of the core creek watershed have all adopted ordinances that are contained in the Neshaminy Creek stormwater management plan. Enforcement of these ordinances is the responsibility of the local government.

Comment
What are meant by the following terms: 41,960 ft. of waterway, 29,450 ft. of terrace, 8,000 ft. of diversion

Response
These all describe agricultural best management practices and the extent of their implementation. The appropriate definitions are as follows:

Waterway (grassed waterway) - A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff. The purpose of a waterway is to convey runoff from terraces, diversions or there water concentrations without causing erosion or flooding and to improve water quality.

Terrace - An earth embankment or ridge and channel constructed across the slope at a suitable spacing and acceptable grade. The purpose of a terrace is to reduce erosion, reduce sediment content in runoff water, intercept and conduct surface runoff of a nonerosive velocity to a stable outlet, prevent gully development, improve farmability, reduce flooding and increase soil moisture.

Diversion - A channel constructed across the slope with a supporting ridge on the lower side. The purpose of a diversion is to diver excess water from on area for use or safe disposal in another.

Comment
There is a pipe that sticks out into the lake near Woodburne Road. The pipe is capped, however, area citizens have seen this pipe leak. Has DEP identified what comes out of the pipe and is it affecting the nutrient loading?
Response
The DEP Southeast Region Office will investigate the nature and use of this pipe and respond appropriately. The inspection will take place by 04/01/99. You will be contacted regarding the results of the inspection.

Comment
Stormwater infiltration practices are the most effective method for reducing sediment and Phosphorus pollution contained in stormwater runoff. Use of this method for remediation needs to be a priority.

Response
Infiltration can be an effective, environmentally sound means of controlling stormwater. We agree that this measure should be closely evaluated during restoration plan development and implemented where feasible.

Comment
Sediment basins will not give needed pollution reductions. The primary method to be used to address the sediment and Phosphorus problems facing the lake are 11 sediment basins.

Response
The sediment basins as shown in table 7 are agricultural best management practices and are not meant to be the answer for all the pollution sources in the watershed. They are only part of a list of control practices that have already been constructed on the watershed.

Comment
Section 303(d) of the Clean Water Act calls for a total maximum "daily" load, not an "annual" load. Therefore, the proposed TMDL which only calls and provides for "annual" load reductions and requirements does not fulfill the requirements of section 303(d) of the Clean Water Act which mandates total maximum "daily" load requirements.

We respectfully request that you redevelop your proposed Lake Luxembourg TMDL so it is in accordance with the requirements of the Clean Water Act, providing for "daily" load requirements. The TMDL as proposed cannot be said to fulfill PA DEP's obligation pursuant to section 303(d) of the Clean Water Act as it pertains to Lake Luxembourg. Approval of this proposed document by EPA could not be said to fulfill their obligations under section 303(d) of the Clean Water Act nor their litigation settlement obligations.

Response
40 CFR Section 130.2(h) states, in part, "...TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Furthermore, in EPA's response to comments on the Federal Register of January 11, 1985 Water Quality Planning and Management; Final Rule, they stated "Therefore, TMDLs and water quality-based effluent..."
limitations may be expressed in terms of an appropriate averaging period, such as weekly or monthly, as long as compliance with applicable WQS is assured.

Name: Chesapeake Bay Foundation, Received 2/22/99

Comment
There was no plan of action delineating the activities DEP would take to control the sources of pollutants causing degradation of these waters.

Response
The TMDL is designed to quantify the allowable loading to the waterbody. This TMDL had a Phase I Clean Lakes Study as an attachment to the document. The Clean Lakes Study outlines remediation activities that should be undertaken. Additional measures to meet the TMDL objectives must come from the local level, PADEP, along with other agencies and organizations, can assist in this effort by providing funding through grant programs and by providing technical assistance, facilitation, and guidance to local residents.

Comment
The comment period for the TMDL of thirty days was too short.

Response
In the future we will try to allow for a longer comment period of up to 60 days. It should be noted that the TMDL was also posted on our internet site on January 14, 1999 providing a 39 day period of public accessibility. Notice was run in local newspaper on January 20, 1999 and January 27, 1999.

Name: Hyman, Julius and Helen, Received 2/23/99

Comment
The Hymans identified several potential sources of sediment and phosphorus loads to Lake Luxembourg, and suggested practices for reducing sediment and phosphorus loads.

