Lake Fremont

Sub-Watershed Assessment

Prepared by:

Sherburne Soil & Water Conservation District

In partnership with

City of Zimmerman, MN

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Executive Summary

At 493 acres and with 5.32 miles of shoreline, Lake Fremont (DNR ID 71001600) is the largest developed recreation lake in Sherburne County, MN. Though it is large, the lake is almost entirely within the littoral (vegetated) zone with an average depth of 5.2 ft and a maximum depth of 8.0 ft. The lake is dotted with year-long and seasonal homes along its western, southern and southeastern shorelines while a seasonal road winds along the lake's north and northeast / east shorelines. This seasonal road separates the lake from several large wetlands, a county park, and rural housing developments and agricultural land. Lake Fremont is partially located within the City of Zimmerman as well as Livonia Township.

Lake Fremont has been known to exhibit abundant plant growth and the occasional algae bloom which at times reduces water clarity of the lake. In 2011, following two years of water quality monitoring through the Minnesota Pollution Control Agency's Intensive Watershed Monitoring program, the lake was found to not be meeting water quality standards and was listed on the State of Minnesota's impaired waterbodies list for excessive nutrient content. With the City of Zimmerman to enact street and water/sewer infrastructure repairs to the Lake Fremont area in the near future, city officials and Sherburne Soil and Water Conservation District staff discussed the possibility of utilizing a Sub-Watershed Analysis (SWA) study to assess possible stormwater treatment opportunities that could be incorporated during or after this construction.

The SWA study was undertaken in 2020. A SWA is intended to identify potential projects within a target area to improve the water quality of a defined receiving waterbody. These potential projects are often practices that are needed to be retrofit into existing developed landscapes. In this study, instead of aiming for a certain number of projects or achieving a certain cost budget, the focus is to identify feasible practices in specific locations then examine their cost efficiency compared to pollutant reduction. This this report, both the costs to install the practice and the estimated pollutant reduction are compared to determine the cost effectiveness (amount of pollutant removed per dollar spent).

The Lake Fremont watershed was delineated then further delineated into 26 sub-watersheds. Pollutant estimates for two parameters, Total Suspended Solids (TSS) and Total Phosphorus (TP) were estimated through the use of the environmental modeling program WinSLAMM, the Source Loading and Management Model for Windows. The model first was run using baseline conditions, which included existing stormwater or other Best Management Practices (BMPs). To minimize costs with the study, the model was not calibrated so can only be used as an estimation tool to provide relative information. Specific model inputs are detailed in Appendix A.

Following the initial modeling of all sub-watersheds, 14 of these sub-watersheds were determined priority areas for further analysis due to their high pollutant or water volume annual load, high load per acre, proximity to the receiving waterbody, and overall condition of the sub-watershed (are any retrofit opportunities available?). Staff from the City Zimmerman and Sherburne SWCD visited the sub-watersheds located within the city limits and, using aerial maps and on-the-ground observations, identified potential BMP locations. Sherburne SWCD conducted a separate visit to watershed areas outside the City of Zimmerman to further identify BMP potentials. In total, 40 potential projects were identified.

Costs associated with project design, administrative duties, construction, and operation and maintenance associated with these BMP types were estimated based upon the best available information. Cost data were assumed over a 30-year lifespan and compared against the model benefits (pollutant reduction) to rank projects according to a cost-benefit variable (cost-effectiveness). Although the highest ranked projects in this analysis should be considered for potential retrofit projects, it is acknowledged that other variables must be considered before implementation. Considerations for funding limitations, landowner interest, educational opportunity / visibility, site-specific feasibility and construction timing or other factors must be weighed prior to determining which retrofit projects to pursue.

Table 1 and Table 2 display the findings of this study, including the applicable potential stormwater retrofit options within the priority areas along with the BMP types, their pollutant reduction potential, overall cost and cost effectiveness. Table 1 lists each potential project in order of cost-effectiveness with respect to phosphorus, the pollutant of highest concern for Lake Fremont. Table 2 displays the BMP list within the multiple municipalities this watershed covers. The most cost-effective options are listed first, while lesser cost-effective options fall lower on the list.

Based upon WinSLAMM modeling, the 2,170 acre study area including 26 sub-watersheds contributes an estimated 228.75 acre-feet of runoff, 332 pounds of phosphorus, and 141,509 pounds of solids annually. Implementing all potential BMP practices within the 14 priority sub-watersheds would result in an estimated reduction of 36 lbs of phosphorus and 18,928 lbs of sediment, or nearly 11% of the annual load for these two pollutants. However, it is recognized that installing all of these recommendations is not feasible due to funding availability, site-specific detailed conditions, and participation of willing landowners. Instead, it is recommended that projects be pursued in order of cost effectiveness according to Tables 1 and 2 in order to achieve the greatest pollution reduction for the smallest amount of cost. Installation of projects in series will result in lower total treatment than the simple sum of treatment achieved by the individual projects due to treatment train effects. Reported treatment levels are depending upon optimal site selection and sizing. More detail about each project can be found in the catchment profile page of this report.

Finally, it should be noted that the cost estimates and pollution reduction estimates in this report are fine-tuned to be as accurate as possible; however, costs are estimated conservatively and pollutant reduction numbers may change based upon more detailed investigation. Site specific conditions, final BMP designs, fluctuations in material costs and bids from contractors will vary with any installed work. Users of this report should recognize that final numbers may vary from reported estimates here, but a scalable approach can be used when determining priority projects to pursue. In other words, in the priority ranking tables below the project costs and pollution reduction estimates may all be higher or lower, however the end costs should impact each project similarly so the higher ranking projects should still rank high given a different cost or pollutant reductions structure. Thus, this report should be considered a guidance tool for informed decision making on potential BMP retrofit projects.

Table 1. Ranked BMP summary from an assessment of Lake Fremont sub-watersheds. List includes BMP options within 14 of 26 sub-watershed areas. Table sorted by 30-year cost / lb. removal of total phosphorus. Note: VS = Vegetated Swale, RG = Rain Garden, HD = Hydrodynamic Device, FS = Filter Strip, IB = Infiltration Basin.

Project Rank	Sub-watershed	Project ID	Municipality	BMP Type	Volume Reduction (acft/yr)	TSS Reduction (lbs/yr)	TP Reduction (lbs/yr)	Project Cost	30-yr Avg Cost/1,000 lb-TSS	30-yr Avg Cost/lb-TP
1	10	10-2	Baldwin Township	1.35 ac FS	-	3,540	4.79	$4,247	$43	$32
2	10	10-1	Livonia Township	2.01 ac FS	-	2,705	3.64	$4,586	$60	$45
3	11	11-2	Livonia Township	1.06 ac FS	-	1,680	2.66	$4,100	$87	$55
4	16	16-1	Livonia Township	1.7 ac FS	-	1,991	2.70	$4,426	$79	$58
5	14	14-4	Livonia Township	1.08 ac FS	-	981	1.38	$4,111	$150	$107
6	14	14-2	Livonia Township	1,500 sqft IB	0.16	489	2.27	$33,120	$2,431	$524
7	19	19-1	Livonia Township	750 sqft RG	0.40	552	1.65	$28,860	$1,897	$635
8	16	16-2	Livonia Township	3,000 sqft IB	2.01	1,114	3.23	$63,120	$1,965	$678
9	21	21-3	City of Zimmerman	30 lnft VS	0.26	166	0.37	$5,220	$1,530	$696
10	14	14-1	Livonia Township	1,500 sqft IB	0.30	641	1.62	$33,120	$1,855	$734
11	22	22-3	City of Zimmerman	30 lnft VS	0.23	154	0.34	$5,220	$1,649	$747
12	24	24-3	City of Zimmerman	250 sqft RG	0.62	373	0.81	$15,860	$1,645	$762
13	14	14-3	Livonia Township	500 sqft RG	0.11	490	1.01	$22,360	$1,695	$822
14	24	24-2	City of Zimmerman	30 lnft VS	0.20	128	0.28	$5,220	$1,984	$898
15	20	20-3	City of Zimmerman	500 sqft RG	0.69	366	0.80	$22,360	$2,015	$923
16	14	14-5	Livonia Township	500 sqft RG	0.14	367	0.88	$22,360	$2,262	$944
17	21	21-1	City of Zimmerman	30 lnft VS	0.20	122	0.27	$5,220	$2,082	$944
18	4	4-1	Livonia Township	250 sqft RG	0.38	227	0.49	$15,860	$2,703	$1,245
19	21	21-2	City of Zimmerman	30 lnft VS	0.15	91	0.20	$5,220	$2,791	$1,283
20	20	20-4	City of Zimmerman	250 sqft RG	0.35	160	0.35	$15,860	$2,979	$1,364
21	1	1-4	City of Zimmerman	250 sqft RG	0.34	206	0.45	$15,860	$2,979	$1,364
22	14	14-6	Livonia Township	250 sqft RG	0.05	145	0.44	$15,860	$4,232	$1,395
23	23	23-1	City of Zimmerman	250 sqft RG	0.34	202	0.44	$15,860	$3,038	$1,395
24	20	20-1	City of Zimmerman	250 sqft RG	0.31	141	0.31	$15,860	$3,282	$1,497
25	22	22-1	City of Zimmerman	250 sqft RG + 30 lnft VS	0.36	219	0.49	$18,800	$3,377	$1,510
26	1	1-3	City of Zimmerman	250 sqft RG	0.31	186	0.40	$15,860	$3,299	$1,534
27	11	11-1	Livonia Township	250 sqft RG	0.21	173	0.38	$15,860	$3,547	$1,615
28	2	2-2	City of Zimmerman	250 sqft RG	0.25	148	0.32	$15,860	$4,146	$1,888
29	20	20-2	City of Zimmerman	250 sqft RG	0.21	78	0.17	$15,860	$4,949	$2,248
30	2	2-3	Livonia Township	250 sqft RG	0.21	123	0.27	$15,860	$4,989	$2,316
31	1	1-1	City of Zimmerman	4' HD + 30 lnft VS	0.33	227	0.50	$24,000	$5,441	$2,470
32	2	2-1	City of Zimmerman	250 sqft RG	0.16	96	0.21	$15,860	$6,392	$2,854
33	1	1-5	City of Zimmerman	250 sqft RG	0.15	86	0.19	$15,860	$7,136	$3,230
34	22	22-2	City of Zimmerman	4' HD	-	121	0.30	$19,440	$8,331	$3,327
35	22	22-4	City of Zimmerman	250 sqft RG	0.11	66	0.15	$15,860	$9,298	$4,232
36	1	1-2	City of Zimmerman	4' HD	-	68	0.22	$19,440	$14,824	$4,582
37	25	25-2	City of Zimmerman	4' HD	-	113	0.22	$19,440	$8,920	$4,603
38	24	24-1	City of Zimmerman	4' HD	-	78	0.18	$19,440	$12,923	$5,508
39	23	23-2	City of Zimmerman	4' HD	-	62	0.15	$19,440	$16,258	$6,545
40	25	25-1	City of Zimmerman	4' HD	-	53	0.13	$19,440	$19,019	$7,695

Table 2a. Ranked BMP summary from an assessment of Lake Fremont sub-watersheds, City of Zimmerman. Table sorted by 30-year cost / lb. removal of total phosphorus. Note: VS = Vegetated Swale, RG = Rain Garden, HD = Hydrodynamic Device, FS = Filter Strip, IB = Infiltration Basin.

City Project Rank	Sub-watershed	Project ID	Municipality	BMP Type	Volume Reduction (acft/yr)	TSS Reduction (lbs/yr)	TP Reduction (lbs/yr)	Project Cost	30-yr Avg Cost/1,000 lb-TSS	30-yr Avg Cost/lb-TP
1	21	21-3	City of Zimmerman	30 lnft VS	0.26	166	0.37	$5,220	$1,530	$696
2	22	22-3	City of Zimmerman	30 lnft VS	0.23	154	0.34	$5,220	$1,649	$747
3	24	24-3	City of Zimmerman	250 sqft RG	0.62	373	0.81	$15,860	$1,645	$762
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10	23	23-1	City of Zimmerman	250 sqft RG	0.34	202	0.44	$15,860	$3,038	$1,395
11	20	20-1	City of Zimmerman	250 sqft RG	0.31	141	0.31	$15,860	$3,282	$1,497
12	22	22-1	City of Zimmerman	250 sqft RG + 30 lnft VS	0.36	219	0.49	$18,800	$3,377	$1,510
13	1	1-3	City of Zimmerman	250 sqft RG	0.31	186	0.40	$15,860	$3,299	$1,534
14	2	2-2	City of Zimmerman	250 sqft RG	0.25	148	0.32	$15,860	$4,146	$1,888
15	20	20-2	City of Zimmerman	250 sqft RG	0.21	78	0.17	$15,860	$4,949	$2,248
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22	25	25-2	City of Zimmerman	4' HD	-	113	0.22	$19,440	$8,920	$4,603
23	24	24-1	City of Zimmerman	4' HD	-	78	0.18	$19,440	$12,923	$5,508
24	23	23-2	City of Zimmerman	4' HD	-	62	0.15	$19,440	$16,258	$6,545
25	25	25-1	City of Zimmerman	4' HD	-	53	0.13	$19,440	$19,019	$7,695

Table 2b. Ranked BMP summary from an assessment of Lake Fremont sub-watersheds, Baldwin and Livonia Townships. Table sorted by 30-year cost / lb. removal of total phosphorus. Note: VS = Vegetated Swale, RG = Rain Garden, HD = Hydrodynamic Device, FS = Filter Strip, IB = Infiltration Basin.

Township Project Rank	Sub-watershed	Project ID	Municipality	BMP Type	Volume Reduction (acft/yr)	TSS Reduction (lbs/yr)	TP Reduction (lbs/yr)	Project Cost	30-yr Avg Cost/1,000lb-TSS	30-yr Avg Cost/lb-TP
1	10	10-2	Baldwin Township	1.35 ac FS	-	3,540	4.79	$4,247	$43	$32
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5	14	14-4	Livonia Township	1.08 ac FS	-	981	1.38	$4,111	$150	$107
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8	16	16-2	Livonia Township	3,000 sqft IB	2.01	1,114	3.23	$63,120	$1,965	$678
9	14	14-1	Livonia Township	1,500 sqft IB	0.30	641	1.62	$33,120	$1,855	$734
10	14	14-3	Livonia Township	500 sqft RG	0.11	490	1.01	$22,360	$1,695	$822
11	14	14-5	Livonia Township	500 sqft RG	0.14	367	0.88	$22,360	$2,262	$944
12	4	4-1	Livonia Township	250 sqft RG	0.38	227	0.49	$15,860	$2,703	$1,245
13	14	14-6	Livonia Township	250 sqft RG	0.05	145	0.44	$15,860	$4,232	$1,395
14	11	11-1	Livonia Township	250 sqft RG	0.21	173	0.38	$15,860	$3,547	$1,615
15	2	2-3	Livonia Township	250 sqft RG	0.21	123	0.27	$15,860	$4,989	$2,316

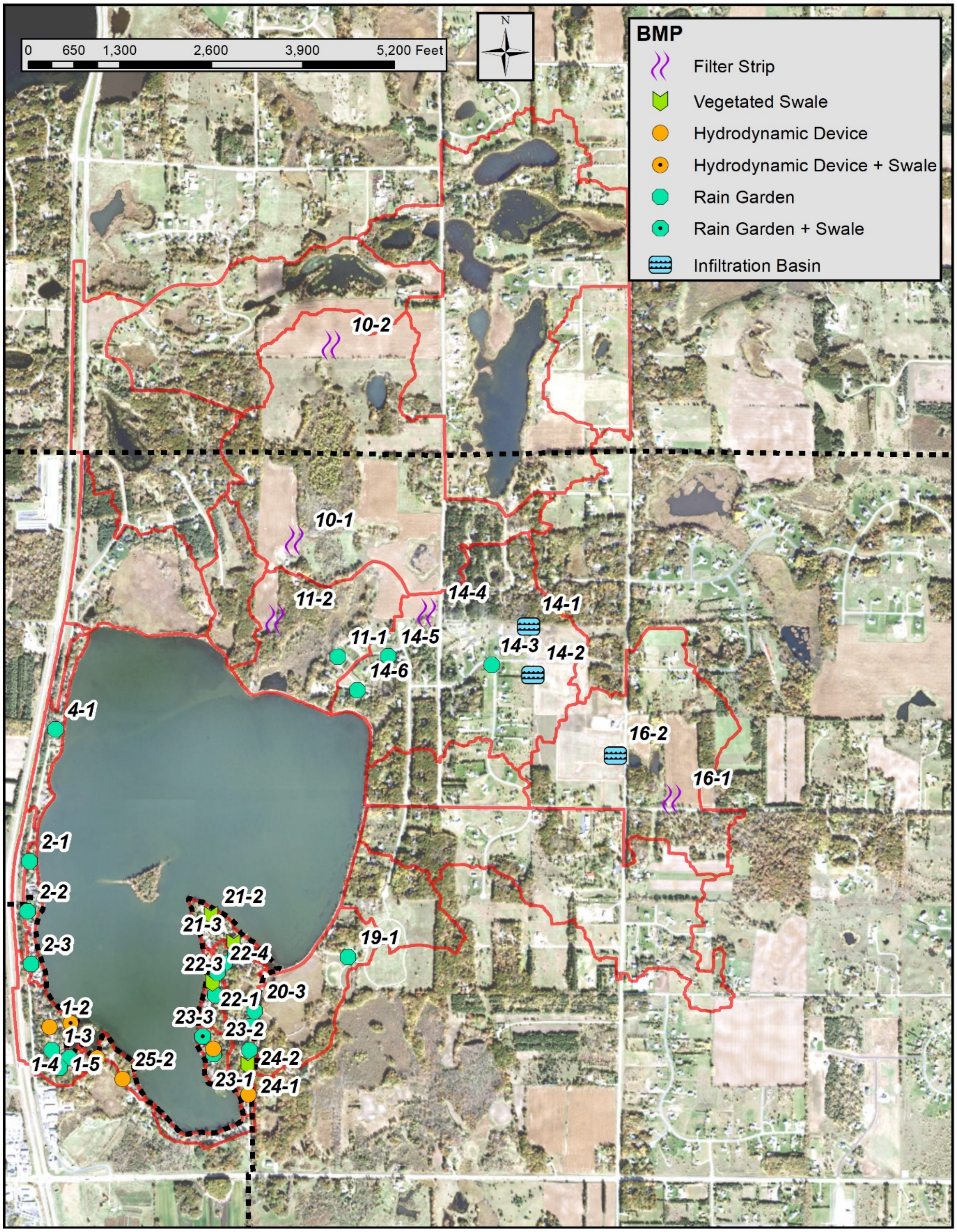


Figure 1. Map of BMP options identified and modeled within the Lake Fremont SWA.

Introduction

Many factors are considered when choosing which sub-watersheds to analyze for BMP retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Sub-watershed analyses supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the process also rank highly. For some communities a sub-watershed analysis complements their Municipal Separate Storm Sewer System (MS4) stormwater permit. The focus is always on a high priority waterbody.

