City of Muskego Comprehensive Stormwater Management Plan Phase 2

CITY OF MUSKEGO

WISCONSIN
DEPT. OF NATURAL RESOURCES

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CHAPTER 1

EXECUTIVE SUMMARY

PROJECT BACKGROUND

The City of Muskego (City) has been actively addressing storm water management issues within the community for many years. This Storm Water Management Plan, the second of a 2-phase comprehensive analysis of the City's present and future storm water management needs, is a reflection of the City's commitment to storm water management issues. The "Phase 1" project area, which was studied in 1995, encompassed approximately 4,600 acres in the northern portion of the City. The "Phase 2" study (documented in this report) encompasses approximately 12,450 acres and includes most of the remaining area of the City, in addition to a small portion of land in the Town of Norway that contributes direct runoff to the City (see Figure 2-1). The general goals of both the Phase 1 and Phase 2 studies are the same: to correct and prevent flooding resulting from storm water runoff and to reduce the amount of pollutants conveyed in storm water runoff.

With the exception of the Lake Denoon watershed, the entire Phase 2 project area lies within the "Muskego-Wind Lakes Priority Watershed." The Muskego-Wind Lakes Priority watershed was designated a "priority watershed" in 1991 under the Wisconsin Nonpoint Source Water Pollution Abatement Program. This program provides state funding for the prevention of nonpoint source pollution, and is administered by the Wisconsin Department of Natural Resources (WDNR) and the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP). Under this program, a plan (commonly called a "Priority Watershed Plan") for the Muskego-Wind Lakes watershed was developed, which:

- Identified critical sources of nonpoint pollution;
- Set water resource objectives for the wetlands, streams, and lakes within the watershed;
- Established pollution reduction goals;
- Recommended a set of actions to reach the pollutant reduction goals; and
- Set a budget and schedule to carry out the recommendations of the plan.

To assist in carrying out the priority watershed plan, the City of Muskego received two grants from the WDNR to partially fund a more detailed storm water management plan: a Local Assistance Grant for the Big Muskego Lake drainage area and a Lake Planning Grant for the Lake Denoon watershed. The City of Muskego contracted with Earth Tech, Inc. (formerly Rust Environment & Infrastructure) to conduct this Phase 2 Storm Water Management Study.

PURPOSE AND OBJECTIVES

The primary purpose of the Storm Water Management Plan is to describe an approach to remediate existing water quantity and quality problems from storm water runoff and to prevent future problems as a result of expected growth. The objectives were developed based upon the WDNR's recommendations set forth in the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*, discussions with the City/WDNR/Earth-Tech project team, and interactions with the City of Muskego Storm Water Advisory Committee. In summary, the objectives of this project are:

- Attain the pollutant reduction goals stated in *A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. Table 1 1 below shows the lake pollutant reduction goals from runoff within the City of Muskego.

Table 1-1: Lake Pollutant Reduction Goals

Lake	% Reduction, Sediment	% Reduction, Phosphorus
Little Muskego	69	58
Big Muskego	39	69
Wind Lake	57	73
Lake Denoon*	60	60

* Pollution reduction goals calculated using WILMS method described in Chapter 3.
Other pollution reduction objectives from Tables 3-16 and 3-17 pages 70-71 in *A Nonpoint Source Control Plan for the Muskego-Wind lakes Priority Watershed Project.*

In addition to pollution control, the plan should address the current and future flood control needs of the project area, including the protection of the existing storm water system infrastructure from future development runoff. Additional project goals are listed in Chapter 2.

PROJECT SETTING

To assess current storm water management levels in the City and make recommendations, it was necessary to gather information and analyze selected natural resource and infrastructure features of the project area. Topics analyzed included subbasins of the project area, existing storm water conveyance and storage facilities, soils, existing and future land use, precipitation, water resources, storm water quality, storm water regulatory framework, and City operations relating to storm water. The full report discusses these subjects in detail.

The project area was subdivided into four major drainage basins. These basins are the portions of the project area that drain to: (1) Little Muskego Lake (via Linnie Lac), (2) Big Muskego Lake, (3) Lake Denoon, and (4) Wind Lake. Within these major basins, 65 subbasins were delineated. Subbasins are the basic building blocks of the nonpoint source pollution and hydrologic analyses.

RESULTS AND RECOMMENDATIONS

Using the data obtained about the project setting, characteristics of runoff quality and quantity were analyzed. This analysis was conducted using several computer models. These results were used to determine where the City's efforts to manage storm water should be focused.

The heart of the storm water management plan is a set of specific recommendations, which will reduce the City's nonpoint source pollution load and reduce the potential for storm water flooding problems. Storm water management practices can be divided into two general categories: structural and nonstructural. A structural practice refers to a specific physical object, such as a detention pond, grass swale, or constructed channel that is used to manage storm water. A nonstructural practice refers to a program, action or change in behavior that is undertaken to improve storm water management.

Recommended Nonstructural Measures

- Cropland Management Improved Tillage Method: In general, there has been an improvement in tillage practices in the project area based on measures already taken under the Muskego-Wind Lakes Priority Watershed Project. However, continuing the practices adopted in this program will allow annual goals for sediment reductions to be realized for the future.

- Ordinance Development and Enforcement: The Muskego Storm Water Advisory Committee prepared and approved a draft Storm Water Management Ordinance that requires new developments to provide detention peak flow control and nonpoint source pollution control. At the time of this report, the ordinance awaits review and approval by the City Council. If adopted, this ordinance may be the single most important aspect of the Storm Water Management Plan, as it enables the City to manage the ongoing issues of storm water quality and peak flows. In the interim, the City should continue to vigorously enforce the current construction erosion control ordinance, which provides adequate authority to control sediment from construction sites.

- Operations and Maintenance Recommendations: Even though the Phase 2 project area is predominantly agricultural lands, maintenance of the existing storm water conveyance system should be carried out on a routine basis. Swales, ditches, and culverts within the City's jurisdiction should be inspected periodically to ensure that they are clear and free of debris, and that the ditches are not eroding. This will minimize the risk of localized flooding should a large storm event occur. Additionally, a number of culverts have been identified as being inadequate for handling a 10-year storm. Recommendations for modifications to these culverts are presented in the report.

- Public Information and Education: It is recommended that the City develop a public education and information program. Optimum use should be made of the information, strategies, and materials developed by the WDNR and the UW-Extension. The education program should focus on informing the public about things that can be done around the home and in daily activities to reduce nonpoint source pollution. Preferably, the education/information program will be regional in nature. Whenever possible, the City should work with other area communities to educate the public on storm water issues.

- Continued Application for Grants: It is recommended that the City continue to apply for Local Assistance Grants and Nonpoint Source Grants available through the WDNR to help finance the administrative, construction, and other implementation costs of the City's growing nonpoint source pollution control program. The purposes of these two types of grants and the extent of state participation are described in the next chapter.

Recommended Structural Measures

In many instances, nonstructural measures are preferred due to their low cost and low impact on the surroundings. However, in certain cases structural measures can be a practical and cost-effective way to reduce nonpoint source pollution. Structural Best Management Practices (BMPs) have been separated into 5 categories. System 1 BMPs refer to the required wet detention/water quality ponds in a basin that would be associated with new development. The required amount of ponds is based on compliance with the City's proposed storm water ordinance. The required amount of ponds is summarized in Table 1-2.

Table 1-2: System 1 Structural BMPs (Future Development BMPs)

Basin	Total Pond Area Required (acres)
Linnie Lac/Little Muskego	51
Big Muskego	133
Wind Lake	30
Lake Denoon	17.3

Systems 2, 3, and 4 BMPs refer to regional treatment facilities in the Lake Denoon, Wind Lake, and Linnie Lac/Little Muskego Lake and Basins respectively. These systems are described and summarized in Table 1-3.

Table 1-3: System 2, 3, and 4 Structural BMPs (Regional BMPs)

Basin	BMP Description
Lake Denoon	Construction of a 2.3-acre water quality pond to treat the Subbasin M3 (north of Kelsey Road). It should also be noted that it is recommended that the existing ponds in the Lake Meadows Subdivision be restored (dredged) to meet the standards set forth in the draft storm water ordinance.
Wind Lake	The Wind Lake Management District is currently creating a wetland treatment system in the area north of Muskego Dam Road and west of the lake's outlet channel. The wetlands will treat runoff of pollutants from agricultural lands. The City should continue its support of this project.
Linnie Lac/Little Muskego	This system utilizes the existing quarry pits for the development of a regional water quality pond that could treat the nonpoint source pollution from new developments where water quality ponds were not feasible, and from existing developments and agricultural lands that will not be treated through enforcement of the proposed storm water ordinance. Depending upon the upstream water quality management practices, a pond at the quarry site may need to be up to 10 acres in size. This recommendation is dependent upon the long-term operations of the gravel operation and the potential for public ownership of the property in the future.

System 5 BMPs refer to streambank buffer strips. These are thickly vegetated riparian areas next to drainageways (100 feet wide on each side of drainageway), which trap sediment and other pollutants associated with storm water runoff. The buffer strips are recommended for channels in agricultural areas that are not expected to develop in the near future. The proposed buffer strips per basin are summarized in Table 1-4.

Table 1-4: System 5 Structural BMPs (Stream Bank Buffer Strips)

Basin	Stream Length for Buffers (ft)	Buffer Area (acres)
Lake Denoon	2,760	12.7
Wind Lake	5,960	27.3
Big Muskego Lake	37,250	171

Implementation of the above described BMPs to the basins within this study is expected to achieve the sediment and phosphorus load reductions summarized in Table 1-5.

Table 1-5: Sediment and Phosphorus Load Reductions

Basin	Reduction of Sediment Load	Reduction of Phosphorus Load
Lake Denoon	58%	48%
Linnie Lac/Little Muskego	71%	77%
Wind Lake	65%	54%
Big Muskego Lake	26%	46%

IMPLEMENTATION PLAN

The full report contains an implementation plan to carry out the structural and nonstructural recommendations. The implementation plan does not lay out a specific timetable for completing these recommendations. Rather, it ranks recommendations by their cost-effectiveness, and suggests other factors that should be considered when scheduling projects. The City of Muskego is the primary responsible party for implementing the recommendations of this plan. Technical and financial assistance are available from outside sources for many of the recommendations. These outside sources include WDNR and other public agencies, private developers, and consulting engineering firms. There is a number of funding mechanisms that can be used to finance the recommendations of this storm water management plan. These funding options include subdivision exactions and fees-in-lieu-of from private sources, City General Funds, State (WDNR) grants, special taxing districts, bonds, and storm water utilities.

CONCLUSION

This project sets out a comprehensive storm water management plan for the City of Muskego. Implementing the structural and nonstructural recommendations of this plan will reduce current and future nonpoint source pollution loads and result in substantial compliance with the Muskego - Wind Lake Priority Watershed Project recommendations. In addition, the water quality of Lake Denoon will be maintained or improved. Finally, the plan provides the City with most of the information necessary to comply with the WDNR NR 216 storm water permit regulations.

The storm water management program recommended in this document is an ongoing process. Storm water management requires a long-term commitment to installing, maintaining, and repairing the physical infrastructure, and the continued monitoring of City activities to reduce nonpoint pollution.

CHAPTER 2

INTRODUCTION

PURPOSE AND OBJECTIVES

The purpose of the Storm Water Management Plan for the City of Muskego is to implement the recommendations set forth in the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. The Storm Water Management Plan for the City of Muskego addresses remediation of existing water quantity and quality problems from storm water runoff and prevention of future similar problems as a result of expected growth (see Figure 2-1).

Early in the planning program, a variety of means was used to establish specific objectives that would be used to guide preparation of this Storm Water Management Plan. These means included review of the recommendations set forth in *A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*, discussions within the City/WDNR/Earth Tech project team, and interaction with the City of Muskego Ad Hoc Storm Water Advisory Committee. The Advisory Committee was established during the first phase of the City's storm water planning effort and was re-established for this Phase 2 study. The Committee is comprised of members representing various interest groups of the City.

The objectives for this project are as follows:

1. Attain the pollutant reduction goals stated in *A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. Table 2-1 below shows the lake pollutant reduction goals for runoff within the City of Muskego.

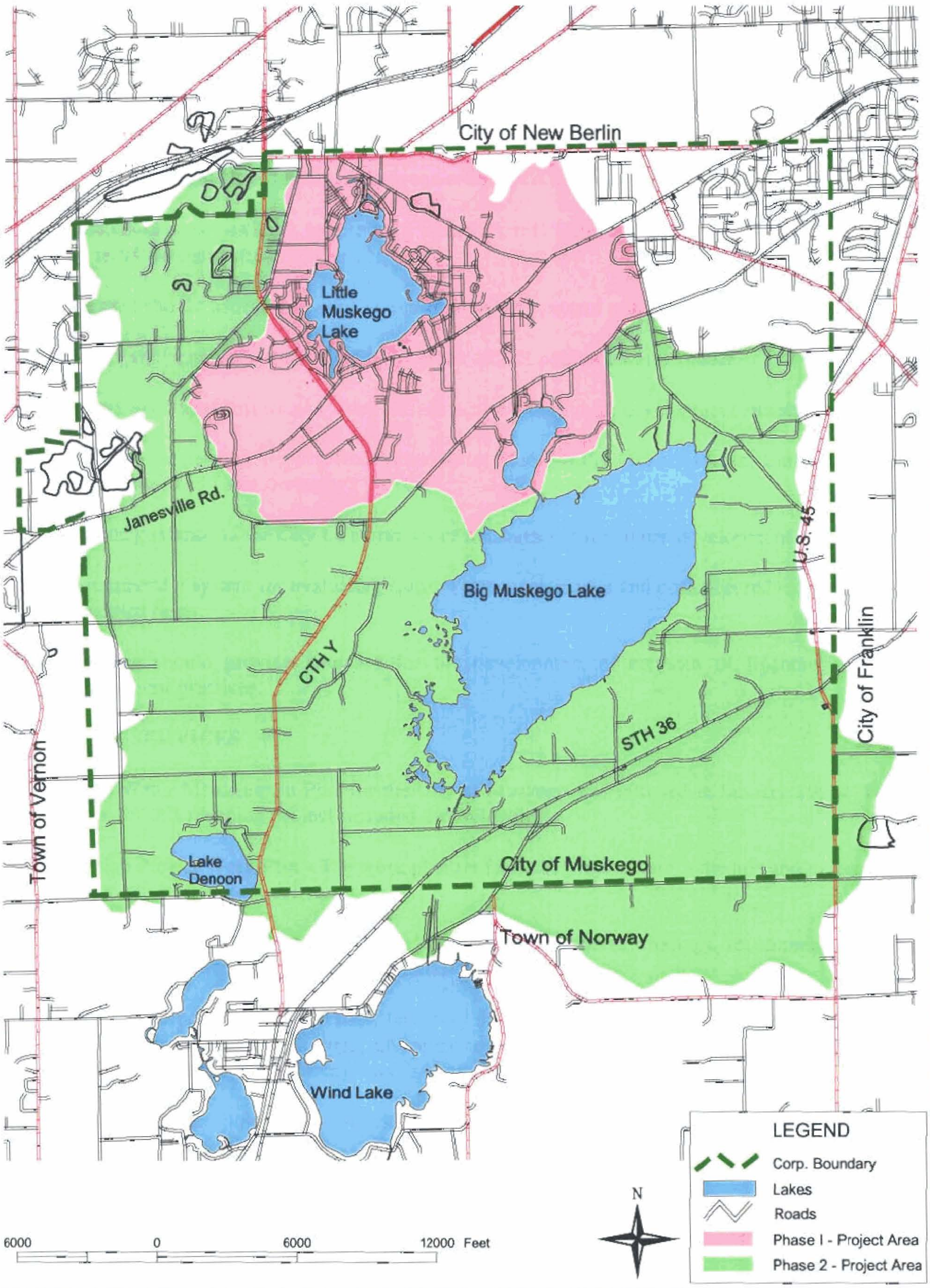
Table 2-1: Lake Pollutant Reduction Goals

Lake	% Reduction, Sediment	% Reduction, Phosphorus
Little Muskego	69	58
Big Muskego	39	69
Wind Lake	57	73
Lake Denoon*	60	60

* Pollution reduction goals calculated using WILMS method described in Chapter 3
Pollution reduction objectives from Tables 3-16 and 3-17 pp 70-71 in *A Nonpoint Source Control Plan for the Muskego-Wind lakes Priority Watershed Project.*

2. Contribute to attainment of the pollution reduction goals set forth in *A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. Pollution reduction goals for urban areas as stated in the watershed plan include:

   - Effective construction erosion controls on all developing lands;
   - Reduce mass loading of sediments by amounts reported in Table 2-1 from 1992 land use conditions;



CITY OF MUSKEGO
PHASE II STORMWATER STUDY AREA
FIGURE 2-1

EARTH TECH

CITY OF MUSKEGO

May 1999

2. (continued)

   - Improve urban housekeeping practices to reduce the amount of contaminants reaching surface waters;

   - In newly developed areas, reduce sediment loads to receiving waters by 80 to 90 percent; and

   - Reduce sediment loads to receiving waters from streambank erosion by 62 (Big Muskego Lake) to 95 percent (Muskego Canal).

3. The plan should address the current and future flood control needs of the project area.

4. Protect and enhance wetland quality from the effects of storm water runoff.

5. Protect existing storm water system infrastructure from future development runoff.

6. Minimize the negative impacts from storm water runoff to Big Muskego Lake, Little Muskego Lake, Wind Lake, and Lake Denoon.

7. Provide guidance to the City on storm water management for future development.

8. Recommend a system for evaluating storm water management and pollution reduction progress on a scheduled basis.

9. The plan should provide guidance for the development of methods of financing storm water management practices.

SCOPE OF SERVICES

This Storm Water Management Plan for the City of Muskego was initiated in January 1996. The scope of services for this planning project included the following:

1. Develop Project Work Plan - The work plan set forth the project team, schedule and milestones, lines of communication, and deliverables.

2. Meet with Citizen Advisory Committee to present project status, findings, recommendations, and to receive review comments, suggestions, and direction.

3. Define Project Setting - Collect data, inventory the stormwater conveyance system, delineate drainage patterns, create a database system, inventory soils, assess land use, create a geographic information system, summarize water quality data, and assess operations/maintenance.

4. Establish Project Objectives - Solicit ideas from a variety of sources and assemble into a set of objectives.

5. Collect Available Data - Collect, review, and evaluate information relevant to the development of a Storm Water Management Plan for the study area. This information will be obtained through meetings with appropriate City officials and other agency staff.

6. Perform Analyses - Select computer models, calculate stormwater flows and volumes, evaluate hydraulic capacities, and compute nonpoint source pollutant loads.

7. Identify Critical Areas - Locate sources of nonpoint pollution and flood prone areas.

8. Formulate and Evaluate Alternatives - Consider wetland/environment corridor preservation, solve existing flooding problems, prevent new flooding problems, select best management practices for pollutant reduction, site best management practices, and suggest operation/maintenance improvements.

9. Develop a draft stormwater management ordinance.

10. Prepare Implementation Plan - Address priorities, implementation, schedule, information/education activities, responsible agencies/entities, legal requirements, estimate budgets, and evaluate funding mechanisms.

