Coon Lake
Stormwater Retrofit Analysis

Prepared by:

Anoka Conservation District

for the

SUNRISE RIVER WATERSHED MANANGEMENT ORGANIZATION

August 2014

Cover photo: Aerial photograph of Coon Lake in 2011.

Table of Contents

Map of stormwater catchments referred to in this report

Executive Summary

This study provides recommendations for cost effectively improving the treatment of stormwater from areas draining to Coon Lake. The lake and its surrounding subwatershed are located in northeastern Anoka County within the Cities of East Bethel, Ham Lake, Columbus, and Linwood Township. Coon Lake is the largest lake in the county, covering 1,481 acres, and is a popular destination for local anglers and recreation enthusiasts.

Improving Coon Lake water quality is a high priority because recent annual average phosphorus concentrations have been near or slightly above the state water quality standard for phosphorus, 40 µg/L (3 years since 2006; ACD 2014). These higher nutrient concentrations increase algal production and lead to poor recreational conditions.

The Coon Lake subwatershed covers 6,226 acres, of which the lake represents 24% of that area. The remaining acreage is predominantly wetlands (31%), forests (17%), agricultural/pastoral land (14%), undeveloped open space (5%), and residential lots (4%). Most of these residential properties are clustered along the shores of Coon Lake in the Cites of Ham Lake and East Bethel. The Coon Lake Beach neighborhood on the eastern shore of Coon Lake is the most densely populated area. Many proposed stormwater projects are located in this neighborhood.

This stormwater analysis focuses on "stormwater retrofitting" and ranking projects on cost effectiveness. Stormwater retrofitting refers to adding stormwater treatment to an already built-up area, where little open land exists. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this stormwater analysis we estimated both costs and pollutant reductions and used them to calculate cost effectiveness of each possible project.

Areas that drain to Coon Lake were delineated using available GIS watershed information, maps of stormwater conveyance features (where available), and advanced GIS terrain analysis technologies. Those areas were then divided into 7 smaller stormwater drainage areas, or catchments. For each catchment, modeling of stormwater volume and pollutants was completed using water quality software for urban (WinSLAMM) and rural agrarian (SWAT) landscapes. Base (without any stormwater treatment) and existing (with present day stormwater treatment) conditions were modeled. In total, under existing conditions the subwatershed contributes an estimated 2,455 acre feet (ac-ft) of runoff, 809 pounds of phosphorus, and 81 tons of suspended solids each year.

Potential stormwater retrofits identified during this analysis were modeled to estimate reductions in volume, total phosphorus (TP), and total suspended solids (TSS). Finally, cost estimates were developed for each retrofit project, including up to 30 years of operations and maintenance. Projects were ranked by cost effectiveness with respect to their reduction of TP.

A variety of stormwater retrofit approaches were identified. They include:

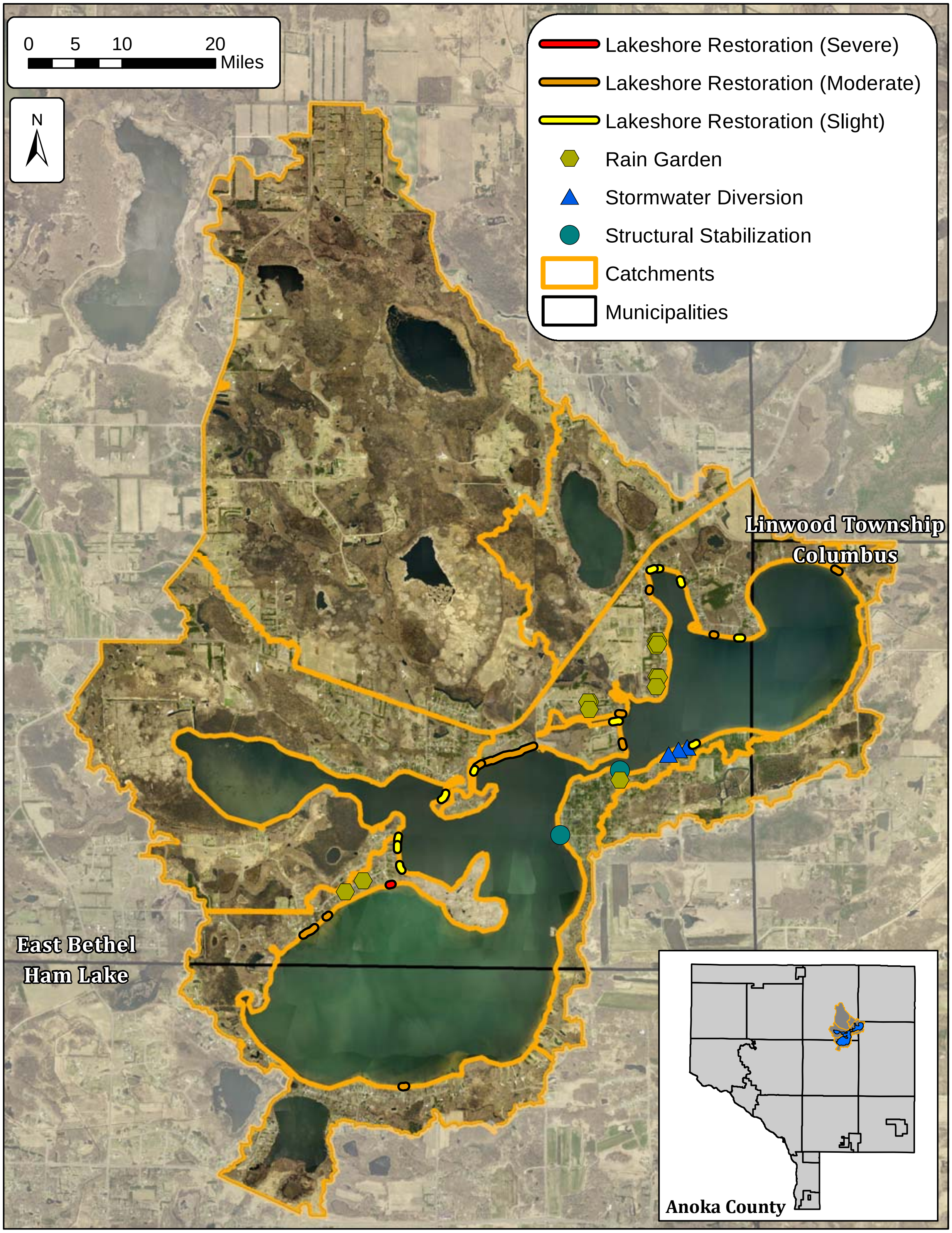
- Maintenance of, or alterations to, existing stormwater treatment practices,
- Residential curb-cut rain gardens,
- Lakeshore restorations,
- Stabilization of erosion sites, and
- Stormwater redirection.

This report provides conceptual sketches or photos of recommended stormwater retrofitting projects. The intent is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property.

The tables on the next pages summarize 30 potential projects organized from most cost effective to least, based on cost per pound of TP removed. If all of these practices were installed, pollutant loading to Coon Lake could be reduced by 25.3 lbs of TP and 12.8 tons of TSS. The 25.3 lbs-TP reduction could potentially reduce algal growth in the lake by 6.3 tons (assuming 1 lb phosphorus = 500 lbs algae). Reported treatment levels are dependent upon optimal site selection and sizing. More detail about each project can be found in the *Catchment Profile* pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in this report.

Installing all of these projects is unlikely due to funding limitations and landowner interest. Instead, it is recommended that projects be installed in order of cost effectiveness (pounds of pollution reduced per dollar spent). Other factors, including a project's educational value, visibility, construction timing, total cost, or non-target pollutant reduction also affect project installation decisions and will need to be weighed by resource managers when selecting projects to pursue.

Proposed stormwater retrofits in the Coon Lake subwatershed



Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. TSS and volume reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Retrofit Type (refer to catchment profile pages for additional detail)	Catchment	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)
1	Lakeshore Restoration LR-87	CL-5	1	2.6	3,683	0.1	$14,180	$122	$232
2	Lakeshore Restoration LR-28	CL-4	1	1.0	1,440	0.1	$8,105	$81	$351
3	Lakeshore Restoration LR-63	CL-4	1	1.2	1,542	0.2	$15,155	$222	$606
4	Lakeshore Restoration LR-39	CL-4	1	0.7	941	0.1	$10,555	$78	$614
5	Lakeshore Restoration LR-50	CL-4	1	0.8	941	0.1	$11,780	$155	$684
6	Lakeshore Restoration LR-95	CL-5	1	1.9	2,204	0.4	$29,705	$513	$791
7	Lakeshore Restoration LR-103	CL-5	1	0.6	774	0.1	$11,330	$146	$872
8	Lakeshore Restoration LR-61	CL-4	1	0.9	1,093	0.1	$14,625	$176	$887
9	Residential Rain Gardens	CL-4	1, 2, 4	0.6-1.9	190-592	0.4-1.4	$10,110-$34,600	$225-$900	$936-$1,081
10	King Road Stormwater Diversion	CL-6	1	0.9	290	0.7	$14,490	$365	$942
11	Laurel Road Stormwater Diversion	CL-6	1	0.9	295	0.7	$14,490	$365	$942
12	Lakeshore Restoration LR-62	CL-4	1	3.1	3,831	0.5	$64,055	$900	$979
13	Lakeshore Restoration LR-19	CL-7	1	0.6	762	0.1	$13,130	$182	$1,032
14	Maple Road Stormwater Diversion	CL-6	1	0.8	240	0.6	$14,490	$365	$1,060
15	Forest Road Boat Launch Structural Stablization	CL-6	1	0.4	550	0.0	$10,925	$75	$1,098

* Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the same source area.

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16	Lakeshore Restoration LR-93	CL-5	1	0.4	493	0.1	$9,830	$116	$1,108
17	Residential Rain Gardens	CL-5	1, 2	0.5-0.9	159-277	0.4-0.7	$10,110-$20,220	$225-$450	$1,124-$1,249
18	Lakeshore Restoration LR-37	CL-4	1	0.5	528	0.1	$12,155	$162	$1,134
19	Lakeshore Restoration LR-36	CL-4	1	0.3	358	0.1	$8,180	$83	$1,184
20	Lakeshore Restoration LR-9	CL-6	1	0.5	629	0.1	$12,680	$173	$1,190
21	Lakeshore Restoration LR-34	CL-4	1	0.4	396	0.1	$11,855	$156	$1,378
22	Lakeshore Restoration LR-27	CL-4	1	0.4	410	0.1	$11,930	$158	$1,388
23	Lincoln Dr. Boat Launch Structural Stablization	CL-6	1	0.4	583	0.0	$14,519	$75	$1,397
24	Community Center Rain Garden	CL-6	1	0.3-0.5	100-143	0.3-0.4	$10,110-$15,110	$225	$1,457-$1,873
25	Lakeshore Restoration LR-85	CL-5	1	0.5	459	0.2	$15,305	$225	$1,470
26	Lakeshore Restoration LR-83	CL-5	1	0.4	379	0.1	$13,430	$188	$1,588
27	Lakeshore Restoration LR-84	CL-5	1	0.4	385	0.2	$13,430	$188	$1,588
28	Lakeshore Restoration LR-68	CL-3	1	0.6	456	0.3	$19,505	$309	$1,599
29	Lakeshore Restoration LR-60	CL-4	1	0.5	504	0.1	$17,105	$261	$1,662
30	Lakeshore Restoration LR-65	CL-4	1	0.3	405	0.1	$13,055	$108	$1,811

* Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the same source area.

About this Document

This Stormwater Retrofit Analysis is a watershed management tool to help prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

Document Organization

This document is organized into three major sections, plus references and appendices. Each section is briefly described below.

Background and Analytical Process

This section gives the reader a brief description of the area of research, including information on lake health, water quality, and the surrounding subwatershed. The section also describes the elements used to propose and rank stormwater retrofit projects for reducing particular target pollutants.

Catchment Profiles

The Coon Lake subwatershed was divided into stormwater catchments for the purpose of this analysis. See *Appendix* B for a guide to reading *Catchment Profiles*. Each catchment was given a unique ID number. For each catchment, the following information is detailed:

Catchment Description

Within each *Catchment Profile* is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant and volume loads. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described. Existing stormwater practices are noted, and their estimated effectiveness presented.

Retrofit Recommendations

The recommendation section describes the conceptual retrofit(s) that were scrutinized. It includes tables outlining the estimated pollutant removals by each, as well as costs. A map provides promising locations for each retrofit approach.

Retrofit Ranking

This section ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by cost per pound of total phosphorus (TP) removed for each project over 30 years. The final cost per pound treatment value includes installation and maintenance costs.

There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Other considerations for prioritizing installation may include:

- Non-target pollutant reductions
- Timing projects to occur with other road or utility work
- Project visibility
- Availability of funding
- Total project costs
- Educational value

References

This section identifies various sources of information synthesized to produce the protocol utilized in this analysis.

Appendices

This section provides supplemental information and/or data used during the analysis. Included in the appendices is the methods section, which outlines general procedures used when analyzing the subwatershed. This section describes the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis, and project ranking.

Abbreviations

Listed below are some abbreviations used frequently throughout the text:

BMP: Best Management Practice

BWSR: Board of Water and Soil Resources

CL: Coon Lake

CLP: Curly-leaf Pondweed

TP: Total Phosphorus

TSS: Total Suspended Solids

SWAT: Soil and Water Assessment Tool

WinSLAMM: Source Loading and Management Model for Windows

Background

Coon Lake is the largest lake in Anoka County, covering 1,481 acres in the northeastern portion of the county. The lake's maximum depth is 27 ft., and the lake has a disproportionately large littoral area for its size (74%, MNDNR 2014). The lake is widely used for both fishing and recreation. Fishing on the lake is best for Northern Pike and Bluegill, although Crappie and Bass populations have also reemerged in recent years.

The subwatershed spans four cities: Ham Lake, East Bethel, Columbus, and Linwood Township. The majority of the subwatershed lies in East Bethel. Land cover varies, including wetlands (31%), open water (27%, totaling the areas of Coon, Little Coon, Devil, and Anderson Lakes), forests (17%), agricultural/pastoral land (14%), undeveloped open space (5%), residential lots (4%), and grasslands (2%). Most soil in the subwatershed is hydric, due to the overwhelmingly large amount of wetlands and open water. Non-hydric soils are generally sandy and well-drained Zimmerman and Lino soils. Topography is relatively flat, but comparable to similar watersheds in east central MN. Outflow from the lake flows east, becoming the South Branch of the Sunrise River further downstream. Coon Lake is considered a 'subwatershed' of the larger Sunrise River and St. Croix River 'watersheds.'

Water quality data is gathered in two locations in Coon Lake, the East and West Bays. Water quality data from the 2013 Anoka County Water Almanac (ACD 2014) shows improving water quality in the lake over the last few years, referenced by decreases in TP concentration and increases in Secchi depth. However, measurements taken back to 2006 show at least 3 occasions in which East Bay TP has been near to or above the state water quality standard. The cause of the recent decrease in TP and increase in water clarity in the lake is at this moment unknown. It is also unknown whether this trend represents a long-term improvement in water quality or a short-term oscillation. Given the likely increase in residential and commercial development and intensification of agricultural production in the region, steps should still be taken to improve water quality.

The Sunrise River Watershed Management Organization (SRWMO) contracted the Anoka Conservation District to complete this stormwater retrofit analysis for the purpose of identifying and assessing projects to improve stormwater quality in the Coon Lake subwatershed. Overall loading of TP, total suspended solids (TSS), and stormwater volume were determined for subdivided drainage basins within the subwatershed. Proposed retrofit treatment conditions were modeled with the Soil and Water Assessment Tool (SWAT), Source Loading and Management Model for Windows (WinSLAMM), and the Board of Water and Soil Resources' Pollution Reduction Calculator (BWSR PRC) to determine each practice's capability for removing pollutants. Finally, each project was ranked based on the cost-effectiveness of the project to reduce TP loading to the lake.

Analytical Process

This Stormwater Retrofit Analysis is a watershed management tool to identify and prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

Scoping includes identifying the objectives and bounds of the analysis in terms of target pollutant, geography, and practices.

Desktop analysis involves the utilization of high resolution aerial photography, digital elevation data (LiDAR), soils, hydrography, parcels, stream and ditch networks, wetlands, culverts, and land use data to narrow the scope of analysis and facilitate field investigation.

Field investigation involves driving and walking through the subwatershed along every public road and parcel to observe field conditions in search of problem sites and opportunities. Problem areas include active erosion, land management practices that contribute to water quality degradation, and artificial drainage. Most problem areas present an opportunity for corrective action, including hydrologic restoration, revegetation, ponding, soil stabilization, and land management practice improvements. As part of the field investigation, an erosion inventory of the entire shoreline of Coon Lake was completed.

Modeling involves several methods to estimate target pollutant removals associated with potential projects. Since no single modeling methodology currently available is suited to model benefits from the variety of projects identified in this report, several methodologies had to be employed. Modeling practices are explained in *Appendix A* and include SWAT, WinSLAMM, and the BWSR PRC. WinSLAMM and SWAT can determine pollutant loading across the landscape and through ponds and wetlands (in the case of SWAT) but are not able to determine loading from some other factors including in-lake nutrient cycling and uptake by plants and algae. These models, though, have particular utility in determining the efficacy of stormwater projects.

Cost estimating is critical for the comparison and ranking of projects, development of work plans, and pursuit of grants and other funds. Project installation costs are only one element included in cost estimates provided in this analysis. Engineering, landowner outreach, construction oversight, project administration, and long term maintenance costs were also considered. In addition to this, expected project life was incorporated into the estimate. All project costs should be verified against local experience.

Project ranking is essential to identifying which projects to pursue to achieve water quality goals. In this analysis projects were ranked by cost-effectiveness in reducing TP delivery to Coon Lake.

Project selection involves considerations other than project ranking, including but not limited to total cost, treatment train effects, social acceptability, and political feasibility.

Each of these items is explained in greater detail in Appendix A.

Analytical Elements

Many elements come into play when developing a stormwater retrofit analysis. Each analysis must be customized to the target pollutant, locally acceptable practice type, local fiscal capacity, and watershed characteristics. The following describes how these elements were considered.

Target Pollutants

The table below 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.

Target pollutants addressed in this report

Target Pollutant	Description
Total Phosphorus (TP)	Phosphorus is a nutrient essential to plant growth and is commonly the factor that limits the growth of plants in surface waterbodies. TP is a combination of particulate phosphorus, which is bound to sediment and organic debris, and dissolved phosphorus, which is in solution and readily available for plant growth (active). Excess phosphorus contributes to eutrophication of water bodies. TP was the primary pollutant of study in this analysis and used to rank all stormwater retrofit projects by cost-effectiveness.
Total Suspended Solids (TSS)	Very small mineral and organic particles that can be dispersed into the water column due to turbulent mixing (MPCA website). TSS loading can create turbid and cloudy water conditions and carry with it particulate phosphorus. As such, reductions in TSS will also result in TP reductions.
Volume	Higher runoff volumes and velocities can carry greater amounts of TSS to receiving waterbodies. It can also exacerbate in-stream erosion, thereby increasing TSS loading. As such, reductions in volume will reduce TSS loading and, by extension, TP loading.

Potential Project Types

A variety of stormwater retrofit approaches were identified. The table below describes projects included in this analysis. Additional project types were considered but not included for a variety of reasons. A complete list of the considered project types is noted in *Appendix A*. Concept designs are also noted in *Appendices C and D*.

Project types identified in the Coon Lake subwatershed

Project Type	Code	Description	Project Life	Modeling Method
Residential Rain Gardens	RG	Small depressions in residential landscapes designed to capture and treat runoff through infiltration and/or filtration	20	Win SLAMM
Lakeshore Restorations	LR	Stabilization of active lakeshore erosion through structural and bioengineering techniques	10	BWSR Pollution Reduction Calculator
Stormwater Diversions	SD	Divert water from impervious surface to depression which will infiltrate water and retain pollutants	30	WinSLAMM
Structural Stabilization of Boat Launch	SS	Due to high upstream stormwater flows, erosion along launches is supplying excess TSS and TP to the lake	20	BWSR Pollution Reduction Calculator

Project Categories

Projects fall into one of three general categories: cultural, vegetative, and structural. Cultural practices are those that must be continued by land use managers each year in order for the benefits to persist. Vegetative practices are installed and may persist without active management or maintenance but are also easy and inexpensive to remove or denude, either intentionally or inadvertently. Structural practices are physically robust measures that also require maintenance but are difficult and expensive to remove. Thus, the resultant benefits are much less likely to be rapidly lost, barring catastrophic structural failure. The durability of a project, and therefore the persistence of benefits, is greatest for structural practices and least for cultural practices. This is not meant to imply that cultural practices should not be pursued with educational and technical assistance outreach programs, but they were not the focus of this report because of their temporal nature and difficulty to model. The table on the following page summarizes the categories which were included in this report and why.

Project types considered and not considered throughout this study.

Project Type	Type	Included in Report	Rationale	Cost-Effectiveness
Residential Rain Gardens	Structural	Yes	One of few options for residential areas	Moderate
Lakeshore Restorations	Structural/ Vegetative	Yes	100% of benefits to lake	High-Low
Invasive Species Treatment (In-lake)	Cultural	No	Primarily done to remove invasives but indirect benefit may be nutrient reduction, no clear correlation found to reduction in nutrient concentration, therefore unable to model	High
Goose Removal	Cultural	No	Wholly cultural, can't model benefits, vegetative buffers may deter geese and provide more durable benefits	Unknown
Vegetated Swales	Vegetative	Yes	Highly cost-effective as you can often utilize existing ditches, easy to maintain	High
Manure Application	Cultural	No	Wholly cultural, can't model benefits	High
Nutrient Management	Cultural	No	Wholly cultural, can't model benefits	High
Street Sweeping	Cultural	No	Presumed to occur and added to models based on city correspondence	High
Structural Stabilization	Structural	Yes	100% of benefits to lake (for projects at boat launches)	Medium-High
Stormwater Diversion	Structural	Yes	Can utilize existing ditches by diverting flow	Medium
SSTS Remediation	Structural	No	Can't model benefits	Unknown

Cost Estimates

Providing reasonable cost estimates is essential to ranking projects by cost-effectiveness, developing long term work plans, and securing funds. To capture the full cost of projects, construction costs, project design, project maintenance, promotion, and administration were included. These values are listed in detail in the tables and table footnotes within the *Catchment Profiles* section of this report.

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, drafting, engineering, and construction oversight.

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.

Map of stormwater catchments referred to in this report. Catchment Profiles on the following pages provide additional detail.

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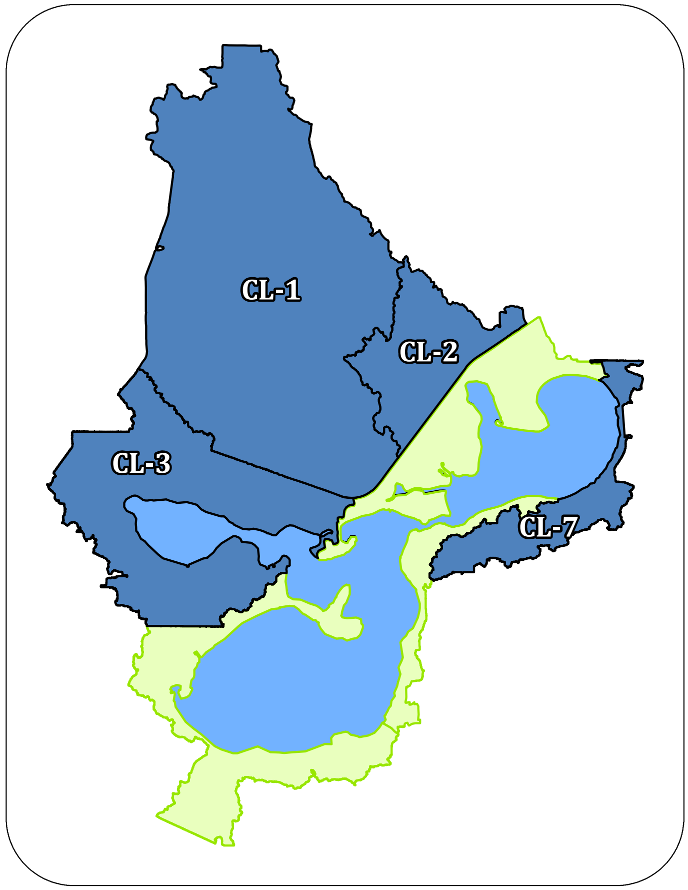
Section 1: Rural Catchments

Rural Catchments Summary	
Acres	3,367
Dominant Land Cover	Wetlands, Forest
TP (lbs/yr)	454
TSS (lbs/yr)	74,730
Volume (ac-ft/yr)	2,214



AREA SUMMARY

The Coon Lake subwatershed is predominantly rural and undeveloped, with 82% of land cover across the subwatershed either forest, grasslands, wetlands, undeveloped open space, or open water. The remaining 18% is a mix between agricultural and pastoral land in the north and residential lakeshore lots surrounding Coon Lake in the south.

Catchments CL-1, CL-2, CL-3, and CL-7 had less than 0.5 parcel units per acre. Therefore, these catchments were considered “rural” and modeled with SWAT.

EXISTING TREATMENT

Catchment CL-1

Runoff generated in the low-density residential neighborhoods and agricultural parcels in catchment CL-1 flow through a series of small lakes and wetlands before leaving the catchment under Highway 22. This channel, known as Ditch 56, discharges directly into Coon Lake 600 ft south of Highway 22. Included in the catchment are Devil Lake and Goose Lake. Stormwater traveling through these waterbodies can be treated for sediment and phosphorus as sediment and particulate phosphorus drop out of suspension and dissolved phosphorus is used biologically by plants and animals in the lakes and wetlands. Conversely, these waterbodies can also be a source for pollutants, particularly dissolved phosphorus. Phosphorus can be released from sediments during periods of anoxia, typically occurring from mid- to late-summer.

Catchment CL-2

Similar to CL-1, stormwater runoff in catchment CL-2 flows through Anderson Lake and another wetland before discharging south of Highway 22 between Sportsman Road and Isetta St. These waterbodies provide similar pollutant treatment to those in CL-1.

Catchments CL-3 and CL-7

Catchments CL-3 and CL-7 are adjacent to Coon Lake and much of the runoff from these catchments flows untreated to the waterbody. Most of the catchment CL-3's land cover is either wetlands or forests (74% combined), which typically have less pollutant generation potential than lakeshore residential or agricultural properties. Catchment CL-7 has a slightly larger percentage of residential and agricultural area (34% combined) but much of the stormwater from this land use flows through a wetland complex prior to entering Coon Lake.

Rural Catchments Summary

Street cleaning is provided by the City of East Bethel at least once per year in spring. This treatment is employed along urban streets to remove organic and sediment debris left over from snowmelt and rain events. Although some of the near-lake roads in these catchments are swept, many in the upper portions of the subwatershed are not treated. As coverage of this BMP is sparse across all of the rural catchments it was not included for SWAT analysis. This treatment was included for the urban catchments modeled with WinSLAMM.

Existing pollutant loading from rural catchments

			Existing Pollutant Loading					
Catchment	Area (acres)	Parcel Units	TP (lbs/yr)	TP (lbs/ac)	TSS (lbs/yr)	TSS (lbs/ac)	Volume (ac-ft/yr)	Volume (ac-ft/ac)
CL-1	2,125	355	201	0.09	34,126	16	1,126	0.53
CL-2	368	93	67	0.18	7,871	21	225	0.61
CL-3	906	336	156	0.17	25,307	28	677	0.75
CL-7	268	319	30	0.11	7,426	28	186	0.69

EXISTING CONDITIONS SUMMARY

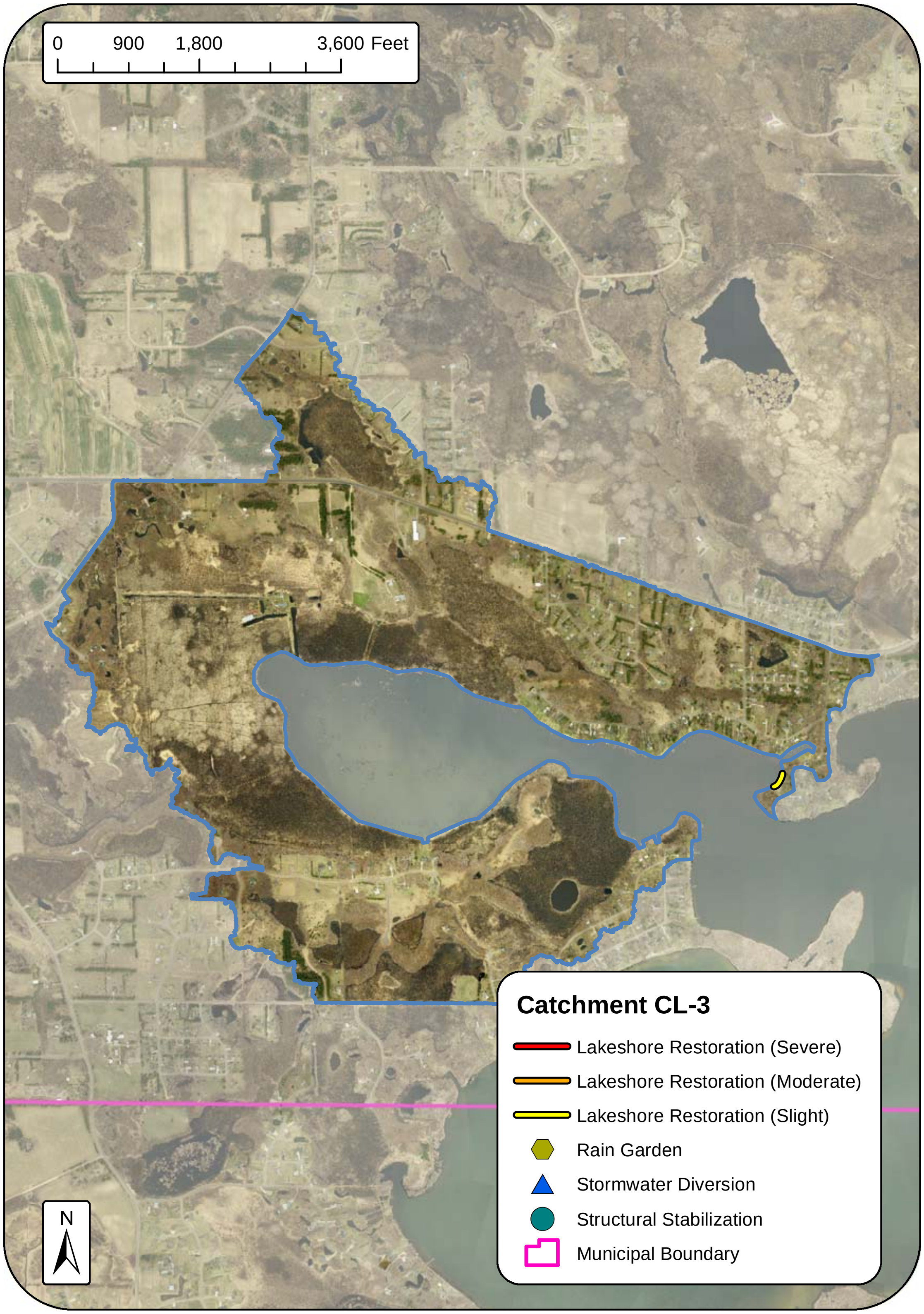
The table above shows the existing loading from rural catchments around Coon Lake as determined from SWAT modeling. In total, the 3,667 acres in these rural catchments annually supply 454 lbs-TP, 74,730 lbs-TSS, and 2,214 ac-ft of water volume to Coon Lake. These values do not take into account in-lake process such as nutrient cycling, nutrient uptake by plants and algae, or shoreline erosion. The table only lists pollutant input from Coon Lake's surrounding subwatershed.

Total pollutant loading across all variables (TP, TSS, and water volume in this study) was largest in catchment CL-1, driven predominantly by its large area (at least twice the size as any other catchment in the subwatershed). When looking at areal loading, or total pollutant loading as a function of drainage area in acres (ac), CL-2 and CL-3 were the largest sources of TP in the rural catchments. CL-3 and CL-7 were the largest sources of TSS. The higher pollutant totals in CL-2, CL-3, and CL-7 as compared to CL-1 isn't surprising as the lake-wetland complexes in CL-1 capture more sediment and other pollutants through sedimentation and nutrient uptake. Little to no residential or agricultural runoff in CL-1 flows to Coon Lake without being intercepted by a small lake or wetland.

RETROFIT RECOMMENDATIONS

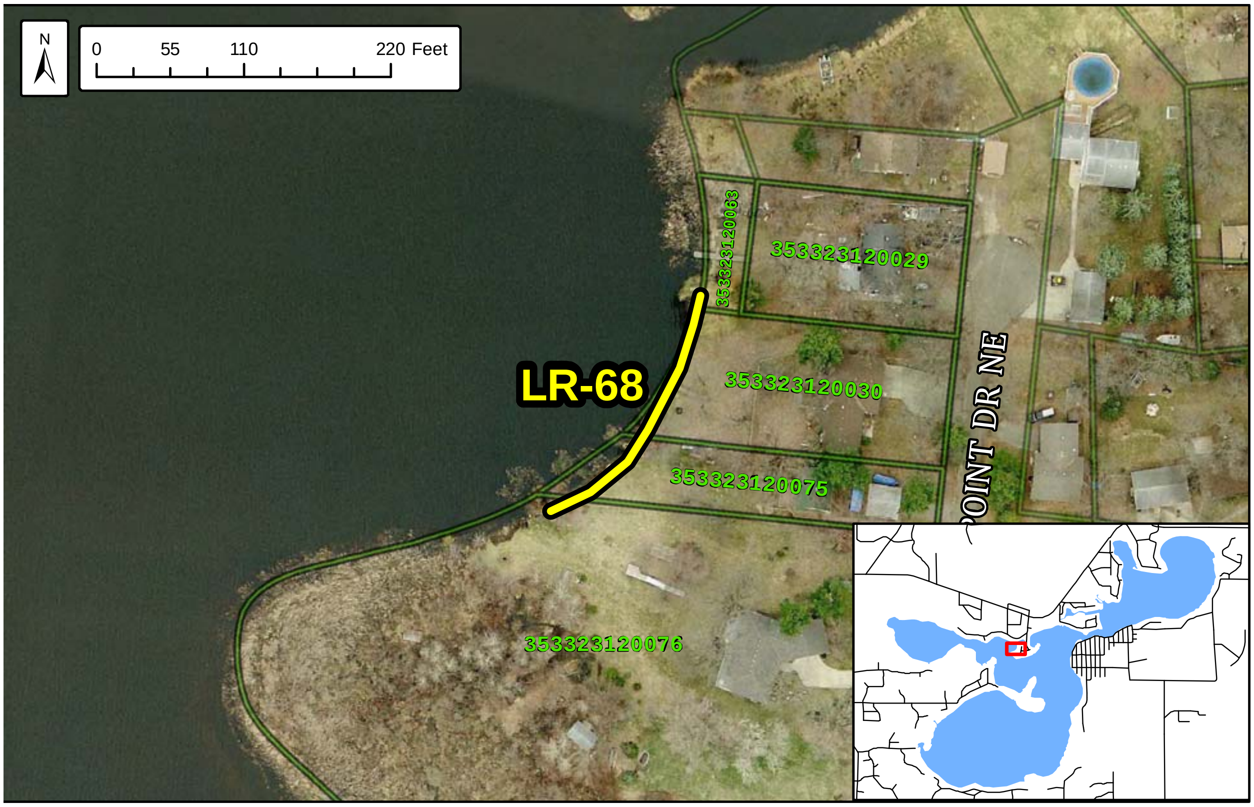
Only two viable and cost-effective opportunities were found for stormwater BMPs in the rural catchments. Both of these proposed practices are lakeshore restorations along Coon Lake. One is in catchment CL-3 while the other is in catchment CL-7. The *Project Profiles* on the following pages describe these projects in detail.