Fremont Lake is one of the largest waterbodies in Sherburne County, Minnesota at approximately 493 acres in size. The lake is relatively shallow with an average depth of 5.2 feet and maximum of 8.0 feet. The watershed that drains to the lake consists of 2,176 acres of land – partially rural within the Township of Livonia, and partially urban within the City of Zimmerman. The lake's southern outlet drains into an unnamed ditch which eventually spills into Tibbets Brook, then the Elk River, and then into the Mississippi River just outside of the City of Elk River. Currently, Lake Fremont is on the State of Minnesota's impaired waterbodies list for holding excessive nutrient content which feeds abundant plant growth as well as mid and late summer algae blooms. Recently collected data from 2019 and 2020 suggests the lake's nutrient content, algae abundance, and water clarity is improving from the 2009 and 2010 conditions that resulted in its impaired listing status.

With the water quality in the lake improving and the City of Zimmerman soon undertaking a large-scale road construction project along the lake, city and SWCD staff began discussions in 2019 of assessing the landscape for potential BMP retrofit opportunities. Completing this assessment would allow for a better understanding of the priority sub-watersheds surrounding the lake, an opportunity for added BMP inclusion during upcoming road construction, and the foundation of targeted and prioritized analysis which is helpful for writing competitive grant applications for retrofit funding. The City of Zimmerman and Sherburne SWCD began this subwatershed analysis in early 2020.

Analytical Process and Elements

This sub-watershed analysis is a management tool that can help to identify and prioritize potential BMP retrofit projects by performance and cost-effectiveness. This tool helps to maximize the value of each dollar spent. The process used for this analysis is outlined in the following pages and was modified from the Center for Watershed Protection's Urban Stormwater Retrofit Practices, Manuals 2 and 3 (Schueler & Kitchell, 2005 and Schueler et al. 2007). Locally relevant design considerations were also incorporated into the process (Technical Documents, Minnesota Stormwater Manual, 2014).

Scoping includes determining the objectives of the retrofits (volume reduction, target pollutant, etc.) and the level of treatment desired. It involves meeting with local stormwater managers, city staff and other partners to determine the issues in the watershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to analyze in large subwatersheds, a focus area may be determined.

In this analysis, the focus areas first consisted of the 25 sub-watersheds draining towards Lake Fremont. Following additional research into these areas, the list was paired back to 15 sub-watersheds that were determined to have higher modeled pollutant loads as well as capacity for improvement. These watersheds include primarily urban lakeshore residence areas, suburban 1-2 acre lot areas, and limited rural agricultural or pasture/prairie land. Existing stormwater infrastructure maps, topography data, and direct observations of flow following rain events were used to determine drainage boundaries for the sub-watersheds included in this analysis. Stormwater infrastructure plans were provided by Bolton-Menk which aided in catchment delineation, existing treatment conditions and retrofit scoping.

The targeted pollutants for this study were TP and TSS, though volume was also estimated and reported as it is necessary for pollutant loading calculations and potential retrofit project considerations. Table 3 describes the target pollutants and their role in water quality degradation. Projects that effectively reduce loading of multiple target pollutants can provide greater immediate and long-term benefits.

It should be noted that although chloride is an emerging stormwater pollutant of concern, particularly in urban areas, this report does little to address it. Chloride dissolves readily in stormwater and is unable to be "treated" using traditional stormwater practices. In order to reduce chloride from reaching Lake Fremont, resources are best spent investigating ways to utilize "Smart Salting" technology and techniques which result in less road salt on area roads. Residential water softeners are an additional source of chloride to groundwater, so education and outreach on how to use these machines as efficiently as possible is encouraged.

Table 3: Target Pollutants

Total Phosphorus (TP)	Phosphorus is a nutrient essential to plant growth and is commonly the factor that limits the growth of plants in surface water bodies. TP is a combination of particulate phosphorus (PP), which is bound to sediment and organic debris, and dissolved phosphorus (DP), which is in solution and readily available for plant growth (active).
Total Suspended Solids (TSS)	Very small mineral and organic particles that can be dispersed into the water column due to turbulent mixing. TSS loading can create turbid and cloudy water conditions and carry with it TP. As such, reductions in TSS will also result in TP reductions.
Volume	Higher runoff volumes and velocities can carry greater amounts of TSS and TP to receiving water bodies. It can also exacerbate soil erosion, thereby increasing TSS and TP loading. As such, reductions in volume may reduce TSS loading and, by extension, TP loading.

Desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that do not need to be analyzed because of existing stormwater treatment or disconnection from the target water body. Accurate GIS data are extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography (Light Detection and Ranging [LiDAR] was used for this analysis), surface hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and the stormwater drainage infrastructure.

Field investigation is conducted after potential retrofits are identified in the desktop analysis to evaluate each site and identify additional opportunities. During the investigation, the drainage area and surface stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search. As part of the field investigation for this study, Sherburne SWCD staff visited the area following a ~1 inch event in spring 2020 to determine flow paths in several questionable areas. A small scale culvert survey was also conducted to feed these routing structures into the GIS watershed delineation system.

Modeling involves assessing multiple scenarios to estimate pollutant loading and potential reductions by proposed retrofits. WinSLAMM (version 10.4.0), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis. This is important for estimating treatment train effects associated with multiple BMPs in series. Furthermore, it allows for estimation of volume and pollutant loading at the outfall point to the waterbody, which is the primary point of interest in this type of study.

WinSLAMM estimates volume and pollutant loading based on acreage, land use, and soils information. Therefore, the volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential projects. Soils throughout the study area were predominantly sandy based on the information available in the Sherburne County soil survey. Specific model inputs (e.g. pollutant probability distribution, runoff coefficient, particulate solids concentration, particle residue delivery, and street delivery files) are detailed in Appendix A.

The initial step was to create a "base" model which estimates pollutant loading from each catchment in its present-day state without taking into consideration any existing stormwater treatment. To accurately model the land uses in each catchment, a full watershed delineation was completed using the watershed ArcGIS Spatial Analysis tools and modified manually as necessary using stormwater infrastructure data. The drainage areas were then consolidated into catchments using ArcGIS Spatial Analysis. Land use data were used to calculate acreages of each land use type within each catchment. Soil types throughout the subwatershed were modeled as sand in this analysis based on the information available in the Sherburne County soil survey. Entering the acreages, land use, and soil data into WinSLAMM ultimately resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment.

Several practices were identified on the limited agricultural lands in the Lake Fremont watershed. WinSLAMM is best suited as an urban / suburban model and not intended for use in an agricultural setting. As such, inputs from the program RUSLE2 (Revised Universal Soil Loss Equation, Version 2) were utilized to assist in model calibration and pollution reduction estimations from several agricultural BMPs.

Once the "base" model was established, an "existing conditions" model was created by incorporating notable existing stormwater treatment practices in the catchment for which data were available from the City of Zimmerman. For example, street cleaning with mechanical or vacuum street sweepers, stormwater treatment ponds, hydrodynamic devices, and others were included in the "existing conditions" model if information was available.

Finally, each proposed BMP practice was added individually to the "existing conditions" model and pollutant reductions were estimated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that each practice was modeled individually, and the benefits of projects may not be additive, especially if serving the same area (i.e. treatment train effects). Reported treatment levels are dependent upon optimal site selection and sizing. Additional information on the WinSLAMM models can be found in Appendix A.

Cost estimating is essential for the comparison and ranking of projects, development of work plans, and pursuit of grants and other funds. All estimates were developed using 2016 dollars. Costs throughout this report were estimated using a multitude of sources. Costs were derived from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals (Schueler & Kitchell, 2005 and Schueler et al. 2007) and recent installation costs and cost estimates provided to the Sherburne SWCD by personal contacts. Cost estimates were annualized costs that incorporated the elements listed below over a 30-year period.

Project promotion and administration includes local staff efforts to reach out to landowners, administer related grants, and complete necessary administrative tasks.

Design includes site surveying, engineering, and construction oversight.

Land or easement acquisition cover the cost of purchasing property or the cost of obtaining necessary utility and access easements from landowners.

Construction calculations are project specific and may include all or some of the following; grading, erosion control, vegetation management, structures, mobilization, traffic control, equipment, soil disposal, and rock or other materials.

Maintenance includes annual inspections and minor site remediation such as vegetation management, structural outlet repair and cleaning, and washout repair.

In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater retrofit analysis, and therefore cost estimates account for only general site considerations. Detailed feasibility analyses may be necessary for some projects.

Project ranking is essential to identify which projects could be pursued to achieve water quality goals. The intent of this analysis is to provide the information necessary to enable local natural resource managers to successfully secure funding for the most cost-effective projects to achieve water quality goals. This analysis ranks potential projects by cost-effectiveness to facilitate project selection. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Local resource management professionals will be responsible to select projects to pursue. Several considerations in addition to project cost-effectiveness for prioritizing installation are included.

If all identified practices were installed, significant pollution reduction could be accomplished. However, funding limitations and landowner interest will likely be limiting factors for implementation. The tables on the following pages rank all modeled projects by cost-effectiveness.

Projects were ranked in terms of the 30 year cost per pound of total phosphorus removed (Tables 1 and 2), but could be ranked with respect to the cost per 1,000 pound of total suspended solids removed as well.

Project selection involves considerations other than project ranking. The combination of projects selected for pursuit could strive to achieve TSS and TP reductions in the most cost-effective manner possible. Several other factors affecting project installation decisions should be weighed by resource managers when selecting projects to pursue. These factors include but are not limited to the following:

- Total project costs
- Cumulative treatment
- Availability of funding
- Economies of scale
- Landowner willingness
- Project combinations with treatment train effects
- Non-target pollutant reductions
- Timing coordination with other projects to achieve cost savings
- Stakeholder input
- Number of parcels (landowners) involved
- Project visibility
- Educational value
- Long-term impacts on property values and public infrastructure

BMP Descriptions

BMP types proposed throughout the target areas are detailed in this section. This was done to reduce duplicative reporting. For each BMP type, the method of modeling, assumptions made, and cost estimate considerations are described.

BMPs were proposed for a specific site within the research area. Each of these projects, including site location, size, and estimated cost and pollutant reduction potential are noted in detail in the Catchment Profiles section. Project types included in the following sections are:

- Bioretention
- Curb-cut Rain Garden
- Vegetated Swale (urban setting)
- Filter Strip (rural setting)
- Infiltration Basin
- Hydrodynamic Device
- Permeable Pavement
- Iron-Enhanced Sand Filter Pond Bench
- Modification to an Existing Pond
- New Stormwater Pond

Bioretention

Bioretention is a BMP that uses soil and vegetation to treat stormwater runoff from roads, driveways, roof tops, and other impervious surfaces. Differing levels of volume and/or pollutant reductions can be achieved depending on the type of bioretention selected.

Bioretention can function as either filtration (biofiltration) or infiltration (bioinfiltration). Biofiltration BMPs are designed with a buried perforated drain tile that allows water in the basin to discharge to the stormwater drainage system after having been filtered through the soil. Bioinfiltration BMPs have no underdrain, ensuring that all water that enters the basins will either infiltrate into the soil or be evapotranspired into the air. Bioinfiltration provides 100% retention and treatment of captured stormwater, whereas biofiltration basins provide excellent removal of particulate contaminants but limited removal of dissolved contaminants, such as dissolved phosphorus.

The treatment efficacy of a particular bioretention project depends on many factors, including but not limited to the pollutant of concern, the quality of water entering the project, the intensity and duration of storm events, project size, position of the project in the landscape, existing downstream treatment, soil and vegetation characteristics, and project type (i.e. bioinfiltration or biofiltration). Optimally, new bioretention will capture water that would otherwise discharge into a priority waterbody untreated.

The volume and pollutant removal potential of each bioretention practice was estimated using WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. Labor costs for project outreach and promotion, project design, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs. If multiple projects were installed, cost savings could be achieved on the administration and promotion costs (and possibly the construction costs for a large and competitive bid).

Please note infiltration BMPS would require site investigations to verify soils are appropriate.

Curb-cut Rain Gardens

Curb-cut rain gardens capture stormwater that is in roadside gutters and redirects it into shallow roadside basins. These curb-cut rain gardens can provide treatment for impervious surface runoff from one to many properties and can be located anywhere sufficient space is available. Because curb-cut rain gardens capture water that is already part of the stormwater drainage system, they are more likely to provide higher benefits. Generally, curb-cut rain gardens were proposed in areas without sufficient existing stormwater treatment and located immediately up-gradient of a catch basin serving a large drainage area. Bioinfiltration was solely proposed (as

Figure 2: Sherburne County curb-cut rain garden

opposed to biofiltration) as the available soil information suggested infiltration rates could be sufficient to allow complete draw-down within 24-48 hours following a storm event (Figure 2).

All curb-cut rain gardens were presumed to have a 12” ponding depth, pretreatment, mulch, and perennial ornamental and native plants. The useful life of the project was assumed to be 30 years and so all costs are amortized over that time period. Additional costs were included for rehabilitation of the gardens at years 10 and 20. Annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

Vegetated Swale

Figure 3: Vegetated swale. Photo by MN Pollution Control Agency (MN Stormwater Manual).

One option for retrofitting a stormwater BMP within an existing boulevard or along a roadside is a vegetated swale. Swales typically range from 5-50’ in length, house a rich native plant community, and can be installed along a roadside or even between an existing sidewalk and roadway curb (Figure 3). Unlike rain gardens, these practices are typically much shallower (1-3” in depth) and may have a curb-cut inlet and outlet. Although many rain gardens have outlets in the form of underdrains or risers, the swale outlet allows for a nearly continuous flow of stormwater through the practice. Although infiltration does occur, the primary form of treatment is the settling of pollutants as stormwater flows through the dense plant community.

This practice was modeled to estimate the pollutant reduction capacity for TSS, TP, and stormwater volume in medium density residential drainage areas ranging from 0.25 to 4 acres. A 20’ long (parallel to roadway), 4’ wide (perpendicular to roadway), and 3” deep bioswale was modeled with an infiltration rate of 2.5”/hour. No underdrain was modeled with this practice as they are designed to be flow-through systems with limited ponding (≤ 3”). Additional model inputs are noted in Appendix A.

Filter Strip

In the context of this report, a filter strip is primarily an agricultural BMP used at a field’s edge to reduce pollutant transport. The strip is typically a minimum of 50 ft in width, and is installed as long as necessary to capture the full extent of runoff in the immediate area. The BMP utilizes perennial vegetation planted in a dense pattern to slow the velocity of water and capture sediment before it enters nearby waterways. Deep root structures help to hold the soil here in place and facilitate some connection to groundwater, but the structure itself is not designed for infiltration – more so for filtration of passing water.

Infiltration Basin

Infiltration basins function identically to the curb-cut rain gardens previously described in this bioretention section. However, these basins are proposed in locations where a large amount of space is available. This presents an opportunity to construct a large-scale (i.e. > 500 sq.-ft.) infiltration basin. This allows stormwater runoff to fill the basin and be filtered by the soil and vegetation.

Probable project cost includes installation of the project as well as promotion, administrative, and design costs, all in 2016 dollars. A reduced construction cost (i.e. $15 to $20 per ft.2) relative to other bioretention practices was proposed for the infiltration basin because of assumed cost savings with a larger project. Furthermore, the large open spaces available at each of the proposed project locations could allow the basins to be constructed without retaining walls, which would result in a significant cost savings. Maintenance was assumed to be completed by city public works crews. Maintenance costs were also included for rehabilitation of the basin every 10 years for the life of the project.

It should be noted that no suitable locations were identified for infiltrations within the priority areas in the study. Should future opportunities arise, these retrofits could be modeled for estimated pollutant reductions.

Hydrodynamic Devices

In heavily urbanized settings stormwater is immediately intercepted along roadway catch basins and conveyed rapidly via storm sewer pipes to its destination. Once stormwater is intercepted by catch basins, it can be very difficult to supply treatment without large end-of-pipe projects such as regional ponds. One of the possible solutions is the hydrodynamic device (Figure 4). These are installed in-line with the existing storm sewer network and can provide treatment for up to 10-15 acres of upland drainage. This practice applies some form of filtration, settling, or hydrodynamic separation to remove coarse sediment, litter, oil, and grease. These devices are particularly useful in small but highly urbanized drainage areas and can be used as pretreatment for other downstream stormwater BMPs.

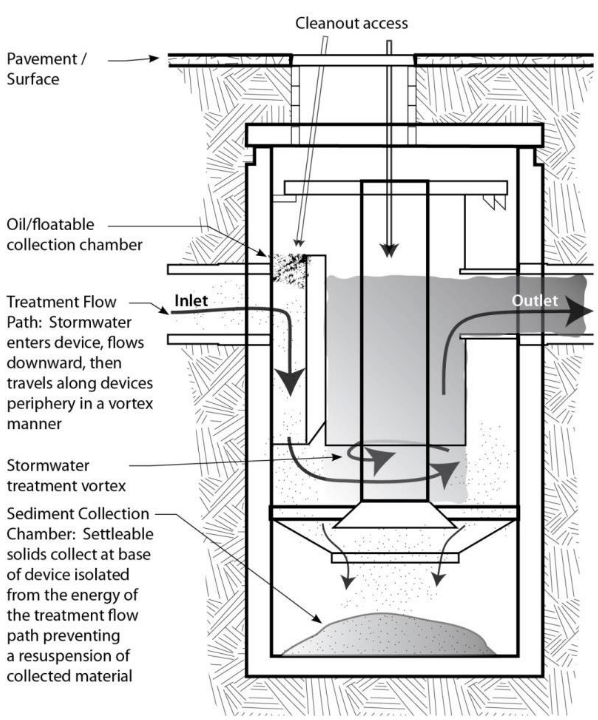


Figure 4: Hydrodynamic device schematic.

Each device's pollutant removal potential was estimated using WinSLAMM. Devices were sized based on upstream drainage area to ensure peak flow does not exceed each device's design guidelines. For this analysis, Downstream Defender devices were modeled based on available information and to maintain continuity across other similar reports d. Devices were proposed along particular storm sewer lines and often just upstream of intersections with another, larger line. Model results assume the device is receiving input from all nearby catch basins noted.

In order to calculate the cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Modification to an Existing Pond

Developments prior to enactment of stormwater rules often included wet detention ponds which were frequently designed purely for flood control based on the existing land use, impervious cover, soils, and topography. Changes to stormwater rules since the early 1970's have altered the way ponds are designed.

Enactment of the National Pollution Discharge Elimination System (NPDES) in 1972 followed by research conducted by the Environmental Protection Agency in the early 1980's as part of the Nationwide Urban Runoff Program (NURP) set standards by which stormwater best management practices should be designed. Municipal Separate Storm Sewer System (MS4) guidelines issued in 1990 (affecting cities with more than 100,000 residents) and 1999 (for cities with less than 100,000 residents) required municipalities to obtain an NPDES permit and develop a plan for managing their stormwater.

Listed below are five strategies which exist for retrofitting a stormwater pond to increase pollutant retention (modified from Urban Stormwater Retrofit Practices):

- Excavate pond bottom to increase permanent pool storage
- Raise the embankment to increase flood pool storage
- Widen pond area to increase both permanent and flood pool storage
- Modify the riser
- Update pool geometry or add pretreatment (e.g. forebay)

These strategies can be employed separately or together to improve BMP effectiveness. Each strategy is limited by cost-effectiveness and constraints of space on the current site. Pond retrofits are preferable to most new BMPs as additional land usually does not need to be purchased, stormwater easements already exist, maintenance issues change little following project completion, and construction costs are greatly cheaper. There can also be a positive effect on reducing the rate of overflow from the pond, thereby reducing the risk for erosion (and thus further pollutant generation) downstream.