11. Produce report and deliver mapping and database.

This is a planning investigation, not an engineering design, and as such, is intended to define systems and problems, explore a range of alternative solutions, and recommend the course of action. Implementation of facilities recommended in this report will require preparing detailed design and construction documents and possibly obtaining WDNR and other state or federal permits.

CHAPTER 3

NATURAL RESOURCES AND INFRASTRUCTURE

This chapter discusses selected natural resource and infrastructure features of the project area pertinent to this study. Topics presented include: subbasins of the project area, existing storm water conveyance and storage facilities, soils, existing and future land use, precipitation, water resources, storm water quality, and a storm water regulatory framework.

SUBBASINS

The project area was subdivided into small watersheds called subbasins. Subbasins are the basic building blocks of the hydrologic analysis. For the purpose of this project, the area was partitioned into 65 subbasins, each draining to either Little Muskego Lake, Big Muskego Lake, Lake Denoon, or Wind Lake. The subbasins ranged in size from 5 to 889 acres, with an average size of 196 acres. Subbasin boundaries are shown in Figure 3-1.

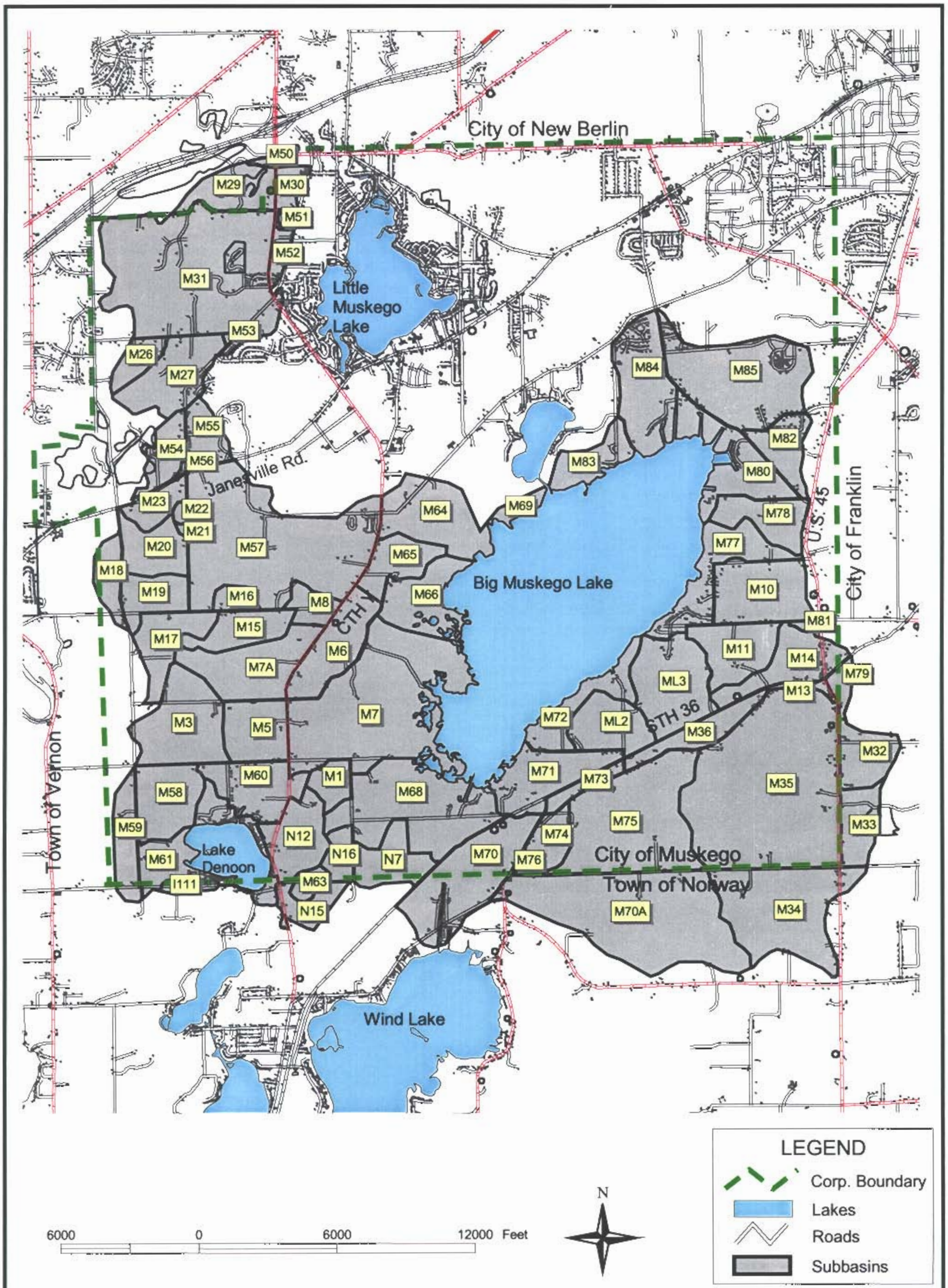
Elevations within the project area vary from approximately 960 feet above mean sea level in the northwestern portions to approximately 771 feet above mean sea level at Big Muskego Lake, for a total relief of approximately 190 feet. Subbasins were delineated using 2-foot topographic maps, supplemented with field reconnaissance. The subbasin boundaries, along with most of the other natural resource and infrastructure data discussed in this chapter, were entered into the Geographic Information System (GIS) to facilitate data utilization.

STORM WATER CONVEYANCE AND STORAGE SYSTEM

The storm water conveyance system consists of swales, roadside ditches, storm sewers, culverts, and channels (both natural and constructed). Storm water storage locations within the project area include natural wetlands, wetland remnants, and constructed storm water detention facilities.

Knowledge of the conveyance and storage system is essential to watershed planning efforts because this system determines the route by which storm water and its pollutants move from the land surface through the watershed to Little Muskego Lake, Big Muskego Lake, Wind Lake, and Lake Denoon. The system also affects flow velocity and discharge as well as localized flooding due to drainage backup. Data and information on the conveyance system, particularly storm sewers and culverts, are helpful in diagnosing the cause of local flooding problems.

Figure 3-2 shows the drainage system with the storm sewers, culverts, open channels, and storm water detention ponds located. The network is primarily open channels with limited storm sewer piping. Most of the storm sewer areas are located in the northern portions of the study area, the majority of which convey storm water to Little Muskego Lake.

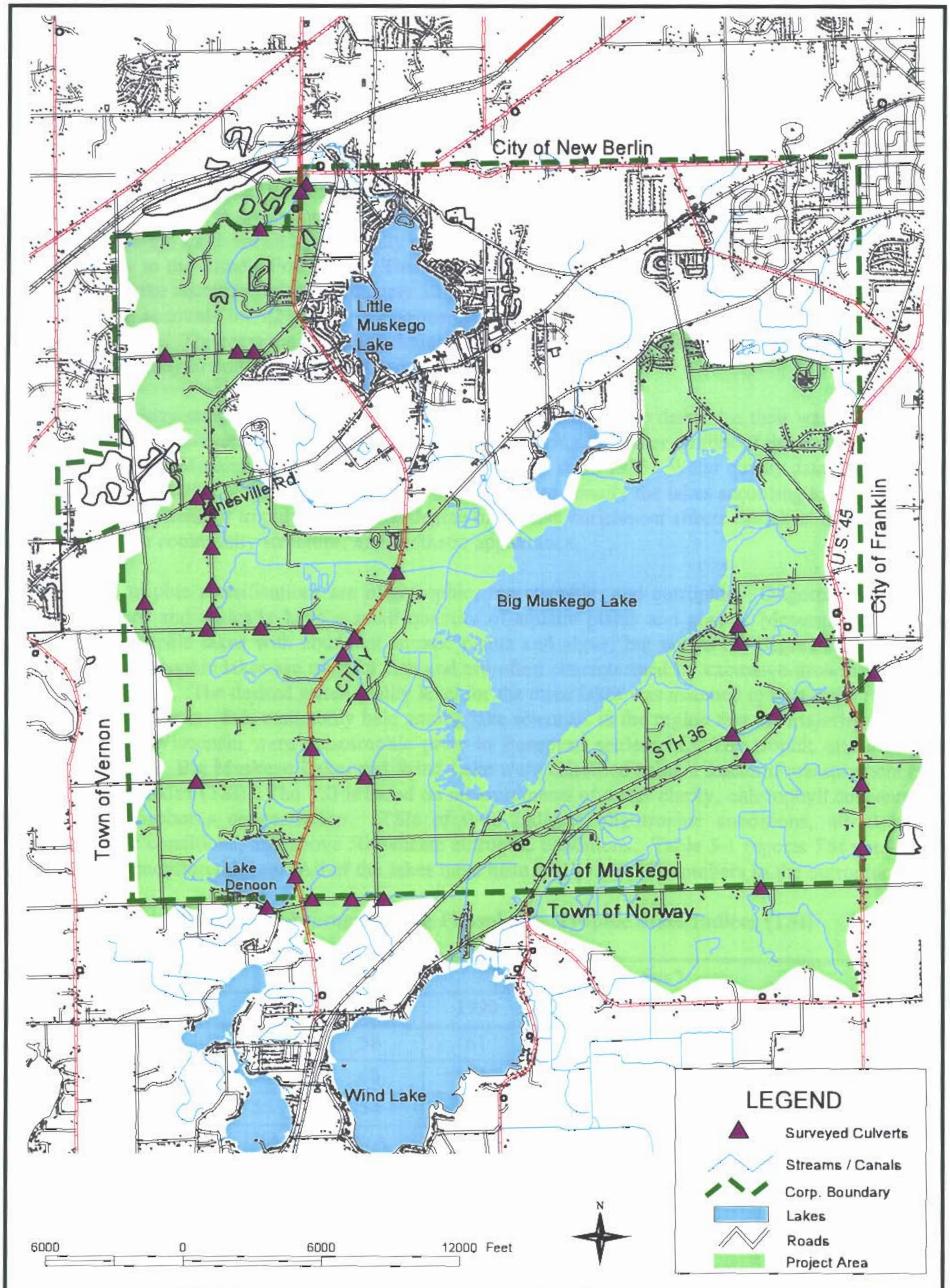


EARTH TECH

CITY OF MUSKEGO
PHASE II STORMWATER MANAGEMENT PLAN
SUB-BASINS
FIGURE 3-1

CITY OF MUSKEGO

MAY 1999



EARTH TECH

CITY OF MUSKEGO
PHASE II STORMWATER MANAGEMENT PLAN
CONVEYANCE SYSTEMS
FIGURE 3-2

CITY OF MUSKEGO

MAY 1999

WATER RESOURCES

One of the main goals of this storm water project is to improve the water quality of the surface water bodies in the project area. The surface water resources in the project area consist of four lakes: Big Muskego Lake, Lake Denoon, Little Muskego Lake, and Linnie Lac Lake. A fifth lake, Wind Lake, lies outside of the study area, yet it receives approximately 22 percent of the project area's drainage and is, therefore, included in the analysis of this study. Linnie Lac Lake, Little Muskego Lake, Big Muskego Lake, and Wind Lake are all hydraulically connected through a series of natural and constructed channels, which flow to the Illinois-Fox River. The area draining to Linnie Lac Lake and subsequently to Little Muskego Lake accounts for approximately 12 percent of the total project area while the area draining to Wind Lake accounts for 22 percent. The majority of the total project area (59 percent) drains to Big Muskego Lake. The remaining enclosed drainage area, Lake Denoon drainage area, accounts for 7 percent of the total study area. These general areas are shown in Figure 3-2.

Water chemistry samples from three of the lakes have been analyzed to determine their water quality. The United States Geological Survey (USGS) has been monitoring the water quality of three of the lakes (Big Muskego, Little Muskego, and Lake Denoon) intermittently since 1985. Water quality data is not available on Linnie Lac Lake. This water quality data can be used to classify the lakes according to their degree of nutrient enrichment, or trophic status. The degree of nutrient enrichment affects the lakes' quantity of plant material, fish community structure, and aesthetic appearance.

The three trophic classifications are oligotrophic, mesotrophic, and eutrophic. Oligotrophic lakes are nutrient poor and typically have a small quantity of aquatic plants and algae. Mesotrophic lakes are moderately fertile lakes with abundant aquatic plants and algae, but not to the degree that they are a nuisance. Eutrophic lakes are nutrient rich and are often characterized by excessive growths of aquatic plants and algae. The desired water quality level for the three lakes was assumed to be a mesotrophic lake water quality status. It is commonly held among lake scientists in the region that the majority of lakes in southeastern Wisconsin were mesotrophic prior to European settlement. The trophic status of Little Muskego Lake, Big Muskego Lake, and Wind Lake were classified using a standard measurement called trophic state index (TSI). The TSI is based on measurements of water clarity, chlorophyll concentration, or total phosphorus concentration. TSIs of 0-40 indicate oligotrophic conditions, 40-50 indicate mesotrophic conditions, and above 50 indicate eutrophic conditions. Table 3-1 reports TSI numbers for each of the monitored lakes. All of the lakes have historically had TSI numbers in the eutrophic range.

Table 3-1: Average Spring Phosphorus Trophic State Indices (TSI)

Lake	Trophic State Index*						
	1988	1989	1990	1991	1992	1993	1994
Little Muskego	60	58	61	54	49	55	52
Big Muskego	69	68	71	75	53	61	64
Wind	55	54	69	62	61	61	60
Denoon	N/A	N/A	N/A	55	52	58	54

* Source: A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project, WDNR, 1993

Linnie Lac Lake

Linnie Lac Lake is a 5-acre impoundment, which drains into Little Muskego Lake. At the time this report was written, the lake had been drawn down due to dam failure. The impoundment had been at least

100 years old and had accumulated large quantities of sediment, resulting in shallow water depths (less than 5 feet). Pollution loadings to Linnie Lac Lake have a significant impact on Little Muskego Lake downstream, since the impoundment does not trap sediment very effectively due to its shallow depth. The *Nonpoint Source Control Plan for the Muskego- Wind Lakes Priority Watershed Project* identified the nonpoint source pollution reduction goals for the Linnie Lac Lake watershed to be a 63 percent reduction in sediment loadings and a 59 percent reduction in phosphorus loadings.

Little Muskego Lake

Little Muskego Lake is a 506-acre lake, which receives the drainage from Linnie Lac Lake and flows into Big Muskego Lake. Water quality data indicates that the lake is eutrophic, bordering on mesotrophic (Table 3-1). The Southeastern Wisconsin Regional Planning Commission (SEWRPC) prepared a Lake Management Plan for the lake in 1997. The *Nonpoint Source Control Plan for the Muskego- Wind Lakes Priority Watershed Project* identified the nonpoint source pollution reduction goals for the Little Muskego Lake watershed to be a 69 percent reduction in sediment loadings and a 58 percent reduction in phosphorus loadings. Drainage from this project area enters Little Muskego Lake only indirectly through the Linnie Lac impoundment area.

Big Muskego Lake

Big Muskego Lake is a 1,966-acre lake, which receives the drainage from Little Muskego Lake and flows into Wind Lake. Water quality data indicates that the lake is eutrophic (Table 3-1). Much of the lake exhibits the characteristics of a large, shallow marsh and provides good waterfowl habitat. The lake has suffered from prolonged discharge of raw sewage, resulting in poor water quality and accumulations of nutrient rich sediments. In the past few years lake rehabilitation efforts conducted by the Big Muskego Lake/Bass Bay Protection and Rehabilitation District, the City of Muskego, WDNR, and Waukesha County included:

- Fish eradication to remove rough fish,
- Fish restocking to establish a healthy fishery,
- An alum treatment for phosphorus control in Bass Bay in 1998, and
- Lake draw down to consolidate sediments and re-establish important shoreline wetlands.

The *Nonpoint Source Control Plan for the Muskego- Wind Lakes Priority Watershed Project* identified the nonpoint source pollution reduction goals for the Big Muskego Lake watershed to be a 47 percent reduction in sediment loadings and a 41 percent reduction in phosphorus loadings.

Wind Lake

Wind Lake is a 936-acre lake, which receives the drainage from Big Muskego Lake. Three reports have been written pertaining to Wind Lake water quality; *Hydrology and Water Quality of Wind Lake in Southeastern Wisconsin* (U.S.G.S., 1990), *A Management Plan for Wind Lake, Racine County, Wisconsin* (SEWRPC, 1991), and *A Nonpoint Source Control Plan for the Muskego- Wind Lakes Priority Watershed Project* (WDNR, 1993).

The water quality data collected by the USGS since 1985 indicates that Wind Lake is a eutrophic lake. The excessive phosphorus inputs to the lake are distributed as follows: 50 percent from internal cycling of bottom sediment nutrients, 34 percent from surface drainage from Big Muskego Lake, and 16 percent from direct drainage to the lake and atmospheric deposition. Wind Lake was also treated with alum in the spring of 1998 for the purpose of reducing the amount of available phosphorus in the lake's bottom sediments. The *Nonpoint Source Control Plan for the Muskego- Wind Lakes Priority Watershed Project* identified the nonpoint source pollution reduction goals for the Wind Lake watershed to be a 57 percent reduction in sediment loadings and a 49 percent reduction in phosphorus loadings.

Lake Denoon Goals

The pollution reduction goals for Lake Delton were not given in *A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed*. Therefore, the nonpoint source water quality goals for Lake Denoon were determined by identifying a desired water quality level within the lake and using a lake water quality model to calculate the reduction of nonpoint source pollution loadings that would be needed to achieve that goal. A total reduction in both sediment and phosphorus was estimated to be 45 percent by the method described below.

The desired water quality level for Lake Denoon was assumed to be a mesotrophic lake water quality status. Lake water quality analysis of Lake Denoon indicates that it is currently eutrophic (Table 3-1). The average spring turnover phosphorus concentrations over four years (1991-1994) was 0.030 mg/l, while the top level mesotrophic phosphorus concentration is only 0.016 mg/l.

The Wisconsin Lake Model Spreadsheet (WILMS) was used to determine what level of phosphorus reduction would be required to bring the lake to a mesotrophic status. The WILMS spreadsheet uses a number of predictive lake water quality models. The model was selected based upon how close the model predictions for phosphorus concentrations came to the actual spring phosphorus concentrations. The Vollenweider 1975 lake model for natural lakes made the most accurate prediction. To achieve a mesotrophic status, the spring phosphorus concentration would need to be reduced to 0.016 mg/l. The model predicted that a 45 percent reduction of phosphorus would be required to achieve a mesotrophic status. It was assumed that the majority of phosphorus to the lake was transported by sediment, so by association, the water quality goal for Lake Denoon was determined to be a 45 percent reduction of phosphorus and sediment.

SOILS

The soils in the project area are important partly because soil properties are a primary factor in determining the volume of runoff associated with a given rainfall. The U.S. Department of Agriculture Soil Conservation Service (renamed to the Natural Resource Conservation Service) classifies soils based on their runoff potential in hydrologic groups of A, B, C, or D. Hydrologic soil Group A soils have a high infiltration capacity and low runoff potential (generally sandy type soils). At the other end of the spectrum, soil Group D soils have a low infiltration capacity and a high runoff potential (generally high clay content soil). A mixed hydrologic soil group (e.g., B/D) exhibits characteristics of "B" type soils under unsaturated conditions, but takes on characteristics of a "D" type soil during saturated conditions. These types of soils are usually found in and around wetland areas. The distribution of soils within the project area is shown in Table 3-2 below.