Response
The TMDL establishes allowable sediment and phosphorus loads to Lake Luxembourg. Its purpose was not to define individual non-point sources nor propose a comprehensive restoration plan. Although a list of existing and anticipated management practices were a component of the TMDL report, the detailed information necessary to categorize individual non-
point sources and recommend additional specific remediation measures
must be developed during preparation of a comprehensive restoration plan
for the lake. The information submitted by the Hymans will be a valuable
information source for those who will be responsible for local restoration
plan development.
Appendix F

USEPA’s Revised TMDL for Lake Luxembourg and Core Creek
The ArcView Generalized Watershed Loading Function (AVGWLF) and its counterpart, the Pollution Reduction Impact Tool (PRedICT), allow watershed managers, planners, and other environmental professionals to predict and quantify pollutant loads within selected watersheds. The system relies on GIS-based land use, weather, soil, and other spatially-referenced data. Through calculations and algorithms, the AVGWLF model allows the user to assess what impact, in terms of nitrogen, phosphorus, and sediment pollution, the land use will have on a body of water.

The PredICT software allows users to create various “scenarios” in which current landscape conditions and pollutant loads can be compared against potential future conditions. This tool can be used to quantify the effectiveness of different pollution strategies such as agricultural and urban Best Management Practices (BMPs). After inputting BMP data, the software calculates the expected load reduction and cost of implementing the specified strategies.

The Pennsylvania Department of Environmental Protection (DEP) has developed Total Maximum Daily Loads (TMDLs) based on data derived from AVGWLF modeling. The Core Creek Watershed TMDL, which calls for a 25% reduction in total sediment loading, was based on AVGWLF land use data from 1994. However, there have been major land use changes throughout the Core Creek Watershed in the past decade with agricultural land being converted into low density urban developments. In order to assess where potential sediment load reductions can come from, it is important to use the same computer model that was used to develop the TMDL (AVGWLF). In addition, the most recent land use data must be used to obtain more accurate results. In this assessment, land use was derived from 2000 Multi Resolution Land Cover data which better reflects the ongoing development of the watershed. Periodically, updated versions of AVGWLF are released that reflect the most recent land use and best current knowledge of BMP efficiency and cost values.

To supplement the data derived from AVGWLF, field assessments were conducted to provide more detailed understanding of land use and to determine the existence and effectiveness of current BMPs. During the fall and winter months of 2003, the farming communities within the watershed were visited. It was determined that farmers did not seem to need very much assistance with their BMPs and that their operations are very conservation oriented even though the TMDL report states that sedimentation from agricultural activity is the major problem in the Core Creek (See Appendix 1).

To better assess the implications of increased development within the watershed, further field visits focused on urban BMPs. In an assessment of detention basins and new development plans in September 2004, it was determined that approximately 89% of the urban land is drained by basins (See Appendix 2). Based on these findings, there is potential to achieve sediment load reductions and achieve water quality goals by constructing more detention basins or retrofitting current basins for increased infiltration efficiency.

Another area in which load reduction strategies could be implemented is streambank stabilization and the planting of vegetative buffers. Site assessments in September 2004 indicated that there is an adequate vegetative buffer bordering most of Core Creek, leaving little potential for future improvements. However, an estimated 1.5 miles of urban land and 0.5 miles of agricultural land could benefit from the planting of a wider vegetative buffer strip. It was determined that streambank stabilization holds the greatest potential for achieving the load reductions called for in the TMDL. Tentatively, the model calls for five miles of bank
stabilization, but further stream assessments are needed to determine the feasibility of such projects.

As the Core Creek Watershed TMDL report does not include information about the best way to mitigate the effects of the nonpoint source pollution, the results of the AVGWLF and PredICT modeling demonstrate a great way for local practitioners to assess what types of projects are necessary to meet the load reductions. Based on the computer model output and need to address the changing land use within the Core Creek Watershed to focus on urban sources of pollution, the following strategies are recommended in order to achieve the load reductions called for in the TMDL (See also Appendix 3):