For this analysis, all existing ponds were modeled in the water quality model WinSLAMM to estimate their effectiveness based on best available information for pond characteristics and land use and soils. One proposed modification, excavating the pond bottom to increase storage, often has a very wide range in expected cost due to the nature of the excavated soil. If the soil has been contaminated and requires landfilling, the cost for disposal can quickly lead to a doubling in project cost. For this reason, projects which include the excavation of ponds have been priced based on the following criteria:

- Management Level 1: Dredged pond soil is suitable for use or reuse on properties with a residential or recreational use
- Management Level 2: Dredged pond soil is suitable for use or reuse on properties with an industrial use
- Management Level 3: Dredged pond soil is considered significantly contaminated and must be managed specifically for the contaminants present.

Costs within each of these levels can range widely, but were estimated to be $20/cu.-yd, $35/cu.-yd, and $50/cu.yd for levels 1, 2, and 3, respectively.

It should be noted that no pond modifications were identified during the course of this study. Detailed inventories of stormwater pond performance (intake / outfall water quality, pond depth, flow rates, etc.) could be collected to better assess current performance and if a need exists for modification.

New Stormwater Pond

If properly designed, wet retention ponds have controlled outflows to manage discharge rates and are sized to achieve predefined water quality goals. Wet retention ponds treat stormwater through a variety of processes, but primarily through sedimentation. Ponds are most often designed to contain a permanent pool storage depth; it is this permanent pool of water that separates the practice from most other stormwater BMPs, including detention ponds.

Wet retention pond depth generally ranges from 3-8' deep. If ponds are less than 3' deep, winds can increase mixing through the full water depth and re-suspend sediments, thereby increasing turbidity. Scour may also occur during rain events following dry periods. If more than 8' deep, thermal stratification can occur creating a layer of low dissolved oxygen near the sediment that can release bound phosphorus. Above the permanent pool depth is the flood depth, which provides water quality treatment directly following storm events. Separating the permanent pool depth and the flood depth is the primary outlet control, which is often designed to control outflow rate. Configurations for the outlet control may include a V-notch or circular weir, multiple orifices, or a multiple-stage weir. Each of these can be configured within a skimmer structure or trash rack to provide additional treatment for larger, floatable items. Above the flood depth is the emergency control structure, which is available to bypass water from the largest rainfall events, such as the 100-year precipitation event. Ponds also often include a pretreatment practice, either a forebay or sedimentation basin adjacent to the pond or storm sewer sumps, hydrodynamic devices, or other basins upstream of the practice.

Outside of sedimentation, other important processes occurring in ponds are nutrient assimilation and evapotranspiration by plants. The addition of shoreline plants to pond designs has increased greatly since the 1980's because of the positive effects these plants were found to have for both water quality purposes and increasing terrestrial and aquatic wildlife habitat. The ability of the pond to regulate discharge rates should also be noted. This can reduce downstream in-channel erosion, thereby decreasing TSS and TP loading from within the channel.

With the multitude of considerations for these practices, ponds must be designed by professional engineers. This report provides a rudimentary description of ponding opportunities and cost estimates for project planning purposes. Ponds proposed in this analysis are designed and simulated within the water quality model WinSLAMM, which takes into account upland pollutant loading, pond bathymetry, and outlet control device(s) to estimate stormwater volume, TSS, and TP retention capacity. The model was run with and without the identified project and the difference in pollutant loading was calculated.

In order to calculate cost-benefit, the cost of each project is estimated. All new stormwater ponds are assumed to involve excavation and disposal of soil, installation of inlet and outlet control structures and emergency overflow, land acquisition, erosion control, and vegetation management. Project engineering, promotion, administration, construction oversight, and long-term maintenance are considered in order to capture the true cost of the effort.

It should be noted that no pond modifications were identified during the course of this study.

Additional Conservation Considerations

The intent of this study was to examine the existing conditions and mitigation potential for surface water flow ("stormwater") related pollution, with a specific receiving waterbody (Lake Fremont) in mind. Other conservation-minded activities were noted during the course of this study which were out of the original scope, but are included below for the reader's general information.

Hydrologic connectivity and fish passage: The Lake Fremont outlet forms the beginning of a ditch network that connects to Tibbets Brook, then the Elk River, then the Mississippi River. The outlet currently leaves the lake's southern side and runs through an approximate 170 ft long straightened underground channel before daylighting on the southwest side of Fremont Lane. During upcoming street construction work is scheduled to be completed in this area. The City of Zimmerman may consider working with Minnesota Department of Natural Resources staff to identify outlet structure elements that better facilitate fish passage to and from the lake. These elements may include water quality benefits as well, such as riffle patterns which facilitate oxygen transfer from the atmosphere to the water. Funding opportunities may be available for this work, such as through the DNR's Conservation Partners Legacy Grant Program. More information on this grant program and the applicable types of projects it funds can be found online at the following website: https://www.dnr.state.mn.us/grants/habitat/cpl/index.html. Sherburne SWCD staff would be happy to work with the city and DNR on this project should the city wish to pursue it further.

Shoreline erosion: Erosion along shoreline can unfortunately be common as waves, wind and ice batter the shorelines, vegetation management changes, and developmental pressure increases. As a shoreline erodes, it can deposit sediment and nutrients into a lake which may lead to algae proliferation and habitat alteration. It also can be frustrating to a landowner to see their property "washing away". Of course, shoreline erosion occurs in various degrees and so the remedy for a degrading shoreline changes with the extent of the issue present. The best proven methods for shoreline erosion control are 1) increasing native vegetation on the toe, slope and upland areas of the shoreline, 2) combatting serious erosion situations with bioengineered products or rock rip rap (in extreme cases or steep slopes), 3) altering the grade of the slope or 4) a combination of all techniques. Each shoreline is different and so a unique approach may need to be considered depending on the slope, soils, cause of disturbance, position on the lake, etc. Sherburne SWCD provides technical assistance to landowners through our shoreline management program – for more information visit: https://www.sherburneswcd.org/water-management.html.

Hobby farm and animal waste: Sherburne County hosts numerous small animal operations, sometimes called small farms or hobby farms. Consisting of small operations with chickens, goats, sheep, alpacas, horses or cows these farms offer rich recreational experiences for families. Resource concerns related to animal waste may or may not occur on these farms related to the quality of soils, vegetation management, waste management and proximity to surface or ground water.

Sherburne SWCD has staff with expertise in small farm operations and animal waste management and can offer free technical assistance through a Small Farms Program for county residents. Visit the SWCD's website for more information on soil health, pasture management, nutrient management and more: https://www.sherburneswcd.org/rural-resource-management.html.

Study Area

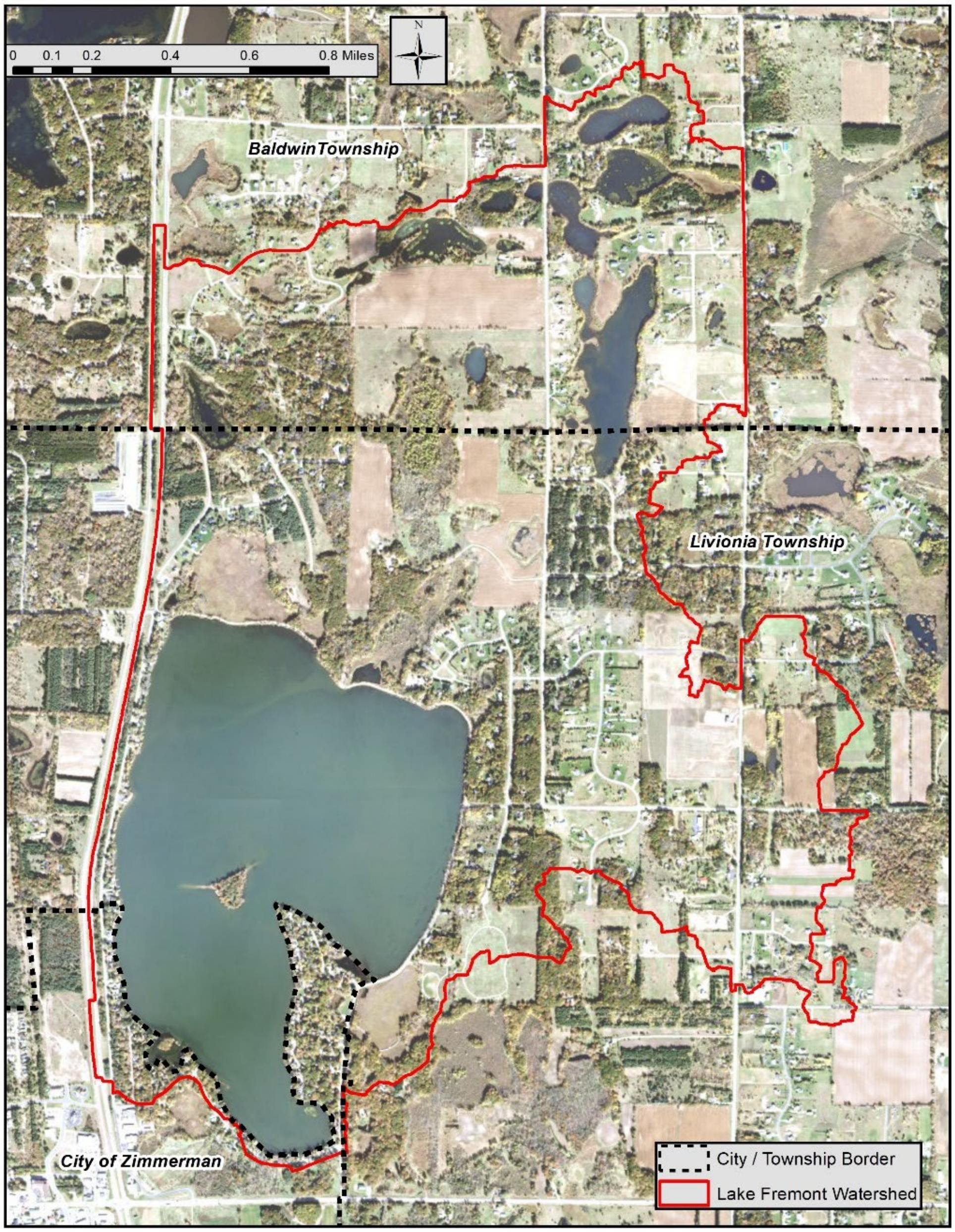


Figure 5: Lake Fremont watershed.

In determining the applicable study area for this exercise, a number of resources were utilized including previous available watershed delineations, stormwater routing information provided by the City of Zimmerman and Bolton & Menk, aerial photography and LIDAR information. These resources were compiled into a GIS databased and used to create the map depicted on Figure 5, which represents the watershed, or contributing stormwater catch-basin for Lake Fremont. This area is approximately 2,170 acres in size. GIS software (ESRI ArcMap Spatial Analyst) was utilized to delineate the full watershed. Following this exercise several questionable existed which required further examination. SWCD staff completed a culvert inventory of key areas of the watershed and also examined flow characteristics in several ditches following a June 2020 rain event to assist delineating the full watershed as well as sub-watersheds as described in the text that follows. Stormwater infrastructure is depicted in Figure 6.

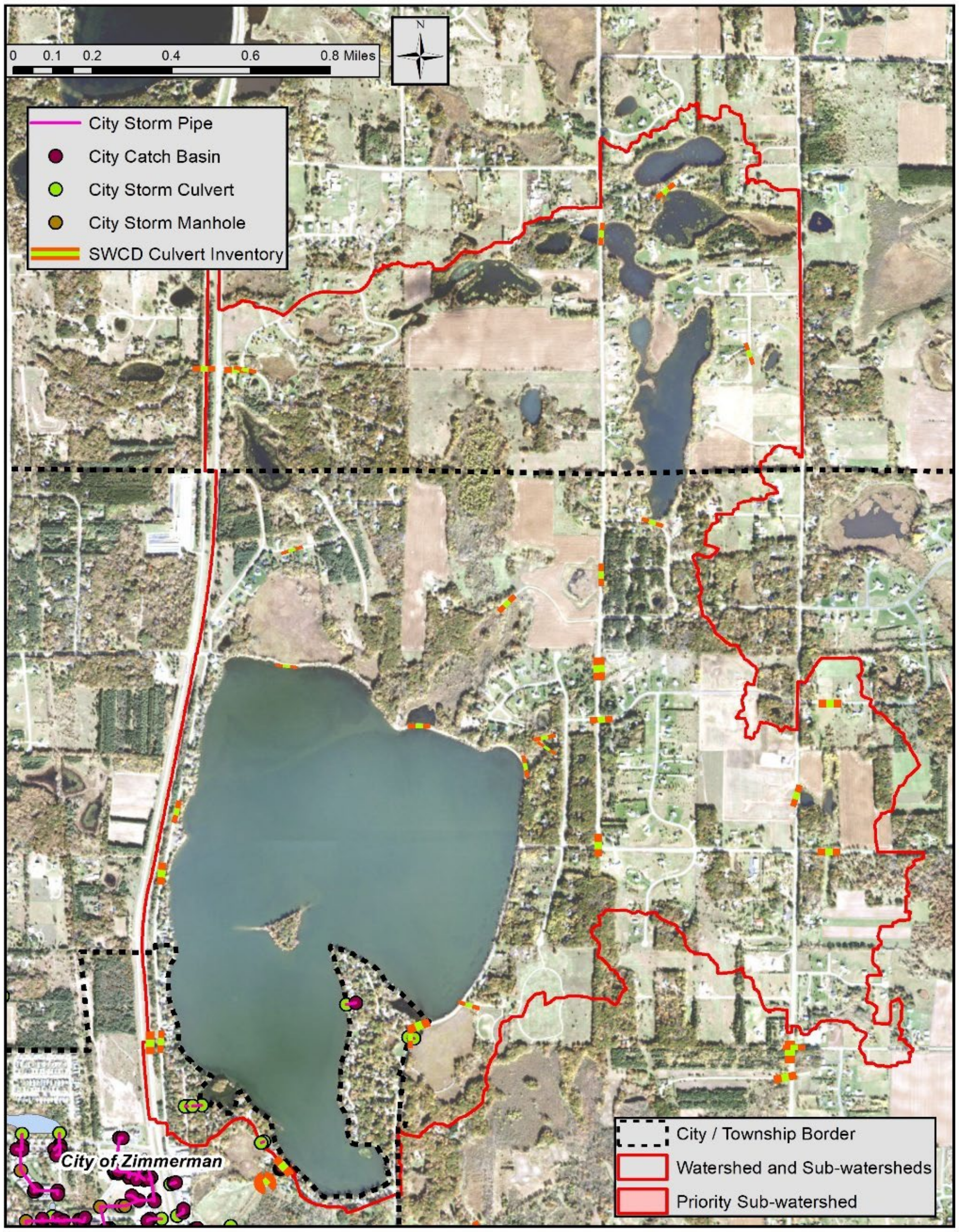


Figure 6: Lake Fremont watershed with City of Zimmerman stormwater infrastructure and SWCD identified culvert locations.

The aforementioned resources were used within a GIS database to delineate 26 sub-watershed catchments within the Lake Fremont watershed. Following sub-watershed delineation, the stormwater modeling program WinSLAMM was used to estimate current stormwater pollutant contributions from each of the sub-watersheds. The current pollution load from each sub-watershed was estimated and ranked in terms of most phosphorus and solids produced per acre basis. The result was the determination of 14 priority basins which, due to their unique conditions, were estimated to have higher pollutant loads per area and thus should be approached first for pollution reduction (Figure 7). Local knowledge of conditions and the opportunity to retrofit during upcoming construction played a role in priority area selection as well.

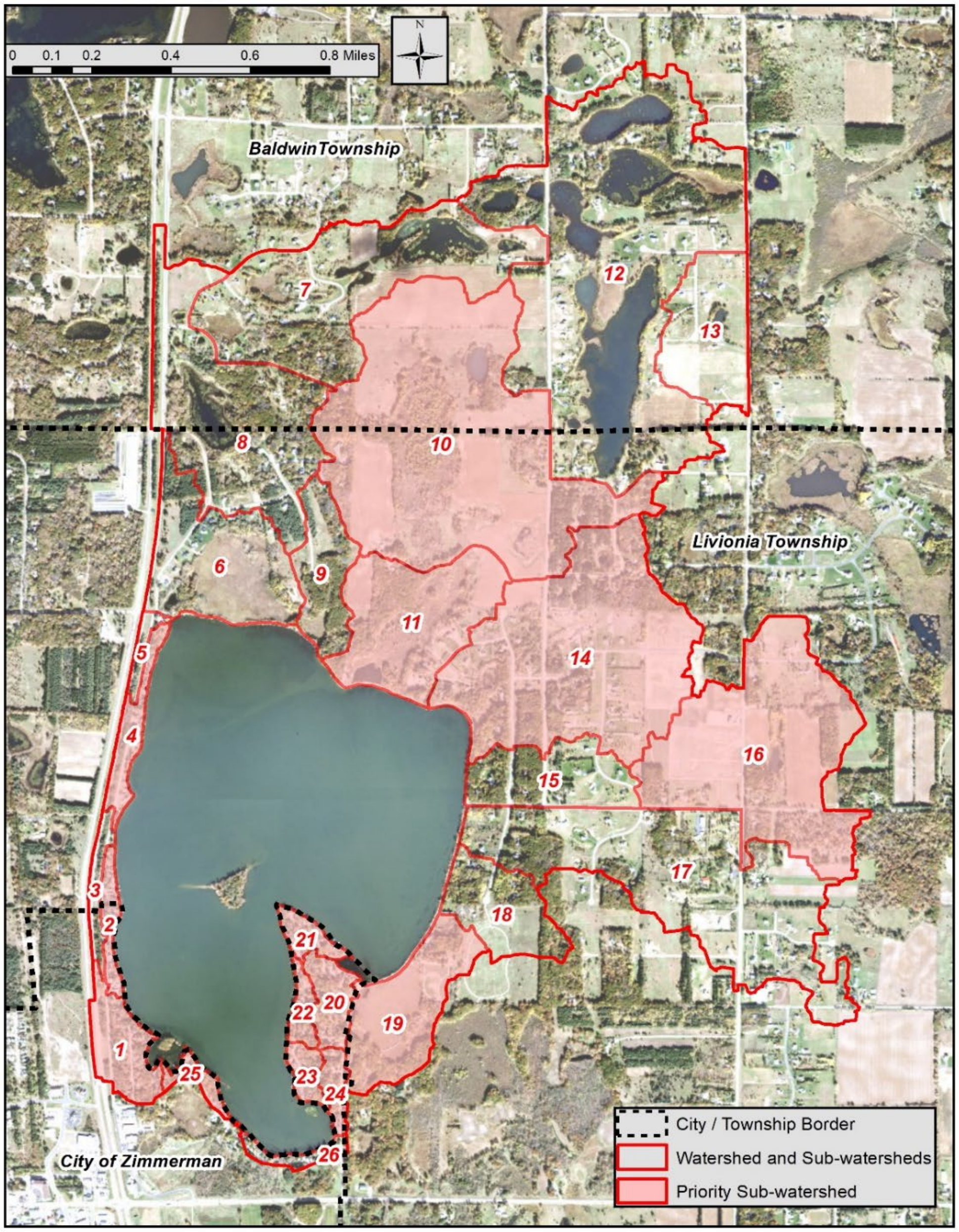


Figure 7: Lake Fremont sub-watershed priority and non-priority areas.