Table 3-2: Soil Hydrologic Groups Within the City of Muskego Project Area

Hydrologic Group	Acres	%
A	10	0.1%
A/D	1,972	15.8%
B	1,658	13.3%
B/D	1,621	13.0%
C	6,603	53.1%
C/D	19	0.2%
D	562	4.5%
Totals	**12,446**	**100%**

Caution must be used when characterizing the soils of an urban area from the USDA Soil Surveys. The high degree of land disturbing activities in the project area changes the soil's physical properties. Short of actually conducting soil infiltration tests in the field, however, the soil survey is the best source of information regarding infiltration rates. For purposes of this planning level study, the USDA Soil Survey was used. For implementation of site specific recommendations from this report, field measurements are necessary to properly construct the best management practices.

LAND USE

Type and distribution of land use—both existing and future—are important elements in a water quality and flood control investigations. The type and amount of nonpoint source pollution and the volume and timing of runoff are directly influenced by land use. Although the underlying soil type, as already noted, is an important factor in determining runoff amounts, the land use can also significantly impact runoff amounts and the time it takes runoff to reach its destination. Adverse effects usually occur when land is converted from rural to urban uses because such conversion results in a large increase in impervious surface, and therefore, an increase in the volume of runoff and decrease in runoff time. The net effect can be very large increases in peak flow, flood stages, areas of inundation, and nonpoint source pollutant generation and transport.

Existing Land Use: Existing land use was delineated based on 1995 SEWRPC digital aerial orthophotographs. Field surveys were then conducted to update the land cover to 1996 conditions. Figure 3-3 compares the 1996 land use with the projected future land use conditions. Figure 3-4 is a map of the project area's 1996 land use. The project area is dominated by agricultural land use with residential lands as the next largest group.

Future Land Use: Future land use was developed using the City's zoning map. Several assumptions were made in completing the future land use map:

- The lands developed in 1996 would remain under that condition in the future.
- The mapped wetlands within the project area (as mapped by WDNR) would remain intact in the future.
- "Future" land use is defined to mean the condition of the project area under a "full build-out" situation. No specific date was estimated as to when this condition may exist.

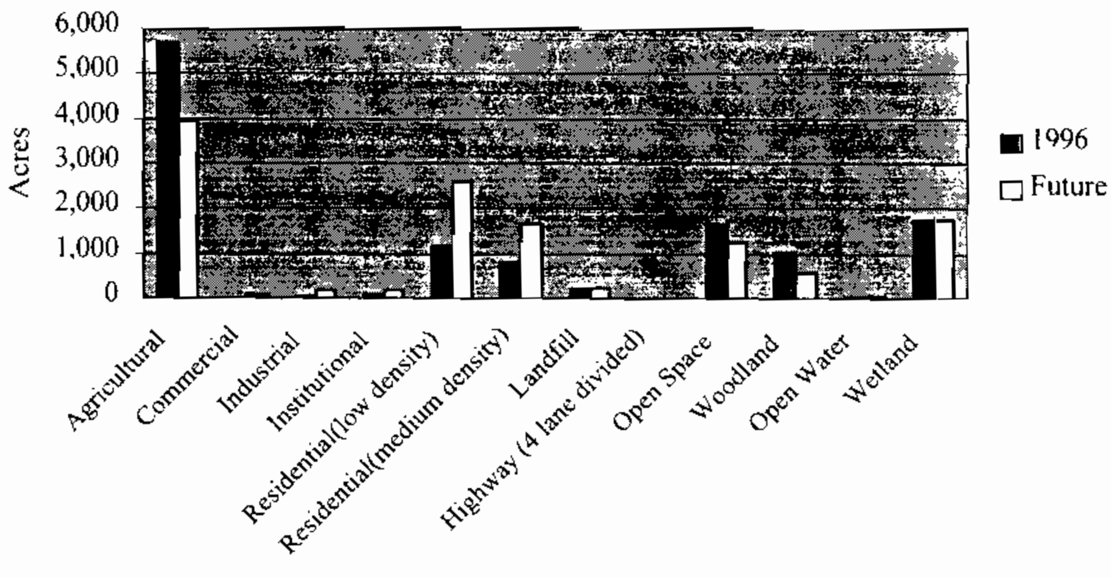
Figure 3-5 shows the predicted future land use of the project area.

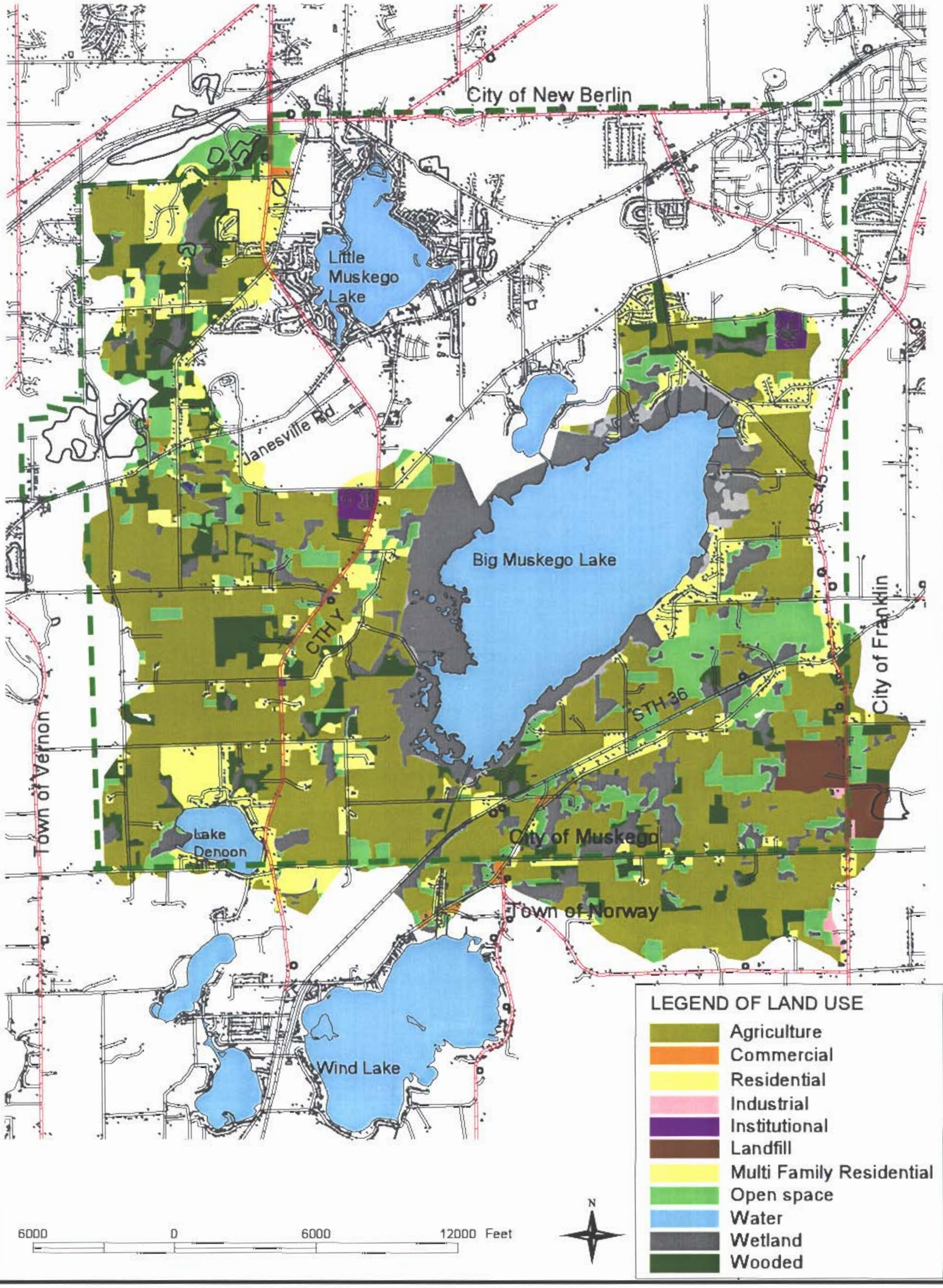
Table 3-3: Land Use Comparison

	1996 Land Use		Future Land Use	
	Acres	%	Acres	%
Agricultural	5,669	45.5%	3,950	31.7%
Commercial	16	0.1%	76	0.6%
Industrial	26	0.2%	200	1.6%
Institutional	97	0.8%	164	1.3%
Residential(low density)	1,179	9.5%	2,579	20.7%
Residential(medium density)	818	6.6%	1,671	13.4%
Landfill	215	1.7%	215	1.7%
Highway (4 lane divided)	0	0.0%	3	0.0%
Open Space	1,653	13.3%	1,247	10.0%
Woodland	1,017	8.2%	562	4.5%
Open Water	33	0.3%	30	0.2%
Wetland *	1,725	13.9%	1,749	14.1%
Total:	12,446	100%	12,446	100%

*wetland increase due to restoration of wetlands from a WDOT mitigation project

Figure 3-3: Comparison of 1996 and Future Land Use (acres)



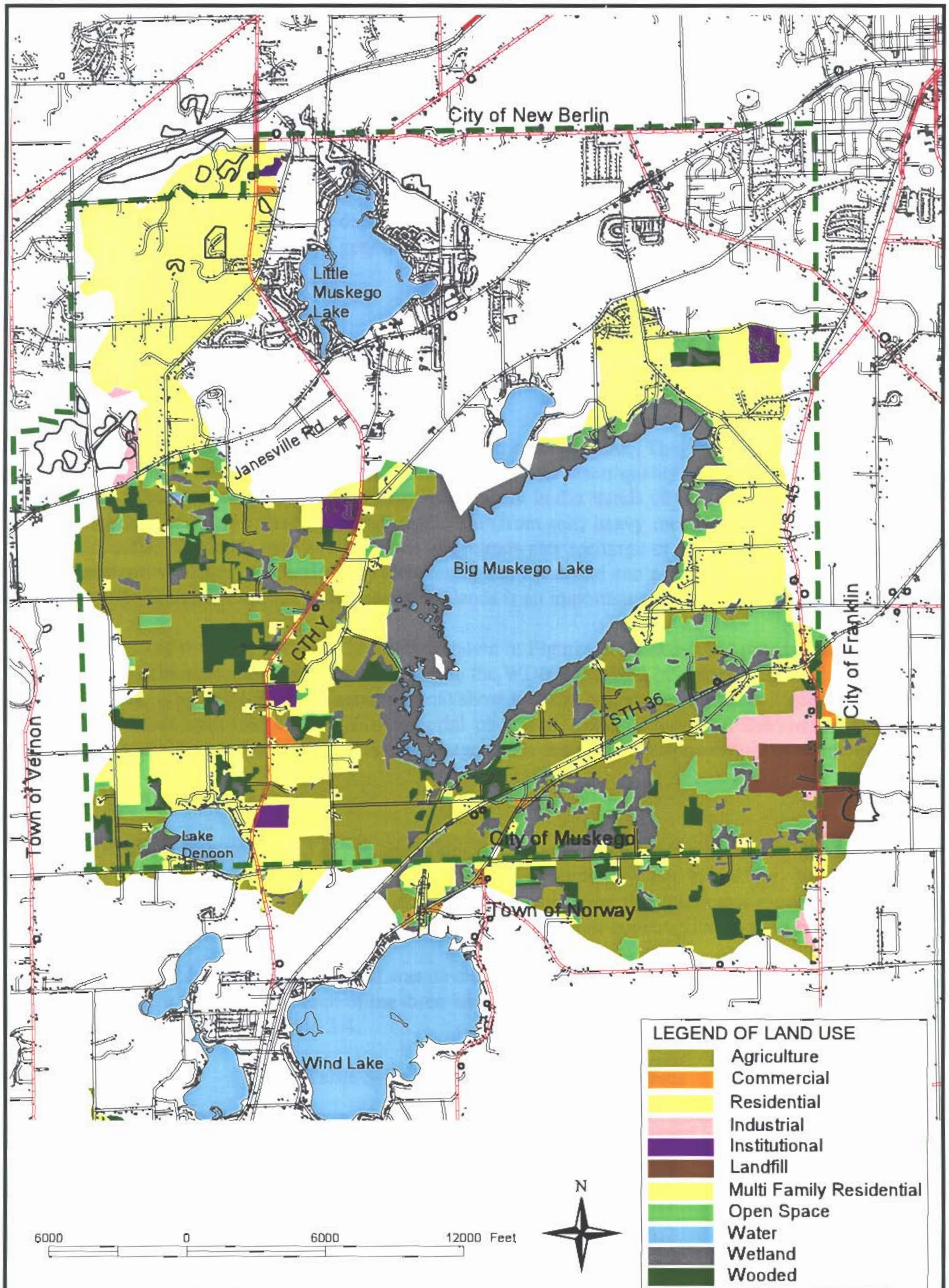


EARTH TECH

CITY OF MUSKEGO
PHASE II STORMWATER MANAGEMENT PLAN
1996 LAND USE
FIGURE 3-4

CITY OF MUSKEGO

MAY 1999



EARTH TECH

CITY OF MUSKEGO
PHASE II STORMWATER MANAGEMENT PLAN
FUTURE LAND USE
FIGURE 3-5

CITY OF MUSKEGO

MAY 1999

Comparison of Existing and Future Conditions: Table 3-3 and Figure 3-3 compare the existing (1996) with the predicted future land use. The major predicted changes are the increase in residential lands and decrease in agricultural and open space lands over the next 10 to 20 years. This is important because the decrease in open space land use and the increase in the industrial, commercial, and residential land uses will result in significant increases in the volume of storm water runoff and urban nonpoint source pollutants unless management measures are implemented. On the other hand, the reduction in cropland within the project area will likely result in a decrease in the sediment pollutant amounts. This is because a stable, landscaped mixed urban area will generally cause less sediment pollution than croplands.

WETLANDS

Wetlands are areas that are perennially or seasonally inundated, have hydric soils, and support wetland vegetation adapted to these conditions. Much of the study area's wetlands (1700 acres) consist of shallow emergent marsh mixed with sedge meadow.

Wetlands perform functions important to storm water management. They provide areas for detention of storm water flows and reduce peak flows. They also provide water quality treatment through the vegetative uptake of nutrients and the physical settling of sediment in the stands of vegetation. However, untreated urban storm water can damage wetland vegetation (from salt, heavy metals, and the "flashy" nature of urban runoff). Wetlands may also be areas of groundwater recharge or discharge. Beyond storm water management, wetlands are particularly rich ecological areas and can provide important wildlife and fish habitat. For these reasons, the protection of wetlands is an important element of storm water management.

The locations of wetlands in the study area are shown in Figures 3-4 and 3-5. Approximately 1,700 acres of wetlands exist within the project area, based on the WDNR Wetland Inventory Maps for the project area (April 1992). The WDNR maps (aerial photos) show wetland boundaries for areas 2 acres and greater in size. For areas indicated on the WDNR aerial photos of wetlands less than 2 acres, an approximate boundary was added to the project maps using larger scale aerial photographs and topographic information.

FLOODPLAINS

Floodplains are usually defined as the area along a stream or lake, which would be inundated during a 100-year recurrence interval flood. The floodplain is generally not suited for development since development would be periodically flooded. Development in the floodplain can exacerbate the severity of a flood. There are a number of state regulations that prohibit construction in the floodplain.

A detailed Flood Insurance Study (FIS) was developed for the City of Muskego in 1982. In this report, lake stages were computed for each of the three lakes within the City limits under various flood conditions. These stages are shown in Table 3-4.

Table 3-4: Summary of Lake Elevations

Lake	10-year	50-year	100-year*	500-year
Lake Denoon	780.7	781.1	781.2	781.5
Muskego Lake	773.5	773.8	774.1	774.2
Little Muskego Lake	793.7	794.1	794.2	794.4

* Regional Flood Elevation (RFE) - Used as the regulatory elevation for floodplain management

Several streams within the City limits were also studied and reported in the FIS. These include:

Tess Corners Creek, Muskego Canal, Jewel Creek, Unnamed Tributary of Muskego Canal, Tess Corners Creek Tributary North, and Lake Denoon Tributary. One hundred-year flood profiles for each of the streams can be found in the FIS.

PRECIPITATION

The watershed has a climate characterized by markedly different seasons with correspondingly large variations in temperature and precipitation type, amount, and intensity. The average annual rainfall for the project area is 33.20 inches (NOAA, Union Grove station). This total amount is distributed throughout the year. For the north central portion of the United States, an average of 55 separate precipitation events occurs annually (Urbonas B. and Stahre P., 1993). The primary source used to predict rainfall amounts for individual events, and the intensity of the precipitation events was the USDA, Soil Conservation Service Technical Paper No. 40: "The Rainfall Frequency Atlas of the United States" (compiled by the U.S. Department of Commerce). Also, the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) Technical Report, Volume 3, No. 5 ("Development of Equations for Rainfall Intensity-Duration-Frequency Relationship"), was consulted.

Storms were analyzed for this study to determine which types of storms resulted in critical peak flows for flooding conditions. Precipitation events can be characterized in many ways; two parameters are: *recurrence interval* and *duration*. A storm's *recurrence interval* is a statistical prediction of how often a storm of a certain size is likely to occur. For example: a "10-year storm" on the average will occur once in 10 years. The *duration* of a storm is the length of time the precipitation is falling. Each combination of *recurrence* and *duration* results in a unique rainfall amount (in inches). Table 3-5 summarizes the storm events and precipitation amounts analyzed for this project.

Table 3-5: Recurrence-Duration-Rainfall-Depth (inches)

Duration	Recurrence Interval			
	2-Year	10-Year	25-year	100-year
1-Hour	1.41	1.92	2.23	2.69
2-Hour	1.62	2.30	2.65	3.20
6-Hour	2.00	2.95	3.40	4.10
12-Hour	2.40	3.40	3.95	4.90
24-Hour	2.65	3.95	4.50	5.60

Source: U.S. Department of Commerce, Climatological Data, Annual Summary, Wisconsin. 1995,

The rainfall data for pollutant loading analyses came from Mitchell Field (Milwaukee) rainfall records for the year 1981. This is defined by the WDNR to be a "typical" year of rainfall and is assumed to best predict the potential average runoff and pollutant loadings. The Source Load and Management Model (SLAMM), the model used to predict nonpoint source pollution loads, uses the 1981 rainfall year to generate the pollutant loadings for the 1996 and future land use conditions.

STORM WATER REGULATORY FRAMEWORK

Over the past few years, several changes have occurred in the federal, state, and local levels of government resulting in significant impacts to storm water quality and storm water management. Below is a summary of the major programs at each governmental level, which in some way affect storm water regulatory issues. The regulations summarized below are constantly evolving, and the requirements may change over time.