RETROFIT RECOMMENDATIONS



Project ID: CL-3 Lakeshore Restoration - LR-68

Drainage Area – 0.8 acres from residential lakeshore properties
Location – West of Breezy Point Dr. along the northern shore of Coon Lake
Property Ownership – Private; 4 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 206 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-68

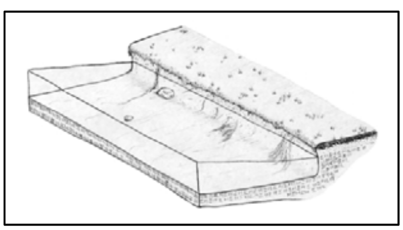
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	206	linear-ft				
	TP (lb/yr)	0.6	0.4%				
	TSS (lb/yr)	456	1.8%				
	Volume (ac-ft/yr)	0.3	0.0%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$15,450					
	Total Estimated Project Cost (2014)	**$19,505**					
	Annual O&M***	$309					
Efficiency	30-yr Average Cost/lb-TP	**$1,599**					
	30-yr Average Cost/1,000lb-TSS	**$2,103**					
	30-yr Average Cost/ac-ft Vol.	**$3,197**					

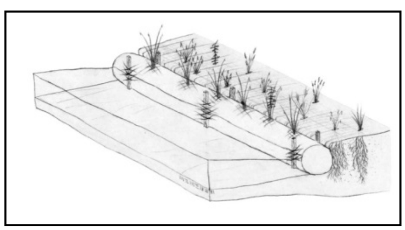
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

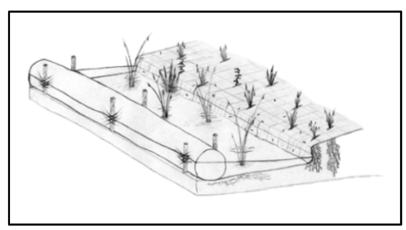
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

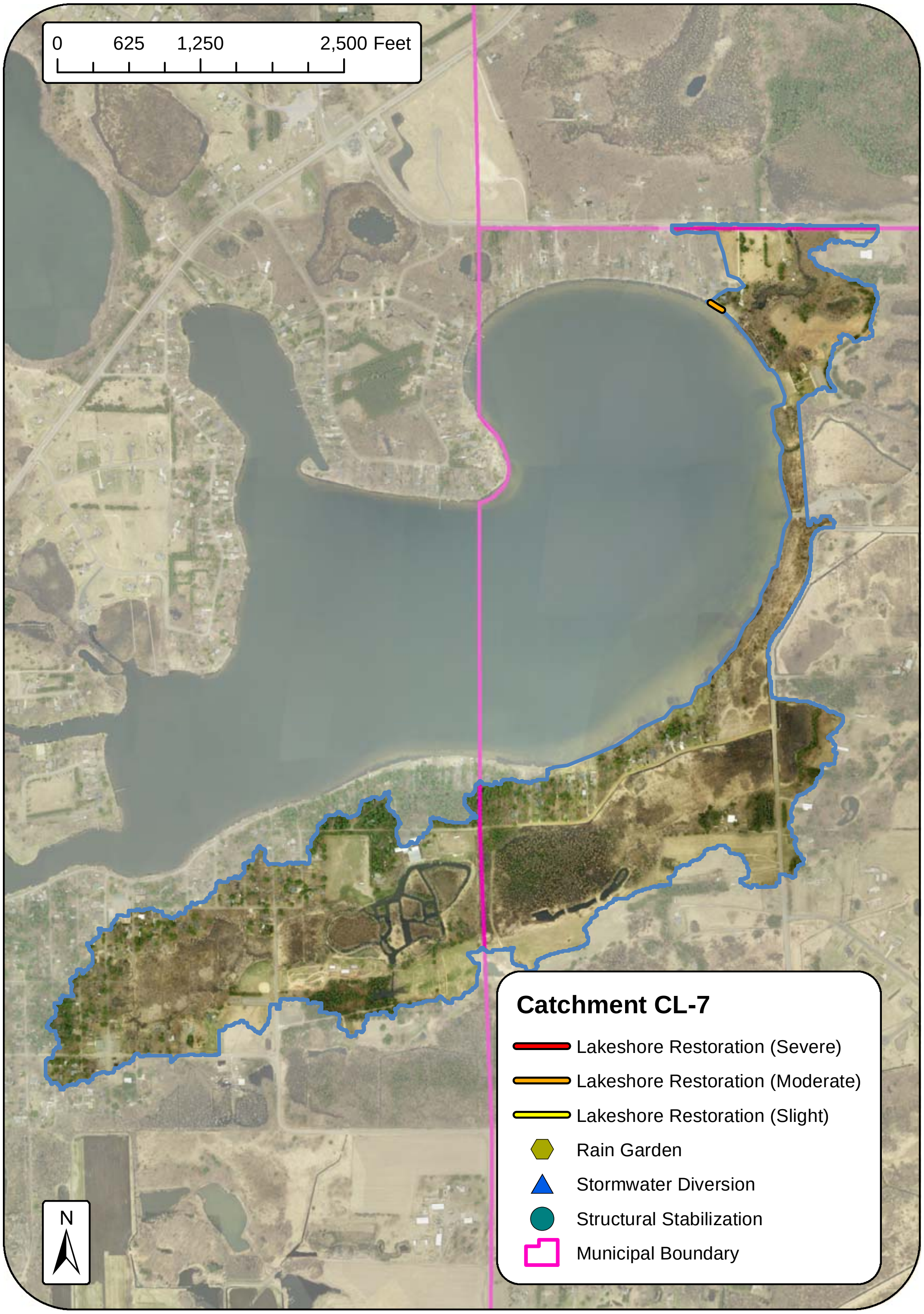
Conceptual images – Native Plant Restorations





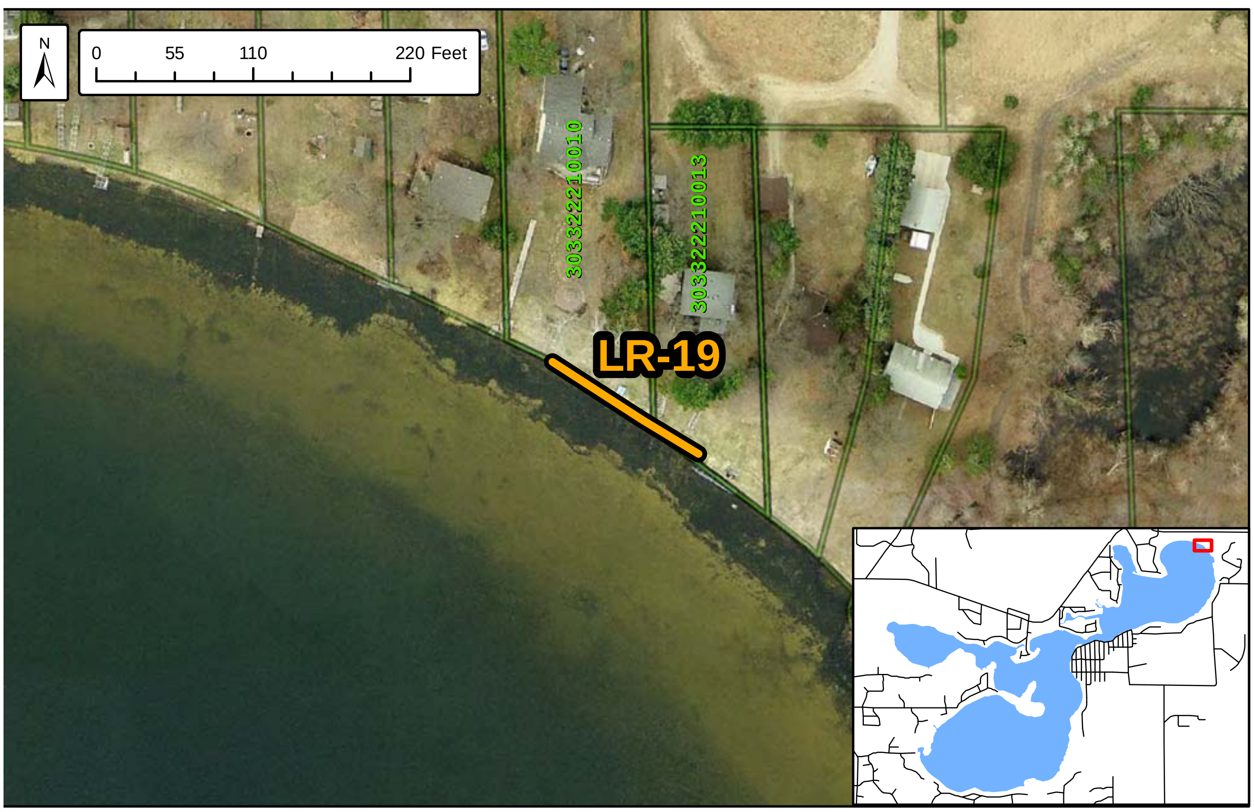


RETROFIT RECOMMENDATIONS



Project ID: CL-7 Lakeshore Restoration - LR-19

Drainage Area – 0.5 acres from residential lakeshore properties
Location – South of 197th Ave. along the northeastern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 121 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-19

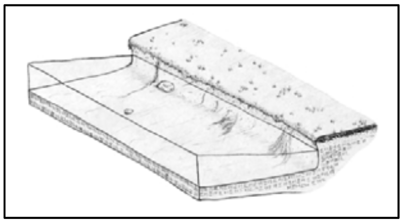
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	121	linear-ft				
	TP (lb/yr)	0.6	2.0%				
	TSS (lb/yr)	762	10.3%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$9,075					
	Total Estimated Project Cost (2014)	**$13,130**					
	Annual O&M***	$182					
Efficiency	30-yr Average Cost/lb-TP	**$1,032**					
	30-yr Average Cost/1,000lb-TSS	**$813**					
	30-yr Average Cost/ac-ft Vol.	**$6,192**					

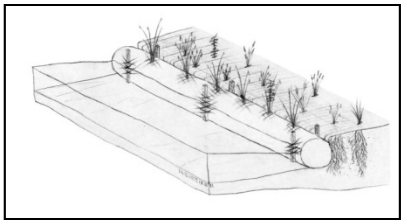
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

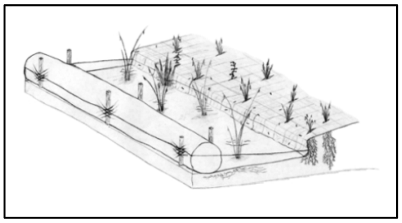
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

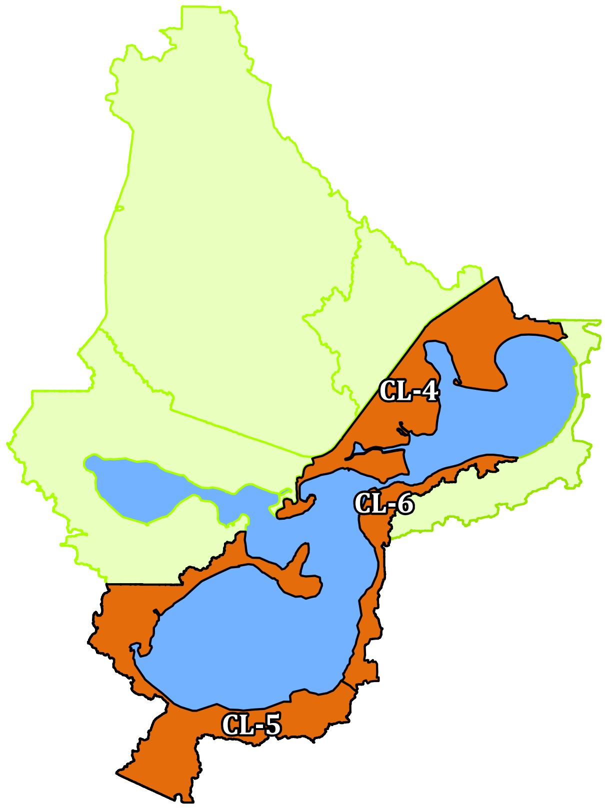






Section 2: Urban Catchments

Existing Network Summary	
Acres	1,074
Dominant Land Cover	Residential
TP (lbs/yr)	355
TSS (lbs/yr)	86,998
Volume (ac-ft/yr)	240



CATCHMENT PROFILES

AREA SUMMARY

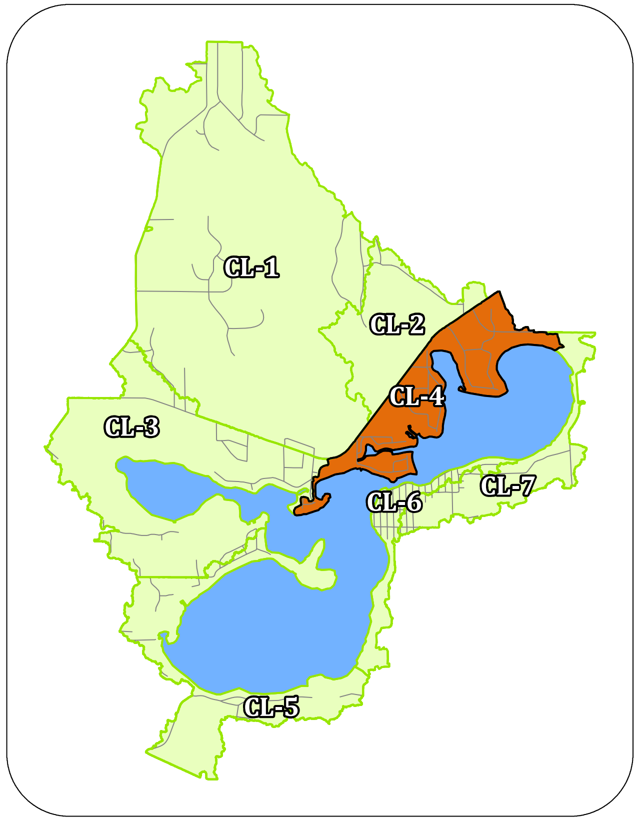
Urban catchments CL-4, CL-5, and CL-6 are clustered around Coon Lake's northern and southern shore. These catchments are predominantly developed single-family and seasonal residential lots, although wetlands, forests, and undeveloped open space still dot the landscape. With more than 0.5 parcel units per acre, these catchments were considered "urban" and therefore modeled with WinSLAMM. Additional information is provided about each of these catchments in the subsequent *Catchment Profiles*.

EXISTING NETWORK TREATMENT

Existing stormwater treatment across these catchments includes two practices. First, street cleaning is performed at least once per year by the Cities of East Bethel and Ham Lake. Second, there is a grass swale and weir system along Front Blvd. in catchment CL-4 which treats the single-family residential lots along both sides of the roadway. With exception to these treatment practices, all other stormwater generated within these catchments either infiltrates or flows untreated to Coon Lake. It is noteworthy that curb and gutter stormwater conveyances are minimally present in many areas, and this was reflected in the WinSLAMM models.

Catchment CL-4

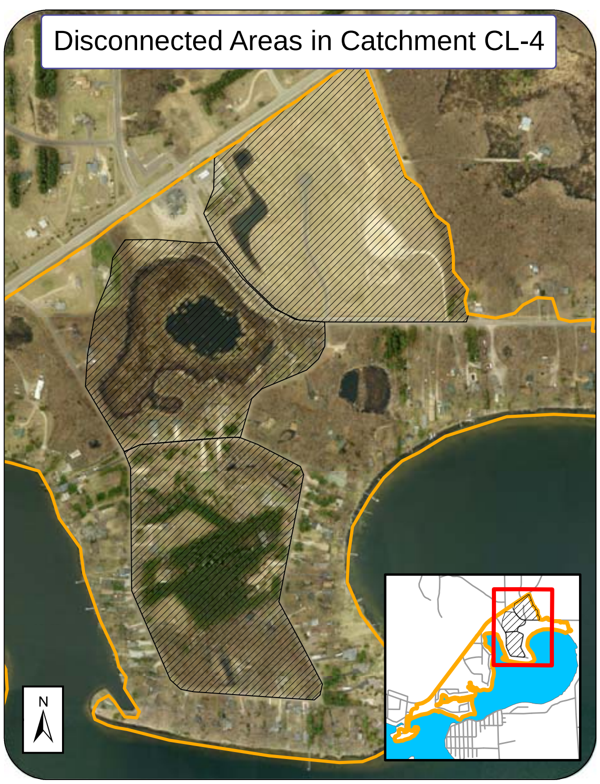
Existing Catchment Summary	
Acres	419
Dominant Land Cover	Residential
Parcels	340
TP (lbs/yr)	127.7
TSS (lbs/yr)	34,534
Volume (ac-ft/yr)	89.6



CATCHMENT DESCRIPTION

Catchment CL-4 lies on the northern shores of Coon Lake. The western boundary of the catchment is Viking Blvd. The catchment is predominantly single family residential lots with well-drained Zimmerman soils.

Stormwater runoff generated within the catchment is directed towards stormwater outflows into the lake. One of these, a small ditch between Front Blvd and Sportsman Road, also drains catchment CL-2. Other prominent outfalls are located along Front Blvd. and Thielen Blvd.



EXISTING STORMWATER TREATMENT

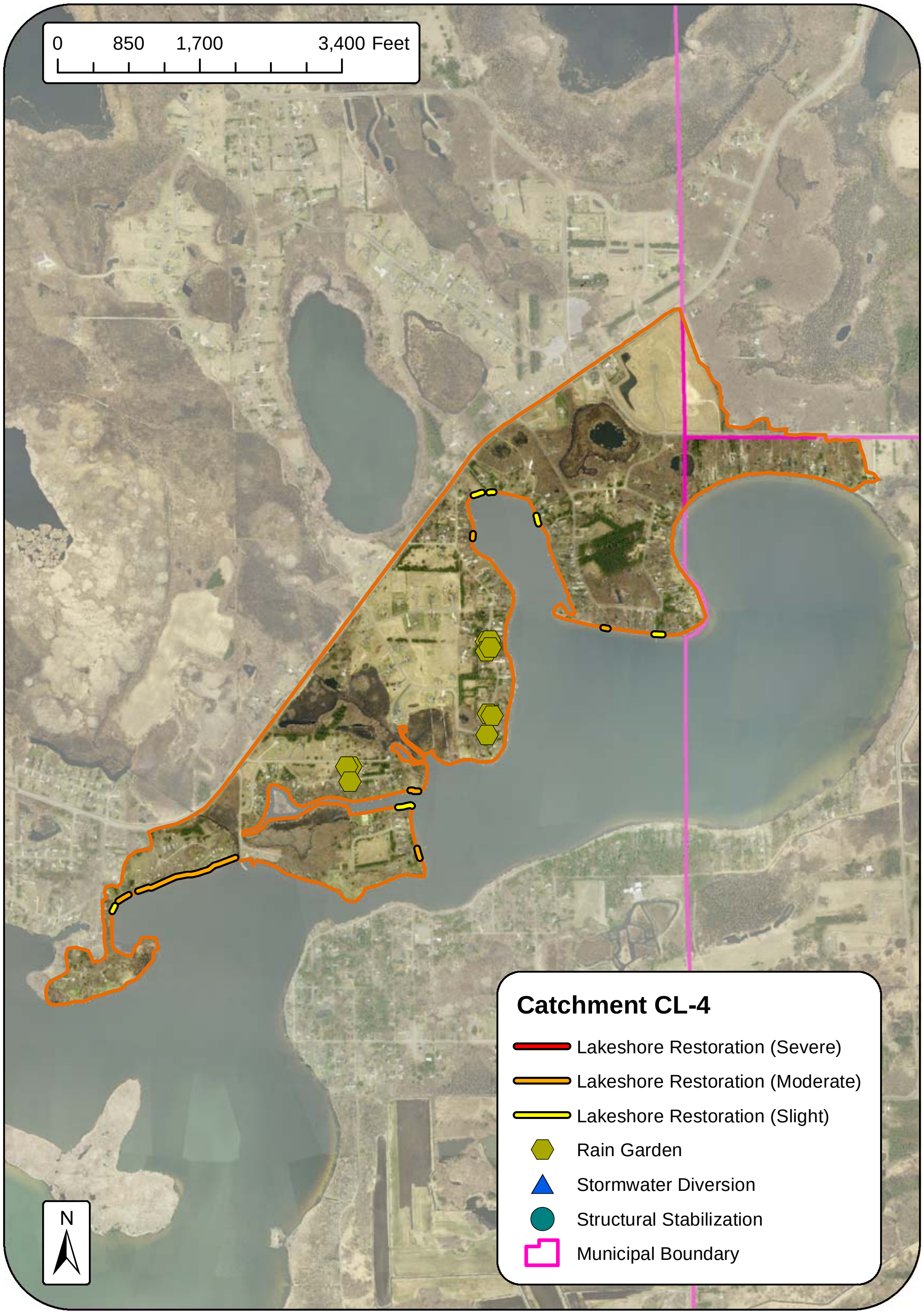
There are two existing stormwater practices in CL-4 treating stormwater runoff into Coon Lake. These practices reduce pollutant loading in the catchment by 12.8 lb-TP/yr and 5,394 lb-TSS/yr. The first is at the stormwater outfall along Front Blvd, which has an engineered grass swale with multiple weirs treating stormwater runoff from Front Blvd, 195th Ave, and Lever St. Secondly, catchment-wide street sweeping is provided by the City of East Bethel at least once per year in spring.

Three areas within this catchment totaling 84.6 acres are hydraulically disconnected from the lake (see map to left). Catch basins along streets surrounding these areas direct stormwater to depressions that have no obvious outlet. As these areas do not contribute stormwater runoff to Coon Lake under all but extreme conditions, they were excluded from model analysis.

Catchment-Wide Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Grass swale, street sweeping			
	TP (lb/yr)	140.5	12.8	9%	**127.7**
	TSS (lb/yr)	39,928	5,394.0	14%	**34,534**
	Volume (ac-ft/yr)	90.5	0.9	1%	**89.6**

RETROFIT RECOMMENDATIONS



Project ID: CL-4 Residential Rain Gardens

Drainage Area – 18.8 acres

Location – Central portion of catchment CL-4 along Front Blvd., Hupp St., and Channel Lane

Property Ownership – Private

Description – Most stormwater pollutants generated in this catchment derive from the residential properties along the lake. Little space is available for large retrofits which can treat multiple properties along the lakeshore. However, there are some opportunities to install curb-cut rain gardens (see *Appendix C* for design options). Up to nine ideal rain garden locations were identified (see map on the previous page). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical landowner participation rates, scenarios with 1, 2 and 4 rain gardens were analyzed to treat the residential land use. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

Conceptual images –

Before/24 -48 hours after rain

During rain

Curb-Cut Rain Gardens

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		2		4	
	Total Size of BMPs	250	sq-ft	500	sq-ft	1,000	sq-ft
	TP (lb/yr)	0.6	0.5%	1.1	0.9%	1.9	1.5%
	TSS (lb/yr)	190	0.6%	335	1.0%	592	1.7%
	Volume (ac-ft/yr)	0.4	0.4%	0.8	0.9%	1.4	1.6%
Cost	Administration & Promotion Costs*	$4,234		$8,468		$11,096	
	Design & Construction Costs**	$5,876		$11,752		$23,504	
	Total Estimated Project Cost (2014)	**$10,110**		**$20,220**		**$34,600**	
	Annual O&M***	$225		$450		$900	
Efficiency	30-yr Average Cost/lb-TP	**$937**		**$1,022**		**$1,081**	
	30-yr Average Cost/1,000lb-TSS	**$2,958**		**$3,355**		**$3,468**	
	30-yr Average Cost/ac-ft Vol.	**$1,405**		**$1,405**		**$1,467**	

*For 1-2 gardens: 58 hours/BMP at $73/hour

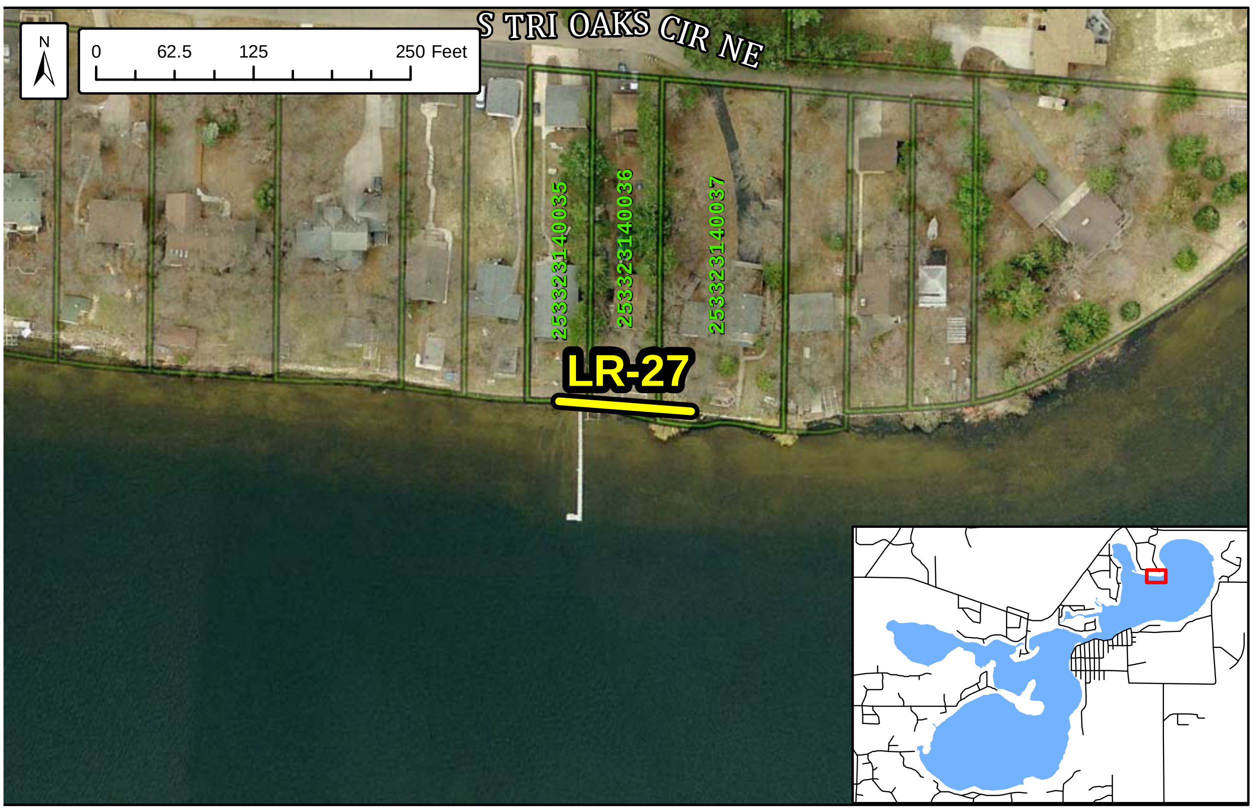
*For 4 gardens: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**($20/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150 for 10-year rehabilitation) + ($75 for routine maintenance)

Project ID: CL-4 Lakeshore Restoration - LR-27

Drainage Area – 0.3 acres from residential lakeshore properties
Location – South of S Tri Oaks Circle NE and along the northern shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 105 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-27

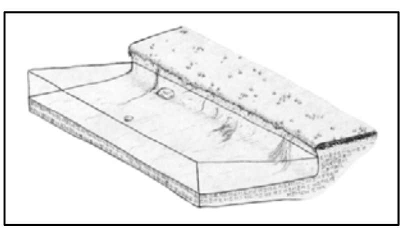
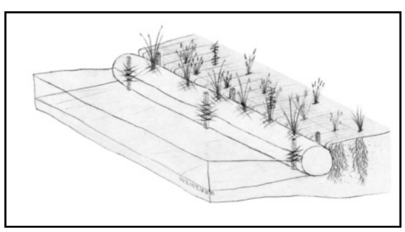
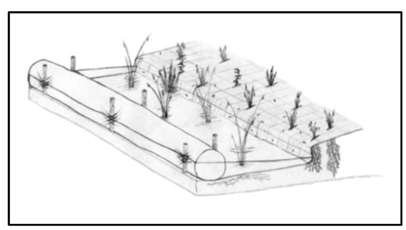
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	105	linear-ft				
	TP (lb/yr)	0.4	0.3%				
	TSS (lb/yr)	410	1.2%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$7,875					
	Total Estimated Project Cost (2014)	**$11,930**					
	Annual O&M***	$158					
Efficiency	30-yr Average Cost/lb-TP	**$1,388**					
	30-yr Average Cost/1,000lb-TSS	**$1,354**					
	30-yr Average Cost/ac-ft Vol.	**$5,552**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

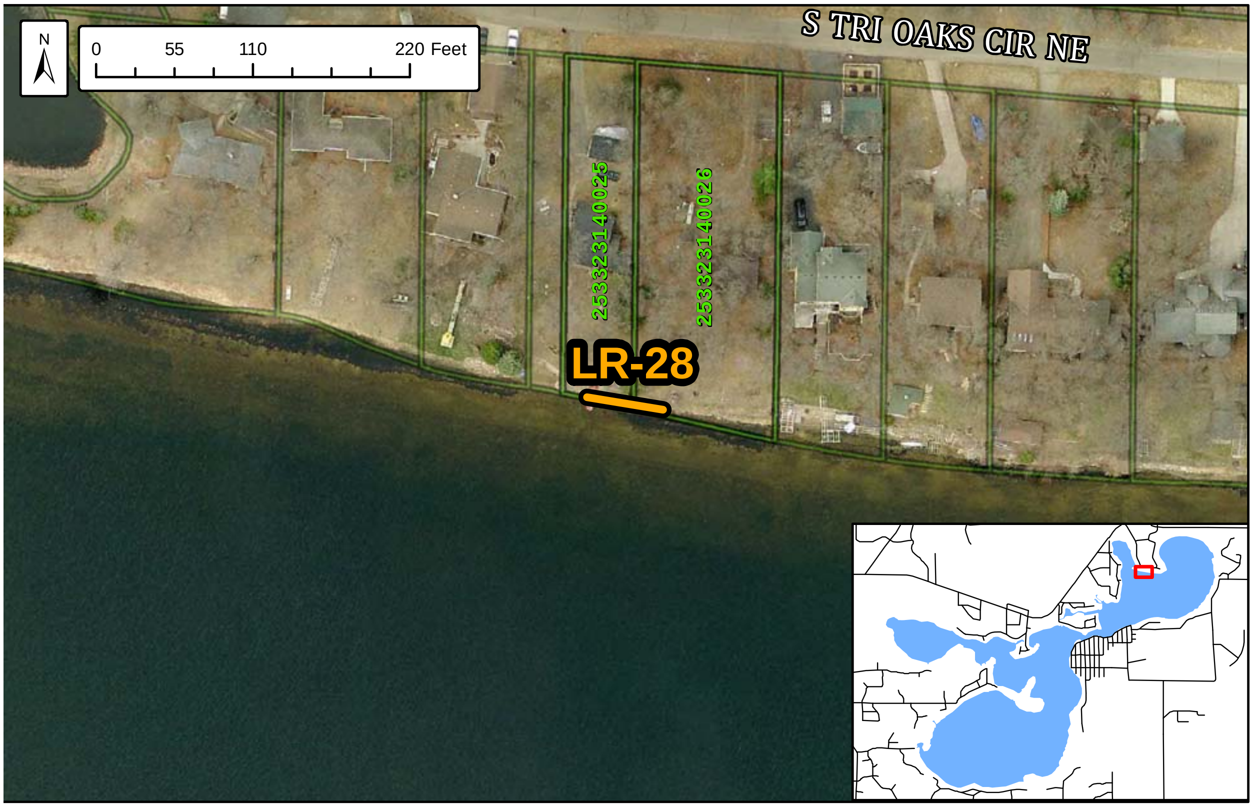
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-4 Lakeshore Restoration - LR-28

Drainage Area – 0.2 acres from residential lakeshore properties
Location – South of S Tri Oaks Circle NE and along the northern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A moderately-large eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 54 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. The cost estimate for installation assumes only manual grading will be necessary on the site. If grading with heavy equipment is necessary then the estimated project cost should be increased to $125 per linear-ft.

Lakeshore Restoration – LR-28

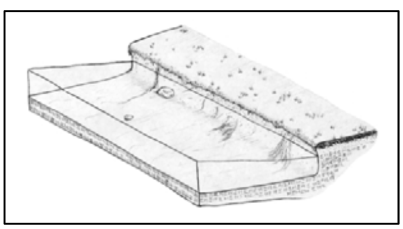
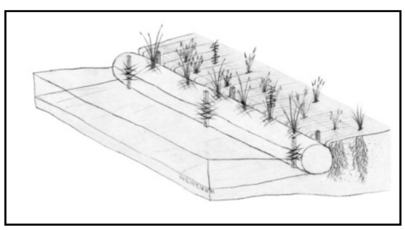
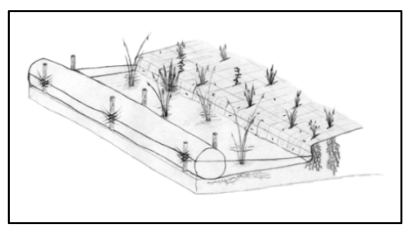
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	54	linear-ft				
	TP (lb/yr)	1.0	0.8%				
	TSS (lb/yr)	1,440	4.2%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$4,050					
	Total Estimated Project Cost (2014)	**$8,105**					
	Annual O&M***	$81					
Efficiency	30-yr Average Cost/lb-TP	**$351**					
	30-yr Average Cost/1,000lb-TSS	**$244**					
	30-yr Average Cost/ac-ft Vol.	**$3,512**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

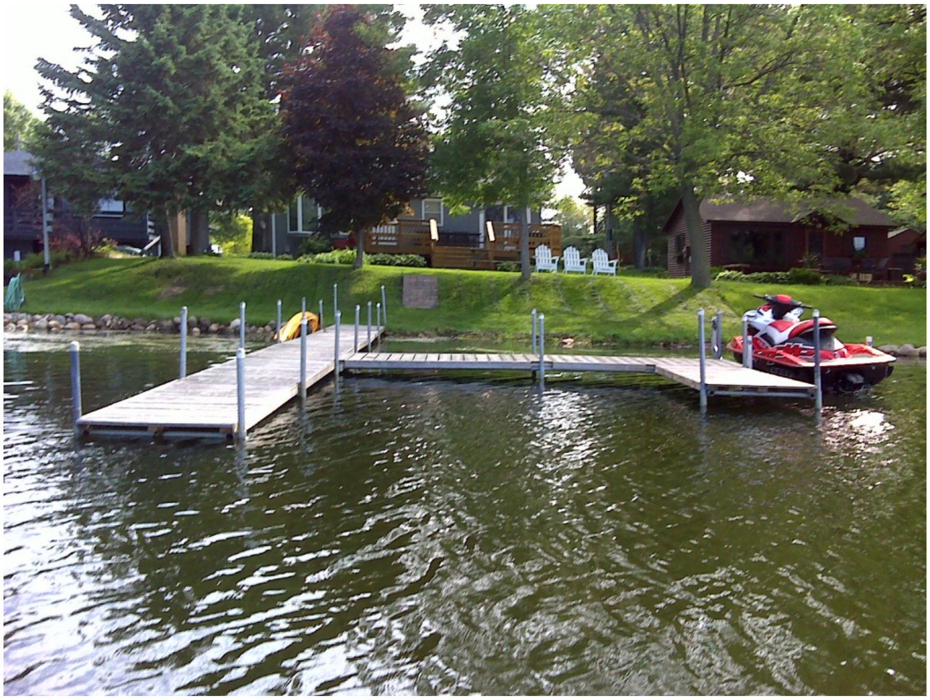
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

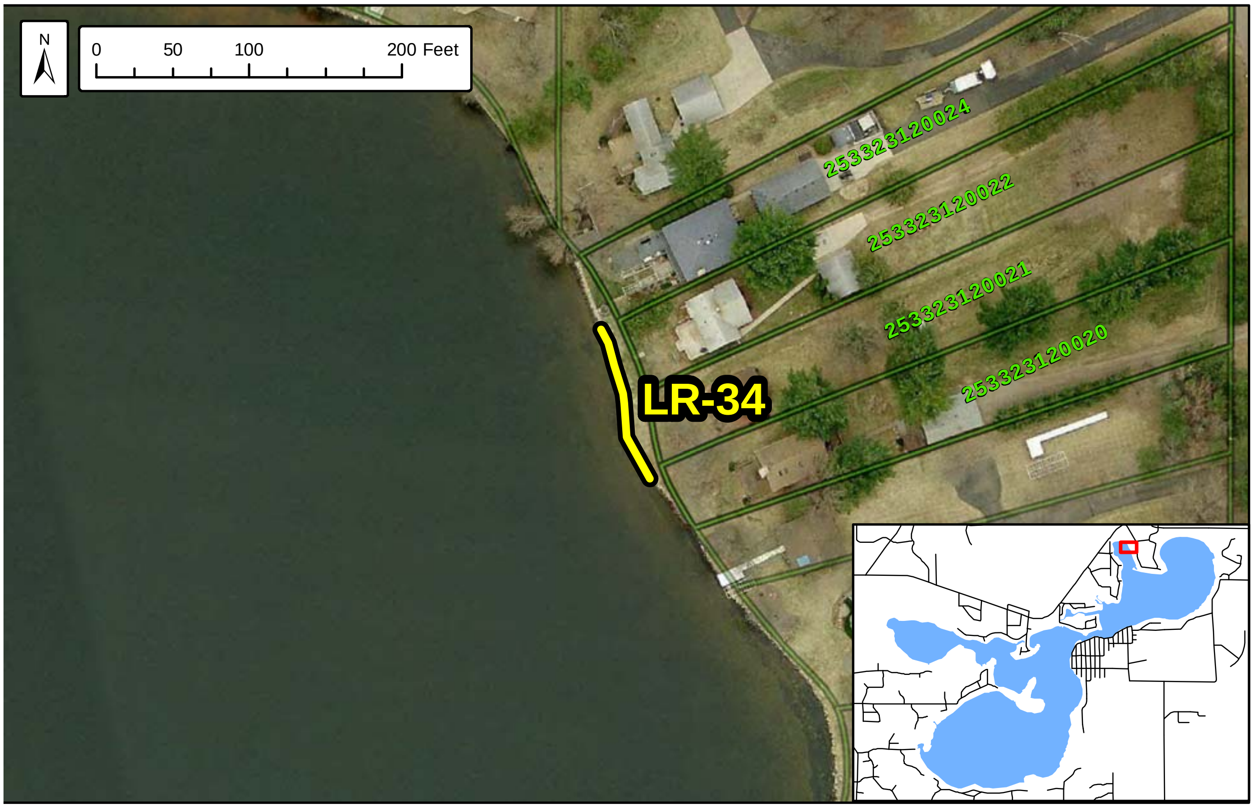
Conceptual images – Native Plant Restorations


Project ID: CL-4 Lakeshore Restoration - LR-34



Drainage Area – 0.2 acres from residential lakeshore properties
Location – West of W Tri Oaks Circle NE and along the northern shore of Coon Lake
Property Ownership – Private; 4 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A moderately-large eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 104 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. The cost estimate for installation assumes only manual grading will be necessary on the site. If grading with heavy equipment is necessary then the estimated project cost should be increased to $125 per linear-ft.