<table>
<thead>
<tr>
<th>BMP</th>
<th>Amount</th>
<th>% of Total Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detention Basin Construction</td>
<td>To drain 135 Acres</td>
<td>12.5</td>
</tr>
<tr>
<td>Streambank Stabilization</td>
<td>5 Miles</td>
<td>86.8</td>
</tr>
<tr>
<td>Vegetated Buffer-Agriculture</td>
<td>2640 feet</td>
<td></td>
</tr>
<tr>
<td>-Urban</td>
<td>7920 feet</td>
<td></td>
</tr>
</tbody>
</table>

Total estimated cost- $1,520,939.45
Achieves 23.1% reduction in total sediment load

The AVGWLF and PRedICT models are continuously developing as more accurate land use data is obtained and more is learned about BMP efficiencies and costs. These results and recommendations are based on the most recent update of the model, but as the watershed continues to change, the pollutant loads and most efficient allocation of BMPs may also vary slightly. The next step in developing an effective implementation plan for sediment load reductions in Core Creek involves conducting further stream assessments to determine the feasibility of stabilizing the recommended miles of streambank and planting the vegetative buffers along the banks of Core Creek.

The retrofiting of existing detention basins and installation of more efficient infiltration systems remains another attractive alternative for achieving water quality goals. Studies in the Pine Run subwatershed show that converting existing detention basins into more efficient infiltration systems can be very effective in improving water quality. Because the Pine Run subwatershed is similar to Core Creek in land use, many of the findings may prove transferable, offering an alternative to allocating BMPs to focus primarily on sediment load reductions. Future studies should be conducted to assess the feasibility of achieving more load reductions from detention basin retrofits.
Appendix 1: Core Creek Farming Community BMP Field Assessment:
Daniel Van Nostrand- February 26, 2004

Paul Flemming (Shadybrook Farm):
• BMP repair on terraces needed. Water is not draining properly in some areas because the terraces have become too flat.
• New Waterways need to be installed on southern portion of property adjacent to the new housing development. There are two different options for these waterways. Waterways can be directed toward housing developments’ waterway -> retention pond from two locations or water can be diverted to the small creek that runs through the woods that border the northern section of the field.
• Other than that, their other BMPs are still in good shape. He will be working on spreading his two compost piles so there is not as much sediment running into his basins.
• Signed the consent form for the conservation plan.

Doug Wright (Breezyvale Farm):
• Would like to extend his manure storage pit about five or six feet and make it about 8-9 feet deep. This project would be adjacent to his existing pit and the existing pit will be connected.
• His other BMP’s are working fine.
• Signed the consent form for the conservation plan

William Sterling (Sterling Farm):
• One of his waterways that drains about four terraces might need to be redone because it is becoming too flat.
• His other terraces and waterways are working and do not need to be repaired or redone. They had some problems in the past getting the ground cover to stabilize in some areas and he does not want to tear up the areas if they are only in a small amount of disrepair.
• Signed the consent form for the conservation plan.

Upon site investigation, it can be extrapolated that close to 80% of each field in row crop cultivation is treated by terraces and diversions. However, this information cannot be entered into Predict unless a new “user defined” BMP is created and the reduction numbers for terraces and diversions are entered at the BMP efficiency screen. The farms surveyed were thought to be representative of all the farms in the watershed and therefore, the 80% treatment coverage was used for the Core Creek Watershed.
Appendix 2: Core Creek Hi/Low Density Development and Detention Basin Assessment:

September 9, 2004- Fred Suffian, Jordan Parman, Tanya Dierolf

September 16, 2004- Jordan Parman and Tanya Dierolf

Three Subdivisions appeared to be lacking detention basins:

Estimated 80 acre development on Hill Haven Road, just south of Lower Dolington Road
Roughly dated as 8-10 years old, potential room for one

Estimated 100 acre development “Windemere” on Stanford Road, east of Lower Dolington Road,
Roughly dated as 20 years old, potential room for one

Estimated 70 acre development on Spring Lane, east of Lindenhurst Road, appears to drain into small tributary that flows directly into Core Creek to the south, roughly dated as 25 years old, difficult to add detention basin

Total estimated area of low development land without detention basins- 250 acres
Total estimated area of total low development land in Core Creek- 2400 acres
Total estimated area of low development land drained by detention basin- 2150 acres
Percent of disturbed acres drained by detention basins in the six sample developments- 100%
Percentage of total urban land drained by detention basins- 89.6%