Federal Government

Storm Water Permit Program

In 1987, the Federal Government passed the amended Clean Water Act, which included several regulations related to storm water management and nonpoint source pollution control. The programs are administered by the U.S. Environmental Protection Agency (USEPA), which issued final regulations (40 CFR, part 122) in 1990, and are targeted to controlling nonpoint source pollution from municipal, industrial, and construction site runoff. The federal program directs municipalities greater than 100,000 in population to inventory, monitor, and develop plans to reduce the pollutants found in municipal runoff. The municipalities must obtain "pollution permits" to regulate the quality of their runoff. Selected industries must also obtain permits to regulate their runoff quality. Industries must monitor their runoff quality and develop Storm Water Pollution Prevention Plans (SWPPPs) in compliance with the program. Construction sites greater than 5 acres in size must develop construction erosion control plans to minimize the pollutants in runoff from these sites.

In 1997, new draft rules for a Phase 2 storm water permit program were released. These rules are available for public review at this time and are expected to be finalized by late 1999. Some of the changes that are being considered include:

- Requiring urban areas of populations 50,000 or greater (or of a certain population density) to be included in the program;
- Requiring states to assess impacts from municipalities down to populations of 10,000; and
- Defining minimum measures for permitted municipalities to implement (such as construction erosion control, storm water management on new developments, illicit discharge control, and public information/education).

404 Permit Program

Section 404 of the Clean Water Act provides the authority to the federal government for administering activities which may impact navigable waters of the United States. This program is generally administered by the U.S. Army Corps of Engineers. Activities requiring a 404 permit include placing fill or dredging a navigable waterway or wetland. The permitting process is coordinated by the Regional Office of the WDNR.

State Government

Storm Water Permit Program (NR 216)

In Wisconsin, the State's WDNR has taken on the responsibility to carry out the federal storm water management program (40 CFR, part 122). The WDNR developed an administrative code to implement the program (commonly referred to as "NR 216"). In addition to the larger cities (populations greater than 100,000), the state program allows for the inclusion of other communities to be regulated by NR 216. Other categories of cities to be regulated under the NR 216 programs are those cities in the "Great Lakes Areas of Concern," and communities within priority watershed areas with populations greater than 50,000.

At this time, the City of Muskego is not under consideration for regulation under NR 216. Certain types of industries within the City of Muskego, however, will be affected by these rules.

Wisconsin Nonpoint Source Pollution Abatement Program (NR 120)

Because this study is partially funded through the State's Nonpoint Source Pollution Abatement Program, the City must comply with the program's policies as defined in the administrative rules NR 120. The City must comply with the WDNR's "core program" as described in the Priority Watershed Plan in order to accept continued funding through the priority watershed program. The core program includes requirements for: maintaining and enforcing a construction site erosion control ordinance; conducting a water quality focused information and education program; and evaluating and improving its urban "housekeeping practices" (housekeeping practices include items such as: pet waste ordinances, street sweeping, catch basin cleaning, and proper disposal of snow and street sweeper dirt.)

Currently, the program is under review to determine whether modifications may improve the effectiveness of the urban and rural nonpoint pollution control. These changes will likely require public hearings, legislative action, and administrative rule changes.

State Wetland Permit Requirements (NR 103)

In 1991, the State of Wisconsin adopted administrative rules (NR 103), which described a review process to be used by WDNR for projects affecting delineated wetlands. The NR 103 process applies to projects funded through the Wisconsin Nonpoint Source Pollution Abatement Program, if impacts on wetlands are involved. The impacts may be direct (such as constructing a structural management practice within the boundaries of the wetland) or indirect (such as changes in the hydrology of a nearby wetland). The review criteria to be used by the WDNR include: (1) is the project wetland-dependent? (2) are there practical alternatives? (3) what are the impacts on wetland water quality standards? (4) what are the cumulative impacts? and (5) what are potential secondary impacts? Projects that are not wetland-dependent and have practical alternatives will be denied a permit for proceeding. Applications for this permit are handled through the Regional Office of the WDNR.

State Water Regulation Permit (Chapter 30)

The State of Wisconsin has the authority to regulate activities that affect navigable waterways. This includes lakes, streams, and rivers within Wisconsin. Almost all waterways with a defined channel and bank are considered "navigable" if the channel carries water for a portion of the year. Projects (regardless of the funding source) that place fill in or remove fill from a waterway, or in any way impact navigation, require a permit through the "Chapter 30" process. Projects such as stream bank stabilization, dredging, or "improvements" to an existing channel likely will require this permit.

The permit application process is generally coordinated with local zoning and/or shoreland requirements. Applications for this permit are handled through the Regional Office of the WDNR.

Local Government

Construction Site Erosion Control Ordinance (Chapter 29)

The City adopted a construction site erosion control ordinance in 1986. The ordinance was based on a draft model ordinance developed cooperatively by the Wisconsin League of Municipalities and the WDNR. Provisions of the ordinance for construction sites include:

- The submittal of an erosion control plan to the City from the landowner;
- The approval of the plan and issuance of a permit from the City; and
- The inspection of the construction site to check for compliance with the erosion control plan.

It is important to note that the City's ordinance applies to land disturbing activities before a building permit is issued and after final inspections are conducted. This means that the erosion control measures during these periods can be more restrictive than measures that occur during the construction of a residential building. Erosion control during the actual building phase is regulated by the State of Wisconsin through the Uniform Dwelling Code.

City Subdivision and Platting Ordinance (Chapter 18)

The City's subdivision ordinance was most recently updated in August of 1994. It includes regulations that refer to the erosion control ordinance. In addition, shore land planting, sediment control measures, and storm water management requirements (related to runoff volumes) are included in the ordinance.

As a part of this Phase 2 study, a more comprehensive storm water management ordinance has been developed. A Citizen Advisory Committee carefully reviewed the ordinance, made revisions, and a draft ordinance is being considered for adoption. The proposed ordinance contains more restrictive requirements for controlling the peak flow runoff and for reducing nonpoint source pollution loads from newly developed sites.

Proposed Storm Water Management Ordinance

As a component of this study, a Storm Water Advisory Committee drafted an ordinance for management of storm water (both peak flow and nonpoint source pollution) from new developments and redevelopment within the City. The ordinance affects nearly all new development except for agricultural activities. The ordinance defines the level of peak flow reduction from post-development conditions, the minimum carrying capacity of the storm water conveyance system, and the amount of sediment reduction from new developments. Other issues, such as methods for hydrologic calculations, maintenance of storm water management structures, and administrative procedures, are also addressed. A guide document is also under development to inform developers on the compliance requirements. The draft ordinance is under consideration by the City for adoption at this time.

CHAPTER 4

HYDROLOGIC/HYDRAULIC AND NONPOINT POLLUTANT ANALYSIS: METHODOLOGY AND RESULTS

RELATIONSHIP BETWEEN WATER QUANTITY AND QUALITY

Achieving the established water quality and flood control objectives requires an understanding of the hydrologic, hydraulic, and water quality characteristics of the City of Muskego project area. The volume (e.g., acre-feet) and rate (e.g., cubic feet per second) of storm water runoff under existing and future land use conditions are the most important aspects of the project area's hydrology and hydraulics.

Water quality characteristics include the physical, chemical, and biological attributes of storm water runoff under existing and future conditions. As rain falls on rooftops, lawns, parking lots, streets, highways, and agricultural land, the storm water runoff picks up materials such as sediment, nutrients, pesticides, road salt, oil, heavy metals, and bacteria. These materials can have an adverse effect on each of the lakes and connecting tributaries. This detrimental impact is called nonpoint pollution.

METHODS AND RESULTS OF DRAINAGE SYSTEM CAPACITY ANALYSIS

Introduction

Computer modeling was conducted to determine sites within the project area's drainage system that would flood under certain rainstorm conditions. Flooding occurs when the storm water conveyance system (roadside ditches, culverts, channels, and storm sewers) does not have the capacity to carry away the storm water runoff. When the system's capacity is not adequate, storm water pools on streets and property. Eight major drainage systems in the City, each with their own discharge point (to Big Muskego Lake, the Muskego Canal, Lake Denoon, or Linnie Lac Lake) were evaluated for the system's ability to convey the runoff from four different size storms.

Procedure

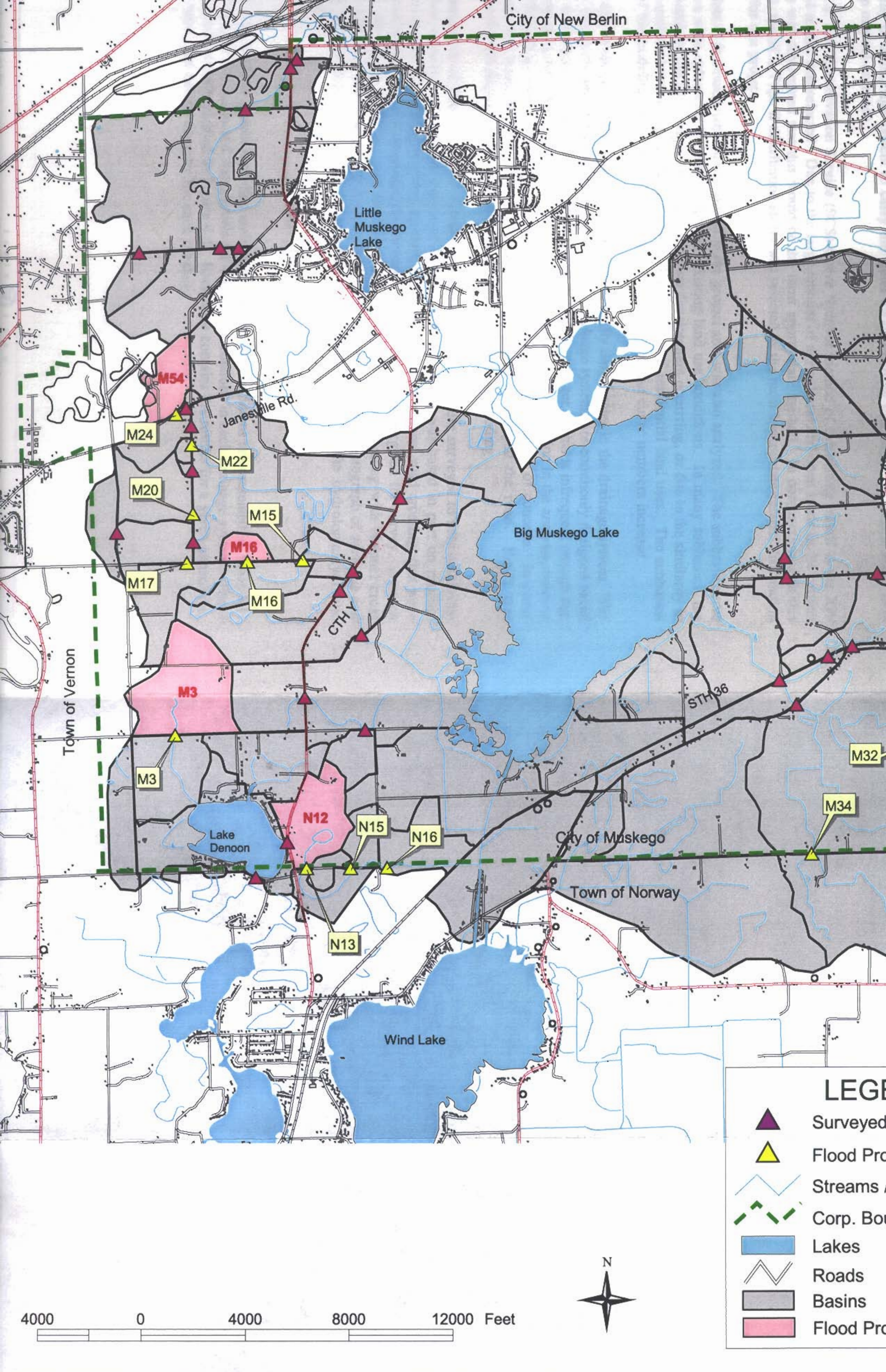
The process used to evaluate the drainage system's capacity and locate potential flooding concerns is explained below.

1. The Storm Water Management Model (SWMM), developed by the U.S. EPA, was used for the hydrologic/hydraulic (flooding) analysis for the project area. The program has the ability to combine and route water flows through a variety of channels, pipes, and ponds. The model works in two steps:

    1) *hydrologic* simulation: The hydrologic simulation generates the <u>amount</u> of water flowing from each subbasin; and

    2) *hydraulic* simulation: The hydraulic simulation takes the amount of water generated and moves the water through the drainage system (ditches, culverts, channels, storm sewers, and storage areas). The hydraulic simulation calculates the depth of water in the channels and pipes, and how high the water will back up if the channels or pipes are not large enough to convey the water.

2. The project area was broken up into separate drainage systems for modeling (Figure 4-1).



CITY OF MUSKEGO
PHASE II STORMWATER MANAGEMENT PLAN

3. The computer modeling and the predicted flooding potential is based on analyzing various size rain storms (2-year, 10-year, 25-year, and 100-year storms). The rainstorms are defined by their *duration* and *recurrence interval*. The concepts of *duration* and *recurrence interval* were previously discussed. Table 3-7 presents the rainfall amounts associated with each duration and recurrence interval. It was found that the 12-hour duration storms generally produced the highest peak flow and the most surcharging of the drainage system. "Surcharging" is a condition where rate of runoff exceeds the capability of a drainage system to carry the water away. During this condition, storm water may overtop or pool on roads.

4. The U.S. Soil Conservation Service (SCS) Curve Number method of calculating runoff in the XP-SWMM model was selected. Due to the large amount of agricultural and open lands in the project area, it was determined that this would be the most appropriate method. In conjunction with this method, the SCS Type II distribution storm was selected as the most appropriate rainfall distribution to use for this project.

6. The effect of increased urban development in the project area was also analyzed. The subbasin curve numbers were calculated for both future and existing land use conditions. In many subbasins, the curve numbers did not change over time due to no development occurring, or due to the similarity in curve numbers between agricultural lands in clayey soils and residential land uses. The subbasins selected for modeling under future conditions were those that had curve numbers increase.

7. The results of the analysis were used to determine capacity deficiencies in the drainage system. The 10-year rainstorm was chosen as the key rainstorm. Drainage systems are commonly designed based upon conveying the 10-year storm. Flooding that occurs from larger storms is infrequent enough that it is not considered a major hindrance to community activities. As a criterion in the analysis, culverts which flooded to within 1 foot of the road surface were identified as areas of concern. In many instances, the water backed up to the ground elevation and overtopped the road. Roads that overtopped even during the 2-year storm are particularly prone to flooding.

8. As a component of this project, 55 culverts underlying roadways were surveyed to help determine their flow capacity. The identification of culverts to be surveyed was based in part on random selection as well as discussions with City staff. Through these discussions, road crossings that were prone to flooding or were otherwise problematic were identified and targeted for survey. At each culvert, the length, opening, road elevation, and slope were measured along with channel cross sections upstream and downstream from each culvert. There was also a photograph of each site and the physical condition was noted. These measurements were used in the hydrologic/hydraulic modeling.

Results

The results of the drainage system modeling under existing land use conditions are presented in Table 4-1. The table shows the flow rates and water levels for each of the conduits in each drainage system. These systems and conduits are identified in Figure 4-1. Each table contains the results for a given storm size, the length, shape, and design capacity for each conduit.

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
M26 SYSTEM												
DM26	Natural	0.82	1,100	17.0	4.0	920	4.1	920	7.5	920	9.7	920
CM26	Circular	1.25	31	3.0	1.0	908	2.1	908	2.6	909	3.4	910
CM26	Circular	1.25	32	2.1	0.6	908	2.0	908	3.0	909	5.2	910
D262	Trapezoidal	2.00	4,600	830.2	1.6	907	4.0	907	5.6	907	8.6	907
CM28	Circular	1.50	38	11.2	1.9	867	5.2	867	7.5	867	11.6	868
D531	Natural	3.39	1,430	347.3	0.7	863	2.7	863	3.8	863	7.5	863
DM27	Natural	1.36	610	56.1	0.2	864	5.2	864	9.7	864	20.5	864
CM27	Circular	3.00	34	30.4	0.2	858	5.2	859	9.7	859	20.5	860
DM272	Trapezoidal	2.00	800	77.9	0.2	858	5.2	858	9.7	858	20.5	859
D273	Trapezoidal	4.00	1,500	161.3	2.5	846	11.8	846	13.5	846	21.0	846
DM31	Natural	4.13	3,300	58.3	53.4	846	58.0	846	58.0	846	58.1	846
CM31	Circular	4.00	36	118.1	53.1	841	57.7	842	57.9	842	58.0	842
D312	Natural	5.36	2,700	343.5	52.9	841	57.6	841	57.9	841	57.9	841
CM29	Circular	6.00	132	59.9	55.9	833	66.2	833	74.0	833	96.9	834
D291	Natural	5.76	230	350.9	55.9	832	66.2	833	74.1	833	96.9	833
CM30	Circular	6.00	29	42.6	57.0	832	70.0	832	80.6	832	107.8	833
D301	Natural	6.36	2,100	995.9	57.1	829	70.2	830	80.5	830	108.5	830
M54 SYSTEM												
C54	Circular	2.00	80	9.7	2.6	808	7.6	809	10.5	809	13.7	810
D541	Trapezoidal	2.00	390	74.1	2.6	808	7.6	808	10.6	808	13.7	808
D23	Trapezoidal	2.00	280	66.8	0.7	799	3.6	800	6.5	800	11.9	800

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
CM25	Circular	1.50	69	5.6	4.4	818	7.1	819	7.2	819	7.2	819
CM24	Circular	2.00	58	30.6	4.4	815	7.1	815	7.2	815	7.2	815
D567	Natural	2.32	300	96.5	4.4	812	7.1	812	7.2	812	7.2	812
D568	Natural	2.32	600	62.2	4.3	803	7.1	804	7.1	804	7.2	804
CM23	Circular	1.50	30	5.7	2.1	795	3.6	796	3.8	796	6.2	796
CM23	Circular	1.50	30	6.5	2.3	795	3.8	796	4.0	796	6.3	796
D232	Natural	1.89	660	58.8	4.7	795	7.6	795	7.9	795	12.5	796
C55	Circular	2.00	60	31.6	28.0	814	29.5	814	30.3	815	32.5	816
D555	Trapezoidal	2.00	1,920	43.0	32.2	810	32.6	810	33.3	810	34.3	810
D233	Trapezoidal	3.00	1,000	22.9	20.5	790	20.6	790	20.5	790	20.5	790
CM22	Circular	1.50	31	7.7	7.8	795	10.6	796	10.6	796	10.6	796
D225	Trapezoidal	2.00	20	373.6	2.1	790	5.4	790	6.0	790	6.9	790
C234	Circular	3.50	25	48.7	23.7	788	26.7	788	26.7	788	27.3	788
D235	Trapezoidal	3.00	2,260	67.1	28.7	788	31.1	788	30.6	788	30.9	788
CM18	Circular	3.25	40	58.7	29.6	809	50.5	810	60.0	811	74.4	811
D181	Natural	2.21	2,820	25.2	18.1	807	19.6	807	21.0	807	23.1	807
D17	Natural	1.56	1,100	45.9	22.2	815	38.5	816	39.1	816	45.8	816
CM17	Circular	2.00	36	15.3	6.3	804	11.5	804	14.0	805	16.5	805
CM17	Circular	2.00	36	9.6	10.4	804	12.5	804	13.6	805	15.0	805
D172	Natural	1.48	320	118.8	16.7	802	23.9	802	27.7	802	31.4	802
CM19	Circular	2.00	31	23.2	15.8	800	19.9	801	22.3	801	23.6	801
D191	Trapezoidal	4.00	1,755	175.9	15.8	799	19.9	799	22.3	799	23.6	799