A breakdown of each sub-watershed based upon its initial (pre-treatment) conditions along with its current conditions (with existing treatment structures) is provided in Table 4. The stormwater model currently estimates that existing treatment BMPs (stormwater ponds, street cleaning, catch basins and wetlands) are reducing stormwater volume by 7.8%, suspended solids by 24.2%, and phosphorus by 25.4%.

Table 4: Lake Fremont sub-watershed WinSLAMM results.

Sub-Watershed	Soil Group	Area (acres)	Initial Runoff Volume (cuft)	Initial Solids (lbs)	Initial Phosphorus (lbs)	Current Runoff Volume (cuft)	Current Total Solids (lbs)	Current Total Phosphorus (lbs)
1	A	23.04	402,597	5,814	12.82	402,597	5,315	11.67
2	A	8.24	143,984	2,079	4.59	143,984	1,901	4.18
3	A	8.27	38,174	731	1.87	38,174	666	1.72
4	A	14.04	245,333	3,543	7.81	245,333	3,239	7.11
5	A	5.00	11,278	339	0.93	11,278	300	0.84
6	A/D	68.26	415,328	6,925	16.15	415,250	4,455	9.91
7	A/D	126.61	1,041,000	16,995	37.94	673,004	10,530	23.17
8	A	114.57	474,800	8,851	21.45	475,211	7,628	18.59
9	A	31.22	237,686	3,838	8.35	238,199	2,554	5.30
10	A	241.04	1,140,000	20,771	55.93	1,140,000	20,771	52.86
11	A/D	72.57	581,026	11,404	26.59	579,751	7,912	17.81
12	A	285.26	1,883,000	31,818	74.34	1,414,000	8,472	17.25
13	A/D	47.35	215,612	4,133	10.54	215,774	3,803	9.67
14	A	166.10	1,080,000	19,168	46.65	1,075,000	16,047	38.56
15	A	40.10	185,100	3,435	8.25	185,099	3,435	8.25
16	A	136.43	629,667	12,070	30.78	629,667	12,070	30.78
17	A/D	153.30	708,875	12,726	28.56	708,875	12,726	28.56
18	A/D	34.86	160,913	3,084	7.87	160,913	3,084	7.87
19	A/D	50.30	273,627	5,015	13.45	270,059	3,858	10.53
20	A	14.24	248,827	3,594	7.93	248,827	3,285	7.22
21	A/D	7.73	136,995	1,978	4.36	136,997	1,809	3.97
22	A/D	6.81	118,997	1,719	3.79	118,997	1,571	3.45
23	A/D	6.99	122,142	1,764	3.89	122,142	1,613	3.54
24	A	7.42	129,656	1,872	4.13	129,656	1,712	3.76
25	A	5.72	99,950	1,443	3.18	99,950	1,320	2.90
26	A	6.10	108,512	1,567	3.46	108,512	1,433	3.15
Totals		**1681.6**	**10,833,079**	**186,676**	**445.60**	**9,987,249**	**141,509**	**332.60**

Soils

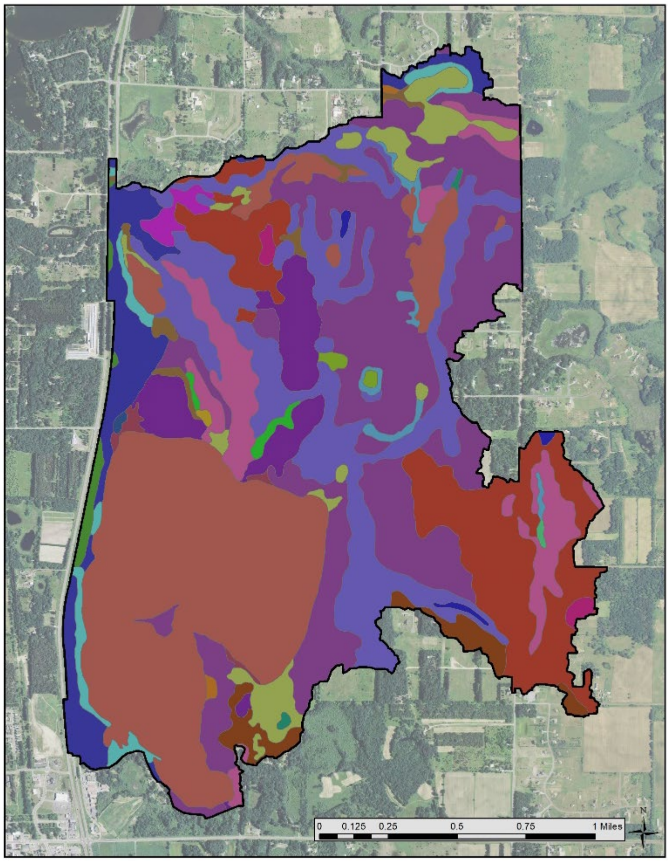


Figure 8: Lake Fremont watershed area soils.

Most of Sherburne County lies within the Anoka Sand Plains, a broad area that years ago was lake bottom. Sand dunes, kettle lakes and tunnel valleys are prominent features in the region and are associated with glacial activity. These sandy soils are excessively drained, making for high infiltration rates and relatively low organic matter. While bedrock in the western portion of the county underlie the top soil at depths of 0-100 feet, the eastern areas of the county where Lake Fremont is located hold sedimentary rocks under topsoil with bedrock being found 50-300 feet below the soil. These soils make for high movement conditions, so infiltration based practices are most suitable. However, sandy soils need to be carefully managed due to the potential for leaching of pollutants with groundwater.

Non-Priority Sub-watershed Profiles

The remaining portion of this document will present each of the 14 priority sub-watersheds to the reader. The sub-watershed profile will describe the characteristics of the area including the dominant land use, hydrology, existing treatments, and potential stormwater retrofit practices that were identified as part of this study. While these profiles will be of great importance to examine the most efficient conservation practices, a reflection of the non-priority profiles is included below for context. Non-priority sub-watershed areas can be viewed on Figure 7.

Sub-watershed 3: This sub-watershed is relatively small in size and consists of a drainage area lying between Hwy 169 and Fremont Drive. A single culvert was identified that forms a connection with Lake Fremont. The area is nearly completely vegetated and holds exceptionally sandy soils, so it is likely that water from the small catchment infiltrates most often before spilling into the lake.

Sub-watershed 5: Similar in setting to Sub-watershed 3, this small catchment is minimally developed and no clear connection exists to the lake. Thus, it was not selected as priority.

Sub-watershed 6: This region holds some rural residential development but also consists of a large wetland complex, separated from Lake Fremont by a minimal maintenance gravel road. Several culverts occur along the road to form a direct connection to the lake. Then entire watershed flows through this wetland. Wetlands are known to have great filtration and pollutant retention components. In some circumstances wetlands can flush nutrients into nearby waterways, however advanced monitoring of the wetland is necessary to make that determination. Based upon initial observations the wetland complex in Sub-watershed 6 is likely playing a positive role in reducing pollutant transport to the lake.

Sub-watershed 7: This region includes rolling terrain and several small wetlands. Additionally, the contours suggest that any overflow from this area spills into Sub-watershed 8 and eventually into the wetland complex in Sub-watershed 6. It is currently thought that the multiple wetlands are effectively mitigating pollution stemming from this area.

Sub-watershed 8: This region has a fair amount of elevation relief. It accepts water from Sub-watershed 7 and discharges (likely under heavy rain events only) into Sub-watershed 6. Due to the abundance of vegetated land and several wetlands, this region likely has good natural pollution mitigation in place.

Sub-watershed 12: This sub-watershed holds several ponds and Prairie Hill Lake. Modeling results indicate that the sub-watershed only discharges from its terminal end (outlet of Prairie Hill Lake) under moderate to high rain events. The multiple waterbodies are likely acting as “sinks” for the watershed and effectively collecting and treating surface runoff water.

Sub-watershed 13: Sub-watershed 13 is relatively small in size and holds much vegetated land, consisting of rural residential lots with minimal impervious surface. The area also discharges into Prairie Hill Lake, which modeling suggests is able to accept fluctuations in rainfall and capture pollutants effectively.

Sub-watershed 15: This region holds a fair amount of elevation relief that leads towards Lake Fremont and rural and suburban residential parcels. The sub-watershed also is fairly well vegetated, particularly in the near-lake region, which offers filtration of surface water runoff before it enters the lake.

Sub-watershed 17: This sub-watershed is fairly large in size, and also has rolling terrain that creates hills and "pockets" of areas for water to sit. These natural lowland areas were observed to not hold water long-term (based upon visual observation of vegetation species present) so it is thought that they catch stormwater and infiltrate to the ground fairly effectively. As with Sub-watershed 15, the area holds an abundance of forest and grassland near the lake which acts as a filtration buffer.

Sub-watershed 18: This delineated sub-watershed is smaller in size, holds well-vegetated larger residential parcels, and also incorporates a portion of the Grams Regional Park prairie land. It is believed that good filtration of surface runoff is in place here.

Sub-watershed 26: Located directly on the shoreline of Lake Fremont, this area consists of the south side of Fremont Lane and tightly packed residences along the lake. The area does not have much space for BMP retrofits, and modeling suggests a limited impact on surface water discharge compared to other urban sub-watersheds in the area.

BMP Identification Process Note

As previously noted, potential BMPs were identified through aerial map reviews, on the ground observations and conversations with City of Zimmerman staff. This section of the report is included to review some of the discoveries and challenges involved with this process.

Urban / lakeshore sub-watersheds: The southern side of the lake, primarily within the City of Zimmerman, holds numerous smaller lots. This proved to be a challenge for identifying areas with the necessary space needed for potential BMPs. Smaller practices such as rain gardens require a certain footprint, but must also meet setback requirements from wells, structures, groundwater table, etc. In this environment obstacles such as trees, tree roots, mailboxes, pavement, and other items can present a challenge as well. Finally, as you near the lakeshore area the distance from the surface to groundwater table decreases. The Minnesota Stormwater Manual requires at minimum a three-foot separation between the bottom of an infiltration practice and the groundwater, and in some cases a potential infiltration BMP had to be removed from consideration due to this requirement. However, when possible alternatives such as vegetative swales were considered.

Overall, the urban / lakeshore region holds some potentials for BMP implementation. With upcoming street construction additional opportunities may present themselves and these should be considered along with the existing identified opportunities – particularly if the practice is identified within a priority sub-watershed.

Rural sub-watersheds: The extended landscape in Lake Fremont watershed is primarily rural residential lots, with some expanses of forests, wetlands, and some (minimal) agriculture. The larger lot sizes here offer opportunities for BMP placement. Numerous "pockets" where water collects and infiltrates were observed. In some areas these lowlands infiltrate quickly and are occupied by turfgrass, shrubs, trees, etc. In other areas small wetland complexes develop. Overall many sub-watersheds are treating surface water runoff effectively. Beyond the projects that were identified, landowners in this region can work to address stormwater emitting from impervious areas with small conservation practices on a parcel by parcel basis.

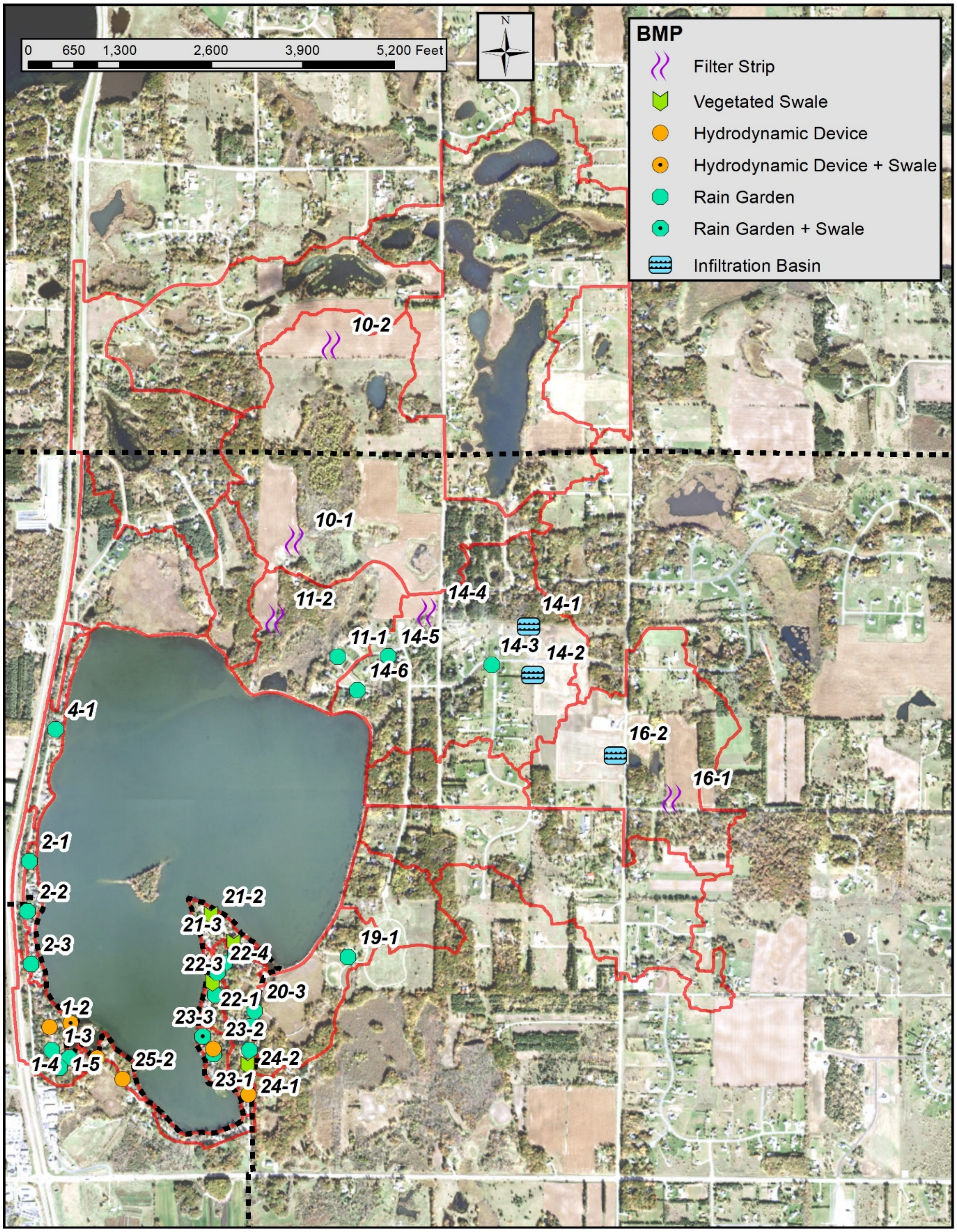
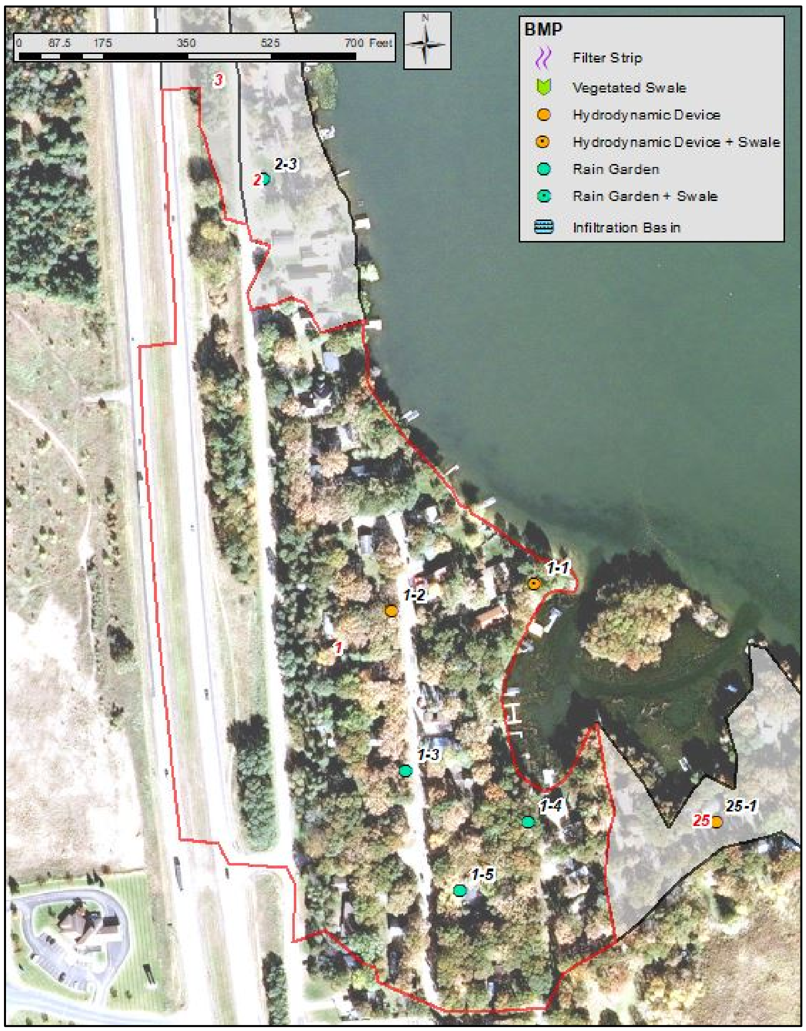


Figure 8. Map of all BMP options identified and modeled within the Lake Fremont SWA.

Priority Sub-watershed 1

Sub-watershed Characteristics	
Acres	23.0
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

This sub-watershed lies on the southwest side of Lake Fremont. The landscape holds several steep sloped areas as it leads to the lake. Part of the catchment includes a piece of the Hwy 169 corridor which is hydrologically connected to the lake through a culvert.



Existing Conditions		Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	12.8	1.2	9%	**11.7**
	TSS (lb/yr)	5,814	499.0	9%	**5,315**
	Volume (acre-feet/yr)	9.2	0.0	0%	**9.2**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 5: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 1-1

4' Hydrodynamic Device + Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.50	4.3%
	TSS (lb/yr)	227	4.3%
	Volume (acre-feet/yr)	0.33	3.6%
Cost	Administration & Promotion Costs*	$3,000	
	Design & Construction Costs**	$21,000	
	Total Estimated Project Cost	**$24,000**	
	Annual O&M***	$435	
Efficiency	30-yr Average Cost/lb-TP	**$2,470**	
	30-yr Average Cost/1,000lb-TSS	**$5,441**	
	30-yr Average Cost/ac-ft Vol.	**$3,742**	

*Indirect Cost: (50 hours at $60/hr)

**Direct Cost: ($9,000 HD materials + $50/sqft swale) + ($11,000 labor & construction)

***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)+$75/yr

Project ID 1-2

4' Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	4	ft dia
	TP (lb/yr)	0.22	1.9%
	TSS (lb/yr)	68	1.3%
	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*	$1,440	
	Design & Construction Costs**	$18,000	
	Total Estimated Project Cost	**$19,440**	
	Annual O&M***	$360	
Efficiency	30-yr Average Cost/lb-TP	**$4,582**	
	30-yr Average Cost/1,000lb-TSS	**$14,824**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (24 hours at $60/hr)

**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)

***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Project ID 1-3

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.40	3.4%
	TSS (lb/yr)	186	3.5%
	Volume (acre-feet/yr)	0.31	3.4%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,534**	
	30-yr Average Cost/1,000lb-TSS	**$3,299**	
	30-yr Average Cost/ac-ft Vol.	**$1,966**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 1-4

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.45	3.9%
	TSS (lb/yr)	206	3.9%
	Volume (acre-feet/yr)	0.34	3.7%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,364**	
	30-yr Average Cost/1,000lb-TSS	**$2,979**	
	30-yr Average Cost/ac-ft Vol.	**$1,782**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

	Project ID 1-5		
	Curb-Cut Rain Garden		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.19	1.6%
	TSS (lb/yr)	86	1.6%
	Volume (acre-feet/yr)	0.15	1.6%
Cost	**Administration & Promotion Costs***	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,230**	
	30-yr Average Cost/1,000lb-TSS	**$7,136**	
	30-yr Average Cost/ac-ft Vol.	**$4,147**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Priority Sub-watershed 2

Sub-watershed Characteristics	
Acres	8.2
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman / Livonia Township

This sub-watershed lies along the western edge of Lake Fremont, paralleling Fremont Drive. Residential lots here average 0.25 acres in size. Stormwater travels mostly overland towards the lake in opportunistic paths. The sub-watershed is split almost equally between City of Zimmerman and Livonia Township jurisdiction.