Lakeshore Restoration – LR-34

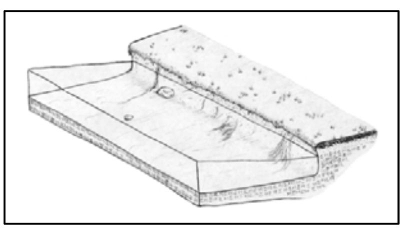
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	104	linear-ft				
	TP (lb/yr)	0.4	0.3%				
	TSS (lb/yr)	396	1.1%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$7,800					
	Total Estimated Project Cost (2014)	**$11,855**					
	Annual O&M***	$156					
Efficiency	30-yr Average Cost/lb-TP	**$1,378**					
	30-yr Average Cost/1,000lb-TSS	**$1,392**					
	30-yr Average Cost/ac-ft Vol.	**$5,512**					

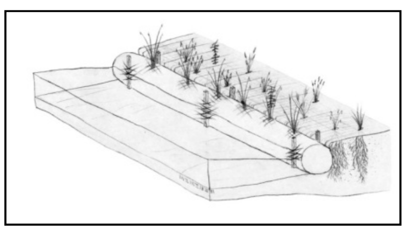
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

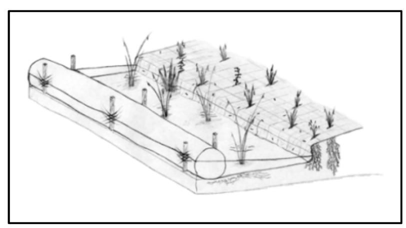
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

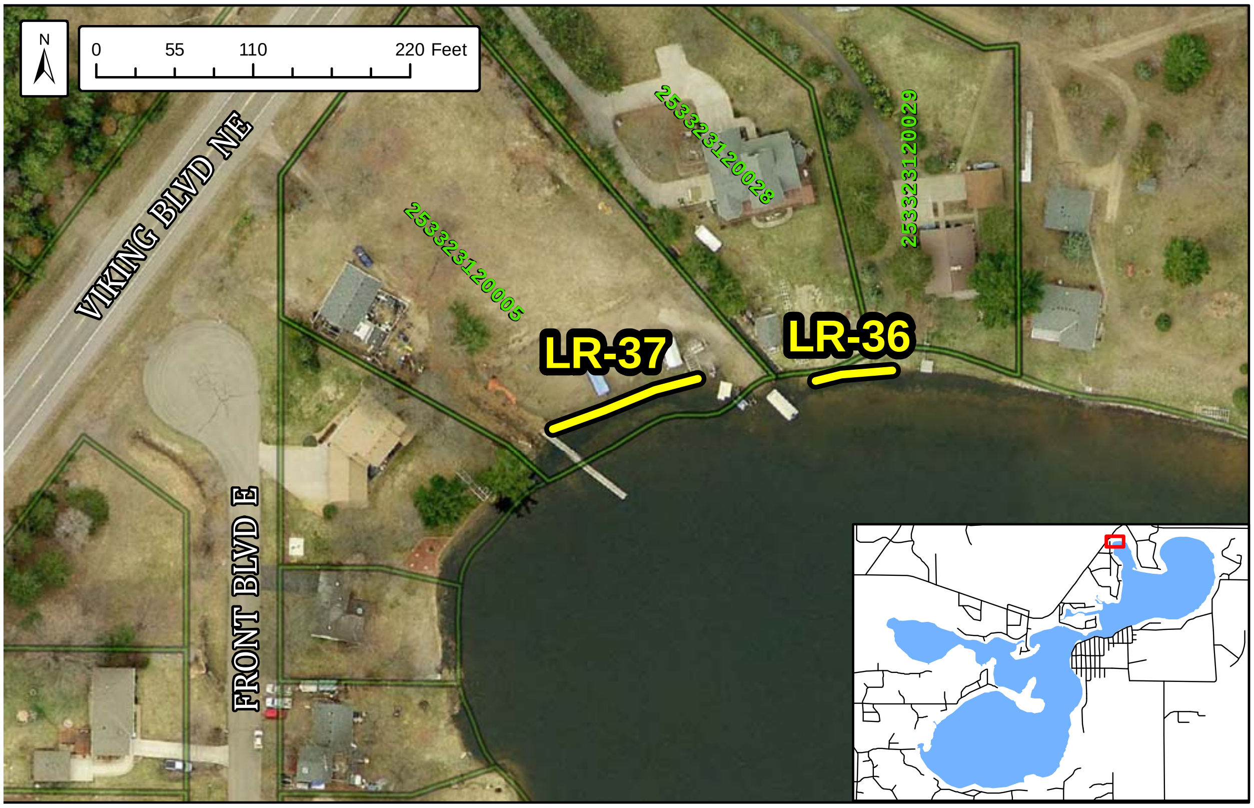






Project ID: CL-4 Lakeshore Restoration - LR-36

Drainage Area – 0.3 acres from residential lakeshore properties
Location – Southeast of Viking Blvd. along the northern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 55 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-36

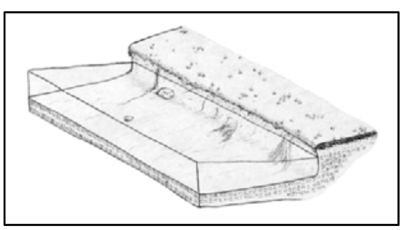
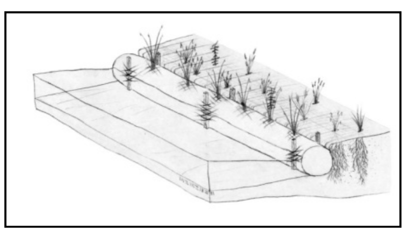
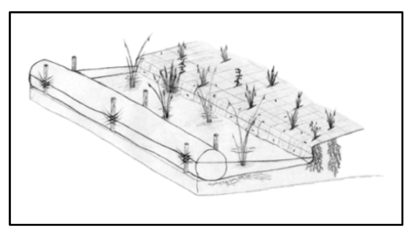
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	55	linear-ft				
	TP (lb/yr)	0.3	0.2%				
	TSS (lb/yr)	358	1.0%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$4,125					
	Total Estimated Project Cost (2014)	**$8,180**					
	Annual O&M***	$83					
Efficiency	30-yr Average Cost/lb-TP	**$1,184**					
	30-yr Average Cost/1,000lb-TSS	**$992**					
	30-yr Average Cost/ac-ft Vol.	**$3,552**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

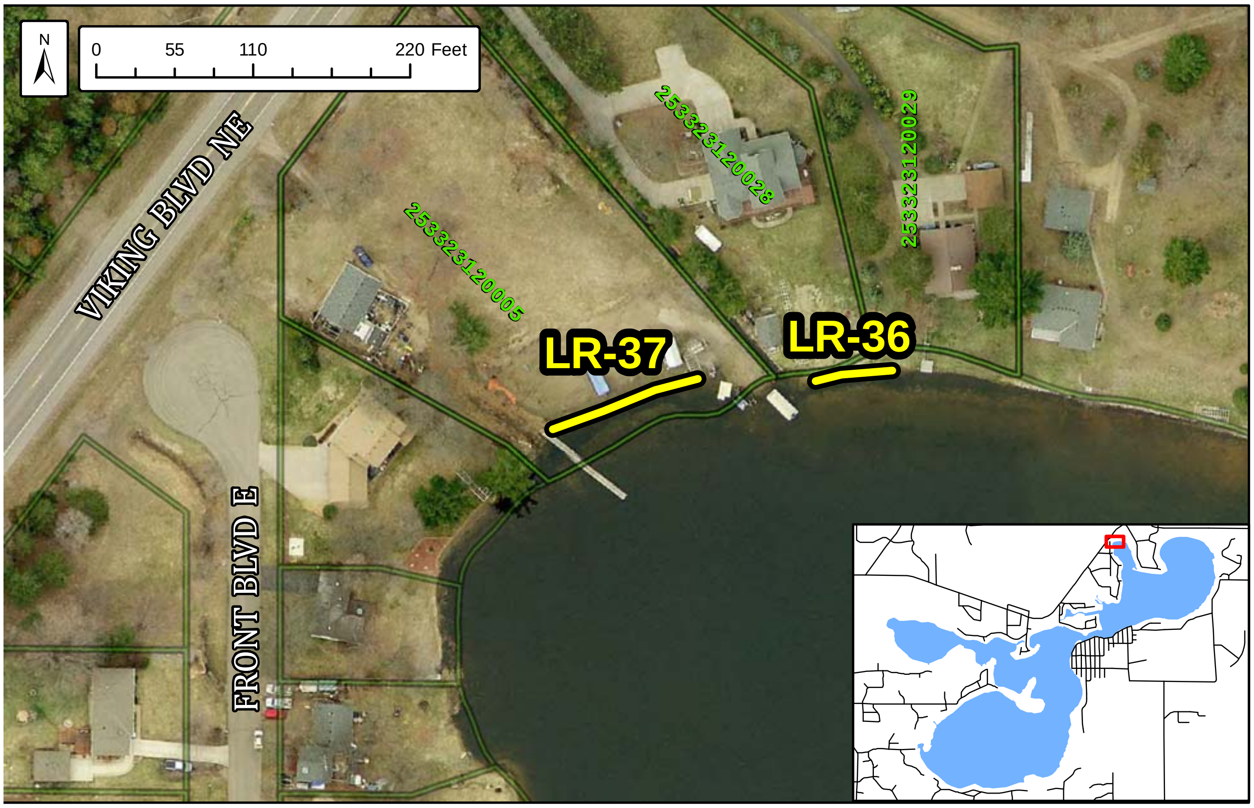
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-4 Lakeshore Restoration - LR-37

Drainage Area – 0.3 acres from residential lakeshore properties
Location – Southeast of Viking Blvd. along the northern shore of Coon Lake
Property Ownership – Private; 1 property intercepts the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 108 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-37

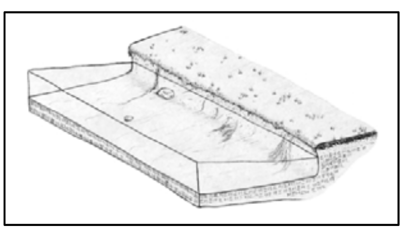
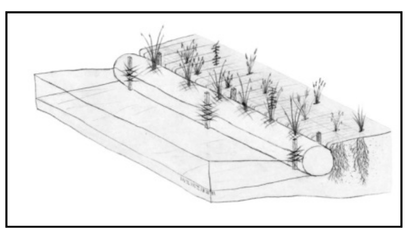
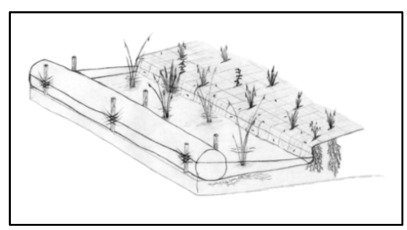
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	108	linear-ft				
	TP (lb/yr)	0.5	0.4%				
	TSS (lb/yr)	528	1.5%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$8,100					
	Total Estimated Project Cost (2014)	**$12,155**					
	Annual O&M***	$162					
Efficiency	30-yr Average Cost/lb-TP	**$1,134**					
	30-yr Average Cost/1,000lb-TSS	**$1,074**					
	30-yr Average Cost/ac-ft Vol.	**$5,672**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

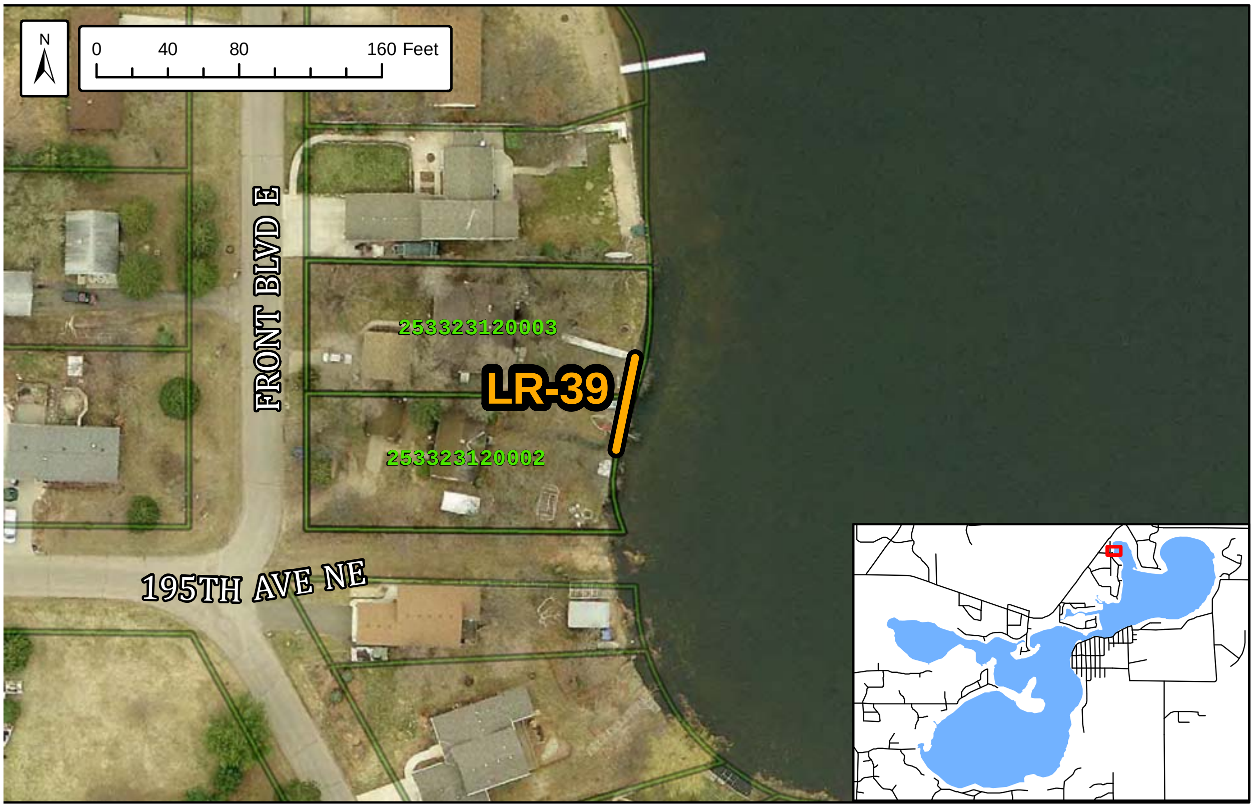
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-4 Lakeshore Restoration - LR-39

Drainage Area – 0.2 acres from residential lakeshore properties
Location – East of Front Blvd. along the northern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A moderately-large eroding face along the shore is evidence of an unstable bank. Railroad ties have been installed over a portion of the shore to help mitigate erosion but are failing. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 52 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. Construction costs were estimated at $125 per linear-ft. to include the increased cost of removing railroad ties.

Lakeshore Restoration – LR-39

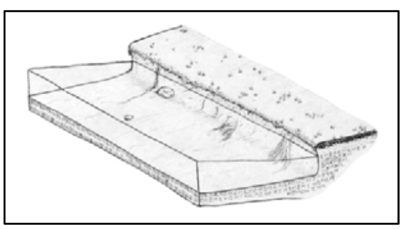
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	52	linear-ft				
	TP (lb/yr)	0.7	0.5%				
	TSS (lb/yr)	941	2.7%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$6,500					
	Total Estimated Project Cost (2014)	**$10,555**					
	Annual O&M***	$78					
Efficiency	30-yr Average Cost/lb-TP	**$614**					
	30-yr Average Cost/1,000lb-TSS	**$457**					
	30-yr Average Cost/ac-ft Vol.	**$4,298**					

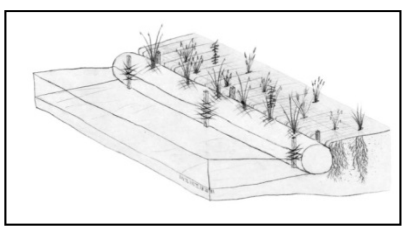
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

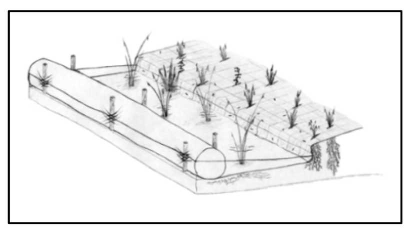
**$125/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

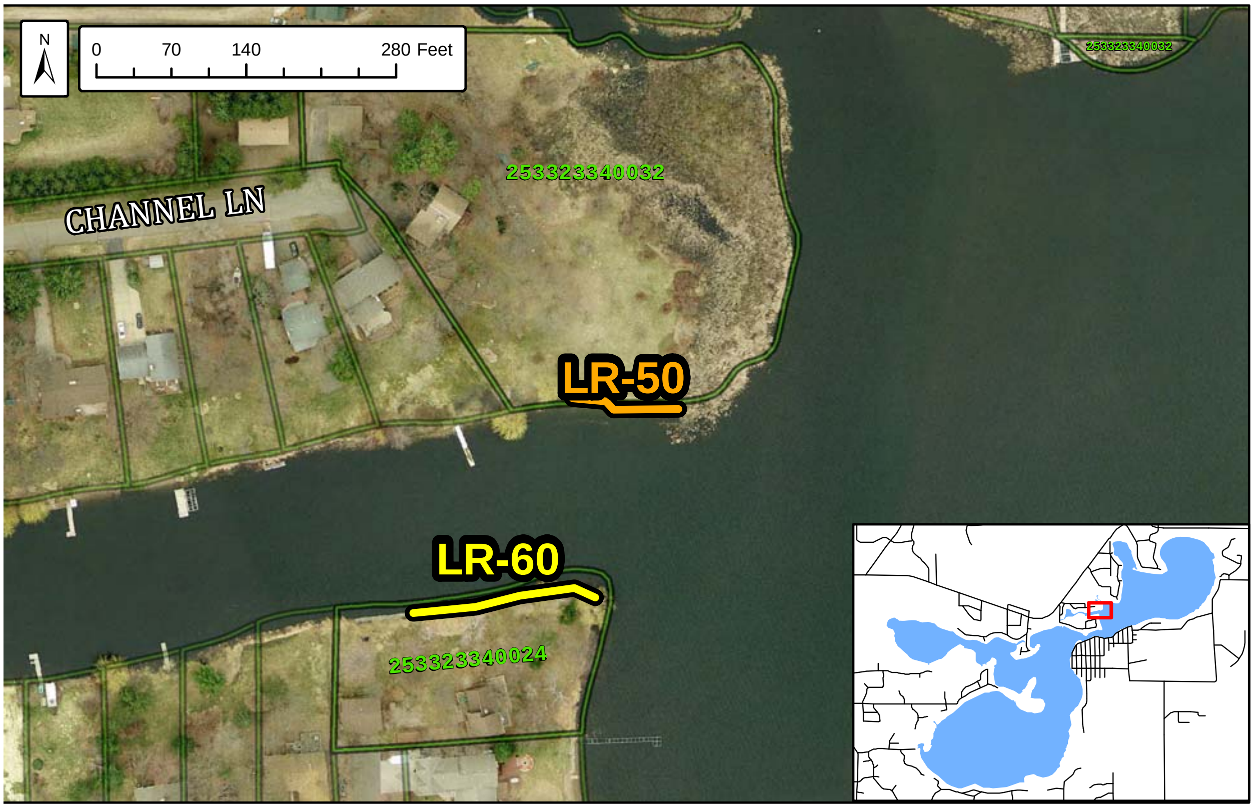






Project ID: CL-4 Lakeshore Restoration - LR-50

Drainage Area – 0.3 acres from residential lakeshore properties
Location – Southeast of Channel Lane along the northern shore of Coon Lake
Property Ownership – Private; 1 property intercepts the eroded shoreline
Erosion Severity – Moderate
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 103 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-50

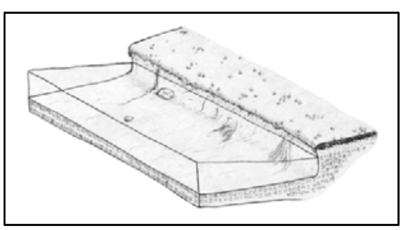
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	103	linear-ft				
	TP (lb/yr)	0.8	0.6%				
	TSS (lb/yr)	941	2.7%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$7,725					
	Total Estimated Project Cost (2014)	**$11,780**					
	Annual O&M***	$155					
Efficiency	30-yr Average Cost/lb-TP	**$684**					
	30-yr Average Cost/1,000lb-TSS	**$581**					
	30-yr Average Cost/ac-ft Vol.	**$5,472**					

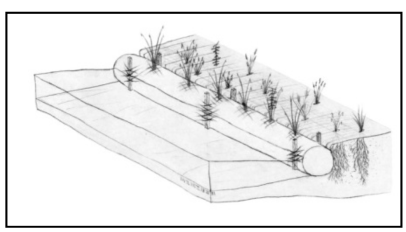
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

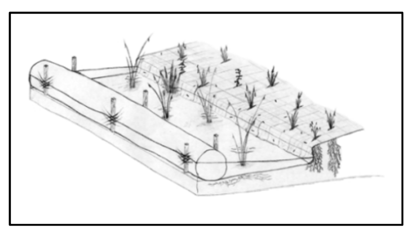
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

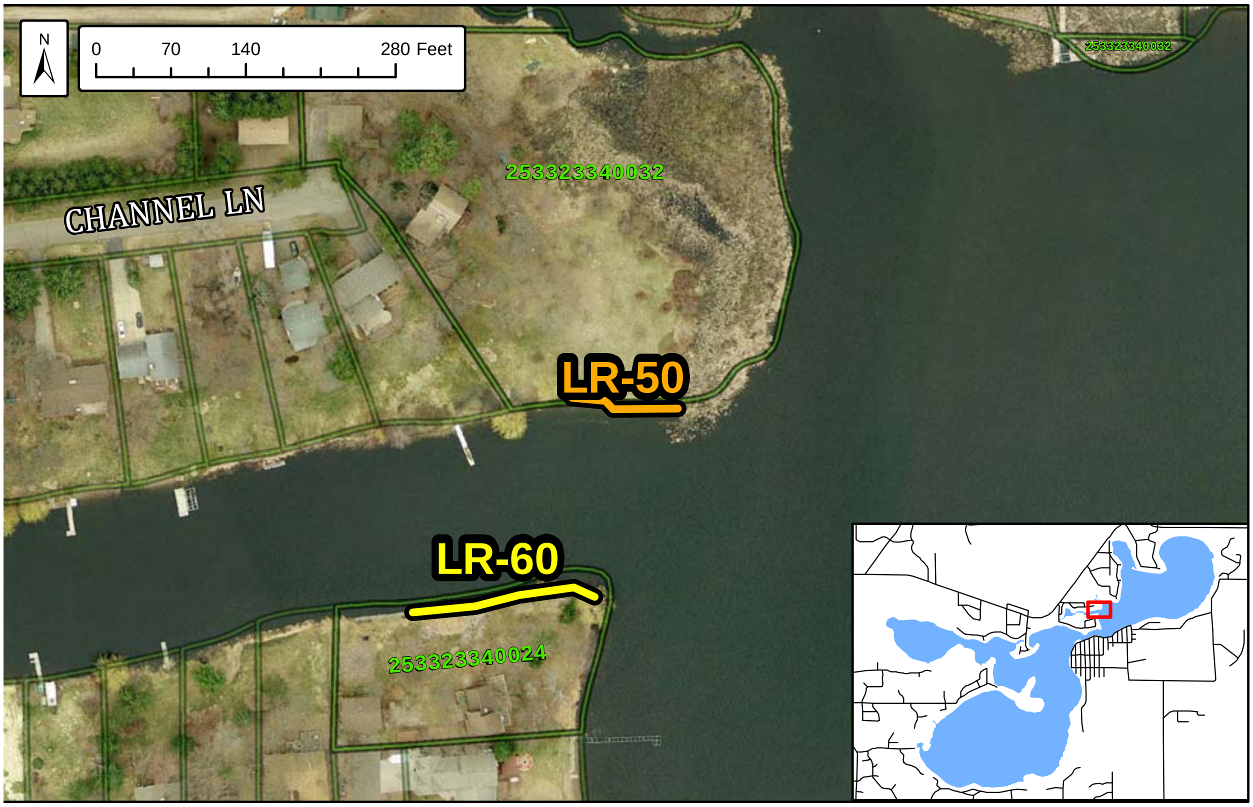






Project ID: CL-4 Lakeshore Restoration - LR-60

Drainage Area – 0.3 acres from residential lakeshore properties
Location – North of Jewell St. along the northern shore of Coon Lake
Property Ownership – Private; 1 property intercepts the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 174 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-60

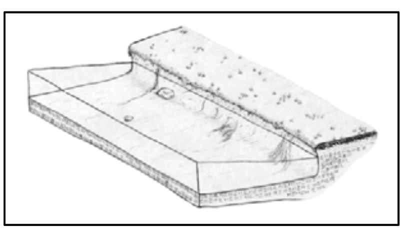
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	174	linear-ft				
	TP (lb/yr)	0.5	0.4%				
	TSS (lb/yr)	504	1.5%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$13,050					
	Total Estimated Project Cost (2014)	**$17,105**					
	Annual O&M***	$261					
Efficiency	30-yr Average Cost/lb-TP	**$1,662**					
	30-yr Average Cost/1,000lb-TSS	**$1,649**					
	30-yr Average Cost/ac-ft Vol.	**$8,312**					

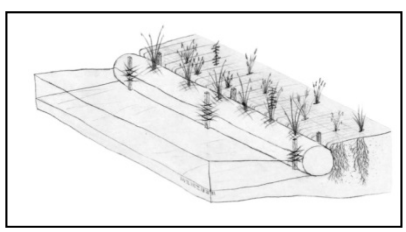
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

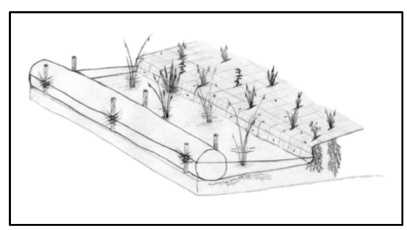
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

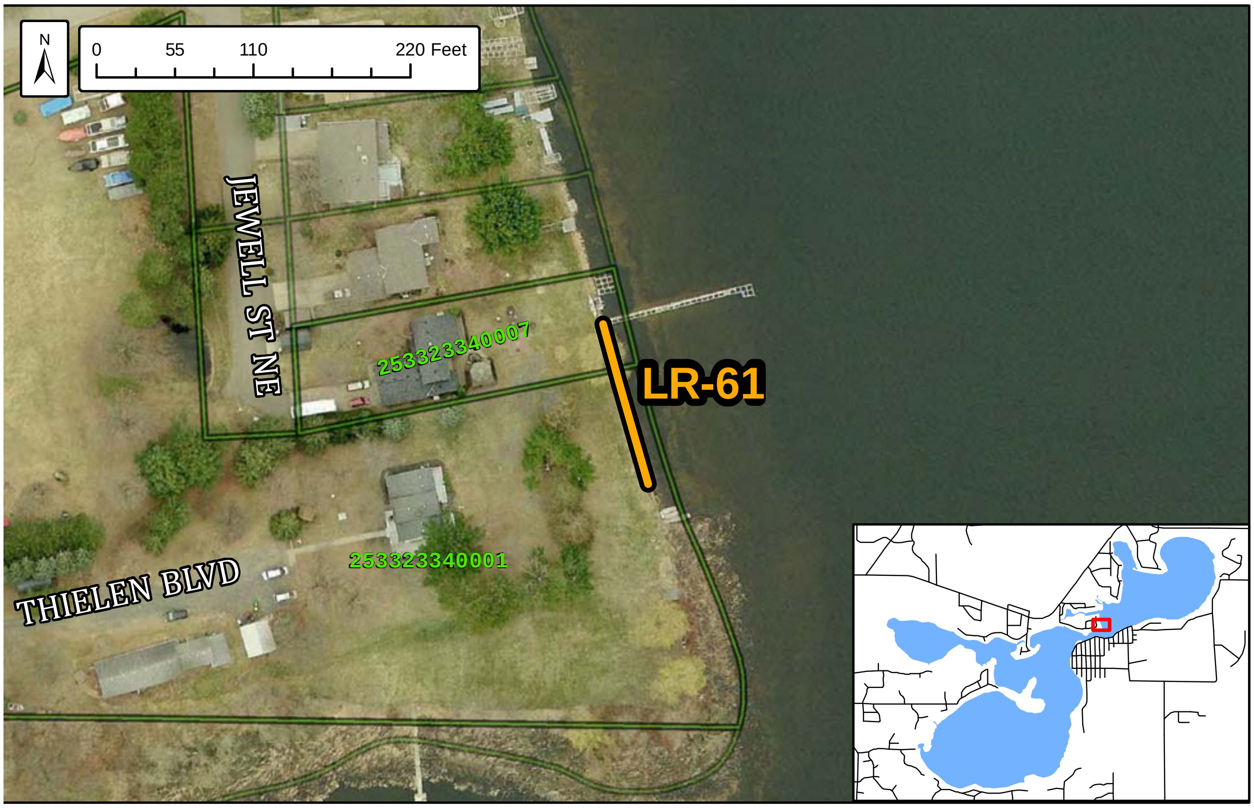






Project ID: CL-4 Lakeshore Restoration - LR-61

Drainage Area – 0.6 acres from residential lakeshore properties
Location – East of Jewell St. along the northern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A moderately-large eroding face along the shore is evidence of an unstable bank. A rock toe restoration may be necessary to stabilize the bank. This would likely also require heavy equipment to achieve a workable grade. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 117 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. Construction costs were estimated at $125 per linear-ft. to include the increased cost of the rock toe restoration and using heavy equipment.

Lakeshore Restoration – LR-61

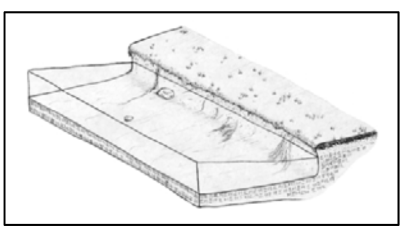
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	117	linear-ft				
	TP (lb/yr)	0.9	0.7%				
	TSS (lb/yr)	1,093	3.2%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$14,625					
	Total Estimated Project Cost (2014)	**$18,680**					
	Annual O&M***	$176					
Efficiency	30-yr Average Cost/lb-TP	**$887**					
	30-yr Average Cost/1,000lb-TSS	**$730**					
	30-yr Average Cost/ac-ft Vol.	**$7,982**					

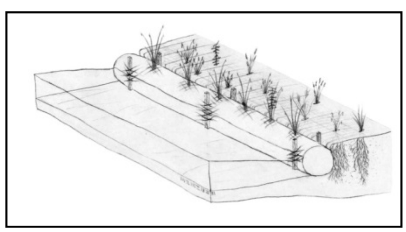
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

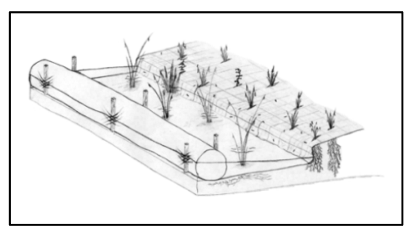
**$125/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations







Project ID: CL-4 Lakeshore Restoration - LR-62

Drainage Area – 11.5 acres of low density residential lots and campgrounds
Location – South of Viking Blvd. along the northern shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A small- to moderately-sized eroding face along the shore is evidence of an unstable bank. Approximately 1,250 ft of shoreline were flagged, with about half of this distance showing clear evidence of erosion. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore. The native grass buffer is recommended over the full shoreline, not just where wave erosion is prominent, to reduce the pollutant input from overland runoff.

Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 600 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. Construction costs were estimated at $100 per linear-ft. to include the increased cost of planting native grasses across the full 1,250 ft shoreline (not just the 600 ft of eroding shore).

Lakeshore Restoration – LR-62

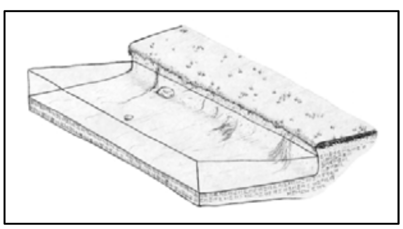
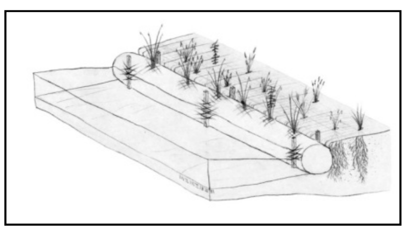
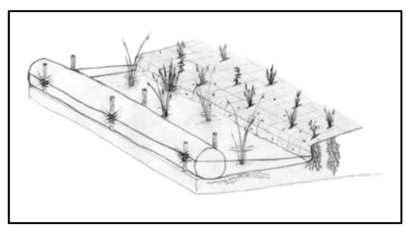
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	600	linear-ft				
	TP (lb/yr)	3.1	2.4%				
	TSS (lb/yr)	3,831	11.1%				
	Volume (ac-ft/yr)	0.5	0.6%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$60,000					
	Total Estimated Project Cost (2014)	**$64,055**					
	Annual O&M***	$900					
Efficiency	30-yr Average Cost/lb-TP	**$979**					
	30-yr Average Cost/1,000lb-TSS	**$792**					
	30-yr Average Cost/ac-ft Vol.	**$6,070**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$100/linear-ft for materials and labor

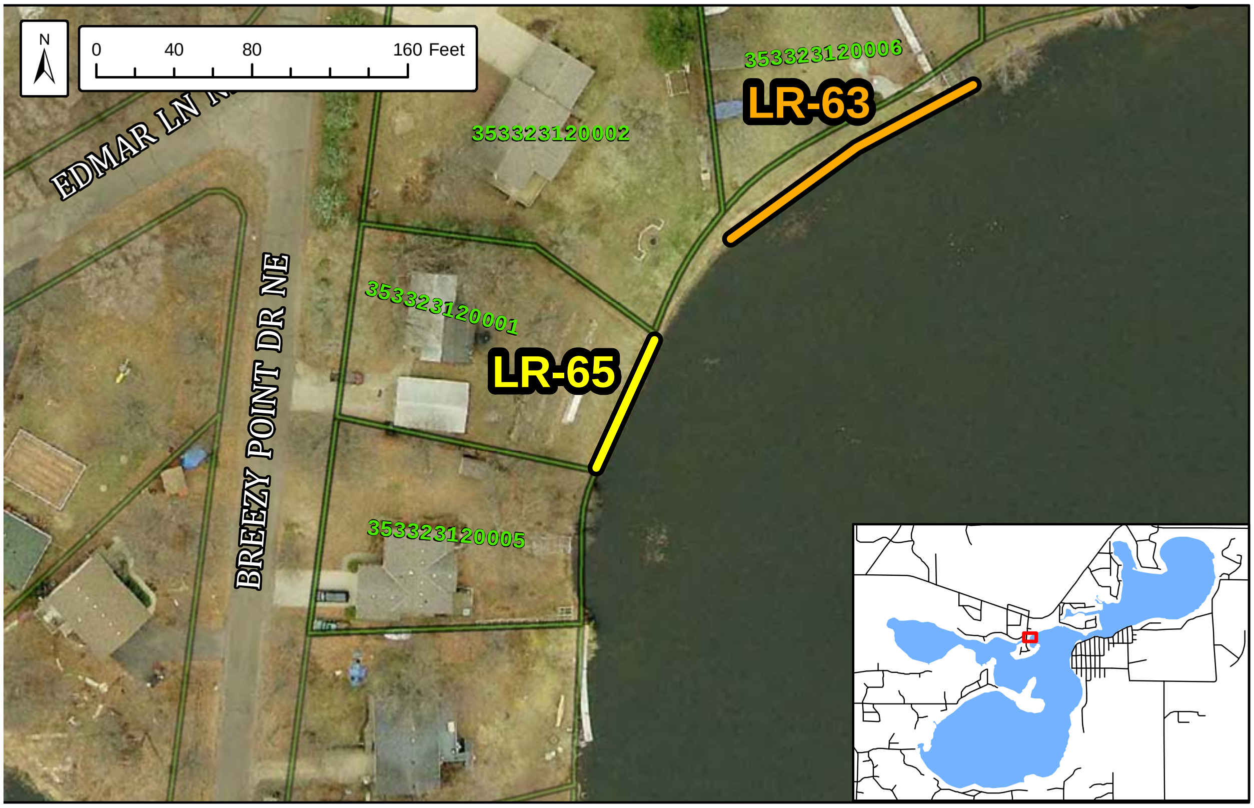
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-4 Lakeshore Restoration - LR-63

Drainage Area – 0.7 acres from residential lakeshore properties
Location – East of Breezy Point Dr. along the northern shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 148 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-63

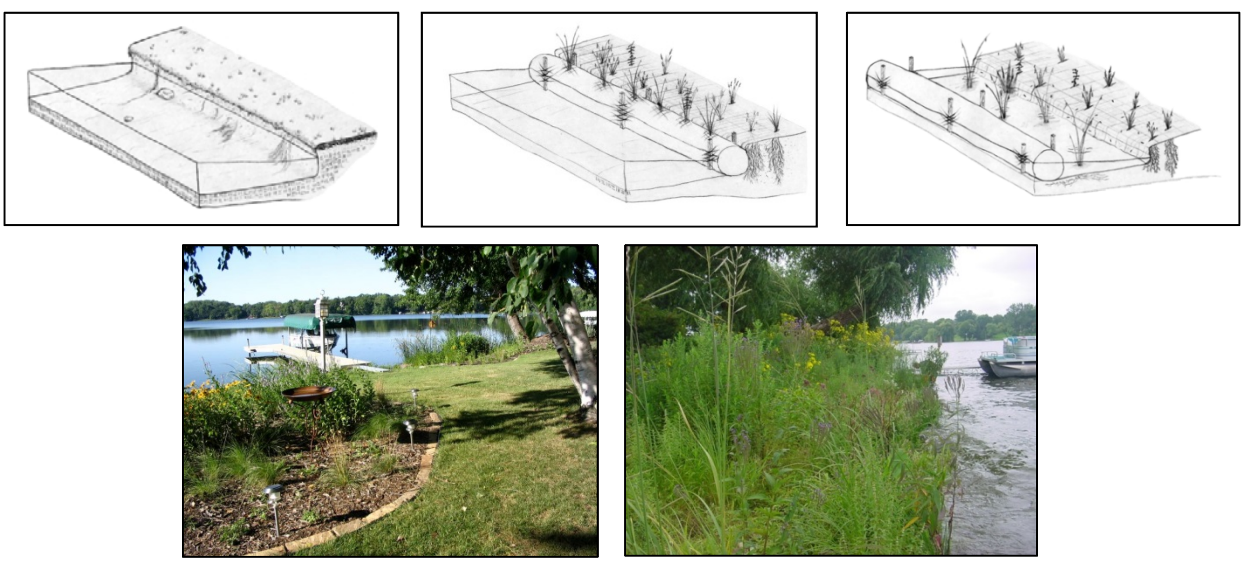
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	148	linear-ft				
	TP (lb/yr)	1.2	0.9%				
	TSS (lb/yr)	1,542	4.5%				
	Volume (ac-ft/yr)	0.2	0.2%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$11,100					
	Total Estimated Project Cost (2014)	**$15,155**					
	Annual O&M***	$222					
Efficiency	30-yr Average Cost/lb-TP	**$606**					
	30-yr Average Cost/1,000lb-TSS	**$472**					
	30-yr Average Cost/ac-ft Vol.	**$3,636**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

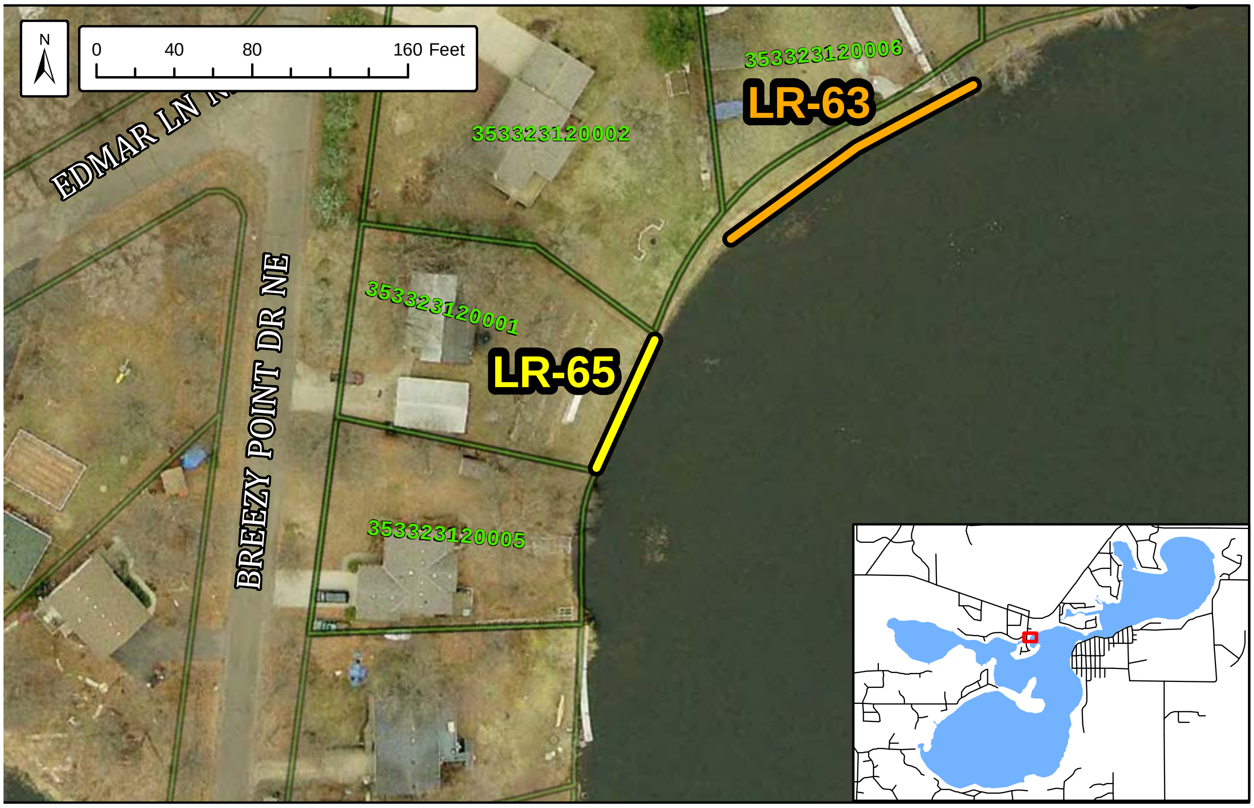
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations



Project ID: CL-4 Lakeshore Restoration - LR-65

Drainage Area – 0.2 acres from residential lakeshore properties
Location – East of Breezy Point Dr. along the northern shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A moderately-sized eroding face along the shore is evidence of an unstable bank. A rock toe restoration may be necessary to stabilize the bank. This would likely also require heavy equipment to achieve a workable grade. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore. It is possible that the apparent sloughing seen during the 2014 shoreline survey is evidence of a recent ice heave. If this is the case then it is simply recommended that the shore is stabilized to conditions prior to the heave.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 72 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. Construction costs were estimated at $125 per linear-ft. to include the increased cost of the rock toe restoration and the use of heavy equipment.