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr Flow (cfs)	2-yr. 12 hr Water Elev. (NGVD)	10-yr. 12 hr Flow (cfs)	10-yr. 12 hr Water Elev. (NGVD)	25-yr. 12 hr Flow (cfs)	25-yr. 12 hr Water Elev. (NGVD)	100-yr. 12 hr Flow (cfs)	100-yr. 12 hr Water Elev. (NGVD)
CM20	Circular	2.25	31	15.4	16.4	800	22.6	800	23.7	800	24.5	800
D201	Natural	0.60	500	6.1	5.4	800	5.4	800	5.4	800	5.4	800
D192	Trapezoidal	4.00	1,215	190.2	21.2	792	24.9	792	26.9	792	27.7	792
CM21	Circular	1.25	44	3.3	3.2	805	4.4	806	4.8	807	5.4	807
D211	Trapezoidal	2.00	1,170	135.2	3.0	803	4.3	803	4.7	803	5.3	803
D193	Trapezoidal	4.00	1,720	206.3	21.2	785	24.9	786	26.9	786	27.7	786
D194	Trapezoidal	5.00	3,800	101.2	31.2	778	54.3	779	58.2	779	60.3	779
D57	Natural	10.15	2,770	766.9	134.4	777	256.6	779	296.8	779	372.7	780
CM9	Circular	6.50	88	246.2	64.5	775	124.7	777	140.7	777	181.5	778
CM9	Circular	6.50	88	259.5	68.4	775	129.2	777	145.1	777	184.4	778
D572	Natural	10.34	2,000	2,129.0	132.3	775	253.0	776	284.3	776	364.8	777
M16 SYSTEM												
CM16	Circular	2.75	32	29.5	25.6	808	38.4	809	38.4	809	38.4	809
D161	Natural	1.30	3,150	30.5	23.4	807	29.1	807	29.0	807	28.8	807
CM15	Circular	2.50	37	17.5	27.1	790	36.2	790	39.9	791	42.2	791
D151	Natural	2.15	1,200	47.4	27.1	788	32.7	789	32.7	789	32.7	789
D8	Natural	1.18	1,050	18.3	18.3	781	18.3	781	18.3	781	18.3	781
CM8	Circular	4.00	78	8.8	15.7	778	17.0	778	17.2	778	17.3	778
D82	Natural	2.15	750	63.6	15.7	778	17.0	778	17.2	778	17.3	778
CM7	Circular	4.00	75	75.2	68.8	780	93.1	782	102.9	783	121.3	783
PM72	Circular	4.00	150	42.6	68.8	778	93.1	780	95.5	780	96.8	780
D83	Natural	4.33	1,850	67.2	10.9	775	11.9	775	12.4	775	13.2	775

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
CM6	Circular	5.25	32	102.4	78.4	776	126.9	777	150.4	778	182.7	779
D61	Natural	5.24	4,300	86.2	27.3	776	55.9	777	70.5	777	83.0	778
CM5	Circular	3.50	95	35.4	43.3	782	68.8	784	77.8	785	90.4	786
D51	Natural	4.53	3,200	202.3	45.7	781	71.3	782	80.2	782	94.4	782
CM1	Circular	2.50	57	17.2	5.6	771	11.0	772	14.1	772	19.2	773
D11	Natural	2.55	4,050	44.3	26.8	772	47.2	773	47.9	773	47.0	774
D7	Trapezoidal	6.00	3,950	285.8	144.7	770	256.5	771	313.0	771	374.3	772
D68	Trapezoidal	7.00	2,700	635.9	208.1	769	359.5	769	427.5	770	527.9	770
M3 SYSTEM												
CM3	Circular	4.00	42	89.0	108.2	805	116.4	805	116.4	805	116.4	805
DM31	Natural	5.54	1,300	1,957.3	108.2	800	116.4	800	116.4	800	116.4	800
DM58	Trapezoidal	7.00	2,400	3,251.0	126.1	786	245.7	786	321.4	786	459.7	787
M60 SYSTEM												
D60	Trapezoidal	8.00	800	1,798.3	99.3	780	186.3	781	235.1	782	313.1	783
C61	Circular	6.00	80	181.4	95.9	780	171.8	781	202.8	782	254.0	783
N12 SYSTEM												
DN12	Natural	6.46	1,160	212.5	3.7	777	7.8	777	13.4	777	15.1	778
CN12	Circular	2.50	74	16.5	3.9	775	7.8	775	13.2	776	14.8	776
D132	Natural	3.33	2,840	21.5	4.5	775	9.2	775	13.0	776	14.7	776
CN13	Circular	1.25	32	2.0	4.5	782	4.5	783	4.5	783	4.5	784
DM632	Natural	2.81	420	118.6	4.5	779	4.5	779	4.5	779	4.5	779
P633	Circular	3.00	74	32.0	0.0	779	0.0	779	0.0	779	0.8	779

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
P634	Circular	3.00	250	55.3	4.5	778	4.5	778	4.5	778	4.6	779
P635	Orifice					776		777		778		779
P636	Circular	1.00	30	0.2	0.4	776	0.6	777	0.6	778	0.7	779
D637	Trapezoidal	1.50	60	43.5	2.9	775	3.2	775	3.7	775	3.8	775
D15	Natural	4.03	2,140	58.5	13.6	775	28.4	775	30.2	775	31.8	775
CN15	Circular	3.00	66	48.9	13.9	775	22.1	775	22.2	775	22.2	775
DN157	Natural	4.86	550	119.9	15.2	775	19.1	775	22.4	775	22.9	775
CN16	Circular	3.00	47	9.1	40.4	775	46.0	775	46.7	775	46.5	775
DN165	Natural	6.10	2,500	76.7	29.3	774	29.7	774	29.7	774	29.6	774
DN7	Natural	5.57	600	168.9	173.1	773	242.6	774	248.2	774	248.8	774
DN81	Natural	6.04	1,150	504.2	65.0	771	78.8	772	131.9	772	201.7	772
CN8	Circular	5.00	29	368.3	65.9	771	80.1	772	80.1	772	81.1	772
DN83	Natural	6.30	820	811.0	69.6	771	111.1	771	112.8	771	112.6	772
CN7	Circular	4.00	266	79.8	51.7	771	61.7	771	68.5	771	70.6	772
CN7	Circular	4.00	274	53.5	53.9	771	59.9	771	62.9	771	67.8	772
DN77	Trapezoidal	4.50	33	1,567.5	106.2	769	122.2	769	131.5	769	138.4	769
M32 SYSTEM												
CM33	Circular	1.00	68	0.6	1.5	793	2.5	793	2.8	794	3.5	794
D331	Trapezoidal	2.00	5,157	23.4	7.1	793	2.3	793	2.7	793	3.4	793
CM34	Circular	4.00	44	35.2	70.2	778	99.8	780	111.6	780	124.3	780
D341	Natural	2.06	7,227	8.5	11.9	778	13.8	780	13.9	780	13.9	780
CM32	Circular	2.00	61	41.0	34.0	805	39.2	806	39.6	806	39.6	806

TABLE 4-1
Storm Water Conveyance System Existing Conditions
City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
D321	Natural	2.58	5,525	21.8	26.7	802	26.7	802	26.7	802	26.7	802
D35	Natural	4.83	850	277.8	77.3	774	77.3	774	77.3	774	77.3	774
BM35	Natural	8.29	28	1,063.7	51.9	773	52.0	773	52.0	773	51.8	773
D352	Natural	6.03	1,100	146.0	51.9	773	51.9	773	51.9	773	51.8	773
C79	Circular	2.00	150	10.0	6.5	798	8.1	798	8.0	798	8.0	798
D791	Natural	2.70	2,320	274.1	6.4	796	7.9	796	7.9	796	7.9	796
CM13	Circular	1.50	95	5.3	6.1	777	8.5	777	9.3	778	10.6	778
D131	Natural	0.98	1,550	7.6	6.0	776	7.1	776	6.8	776	6.2	776
CM14	Circular	6.00	79	271.6	28.4	775	52.7	776	65.3	776	86.5	777
D141	Trapezoidal	1.00	1,580	38.2	27.4	774	36.2	775	38.7	776	42.4	777
CM36	Rectangle	6.00	88	181.8	43.9	772	55.1	772	60.4	772	69.8	773
CM36	Rectangle	6.00	88	17.1	42.3	772	53.2	772	58.4	772	67.7	773
D361	Natural	8.08	3,150	2,108.1	86.2	772	107.9	772	118.8	772	137.0	772
M11 SYSTEM												
CM12	Circular	1.50	70	9.6	0.8	813	3.4	813	4.9	814	5.9	814
D812	Trapezoidal	2.00	3,950	157.7	1.8	810	5.5	810	4.6	810	5.6	810
CM11	Circular	2.00	61	3.5	4.3	774	9.0	774	11.3	775	14.4	775
D112	Natural	3.17	850	90.5	4.4	773	9.3	774	11.7	774	14.9	774
CM10	Circular	2.50	37	48.0	9.5	773	17.1	773	19.1	774	20.6	774
D101	Natural	2.14	1,450	14.9	14.9	773	21.3	773	21.3	773	21.7	774

TABLE 4-2
Storm Water Conveyance System Future Conditions

City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
M26 SYSTEM												
DM26	Natural	0.82	1100	17.0	5.0	920	6.7	920	7.8	920	10.1	920
CM26	Circular	1.25	30.5	3.0	2.3	909	2.7	909	3.0	909	3.4	910
CM26	Circular	1.25	32	2.1	2.4	909	3.5	909	4.2	909	5.3	910
D262	Trapezoidal	2.00	4600	830.2	4.6	907	6.2	907	7.2	907	8.7	907
CM28	Circular	1.50	38	11.2	4.8	867	9.5	868	12.2	868	15.6	870
D531	Natural	3.39	1430	347.3	2.2	863	6.0	863	7.9	863	11.2	863
DM27	Natural	1.36	610	56.1	1.6	864	8.8	864	14.8	864	40.9	865
CM27	Circular	3.00	34	30.4	1.6	858	8.8	859	14.8	859	39.6	861
DM272	Trapezoidal	2.00	800	77.9	1.6	858	8.8	858	14.8	858	39.6	859
D273	Trapezoidal	4.00	1500	161.3	3.8	846	15.2	846	18.1	846	40.3	846
DM31	Natural	4.13	3300	58.3	56.5	846	58.0	846	58.1	846	58.1	846
CM31	Circular	4.00	35.5	118.1	55.7	842	57.9	842	57.9	842	58.0	842
D312	Natural	5.36	2700	343.5	55.5	841	57.8	841	57.9	841	57.9	841
CM29	Circular	6.00	132	59.9	61.0	833	75.3	834	90.5	834	124.9	835
D291	Natural	5.76	230	350.9	61.1	832	75.4	833	90.5	833	125.1	834
CM30	Circular	6.00	29	42.6	63.1	832	82.0	832	99.6	833	139.9	834
D301	Natural	6.36	2100	995.9	62.9	829	82.0	830	100.2	830	140.9	830
M54 SYSTEM												
C54	Circular	2.00	80	9.7	6.3	809	12.0	810	14.1	810	17.7	811

TABLE 4-2
Storm Water Conveyance System Future Conditions

City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
D541	Trapezoidal	2.00	390	74.1	6.3	808	12.0	808	14.1	808	17.7	808
D23	Trapezoidal	2.00	280	66.8	1.5	799	5.8	800	8.9	800	14.5	800
D567	Natural	2.32	300	96.5	5.5	812	7.2	812	7.2	812	7.2	812
D568	Natural	2.32	600	62.2	5.4	803	7.1	804	7.2	804	7.2	804
CM23	Circular	1.50	30	5.7	2.6	795	3.6	796	4.4	796	7.4	796
CM23	Circular	1.50	30	6.5	2.8	795	3.8	796	4.5	796	7.6	796
D232	Natural	1.89	660	58.8	5.4	795	7.4	795	8.9	795	15.0	796
C55	Circular	2.00	60	31.6	30.1	815	33.9	816	33.9	816	33.9	816
D555	Trapezoidal	2.00	1920	43.0	34.0	810	35.3	810	35.0	810	35.3	810
D233	Trapezoidal	3.00	1000	22.9	20.6	790	20.7	790	20.7	790	20.6	790
CM22	Circular	1.50	31	7.7	7.8	795	10.6	796	10.6	796	10.6	796
D225	Trapezoidal	2.00	20	373.6	2.1	790	5.4	790	6.1	790	6.9	790
C234	Circular	3.50	25	48.7	23.9	788	27.1	788	27.1	788	27.3	788
D235	Trapezoidal	3.00	2260	67.1	29.0	788	32.4	788	32.4	788	31.7	788
CM18	Circular	3.25	40	58.7	29.5	809	50.5	810	60.1	811	74.6	811
D181	Natural	2.21	2820	25.2	18.1	807	20.2	807	22.0	807	24.3	807
D17	Natural	1.56	1100	45.9	17.1	815	38.5	816	41.8	816	46.5	816
CM17	Circular	2.00	36	15.3	4.8	804	12.8	805	16.1	805	16.8	805
CM17	Circular	2.00	36	9.6	9.4	804	13.0	805	14.7	805	15.1	805
D172	Natural	1.48	320	118.8	14.2	802	25.8	802	30.8	802	31.8	802
CM19	Circular	2.00	31	23.2	14.5	800	21.0	801	23.0	801	23.7	801

TABLE 4-2
Storm Water Conveyance System Future Conditions

City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
D191	Trapezoidal	4.00	1755	175.9	14.5	799	21.0	799	23.0	799	23.7	799
CM20	Circular	2.25	31	15.4	16.5	800	22.6	800	23.7	800	24.5	800
D201	Natural	0.60	500	6.1	5.4	800	5.4	800	5.4	800	5.4	800
D192	Trapezoidal	4.00	1215	190.2	19.8	792	26.0	792	27.6	792	28.5	792
CM21	Circular	1.25	44	3.3	3.2	805	4.4	806	4.8	807	5.4	807
D211	Trapezoidal	2.00	1170	135.2	3.0	803	4.3	803	4.7	803	5.3	803
D193	Trapezoidal	4.00	1720	206.3	19.8	785	26.0	786	27.6	786	28.5	786
D194	Trapezoidal	5.00	3800	101.2	32.8	778	54.8	779	57.5	779	61.6	779
D57	Natural	10.15	2770	766.9	137.7	777	258.3	779	297.5	779	372.9	780
CM9	Circular	6.50	88	246.2	66.1	775	125.5	777	140.9	777	181.7	778
CM9	Circular	6.50	88	259.5	70.1	775	130.0	777	145.3	777	184.5	778
D572	Natural	10.34	2000	2,129.0	135.5	775	254.8	776	284.9	776	365.3	777
N12 SYSTEM												
DN12	Natural	6.46	1160	212.5	3.6	777	7.8	777	13.4	777	15.1	778
CN12	Circular	2.50	74	16.5	3.8	775	7.8	775	13.2	776	14.8	776
D132	Natural	3.33	2840	21.5	4.5	775	9.2	775	13.0	776	14.7	776
CN13	Circular	1.25	32	2.0	4.5	782	4.5	783	4.5	783	4.5	784
DM632	Natural	2.81	420	118.6	4.5	779	4.5	779	4.5	779	4.5	779
P633	Circular	3.00	74	32.0	0.0	779	0.0	779	0.0	779	0.8	779
P634	Circular	3.00	250	55.3	4.5	778	4.5	778	4.5	778	4.6	779
P635	Orifice					776		777		778		779

TABLE 4-2
Storm Water Conveyance System Future Conditions

City of Muskego Storm Water Management Plan - Phase II Project Area

Conduit I.D.	Conduit Class	Conduit Diam./Depth (feet)	Conduit Length (feet)	Conduit Capacity (cfs)	2-yr. 12 hr		10-yr. 12 hr		25-yr. 12 hr		100-yr. 12 hr	
					Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)	Flow (cfs)	Water Elev. (NGVD)
P636	Circular	1.00	30	0.2	0.4	776	0.6	777	0.6	778	0.7	779
D637	Trapezoidal	1.50	60	43.5	2.9	775	3.6	775	3.7	775	3.9	775
D15	Natural	4.03	2140	58.5	13.6	775	28.4	775	29.8	775	32.3	775
CN15	Circular	3.00	66	48.9	13.9	775	22.1	775	22.2	775	22.2	775
DN157	Natural	4.86	550	119.9	15.1	775	19.0	775	22.4	775	23.0	775
CN16	Circular	3.00	47	9.1	40.5	775	46.0	775	46.7	775	46.5	775
DN165	Natural	6.10	2500	76.7	29.3	774	29.7	774	29.7	774	29.6	774
DN7	Natural	5.57	600	168.9	172.7	773	242.6	774	248.3	774	248.9	774
DN81	Natural	6.04	1150	504.2	66.2	771	79.9	772	134.1	772	202.6	772
CN8	Circular	5.00	29	368.3	67.0	771	81.2	772	81.5	772	82.5	772
CN7	Circular	4.00	266	79.8		771	61.5	771	64.7	771	66.9	772
CN7	Circular	4.00	274	53.5		771	60.8		63.8		67.6	
DN77	Trapezoidal	4.50	33	1,567.5	108.2	769	123.3	769	128.5	769	134.5	769

The results for future conditions are shown in Table 4-2. Only systems N12 (west of the Muskego Canal), M26 (from Field Road to Linnie Lac Lake), and N54 (from the intersection of Janesville and Hillendale Roads east to Big Muskego Lake) were modeled since they were the only areas with increases in Curve Numbers under future conditions. Changes in future land use had minor effects on the drainage capacity of the systems. The frequency of road overtopping in system M54 increased at culvert CM25 (northeast corner of Hillendale and Janesville Roads) from overtopping in the 25-year storm under existing conditions to overtopping in the 10-year storm under future conditions. The frequency of road overtopping in system N12 was not increased. System N26 experienced no road overtopping under either existing or future conditions.

Flooding Problem Areas

Flooding problem areas were identified with results of the computer modeling and by interviewing residents of the area for anecdotal information on flooding. Flooding problem areas were focused on areas that threatened roads and property. There were a number of channels through wetlands and open areas that flooded but did not result in property damage. These situations are not analyzed in this document.

Table 4-3 presents the identified drainage system capacity problem areas, the severity of the flooding, the causes of the problems, and supporting evidence from local observations. The information in the "comments" column is from discussions with City staff and citizen observation. These areas are located in Figure 4-1.