6 Sample Subdivision Plans and Detention Basin Drainage:

1. “The Reserve at Newtown”- 24 lots, 1700 feet of frontage on Upper Silver Lake Road,
Yardley Run residential community borders on east and southeast, farmland borders to north and southwest
Total Area- 77.3 acres
Disturbed Area- 77.3 acres
Area drained- 73.09 acres

2. “Newtown Corporate Center”- Core Creek to east with wetlands, Silver Lake Road to west
Total Area- 58.77 acres
Basin #1 drains 23.71 of 22.5 disturbed acres
Basin #2 drains 18.04 of 16.19 disturbed acres
Basin #3 drains 8.15 of 2.02 disturbed acres

3. “Villas at Shady Brook” on NW corner of Yardley Langhorne Road and Township Line Road
Total Area- 100.7 acres
Basin #1 drains 18.2 of 14.8 disturbed acres
Basin #2 drains 28.5 of 27.4 disturbed acres
Basin #3 drains 31.6 of 30.8 disturbed acres
Basin #4 drains 81.8 of 24.9 disturbed acres
Basin #5/Trap #1 drains 4.8 acres
Basin #5/Trap #2 drains 1.7 acres
4. ‘Community Association of Underwriters Office Park’- just west of Core Creek and Lindenhurst Road  
   Total Area- 24 acres  
   Total Disturbed Area- 15 acres  
   Area drained- 15 acres

5. “Law School Admission Council”- north of Penn St. within the Newtown Industrial Commons  
   Total Area- 7.0941 acres  
   Total Disturbed Area- 6.01 acres  
   Area drained- 6.98 acres

6. “Newtown Commons”- NW corner of Newtown Yardley Road and Lindenhurst Road, Core Creek on NW border of subdivision  
   Total Area- 15.12 acres  
   Disturbed Area- 11 to 12 acres  
   Basin #1 drains- 5.08 acres (all disturbed)  
   Basin #2 drains- 6.94 acres (all disturbed)
Appendix 3: PRedICT Frames for 23.1% Total Sediment Load Reduction in Core Creek:
Mean Annual Load Data Editor, Agricultural Land BMP Scenario Editor
Urban Land BMP Scenario Editor, Estimated Load Reductions
Appendix G

Detailed Information on the BMPs
Proposed for Implementation
Vegetative filter strip

Vegetative filters are designed to remove suspended solids and other pollutants from stormwater runoff flowing through them. They may be composed of planted and/or naturally occurring grasses and herbaceous and woody vegetation. NJDEP recommends using plants with dense growth patterns (e.g., turf-forming grasses and dense forest floor vegetation). The required length of the vegetative filter is based in part upon the type of soils within its drainage area.

In order to maintain pollutant removal, all runoff to a vegetated filter must both enter and flow through as sheet flow (e.g., from yards, parking lots and driveways).

Advantages:

- Effective in reducing sediment and other solids and particulates, as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients.
- Very useful for parking and driveway areas on residential and commercial sites.
- Can provide wildlife habitat.
- Can create shade along waterbodies, lowering aquatic temperatures.

Disadvantages:

- Occupies more land than many other stormwater BMPs.
- Can only treat sheet flow.
- Only effective on gentle slopes (<2%) and/or areas that slow down, pond and/or disperse runoff over the entire filter width.
- Not intended to treat concentrated discharges from storm sewers, swales, and channels.
- Only useful for small areas (<1 acre); maximum drainage area is 100 feet long for impervious surfaces and 150 feet long for pervious surfaces.
- Vegetation must be fully established (min. one full growing season) before filter is functional.

Estimated Costs:

EPA uses the cost of seed ($0.30/ft²) and sod ($0.70/ft²) to calculate a range of $13,000 to $30,000/acre of vegetative filter area or impervious area treated (EPA 2002). Note: since the vegetative filter area may have been seeded or sodded in the absence of this BMP, additional costs (for design and installation of berm and gravel layer) may be minimal. Typical maintenance costs are about $350/acre/year (EPA 2002) and may overlap with regular landscape maintenance costs.

Maintenance Requirements:

At project completion: Repair or replace any damage to the sod, vegetation, or evenness of grade as need
As needed: Mow grass (maintain 3 to 4 in. height); remove sediment when accumulated to 25% of original capacity
After every rainfall >1 inch: Ensure that filter is draining within normal time (max. 72 hours; if infiltration rate has dropped to an unacceptable level, the filter may need to be tilled and replanted)
Four times/year (twice during both growing and nongrowing season): Remove debris; inspect vegetation health, density and diversity and replant if necessary (maintain vegetative cover at 85%)
Once/year: Inspect vegetation for rills and gullies and repair if necessary; seed or sod bare areas.