Lakeshore Restoration – LR-65

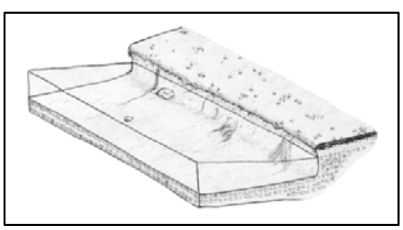
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	72	linear-ft				
	TP (lb/yr)	0.3	0.2%				
	TSS (lb/yr)	405	1.2%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	9,000					
	Total Estimated Project Cost (2014)	**$13,055**					
	Annual O&M***	$108					
Efficiency	30-yr Average Cost/lb-TP	**$1,811**					
	30-yr Average Cost/1,000lb-TSS	**$1,341**					
	30-yr Average Cost/ac-ft Vol.	**$5,432**					

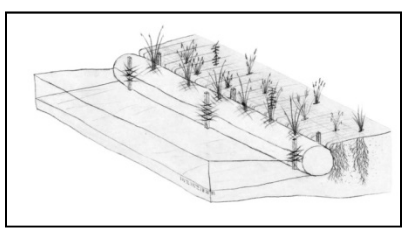
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

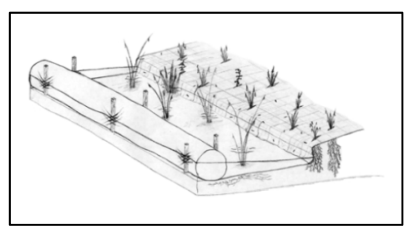
**$125/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

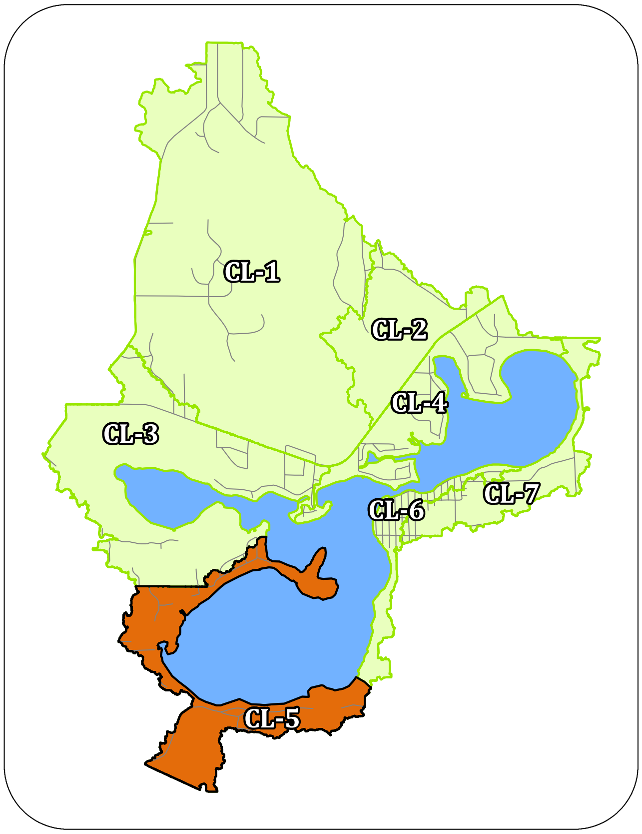






Catchment CL-5

Existing Catchment Summary	
Acres	509
Dominant Land Cover	Residential
Parcels	347
TP (lbs/yr)	160.5
TSS (lbs/yr)	35,883
Volume (ac-ft/yr)	104.4



CATCHMENT DESCRIPTION

This catchment surrounds the southern portion of Coon Lake and completely encompasses Little Coon Lake. The boundary between the cities of East Bethel and Ham Lake bisects the catchment. Land use is mostly low to medium density residential in the northern and southern portions of the catchment with wetlands and undeveloped open space to the west. Stormwater generated within the catchment either flows right into the lake or is directed to the lake via catch basins along adjacent roadways.

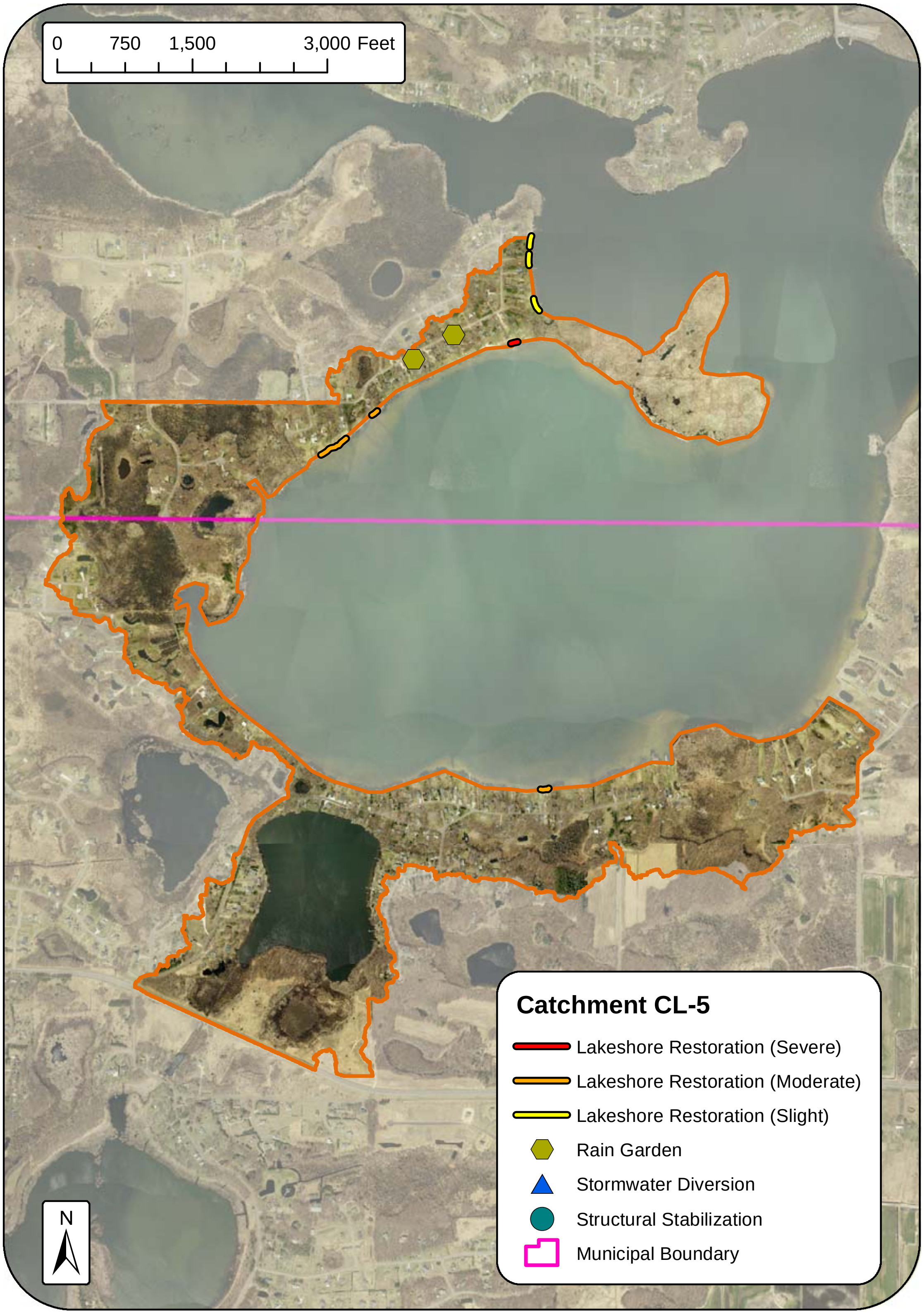
EXISTING STORMWATER TREATMENT

The only existing stormwater treatment is street cleaning provided at least once per year catchment-wide by the Cities of East Bethel and Ham Lake. The City of Ham Lake usually sweeps twice per year, once in spring and once in fall. The City of East Bethel sweeps at least once per year in spring, but will sweep additional times when necessary. For this analysis, street sweeping was assumed to occur catchment- wide once per year in spring to ensure at least a conservative estimate of pollutant removal from this BMP.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street sweeping			
	TP (lb/yr)	172.8	12.3	7%	**160.5**
	TSS (lb/yr)	41,229	5,346.0	13%	**35,883**
	Volume (ac-ft/yr)	104.4	0.0	0%	**104.4**

RETROFIT RECOMMENDATIONS



Project ID: CL-5 Residential Rain Gardens

Drainage Area – 5.6 acres
Location – Along Lakeview Point Dr. in northern portion of the catchment
Property Ownership – Private
Description – Most stormwater runoff and pollutants derived from this catchment come from the residential properties around the lake. Very little space is available around these properties for stormwater retrofits which could treat multiple properties. However, there are some opportunities to install curb-cut rain gardens to treat the residential land use (see *Appendix C* for design options). Two promising rain garden locations were identified along Lakeview Point Dr. (see map on the previous page), though more may exist. Generally, ideal rain garden locations are immediately up-gradient of a catch basin or outfall serving a large drainage area. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

Conceptual images –

Before/24 -48 hours after rain

During rain

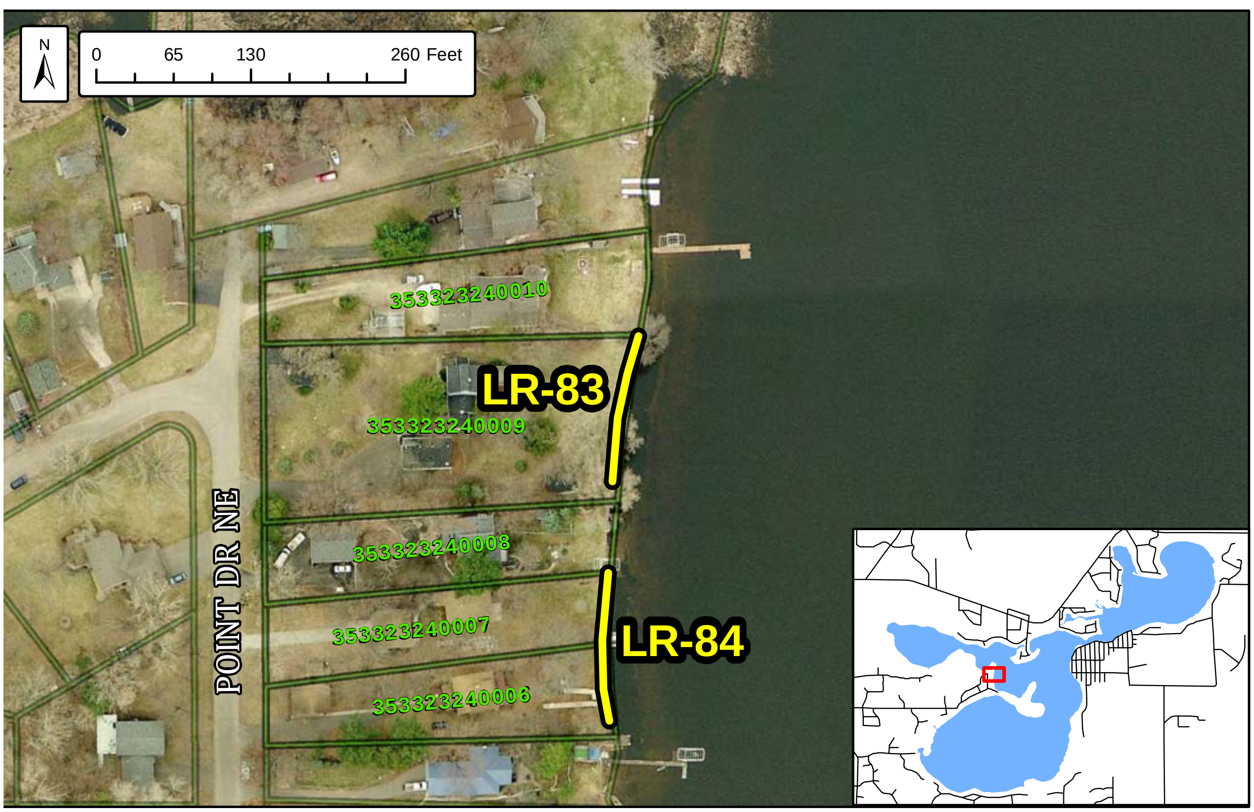
Curb-Cut Rain Gardens

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		2			
	Total Size of BMPs	250	sq-ft	500	sq-ft		
	TP (lb/yr)	0.5	0.3%	0.9	0.6%		
	TSS (lb/yr)	159	0.4%	277	0.8%		
	Volume (ac-ft/yr)	0.4	0.4%	0.7	0.7%		
Cost	Administration & Promotion Costs*	$4,234		$8,468			
	Design & Construction Costs**	$5,876		$11,752			
	Total Estimated Project Cost (2014)	**$10,110**		**$20,220**			
	Annual O&M***	$225		$450			
Efficiency	30-yr Average Cost/lb-TP	**$1,124**		**$1,249**			
	30-yr Average Cost/1,000lb-TSS	**$3,535**		**$4,058**			
	30-yr Average Cost/ac-ft Vol.	**$1,405**		**$1,606**			

*58 hours/BMP at $73/hour
**($20/sq-ft for materials and labor) + (12 hours/BMP at $73/hour)
***Per BMP: ($150 for 10-year rehabilitation) + ($75 for routine maintenance)

Project ID: CL-5 Lakeshore Restoration - LR-83

Drainage Area – 0.6 acres from residential lakeshore properties
Location – East of Point Dr. along the western shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 125 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-83

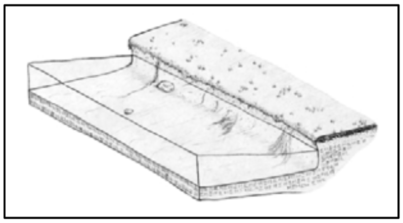
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	125	linear-ft				
	TP (lb/yr)	0.4	0.2%				
	TSS (lb/yr)	379	1.1%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$9,375					
	Total Estimated Project Cost (2014)	**$13,430**					
	Annual O&M***	$188					
Efficiency	30-yr Average Cost/lb-TP	**$1,588**					
	30-yr Average Cost/1,000lb-TSS	**$1,676**					
	30-yr Average Cost/ac-ft Vol.	**$4,886**					

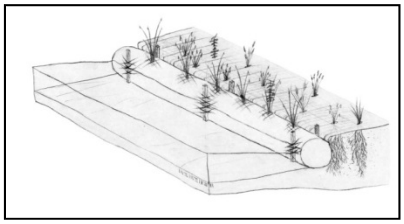
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

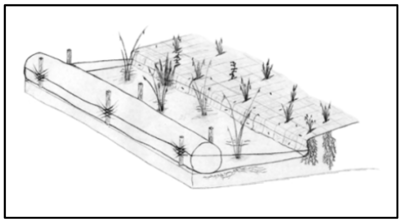
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

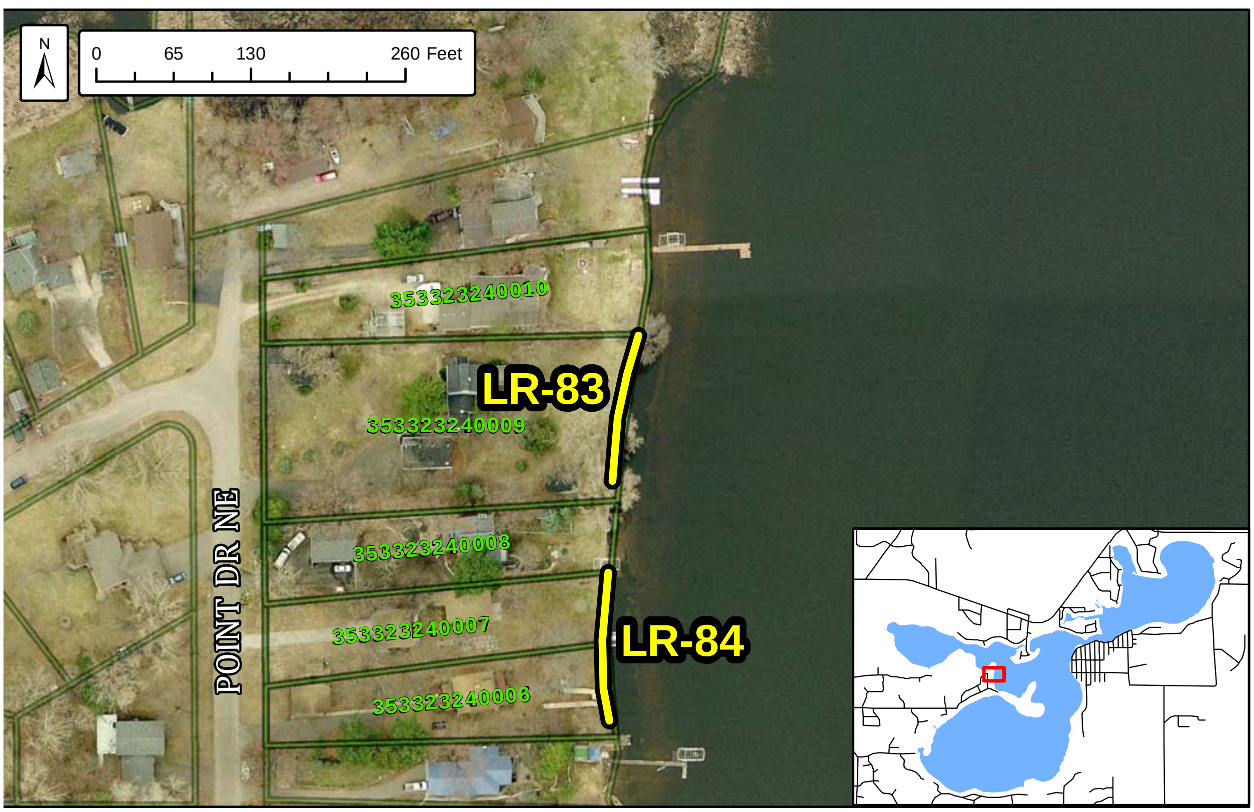






Project ID: CL-5 Lakeshore Restoration - LR-84

Drainage Area – 0.5 acres from residential lakeshore properties
Location – East of Point Dr. along the western shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 125 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-84

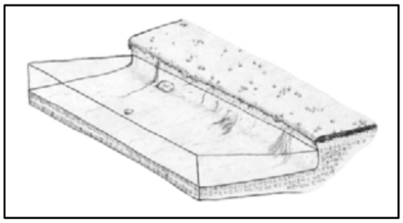
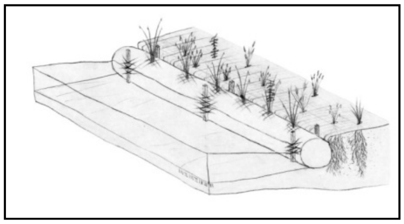
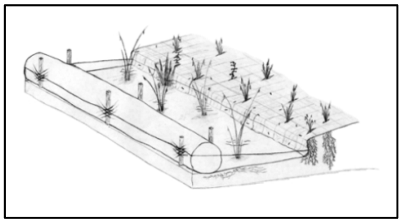
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	125	linear-ft				
	TP (lb/yr)	0.4	0.2%				
	TSS (lb/yr)	385	1.1%				
	Volume (ac-ft/yr)	0.2	0.2%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$9,375					
	Total Estimated Project Cost (2014)	**$13,430**					
	Annual O&M***	$188					
Efficiency	30-yr Average Cost/lb-TP	**$1,588**					
	30-yr Average Cost/1,000lb-TSS	**$1,650**					
	30-yr Average Cost/ac-ft Vol.	**$3,176**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-5 Lakeshore Restoration - LR-85

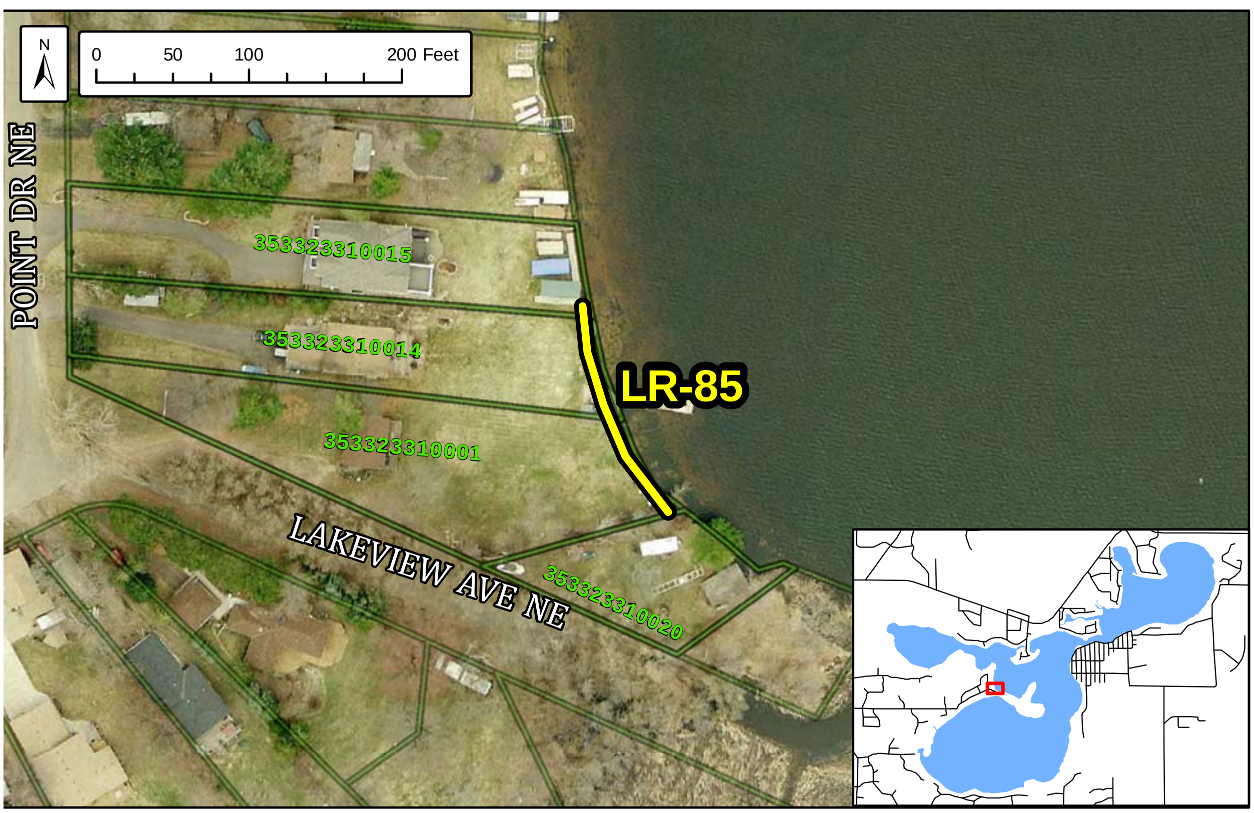
Drainage Area – 0.6 acres from residential lakeshore properties

Location – East of Point Dr. along the western shore of Coon Lake

Property Ownership – Private; 4 properties intercept the eroded shoreline

Erosion Severity – Slight

Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from these properties.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 150 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-85

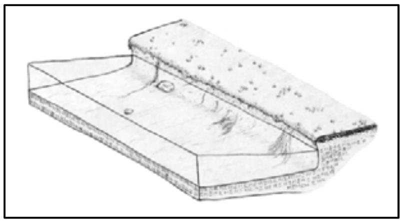
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	150	linear-ft				
	TP (lb/yr)	0.5	0.3%				
	TSS (lb/yr)	459	1.3%				
	Volume (ac-ft/yr)	0.2	0.2%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$11,250					
	Total Estimated Project Cost (2014)	**$15,305**					
	Annual O&M***	$225					
Efficiency	30-yr Average Cost/lb-TP	**$1,470**					
	30-yr Average Cost/1,000lb-TSS	**$1,602**					
	30-yr Average Cost/ac-ft Vol.	**$3,676**					

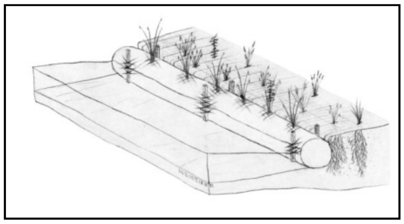
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

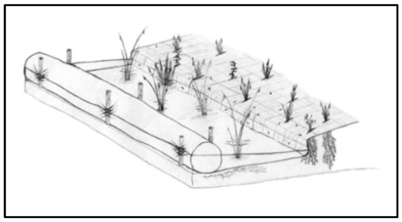
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

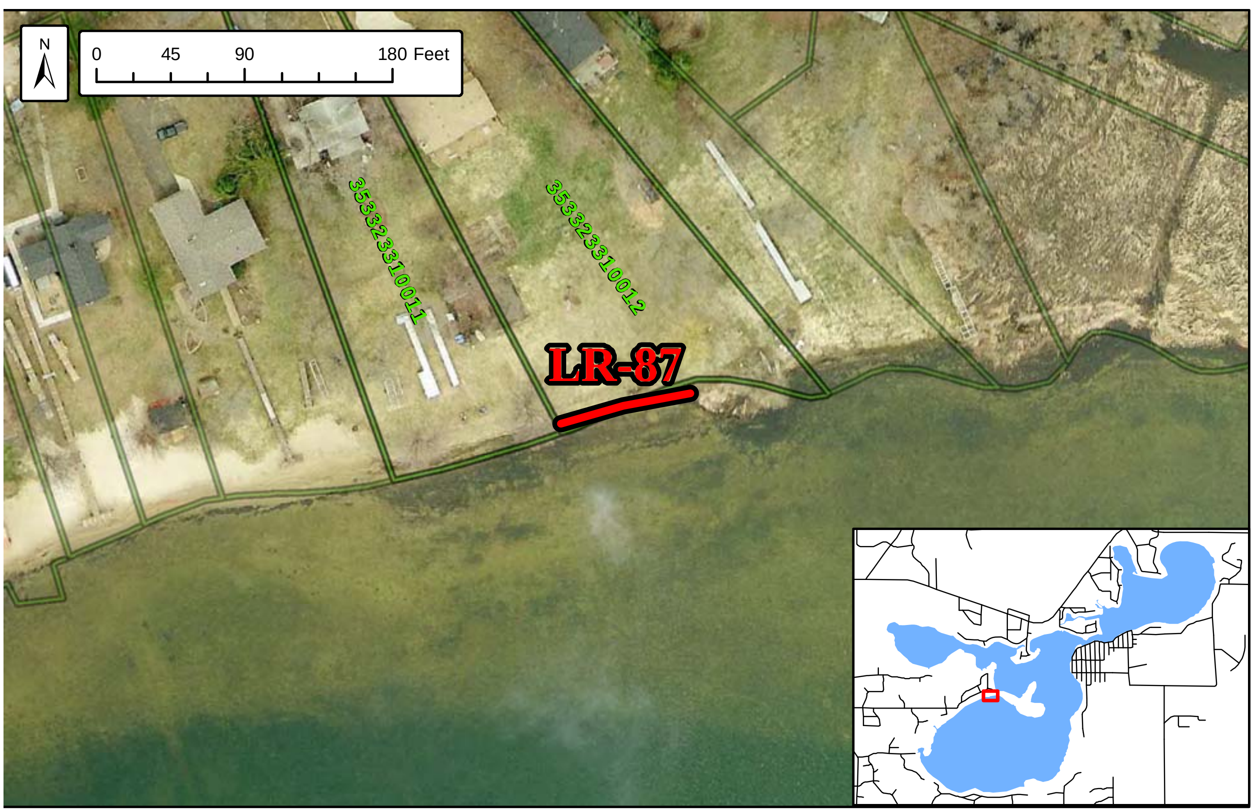






Project ID: CL-5 Lakeshore Restoration - LR-87

Drainage Area – 0.4 acres from residential lakeshore properties
Location – South of Lakeview Point Dr. along the western shore of Coon Lake
Property Ownership – Private; 2 properties intercept the eroded shoreline
Erosion Severity – Severe
Description – A large eroding face along the shore is evidence of an unstable bank. A rock toe restoration may be necessary to stabilize the bank. This would likely also require heavy equipment to achieve a workable grade. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 81 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff. Construction costs were increased to $125 per linear-ft. to include the increased cost of a rock toe restoration and the use of heavy equipment.

Lakeshore Restoration – LR-87

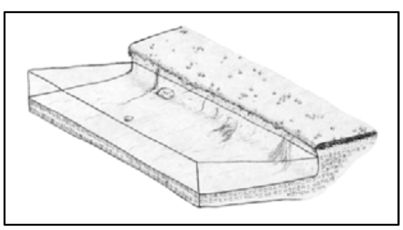
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	81	linear-ft				
	TP (lb/yr)	2.6	1.6%				
	TSS (lb/yr)	3,683	10.3%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$10,125					
	Total Estimated Project Cost (2014)	**$14,180**					
	Annual O&M***	$122					
Efficiency	30-yr Average Cost/lb-TP	**$232**					
	30-yr Average Cost/1,000lb-TSS	**$161**					
	30-yr Average Cost/ac-ft Vol.	**$5,942**					

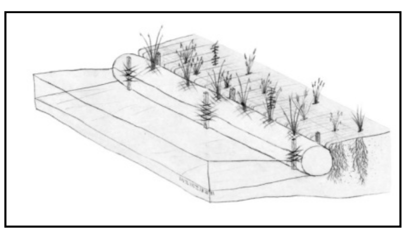
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

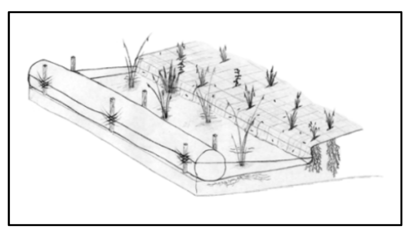
**$125/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

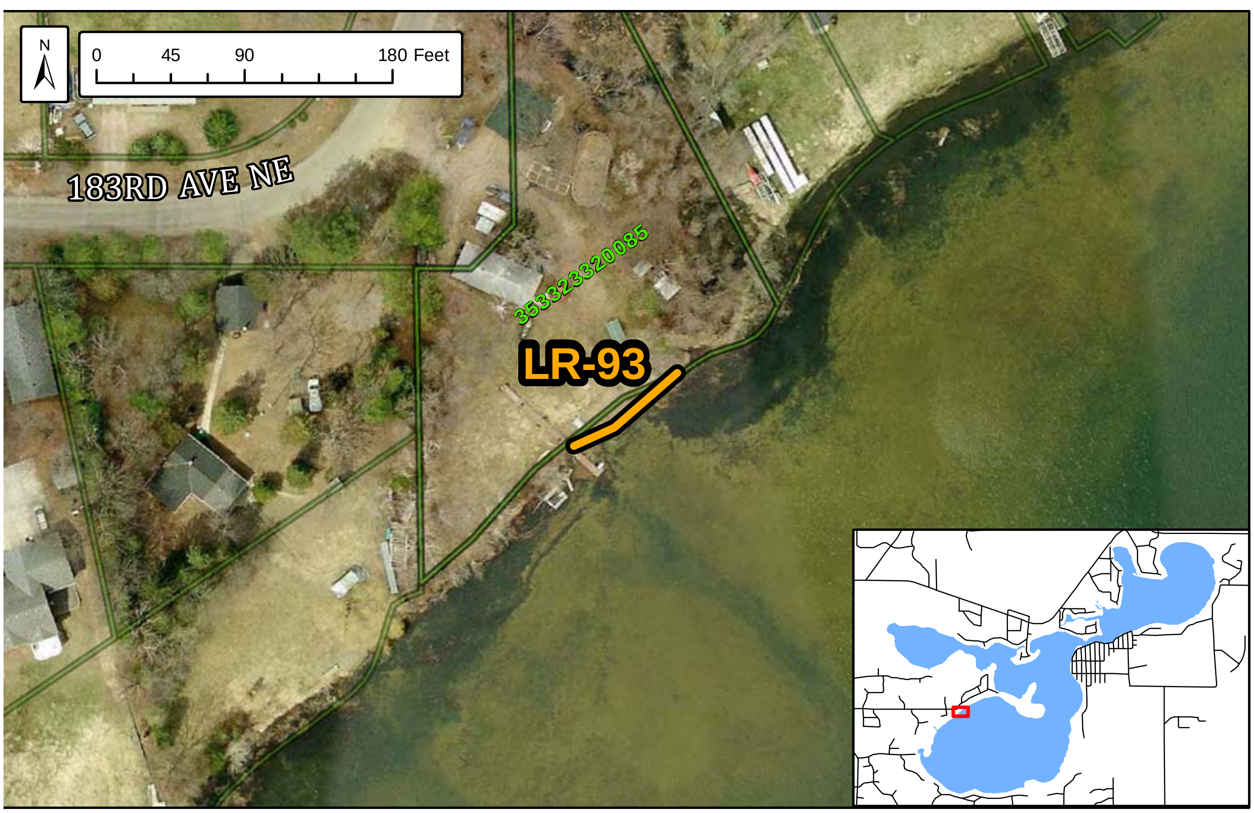






Project ID: CL-5 Lakeshore Restoration - LR-93

Drainage Area – 0.2 acres from residential lakeshore properties
Location – Southeast of Lakeview Point Dr. along the western shore of Coon Lake
Property Ownership – Private; 1 property intercepts the eroded shoreline
Erosion Severity – Moderate
Description – A moderately-sized eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 77 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-93

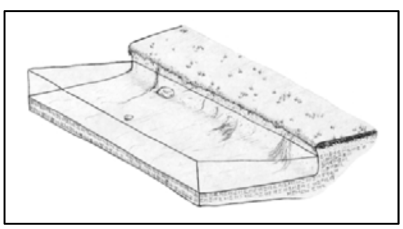
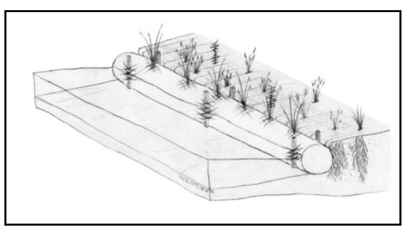
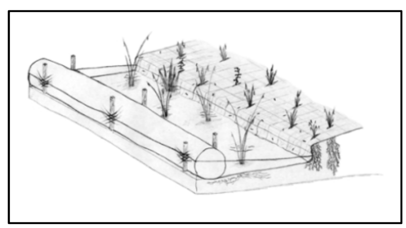
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	77	linear-ft				
	TP (lb/yr)	0.4	0.2%				
	TSS (lb/yr)	493	1.4%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$5,775					
	Total Estimated Project Cost (2014)	**$9,830**					
	Annual O&M***	$116					
Efficiency	30-yr Average Cost/lb-TP	**$1,108**					
	30-yr Average Cost/1,000lb-TSS	**$899**					
	30-yr Average Cost/ac-ft Vol.	**$4,432**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

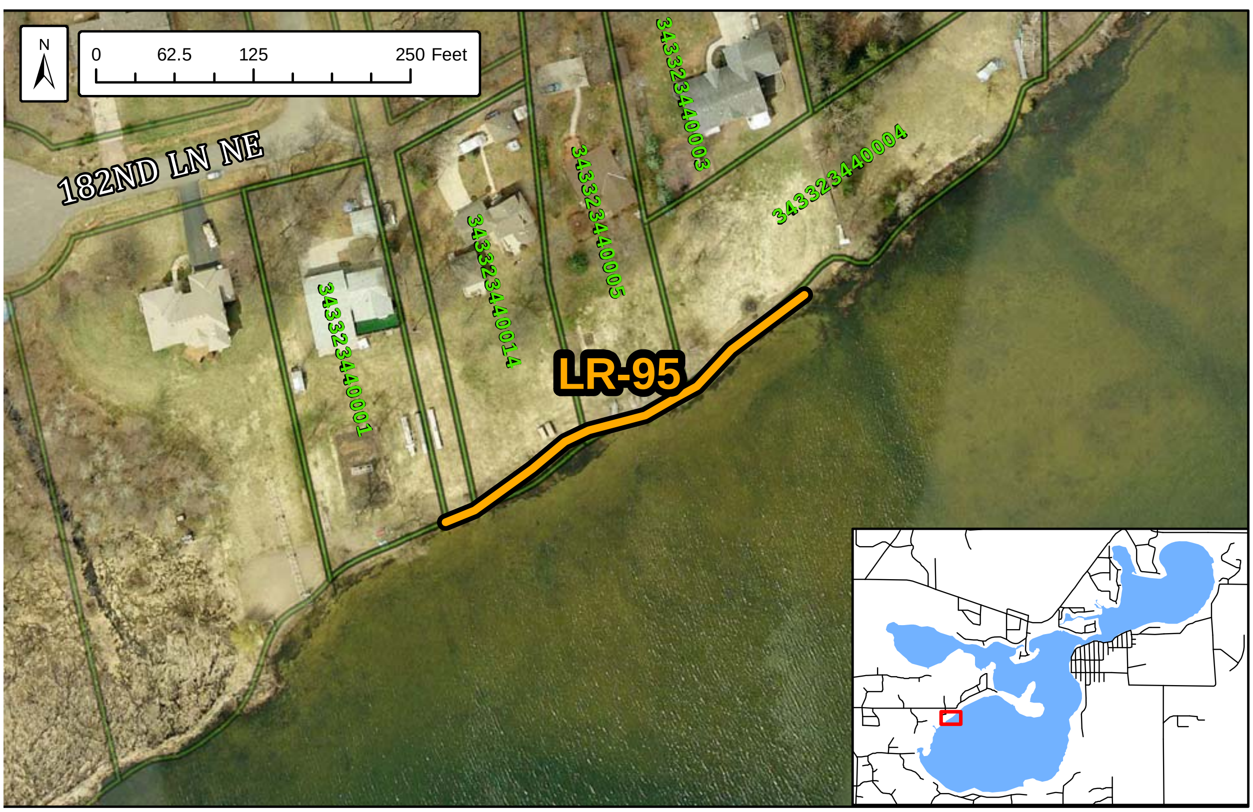
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

Project ID: CL-5 Lakeshore Restoration - LR-95

Drainage Area – 1.5 acres from residential lakeshore properties
Location – South of 182nd Lane along the western shore of Coon Lake
Property Ownership – Private; 4 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A moderately-sized eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 342 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-95

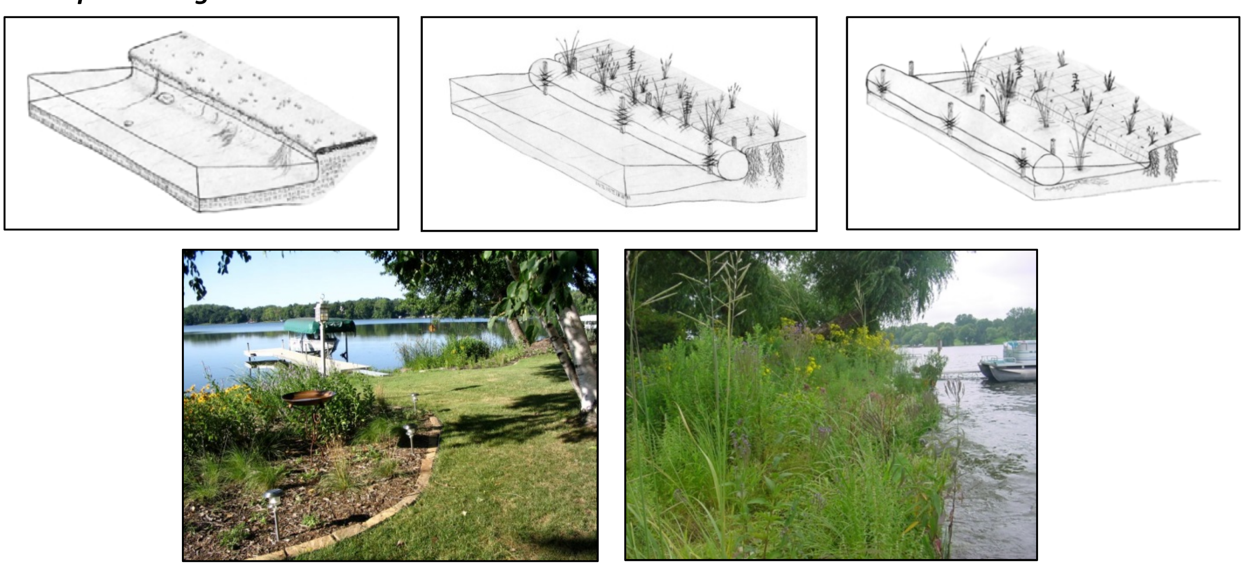
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1					
	Estimated Total Size of BMP	342	linear-ft				
	TP (lb/yr)	1.9	1.2%				
	TSS (lb/yr)	2,204	6.1%				
	Volume (ac-ft/yr)	0.4	0.4%				
Cost	**Administration & Promotion Costs***	$4,055					
	Design & Construction Costs**	$25,650					
	Total Estimated Project Cost (2014)	**$29,705**					
	Annual O&M***	$513					
Efficiency	**30-yr Average Cost/lb-TP**	**$791**					
	30-yr Average Cost/1,000lb-TSS	**$682**					
	30-yr Average Cost/ac-ft Vol.	**$3,758**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

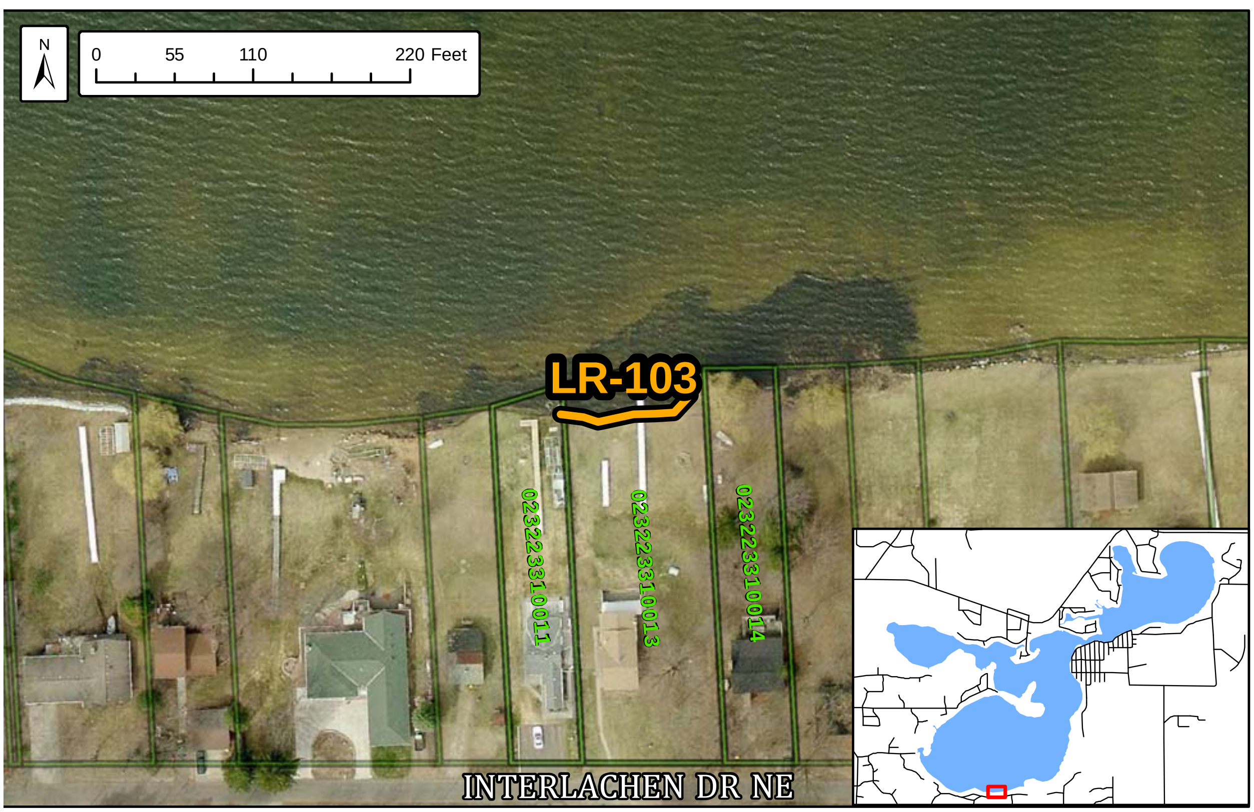
***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations



Project ID: CL-5 Lakeshore Restoration - LR-103

Drainage Area – 0.4 acres from residential lakeshore properties
Location – North of Interlachen Dr. along the southern shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Moderate
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.



Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 97 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-103

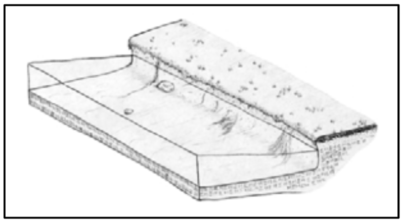
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	97	linear-ft				
	TP (lb/yr)	0.6	0.4%				
	TSS (lb/yr)	774	2.2%				
	Volume (ac-ft/yr)	0.1	0.1%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$7,275					
	Total Estimated Project Cost (2014)	**$11,330**					
	Annual O&M***	$146					
Efficiency	30-yr Average Cost/lb-TP	**$872**					
	30-yr Average Cost/1,000lb-TSS	**$676**					
	30-yr Average Cost/ac-ft Vol.	**$5,232**					

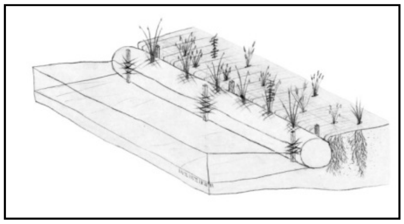
*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

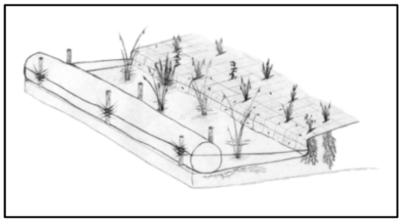
**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

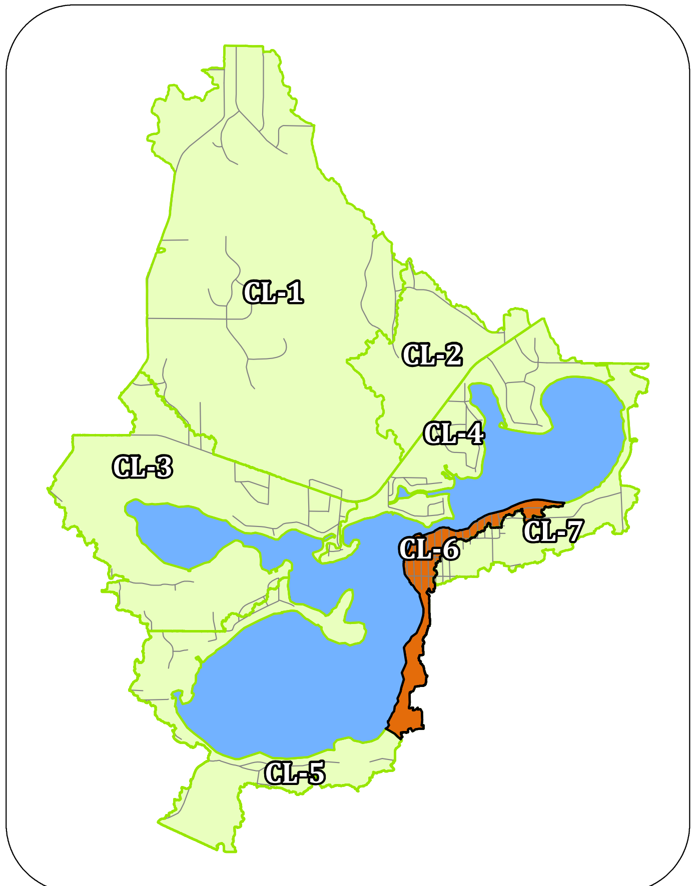






Catchment CL-6

Existing Network Summary	
Acres	146
Dominant Land Cover	Residential
Parcels	380
TP (lbs/yr)	63.7
TSS (lbs/yr)	15,859
Volume (ac-ft/yr)	43.5



CATCHMENT DESCRIPTION

Catchment CL-6 lies on the southeastern and eastern shores of Coon Lake. The northern half of the catchment is the Coon Lake Beach neighborhood in the City of East Bethel. The southern half is split between city-owned property in East Bethel and single-family homes and cabins in the City of Ham Lake.

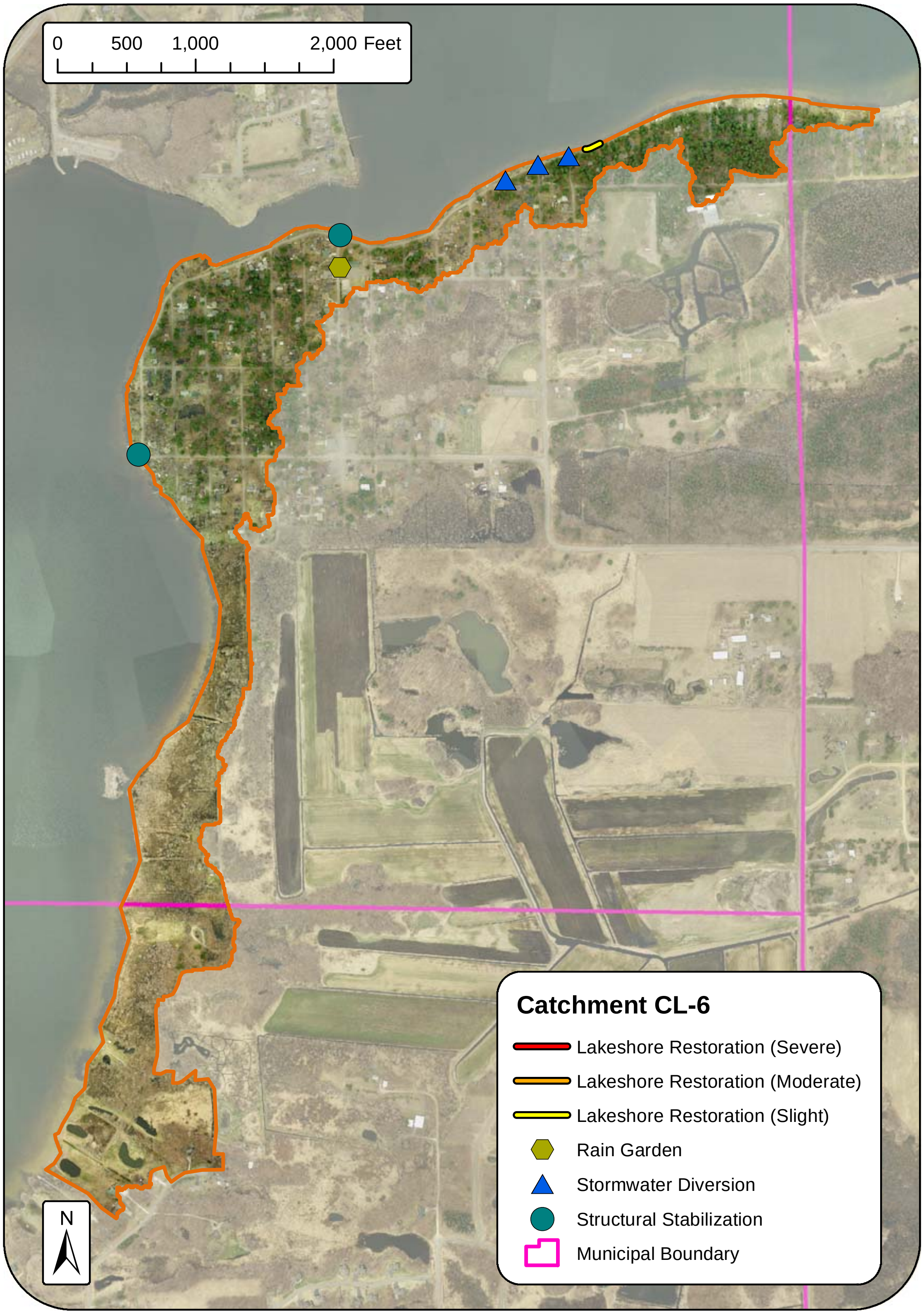
Stormwater runoff generated within the catchment has relatively short flow paths before reaching Coon Lake. Within the Coon Lake Beach neighborhood curb lines and yards elevated above the roadway can accumulate flow from up to a few acres of drainage area and direct discharge straight into the lake.

EXISTING NETWORK TREATMENT

The only form of stormwater treatment in CL-6 is street sweeping provided by the City of East Bethel once per year in spring. Outside of this, no treatment is provided prior to stormwater discharging into the lake.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	**Number of BMPs**	1			
	BMP Types	Street sweeping			
	TP (lb/yr)	68.8	5.1	7%	**63.7**
	TSS (lb/yr)	18,072	2,213.0	12%	**15,859**
	Volume (ac-ft/yr)	43.5	0.0	0%	**43.5**

RETROFIT RECOMMENDATIONS



Project ID: CL-6 Coon Lake Beach Community Center Rain Garden

Drainage Area – 1.0 acre

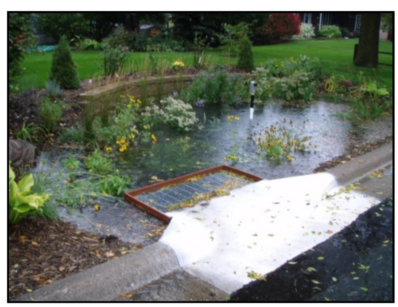
Location – Just north of the western entrance into the Coon Lake Beach Community Center parking lot

Property Ownership – Public

Description – The Coon Lake Beach Community Center and Park is publicly owned and has a significant amount of impervious surface. In addition, the facility is a meeting place for many lake associations and other groups, making it an important piece of the local community around the lake. Combining all of these factors, this site is a great location for a visible stormwater treatment practice. One such project is a rain garden, which could be installed downslope of the western entrance to treat stormwater runoff from the parking lot, tennis court, and community center building (see *Appendix C* for design options). Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table. Two different garden sizes are proposed. The first, with a top area of 250 sq-ft., is the typical size for rain gardens. Due to the space available, a larger garden up to 500 sq-ft. in area could be installed to treat a greater volume of water.

Conceptual images –

Before/24 -48 hours after rain



During rain

Curb-Cut Rain Garden							
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1			
	Total Size of BMPs	250	sq-ft	500	sq-ft		
	TP (lb/yr)	0.3	0.5%	0.5	0.8%		
	TSS (lb/yr)	100	0.6%	143	0.9%		
	Volume (ac-ft/yr)	0.3	0.7%	0.4	0.9%		
Cost	Administration & Promotion Costs*	$4,234		$4,234			
	Design & Construction Costs**	$5,876		$10,876			
	Total Estimated Project Cost (2014)	**$10,110**		**$15,110**			
	Annual O&M***	$225		$225			
Efficiency	30-yr Average Cost/lb-TP	**$1,873**		**$1,457**			
	30-yr Average Cost/1,000lb-TSS	**$5,620**		**$5,096**			
	30-yr Average Cost/ac-ft Vol.	**$1,873**		**$1,822**			

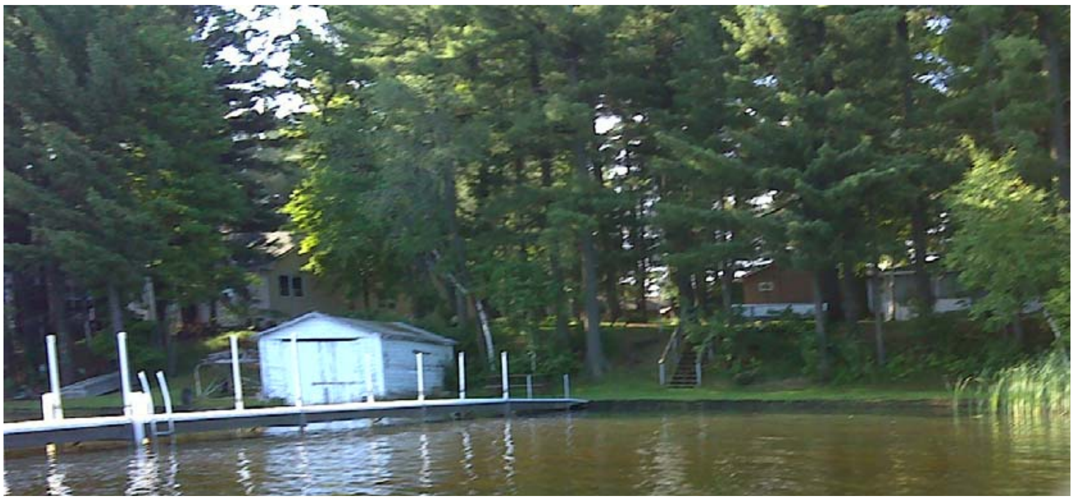
*58 hours/BMP at $73/hour

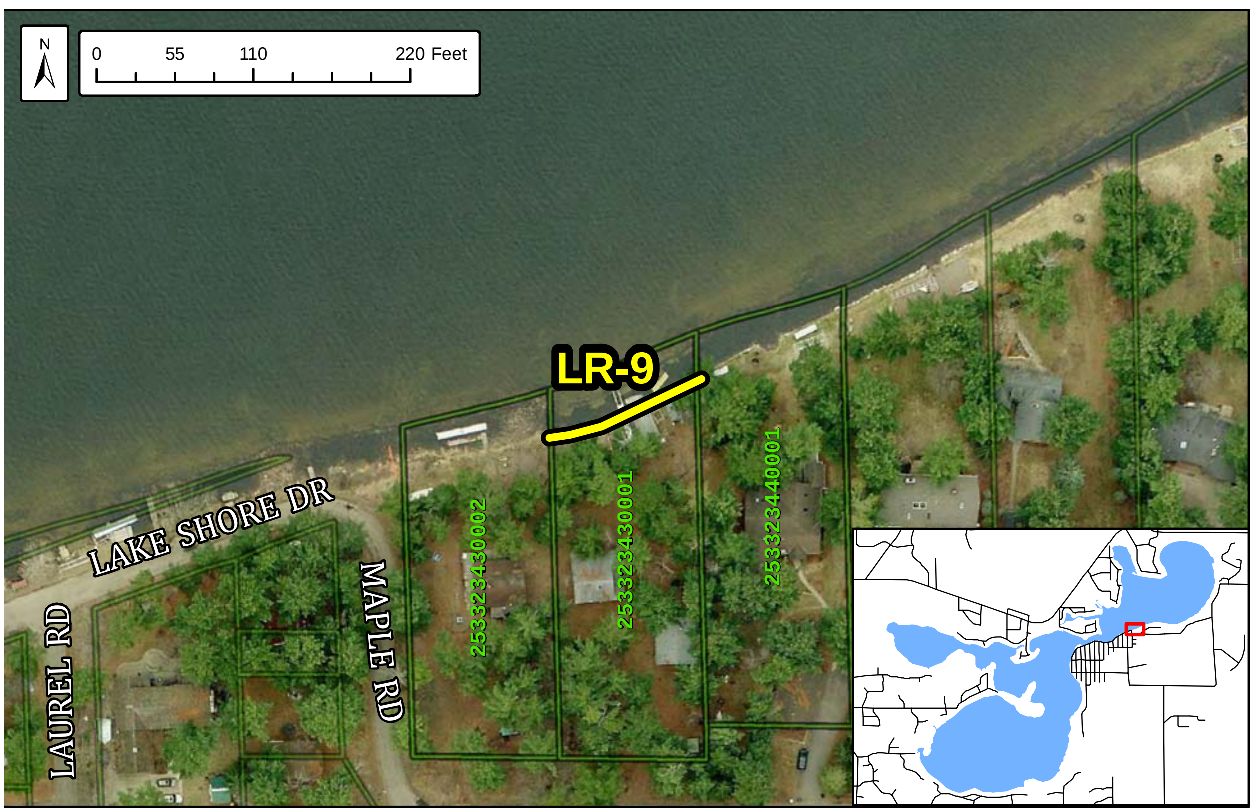
**($20/sq-ft for materials and labor) + (12 hours/BMP at $73/hour)

***Per BMP: ($150 for 10-year rehabilitation) + ($75 for routine maintenance)

Project ID: CL-5 Lakeshore Restoration - LR-9

Drainage Area – 0.3 acres from residential lakeshore properties
Location – West of Maple Road along the southern shore of Coon Lake
Property Ownership – Private; 3 properties intercept the eroded shoreline
Erosion Severity – Slight
Description – A small eroding face along the shore is evidence of an unstable bank. Installation of an erosion control blanket and biolog should eliminate erosion at the site. In addition, planting native grasses along the shore and not mowing to the water's edge should decrease pollutant input from properties along the shore.





Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table if the full 115 ft (estimated) of shoreline are restored. A project installed on a specific property will have lower costs and pollutant reduction totals. Pollutant reduction totals in the table assume stabilization of the bank as well as the installation of a grass buffer along the lakeshore to treat overland stormwater runoff.

Lakeshore Restoration – LR-9

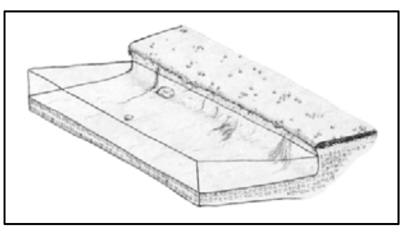
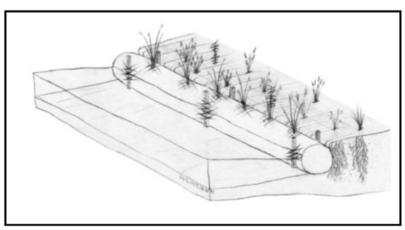
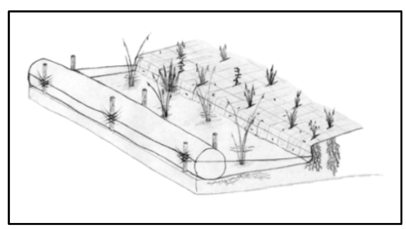
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Estimated Total Size of BMP	115	linear-ft				
	TP (lb/yr)	0.5	0.8%				
	TSS (lb/yr)	629	4.0%				
	Volume (ac-ft/yr)	0.1	0.2%				
Cost	Administration & Promotion Costs*	$4,055					
	Design & Construction Costs**	$8,625					
	Total Estimated Project Cost (2014)	**$12,680**					
	Annual O&M***	$173					
Efficiency	30-yr Average Cost/lb-TP	**$1,190**					
	30-yr Average Cost/1,000lb-TSS	**$946**					
	30-yr Average Cost/ac-ft Vol.	**$5,952**					

*(35 hours at $73/hour for promotion and administration) + ($1,500 for design)

**$75/linear-ft for materials and labor

***$1.5/linear-ft/yr

Conceptual images – Native Plant Restorations

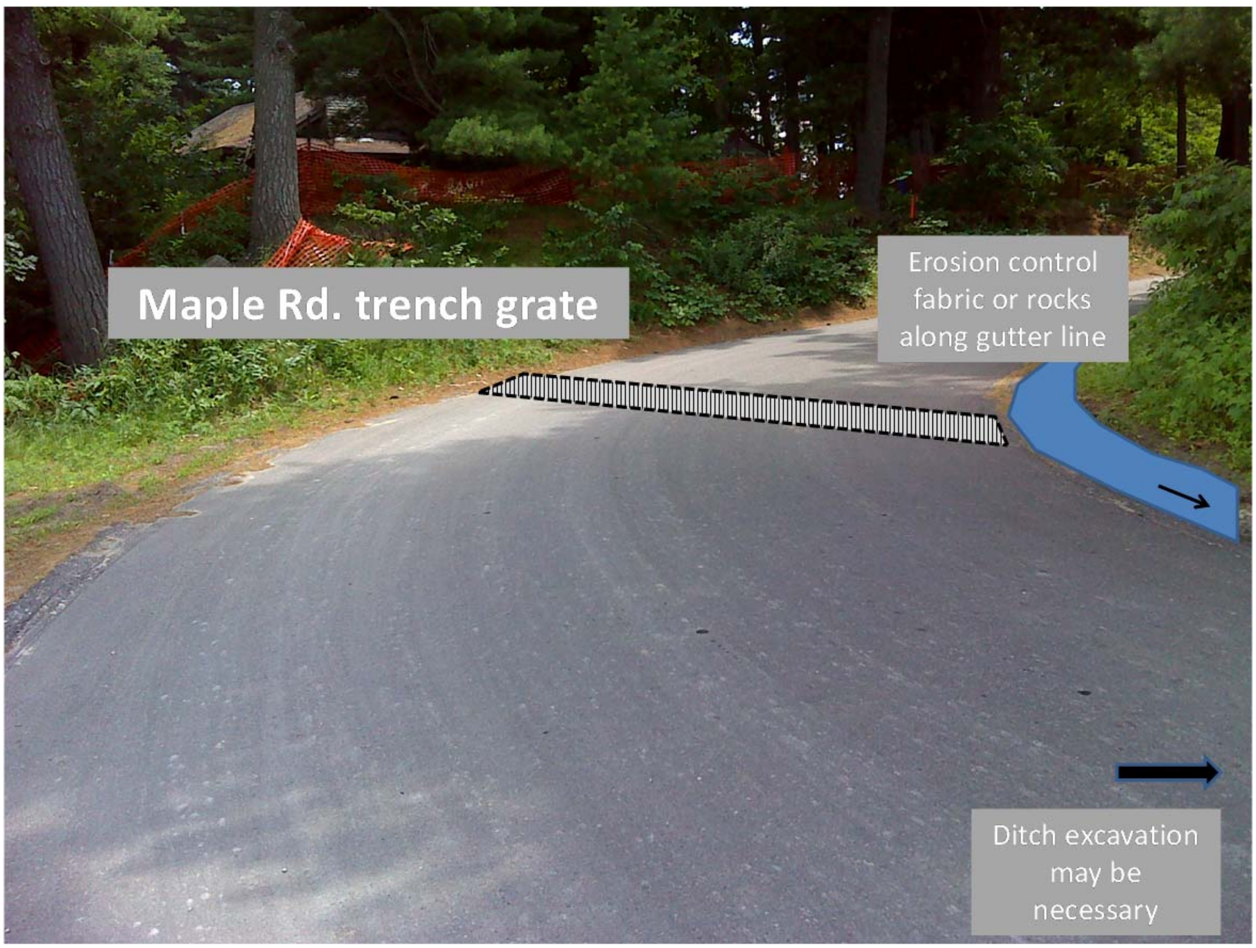
Project ID: CL-6 Maple Road Stormwater Diversion

Drainage Area – 1.4 acres

Location – Maple Road just south of intersection with Lakeshore Dr.

Property Ownership – City of East Bethel if within road right-of-way. May need support of landowner(s) if project will encroach onto private property

Description – Stormwater runoff from residential properties along the western side of Maple Road is currently directed straight into Coon Lake. A stormwater diversion is proposed which will collect stormwater from along the roadway and divert it into the ditches along Lakeshore Dr. A trench grate can be installed along the roadway to collect flow that has not already been diverted to the gutter line. To accommodate this increase in stormflow, the ditch on the western side of Maple Road should be excavated to achieve one ft of average storage depth (if necessary). Inlets from the road side to the ditch should also be reinforced to inhibit erosion that may be occurring from high flows. This can be accomplished with either an erosion control blanket or with rocks. With these enhancements, catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.



Maple Road Stormwater Diversion

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	20	linear-ft				
	TP (lb/yr)	0.8	1.3%				
	TSS (lb/yr)	240	1.5%				
	Volume (ac-ft/yr)	0.6	1.4%				
Cost	Administration & Promotion Costs*	$2,190					
	Design & Construction Costs**	$12,300					
	Total Estimated Project Cost (2014)	**$14,490**					
	Annual O&M***	$365					
Efficiency	30-yr Average Cost/lb-TP	**$1,060**					
	30-yr Average Cost/1,000lb-TSS	**$3,533**					
	30-yr Average Cost/ac-ft Vol.	**$1,413**					

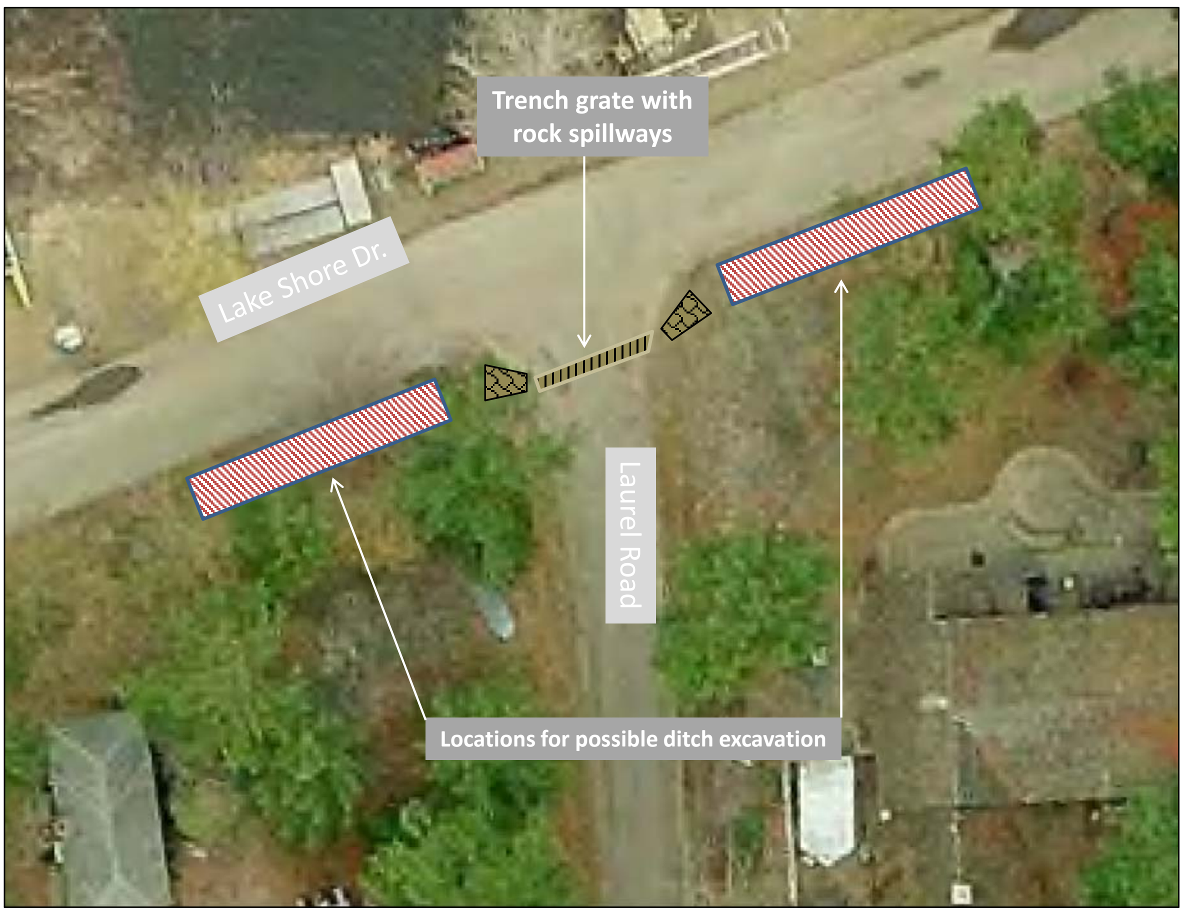
* 30 hours at $73/hour

** ($400/linear-ft * 20 ft. wide road for grate) + ($4,300 for ditch excavation and erosion control)

*** 5 hours at $73/hour for routine maintenance

Project ID: CL-6 Laurel Road Stormwater Diversion

Drainage Area – 2.1 acres (combined from both sides of the street)
Location – Laurel Road just south of intersection with Lakeshore Dr.
Property Ownership – City of East Bethel if within road right-of-way. May need support of landowner(s) if project will encroach onto private property
Description – Stormwater runoff from residential properties along Laurel Road is currently directed straight into Coon Lake. A stormwater diversion is proposed which will collect stormwater from along the roadway and divert it into the ditches along Lakeshore Dr. A trench grate can be installed along the roadway to collect flow that has not already been diverted to the gutter line. To accommodate this increase in stormflow, the ditch on either side of Laurel Road should be excavated to achieve one ft of average storage depth (if necessary). Inlets from the road side to the ditch should also be reinforced to inhibit erosion that may be occurring from high flows. This can be accomplished with either an erosion control blanket or with rocks. With these enhancements, catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.



Laurel Road Stormwater Diversion

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	20	linear-ft				
	TP (lb/yr)	0.9	1.4%				
	TSS (lb/yr)	295	1.9%				
	Volume (ac-ft/yr)	0.7	1.6%				
Cost	Administration & Promotion Costs*	$2,190					
	Design & Construction Costs**	$12,300					
	Total Estimated Project Cost (2014)	**$14,490**					
	Annual O&M***	$365					
Efficiency	30-yr Average Cost/lb-TP	**$942**					
	30-yr Average Cost/1,000lb-TSS	**$2,875**					
	30-yr Average Cost/ac-ft Vol.	**$1,211**					

* 30 hours at $73/hour

** ($400/linear-ft * 20 ft. wide road for grate) + ($4,300 for ditch excavation and erosion control)

*** 5 hours at $73/hour for routine maintenance

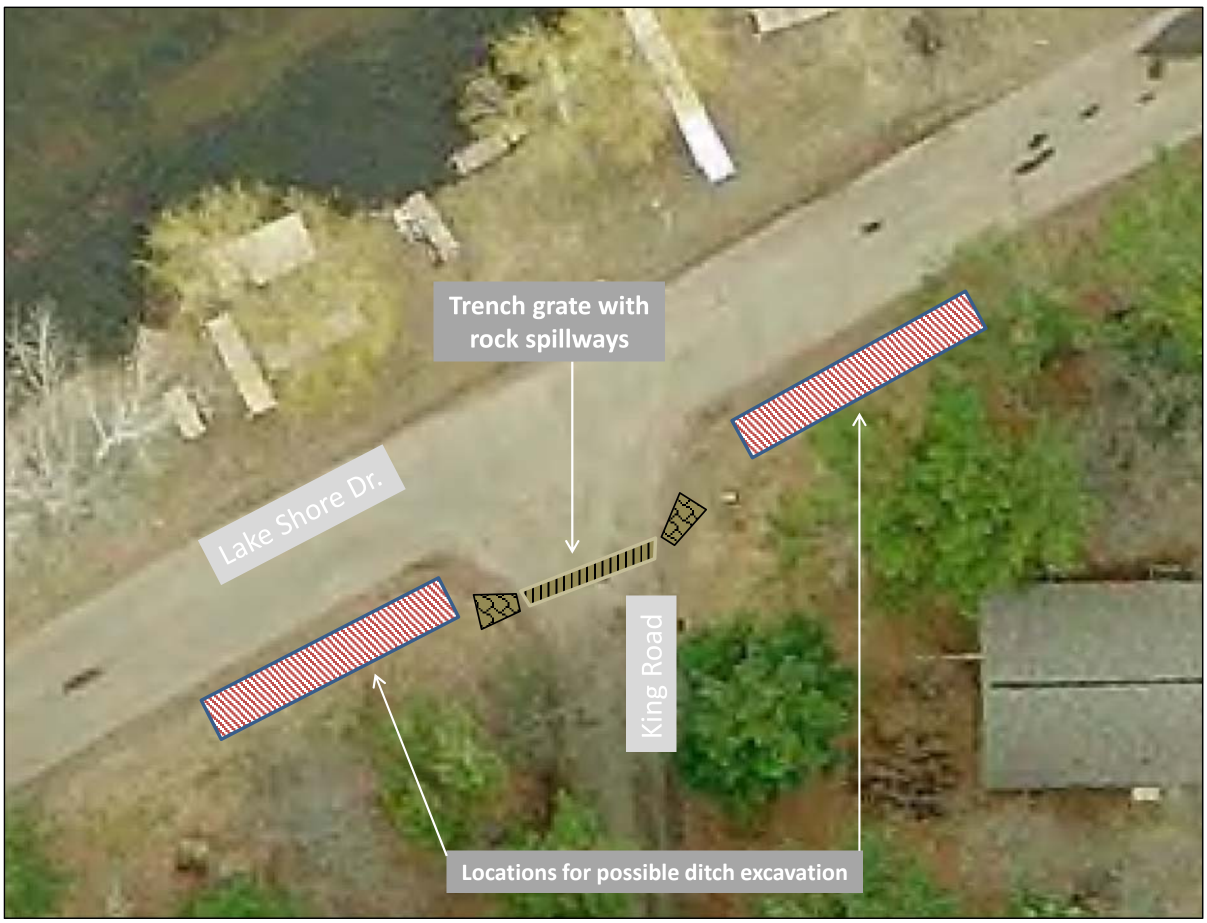
Project ID: CL-6 King Road Stormwater Diversion

Drainage Area – 1.9 acres (combined from both sides of the street)

Location – King Road just south of intersection with Lakeshore Dr.

Property Ownership – City of East Bethel if within road right-of-way. May need support of landowner(s) if project will encroach onto private property

Description – Stormwater runoff from residential properties along King Road is currently directed straight into Coon Lake. A stormwater diversion is proposed which will collect stormwater from along the roadway and divert it into the ditches along Lakeshore Dr. A trench grate can be installed along the roadway to collect flow that has not already been diverted to the gutter line. To accommodate this increase in stormflow, the ditch on either side of King Road should be excavated to achieve one ft of average storage depth (if necessary). Inlets from the road side and trench grate to the ditch should also be reinforced to inhibit erosion that may be occurring from high flows. This can be accomplished with either an erosion control blanket or with rocks. With these enhancements, catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.



King Road Stormwater Diversion

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	20	linear-ft				
	TP (lb/yr)	0.9	1.4%				
	TSS (lb/yr)	290	1.8%				
	Volume (ac-ft/yr)	0.7	1.6%				
Cost	Administration & Promotion Costs*	$2,190					
	Design & Construction Costs**	$12,300					
	Total Estimated Project Cost (2014)	**$14,490**					
	Annual O&M***	$365					
Efficiency	30-yr Average Cost/lb-TP	**$942**					
	30-yr Average Cost/1,000lb-TSS	**$2,924**					
	30-yr Average Cost/ac-ft Vol.	**$1,211**					

* 30 hours at $73/hour

** ($400/linear-ft * 20 ft. wide road for grate) + ($4,300 for ditch excavation and erosion control)

*** 5 hours at $73/hour for routine maintenance

Project ID: CL-6 Lincoln Dr. Structural Stabilization

Drainage Area – 3.3 acres
Location – Lincoln Dr. west of Lake Shore Dr.
Property Ownership – Coon Lake Beach Community
Description – The boat launch at the corner of Lincoln Dr. and Lakeshore Dr. is currently failing and eroding sediment and phosphorus into the lake due to large stormwater runoff velocities along Lincoln Dr. Erosion is also occurring between the end of the curb along Lincoln Dr. and the top of the boat launch. This erosion removed the grass turf, which has since been protected with erosion fabric. The proposed project will replace the sand and rock currently on the launch with large aggregate and concrete planks. The aggregate rocks, between 1.5 and 3 in. in diameter, should extend from the launch to the end of the gutter line to reduce the erosive capacity of water flowing down the gutter line. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table. The values listed in the table represent only the pollutant reduction from stabilizing the launch and eliminating erosion at the site. No treatment is provided from this project to stormwater generated upstream of the launch.

Boat Launch Structural Stabilization

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	530	sq-ft				
	TP (lb/yr)	0.4	0.6%				
	TSS (lb/yr)	420	2.6%				
	Volume (ac-ft/yr)	0.0	0.0%				
Cost	Administration & Promotion Costs*	$2,555					
	Design & Construction Costs**	$11,964					
	Total Estimated Project Cost (2014)	**$14,519**					
	Annual O&M***	$75					
Efficiency	30-yr Average Cost/lb-TP	**$1,397**					
	30-yr Average Cost/1,000lb-TSS	**$1,331**					
	30-yr Average Cost/ac-ft Vol.	**N/A**					

* 35 hours at $73/hour

** $5,464 for materials and $6,500 for contracted labor

*** 8 hours at $73/hour for routine maintenance

Project ID: CL-6 Forest Road Structural Stabilization

Drainage Area – 2.2 acres
Location – Lakeshore Dr. at intersection with Forest Road
Property Ownership – Coon Lake Beach Community
Description – The boat launch at the corner of Lakeshore Dr. and Forest Road is currently failing and eroding sediment and phosphorus into the lake due to large stormwater runoff velocities along Forest Road. The proposed project will replace the sand and rock currently on the launch with large aggregate (1.5-3 in. diameter rock) and concrete planks. A berm may also be recommended at the top of the launch to reduce flow velocity and direct water to turf where sediment settling and infiltration may occur. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table. The values listed in the table represent only the pollutant reduction from stabilizing the launch and eliminating erosion at the site. No treatment is provided from this project to stormwater generated upstream of the launch.

Boat Launch Structural Stabilization

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1					
	Total Size of BMPs	450	sq-ft				
	TP (lb/yr)	0.8	1.3%				
	TSS (lb/yr)	756	4.8%				
	Volume (ac-ft/yr)	0.0	0.0%				
Cost	Administration & Promotion Costs*	$2,555					
	Design & Construction Costs**	$8,370					
	Total Estimated Project Cost (2014)	**$10,925**					
	Annual O&M***	$75					
Efficiency	30-yr Average Cost/lb-TP	**$549**					
	30-yr Average Cost/1,000lb-TSS	**$581**					
	30-yr Average Cost/ac-ft Vol.	**N/A**					

* 35 hours at $73/hour

** $3,370 for materials and $5,000 for contracted labor

*** 8 hours at $73/hour for routine maintenance

Retrofit Ranking

The tables on the following pages summarize potential projects. Potential projects are organized from most cost effective to least, based on cost per pound of TP removed. Installation of projects in series will result in lower total treatment than the simple sum of treatment across the individual projects due to treatment train effects. Reported treatment levels are dependent upon optimal siting and sizing. More detail about each project can be found in the *Catchment Profile* pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in the tables on the next pages.