Table 4-3: Summary of Drainage System Capacity Analysis - Flood Prone Areas Muskego Storm Water Project

Location	Extent of Flooding	Reason for Problem	Comments
M54 SYSTEM			
CM20 – west of Hillendale Rd.	overtops road in 2-yr. storm	insufficient culvert capacity, low road	possible flooding in spring
CM22 - west of Hillendale Rd.	within 1 ft. of road in 10-yr. storm, overtops in 25-yr. storm	insufficient culvert capacity, culvert full of debris, possible downstream constrictions	Possible high water here in spring, but not observed
CM25 – north east corner of Hillendale and Janesville Roads	within 1 ft. of road in 10-yr. storm, overtops in 25-yr. storm	insufficient culvert capacity, possible downstream constrictions	no observed flooding
CM17 - south of Henneberry Rd.	within 1 ft. of road in 10-yr. storm	insufficient culvert capacity, low road	no observed flooding
M16 SYSTEM			
CM16 - north of Henneberry Rd.	overtops road in 10-yr storm	insufficient culvert capacity	flooding observed, shoulder washed out
CM15 - south of Henneberry Rd.	within 1 ft. of road in 10-yr. storm	insufficient culvert capacity	no observed flooding
M3 SYSTEM			
CM3- north of Kelsey Ave.	overtops road in 10-yr. storm	insufficient culvert capacity	flooding observed
N12 SYSTEM			

Table 4-3: Summary of Drainage System Capacity Analysis - Flood Prone Areas
Muskego Storm Water Project

Location	Extent of Flooding	Reason for Problem	Comments
CN13 - north of Muskego Dam Road	overtops road in 2-yr. storm	insufficient culvert, pipes downstream back pitched	verification from residents
CN16 - west of Muskego Dam Road	within 1 ft. of road in 2-yr. storm, overtops in 100-yr.	insufficient culvert capacity	flooding possible, but not observed
CN15 - south of Muskego Dam Road	within 1 ft. of road in 10-yr. but does not overtop	Insufficient culvert capacity	No comments made.
M32 SYSTEM			
CM32 - east of Hwy. 45	Overtops road in 10-yr. storm	insufficient culvert capacity	No comments made.
C79 - east of Hwy. OO	Overtops road in 10-yr. storm	insufficient culvert capacity	assumed elevations and pipe diameter of 24 in.
CM34 - south of Eight-Mile Road	Within 1 ft. of road in 10-yr storm, overtops in 25-yr storm	insufficient culvert capacity	No comments made.

Lake Denoon Water Levels

The increase in water level fluctuations in the lakes was a drainage issue discussed by the Citizen Advisory Committee was. There is anecdotal evidence of increases in water level fluctuations in Lake Denoon after storm events. Water levels are said to rise more rapidly now after rain than in the past. It has been suggested that this increase is due to the increase of urban development in the watershed and the concurrent increase in runoff.

The rapid increases in water levels in Lake Denoon occasionally causes flooding at the lake outlet and other low areas around the lake's shore. Denoon Road is known to flood where the lake outlet is located. High water levels in Lake Denoon have also resulted in the removal of shoreline wetlands. Shoreline wetlands have broken free from shore and floated in the lake before eventually breaking up.

The outlet of the lake is a culvert pipe under the road, which exits to an open channel. The open channel flows through a private residential lot. It appears that the open channel, not the culvert pipe, is the main constriction on the lake outlet. Survey data shows the bottom of the channel is 1 foot higher than the bottom of the pipe. The culvert pipe is generally partially submerged. Ability to increase the capacity of the open channel is limited by site constraints. The channel is close to a house, has several tight curves, and has vertical timber retaining walls for banks.

One solution to the problem of increasing lake levels could include the rebuilding of the existing lake outlet. In this case, the outlet channel would likely require a greater capacity than the existing channel and a properly designed layout to minimize encroachment on existing structures. An alternative solution would include the re-establishment of the historical lake outlet located on the lake's eastern shore. The re-establishment of the historical outlet would likely ease the surcharging problems associated with the existing outlet channel and would help to normalize lake water levels.

A third alternative, which will be recommended regardless of modifications to the outlet channel, is to improve storm water management within the lake's watershed. It will be especially important to reduce peak flows and extend the release time for runoff from new developments.

METHODS AND RESULTS OF NONPOINT POLLUTION LOADING ANALYSIS

INTRODUCTION

The purpose of this analysis is to identify and quantify the amount of nonpoint source pollution runoff in the project area. Pollution sources identified in this analysis include:

- urban storm water runoff,
- agricultural upland erosion,
- streambank erosion.

URBAN STORM WATER RUNOFF MODELING

Model Selection

For water quality simulation, the "Source Loading and Management Model" (SLAMM), developed by the WDNR for use in the State's Nonpoint Source Pollution Abatement Program, was used. This model was selected for several reasons, including:

- The model has been calibrated with extensive water quality monitoring conducted in southeastern Wisconsin. Thus, the model has been shown to accurately predict nonpoint source pollutant loads from urban areas in Wisconsin.

- The model was approved by the City of Muskego and used in the previous storm water study.

- The model was used in the development of the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. Thus, the results of the analysis conducted in the City of Muskego project area can be compared to the previous studies.

- The model is used extensively in nonpoint source pollution and storm water management studies in Wisconsin; thus, the analysis is consistent with other studies.

Background Information

Information used as input to SLAMM included:

- Land use,
- Hydrologic soil grouping,
- Drainage system,
- Existing storm water control practices,
- Annual rainfall,
- Street conditions.

Using this data, SLAMM estimates for each subbasin the annual loading (e.g., pounds or tons per year) of three types of pollutants to the City of Muskego project area drainage system. The pollutants analyzed for this project are sediments, nutrients (phosphorous), and heavy metals (zinc). As a result of the analysis, each subbasin had a pollutant load estimated (for each of the three pollutants) under 1996 and future land use conditions.

AGRICULTURAL UPLAND EROSION

The basis for estimating agricultural erosion was the Universal Soil Loss Equation (USLE). The USLE estimates annual soil erosion on a given field based upon rainfall intensity, soil type, flow length and slope, tillage practice, crop rotation, and cropping system. The USLE estimates the amount of soil eroding from a field but it does not predict how much of that sediment actually reaches a water body. Much of the eroded sediment is deposited down slope on other fields, on densely vegetated areas, or in slow moving drainage ways.

To estimate the amount of soil erosion delivered to the water bodies in the project area, the results of a sediment yield computer model were used. The model, WINHUSLE, developed by the WDNR and the U.S. Soil Conservation Service, takes the results of the basic USLE equation, and estimates the delivery of sediment to water bodies. WINHUSLE analysis was conducted in the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. This study includes the entire Phase 2 storm water management project area, except for the drainage area to Lake Denoon. Sediment delivery ratios for the Lake Denoon drainage area were calculated based on the WINHUSLE modeling in the priority watershed project.

STREAM BANK EROSION

Streambank erosion was identified in the streambank erosion inventory conducted in the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project* (*Table 3-6, p. 44*). These streambank erosion areas were divided into management categories based upon the amount of sediment eroding from them. Recommendations for controls on the more degraded stream banks were then made. The stream bank erosion inventory of the Muskego-Wind Lakes Priority Watershed Project did not include streams in the Lake Denoon sub-watershed. To date, there has been no streambank restoration work completed or planned within this project area except for work being done on the Muskego Canal. A summary of the streambank erosion is in Table 4-4.

Table 4-4: Stream Bank Erosion Summary

Sub-watershed	Degraded Stream Bank (ft)	Eroding Sediment (tons/yr)	Reduction Goal	Tons of Sediment Controlled
Linnie Lac	4700	39	72%	29
Big Muskego	4200	40	62%	25
Wind Lake	6250	25	33%	8
Totals	**15150**	**104**		**62**

Source: *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*

*Note: There is a discrepancy between the sub-watershed delineations in the Priority Watershed Report and this Plan. Half of the Canal West subbasin in the Priority Watershed report actually goes into Big Muskego Lake rather than into Wind Lake.

CONSTRUCTION SITE EROSION

An estimate of the amount of construction site erosion was calculated by estimating the amount of land that will be undergoing development and using a typical construction site erosion rate. The amount of land that will undergo development was estimated by comparing the developed land areas for existing and future land uses as presented in Chapter 3. It is estimated that 2,558 acres will be converted from agricultural, open space, and woodland land uses to a developed condition, primarily residential land use. It was assumed that this would occur over 14 years from 1996 to 2010.

A typical construction site erosion rate for an unmanaged site is 30 tons/acre/year. This rate is commonly used in similar studies by WDNR's Nonpoint Source Pollution Abatement Program. A typical reduction in sediment runoff from a well-managed site may be 75 percent. In addition, not all of the eroded sediment will reach a water body, although the delivery ratio for a construction site will be much greater than that for agricultural land (because the streets and channel systems of a development provide an efficient method of conveying runoff to a downstream water body). Given that there is currently some management for construction site erosion and not all sediment is delivered to the receiving waters, it was assumed that there is a 50 percent reduction in construction site sediment loading before it reaches a water body. Construction site sediment loading calculations are presented below.

Table 4-5: Estimated Construction Site Erosion

Total Developing Area (acres) *	Erosion Rate (tons/acre)	Annual Rate (tons/acre/year)	Annual Rate with 50% Control
2,558	30	5,481	2,741

* between 1996 and 2010

SUMMARY OF ANALYSES OF LOADINGS BY LAND USE

Tables 4-6 and 4-7 compare the results of the nonpoint source pollution loading for 1996 and future land use conditions. Agricultural land uses account for the majority of the sediment and phosphorus loadings because agriculture accounts for the majority of the land use in the project area. Under 1996 conditions, agricultural land uses contribute the majority of the sediment and phosphorus (93 percent and 80 percent respectively). Under future conditions, these agricultural land use contributions are reduced (81 percent for sediment and 56 percent for phosphorus). Heavy metal (zinc) loadings are exclusively from urban land use areas, since agriculture contributes only very small amounts of heavy metals in runoff.

Table 4-6: Nonpoint Pollution Loadings Under 1996 Conditions

	Area		Sediment Load		Phosphorus Load		Lead Load		Zinc Load	
Land Use	acres	%	Tns/Yr	%	Lbs/Yr	%	Lbs/Yr	%	Lbs/Yr	%
Agricultural	5,669	45.6%	1,393	92.6%	4,517	79.9%	0	0.0%	0	0.0%
Commercial	16	0.1%	7	0.5%	29	0.5%	49	13.6%	21	2.7%
Highway	3	0.0%	1	0.1%	4	0.1%	12	3.4%	6	0.7%

Table 4-6: Nonpoint Pollution Loadings Under 1996 Conditions

Land Use	Area		Sediment Load		Phosphorus Load		Lead Load		Zinc Load	
	acres	%	Tns/Yr	%	Lbs/Yr	%	Lbs/Yr	%	Lbs/Yr	%
Industrial	26	0.2%	9	0.6%	73	1.3%	17	4.7%	26	3.3%
Institutional	97	0.8%	19	1.3%	149	2.6%	47	13.1%	98	12.3%
Low Density Residential	1,179	9.5%	41	2.7%	463	8.2%	104	28.8%	370	46.5%
Medium Density Residential	818	6.6%	30	2.0%	340	6.0%	118	32.7%	275	34.5%
Landfill	217	1.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Open Land	1,677	13.5%	3	0.2%	50	0.9%	0	0.0%	0	0.0%
Open Water	33	0.3%	0	0.0%	0	0%	0	0.0%	0	0.0%
Wetland	1,695	13.6%	0	0.0%	0	0%	0	0.0%	0	0.0%
Woodland	1,017	8.2%	2	0.1%	31	0.5%	5	1.4%	0	0.0%
Totals	**12,446**		**1,504**		**5,656**		**347**		**796**	

Table 4-7: Nonpoint Pollution Loadings Under Future Land Use Conditions

Land Use	Area		Sediment Load		Phosphorus Load		Lead Load		Zinc Load	
	acres	%	Tns/Yr	%	Lbs/Yr	%	Lbs/Yr	%	Lbs/Yr	%
Agricultural	3,950	31.7%	1,036	80.4%	2,222	51.6%	0	0.0%	0	0.0%
Commercial	76	0.6%	35	2.7%	138	2.7%	235	28.6%	103	6.9%
Highway	3	0.0%	1	0.1%	4	0.1%	12	1.5%	6	0.4%
Industrial	200	1.6%	68	5.1%	495	9.9%	135	16.5%	193	12.9%
Institutional	164	1.3%	25	1.9%	221	4.4%	63	7.7%	142	9.5%
Low Density Residential	2,579	20.7%	71	5.3%	793	15.8%	183	22.3%	630	42.1%
Medium Density Residential	1,671	13.4%	48	3.6%	522	10.4%	183	22.3%	423	28.3%
Landfill	215	1.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Open Land	1,240	10.0%	2	0.1%	37	0.7%	0	0.0%	0	0.0%
Open Water	30	0.2%	0	0.0%	0	0%	0	0.0%	0	0.0%
Wetland	1,755	14.1%	0	0.0%	0	0%	0	0.0%	0	0.0%
Woodland	562	4.5%	1	0.1%	17	0.3%	0	0.0%	0	0.0%
Totals	**12,446**		**1,287**		**4,448**		**811**		**1,497**	

The changes in pollutant loadings from 1996 to future conditions should be noted. Sediment loadings (even assuming no additional storm water management measures are put in place) will decrease in the project area from a rate of 1,504 tons/year to 1,287 tons/year. This is because of the conversion of agricultural lands to urban developments. The urban land uses will actually result in less sediment loading on a "per acre" basis than the agricultural lands. On the other hand, heavy metal loadings will increase in the future. Heavy metals in storm water are generally the result of increased urban activities such as automobile and truck traffic.

SUMMARY OF NONPOINT SOURCE POLLUTION LOADINGS

A summary of annual nonpoint pollution loadings from agricultural runoff, non-agricultural runoff, construction site erosion, and streambank erosion is presented in Table 4-8. By far the greatest source of sediment is from construction site erosion at 63 percent of the total and then agricultural runoff providing 32 percent of sediment.

Table 4-8: Summary of Nonpoint Source Pollution Loadings

Nonpoint Pollution Source	Annual Sediment Loading (tons/yr)	Percentage of Loading
Agricultural runoff	1,393	32.0%
Non-agricultural runoff	111	2.6%
Construction site erosion	2,741	63.0%
Stream bank erosion	104	2.4%
Total	**4,349**	**100.0%**

IDENTIFYING CRITICAL NONPOINT SOURCE POLLUTION SUBBASINS

Introduction

The entire Muskego project area was divided into 65 small drainage areas (called subbasins). A subbasin is an area from which rainfall flows off the surface to a single point (or outlet). The subbasins for the Muskego project range in size from 5.1 to 889 acres with an average size of 196 acres. The project was divided into subbasins so that the hydrologic (quantity of the runoff) and nonpoint source pollution (quality of the runoff) could be more accurately analyzed, and problems identified.

Identifying Critical Source of Nonpoint Pollution

1. The Source Loading and Management Model (SLAMM) is a computer model that calculates the amount of pollution in the runoff from a land area. The model calculates a "pollutant load" from each subbasin. A pollutant load is an amount of pollution in the runoff measured as a quantity (such as tons or pounds) over a period of time (such as a year). For example: a pollutant load of 10 tons of sediment per year is the amount of sediment contained in the runoff from an average year's rainfall, from a specific land area.

   The model was run on each of the 65 subbasins for 1996 and future land use conditions. Pollutant loads were calculated for sediment, phosphorus, lead, and zinc.

   SLAMM was not used for calculating pollution amounts from agricultural cropland areas. SLAMM is not designed for application to this land use. Sediment loads from croplands were estimated based on cropland data collected during the development of the Muskego-Wind Lakes Priority Watershed Plan. Pollutant loads for each of the major drainage areas are presented in Tables 4-9.

2. The 65 subbasins were grouped by their lake's respective drainage areas (four drainage areas in all). Each of the subbasins within the four drainage areas were ranked (from high to low) by their annual future sediment pollutant load rate (for example: a 10-acre subbasin with a sediment load of 2.5 tons/year has a "unit" load of 0.25 tons/acre/year). Sediment was chosen as the representative pollutant because: (a) SLAMM most accurately predicts this pollutant compared to the other pollutants; (b) many other pollutants (including phosphorus, lead, and zinc) attach to sediment particles, or are in a particulate form; (c) much of the land use is agricultural, which does not typically generate zinc and lead; and (d) management practices that control sediment will also control the other attached pollutants.

3. Critical subbasins were those higher ranked subbasins, which, if treated, resulted in the achievement of the project's pollution reduction goals. The assumed treatment efficiency was 80 percent, typical for wet detention ponds. The results of these rankings are in Tables 4-10, 4-11, 4-12, and 4-13. The higher ranked subbasins in bold are the critical basins. The nonpoint source pollution reduction goals for this project were established in the priority watershed plan *(A Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed*, 1993). The goals as stated in the plan are to reduce annual sediment and phosphorus levels by the amounts listed in Table 2-1. Final identification of reduction needs of heavy metals for each of the lakes will have to be evaluated for individual storm sewer pipes. Surface drainage outfalls will have to be evaluated on a case-by-case basis during project implementation.

CHAPTER 5

ANALYSIS OF POTENTIAL MANAGEMENT PRACTICES AND RECOMMENDATIONS

INTRODUCTION

Several storm water management systems were analyzed as part of the Phase 2 study. The systems consisted of several best management practices (BMPs) located throughout the project area. Each management system analyzed for this project is described below and the approximate locations of the BMPs are shown on Figure 5-1 (in the map pocket at the end of this document). Table 5-1 summarizes the effectiveness of each structural system for each lake basin and the associated costs. It should be noted that due to anticipated conversion of agricultural lands to residential lands, future baseline sediment loads will be reduced from present levels. Furthermore, Table 5-1 takes into account these reductions when computing the overall pollutant load reduction for each system presented. Pollutant load reductions are calculated based on the receiving lake. The costs indicated in Table 5-1 include construction and engineering/design estimates and are representative of planning level costs only. Except for the costs associated with "System 5," (streambank buffer strips) land acquisition costs are not included in the Table 5-1 cost estimates.

Each storm water management system is discussed in detail below. System 1 is considered a "baseline" level of action as well as a requirement of the City's proposed storm water ordinance. It was found that the sediment and phosphorus reduction goals for each of the lakes could not be achieved by implementing System 1 alone. However, by implementing other Systems, *in addition to* the recommendations of System 1, it is more likely that these goals will be achieved.

DESCRIPTION OF STRUCTURAL STORM WATER MANAGEMENT SYSTEMS

Wet Detention Ponds on New Development for Peak Flow and Water Quality Control

System 1 - "Baseline" Requirement

System 1 requires the construction of wet storm water detention basins and water quality ponds associated with all new urban development (in compliance with the City's proposed storm water ordinance). Projected locations and sizes of such detention basins were based on projected future additions of urban land uses as shown in Figure 3-5. Subbasins requiring ponds based on future projected urban land growth are depicted in Figure 5-1. The ponds were sized both to remove pollutants and to reduce peak flood flows.