Ascribed Pollutant Removal Efficiencies:

TSS reduction in postconstruction runoff:
- turf grass – 60%
- native grasses, meadow, planted woods – 70%
- indigenous woods – 80%

Total phosphorus removal rate: 30%
Total nitrogen removal rate: 30%
**Constructed treatment wetland**

Constructed stormwater wetlands are designed to temporarily store stormwater runoff in shallow, vegetated pools. Similar to bioretention systems, they mimic natural systems by using wetland plants to filter runoff, remove pollutants and provide erosion and flood control. They usually have three zones:

1. **Pool** (pond, micropond or forebay): 2 to 6 ft deep, supports submerged and floating vegetation, provides most particulate settling
2. **Marsh** (high or low, depending on standing water depth): 6 to 18 in. deep, mainly emergent wetland vegetation
3. **Semi-wet**: located above pool and marsh zones, inundated only during storm events, supports both wetland and upland plants

Depending on the presence/relative storage volume of each of these zones, constructed wetlands are categorized as either **pond** (relatively deep pool with smaller marsh zone outside it), **marsh** (marsh area > pool zone) or **extended detention wetland** (pool and marsh zones within an extended detention basin).

A constructed wetland must be able to maintain a permanent pool level and is especially suitable for areas where groundwater is close to the surface. If the soil is not sufficiently impermeable, an impermeable liner must be used or other soil modifications must be completed.

**Advantages:**
- Can remove sediment and pollutants adhering to sediment particles (e.g., phosphorus, metals and hydrocarbons)
- Wetland plants and ponds can improve the aesthetic value of a site and provide wildlife habitat.
- Water is generally flushed through the wetlands within a week, reducing potential mosquito breeding.

**Disadvantages:**
- Limited to areas where sufficient water is available to sustain aquatic vegetation between rainfall/runoff events.
- Long-term effectiveness is not well known; pollutant removal rates may decrease over time.
- Without pretreatment (e.g., forebay), wetlands will tend to accumulate sediment rapidly.
- Occupies more land than many other stormwater BMPs (minimum drainage area = 10 to 25 acres).
- If designed too small, tends to dry out frequently and may require re-planting.
- If improperly designed, may encourage mosquito breeding.
- May release nutrients during nongrowing season.

**Estimated Costs:**

EPA modified the following equation developed by Brown and Schueler (1997) to estimate the cost of stormwater wetlands: $C = 30.6V^{0.705}$ (where $C =$ construction, design, and permitting cost and $V =$ wetland volume needed to control the 10-year storm (ft$^3$)). Using this equation, EPA estimates typical construction costs as $57,100 for a 1 acre-foot facility, $289,000 for a 10 acre-foot facility and $1.47 million for a 100 acre-foot facility.

**Maintenance Requirements:**
- **One-time**: replace wetland vegetation to maintain at least 50% surface area coverage after second growing season
- **As needed**: repair eroded areas; remove sediment when 6 in. accumulates (usually 5 to 10 years); mow side slopes
- **Three to four times/year**: clean and remove debris from inlet and outlet structures
- **Twice/year**: inspect and remove accumulated debris
- **Once/year**: inspect for invasive vegetation and remove where possible; supplement wetland plants if at least 50% of surface area has not established; remove wetland plants "choked out" by sediment build-up. Inspect after a rainfall event for clogging of outlet, water releasing too rapidly, erosion at inlet, outlet and on banks, sediment accumulation, and condition of vegetation and emergency spillway

**Ascribed Pollutant Removal Efficiencies (NJDEP):**
- TSS reduction in postconstruction runoff: 90%
- Total phosphorus removal rate: 50%
- Total nitrogen removal rate: 30%
Permanent vegetative stabilization

Permanent vegetative cover is designed to stabilize disturbed areas of bare earth, including construction sites and eroded streambanks. Perennial vegetation should be planted on these areas to decrease erosion by reducing the velocity and volume of overland flow and protecting the bare soil from the impact of falling rain.