In addition to the projects proposed in the table, it is recommended that these cultural practices be continued and, where necessary, increased:

1) Street sweeping conducted at least once per year by the Cities of East Bethel and Ham Lake. This practice removes an estimated 29 lb-TP/yr and 12,567 lb-TSS/yr. This annual reduction is more than any project proposed in this report. Unlike many stormwater BMPs, street sweeping spans the entire subwatershed and is oftentimes the only form of treatment in built-out neighborhoods where other forms of stormwater treatment are not feasible. This practice should be continued and, if possible, increased in frequency when city staff time and/or budget allows.
2) Curly-leaf Pondweed (CLP) and Eurasion Watermilfoil treatment. Early treatment of each, specifically CLP, reduces the amount of vegetation to senesce (or die-off) in mid-summer. Senescing CLP can be a large source of biologically-available phosphorus within waterbodies and can increase the likelihood of algal blooms. The East Bay of Coon Lake has been treated for CLP since 2009. Since 2010, average annual TP concentrations in the East Bay have steadily declined and have been lower than the 29-year historical average in each year. Although no data exists to assert correlation between these events, it is plausible CLP treatment has had a positive influence on water quality.
3) Locating and replacing leaky septic systems along and near the lake. Leaky septic systems can be a significant source of phosphorus and coliform to the lake, depending upon the severity of the leak, proximity to the lake, and soil characteristics between the leaky septic system and the lake. Certainly any septic systems demonstrating a leak which may come into contact with the lake should be repaired or replaced immediately.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. TSS and volume reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Retrofit Type (refer to catchment profile pages for additional detail)	Catchment	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)
1	Lakeshore Restoration LR-87	CL-5	1	2.6	3,683	0.1	$14,180	$122	$232
2	Lakeshore Restoration LR-28	CL-4	1	1.0	1,440	0.1	$8,105	$81	$351
3	Lakeshore Restoration LR-63	CL-4	1	1.2	1,542	0.2	$15,155	$222	$606
4	Lakeshore Restoration LR-39	CL-4	1	0.7	941	0.1	$10,555	$78	$614
5	Lakeshore Restoration LR-50	CL-4	1	0.8	941	0.1	$11,780	$155	$684
6	Lakeshore Restoration LR-95	CL-5	1	1.9	2,204	0.4	$29,705	$513	$791
7	Lakeshore Restoration LR-103	CL-5	1	0.6	774	0.1	$11,330	$146	$872
8	Lakeshore Restoration LR-61	CL-4	1	0.9	1,093	0.1	$14,625	$176	$887
9	Residential Rain Gardens	CL-4	1, 2, 4	0.6-1.9	190-592	0.4-1.4	$10,110-$34,600	$225-$900	$936-$1,081
10	King Road Stormwater Diversion	CL-6	1	0.9	290	0.7	$14,490	$365	$942
11	Laurel Road Stormwater Diversion	CL-6	1	0.9	295	0.7	$14,490	$365	$942
12	Lakeshore Restoration LR-62	CL-4	1	3.1	3,831	0.5	$64,055	$900	$979
13	Lakeshore Restoration LR-19	CL-7	1	0.6	762	0.1	$13,130	$182	$1,032
14	Maple Road Stormwater Diversion	CL-6	1	0.8	240	0.6	$14,490	$365	$1,060
15	Forest Road Boat Launch Structural Stablization	CL-6	1	0.4	550	0.0	$10,925	$75	$1,098

* Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the same source area.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. TSS and volume reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Retrofit Type (refer to catchment profile pages for additional detail)	Catchment	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)
16	Lakeshore Restoration LR-93	CL-5	1	0.4	493	0.1	$9,830	$116	$1,108
17	Residential Rain Gardens	CL-5	1, 2	0.5-0.9	159-277	0.4-0.7	$10,110-$20,220	$225-$450	$1,124-$1,249
18	Lakeshore Restoration LR-37	CL-4	1	0.5	528	0.1	$12,155	$162	$1,134
19	Lakeshore Restoration LR-36	CL-4	1	0.3	358	0.1	$8,180	$83	$1,184
20	Lakeshore Restoration LR-9	CL-6	1	0.5	629	0.1	$12,680	$173	$1,190
21	Lakeshore Restoration LR-34	CL-4	1	0.4	396	0.1	$11,855	$156	$1,378
22	Lakeshore Restoration LR-27	CL-4	1	0.4	410	0.1	$11,930	$158	$1,388
23	Lincoln Dr. Boat Launch Structural Stablization	CL-6	1	0.4	583	0.0	$14,519	$75	$1,397
24	Community Center Rain Garden	CL-6	1	0.3-0.5	100-143	0.3-0.4	$10,110-$15,110	$225	$1,457-$1,873
25	Lakeshore Restoration LR-85	CL-5	1	0.5	459	0.2	$15,305	$225	$1,470
26	Lakeshore Restoration LR-83	CL-5	1	0.4	379	0.1	$13,430	$188	$1,588
27	Lakeshore Restoration LR-84	CL-5	1	0.4	385	0.2	$13,430	$188	$1,588
28	Lakeshore Restoration LR-68	CL-3	1	0.6	456	0.3	$19,505	$309	$1,599
29	Lakeshore Restoration LR-60	CL-4	1	0.5	504	0.1	$17,105	$261	$1,662
30	Lakeshore Restoration LR-65	CL-4	1	0.3	405	0.1	$13,055	$108	$1,811

* Pollution reduction benefits and costs cannot be summed with other projects in the same catchment because they are alternative options for treating the same source area.

References

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Appendix A:
Methods

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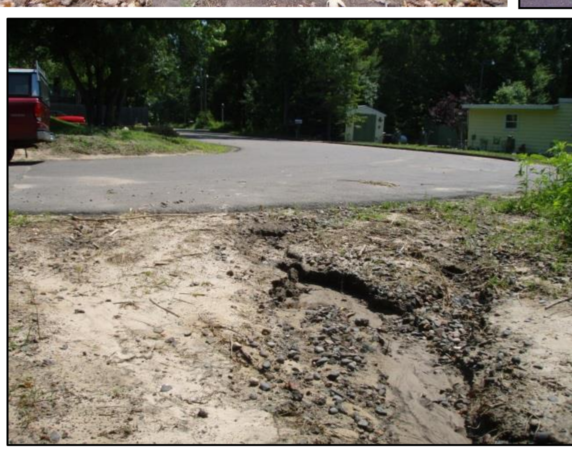
Methods

Why Is This Study Important?

The aim of this report is to locate opportunities where stormwater draining into Coon Lake can be better treated. Stormwater runoff from impervious surfaces like roadways, driveways, parking lots, and roofs, as well as pervious surfaces such as agricultural fields and residential lawns, can carry a variety of pollutants which can adversely affect water quality and conditions in Coon Lake. The effects of these pollutants can include algal blooms from excess nutrients, cloudy water from sediment, and unhealthy lake conditions due to bacteria and other pathogens. If drinking water is affected (as can often be the case with nitrogen leaching in rural wells) human health can be adversely impacted. While stormwater treatment to remove these pollutants is adequate in a few areas in the watershed, most areas were built before modern-day stormwater treatment technologies and requirements or have undersized or non-existent treatment capabilities. This study hopes to remedy this by locating retrofit opportunities.

Coon Lake was chosen for study as it is a high priority water body in Anoka County. It is the largest lake in the county, at 1,486 acres in surficial area, and is a popular destination for local anglers and recreation enthusiasts. In addition, annual phosphorus concentrations have been near to or slightly above the state water quality standard for phosphorus of 40 µg/L (three times since 2006, 2013 Anoka County Water Almanac). These high nutrient concentrations are a likely reason for an increase in algal blooms along shorelines in summer. For this reason total phosphorus (TP) was selected as the target pollutant of study for this analysis. Total suspended solids (TSS) and high flow volume were also investigated.

Examples of pollution from stormwater (top photos) and its resulting effects (bottom photos)



Stormwater Retrofit Analysis Methods

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, 2005, 2007). Locally relevant design considerations were also incorporated into the process (*Minnesota Stormwater Manual*).

Step 1: Retrofit Scoping

Retrofit 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 watershed management organization members to determine the issues in the subwatershed. 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 study area was all land that drains to Coon Lake. Included are areas of residential, agricultural, wetland, grassland, and forested land uses. The subwatershed was divided into seven catchments using a combination of existing subwatershed mapping data, stormwater infrastructure (where it exists), observed topography, and focused terrain analysis using GIS technologies.

The targeted pollutant for this study was TP, though TSS and volume were also modeled and reported. TP was chosen as the primary target pollutant because long term water quality monitoring has identified elevated levels in Coon Lake. TSS was also reported because many other pollutants, such as heavy metals, are transported by these particles. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and potential retrofit project considerations.

Step 2: Desktop Retrofit Analysis

The desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that don't need to be analyzed because of existing stormwater infrastructure 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, hydrology, soils, land use, parcel boundaries, high-resolution aerial photography and the stormwater drainage infrastructure (with invert elevations).

Desktop retrofit analysis features to look for and potential stormwater retrofit projects

Feature	Potential Retrofit Project
Existing Ponds	**Add storage and/or improve water quality by excavating pond bottom, modifying riser, raising embankment, and/or modifying flow routing.**
Open Space	**New regional treatment (pond, bioretention).**
Roadway Culverts	**Add wetland or extended detention water quality treatment upstream.**
Outfalls	**Split flows or add storage below outfalls if open space is available.**
Conveyance system	**Add or improve performance of existing swales, ditches and non-perennial streams.**
Large Impervious Areas (campuses, commercial, parking)	**Stormwater treatment on site or in nearby open spaces.**
Neighborhoods	**Utilize right of way, roadside ditches, curb-cut rain gardens, or filter systems before water enters storm drain network.**

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site and identify additional opportunities. During the investigation, the drainage area and 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.

General list of stormwater BMPs considered for each catchment/site

Stormwater Treatment Options for Retrofitting		
Area Treated	Best Management Practice	Potential Retrofit Project
5-500 acres	Extended Detention	12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.
	Wet Ponds	Permanent pool of standing water with new water displacing pooled water from previous event.
	Wetlands	Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.
0.1-5 acres	Bioretention	Use of native soil, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.
	Filtering	Filter runoff through engineered media and pass it through an under-drain. May consist of a combination of sand, soil, compost, peat, and iron.
	Infiltration	A trench or sump that is rock-filled with no outlet that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering infiltration area.
	Swales	A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.
	Other	On-site, source-disconnect practices such as rain-leader disconnect rain gardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells, or permeable pavements.

Step 4: Treatment Analysis/Cost Estimates

Sites most likely to effectively reduce pollutant loading to the lake and appear to have simple-to-moderate design, installation, and maintenance were chosen for a cost/benefit analysis. Estimated costs included design, installation, and maintenance annualized across a 30-year period. Estimated benefits included are pounds of TP and TSS removed, though projects were ranked only by cost per pound of TP removed annually.

Water Quality and Erosion Models

Two distinct water quality models were used in this analysis, WinSLAMM and SWAT. Each was chosen based on the specialized inputs and features that provide reliable, land use-specific estimates for pollutant loading under existing and proposed conditions. Two separate models were utilized as each is more applicable to either rural or urban landscapes.

WinSLAMM, or the Source Loading and Management Model for Windows, is a water quality model that is well-suited to evaluate runoff in urbanized settings. This model 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" that reflects the actual landscape being considered.

On the other hand, the Soil and Water Assessment Tool (SWAT) is a partially physically-based and partially empirically-based watershed model applied most often to rural settings (although recent software releases have increased the usability in urban environments). This model has additional land cover and soil inputs to reflect the highly varied landscapes across agrarian and undeveloped areas.

Drainage basins were delineated using the ArcView extension of SWAT (ArcSWAT). These basins were then aggregated into catchments to determine the dominant flow paths to Coon Lake. Catchments with greater than 0.5 household units per acre were considered "urban," and modeled with WinSLAMM. Catchments with less than 0.5 household units per acre were modeled with ArcSWAT.

Background Information and Input Parameters for ArcSWAT

Stormwater runoff generated in rural catchments was estimated using ArcSWAT, which combines hydrography, topography, soils, and land cover data in a GIS interface and determines runoff volume and pollutant loading based on these inputs. Beginning with a digital elevation model, ArcSWAT delineated basins in the Coon Lake watershed based on predefined threshold values for minimum basin size. To improve model efficiency, hydrologic response units (HRUs) were derived within each basin based on a unique combination of land cover and soil type. An area was computed for each HRU, as well as an average slope to deliver runoff directly to the basin's outlet. For example, a single 10 acre basin may be split into 20 HRUs, each with a specific land cover and soil type.

Digital elevation model (DEM) data was downloaded from the Minnesota Geospatial Information Office (MNGEO) webpage. To route overland flow under roadways and driveways, culvert locations were determined through desktop analysis and field surveys and "burned" into the landscape.

Land Cover data were provided by the US Geological Survey's National Land Cover Database (NLCD). We used the latest year in which an ArcSWAT look-up table was available: 2006. NLCD 2006 is a 16-class (in the contiguous 48 states) dataset that allowed for compromise between a large and well defined dataset (e.g. Minnesota Land Cover Classification System with >600 classes) and a smaller one which reduces computational time. Because of annual changes to crop coverage, such as rotations between corn and soybeans, all tilled agricultural fields were evaluated similarly. Soils data were provided by the Anoka County Digital Soil Survey and were characterized in ArcSWAT using the Soil Survey Geographic

GIS file sources and use in ArcSWAT modeling and desktop analysis

Dataset	Source	Purpose	Notes
Digital elevation model (DEM)	Minnesota Geologic Information Office (MNGEO)	Model input of topography	Horizontal resolution: meets or exceeds 0.6 m; Vertical resolution: meets or exceeds 0.1 m
Soils	United State Department of Agriculture (USDA) and the Nature Resources Conservation Service (NRCS) - Soils Survey Geographic Database (SSURGO)	Model input, determining BMP viability, locating hydric soils	
Land cover	National Land Cover Dataset (NLCD) 2006	Model input	
Parcel data	Anoka County	Display homeowner information	Downloaded May 2014
Streams	Minnesota Department of Natural Resources (DNR)	Model input (flow routing), map display	Public waters inventory, watercourse delineations
Lakes and wetlands	Minnesota Department of Natural Resources (DNR)	Map display	Public waters inventory, basin delineations
Aerial photography	Pictometry	Verify land cover information, map display	Photos taken during the summer of 2011
Municipal boundary	MNGEO	Map display	
Roads	The Lawrence Group, Minnesota Department of Transportation (MNDOT), Metropolitan Council	Map display, BMP description	
Culverts	Desktop analysis of DEM, field survey	Model input, BMP siting	

Database (SSURGO). Precipitation data were uploaded from the Weather Generator model within ArcSWAT based on historical readings from local climatic stations.

Infiltration and surface runoff were determined within SWAT using a modified version of the SCS curve number (CN) method. Erosion and sediment yield were estimated for each HRU using the Modified Universal Soil Loss Equation (MUSLE). ArcSWAT determined phosphorus transport and transformation using a host of processes in both mineral and organic form, which were summed to determine total phosphorus load.

ArcSWAT Model Calibration

To better correlate the ArcSWAT model with local conditions, each catchment model was calibrated based on local water quality monitoring data. Coon Lake is monitored multiple times each year for TP, TSS, and other parameters, but the streams and ditches that provide input to the lake, of which this analysis is focused, are rarely monitored. The most recent data dates back to 2001 and 2003 for Ditch 56 at its intersection with Viking Blvd. Although TP and TSS measurements were taken during these years, no flow data was acquired. Without reliable hydrologic data, the ArcSWAT model cannot be calibrated solely with water quality data.

Instead, calibration parameters derived from the Sunrise River Watershed SWAT model were used to calibrate the Coon Lake model (Almedinger and Ulrich, 2010). Coon Lake lies in the potmarked headwaters of the Sunrise River. The model developed by Almedinger and Ulrich (2010) was calibrated at multiple locations and along multiple branches of the Sunrise River. Notably, the most upstream monitoring point was along the South Branch of the Sunrise River at Highway 30 in the City of Wyoming. This branch drains Coon Lake, and topographic and hydrologic conditions vary little upstream. Calibration parameters developed by Almendinger and Ulrich (2010) and used in this analysis are listed in great detail in Appendix B of their paper.

To model the effect of reservoirs and wetlands within ArcSWAT, methodology proposed by Almedinger and Ulrich (2010) was employed to determine total ponding depth, area, and retention capacity for both TP and TSS. ArcHydro was utilized to determine the depressional storage area and volume from wetlands and lowland features in the landscape. The depressional storage within each subbasin of a catchment was aggregated across the catchment to determine an overall area and volume treated. ArcHydro is only able to recognize ponding capabilities above the existing water surface, so any permanent (and possibly seasonally permanent) ponding occurring in wetlands and ponds needs to be taken into account as well. To do this, an average 0.25 m depth was assumed across all depressions in the Coon Lake watershed. This depth seems low, but considering that many of these depressions are ephemeral ditches and backyard depressions which only retain water during and directly following storm events, this number is likely close when averaged across an entire catchment. These depressions were modeled within the landscape using the 'Pond' parameter dialog. Principal and emergency spillway area and volume were determined following empirical equations derived by Almedinger and Ulrich (2010):

$$\text{Principal Area} = 0.94 * (\text{ArcHydro Depression Area})$$

$$\text{Emergency Area} = 1.13 * (\text{ArcHydro Depression Area})$$

$$\text{Principal Volume} = 0.91 * (\text{ArcHydro Depression Volume})$$

$$\text{Emergency Volume} = 1.18 * (\text{ArcHydro Depression Volume})$$

In natural systems, sedimentation in waterbodies is controlled by factors including current velocity, wind speed, fetch, and shoreline vegetative coverage. Within ArcSWAT, sedimentation is controlled by an equilibrium sediment concentration, above which all sediment is presumed to fall out of suspension. This value was derived from Almedinger and Ulrich (2010) where D is the mean depth of the pond or reservoir in meters and NSED is the equilibrium sediment concentration in mg/L.

$$\text{NSED} = 100 * \text{D}^{-2}$$

Phosphorus retention generated by the pond or reservoir was determined using the phosphorus settling rate. This parameter was set at 0 m/year for wetlands/ponds and at 10 m/year for reservoirs.

Reservoirs included in the ArcSWAT model are summarized in the table below. Note that South Coon Lake was not modeled as a reservoir as it is directly connected with Coon Lake through a man-made channel.

Rural lakes modeled as reservoirs in ArcSWAT

Lake Name (if any)	Catchment	Area (acres)	Estimated Mean Depth (ft)
N/A	CL-1	12.2	8.0
Devil Lake	CL-1	68.8	8.0
Goose Lake	CL-1	25.0	8.0
Anderson Lake	CL-2	65.6	8.0

Following calibration, the ArcSWAT model was run for a seven year period, 2004-2010. The first two years of the model run were used to bring all conditions into equilibrium. Results from years 2006-2010 were analyzed to determine average annual loading of TP, TSS, and volume. Each reported value represents the 5-year average of these model runs.

ArcSWAT was utilized to determine pollutant loading in rural catchments but was not used to gauge BMP effectiveness as no structural stormwater BMPs were proposed in the upland catchments. Two lakeshore restorations were proposed in rural catchments, but these were modeled with another methodology described later in this section.

Background Information and Input Parameters for WinSLAMM

Volume and pollutant export from catchments with predominantly developed residential and commercial land uses were modeled with WinSLAMM. WinSLAMM is an empirically-based model using stormwater data from upper Midwest to determine load export and best management practice effectiveness. The user can simulate various stormwater treatment practices in her/her model landscape and compare results to existing (without the treatment practice) conditions. WinSLAMM uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.

The initial step was to create a "base" model which estimated 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, we delineated each land use in each catchment using geographic information systems (specifically, ArcMap), and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and accounting for local soil types. This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment.

Once the "base" model was established, an "existing conditions" model was created by incorporating any existing stormwater treatment practices in each catchment. This included street cleaning performed in the residential streets surrounding the lake as well as the constructed grass swale and weir along Front Blvd. west of the lake.

Finally, each proposed stormwater treatment practice was added to the "existing conditions" model and pollutant reductions were generated. 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 we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing. Also, all urban catchments modeled with WinSLAMM discharge stormwater runoff directly to the lake. Therefore, reductions from proposed BMPs directly benefit the lake.

WinSLAMM model inputs

Parameter	File/Method
Land use acreage	ArcMap
Precipitation/Temperature Data	Minneapolis 1959 – the rainfall year that best approximates a typical year.
Winter season	Included in model. Winter dates are 11-4 to 3-13.
Pollutant probability distribution	WI_GEO01.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.

Other BMP Modeling

Stormwater BMPs proposed in this analysis include rain gardens, stormwater diversions, lakeshore restorations, and boat launch stabilizations (listed in the table on the following page). Rain gardens and stormwater diversions were evaluated using the water quality model WinSLAMM. Lakeshore restorations and the structural stabilization of boat launches were each evaluated using other methods.

Stormwater BMPs investigated and modeled in this analysis.

Project Type	Code	Description	Project Life	Modeling Method
Residential Rain Gardens	RG	Small depressions in residential landscapes designed to capture and treat runoff through infiltration and/or filtration.	20	Win SLAMM
Lakeshore Restorations	LR	Stabilization of active lakeshore erosion through structural and bioengineering techniques.	10	BWSR Pollution Reduction Estimator
Stormwater Diversions	SD	Divert water from impervious surface to depression which will infiltrate water and retain pollutants	30	WinSLAMM
Structrural Stabilization of Boat Launch	SS	Due to high upstream stormwater flows, erosion along launches is supplying excess TSS and TP to the lake	20	BWSR Pollution Reduction Estimator

Lakeshore restoration locations were determined following completion of an inventory of all active erosion sites along the entire shoreline of Coon Lake. Instances of erosion were classified according to severity. Erosion severity determinations and soil loss calculations were estimated utilizing the Wisconsin NRCS direct volume method recession rate classifications. Recession rate descriptions were altered slightly to better describe observed field conditions and are shown in the table on the following page.

Phosphorus reduction estimates were based upon the Board of Water and Soil Resources Pollution Reduction Estimator, which estimates phosphorus loading based upon a correlation between voided sediment volume and type with soil density averages and phosphorus concentrations.

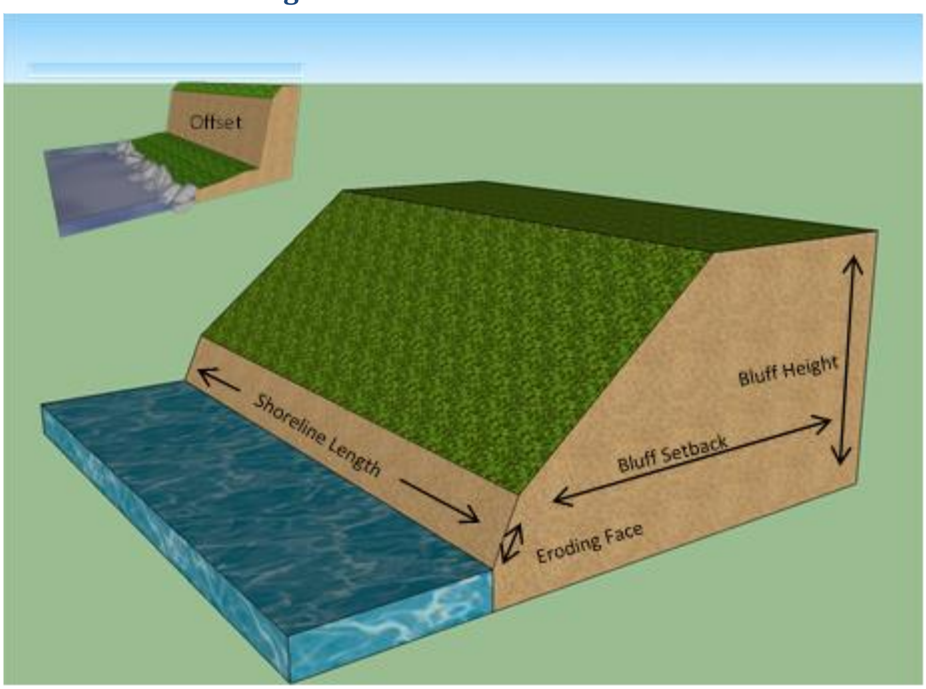
Soil losses associated with lakeshore restoration projects can be estimated using the equation:

$$\left(\text{Lakeshore Soil Loss}\left[\frac{\text{lbs}}{\text{yr}}\right]\right) = \left\{\left(\begin{matrix}\text{Eroding}\\ \text{Face[ft]}\end{matrix}\right) * \left(\begin{matrix}\text{Recession}\\ \text{Rate}\left[\frac{\text{ft}}{\text{yr}}\right]\end{matrix}\right) * \left(\begin{matrix}\text{Shoreline}\\ \text{Length [ft]}\end{matrix}\right) * \left(\begin{matrix}\text{Soil Bulk}\\ \text{Density}\left[\frac{\text{lbs}}{\text{ft}^3}\right]\end{matrix}\right)\right\}$$

Lakeshore recession rate classifications

Severity	Lateral Recession Rate (ft/yr)	Description
Offset	<0.01	Erosion offset from the shoreline. Erosion does not appear to be entering water body but bank failure, bluff slumps, and/or seepage visible.
Slight	0.01-0.059	Some bare shore, but active erosion is minimal. Minor or no vegetative overhang. No exposed tree roots.
Moderate	0.06-0.029	Shore is predominantly bare, with some undercutting and vegetative overhang. Some exposed tree roots, but no slumps or slips.
Severe	0.3-0.5	Shore is bare, with vertical slope and/or severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails.
Very Severe	0.5+	Shore is bare, with washouts, vertical slopes, and severe vegetative overhang. Many fallen trees eroding out and changes in cultural features as above. Multiple types of erosion present.

Schematic illustrating lakeshore erosion terms



For the purpose of this analysis the following assumptions were made:

- Soils along the lakeshore were assumed to be sand, the most prevalent type in the area
- Soils had a bulk density of 100 lbs/ft^3.
- Soils had a TP concentration of 1 lb for every 1,481 lbs of sediment (per page A5 of BWSR manual, BWSR calculator has incorrect correction factor)
- Sediment delivery rates were 100% due to the proximity to the lake

Boat launch stabilizations were assessed in the field to determine the active area of erosion. Total sediment loss over this area was estimated based on the equation:

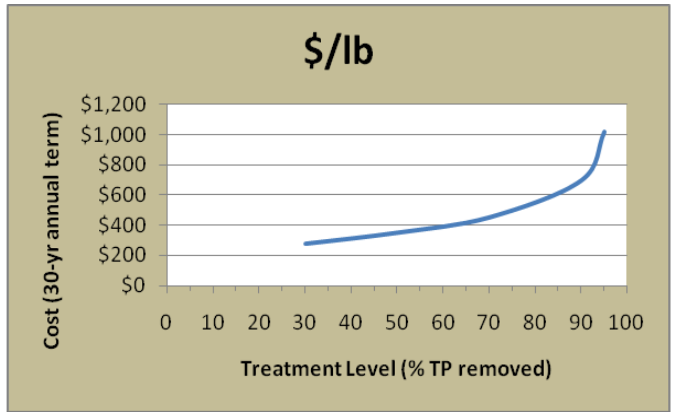
$$\left(\text{Soil Erosion}\left[\frac{\text{lbs}}{\text{yr}}\right]\right) = \left\{(\text{Eroding Area[ft]}) * \left(\text{Recession Rate }\left[\frac{\text{ft}}{\text{yr}}\right]\right) * \left(\text{Soil Bulk Density}\left[\frac{\text{lbs}}{\text{ft}^3}\right]\right)\right\}$$

where the recession rate was assumed to be 0.5 inches/yr, or 0.0417 ft/yr, for proposed projects on Lincoln Dr. and Forest Road. Soil bulk density was assumed to be 100 lbs/ft^3, similar to other lakeshore sands. Phosphorus loss from these sites was also determined from the Board of Water and Soil Resources Pollution Reduction Estimator. This value was assumed to be 1 lb of phosphorus for every 1,481 lbs of sediment. Other pollutants transported from upstream locations to this site will receive no treatment. This project will only reduce erosion at this site and will not treat upstream pollutants. This is unlike other projects including rain gardens, stormwater diversions, and lakeshore restorations (assuming a grass buffer is installed), which each treat pollutants generated on site and upstream of the practice.

Cost Estimates

All estimates were developed using 2014 dollars. Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. 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.

The costs associated with several different pollution reduction levels were calculated. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, stakeholders can best choose the project sizing that meets their goals.



Step 5: Evaluation and Ranking

The cost per pound of phosphorus treated was calculated for each potential retrofit project. Only projects that seemed realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances, or public opinion.

Appendix B:
How to Read Catchment Profiles

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Catchment Profiles and How to Read Them

The analysis contains pages referred to as "Catchment Profiles." These profiles provide the most important details of this report, including:

- Summary of existing conditions, including existing stormwater infrastructure, and estimated pollutant export to Coon Lake
- Map of the catchment
- Recommended stormwater retrofits, pollutant reductions, and costs.

Following all of the catchment profiles (also in the executive summary) is a summary table that ranks all projects in all catchments by cost effectiveness.

To save space and avoid being repetitive, explanations of the catchment profiles are provided below. We strongly recommend reviewing this section before moving forward in the report.

The analyses of each catchment are broken into "base, existing, and proposed" conditions. They are defined as follows:

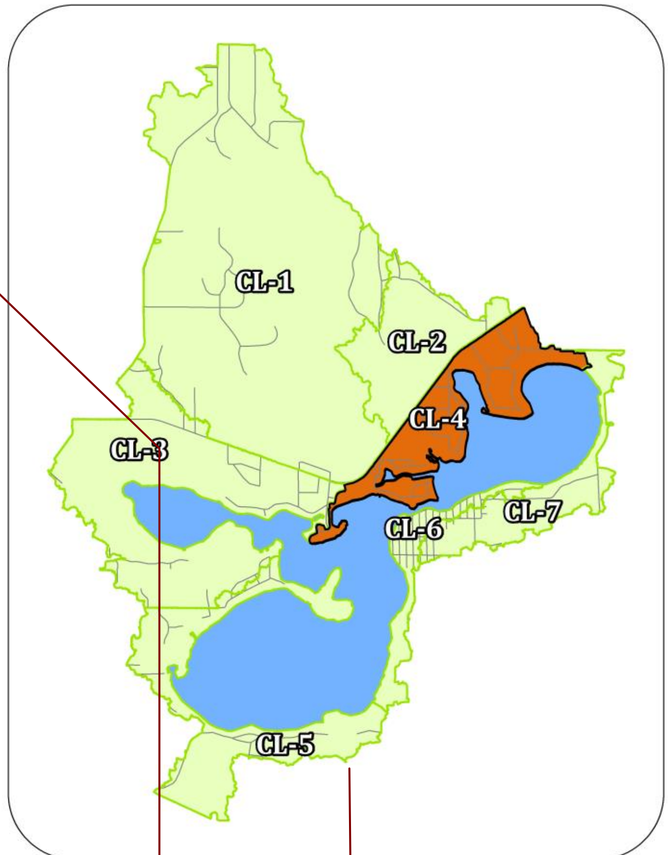
Base conditions -	Volume and pollutant loadings from the catchment landscape without any stormwater practices.
Existing conditions -	Volume and pollutant loadings after already-existing stormwater practices are taken into account.
Proposed conditions -	Volume and pollutant loadings after proposed stormwater retrofits.

The example catchment profile on the following pages explains important features of each profile.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment A

Existing Catchment Summary	
Acres	58.90
Dominant Land Cover	Residential
Parcels	237
TP (lb/yr)	131.2
TSS (lb/yr)	36,410
Volume (acre-feet/yr)	95.2



CATCHMENT DESCRIPTION

Example Catchment is primarily comprised of medium-density, single-family residential development…

EXISTING STORMWATER TREATMENT

Existing stormwater treatment practices within Example Catchment consist of street cleaning with a mechanical sweeper in the spring and fall and a network of stormwater treatment ponds…

Catchment ID banner.

Volume and pollutants generated from this catchment under existing conditions, and excludes existing network-wide treatment practices

Catchment locator map.

HOW TO READ THE CATCHMENT PROFILES

Catchment-level analysis of existing conditions.

Catchment Specific Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Grass swale, street sweeping			
	TP (lb/yr)	140.5	11.4	8%	**129.1**
	TSS (lb/yr)	39,928	4,769.0	12%	**35,159**
	Volume (acre-feet/yr)	90.5	0.9	1%	**89.6**

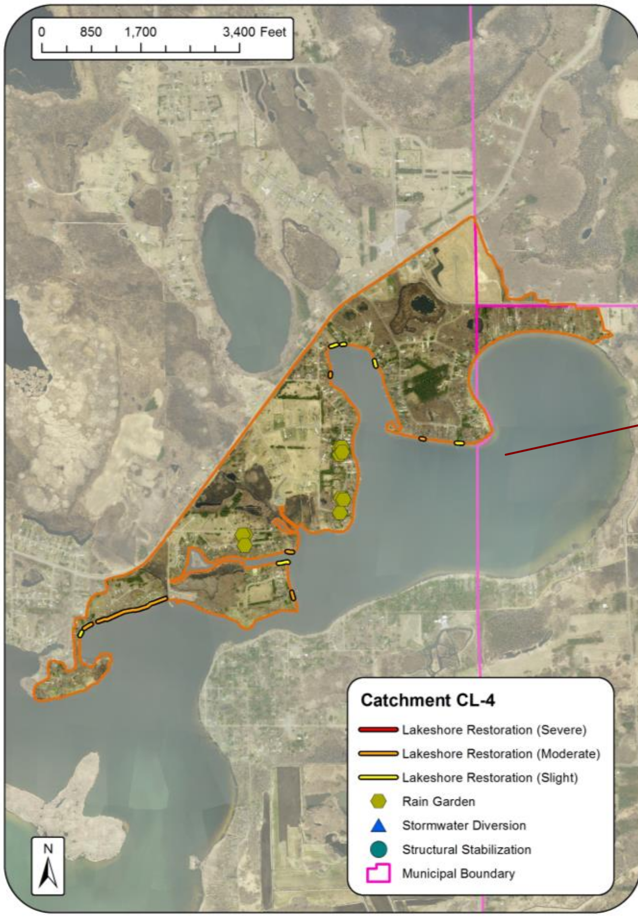
Volume of water and pounds of pollutants generated from the catchment without any stormwater management practices (base conditions).

Pollutants and volume removed by existing stormwater management practices (existing conditions).

Pollutants and volume exiting the catchment after existing practices.

Percent reductions by existing practices.

HOW TO READ THE CATCHMENT PROFILES



Map shows catchment boundaries, stormwater infrastructure (where available), and the locations of proposed stormwater retrofits.

Proposed stormwater retrofits. The project ID corresponds to this project's catchment and project type.

RETROFIT RECOMMENDATIONS

Project ID: CL-4 Residential Rain Gardens

Drainage Area – 18.8 acres
Location – Central portion of catchment CL-4 along Front Blvd., Hupp St., and Channel Lane
Property Ownership – Private
Description – Most stormwater pollutants generated in this catchment derive from the residential properties along the lake. Little space is available for large retrofits which can treat multiple properties along the lakeshore. However, there are some opportunities to install curb-cut rain gardens (see Appendix C for design options). Up to ten ideal rain garden locations were identified (see map on the previous page). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical landowner participation rates, scenarios with 1, 2 and 4 rain gardens were analyzed to treat the residential land use. Catchment-wide volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Catchment Specific Cost/Benefit Analysis

Volume or pollutant removal this project will achieve.

Three "levels" of this project are compared: 1, 2, or 4 rain gardens, for example.

Cumulative pollutant removal achieved by this project and already-existing practices.

Curb-Cut Rain Gardens

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		2		4	
	Total Size of BMPs	250	sq-ft	500	sq-ft	1,000	sq-ft
	TP (lb/yr)	0.6	0.5%	1.1	0.9%	1.9	1.5%
	TSS (lb/yr)	190	0.6%	335	1.0%	592	1.7%
	Volume (acre-feet/yr)	0.4	0.4%	0.8	0.9%	1.4	1.6%
Cost	Administration & Promotion Costs*	$4,234		$8,468		$11,096	
	Design & Construction Costs**	5,876		11,752		23,504	
	Total Estimated Project Cost (2014)	**$10,110**		**$20,220**		**$34,600**	
	Annual O&M***	$225		$450		$900	
Efficiency	30-yr Average Cost/lb-TP	**$937**		**$1,022**		**$1,081**	
	30-yr Average Cost/1,000lb-TSS	**$2,958**		**$3,355**		**$3,468**	
	30-yr Average Cost/ac-ft Vol.	**$1,405**		**$1,405**		**$1,467**	

*For 1-2 gardens: 58 hours/BMP at $73/hour

*For 4 gardens: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**($20/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150 for 10-year rehabilitation) + ($75 for routine maintenance)

Notes on how costs were determined.

Project installation cost estimation.

Cost effectiveness at phosphorus removal. The project cost is divided by phosphorus removal in pounds (30 yrs). Includes operations and maintenance (O&M) over the project life (30 years unless otherwise noted).

Cost effectiveness at suspended solids removal. The project cost is divided by suspended solids removal in pounds (30 yrs). Includes operations and maintenance (O&M) over the project life (30 years unless otherwise noted).

Compare cost effectiveness of various project "levels" in these rows for phosphorus or suspended solids removal. Compare cost effectiveness numbers between projects to determine the best value.

Appendix C:
Rain Garden Design Concepts

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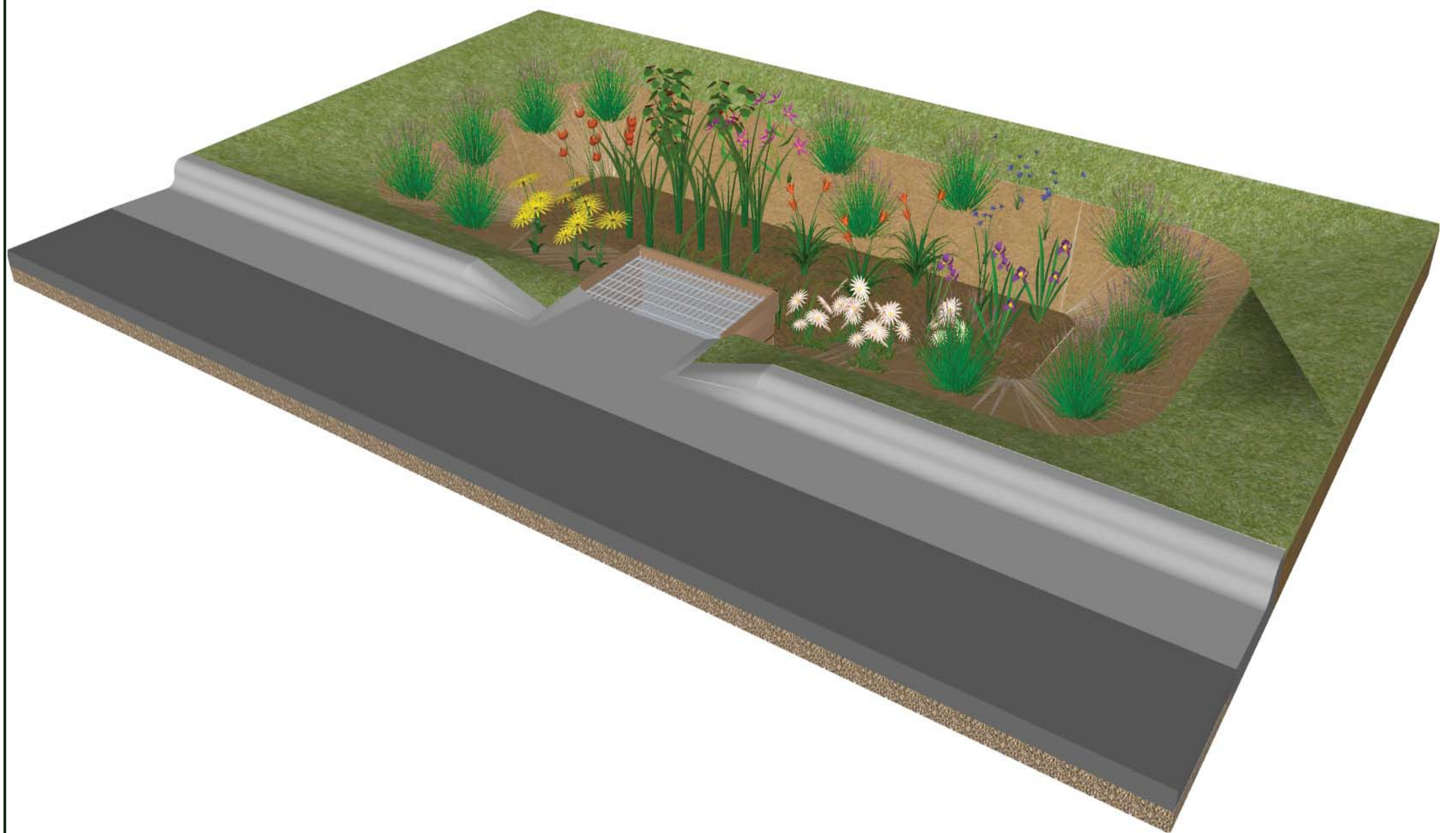
ANOKA COUNTY CURB-CUT RAINGARDENS



Drawing rainwater from the street gutter reduces runoff and pollutants to local water bodies

Prepared by the Anoka Conservation District in association with
the Metropolitan Conservation Districts

URBAN RAINWATER: SLOW IT DOWN AND SOAK IT UP

Under natural conditions the majority of rainwater falling on Anoka County would infiltrate the soil surface to be absorbed by plants or percolate more deeply into the soil to feed groundwater recharge and provide steady base-flow to streams and rivers. As land development has expanded more and more land is covered with impervious surfaces such as roads, parking lots and buildings. This conversion from native vegetation to impervious structure has greatly altered the hydrologic cycle and surface water ecology by greatly increasing runoff rates and effectively washing nutrient laden sediments and other pollutants into local surface waters. Treating and infiltrating urban rainwater as close to the point where it falls as possible is recognized as a vital and effective method for augmenting groundwater resources and reducing surface water quality impacts.