Existing Conditions		Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	4.6	0.4	9%	**4.2**
	TSS (lb/yr)	2,079	178.0	9%	**1,901**
	Volume (acre-feet/yr)	3.3	0.0	0%	**3.3**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 6: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 2-1

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.22	5.1%
	TSS (lb/yr)	96	5.0%
	Volume (acre-feet/yr)	0.16	5.0%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$2,854**	
	30-yr Average Cost/1,000lb-TSS	**$6,392**	
	30-yr Average Cost/ac-ft Vol.	**$3,732**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 2-2

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.33	7.8%
	TSS (lb/yr)	148	7.8%
	Volume (acre-feet/yr)	0.25	7.5%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,888**	
	30-yr Average Cost/1,000lb-TSS	**$4,146**	
	30-yr Average Cost/ac-ft Vol.	**$2,467**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 2-3

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.27	6.3%
	TSS (lb/yr)	123	6.5%
	Volume (acre-feet/yr)	0.21	6.3%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$2,316**	
	30-yr Average Cost/1,000lb-TSS	**$4,989**	
	30-yr Average Cost/ac-ft Vol.	**$2,948**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 4

Sub-watershed Characteristics	
Acres	14.0
Dominant Land Cover	Med Dense Urban
Municipality	Livonia Township

Similar to sub-watershed 2, this sub-watershed parallels Fremont Drive along the west side of the lake. A culvert exists which allows some stormwater from west of Fremont Drive to travel east, entering the lake. Beyond this culvert no stormwater infrastructure currently exists in this area.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	BMP Types	n/a			
	TP (lb/yr)	7.8	0.7	9%	**7.1**
	TSS (lb/yr)	3,543	304.0	9%	**3,239**
	Volume (acre-feet/yr)	5.6	0.0	0%	**5.6**

Treatment Calculations and Cost Analysis

As outlined in the tables below, a single project was identified for this sub-watershed. Other potential BMPs were identified initially but were abandoned due to the presence of obstacles on the properties, steeply sloped landscapes, or other challenges.

Table 7: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 4-1			
Curb-Cut Rain Garden			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.49	6.9%
	TSS (lb/yr)	227	7.0%
	Volume (acre-feet/yr)	0.38	6.7%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,245**	
	30-yr Average Cost/1,000lb-TSS	**$2,703**	
	30-yr Average Cost/ac-ft Vol.	**$1,626**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

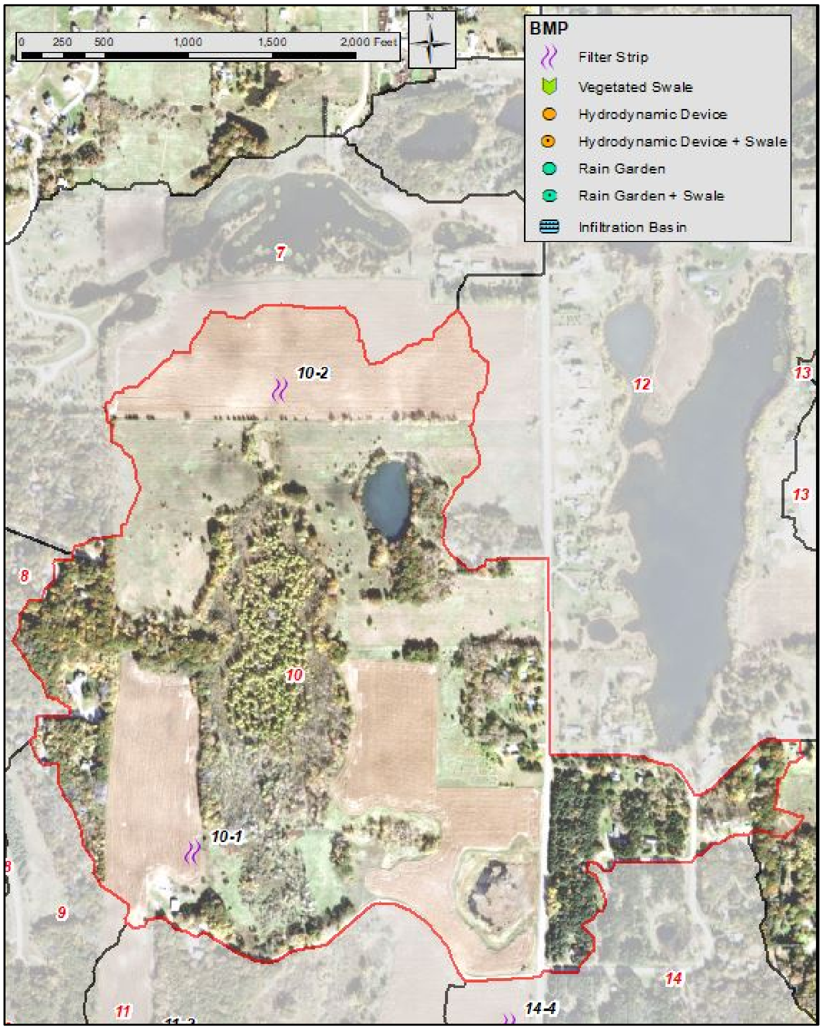
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 10

Sub-watershed Characteristics	
Acres	241.0
Dominant Land Cover	Rural / Ag
Municipality	Baldwin / Livonia Township

Sub-watershed 10 is located along the north side of Lake Fremont and is one of the few areas in the Lake Fremont watershed that holds agricultural land. Pollutant predictions and reductions were calculated with the aid of the RUSLE2 agricultural model for this study.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Wetland Ponds			
	TP (lb/yr)	55.9	3.1	5%	**52.9**
	TSS (lb/yr)	21,929	1158.0	5%	**20,771**
	Volume (acre-feet/yr)	26.2	0.0	0%	**26.2**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 8: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM and RUSLE2 parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 10-1

Cool Season Grass Filter Strip

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	2.01	acres
	TP (lb/yr)	3.64	6.9%
	TSS (lb/yr)	2,705	13.0%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$1,800	
	Design & Construction Costs**	$2,786	
	Total Estimated Project Cost	**$4,586**	
	Annual O&M***	$10	
Efficiency	30-yr Average Cost/lb-TP	**$45**	
	30-yr Average Cost/1,000lb-TSS	**$60**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (30 hours at $60/hour)

**Direct Cost: ($50/lnft for materials and labor) + $1,750 design and oversight)

***Per BMP: ($10/year)

Project ID 10-2

Cool Season Grass Filter Strip

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1.35	acres
	TP (lb/yr)	4.79	9.1%
	TSS (lb/yr)	3,540	17.0%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$1,800	
	Design & Construction Costs**	$2,447	
	Total Estimated Project Cost	**$4,247**	
	Annual O&M***	$10	
Efficiency	30-yr Average Cost/lb-TP	**$32**	
	30-yr Average Cost/1,000lb-TSS	**$43**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (30 hours at $60/hour)

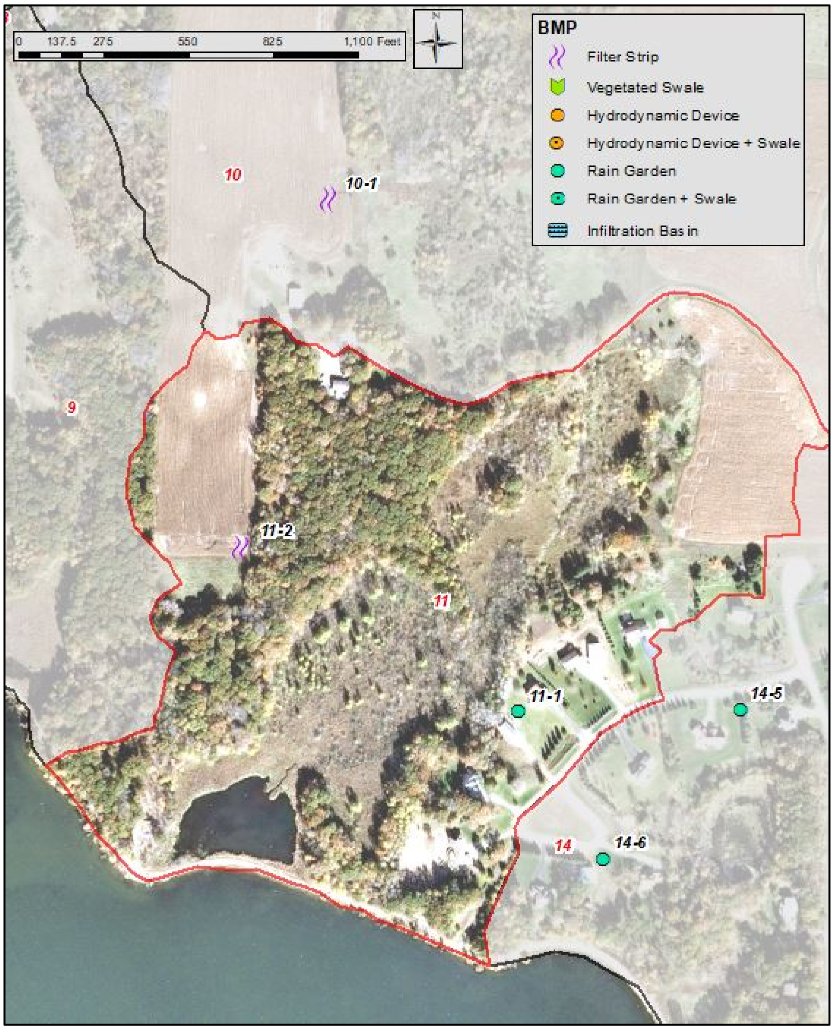
**Direct Cost: ($50/lnft for materials and labor) + $1,750 design and oversight)

***Per BMP: ($10/year)

Sub-watershed 11

Sub-watershed Characteristics	
Acres	72.6
Dominant Land Cover	Low dens residential
Municipality	Livonia Township

This sub-watershed accepts water from sub-watershed 10. It includes a wetland complex, forested areas, agricultural and some suburban residences. The wetland is directly connected to Lake Fremont through a culvert. As with sub-watershed 10 agricultural modeling with RUSLE2 aided in the overall assessment of this sub-watershed.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Wetland Pond			
	TP (lb/yr)	26.6	8.8	33%	**17.8**
	TSS (lb/yr)	11,404	3492.0	31%	**7,912**
	Volume (acre-feet/yr)	13.3	0.0	0%	**13.3**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 9: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM and RUSLE2 parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 11-1

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.38	2.1%
	TSS (lb/yr)	173	2.2%
	Volume (acre-feet/yr)	0.21	1.6%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,615**	
	30-yr Average Cost/1,000lb-TSS	**$3,547**	
	30-yr Average Cost/ac-ft Vol.	**$2,963**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 11-2

Cool Season Grass Filter Strip

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1.06	acres
	TP (lb/yr)	2.66	14.9%
	TSS (lb/yr)	1,680	21.2%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$1,800	
	Design & Construction Costs**	$2,300	
	Total Estimated Project Cost	**$4,100**	
	Annual O&M***	$10	
Efficiency	**30-yr Average Cost/lb-TP**	**$55**	
	30-yr Average Cost/1,000lb-TSS	**$87**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (30 hours at $60/hour)

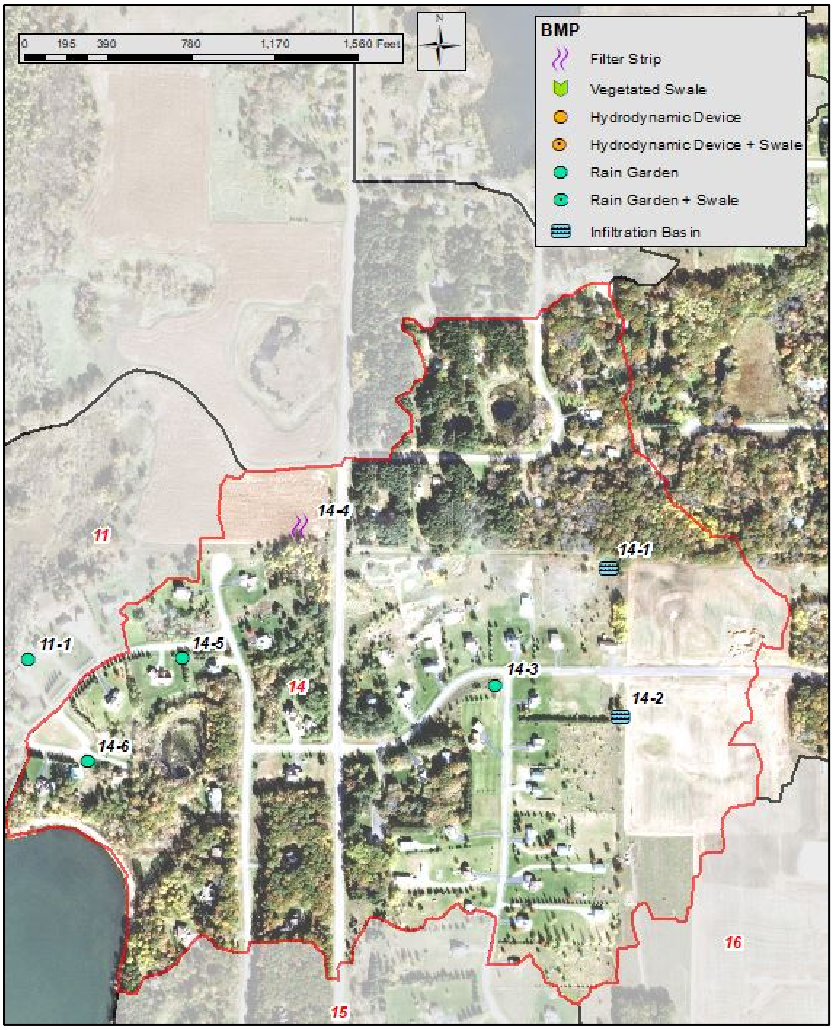
**Direct Cost: ($50/lnft for materials and labor) + $1,750 design and oversight)

***Per BMP: ($10/year)

Sub-watershed 14

Sub-watershed Characteristics	
Acres	166.1
Dominant Land Cover	Rural Suburban
Municipality	Livonia Township

Sub-watershed 14 includes several land use types and also has a fair slope. Areas previously utilized for agriculture are slated for suburban development. WinSLAMM results were supplemented with RUSLE2 modeling predictions for the small piece of agriculture in this sub-watershed.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Wetland Pond			
	TP (lb/yr)	46.7	8.1	17%	**38.6**
	TSS (lb/yr)	19,168	3121.0	16%	**16,047**
	Volume (acre-feet/yr)	24.8	0.6	3%	**24.2**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 10: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM and RUSLE2 parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 14-1 — Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1,500	sq-ft
	TP (lb/yr)	1.62	4.2%
	TSS (lb/yr)	641	4.0%
	Volume (acre-feet/yr)	0.30	1.2%
Cost	Administration & Promotion Costs*	$2,400	
	Design & Construction Costs**	$30,720	
	Total Estimated Project Cost	**$33,120**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$734**	
	30-yr Average Cost/1,000lb-TSS	**$1,855**	
	30-yr Average Cost/ac-ft Vol.	**$3,984**	

*Indirect Cost: (40 hours at $60/hour base cost)
**Direct Cost: ($20/sqft materials and labor) + 12 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 14-2 — Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1,500	sq-ft
	TP (lb/yr)	2.27	5.9%
	TSS (lb/yr)	489	3.0%
	Volume (acre-feet/yr)	0.16	0.7%
Cost	Administration & Promotion Costs*	$2,400	
	Design & Construction Costs**	$30,720	
	Total Estimated Project Cost	**$33,120**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$524**	
	30-yr Average Cost/1,000lb-TSS	**$2,431**	
	30-yr Average Cost/ac-ft Vol.	**$7,399**	

*Indirect Cost: (40 hours at $60/hour base cost)
**Direct Cost: ($20/sqft materials and labor) + 12 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 14-3 — Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	500	sq-ft
	TP (lb/yr)	1.01	2.6%
	TSS (lb/yr)	490	3.1%
	Volume (acre-feet/yr)	0.11	0.5%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$15,400	
	Total Estimated Project Cost	**$22,360**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$822**	
	30-yr Average Cost/1,000lb-TSS	**$1,695**	
	30-yr Average Cost/ac-ft Vol.	**$7,234**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 14-4 — Cool Season Grass Filter Strip

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1.08	acres
	TP (lb/yr)	1.38	3.6%
	TSS (lb/yr)	981	6.1%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$1,800	
	Design & Construction Costs**	$2,311	
	Total Estimated Project Cost	**$4,111**	
	Annual O&M***	$10	
Efficiency	30-yr Average Cost/lb-TP	**$107**	
	30-yr Average Cost/1,000lb-TSS	**$150**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (30 hours at $60/hour)
**Direct Cost: ($50/lnft for materials and labor) + $1,750 design and oversight)
***Per BMP: ($10/year)

Project ID 14-5

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	500	sq-ft
	TP (lb/yr)	0.88	2.3%
	TSS (lb/yr)	367	2.3%
	Volume (acre-feet/yr)	0.14	0.6%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$15,400	
	Total Estimated Project Cost	**$22,360**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$944**	
	30-yr Average Cost/1,000lb-TSS	**$2,262**	
	30-yr Average Cost/ac-ft Vol.	**$6,028**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 14-6

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.44	1.1%
	TSS (lb/yr)	145	0.9%
	Volume (acre-feet/yr)	0.05	0.2%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,395**	
	30-yr Average Cost/1,000lb-TSS	**$4,232**	
	30-yr Average Cost/ac-ft Vol.	**$13,366**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