Due to their low cost, relative ease of establishment and aesthetic appeal, grasses and legumes are the most widely used plant materials for seeding permanent vegetative stabilization sites. A combination of grasses, trees and shrubs may be most effective for providing permanent and aesthetically pleasing stabilization. The specific seed mixture will vary depending on site-specific conditions such as soil type and slope. Native plant species should be used to the extent possible.

Proper site preparation is essential to provide good contact between the soil and the seed, thereby increasing chances for successful vegetative stabilization. Proper site preparation includes grading the site, providing a minimum of 3-4 inches of topsoil, and preparing the seedbed (e.g., tilling and adding soil amendments if necessary).

Advantages:

- No limitations on site size; can be installed over very small or very large areas.
- Low initial costs for materials and labor as compared to other BMPs.
- A wide variety of suitable plant species seeds are available.
- Very useful for “difficult” areas (e.g., steep slopes, sites with limited access, etc.) due to ease of seeding.
- Native vegetation can remove some nutrients and other stormwater pollutants, improve the aesthetic value of the site, and provide wildlife habitat and shade. Environment around root systems can also break down some pollutants.

Disadvantages:

- Can only treat sheet flow.
- Risks of erosion while plants are becoming established and failure due to lack of water and/or appropriate climatic conditions.
- Not intended to treat concentrated discharges from storm sewers, swales, and channels.

Estimated Costs:

Based on EPA’s estimated costs for seed ($0.30/ft²) and sod ($0.70/ft²), the estimated cost for permanent vegetative stabilization ranges from approximately $13,000/acre to $30,000/acre of stabilized land (EPA 2002). However, this cost may vary widely depending on the site-specific conditions and the seed mixture used. Typical maintenance costs are about $350/acre/year (EPA 2002) and may overlap with regular landscape maintenance costs.

Maintenance Requirements:

At project completion: Repair or replace any damage to the sod, vegetation, or evenness of grade as needed
As needed: Mow grass (maintain 3 to 4 in. height); remove sediment when accumulated to 25% of original capacity
After every rainfall >1 inch: Ensure that filter is draining within normal time (max. 72 hours; if infiltration rate has dropped to an unacceptable level, the filter may need to be tilled and replanted)
Four times/year (twice during both growing and nongrowing season): Remove debris; inspect vegetation health, density and diversity and replant if necessary (maintain vegetative cover at 85%)
Once/year: Inspect vegetation for rills and gullies and repair if necessary; seed or sod bare areas.

Ascribed Pollutant Removal Efficiencies:

TSS reduction in postconstruction runoff:
- turf grass – 60%
- native grasses, meadow, planted woods – 70%
- indigenous woods – 80%
Total phosphorus removal rate: 30%
Total nitrogen removal rate: 30%

Source: Menashe 1998
Manufactured treatment device: the “SNOUT”

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, Best Management Products, Inc. <www.bestmp.com>

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality treatment measure or waterbody (NJDEP 2004). The SNOUT is a retrofit device that can be installed within an existing stormwater catch basin to provide treatment of stormwater. It consists of a fiberglass hood (trap) that fits over the outlet pipe of a sumped catch basin or other water quality structure.

The SNOUT can be adapted to filter a variety of different pollutants, but is primarily used to remove sediment, floatables and oil from stormwater.

Advantages:
- Manufactured treatment devices are appropriate for small drainage areas with high impervious cover likely to contribute high hydrocarbon and sediment loadings (e.g., small parking lots and gas stations) (NJDEP 2004).
- Low cost compared to other BMPs.
- Easy to install with hand tools.
- Available in a variety of sizes and configurations; optional add-ons available (e.g., odor control filters, oil booms, custom debris screens).
- Includes “anti-siphon vent” which prevents siphon from developing and drawing surface layer pollutants downstream under full pipe flows.
- Useful retrofit: designed to modify existing stormwater infrastructure (catch basins).

Disadvantages:
- For larger sites, multiple devices may be necessary.
- Manufactured treatment devices are normally used for pretreatment of runoff before discharging to other, more effective stormwater quality treatment facilities (NJDEP 2004).
- May not function as effectively under low flows or in catch basins with shallow sumps (i.e., depth from beneath the invert of the outlet pipe to the bottom of the structure).
- Pollutant removal rates have not been verified by PADEP or NJDEP.