In dense residential ***sub-watersheds*** there is limited suitable public land on which to treat and infiltrate rainwater. In these situations utilizing private land and easements along roadways for treatment becomes an important tool for improving water quality. The curb and gutter system that channels rainwater quickly from your neighborhood can be disconnected with a ***curb-cut*** that directs rainwater from the street into a depressed ***raingarden***. This allows rainwater falling within the catchment area of the raingarden to return to the natural hydrologic cycle of ***infiltration*** and ***evapotranspiration***, effectively reducing downstream flooding, erosion and ***non-point source pollution***. An individual curb-cut raingarden may only mitigate for a small portion of urban runoff, however the treating the rainwater runoff close to its source is an essential strategy in hydrologic restoration and cumulatively curb-cut gardens can actualize significant benefits within an urbanized ***sub-watershed***.

The Anoka Conservation District has designed a set of curb-cut raingardens that can be applied to the physical conditions of your property and to your preference of garden shapes and plant selections. Each garden is designed to provide a water storage capacity of 100 cubic feet. Anoka Conservation

Photo by Rusty Schmidt

District has also designed a modular pretreatment box to be placed at the raingarden inlet to capture sediment and debris prior to water entering the garden. This pretreatment box is a vital component to the longevity and functionality of your raingarden.

Please utilize the key on page 4 to determine the basic design needs of your property and continue to the designated page to select your choice of plant palettes. Plant images are shown of pages 20 and 21.

curb-cut: A section of curb and gutter that has been reconstructed to convey stormwater into a filter strip, rain garden, or other stormwater management strategy.

evapotranspiration: The transfer of liquid water from the earth's surface to atmospheric water vapor as result of transpiration by plants and evaporation by solar energy and diffusion. Evapotranspiration can constitute a significant water "loss" from a watershed.

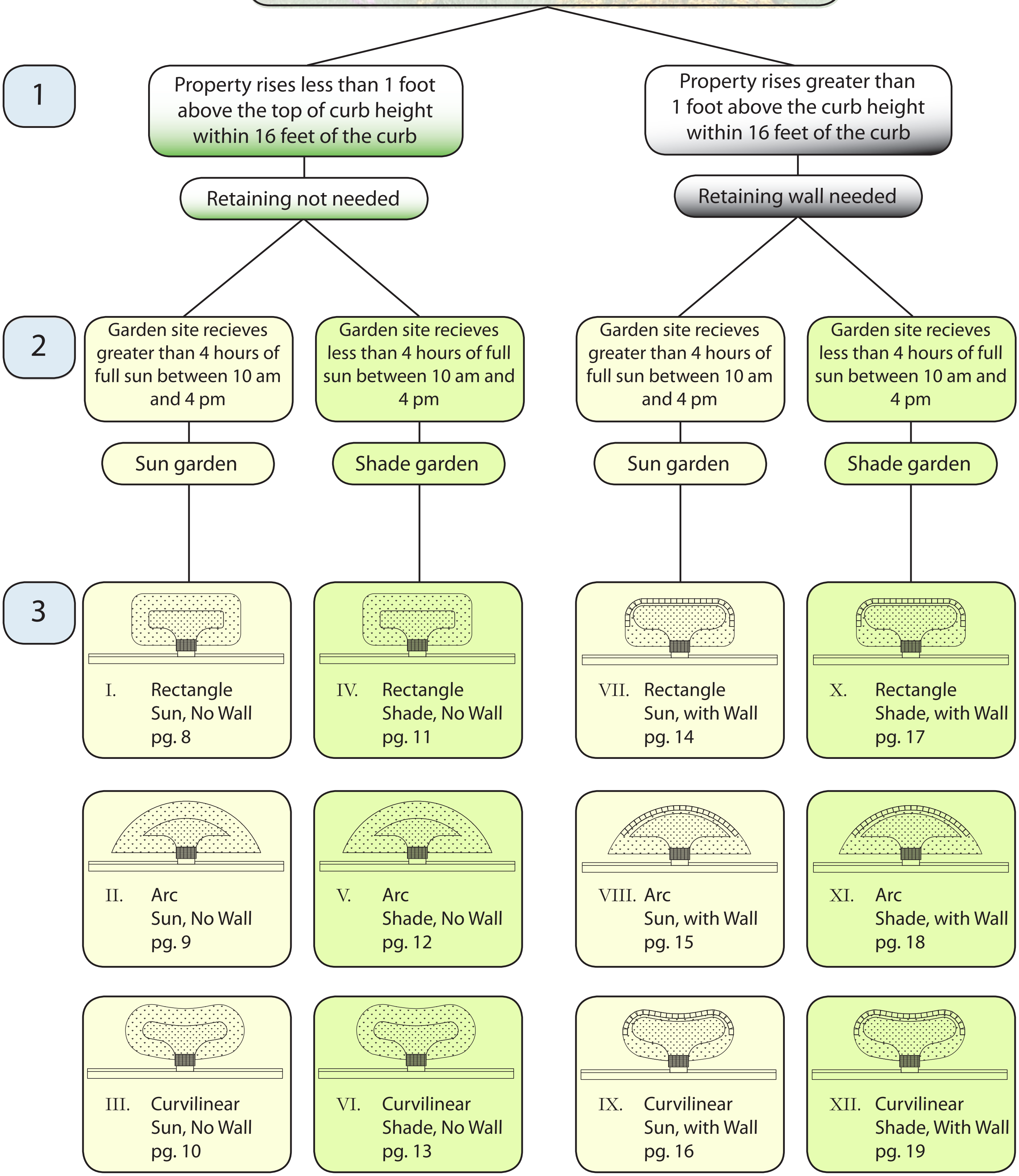
infiltration: Water moving through a permeable soil surface by the force of gravity and soil capillary action. The rate of infiltration is highly dependent on soil type. Infiltration rates within the Anoka Sand Plain are generally very high.

non-point source pollution: Rainwater runoff that has accumulated pollutant loads (nutrients, sediments, petrochemicals etc.) over a large dispersed area. As opposed to point source pollution that has a defined single source.

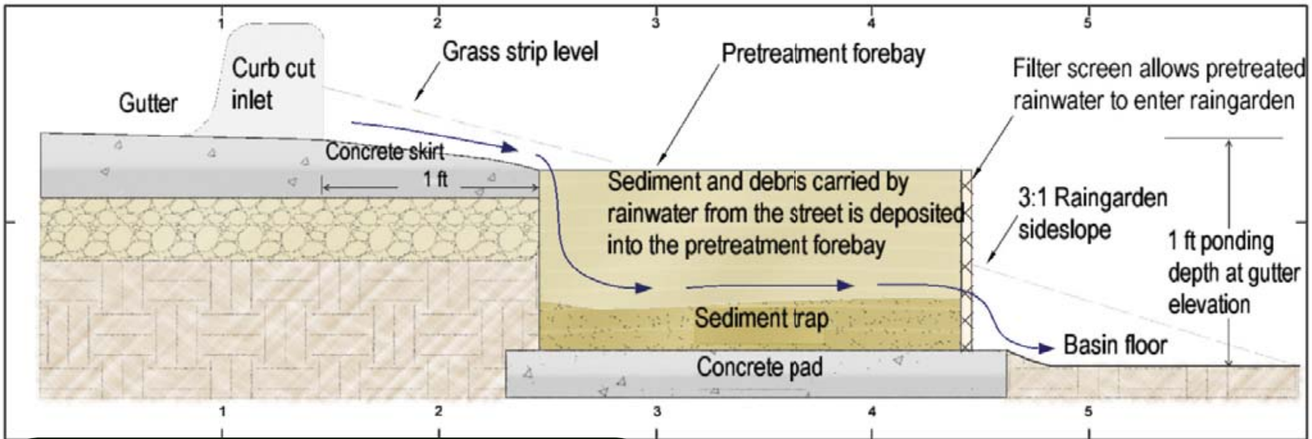
raingarden: A landscaped garden in a shallow depression that receives rainwater runoff from nearby impervious surfaces such as roofs, parking lots or streets. The purpose of a raingarden is to reduce peak runoff flows, increase groundwater recharge and improve water quality in our lakes, streams and wetlands. Peak flow reduction is achieved by temporarily staging runoff within the raingarden basin until it infiltrates into the soil surface or evaporates (typically within 24 hours). This process also increases the quantity and movement of soil water that may feed groundwater recharge. Infiltrated water quality is improved by reducing sediment, nutrient and other chemical pollutant loads through chemical and biological processes in the soil. Downstream water quality is improved in kind by offsetting erosive peak flows and by capturing and treating pollutants higher in the watershed.

sub-watersheds: A discreet portion of a larger watershed, typically less than 2500 acres. Sub-watersheds can be more effectively analyzed and managed for water quality with site scale treatments.

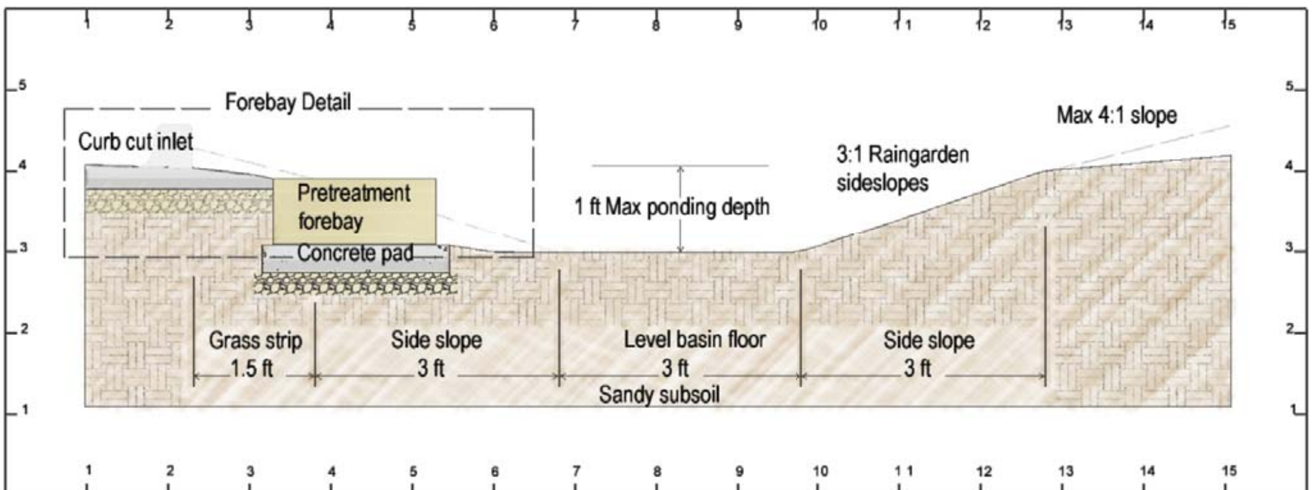
CHOOSE YOUR RAINGARDEN DESIGN



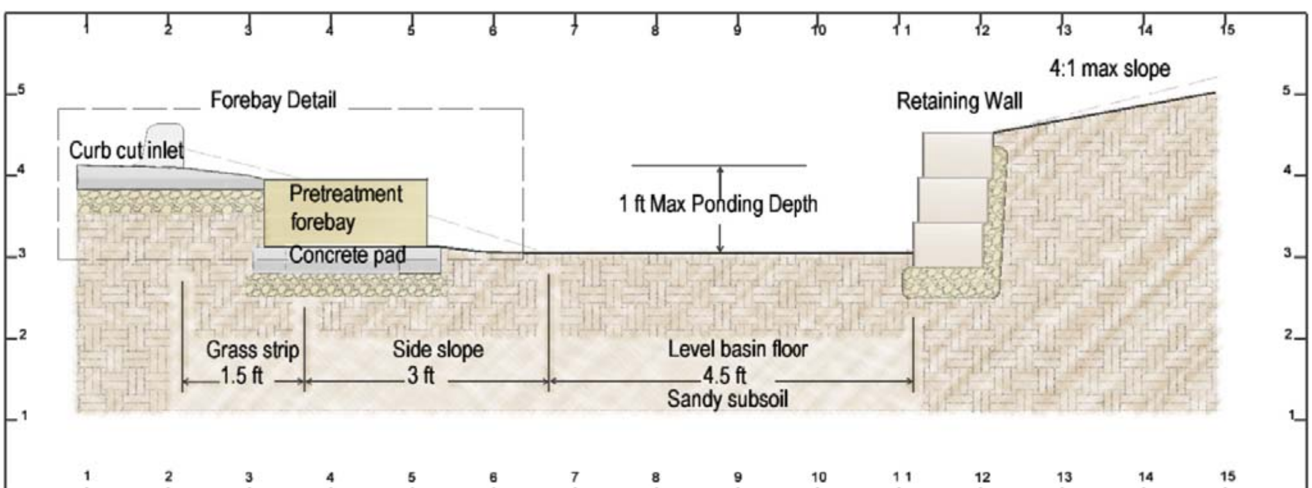
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

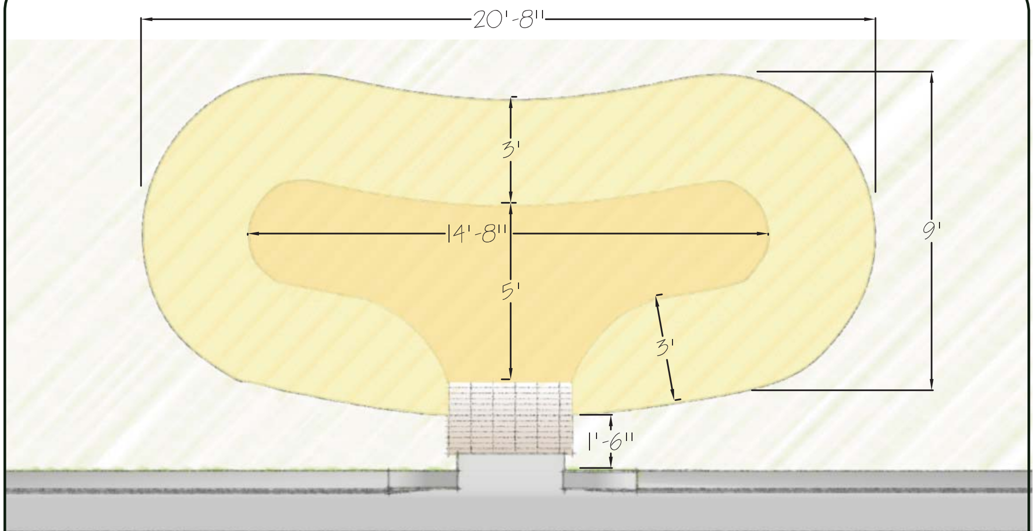


RAINGARDEN WITHOUT RETAINMENT

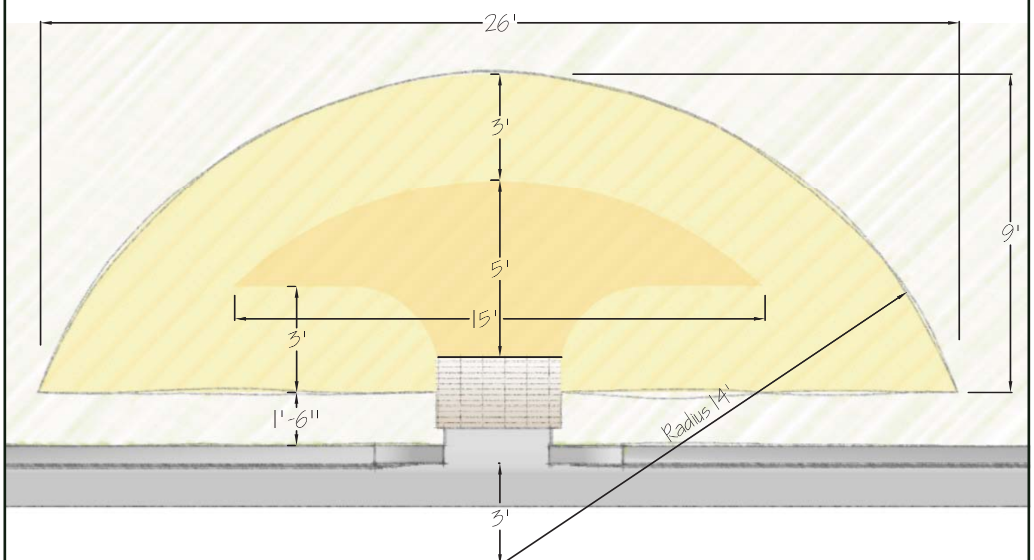


RAINGARDEN WITH RETAINING WALL

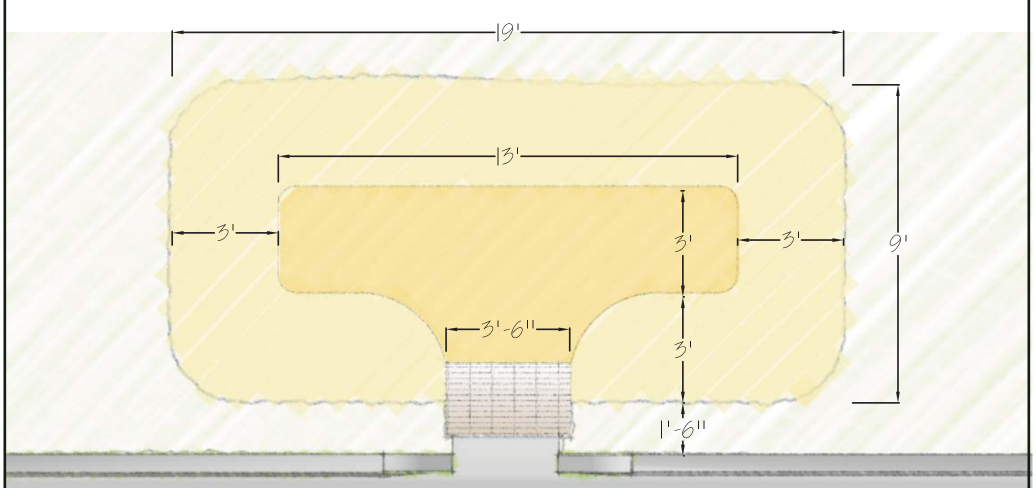
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



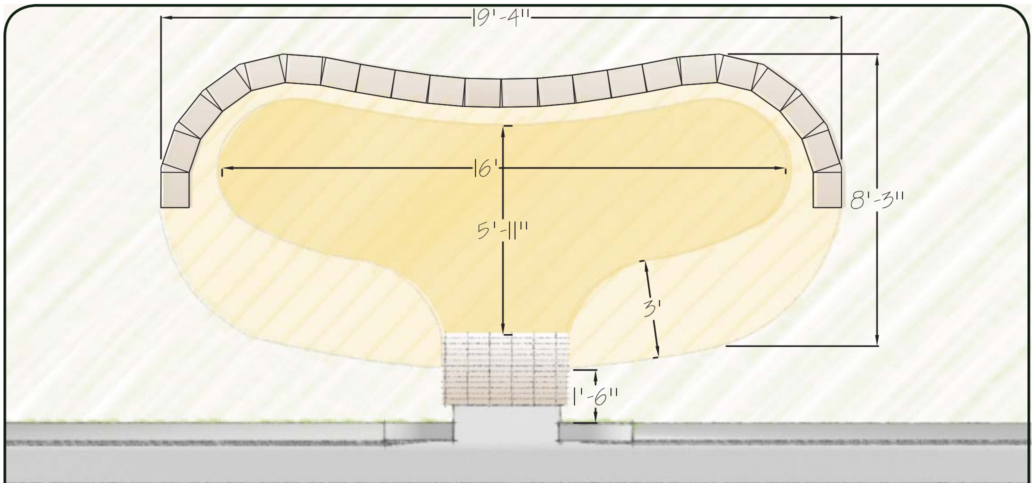
Arc Garden

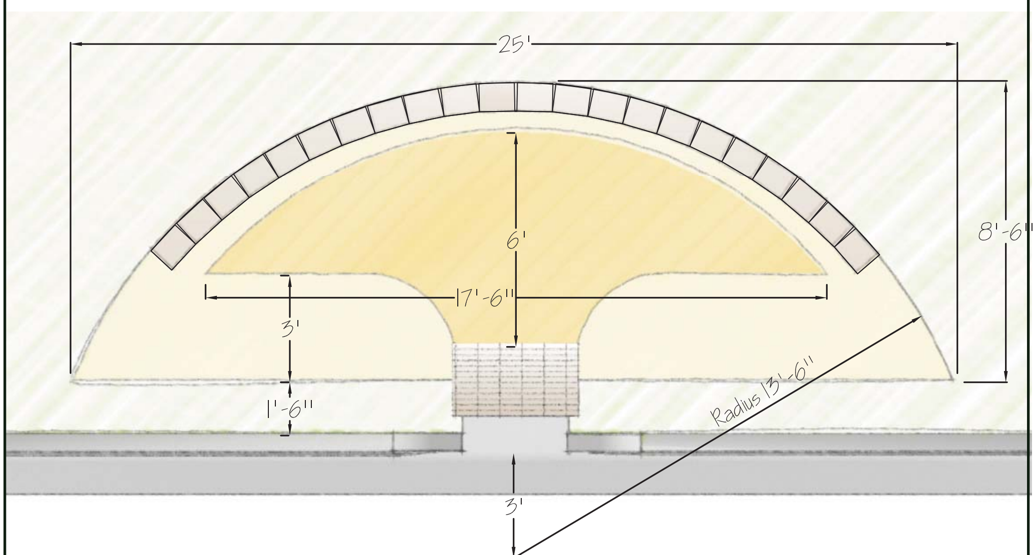


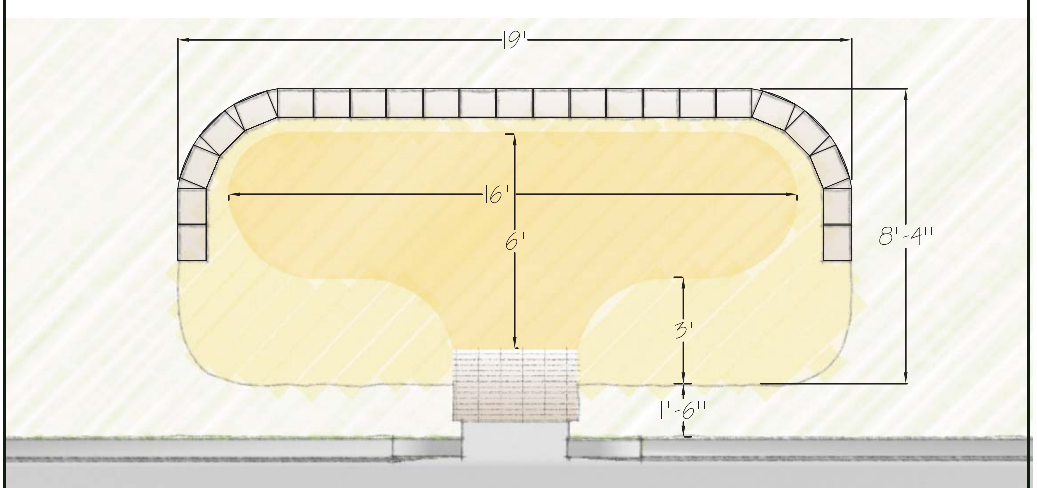
Rectangle Garden

The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

Raingarden Dimensions with a Retaining Wall

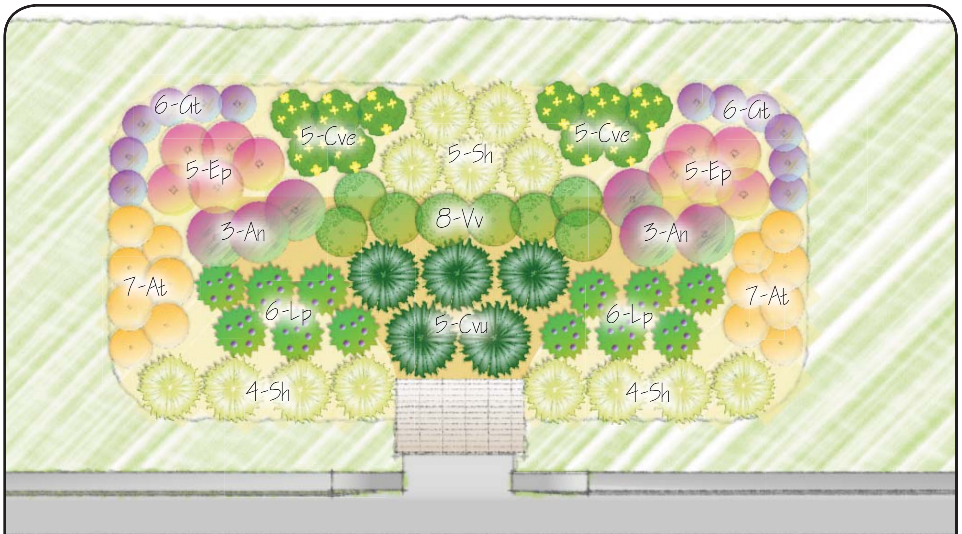




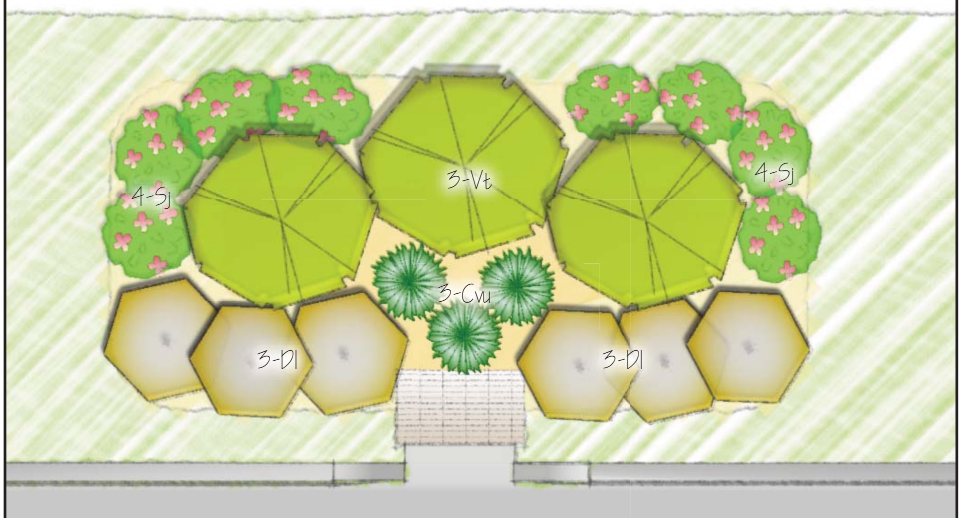


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

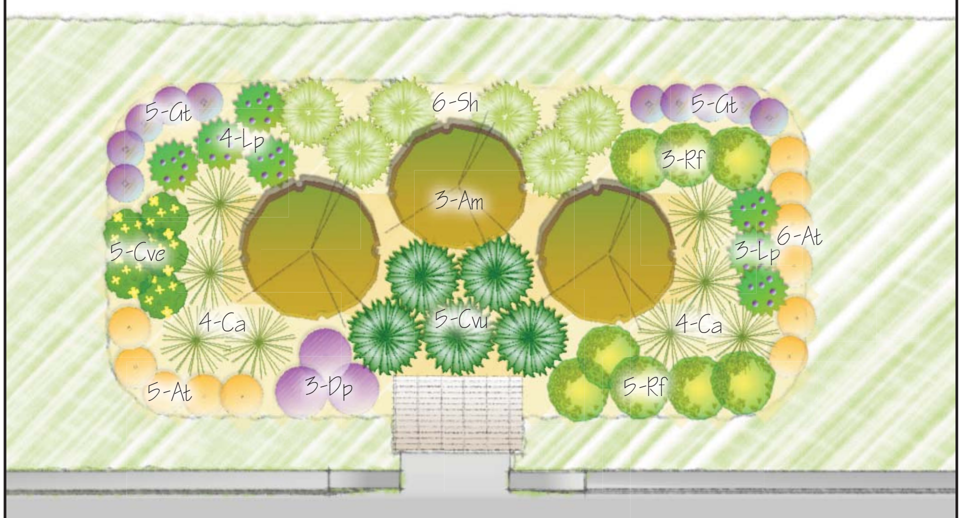
I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

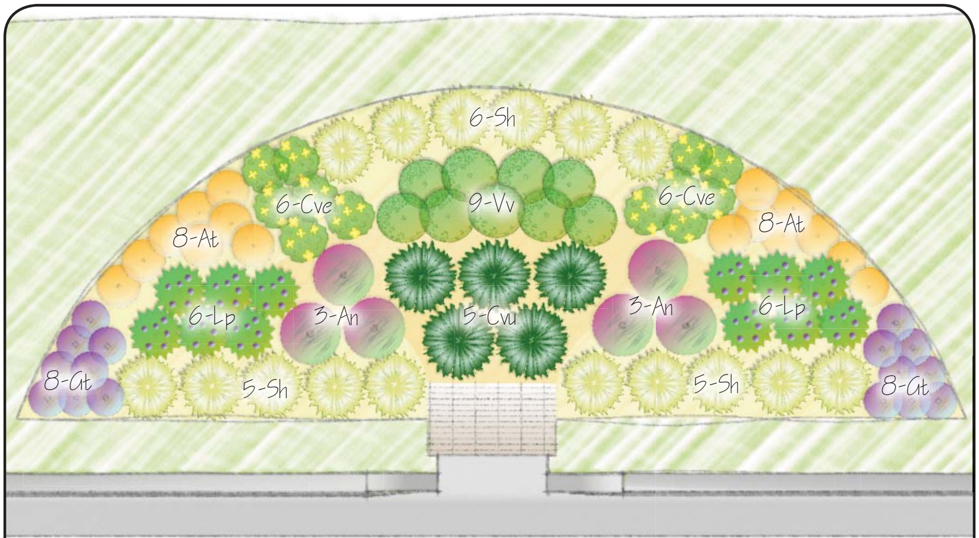


Mixed Shrub/Flower Garden

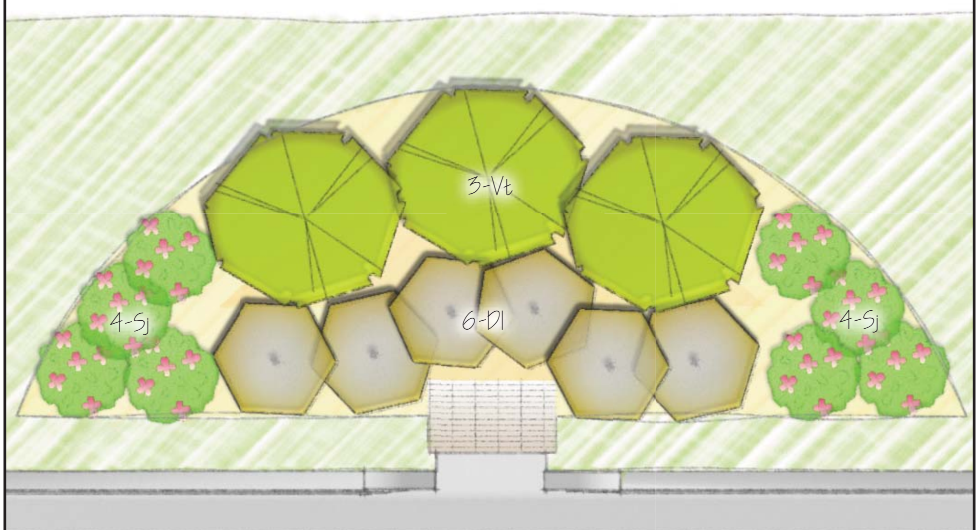
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ep	PURPLE CONEFLOWER *Echinacea purpurea*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

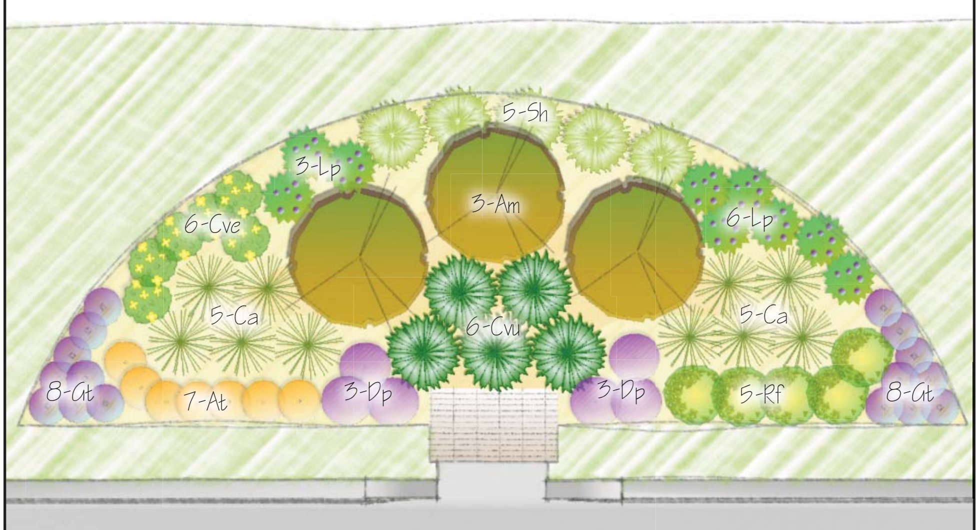
II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

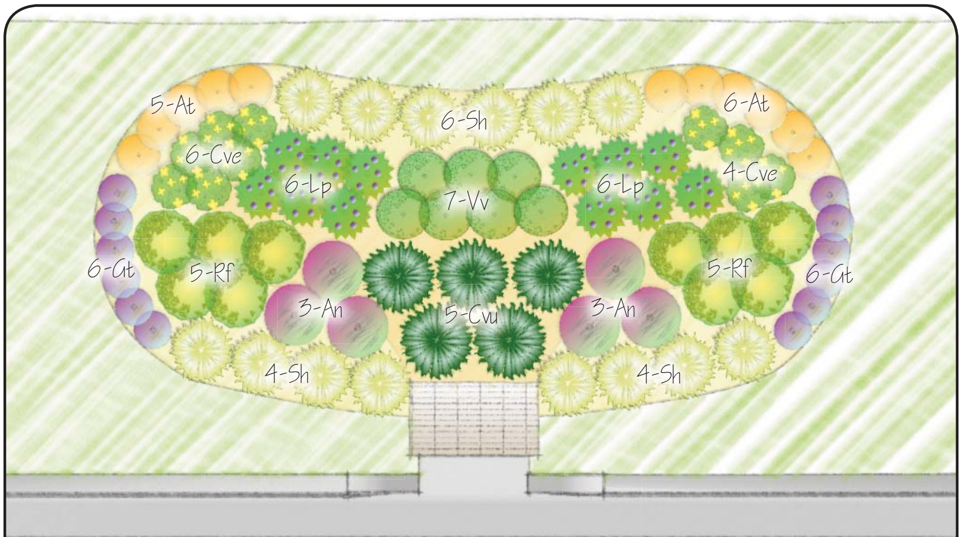


Mixed Shrub/Flower Garden

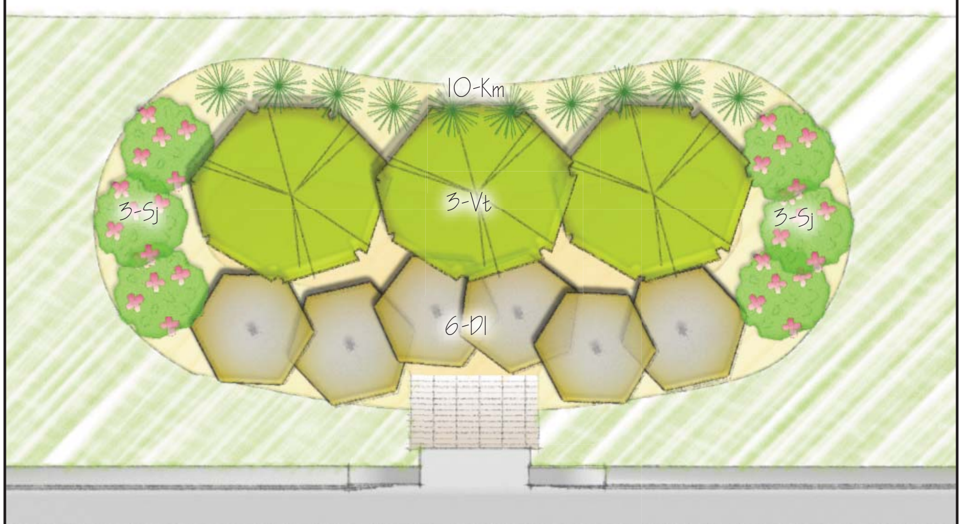
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ep	PURPLE CONEFLOWER *Echinacea purpurea*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

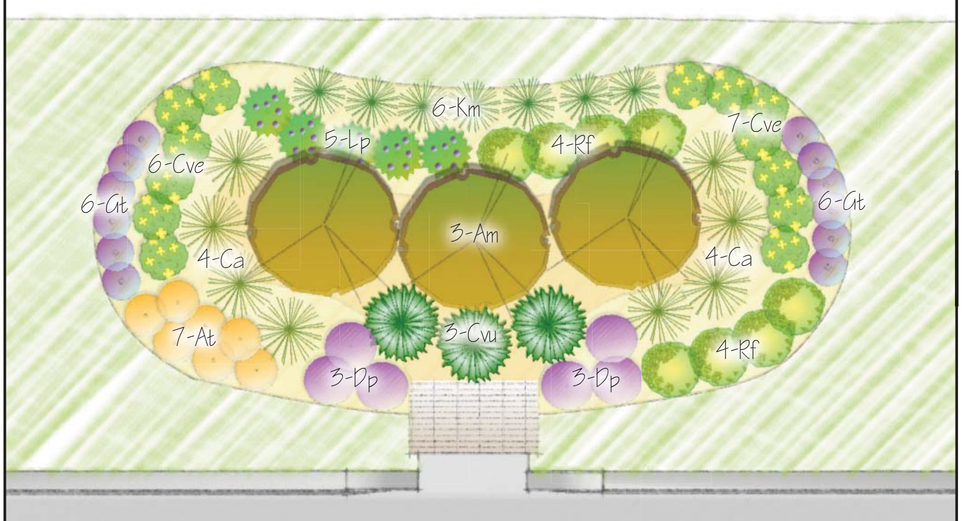
III. Curvilinear Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