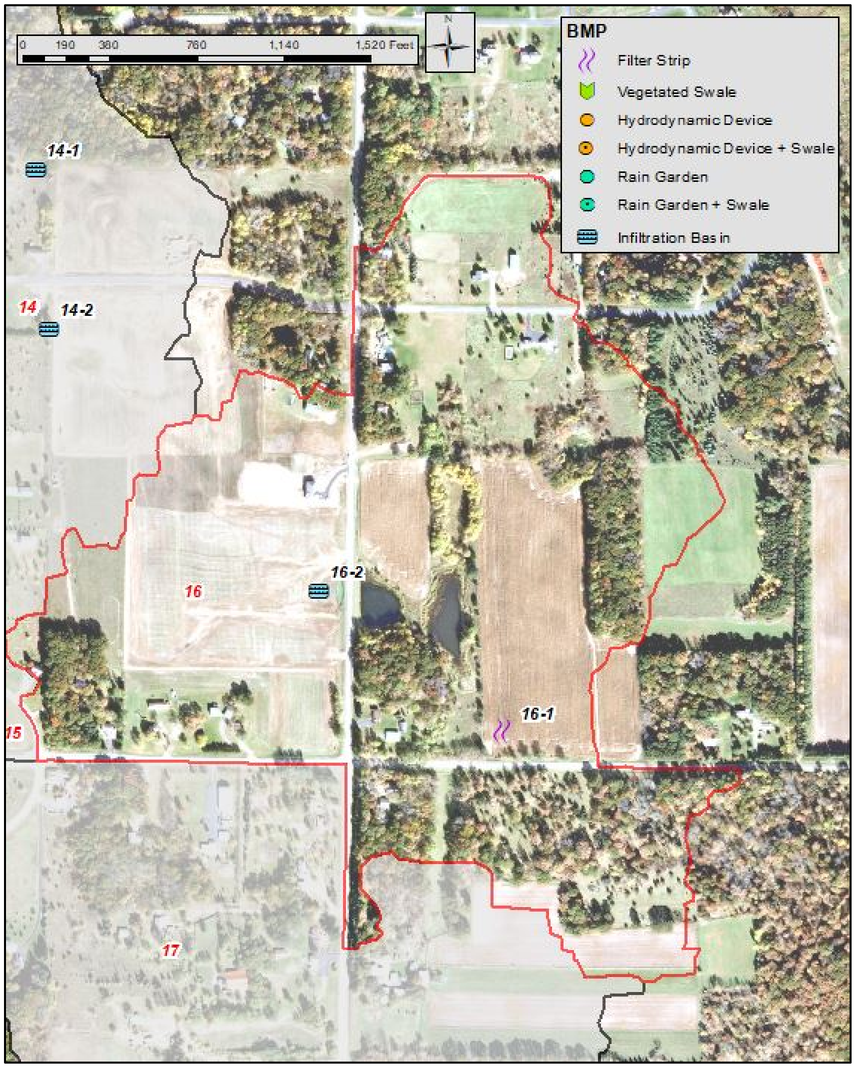
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 16

Sub-watershed Characteristics	
Acres	136.4
Dominant Land Cover	Rural Suburban
Municipality	Livonia Township

Sub-watershed 16 includes some agriculture, some suburban residences and an area currently being developed for additional residences on its western side. As with previous sub-watersheds, RUSLE2 was used to aid predictive modeling for this study.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	0			
	BMP Types	n/a			
	TP (lb/yr)	30.8	0.0	0%	**30.8**
	TSS (lb/yr)	12,070	0.0	0%	**12,070**
	Volume (acre-feet/yr)	14.5	0.0	0%	**14.5**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 11: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM and RUSLE2 parameters, costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 16-1

Cool Season Grass Filter Strip

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	1.70	acres
	TP (lb/yr)	2.70	8.8%
	TSS (lb/yr)	1,991	16.5%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$1,800	
	Design & Construction Costs**	$2,626	
	Total Estimated Project Cost	**$4,426**	
	Annual O&M***	$10	
Efficiency	**30-yr Average Cost/lb-TP**	**$58**	
	30-yr Average Cost/1,000lb-TSS	**$79**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (30 hours at $60/hour)

**Direct Cost: ($50/lnft for materials and labor) + $1,750 design and oversight)

***Per BMP: ($10/year)

Project ID 14-6

Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	3,000	sq-ft
	TP (lb/yr)	3.23	10.5%
	TSS (lb/yr)	1,114	9.2%
	Volume (acre-feet/yr)	2.01	13.9%
Cost	Administration & Promotion Costs*	$2,400	
	Design & Construction Costs**	$60,720	
	Total Estimated Project Cost	**$63,120**	
	Annual O&M***	$85	
Efficiency	**30-yr Average Cost/lb-TP**	**$678**	
	30-yr Average Cost/1,000lb-TSS	**$1,965**	
	30-yr Average Cost/ac-ft Vol.	**$1,090**	

*Indirect Cost: (40 hours at $60/hour base cost)

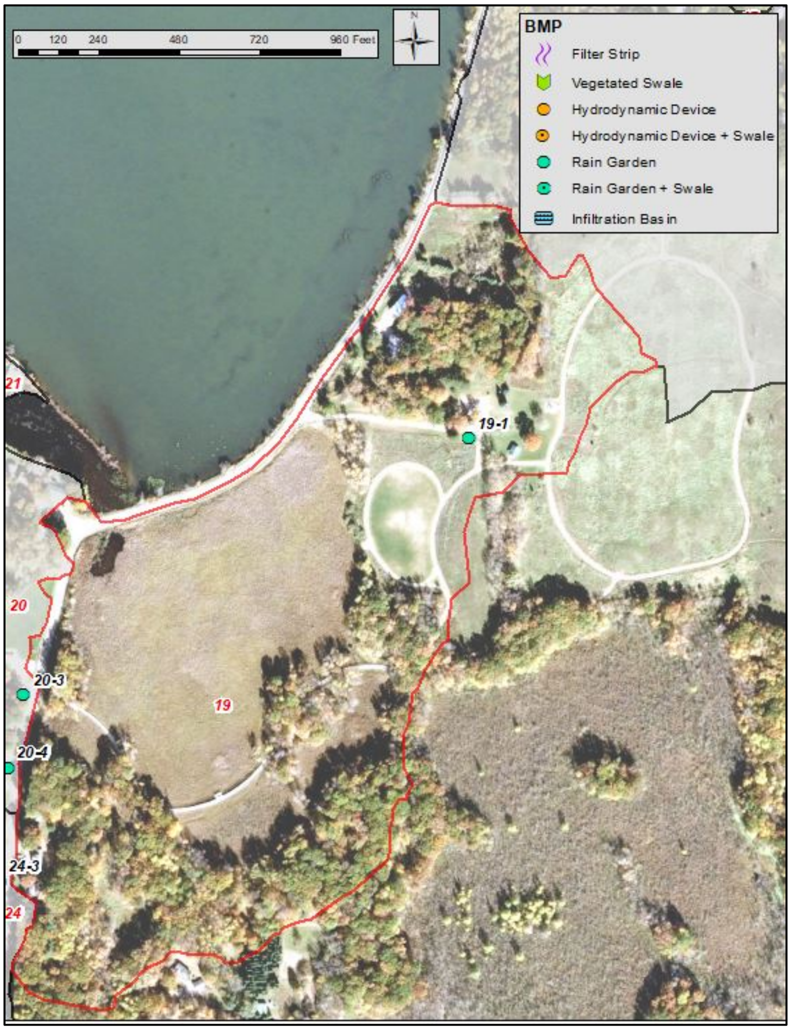
**Direct Cost: ($20/sqft materials and labor) + 12 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 19

Sub-watershed Characteristics	
Acres	50.3
Dominant Land Cover	Suburban Open
Municipality	Livonia Township

Sub-watershed encompasses a portion of the 100+ acre Grams Regional Park. The sub-watershed consists of a large wetland complex, some forest, and the parking lot and walking trails. The sub-watershed has the lowest pollution export of the priority sub-watersheds but the expanse of land does offer opportunity for pollution mitigation, particularly at the parking lot location.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	**Number of BMPs**	1			
	BMP Types	Wetland Pond			
	TP (lb/yr)	13.5	2.9	22%	**10.5**
	TSS (lb/yr)	5,015	1157.0	23%	**3,858**
	Volume (acre-feet/yr)	6.4	0.2	2%	**6.2**

Treatment Calculations and Cost Analysis

As outlined in the tables below, a single project was identified for this sub-watershed – a 750 sqft rain garden that would accept runoff from the parking lot of Grams Regional Park. The parking lot is the sole source of impervious surface in this sub-watershed, which is close in proximity to Lake Fremont.

Table 12: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 19-1			
Curb-Cut Rain Garden			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	750	sq-ft
	TP (lb/yr)	1.65	15.7%
	TSS (lb/yr)	552	14.3%
	Volume (acre-feet/yr)	0.40	6.5%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$21,900	
	Total Estimated Project Cost	**$28,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$635**	
	30-yr Average Cost/1,000lb-TSS	**$1,897**	
	30-yr Average Cost/ac-ft Vol.	**$2,606**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

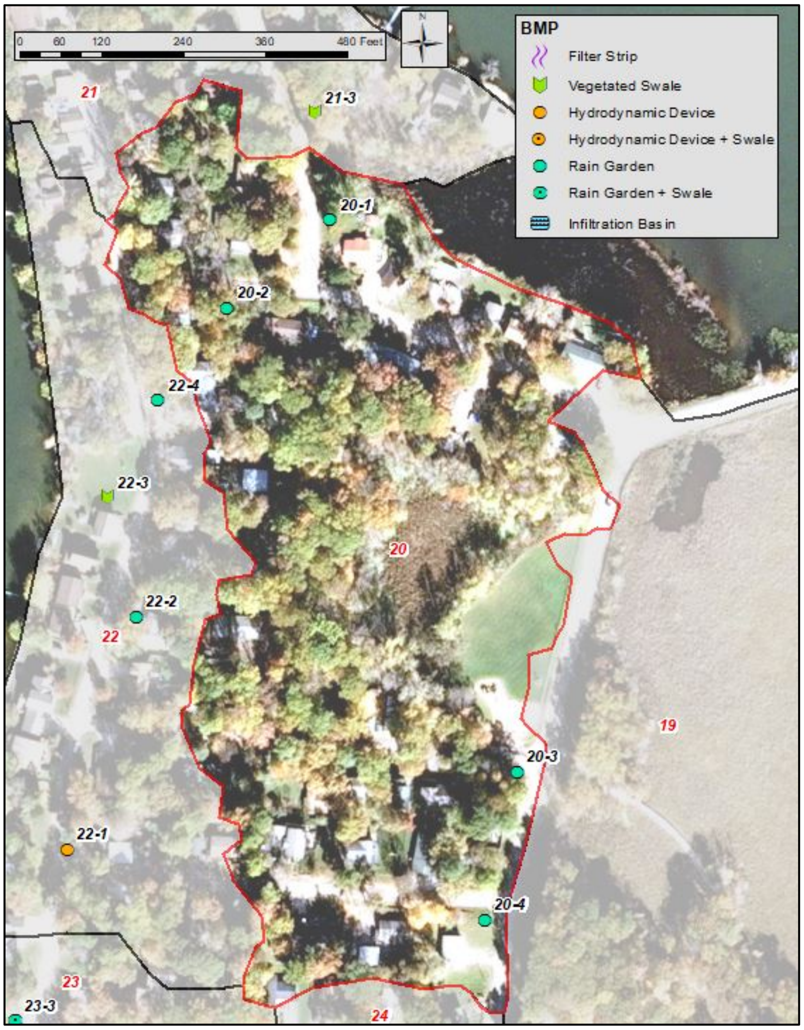
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($350/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 20

Sub-watershed Characteristics	
Acres	14.2
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

This sub-watershed lies on center peninsula of Lake Fremont and includes closely spaced, small parcels in an urban residential setting. Traffic may be higher in this region and include local residents, visitors to the lake public boat launch, and transient vehicles heading to Grams Park.



Existing Conditions		Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Wetland Pond			
	TP (lb/yr)	7.9	0.7	9%	**7.2**
	TSS (lb/yr)	3,594	309.0	9%	**3,285**
	Volume (acre-feet/yr)	5.7	0.0	0%	**5.7**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 13: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 20-1

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.41	5.7%
	TSS (lb/yr)	187	5.7%
	Volume (acre-feet/yr)	0.31	5.5%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,497**	
	30-yr Average Cost/1,000lb-TSS	**$3,282**	
	30-yr Average Cost/ac-ft Vol.	**$1,950**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 20-2

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.27	3.8%
	TSS (lb/yr)	124	3.8%
	Volume (acre-feet/yr)	0.21	3.7%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$2,248**	
	30-yr Average Cost/1,000lb-TSS	**$4,949**	
	30-yr Average Cost/ac-ft Vol.	**$2,908**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 20-3

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	500	sq-ft
	TP (lb/yr)	0.90	12.5%
	TSS (lb/yr)	412	12.5%
	Volume (acre-feet/yr)	0.69	12.1%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$15,400	
	Total Estimated Project Cost	**$22,360**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$923**	
	30-yr Average Cost/1,000lb-TSS	**$2,015**	
	30-yr Average Cost/ac-ft Vol.	**$1,202**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 20-4

Curb-Cut Rain Garden

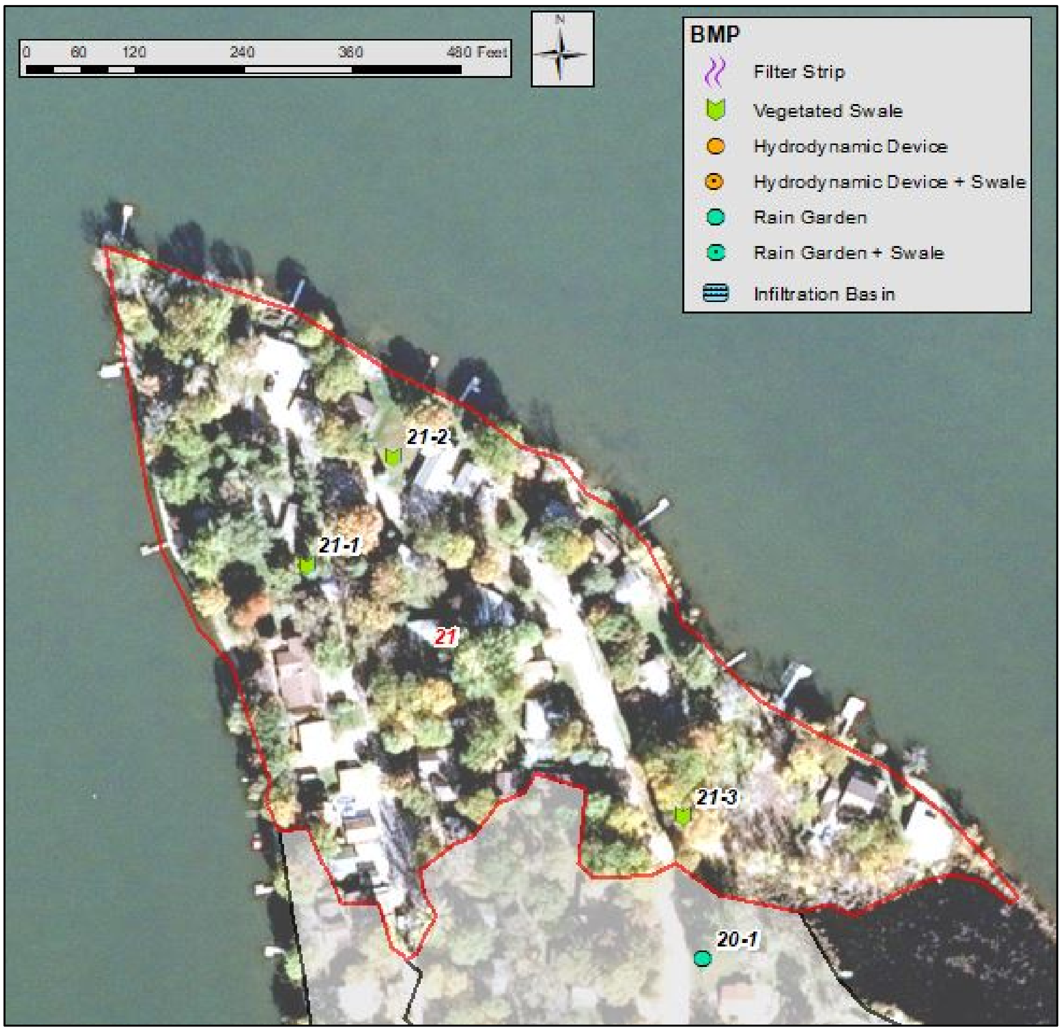
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.45	6.2%
	TSS (lb/yr)	206	6.3%
	Volume (acre-feet/yr)	0.35	6.0%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$1,364**	
	30-yr Average Cost/1,000lb-TSS	**$2,979**	
	30-yr Average Cost/ac-ft Vol.	**$1,777**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 21

Sub-watershed Characteristics	
Acres	14.2
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

This sub-watershed lies on the tip of the Lake Fremont southern peninsula. The density of housing is relatively high here, with 0.10-0.20 acre lots being found. Much of the sub-watershed is too close to groundwater, making infiltration practices infeasible.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	4.4	0.4	9%	**4.0**
	TSS (lb/yr)	1,978	169.0	9%	**1,809**
	Volume (acre-feet/yr)	3.1	0.0	0%	**3.1**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 14: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 21-1

Vegetated Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	30	ln-ft
	TP (lb/yr)	0.27	6.8%
	TSS (lb/yr)	122	6.7%
	Volume (acre-feet/yr)	0.20	6.3%
Cost	Administration & Promotion Costs*	$3,000	
	Design & Construction Costs**	$2,220	
	Total Estimated Project Cost	**$5,220**	
	Annual O&M***	$80	
Efficiency	30-yr Average Cost/lb-TP	**$944**	
	30-yr Average Cost/1,000lb-TSS	**$2,082**	
	30-yr Average Cost/ac-ft Vol.	**$1,279**	

*Indirect Cost: (50 hours at $60/hour)
**Direct Cost: ($50/sqft materials and labor) + 12 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at year 10) + ($75/year for routine maintenance)

Project ID 21-2

Vegetated Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	30	ln-ft
	TP (lb/yr)	0.20	5.0%
	TSS (lb/yr)	91	5.0%
	Volume (acre-feet/yr)	0.15	4.8%
Cost	Administration & Promotion Costs*	$3,000	
	Design & Construction Costs**	$2,220	
	Total Estimated Project Cost	**$5,220**	
	Annual O&M***	$80	
Efficiency	30-yr Average Cost/lb-TP	**$1,283**	
	30-yr Average Cost/1,000lb-TSS	**$2,791**	
	30-yr Average Cost/ac-ft Vol.	**$1,677**	

*Indirect Cost: (50 hours at $60/hour)
**Direct Cost: ($50/sqft materials and labor) + 12 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at year 10) + ($75/year for routine maintenance)