Estimated Costs:
Based on information provided by the manufacturer, the cost for materials to retrofit one catch basin ranges from approximately $200 to over $3,000 (excluding shipping and labor), depending on the size of the catch basin and the number of additional components installed (www.bestmp.com). Materials costs for most municipal catch basins would likely range from $400 to $600 per catch basin.

Maintenance Requirements:
Monthly for the first year: Monitor to ensure proper functioning of device
As needed: clean out sump when half full (usually requires vacuum truck)
Four times/year and after every storm <0.5 in.: inspect all device components expected to receive and/or trap debris for clogging and excessive debris and sediment accumulation; dispose of debris, sediment and other waste material at suitable disposal/recycling sites and in compliance with applicable waste regulations
Once/year: Inspect all structural components for cracking, subsidence and deterioration; flush anti-siphon vent and open and close access hatch

Ascribed Pollutant Removal Efficiencies (estimates provided by Best Management Products, Inc.):
- TSS reduction in postconstruction runoff: up to 50%
- Total phosphorus removal rate: mean of 36% (Princeton Hydro, unpublished data for Lake Peekskill, New York).
- Total nitrogen removal rate: not provided
Manufactured treatment device: Grate Inlet Skimmer Box

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, Suntree Technologies Inc. <www.suntreetech.com>

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality treatment measure, or waterbody (NJDEP 2004). The Suntree Grate Inlet Skimmer Box is a retrofit device that can be installed within an existing stormwater inlet / catch basin. It uses a series of filtration screens to remove sediment, floatables and debris from stormwater.

Advantages:
- Manufactured treatment devices are appropriate for small drainage areas with high impervious cover likely to contribute high hydrocarbon and sediment loadings (e.g., small parking lots and gas stations) (NJDEP 2004).
- Debris collected in the unit is stored in a dry state (helps to contain nutrient pollutant load and reduces mosquito breeding).
- Can be sized to fit any size inlet.
- Low cost compared to other BMPs.
- Easy to install and maintain with hand tools.
- **Useful retrofit**: designed to modify existing stormwater infrastructure (catch basins).

Disadvantages:
- For larger sites, multiple devices may be necessary.
- Manufactured treatment devices are normally used for pretreatment of runoff before discharging to other, more effective stormwater quality treatment facilities (NJDEP 2004).
- Pollutant removal rates have not been verified by PADEP or NJDEP.

Estimated Costs:
Based on information provided by the manufacturer, the cost for materials to retrofit one catch basin ranges from approximately $700 to $1,000.

Maintenance Requirements:
**Monthly for the first year:** Monitor to ensure proper functioning of device
**As needed:** remove skimmer tray and deflection shield; turn over filter box and empty for disposal
**Four times/year and after every storm <0.5 in.:** inspect all device components expected to receive and/or trap debris for clogging and excessive debris and sediment accumulation; dispose of debris, sediment and other waste material at suitable disposal/recycling sites and in compliance with applicable waste regulations
**Once/year:** Inspect all structural components for cracking, subsidence and deterioration

Ascribed Pollutant Removal Efficiencies:
- **TSS reduction in postconstruction runoff:** 73% (England, 2001)
- Total phosphorus removal rate: no data
- Total nitrogen removal rate: no data
REFERENCES CITED


Appendix H

Calculations used to Quantify the Amount of Pollutants Removed as a Result of the Implemented and Future BMPs
APPENDIX H

Details on the Calculations Used to Quantify the Amount of Pollutants Removed through the Implementation of the Identified BMPs.

For the sake of this analysis, the average, watershed-wide pollutant loading rates were calculated for the entire Core Creek watershed. That is, the watershed’s existing total annual pollutant loads (as calculated by USEPA) were divided by watershed’s total area. The resulting average, annual, watershed-wide total phosphorus (TP) and total suspended solids (TSS) loading rates were 0.48 and 603 lbs per acre, respectively.