Wet detention ponds are sized based on the type and extent of land uses in the watershed which they serve (Pitt, 1993). Design criteria for the combination detention/water quality ponds are consistent with those described in the *Wisconsin Storm Water Manual* and include a permanent pool depth ranging from 3 to 8 feet. Wet detention pond sizes were calculated for settling the five-micron sediment particle. It was assumed that a properly sized wet detention pond has a treatment efficiency of 80 percent for sediment and 60 percent for phosphorus. In accordance with the new storm water ordinance, the detention ponds were sized to reduce the 100-year peak flow *after* development to the 2-year peak flow under *natural* land use conditions.

Table 5-2 indicates the recommended pond locations by subbasin and the required detention volume and water quality surface area. As can be seen from the table, water quality design goals can be achieved with minimal pond areas while storm water ordinance based volume control goals require significantly larger pond areas. The costs in Table 5-1 for System 1 represent the total cost to the developer for the construction of ponds in every basin that will undergo future development. Given the planning level nature of this document, it is difficult to predict the exact location and hence the exact number of ponds that will ultimately be constructed in each developing basin. Therefore, the total pond area required to handle storm water runoff from the future developed lands, *in total*, was calculated for each subbasin (see Table 5-2). Within the entire Phase 2 project area, a total of 247 acres of detention area is needed (assuming a maximum storage depth of 5 feet is available). The costs for these ponds were estimated by first calculating the cost of a single 5-acre pond with 5 feet of storage above the permanent pool. This cost, including construction elements such as site clearing, excavation, inlet/outlet structures and engineering fees, is estimated at $344,000. To estimate the cost of constructing ponds necessary to handle the peak flows from all future developed lands, the cost of the 5-acre pond was broken down into a cost per pond acre and then multiplied by the total number of required pond acres. This cost is presented in Table 5-1.

An alternative and perhaps more useful way to address these costs is to provide an estimate of the pond costs for a typical 40-acre, single family residential development. Within the Phase II project area, there are several subbasins that anticipate future development in the 40-acre range. For these subbasins, the cost to the developer ranges from approximately $160,000 to $590,000. The reasons for the variability in costs include differences in slopes, soils, and times of concentrations for the subbasins in question.

TABLE 5-1
Comparison of Management Approaches for Pollution Reduction
City of Muskego Storm Water Management Plan - Phase II

			System 1	System 2	System 3	System 4	System 5
	1996 Base Conditions	Future Conditions	Implement Ordinance	M3 Det. Pond & System 1	M68 Wetland & System 1	Gravel Pit Pond & System 1	Buffer Strips & System 1
Big Muskego							
Annual Sediment Load (tns/yr)	919	811	730				678
% Change		-12%	-21%				-26%
Annual Phosphorus Load (lbs/yr)	2,179	1,924	1,432				1,177
% Change		-12%	-34%				-46%
Lake Denoon							
Annual Sediment Load (tns/yr)	74	60	57	31			55
% Change		-19%	-23%	-58%			-26%
Annual Phosphorus Load (lbs/yr)	471	387	364	244			353
% Change		-18%	-23%	-48%			-25%
Linnie Lac							
Annual Sediment Load (tns/yr)	133	95	73			39	
% Change		-29%	-45%			-71%	
Annual Phosphorus Load (lbs/yr)	573	409	241			130	
% Change		-29%	-58%			-77%	
Wind Lake							
Annual Sediment Load (tns/yr)	379	321	303		131		258
% Change		-15%	-20%		-65%		-32%
Annual Phosphorus Load (lbs/yr)	2,432	2,058	1,938		1,111		1,716
% Change		-15%	-20%		-54%		-29%
Project Area							
Annual Sediment Load (tns/yr)	1,505	1,287	1,163				
Annual Phosphorus Load (lbs/yr)	5,655	4,778	3,975				
Capital Costs			**$17,000,000 (1)**	**$174,400**	**$172,400**	**$248,846**	**$1,509,000 (2)**
Annual Operation & Maintenance			**$170,000**	**$8,720**	**$8,620**	**$12,442**	**$39,150**

(1) This cost will be paid by the developer and not by the City of Muskego. Average cost per acre of pond is $68,800. The cost of ponds associated with a typical 40 acres, single family residential development ranges from approximately $160,000 to $590,000. The reasons for the variability in costs is because of differences in slopes, soils, and times of concentrations for the subbasins analyzed

(2) Cost shown for purchase of buffer strip option; annual land rental costs are estimated to be $22,600

TABLE 5-2

Structural Management Estimates
To Control Storm Water From Future Land Developments

Big Muskego Lake Basin				
Pond Location	Total Basin Area (acres)	Future Developed Area Over Baseline Conditions (acres)	Water Quality Pond Area (Permanent Pool, in acres)	Pond Area Needed to Store Required Volume (acres) *3*
M10	252	160.4	1.3	9.1
M35	1027	132.8	2.7	43.6
M54	104	85.5	1.1	5.4
M55	98	54.4	0.4	4.9
M57	830	22.6	0.2	33.7
M65	130	32.8	0.3	3.8
M78	149	171.4	1.4	5.1
M79	40	39.5	0.7	2.3
M80	52	142.7	1.1	6.0
M83	128	158.0	1.3	*1*
M85	460	231.0	1.8	19.5
Basin Totals		**1231.1**	**12.2**	**133.4**
Lake Denoon Basin				
Pond Location	Total Basin Area (acres)	Future Developed Area Over Baseline Conditions (acres)	Water Quality Pond Area (Permanent Pool, in acres)	Pond Area Needed to Store Required Volume (acres) *3*
M58	196	55.5	0.4	8.7
M60	196	37.4	0.3	8.6
Basin Totals		**92.9**	**0.7**	**17.3**
Linne Lac Basin				
Pond Location	Total Basin Area (acres)	Future Developed Area Over Baseline Conditions (acres)	Water Quality Pond Area (Permanent Pool, in acres)	Pond Area Needed to Store Required Volume (acres) *3*
M27	223	221.9	1.9	9.6
M29	151	144.6	1.2	*2*
M30	48	31.7	0.4	2.5
M31	882	497.1	5.7	38.9
Basin Totals		**895.3**	**9.1**	**51.0**
Wind Lake Basin				
Pond Location	Total Basin Area (acres)	Future Developed Area Over Baseline Conditions (acres)	Water Quality Pond Area (Permanent Pool, in acres)	Pond Area Needed to Store Required Volume (acres) *3*
M68	474	51.4	0.4	*1*
M7	798	158.0	1.5	22.0
N12	181	126.0	1.3	7.8
Basin Totals		**335.3**	**3.2**	**29.8**

1 Storm water runoff from these basins is direct runoff to the lakes. Volume control would be of little value in these situations and has, therefore, not been evaluated.

2 There is a gravel pit in this basin.

3 Assumes maximum storage depth of 5 feet above permanent pool.

Regional Treatment Facilities

Systems 2, 3, and 4

Three Systems for regional treatment facilities were evaluated, each in conjunction with the detention pond component of System 1. These ponds would receive runoff from a variety of land uses including agriculture. The first regional facility, System 2, would include a regional water quality pond in subbasin M3 (tributary to Lake Denoon). Subbasin M3 has the highest sediment load of all subbasins contributing to Lake Denoon. This regional facility would further address the pollutant loadings associated with the agricultural land north of Kelsey Road.

The Wind Lake District is beginning implementation of System 3. This System is a constructed wetland treatment system tributary to Wind Lake in subbasin M68. As designed, the wetland system receives the outflow from Big Muskego Lake and reduces the nutrient content by the bio-filtration action of the constructed wetlands. At this time, the land has been purchased for the wetland treatment system and this control practice is in the planning phase.

In addition to treating the outflow from Big Muskego Lake, the wetland system will be designed to treat the agricultural runoff from the M68 subbasin. Subbasin M68 has the highest sediment load of all subbasins (within the project area) contributing to Wind Lake. The modified constructed wetland treatment system, as proposed, is a *surface flow* wetland. Pollutant removal rates are not as well demonstrated as with wet detention ponds, but there is evidence that they may be more effective at removing dissolved phosphorus than wet detention ponds. It is assumed that a properly designed constructed wetland treatment system has similar treatment efficiency as a wet detention pond with removals of 80 percent for sediment and 60 percent for phosphorus.

The third regional facility, System 4, includes a large detention pond created from quarry pits tributary to Linnie Lac Lake in subbasin M29. Drainage from subbasin M31, which contributes the highest sediment load to Linne Lac Lake, would be treated in this regional facility. This system proposes to incorporate the ponds created by the existing gravel quarry for a future water quality basin. The potential for this recommendation is totally dependent on the long-term operations of the gravel pit and the potential for public ownership of the property in the future.

Approximate locations of the regional facilities are shown in Figure 5-1 (in the map pocket at the end of this document).

Streambank Buffer Strips

System 5

Streambank buffer strips are thickly vegetated riparian areas next to drainageways which trap sediment and other pollutants associated with storm water runoff. Potential areas for buffer strips were identified with the use of air photos and USGS quad maps. To qualify as a buffer strip, the area must be along a defined channel identified on a USGS 1:24,000 topographic map. These buffer strip segments and their estimated pollutant reductions are described in Table 5-3 and are shown in Figure 5-1 in the map pocket.

Assumptions for streambank buffer strip quantities, costs, and pollution removal efficiencies included:

- Average annual unit area phosphorus load from agricultural lands equal 0.55 pounds/acre/year; sediment load of 0.10 tons/acre/year (values represent average of median values presented in USGS

Fact Sheet FS-19-97 for rural lands in southeastern Wisconsin);

- lands contributing runoff to buffer zone does not exceed 400 feet of overland flow; thus: contributing area = (length of buffer) x (400 feet) x (number of sides buffer is on) [Note: the buffer is assumed to be on both sides of channels in all cases];
- Buffer zones are 100 feet wide on each side of the drainageway;
- Buffer zone lands (once they are converted from agricultural lands) contribute no sediment or phosphorus;
- Phosphorus loads from the contributing area is reduced by 60 percent and sediment loads by 70 percent (lowest values reported by Castelle, 1994);
- Costs were estimated based on a combined land rental and maintenance cost of $150/acre/year. Maintenance costs include periodic mowing to prevent overgrowth of grasses and woody debris by shrubs and trees. It was assumed that the initial cost of vegetative establishment along the buffer strips would be nominal. A second set of costs was based on the purchase of the buffer strip land at an average cost of $10,000 per acre.

Table 5-3: Pollutant Reductions from Buffer Strips

Subbasin I.D.	Stream Length for Buffers (ft)	Buffer Area (acres)	Buffer Tributary Area (acres)	Sediment Removed (tons/yr)	Phosphorus Removed (lbs/yr)	Buffer Cost Land Rental ($/yr)	Buffer Costs Land Purchase ($)
M6	2,250	10.3	41.3	3.9	19.3	$1,550	$103,306
M7	7,700	35.4	141.4	13.4	66.1	$5,303	$353,535
M7A	1,450	6.7	26.6	2.5	12.4	$999	$66,575
M8	1,700	7.8	31.2	3.0	14.6	$1,171	$78,053
M15	1,750	8.0	32.1	3.1	15.0	$1,205	$80,349
M34	7,950	36.5	146.0	13.9	68.3	$5,475	$365,014
M35	5,650	25.9	103.8	9.9	48.5	$3,891	$259,412
M57	6,300	28.9	115.7	11.0	54.1	$4,339	$289,256
M65	1,150	5.3	21.1	2.0	9.9	$792	$52,801
M78	1,350	6.2	24.8	2.4	11.6	$930	$61,983
Big Muskego Lake Subtotal	**37,250**	**171**	**684**	**65**	**320**	**$25,654**	**$1,710,285**
M3	1,560	7.2	28.7	2.7	13.4	$1,074	$71,625
M58	1,200	5.5	22.0	2.1	10.3	$826	$55,096
Lake Denoon Subtotal	**2,760**	**12.7**	**50.7**	**5**	**24**	**1,901**	**$126,722**
M68	2,950	13.5	54.2	5.1	25.3	$2,032	$135,445
N12	800	3.7	14.7	1.4	6.9	$551	$36,731
N15	1,600	7.3	29.4	2.8	13.7	$1,102	$73,462
N16	600	2.8	11.0	1.0	5.2	$413	$27,548
Wind Lake Subtotal	**5,950**	**27.3**	**109.3**	**10**	**51**	**4,098**	**$273,186**
Totals:	**45,960**	**211.0**	**844.1**	**80.2**	**394.6**	**$31,653**	**$2,110,193**

RECOMMENDATIONS

Several recommendations were analyzed with respect to meeting the project goals outlined in Chapter 2 of this document. The object of the recommendations presented here is to meet the pollutant reduction goals outlined in the *Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project*. While it is not possible to meet all of the goals for each of the lakes, the recommendations outlined below contribute significantly to attaining the goals.

Recommended Nonstructural Measures

Given the rural characteristics of the Phase 2 project area and the future projected land uses, some types of non-structural BMPs, such as street sweeping and catch basin cleaning, are not applicable. However, there are several non-structural management practices that can be implemented within the Phase 2 project area that will help in improving the overall quality of storm water runoff. These recommended practices are described below. With the exception of improved tillage methods, quantifiable pollutant reduction levels are inherently difficult to estimate for these types of non-structural BMPs and have therefore not been estimated.

Improved Tillage Methods

In general, there has been an improvement in tillage practices in the project area. Landowner participation in sign-ups for tillage reduction measures under the Muskego-Wind Lakes Priority Watershed Project has resulted in an annual reduction of 53 tons of sediment and 172 pounds of phosphorus in the project area. From discussions with the Waukesha County Land Conservation Department, only minor additional gains are expected in the near future under this program. However, continuing the practices adopted in this program will allow these annual sediment reductions to be realized for the future.

Adoption of Storm Water Management Ordinance

The Muskego Storm Water Advisory Committee prepared and approved a draft Storm Water Management Ordinance that requires new developments to provide peak flow detention control and nonpoint source pollution control. The draft ordinance mandates that peak flow from developed lands during the 100-year storm shall not exceed the 2-year pre-development peak flow. Storm water quality is also protected by this ordinance by requiring an 80 percent reduction in the total suspended solids load from the proposed development when compared to the same development without storm water management measures. At the time of this report, the ordinance was under final review by the City Attorney as well as the full Storm Water Advisory Committee and awaits review and approval by the City Council. If adopted, this ordinance may be the single most important aspect of the Storm Water Management Plan, as it enables the City to manage the ongoing issues of storm water quality and peak flows. Furthermore, it provides a vehicle through which the City can better achieve the pollutant reduction goals as outlined in *the Nonpoint Source Control Plan for the Muskego-Wind Lakes Priority Watershed Project.*

In the interim, the City should continue to vigorously enforce the current construction erosion control ordinance. The existing ordinance provides adequate authority to control sediment from construction sites; however, consistent compliance with the ordinance requires a high level of site inspection. Plat reviews for developments within and outside of the City (within the Town of Norway where erosion may impact storm water conveyance systems or water resources within the City), should have an erosion control plan as a plat review requirement. The recommendation may require additional funding to support an increased inspection schedule.

Operation, Maintenance, and Retrofitting of the Existing Storm Water Conveyance System

Even though the Phase 2 project area is predominantly agricultural lands, maintenance of the existing storm water conveyance system should be carried out on a routine basis. Swales, ditches, and culverts within the City's jurisdiction should be inspected periodically to ensure that they are clear and free of debris, and the ditches are not eroding. This will minimize the risk of localized flooding should a large storm event occur. Additionally, a number of culverts previously identified in Chapter 4 are inadequate for handling a 10-year storm. Recommendations for modifications to these culverts are presented below.

Table 5-4 summarizes the recommended culvert replacements necessary to alleviate the flooding problems identified in Table 4-3. The culvert replacement recommendations were made on the basis that storm flow conveyed in existing culverts overtopped roads and threatened property in a 10-year storm event. The recommendations made in the table consist of replacing the existing culvert with a larger culvert capable of handling a larger storm flow. However, other options to consider include installing smaller, parallel culverts to those already in place, raising the road elevation in affected areas, additional storm water detention, or a combination of these options.

The recommended diameter of the replacement culverts outlined in Table 5-4 assumes that the slopes of the new culverts are the same as the current ones, and that the new culverts are made of corrugated metal pipe. The replacement size is based on the criteria of being able to handle the peak flows from the 10-year 12-hour rain storm. Conveying larger or more intense storms than the 10-year 12-hour storm may result in road flooding. However, the frequency of such occurrences is generally considered acceptable by most communities, particularly given the cost of retrofitting the storm sewer system to handle such larger infrequent events.

Table 5-4: Recommended Culvert Replacements

Pipe Location	Pipe I.D. #	Current Size (dia. in.)	Current Capacity (cfs)	10-yr. 12 hr Peak Flow (cfs)	Replacement		
					Size (dia. in.)	Length (ft)	Cost $ *
North of Henneberry Road	CM16	33	29.5	38.5	36	32	$1,800
South of Henneberry Road	CM15	30	17.5	36.2	48	37	$2,250
North of Kelsey Ave.	CM3	48	89	116.5	60	42	$3,700
South of 8 Mile Road	CM34	48	35.2	100	72	44	$9,750
East of Hwy 45	CM32	24	25	39.2	30	61	$2,650
NE corner of Hillendale & Janesville Roads	CM25	18	5.6	7.2	24	69	$2,100
West of Hillendale Road	CM22	18	7.7	10.7	24	31	$950
South of Hennebery Road east culvert	CM17	24	9.6	13	30	36	$1,560
West of Hillendale Road	CM20	27	15.4	22.6	30	31	$1,350
North of Muskego Dam Road	CN13	15	2	4.5	24	32	$980
West of Muskego Dam Road	CN16	36	9.1	46	48	47	$2,850

*costs were obtained from Wisconsin DOT Average Contract Unit Prices-Highway Construction (costs adjusted for 1998 dollars and include labor)

New developments in the City generally incorporate "curb and gutter" street drainage systems along with a storm sewer conveyance system. In the past, some areas of the City were developed with roadside swales, or ditches, as the primary storm water conveyance system. Each approach has advantages and disadvantages in their effect on storm water management. Some of these issues are summarized below.

Table 5-5: Comparison of Curb and Gutter System to Roadside Swale System

Curb and Gutter System	Roadside Swale System
1. higher initial construction costs	1. reduces velocity of storm water, and reduces peak flow of runoff
2. provides no pollution or flow attenuation (results in higher pollution loads and flows)	2. provides infiltration and filtration of storm water (pollution reduction)
3. often seen as "cleaner look"; "better aesthetics"	3. swales may collect litter, sediment, hold standing water
4. easier to incorporate sidewalks into the right of way	

From a strictly storm water management perspective, the roadside swale conveyance system provides improved control of peak flow, runoff volume, and nonpoint source pollution as compared to the curb and gutter system. The roadside swale system can generally reduce sediment pollution by 30 to 40 percent over the curb and gutter system based on SLAMM estimates. However, as noted above, the decision on the type of conveyance system to use is often based on factors in addition to the storm water management issue.