Project ID 21-3

Vegetated Swale

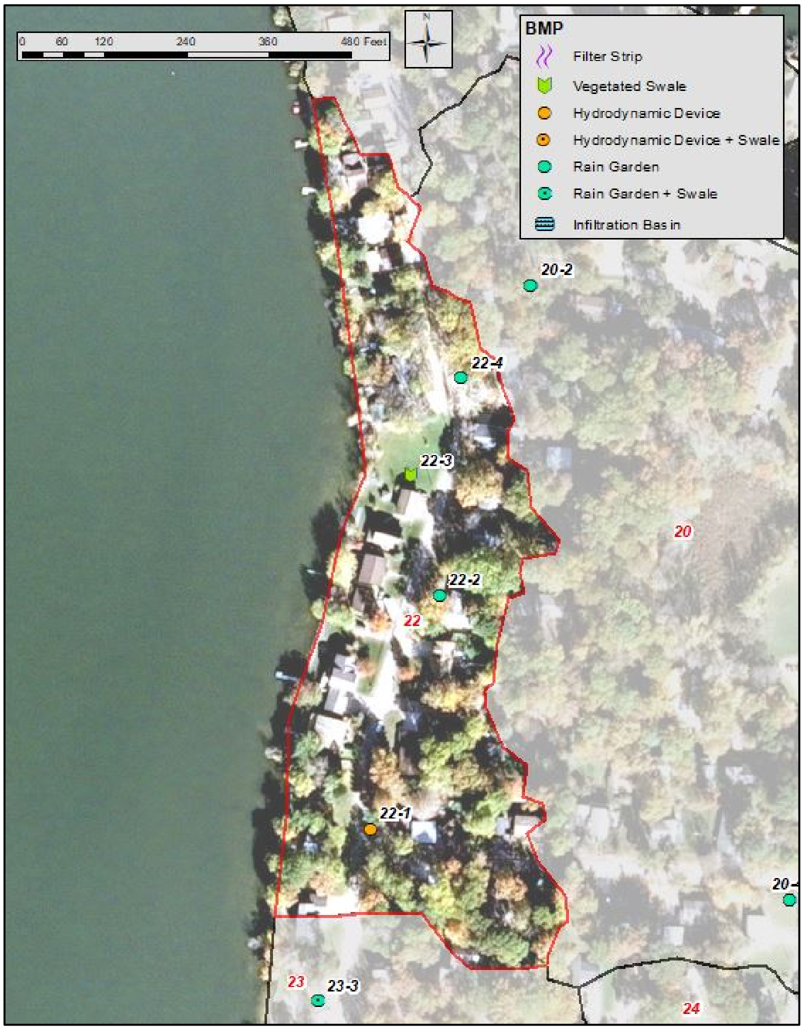
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	30	ln-ft
	TP (lb/yr)	0.37	9.2%
	TSS (lb/yr)	166	9.2%
	Volume (acre-feet/yr)	0.26	8.2%
Cost	Administration & Promotion Costs*	$3,000	
	Design & Construction Costs**	$2,220	
	Total Estimated Project Cost	**$5,220**	
	Annual O&M***	$80	
Efficiency	30-yr Average Cost/lb-TP	**$696**	
	30-yr Average Cost/1,000lb-TSS	**$1,530**	
	30-yr Average Cost/ac-ft Vol.	**$981**	

*Indirect Cost: (50 hours at $60/hour)
**Direct Cost: ($50/sqft materials and labor) + 12 hours/BMP at $60/hour for design)
***Per BMP: ($150/year at year 10) + ($75/year for routine maintenance)

Sub-watershed 22

Sub-watershed Characteristics	
Acres	6.8
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

As with other sub-watersheds on the Lake Fremont peninsula this one numerous parcel lots averaging 0.15-0.20 acres in size. Some relief exists, and the elevation increases from the lake substantially in some areas which will allow for infiltration.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	3.8	0.3	9%	**3.5**
	TSS (lb/yr)	1,719	148.0	9%	**1,571**
	Volume (acre-feet/yr)	2.7	0.0	0%	**2.7**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 15: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 22-1

Curb-Cut Rain Garden + Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	2	
Treatment	Total Size of BMPs	250 sqft RG, 30 lnft swale	
Treatment	TP (lb/yr)	0.49	14.2%
Treatment	TSS (lb/yr)	219	13.9%
Treatment	Volume (acre-feet/yr)	0.36	13.3%
Cost	Administration & Promotion Costs*	$9,600	
Cost	Design & Construction Costs**	$9,200	
Cost	Total Estimated Project Cost	**$18,800**	
Cost	Annual O&M***	$113	
Efficiency	30-yr Average Cost/lb-TP	**$1,510**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$3,377**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$2,037**	

*Indirect Cost: (140 hours at $60/hour base cost) + (10 hours/BMP at $60/hour)

**Direct Cost: ($26/sqft RG, $50/sqft Swale)+10 hours/BMP at $60/hour design)

***Per BMP: ($200/year at years 10 and 20) + ($100/year for routine maintenance)

Project ID 22-2

4' Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	4	ft dia
Treatment	TP (lb/yr)	0.30	8.8%
Treatment	TSS (lb/yr)	121	7.7%
Treatment	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*	$1,440	
Cost	Design & Construction Costs**	$18,000	
Cost	Total Estimated Project Cost	**$19,440**	
Cost	Annual O&M***	$360	
Efficiency	30-yr Average Cost/lb-TP	**$3,327**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$8,331**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (24 hours at $60/hr)

**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)

***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Project ID 22-3

Vegetated Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	30	ln-ft
Treatment	TP (lb/yr)	0.34	9.9%
Treatment	TSS (lb/yr)	154	9.8%
Treatment	Volume (acre-feet/yr)	0.23	8.5%
Cost	Administration & Promotion Costs*	$3,000	
Cost	Design & Construction Costs**	$2,220	
Cost	Total Estimated Project Cost	**$5,220**	
Cost	Annual O&M***	$80	
Efficiency	30-yr Average Cost/lb-TP	**$747**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$1,649**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$1,097**	

*Indirect Cost: (50 hours at $60/hour)

**Direct Cost: ($50/sqft materials and labor) + 12 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at year 10) + ($75/year for routine maintenance)

Project ID 22-4

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	250	sq-ft
Treatment	TP (lb/yr)	0.15	4.2%
Treatment	TSS (lb/yr)	66	4.2%
Treatment	Volume (acre-feet/yr)	0.11	4.2%
Cost	Administration & Promotion Costs*	$6,960	
Cost	Design & Construction Costs**	$8,900	
Cost	Total Estimated Project Cost	**$15,860**	
Cost	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$4,232**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$9,298**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$5,359**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

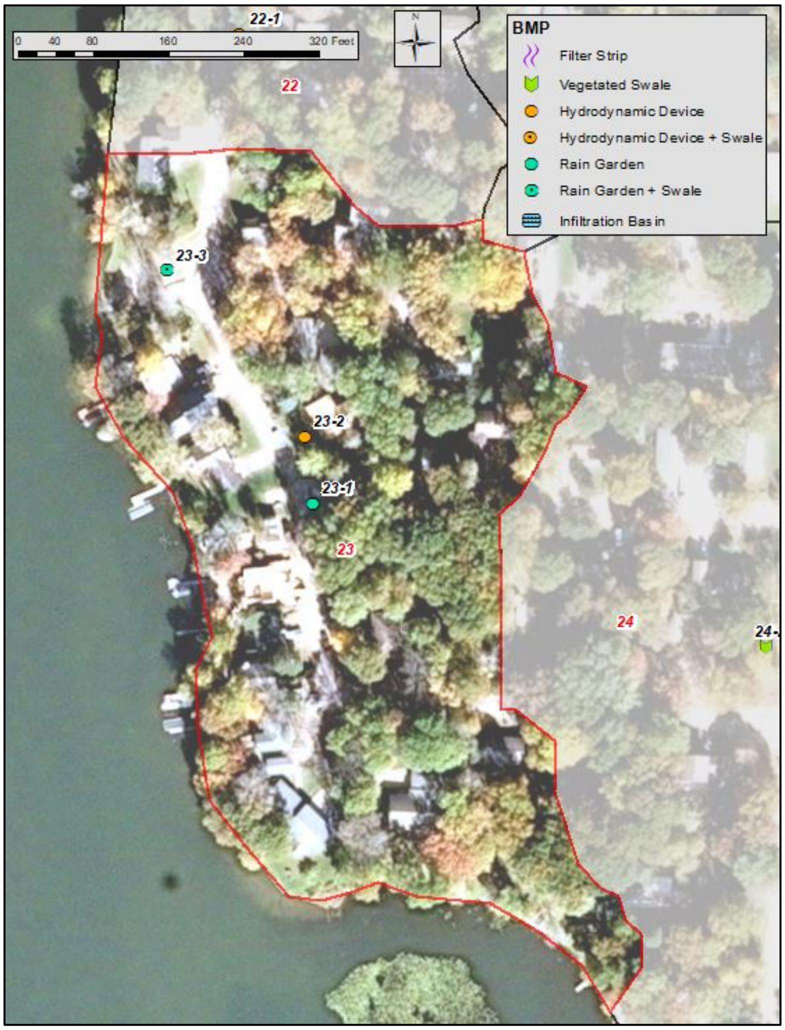
**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 23

Sub-watershed Characteristics	
Acres	7.0
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

This sub-watershed lies on the Lake Fremont peninsula and with others includes numerous relatively small parcels. The Lake Fremont public boat access can be found in this sub-watershed as well and offers some space for potential stormwater mitigation (BMP 23-3). The area likely sees higher than normal traffic due to the public boat launch being located here.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	3.9	0.3	9%	**3.5**
	TSS (lb/yr)	1,764	151.0	9%	**1,613**
	Volume (acre-feet/yr)	2.8	0.0	0%	**2.8**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 16: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 23-1

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment		% Reduction
Treatment	Number of BMPs	1		
	Total Size of BMPs	250	sq-ft	
	TP (lb/yr)	0.44		12.4%
	TSS (lb/yr)	202		12.5%
	Volume (acre-feet/yr)	0.34		12.0%
Cost	Administration & Promotion Costs*	$6,960		
	Design & Construction Costs**	$8,900		
	Total Estimated Project Cost	**$15,860**		
	Annual O&M***	$85		
Efficiency	**30-yr Average Cost/lb-TP**	**$1,395**		
	30-yr Average Cost/1,000lb-TSS	**$3,038**		
	30-yr Average Cost/ac-ft Vol.	**$1,820**		

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Project ID 23-2

4' Hydrodynamic Device

	Cost/Removal Analysis	New Treatment		% Reduction
Treatment	Number of BMPs	1		
	Total Size of BMPs	4	ft dia	
	TP (lb/yr)	0.15		4.3%
	TSS (lb/yr)	62		3.8%
	Volume (acre-feet/yr)	0.00		0.0%
Cost	Administration & Promotion Costs*	$1,440		
	Design & Construction Costs**	$18,000		
	Total Estimated Project Cost	**$19,440**		
	Annual O&M***	$360		
Efficiency	**30-yr Average Cost/lb-TP**	**$6,545**		
	30-yr Average Cost/1,000lb-TSS	**$16,258**		
	30-yr Average Cost/ac-ft Vol.	**n/a**		

*Indirect Cost: (24 hours at $60/hr)

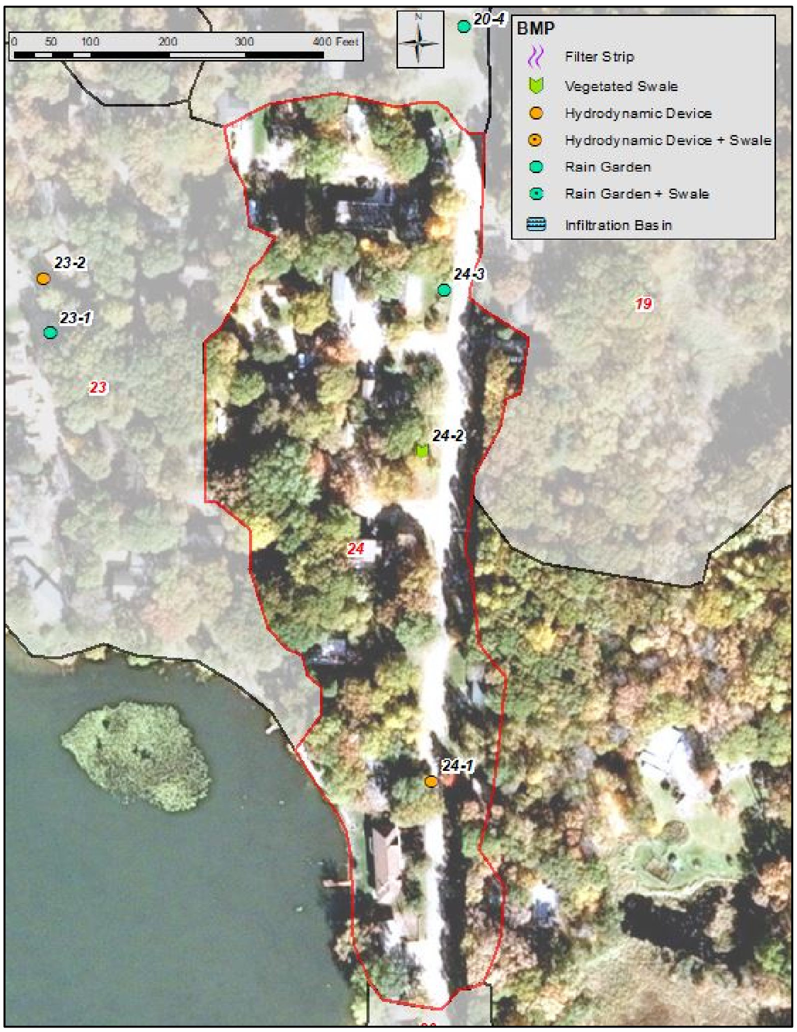
**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)

***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Sub-watershed 24

Sub-watershed Characteristics	
Acres	7.4
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

Sub-watershed 24 is located at the base of the Lake Fremont southern peninsula. This area includes a busy 120th St, so traffic is higher than normal due to including local traffic, public boat launch traffic, and visitors to Grams Regional Park. A fair amount of slope exists in the northern areas.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	4.1	0.4	9%	**3.8**
	TSS (lb/yr)	1,872	160.0	9%	**1,712**
	Volume (acre-feet/yr)	3.0	0.0	0%	**3.0**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 17: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 24-1

4' Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	4	ft dia
	TP (lb/yr)	0.18	4.9%
	TSS (lb/yr)	78	4.6%
	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*	$1,440	
	Design & Construction Costs**	$18,000	
	Total Estimated Project Cost	**$19,440**	
	Annual O&M***	$360	
Efficiency	30-yr Average Cost/lb-TP	**$5,508**	
	30-yr Average Cost/1,000lb-TSS	**$12,923**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (24 hours at $60/hr)

**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)

***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Project ID 24-2

Vegetated Swale

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	30	ln-ft
	TP (lb/yr)	0.28	7.5%
	TSS (lb/yr)	128	7.5%
	Volume (acre-feet/yr)	0.20	6.6%
Cost	Administration & Promotion Costs*	$3,000	
	Design & Construction Costs**	$2,220	
	Total Estimated Project Cost	**$5,220**	
	Annual O&M***	$80	
Efficiency	30-yr Average Cost/lb-TP	**$898**	
	30-yr Average Cost/1,000lb-TSS	**$1,984**	
	30-yr Average Cost/ac-ft Vol.	**$1,299**	

*Indirect Cost: (50 hours at $60/hour)

**Direct Cost: ($50/sqft for materials and labor) + 12 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at year 10) + ($75/year for routine maintenance)

Project ID 24-3

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.81	11.2%
	TSS (lb/yr)	373	11.4%
	Volume (acre-feet/yr)	0.62	10.8%
Cost	Administration & Promotion Costs*	$6,960	
	Design & Construction Costs**	$8,900	
	Total Estimated Project Cost	**$15,860**	
	Annual O&M***	$85	
Efficiency	30-yr Average Cost/lb-TP	**$762**	
	30-yr Average Cost/1,000lb-TSS	**$1,645**	
	30-yr Average Cost/ac-ft Vol.	**$996**	

*Indirect Cost: (104 hours at $60/hour base cost) + (12 hours/BMP at $60/hour)

**Direct Cost: ($26/sq-ft materials and labor) + (40 hours/BMP at $60/hour for design)

***Per BMP: ($150/year at years 10 and 20) + ($75/year for routine maintenance)

Sub-watershed 25

Sub-watershed Characteristics	
Acres	5.7
Dominant Land Cover	Med Dense Urban
Municipality	City of Zimmerman

Sub-watershed 25 can be found along the southern side of Lake Fremont, near the lake's outlet location. The area includes relatively high topographic relief for the region along with smaller lake parcels fit snuggly next to each other. Traffic likely consists of local residents and visitors with minimal transient vehicle traffic.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	3.2	0.3	9%	**2.9**
	TSS (lb/yr)	1,443	123.0	9%	**1,320**
	Volume (acre-feet/yr)	2.3	0.0	0%	**2.3**

Treatment Calculations and Cost Analysis

As outlined in the tables below, several potential projects were identified for this sub-watershed. The tables that follow outline the project type, pollution parameters following installation of the project, the cost of the project and the cost per pound of pollutant reduction. Modeling results are independent of each other; that is, the reductions and costs are associated with each single project and do not reflect savings or additional pollutant reduction that would occur with multiple BMP installations.

Table 18: Sub-watershed potential BMP projects. Pollutant estimates based upon standard WinSLAMM , costs based upon conservative estimates from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals and local project experience.

Project ID 25-1

4' Hydrodynamic Device			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	4	ft dia
	TP (lb/yr)	0.13	4.5%
	TSS (lb/yr)	53	4.0%
	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*	$1,440	
	Design & Construction Costs**	$18,000	
	Total Estimated Project Cost	**$19,440**	
	Annual O&M***	$360	
Efficiency	30-yr Average Cost/lb-TP	**$7,695**	
	30-yr Average Cost/1,000lb-TSS	**$19,019**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (24 hours at $60/hr)
**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)
***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Project ID 25-2

4' Hydrodynamic Device			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	4	ft dia
	TP (lb/yr)	0.22	7.6%
	TSS (lb/yr)	113	8.6%
	Volume (acre-feet/yr)	0.00	0.0%
Cost	Administration & Promotion Costs*	$1,440	
	Design & Construction Costs**	$18,000	
	Total Estimated Project Cost	**$19,440**	
	Annual O&M***	$360	
Efficiency	30-yr Average Cost/lb-TP	**$4,603**	
	30-yr Average Cost/1,000lb-TSS	**$8,920**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: (24 hours at $60/hr)
**Direct Cost: ($9,000 HD materials) + ($9,000 labor & construction)
***Per BMP: (2 cleanings/year)*(3 hrs/cleaning)*$60/hr)

Literature Cited

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Pitt, B., and Voorhees, J., (PV & Associates). 2019. Source Loading and Management Model for Windows (WinSLAMM). Version 10.4.1. Accessible at: http://www.winslamm.com/default.html.

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Schueler, T. and A. Kitchell. 2005. Methods to Develop Restoration Plans for Small urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Appendix A: Modeling Methods.

The following section includes WinSLAMM model details for each type of best management practice modeled for this analysis.

WinSLAMM

Pollutant and volume reductions were estimated using the stormwater model Source Load and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the Upper-Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It has detailed accounting of pollutant loading from various land uses and allows the user to build a model "landscape". WinSLAMM uses rainfall and temperature data from a typical year (1959 data from Minneapolis for this analysis), routing stormwater through the user's model for each storm. WinSLAMM version 10.4.0 was used for this analysis to estimate volume and pollutant loading and reductions. Additional inputs for WinSLAMM are provided in Table 19.

Table 19: General WinSLAMM Model Inputs (i.e. Current File Data).

General WinSLAMM Model Inputs	
Parameter	***File or Method***
Land use acreage	ArcMap with 2015 Land Use
Precipitation / Temperature	Minneapolis 1959 (user preference, best approximates a typical year)
Winter Season	Included in model, 11-12 to 3-18
Pollutant probability distribution	WI_GE001.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use
Street sweeping	2x annually

BMP model designs

The diagrams that follow represent the standard parameters defined for various BMPs used in the modeling process, including existing conditions as well as proposed BMPs.