The average loading rates (see above) were multiplied by the area designed to be treated by each BMP to calculate the average annual pollutant loads (third column in Pollutant Tables). In turn, these average annual pollutant loads were multiplied by the identified BMP pollutant removal efficiencies (fourth column in Pollutant Tables) to quantify the annual amount of each pollutant removed by each BMP (fifth column in Pollutant Tables).
Calculations Used to Quantify the Amount of Total Phosphorus Removed Through the Proposed BMPs

<table>
<thead>
<tr>
<th>Identified BMP</th>
<th>Area Treated By BMP</th>
<th>Average Annual Pollutant Load for Treated Area</th>
<th>Removal Efficiency for TP</th>
<th>Annual TP Removed by BMP (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implemented BMPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two lake shore Stabilization projects</td>
<td>1.6 acres</td>
<td>0.8 lbs</td>
<td>30 %</td>
<td>0.3 lbs</td>
</tr>
<tr>
<td>Two retrofit Installation projects</td>
<td>75 acres</td>
<td>36.2 lbs</td>
<td>20 %</td>
<td>7.2 lbs</td>
</tr>
<tr>
<td>Pocket Wetland</td>
<td>50 acres</td>
<td>24.1 lbs</td>
<td>57 %</td>
<td>13.7 lbs</td>
</tr>
<tr>
<td><strong>Future BMPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streambank Stabilization</td>
<td>15.2 acres</td>
<td>7.3 lbs</td>
<td>30 %</td>
<td>2.2 lbs</td>
</tr>
<tr>
<td>Urban Vegetative Buffers (half of targeted areas vegetated)</td>
<td>1.8 acres</td>
<td>0.9 lbs</td>
<td>22 %</td>
<td>0.2 lbs</td>
</tr>
<tr>
<td>Agricultural Vegetative Buffers</td>
<td>3 acres</td>
<td>1.5 lbs</td>
<td>22 %</td>
<td>0.3 lbs</td>
</tr>
<tr>
<td>Retrofitted Detention Basins</td>
<td>574 acres</td>
<td>276.5 lbs</td>
<td>20 %</td>
<td>55.3 lbs</td>
</tr>
<tr>
<td>Created Meadow</td>
<td>0.5 acres</td>
<td>0.2 lbs</td>
<td>30 %</td>
<td>0.1 lbs</td>
</tr>
<tr>
<td>Conservation Pool – Wetland Complex</td>
<td>3,602 acres</td>
<td>1,671.2 lbs</td>
<td>39 %</td>
<td>652.0 lbs</td>
</tr>
</tbody>
</table>
### Calculations Used to Quantify the Amount of Total Suspended Solids (TSS) Removed Through the Proposed BMPs

<table>
<thead>
<tr>
<th>Identified BMP</th>
<th>Area Treated By BMP</th>
<th>Average Annual Pollutant Load for Treated Area</th>
<th>Removal Efficiency for TSS</th>
<th>Annual TSS Removed by BMP (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implemented BMPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two lake shore Stabilization projects</td>
<td>1.6 acres</td>
<td>969 lbs</td>
<td>60 %</td>
<td>581 lbs</td>
</tr>
<tr>
<td>Two retrofit Installation projects</td>
<td>75 acres</td>
<td>45,219 lbs</td>
<td>50 %</td>
<td>22,609 lbs</td>
</tr>
<tr>
<td>Pocket Wetland</td>
<td>50 acres</td>
<td>30,146 lbs</td>
<td>57 %</td>
<td>17,183 lbs</td>
</tr>
<tr>
<td><strong>Future BMPs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streambank Stabilization</td>
<td>15.2 acres</td>
<td>9,136 lbs</td>
<td>60 %</td>
<td>5,482 lbs</td>
</tr>
<tr>
<td>Urban Vegetative Buffers (half of targeted areas vegetated)</td>
<td>1.8 acres</td>
<td>1,096 lbs</td>
<td>27 %</td>
<td>296 lbs</td>
</tr>
<tr>
<td>Agricultural Vegetative Buffers</td>
<td>3 acres</td>
<td>1,827 lbs</td>
<td>67 %</td>
<td>1,224 lbs</td>
</tr>
<tr>
<td>Retrofitted Detention Basins</td>
<td>574 acres</td>
<td>345,833 lbs</td>
<td>40 %</td>
<td>138,333 lbs</td>
</tr>
<tr>
<td>Created Meadow</td>
<td>0.5 acres</td>
<td>301 lbs</td>
<td>70 %</td>
<td>211 lbs</td>
</tr>
<tr>
<td>Conservation Pool – Wetland Complex</td>
<td>3,602 acres</td>
<td>2,010,911 lbs</td>
<td>57 %</td>
<td>1,146,220 lbs</td>
</tr>
</tbody>
</table>