Public Information and Education

It is recommended that the City develop a public education and information program. Optimum use should be made of the information, strategies, and materials developed by the WDNR and the UW-Extension. The education program should focus on informing the public about practices that can be done around the home and in daily activities to reduce nonpoint source pollution. Preferably, the education/information program would be regional in nature. Whenever possible, the City should work with other area communities to educate the public on storm water issues.

Continued Application for Grants

It is recommended that the City continue to apply for Local Assistance Grants and Nonpoint Source Grants available through the WDNR to help finance the administrative, construction, and other implementation costs of the City's growing nonpoint source pollution control program. The purposes of these two types of grants and the extent of state participation are described in the next chapter.

Recommended Structural Measures

Nonstructural measures can be quite effective at reducing nonpoint source pollution and, in many cases, are preferred due to their low cost and low impact to the surroundings. However, in certain cases structural measures can be an efficient and cost-effective way to reduce nonpoint source pollution. The following is a summary of recommended structural measures for each major watershed within the project study area.

Subbasins: Big Muskego Lake

The storm water management recommendations for the Big Muskego Lake Subbasins are:

1. System 1 (implementation of ordinance for new development): A total of 133 acres of detention pond area will be required within the Big Muskego Lake watershed to meet the storm water management ordinance requirements in 11 subbasins predicted to undergo significant development in the future.

2. System 5: Streambank buffer strips are also recommended in ten selected subbasins (see Table 5-3). Approximately 111 acres of buffer strips would be created, protecting 24,150 feet of stream.

The combination of these systems within the Big Muskego Lake watershed will result in a 26 percent reduction in sediment load and a 46 percent reduction in phosphorus load. While these reductions do not meet the goals outlined in the *Nonpoint Source Control Plan*, they do achieve 67 percent of the sediment reduction goal and 67 percent of the phosphorus reduction goal. The costs of System 5 (streambank buffers) for the Big Muskego watershed are presented in Table 5-3.

Subbasins: Lake Denoon

The storm water management recommendations for the Lake Denoon Subbasins are:

1. System 1 (implementation of ordinance for new development): A total of 17.3 acres of detention pond area will be required within the Lake Denoon watershed to meet the storm water management ordinance requirements for future development in Subbasins M58 and M60

2. System 2: An additional 2.3-acre water quality pond is recommended for nonpoint pollution control from subbasin M3. As was previously mentioned, Subbasin M3 contributes the highest future sediment load to Lake Denoon and control of this load is therefore critical to achieving the pollution reduction goals outlined in the *Nonpoint Source Control Plan*.

3. System 5: Streambank buffer strips are also recommended for Subbasins M58 and M3. Subbasin M58 is already effectively buffered with the recently constructed middle school. The corridor along the stream is in a vegetated state. Streambank buffers in subbasin M3 (north of Kelsey Road) are also recommended. Buffer strips along this portion of the channel will enhance the effectiveness of the water quality pond (recommendation No. 2 above), and prolong the period between dredging of this pond.

4. Rehabilitation of Lake Meadows Subdivision Ponds: During the development of the Lake Meadows Subdivision (on the north side of Lake Denoon), three storm water management ponds were constructed to receive runoff from the residential area. These ponds are filled in with sediment and are no longer functional. One or more of the ponds should be restored to manage storm water from the subdivision to meet the standards of the draft storm water ordinance.

By implementing the recommendations above, a reduction of 58 percent in sediment load and 48 percent in phosphorus load to Lake Denoon can be achieved. The Lake Denoon watershed is not within the project area of the Muskego – Wind Lake Priority Watershed Project, and thus, there are no specified pollution reduction goals set for this watershed. The costs of System 2 are presented in Table 5-1.

Subbasins: Linnie Lac

The storm water management recommendations for the Linnie Lac Subbasins are:

1. System 1 (implementation of ordinance for new development): A total of 51 acres of detention pond area will be required within the Linnie Lac watershed to meet the storm water management ordinance requirements for future development in Subbasins M27, M29, M30, and M31.

2. System 4: This system utilizes the existing quarry pits for the development of a regional water quality pond. This pond could provide two functions: (1) to treat the nonpoint source pollution from upstream new developments where water quality ponds were not feasible and (2) to treat the nonpoint source pollution from existing developments and agricultural lands that will not be treated through enforcement of the proposed storm water ordinance. Depending upon the upstream water quality management practices, a pond at the quarry site may need to be up to 10 acres in size. Implementation of this recommendation is dependent upon acquisition of associated lands at a time when the existing quarry is no longer in operation. The quarry site is outside the corporate limits of Muskego; thus, an agreement with the City of New Berlin would likely be necessary.

Streambank buffer strips are not proposed for the Linnie Lac subbasins because most of the land is predicted to be developed under future conditions.

By implementing the recommendations listed above, a reduction of 71 percent in sediment load and 77 percent in phosphorus load can be achieved. These pollutant reductions exceed the sediment and phosphorus goals outlined in the *Nonpoint Source Control Plan*. It should be noted that these goals could not be achieved through System 1 alone. Therefore, the combination of recommended systems is the best way to achieve these goals. The costs of System 4 are presented in Table 5-1.

Subbasins: Wind Lake

The storm water management recommendations for the Wind Lake Subbasins are:

1. System 1 (implementation of ordinance for new development): A total of about 30 acres of detention pond area will be required within the Wind Lake watershed to meet the storm water management ordinance requirements for future development in Subbasins M7, M68, and N12.

2. System 3: The potential for modifying or expanding the existing Wind Lake wetland treatment system should be investigated for the purpose of treating surface runoff from Subbasin M68. A wetland or wet pond area of approximately 4.5 acres may be necessary to treat the subbasin's drainage area. Subbasin M68 is the highest pollutant-contributing subbasin to Wind Lake within the project area

3. System 5: Streambank buffer strips are also recommended in four selected subbasins (see Table 5-3). Approximately 27 acres of buffer strips would be created, protecting 5,950 feet of stream.

By combining these systems within this watershed, a reduction of 65 percent in sediment load and 54 percent in phosphorus load can be achieved. As was the case for the Lake Denoon watershed recommendations, Wind Lake watershed recommendations include specific treatment of agricultural runoff from subbasin M68. Subbasin M68 contributes the greatest sediment load of all the subbasins draining to Wind Lake, and its treatment is critical to the attainment of the pollutant reduction goals outlined in *the Nonpoint Source Control Plan*. Through the combination of Systems 1, 3, and 5, a reduction of 65 percent in sediment load and 54 percent in phosphorus load can be achieved. These pollutant reductions correspond to 114 percent of the sediment reduction goal and 74 percent of the phosphorus reduction goal as outlined in the *Nonpoint Source Control Plan*. The costs of System 3 are presented in Table 5-1.

CHAPTER 6

IMPLEMENTATION PLAN

This chapter establishes the schedule for the development and implementation of the recommendations detailed in Chapter 5. To be an effective storm water management plan, the following additional issues must be established:

- Implementation schedule (when);
- Agencies and/or entities having responsibility for the recommended measure (who);
- Financing options (how).

IMPLEMENTATION SCHEDULE

The recommendations laid out in Chapter 5 are important in terms of their contribution to nonpoint source pollution reduction, flood control, and solutions to other City storm water problems. However, some have priority over others. The prioritization of recommendations takes into account such items as:

- The time required to implement a recommendation and when it could be implemented.

- Funding sources: public sources may require up to a year to budget and award grant(s) for practice, design, and construction. In addition, state or federal funds that may be available to help fund certain recommendations may have limited time periods of availability.

- Final selection of BMP locations: the recommendations highlight several areas with high potential for siting a BMP. However, final siting of each BMP will depend on several factors that will need to be resolved by the responsible parties.

- Design and engineering services required to properly size and design the practice. This requires lead time before construction and installation of the BMP can begin.

Given the present uncertainty of funding availability, it is difficult to provide a specific timetable at this juncture. However, as funding becomes available, it is recommended that the City begin to implement the most cost-effective BMPs outlined in Chapter 5. Other factors, such as those listed above, may also impact the implementation of a proposed BMP. It is anticipated that the BMPs recommended for future developments will be designed, constructed, and funded at the time the new development occurs.

RESPONSIBLE PARTIES

The City of Muskego is the primary responsible party for implementing the recommendations of this plan. The City has the authority (or the ability to develop its own authority) to carry out all of the recommendations. Technical and financial assistance are available from outside sources for many of the recommendations; however, the City must take the initiative. Support from the City in terms of staff and funding is essential for the recommendations of this plan to be achieved.

Funding assistance for many of the water quality practices may be available through the Muskego-Wind Lakes Priority Watershed Project and/or through the Wisconsin Lake Management Protection Grant Program. In addition, WDNR and the UW-Extension are available to provide technical assistance and advice to the City on storm water management issues. Other agencies, such as SEWRPC, may also be contacted for special issues (such as design criteria and information/education ideas).

Table 6-1 summarizes the primary responsible parties for each recommendation.

Table 6-1: Table of Implementation Responsible Parties

Recommendation/BMP	**Task Description**	**Responsible Party(s)**			
		City	**WDNR or County**	**Private Developer**	**Engr. or Consult.**
Storm Water Ordinance & Construction Erosion (enforcement)	Development Administration Enforcement	◆ ◆ ◆	●	●	●
Information/Education Program	Development Funding Implementation	◆ ◆ ◆	● ● ●		●
Continuation of improved tillage methods	Administration Funding Design/Construction Maintenance	◆ ● ● ◆	● ● ●		
Replacement of flood-prone culverts	Administration Funding Design/Construction Maintenance	◆ ◆ ◆ ◆			 ●
Reconstruction of Lake Meadows Subdivision storm water ponds	Administration Funding Design/Construction Maintenance	◆ ◆ ◆ ◆	 ● ●		 ●
Operation & Maintenance of existing storm water conveyance system	Administration Funding Design/Construction Maintenance	◆ ◆ ◆ ◆			 ●
Construction of stream bank buffer strips	Administration Funding Design/Construction Maintenance	◆ ◆ ● ◆	 ● ●		 ●
Construction of regional detention pond in subbasin M3	Administration Funding Design/Construction Maintenance	◆ ◆ ◆ ◆	 ● ●		 ●
Construction of regional detention pond in subbasin M29 (quarry pit)	Administration Funding Design/Construction Maintenance	◆ ◆ ◆ ◆	 ● ●		 ●

"◆" means primary responsibility; "●" means secondary or shared responsibility

SOURCES OF FUNDING

There is a number of funding mechanisms that can be used to finance the recommendations of this Storm Water Management Plan. Most likely, a combination of private and public funds will be used for different recommendations. The non-structural recommendations are, for the most part, low cost, and the costs can be supported by the tenants of the project area. For example: support for construction erosion control inspection/enforcement can be partially or fully supported through a fee system for the erosion control permit. Structural practices may more appropriately be funded (partially or fully) by city, state, and/or private funds.

Table 6-2 contains a list of these funding options and a summary of the appropriate activities each funding source can be used for. These funding mechanisms can be used individually or in combination. At this time, the City of Muskego is funding its storm water management programs with general revenue funds that are supported through property taxes. As a result of this management plan, the City is considering a storm water management ordinance. This ordinance will require new developments to install storm water management measures at the expense of the developer. These costs likely will be reflected in the land and land development costs.

Table 6-2: Alternative Funding Methods for Storm Water Management Activities

Funding Alternative	Functional Program Elements		
	Storm Water Management Administration & BMP Design	Construction of BMPs and Infrastructure	Operation and Maintenance
Private Funds	◆	◆	◆
City General Funds	◆	◆	◆
State WDNR Grants	◆	◆	
Special Taxing District	◆	◆	◆
Fees/Permits	◆		
Penalties/Fines	◆	◆	
Bonds		◆	
Storm Water Utility	◆	◆	◆

Private Funds

Generally this source is most appropriate for new development storm water management measures. Two basic forms are discussed below.

Subdivision Exactions

As a condition of approval for development, the City can require the developer of a subdivision or large parcel to construct storm water management facilities and dedicate them to the City upon completion. In addition, developers could be required to donate drainage easements or other types of partial rights to the City for storm water management purposes. Thus, the developer would be responsible for funding the capital program while the City would be responsible for funding the operation and maintenance. A caution to this approach is that without a careful review process, the storm water facilities transferred to the City may not be properly designed or discharge from the facilities may aggravate downstream flooding problems. Specific design requirements and review are required to avoid these potential problems.

Fee-In-Lieu-Of

An alternative to requiring developers to construct storm water management facilities is to require payment of an initial "front-end" charge for the capital improvements needed to service their development. The charge would be representative of the development's storm water contribution (quantity and/or quality) to the regional facility in a drainage basin. A fee-in-lieu-of is a technique to generate the funding needed for capital improvements in a watershed. The term is derived from the case in which a developer is required to construct infrastructure, including storm water systems. Since construction of small-scale systems is not always advisable, particularly because of the problems associated with the acceptance of the operation and maintenance costs, the better choice may be a fee paid to the City to construct a larger system. The fee is the developer's share of the regional facility. Fee-in-lieu-of applies only within the City's jurisdiction

The collection of fee-in-lieu-of monies promotes the implementation of regional systems rather than small-scale individual systems. Larger storm water facilities are easier to maintain and can handle larger and/or more severe problems. However, developments may be delayed until sufficient funding is available and/or construction of the regional facility can be completed, unless developers commit to building or providing interim systems and/or solutions which either can be removed or incorporated into the regional system when it is finished. This approach does not provide funding for areas of the City that are already developed.

The storm water management ordinance under consideration by the City provides for this funding option by a developer, where the City deems this to be an appropriate approach.

City General Fund

In Muskego, funds for storm water management are provided from the General Fund. This source can be best considered a "bank" into which revenues are placed and from which most programs are funded. The major income source for the General Fund is ad valorem (property) taxes. This income is based primarily upon the assessed valuation of property within the City. This revenue source can be used for funding administration, renewal/replacement, construction, maintenance, and water quality monitoring. The negative aspect to this approach is that storm water management is funded on a year-to-year basis and long term planning is difficult. Also the storm water needs must "compete" with the other City service needs each year during the budget approval process.

In the City of Muskego, approximately 85 percent of the property value is from residential property with the remaining portion under other land uses. This proportion roughly indicates the sources of property tax revenue.

State (Department of Natural Resources) Grants

Grants are available through the WDNR to help local communities implement nonpoint source pollution control programs. These funds are available to the City of Muskego, because the City is located within the Muskego-Wind Lakes Priority Watershed. The watershed was designated so in 1991 under the Wisconsin Nonpoint Source Water Pollution Abatement Program. Two types of grants available through this program are Local Assistance Grants and Nonpoint Source Grants.

- Local Assistance Grants fund the local administrative costs for the implementation of the priority watershed projects. The state pays up to 100 percent of the cost of additional staff, professional services (such as designing structural BMPs), training, and travel expense.
- Nonpoint Source Grants provide financial help to construct nonpoint source pollution control practices. Nonpoint source grants require between 30 percent to 50 percent of the cost of the project to be paid by the local community. Part or all of the local share may be "in-kind" match.

The City has been involved in and received grants through this program since 1993. However, in recent years the program's budget constraints have significantly reduced the availability of funds.

Other potential state funding programs that may apply to the recommendations in this project are: Lake Management Protection Grants and the Stewardship Program. Both of these sources provide assistance for land acquisition for the purpose of improving water quality. The stream buffer recommendations may be eligible for these funding sources.

Special Taxing/Assessment Districts

Income from a special taxing district or special assessment district is generally dedicated to that district. That is, the area that is designated as "special" for a specifically defined need pays an additional tax or has an increased assessment. The funds from the additional tax or assessment are returned to that area. For example, if storm water management facilities are constructed to benefit a particular drainage basin within the City, then that area could be designated a special taxing district and an additional tax levy could be assigned to the property within the area. This approach requires additional City ordinances and administration.

Fees/Licenses/Permits

Funding from this source is generally limited to the cost of permit review and the inspection of construction. Other revenue sources must be utilized to finance other aspects of the storm water management program such as administration, operation and maintenance, and capital improvements.

Penalties and Fines

Similar to permit fees, penalties and fines are limited in scope. Such income can be placed in the General Fund; however, it may be more reasonable to use the fines to correct the violation or subsequent violations. This type of income could be used to help subsidize a comprehensive storm water management program but would not support the entire program.

Bonds

General obligation, revenue, or special assessment bonds are normally used by governments to pay for large capital improvement programs. Repayment of a bond is normally through the General Fund (i.e., ad valorem tax); however, special assessment district income, as well as utility revenues, can be used to pay the debt service. Bonds would allow large-scale capital improvement programs to be initiated when the facilities are needed rather than waiting until the funds are accumulated.

Storm Water Utility

Using revenues from a user charge system to fund storm water management programs is relatively new in Wisconsin. To date, several Wisconsin communities (including Appleton, Lake Delton, and West Allis) have adopted storm water utilities and are funding storm water management needs through this revenue source.

Like a wastewater or water utility, the storm water utility is user-oriented, with costs allocated according to the level of services received. The objective of the storm water utility is to develop a procedure that equitably allocates the cost of storm water management to landowners for which these services are provided. Payment for storm water management with user fees is still considered unusual by the general public. Another benefit of a utility is that properties which are designated tax exempt from property taxes (schools and churches for example) can be included in the fee structure and assessment of a storm water utility.

Fees are assessed based on the user's relative contribution to storm water runoff, or the potential for runoff. The greater the runoff and/or potential for runoff from a parcel, the greater the contribution to the storm water problem, and therefore the higher the assessed fee. Thus, each parcel of land within a municipality is assessed a fee based on its runoff characteristics. Rate structures have been adopted based on the following parcel factors: impervious area, land use, land area, and dwelling units. In Wisconsin, fees have been determined by the amount of impervious area per parcel. The storm water utility uses these factors to allocate the costs for providing services that meet the goals and objectives specified by the community. This shifts a community from a position of reaction to crises to one of pro-active management.

Generally, storm water utilities provide the most financial relief to single family property owners in communities with an even distribution of residential and developed non-residential land uses. Conversely, in communities such as Muskego, where the predominant land use is residential, funding from utility fees results in relatively little change in the cost to single family residential property owners.

The establishment of a storm water utility to generate revenue provides funding for administration, planning, operation and maintenance, renewal/replacement, capital improvements, and storm water monitoring. The income can also be used to pay the debt service for a storm water capital improvement program, thereby leveraging the utility's annual revenue into a major program.

CONCLUSIONS

This document sets out a comprehensive storm water management plan for the City of Muskego. Implementing the structural and non-structural recommendations will result in substantial compliance with the Muskego - Wind Lake Priority Watershed Project goals. Little Muskego Lake, Big Muskego Lake, and Bass Bay stand to gain the most in water quality benefits as a result of this plan's implementation. In addition, the water quality of Lake Denoon (which is outside of the Muskego-Wind Lakes Priority Watershed Project boundaries) will be maintained or improved through this plan's recommendations. Finally, the plan provides the City with most of the information necessary to comply with the WDNR NR216 storm water permit regulations.

The storm water management program recommended in this document is an ongoing process. Storm water management requires a long-term commitment to installing, maintaining, and repairing the physical infrastructure, and the continued monitoring of City activities to reduce nonpoint pollution.