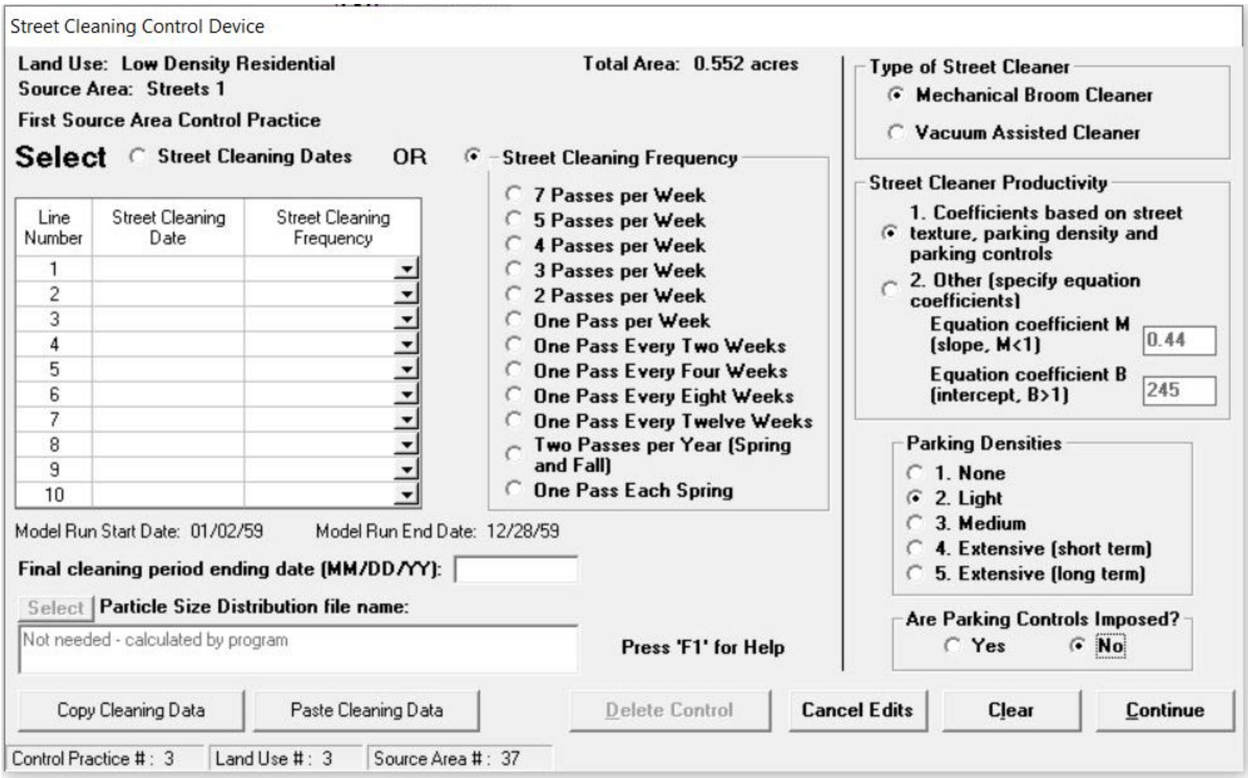

Figure 9: Street Sweeping. Street sweeping model inputs for Lake Fremont study.

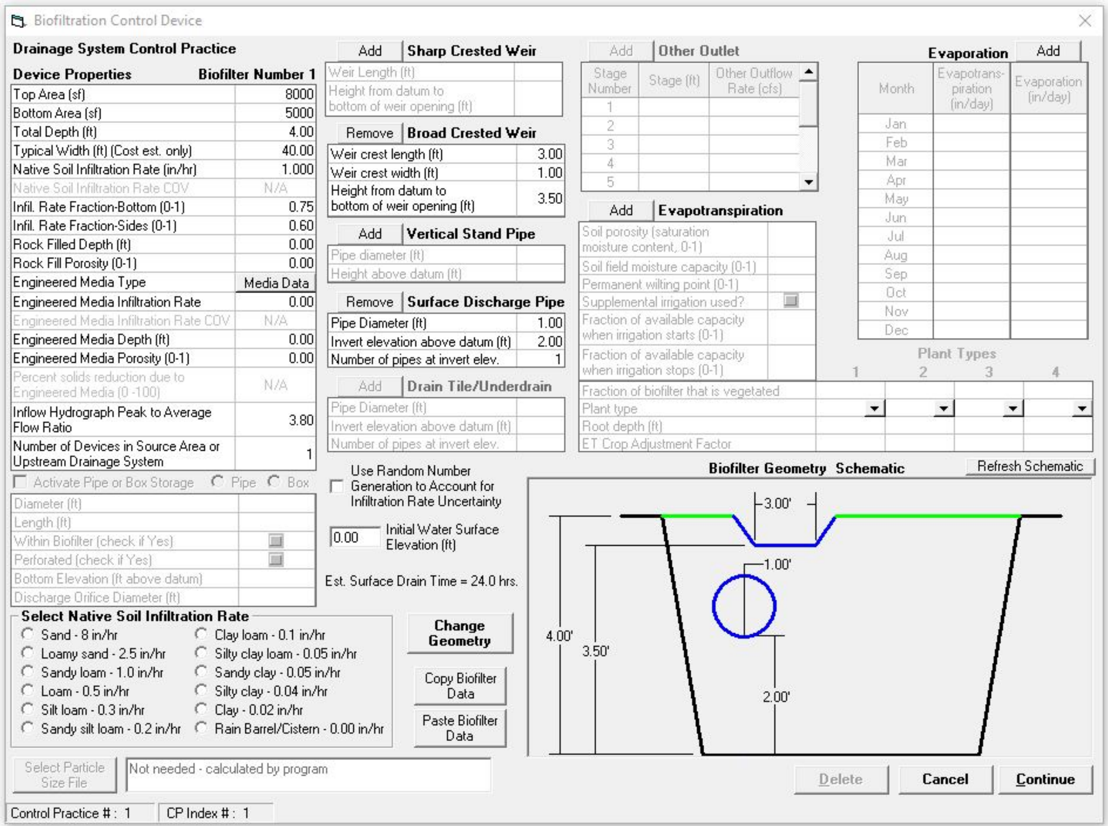

Figure 10: Infiltration Control Device. Model inputs will vary depending on site specific conditions.

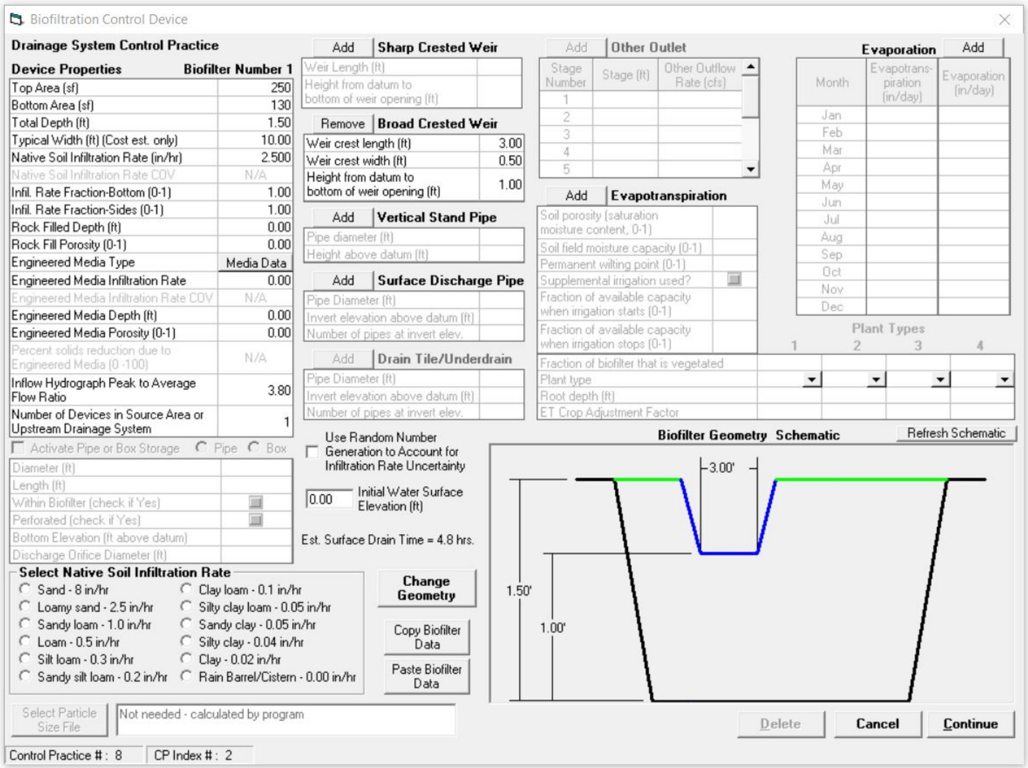

Figure 11: 250 sqft Rain Garden. Standard size used in most modeling applications.

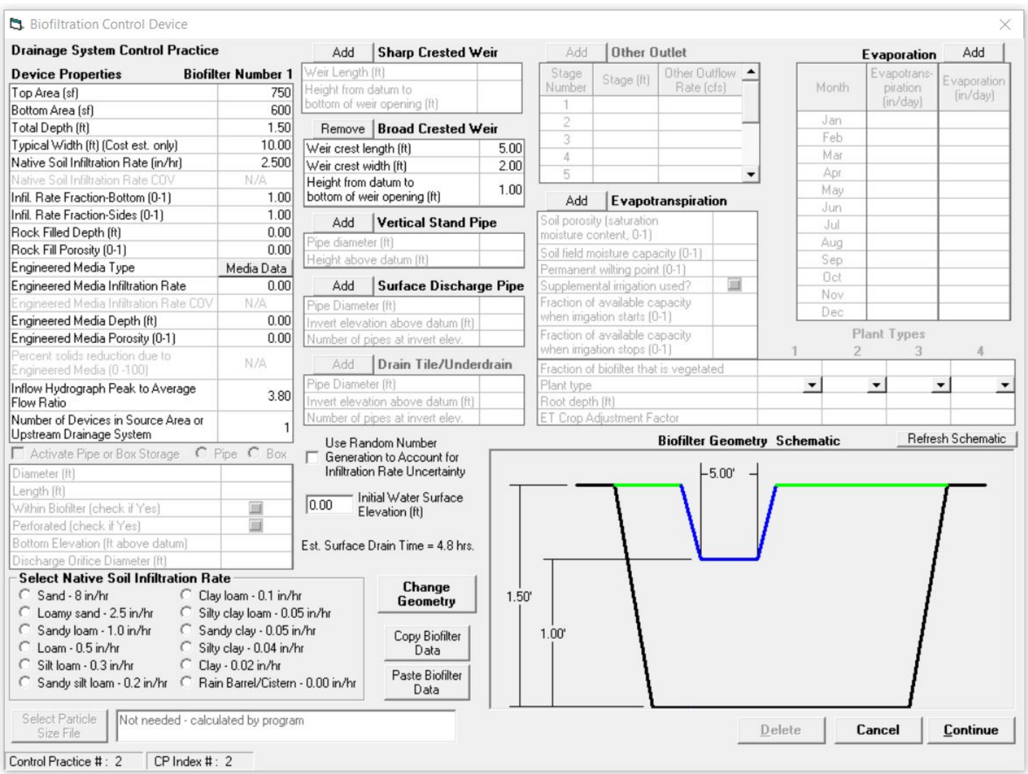

Figure 12: 750 sqft Rain Garden. Standard size used in several modeling scenarios.

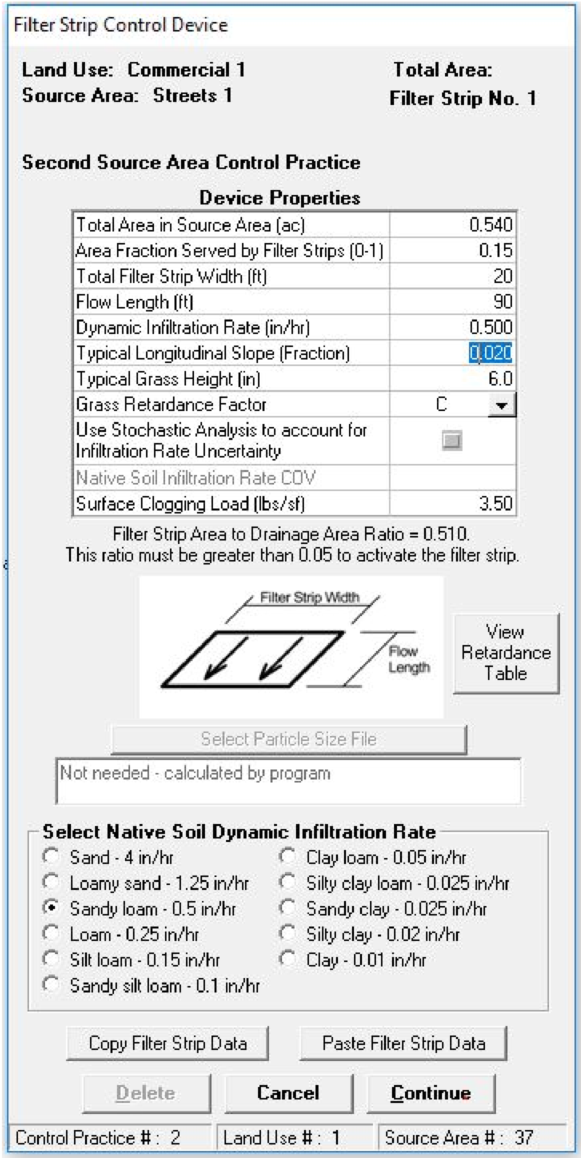

Figure 13: Filter strip. Some properties are standard, others customized given site-specific conditions.

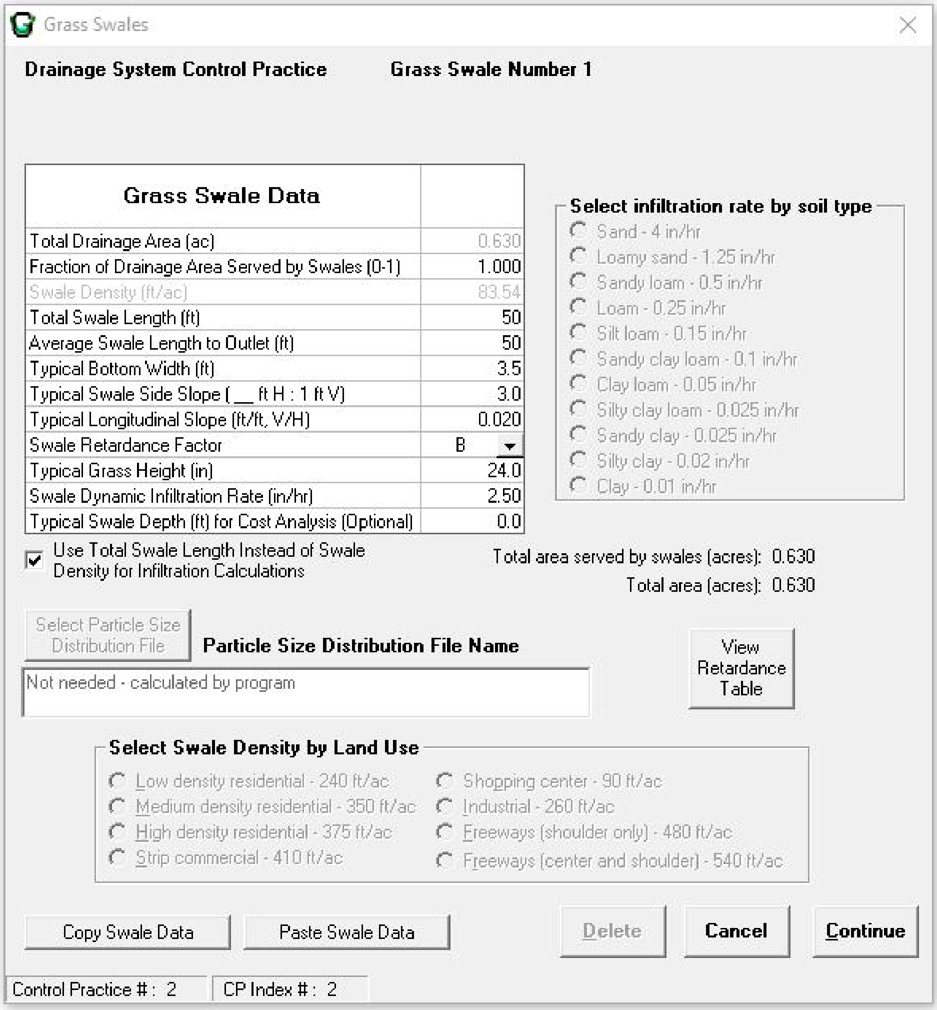

Figure 14: Vegetated Swale. Pictured is an example of a 50 ft swale.

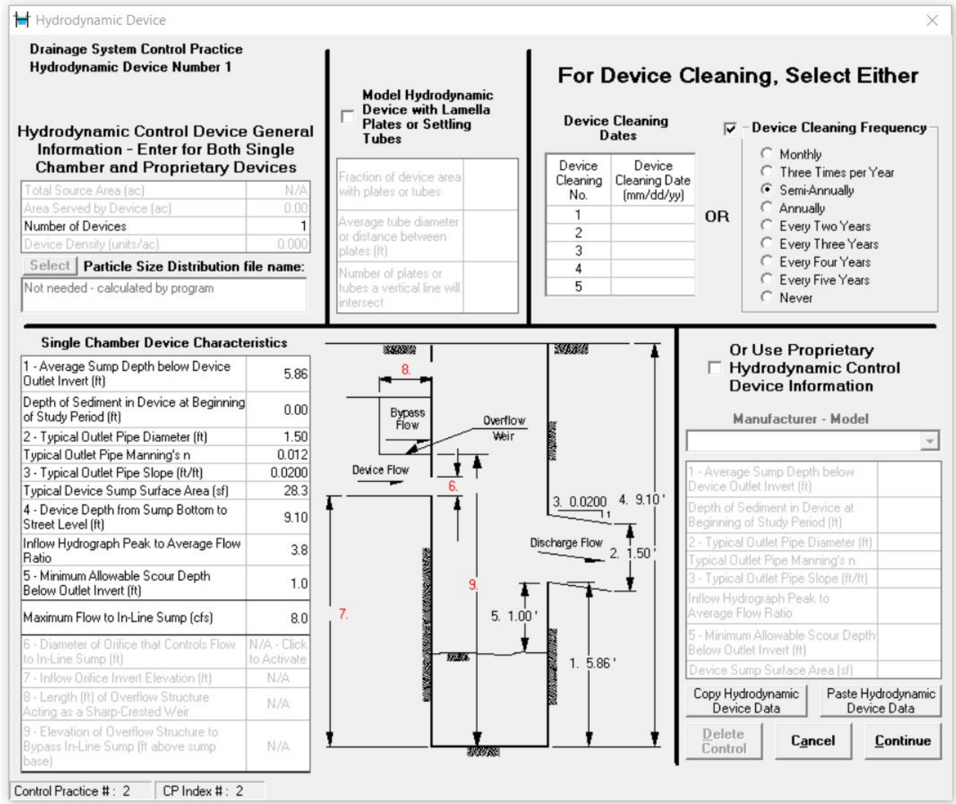

Figure 15: 4 ft Hydrodynamic Device.