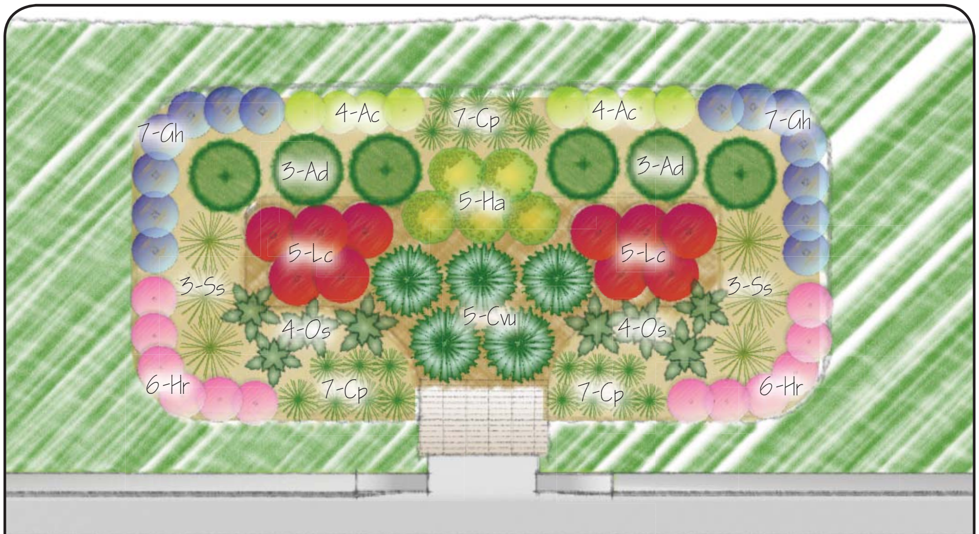


Mixed Shrub/Flower Garden

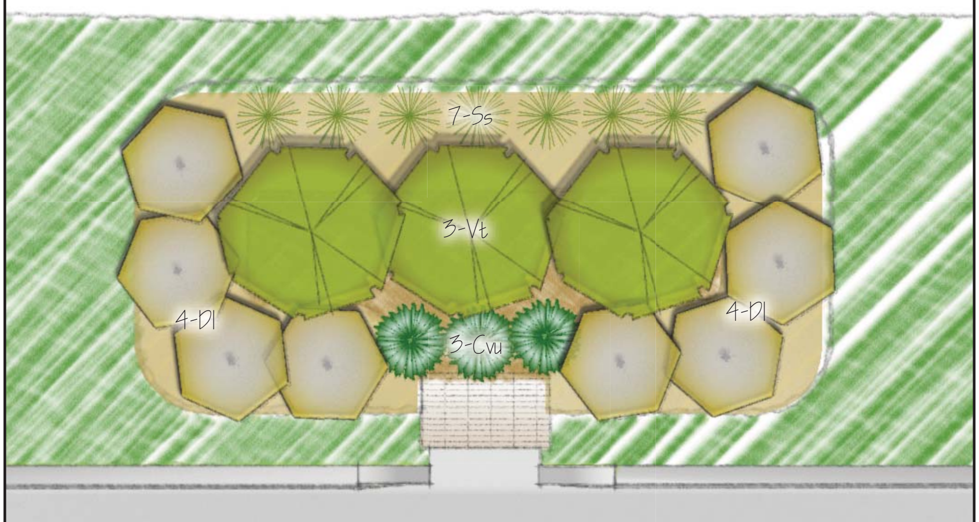
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cvu	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dp	PURPLE PRARIE CLOVER *Dalea purpurea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Km	JUNE GRASS *Koeleria macrantha*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

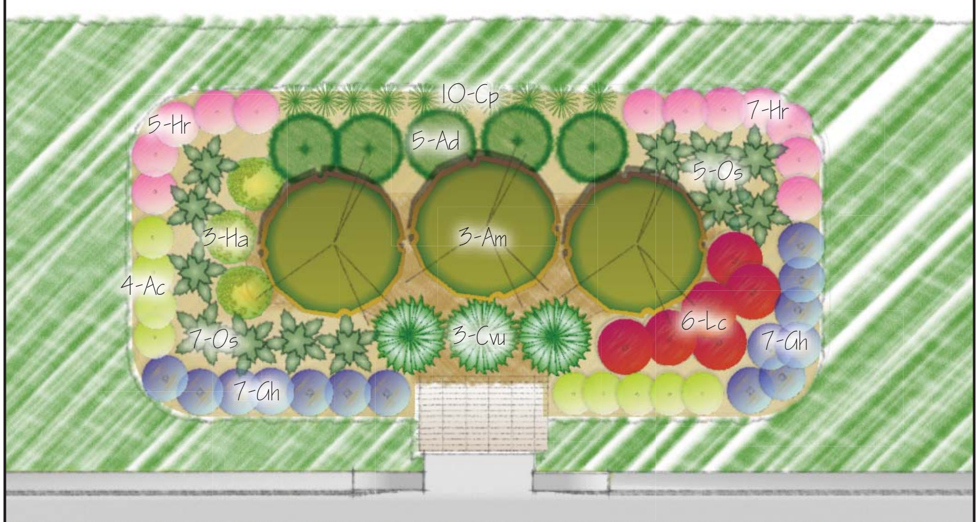
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

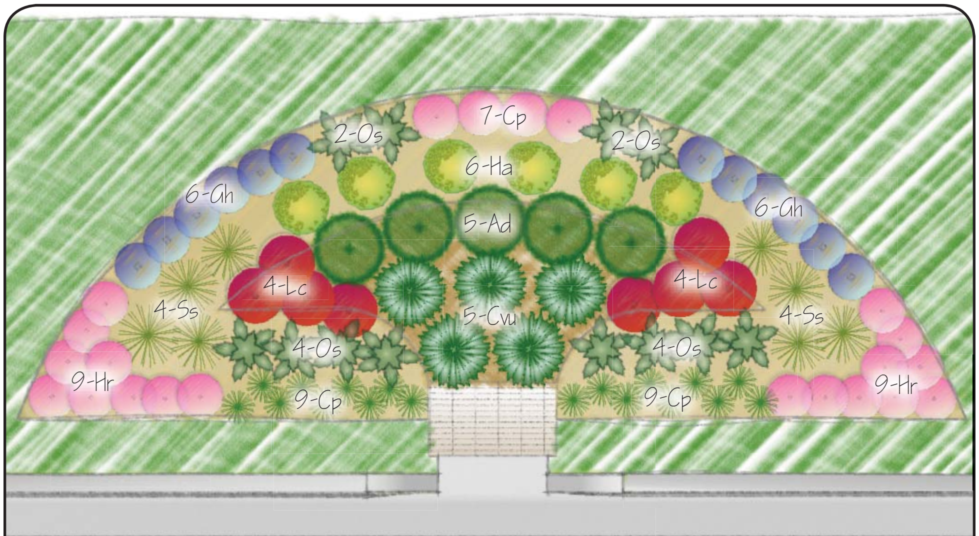


Mixed Shrub/Flower Garden

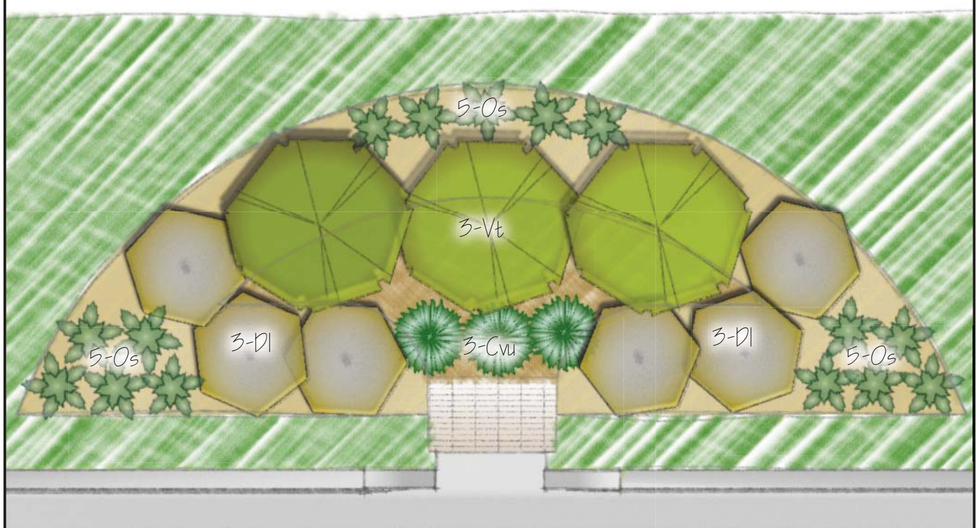
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ac	CANADA ANEMONE *Anemone canadensis*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

V. Arc Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



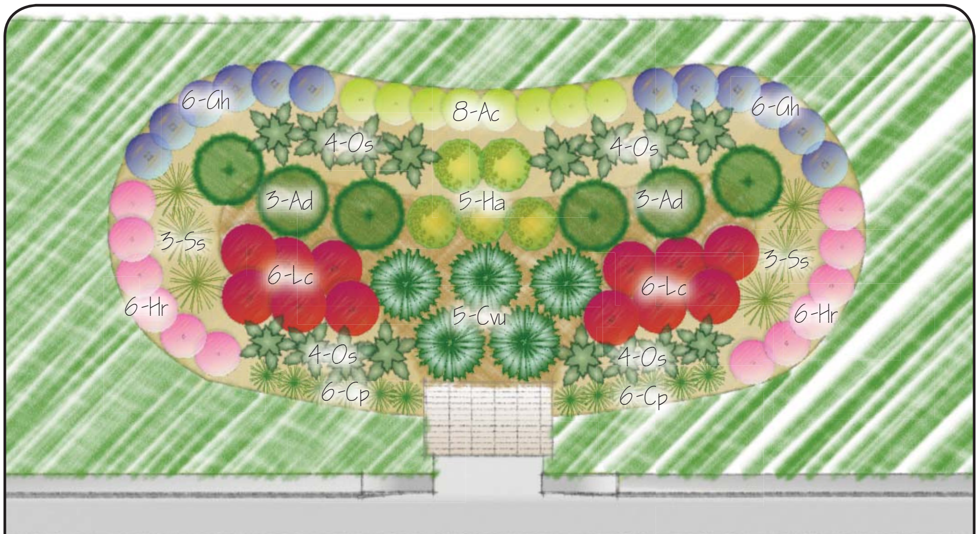
Shrub Garden

Mixed Shrub/Flower Garden

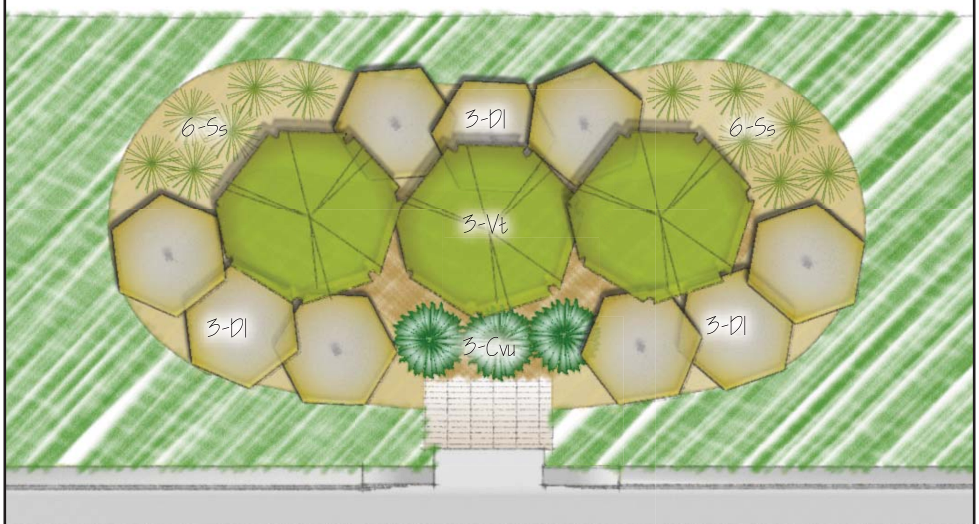
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ac	CANADA ANEMONE *Anemone canadensis*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

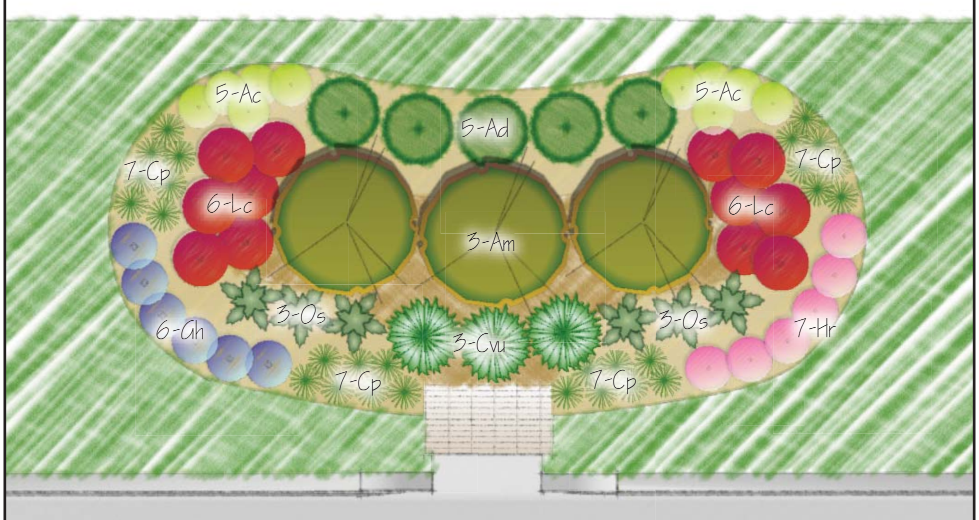
VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

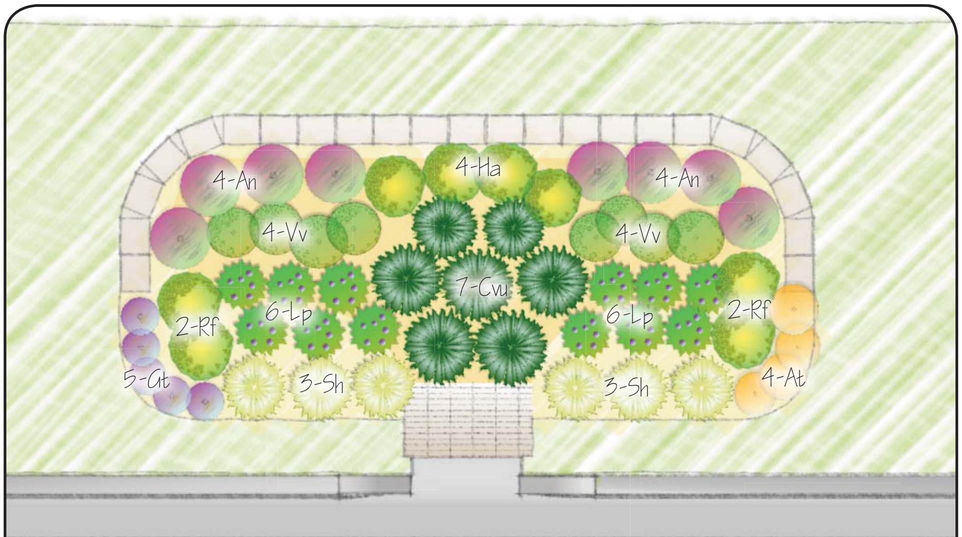


Mixed Shrub/Flower Garden

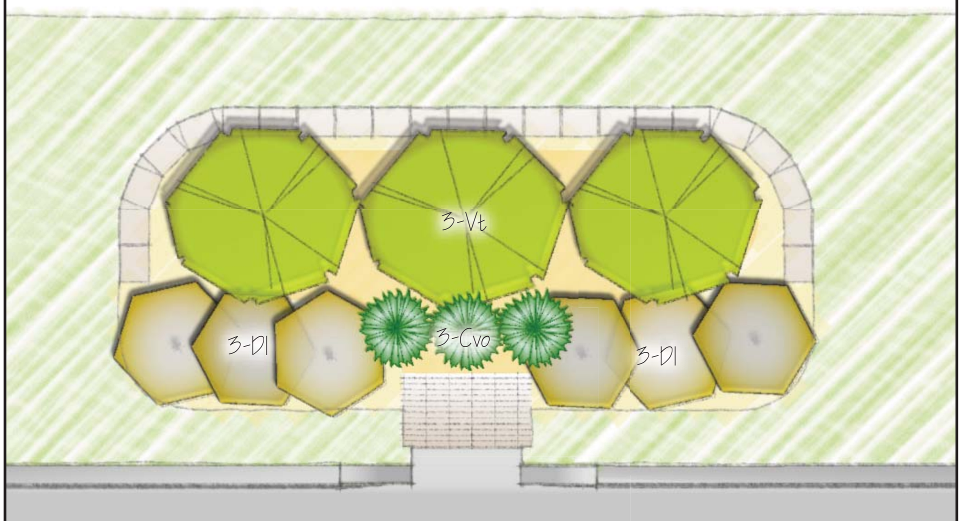
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ac	CANADA ANEMONE *Anemone canadensis*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

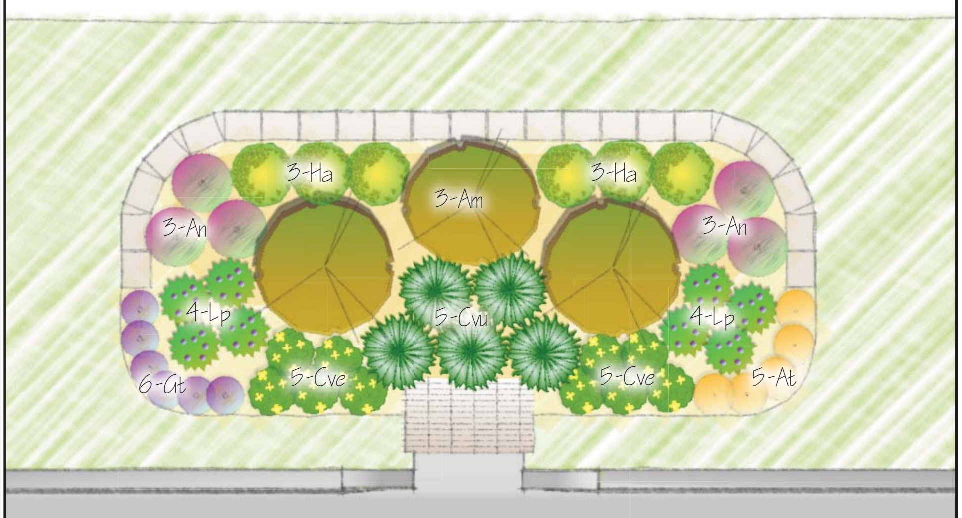
VII. Rectangle Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

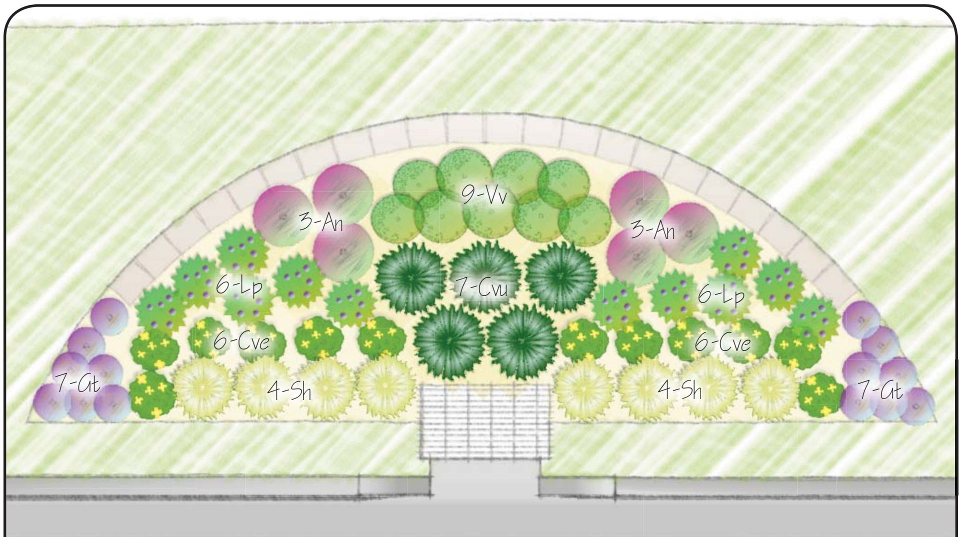


Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Ha	SNEEZEWEED *Helenium autumnale*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Vronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

VIII. Arc Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden

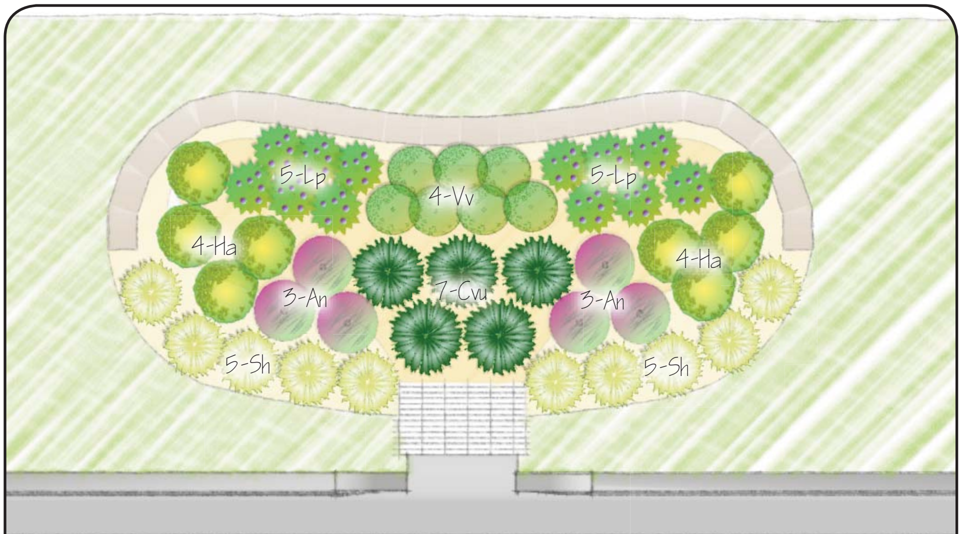
Shrub Garden

Mixed Shrub/Flower Garden

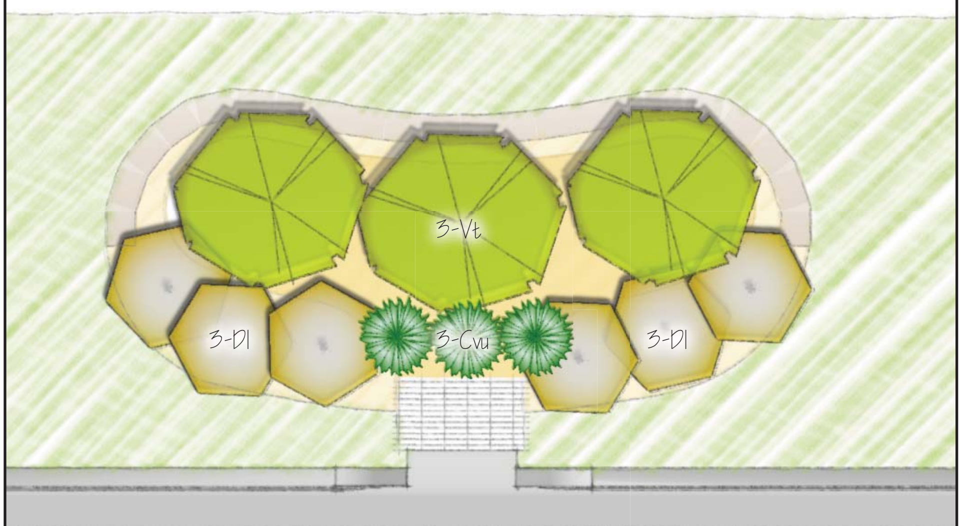
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

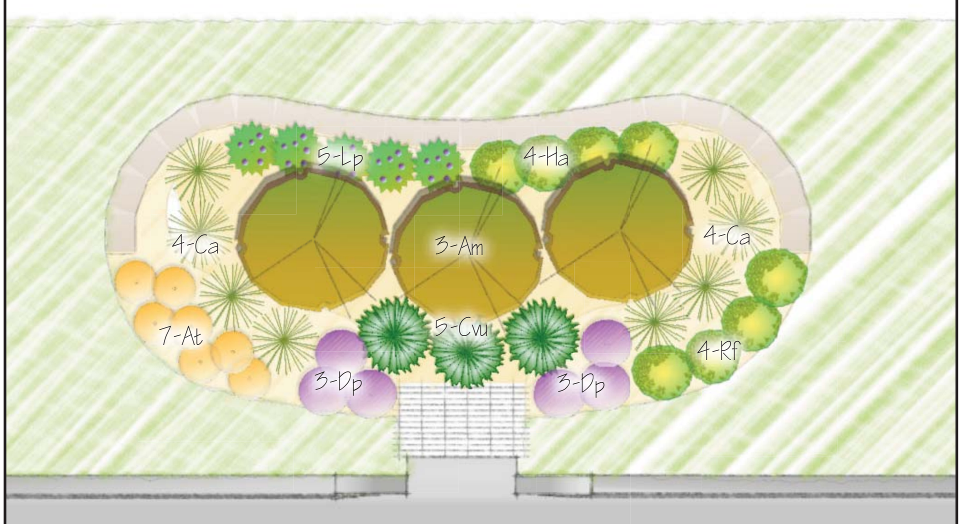
IX. Curvilinear Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



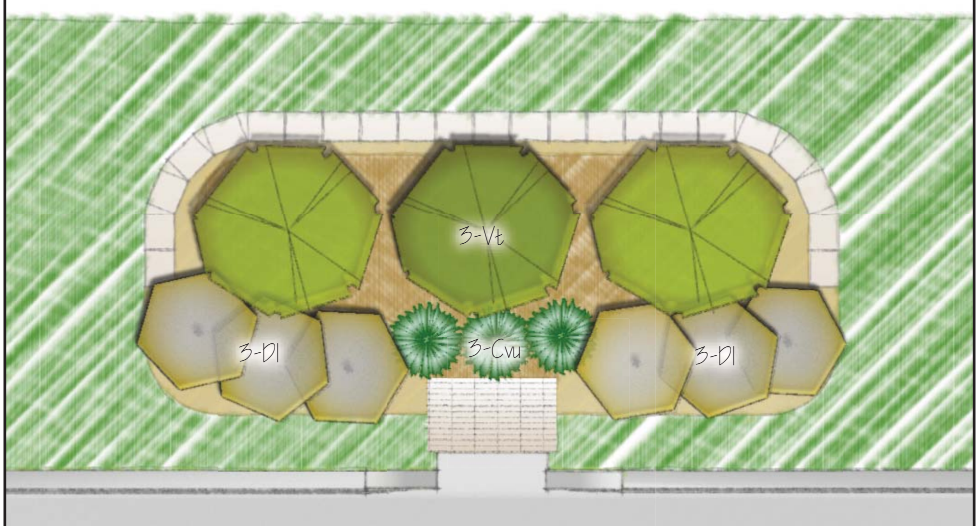
Mixed Shrub/Flower Garden

Plant Key

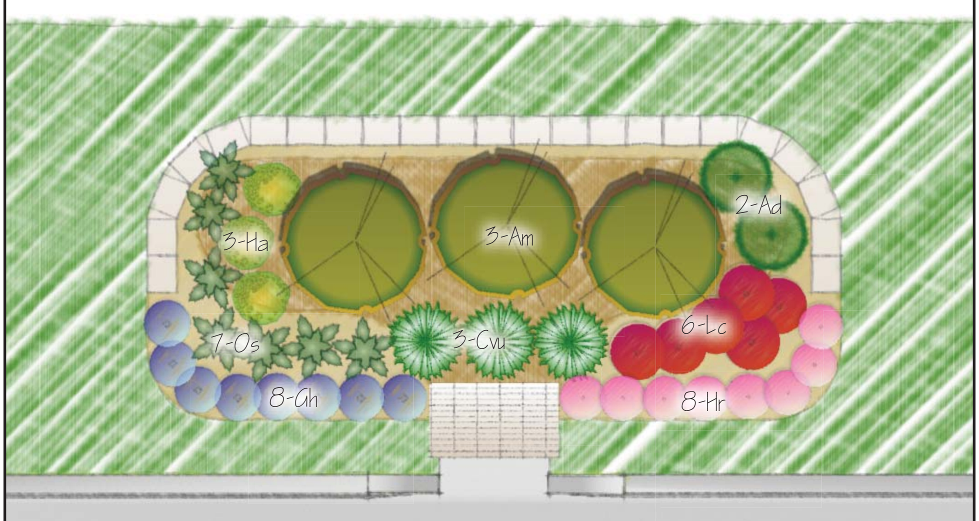
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Vronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

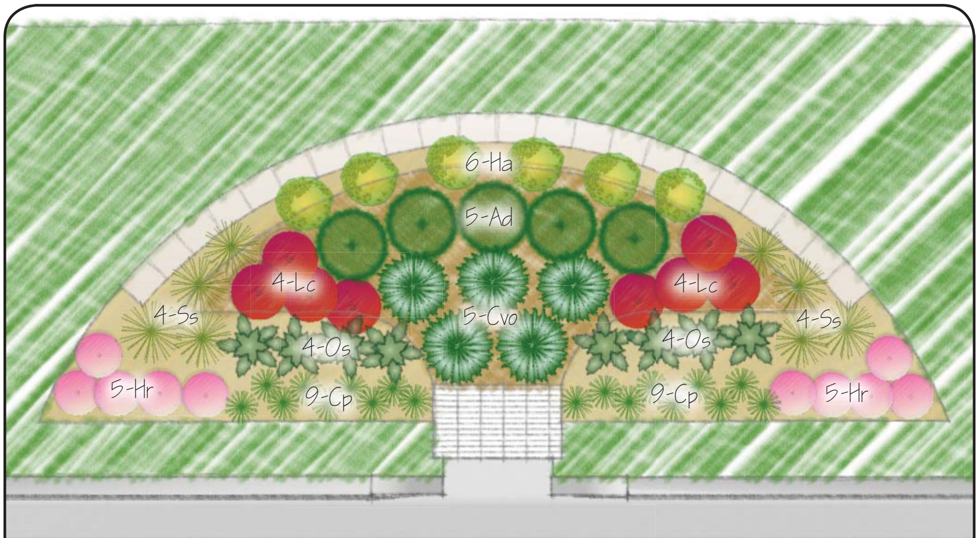


Mixed Shrub/Flower Garden

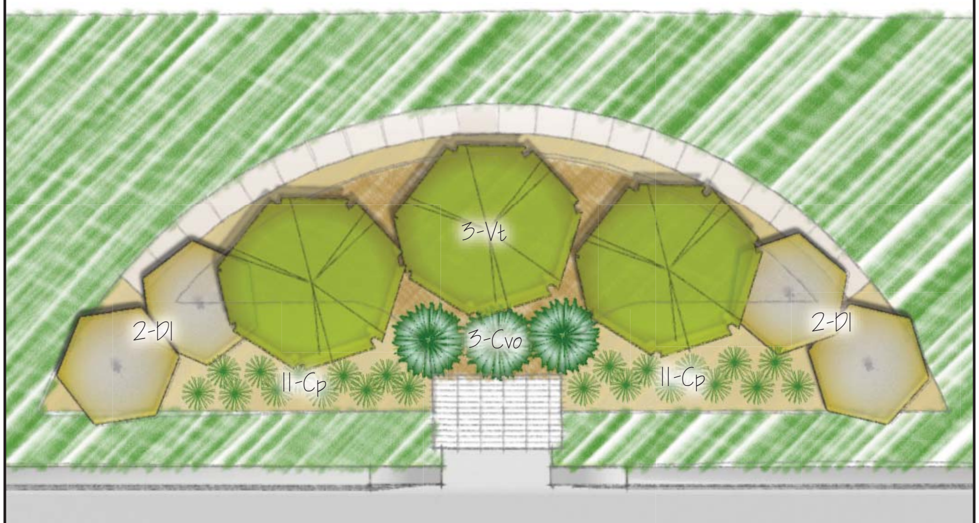
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

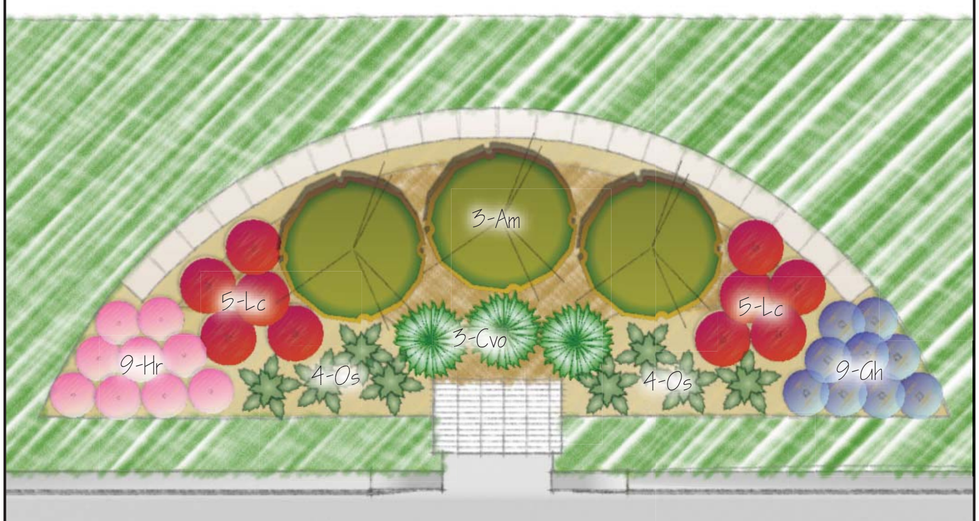
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

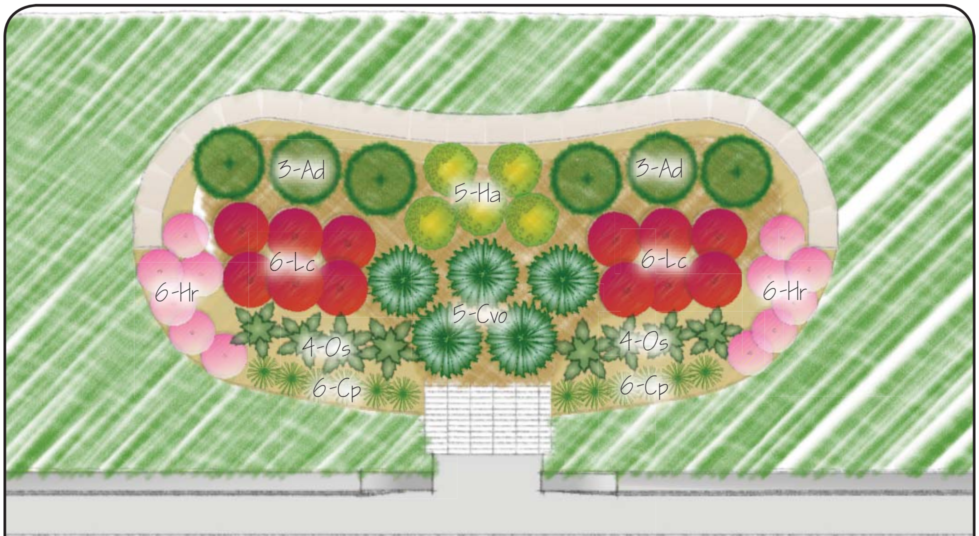


Mixed Shrub/Flower Garden

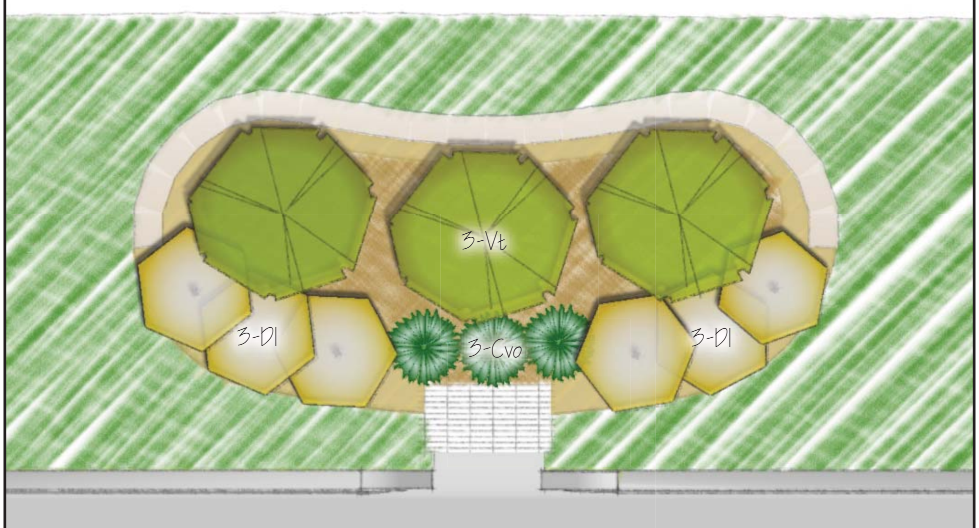
Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvo	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

XII. Curvilinear Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvo	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

FLOWERING PERENNIAL
Plant pallette

CANADA ANEMONE
Anemone canadensis

GOAT'S BEARD
Aruncus diocius

BUTTERFLY MILKWEED
Asclepias tuberosa

ASTER 'PURPLE DOME'
Aster novae-angliae 'Purple Dome'

COREOPSIS 'MOONBEAM'
Coreopsis verticillata 'Moonbeam'

PURPLE PRARIE CLOVER
Dalea purpurea

PURPLE CONEFLOWER
Echinacea purpurea

GERANIUM 'JOHNSON BLUE'
Geranium himalayense x pratense

PRAIRIE SMOKE
Geum trifolium

SNEEZEWEED
Helenium autumnale

ALUMROOT
Heuchera richardsonii

PRAIRIE BLAZING STAR
Liatris pycnostachya

CARDINAL FLOWER
Lobelia cardinalis

SENSITIVE FERN
Onoclea sensibilis

GOLDSTRUM BLACK-EYED SUSAN
Rudbeckia fulgida

CULVERS ROOT
Veronicastrum virginicum

SHRUB
Plant pallette

BLACK CHOKEBERRY
Aronia melonocarpa

DWARF BUSH HONEYSUCKLE
Diervilla lonicera

DART'S RED SPIRAEA
Spiraea japonica

CRANBERRYBUSH VIBURNUM
Viburnum trilobum 'compactum'

GRASSES
Plant pallette

KARL FORESTER GRASS
Calamagrostis acutifolia

PENNSYLVANIA SEDGE
Carex pennsylvanica

FOX SEDGE
Carex vulpinoidea

JUNE GRASS
Koeleria macrantha

LITTLE BLUESTEM
Schizachyrium scoparium

PRAIRIE DROPSEED
Sporobolis heterolepsis

Appendix D:
Retrofit Concepts

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Urban Stormwater Best Management Practices

Retrofit Concepts

Prepared by the Anoka Conservation District in association with the Metropolitan Conservation Districts

Retrofit Concepts: Perimeter Sand Filter

Perimeter sand filters (Delaware filters) consist of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber, which has a shallow permanent pool of water. The first trench captures heavy solids before the runoff spills into the second trench, which consists of a sand layer (typically 18" deep). Water infiltrates through the sand and is collected by an under-drain and delivered, ideally, to another stormwater BMP or existing stormsewer network. If both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The sand may have iron filings added to improve dissolved phosphorus removal.

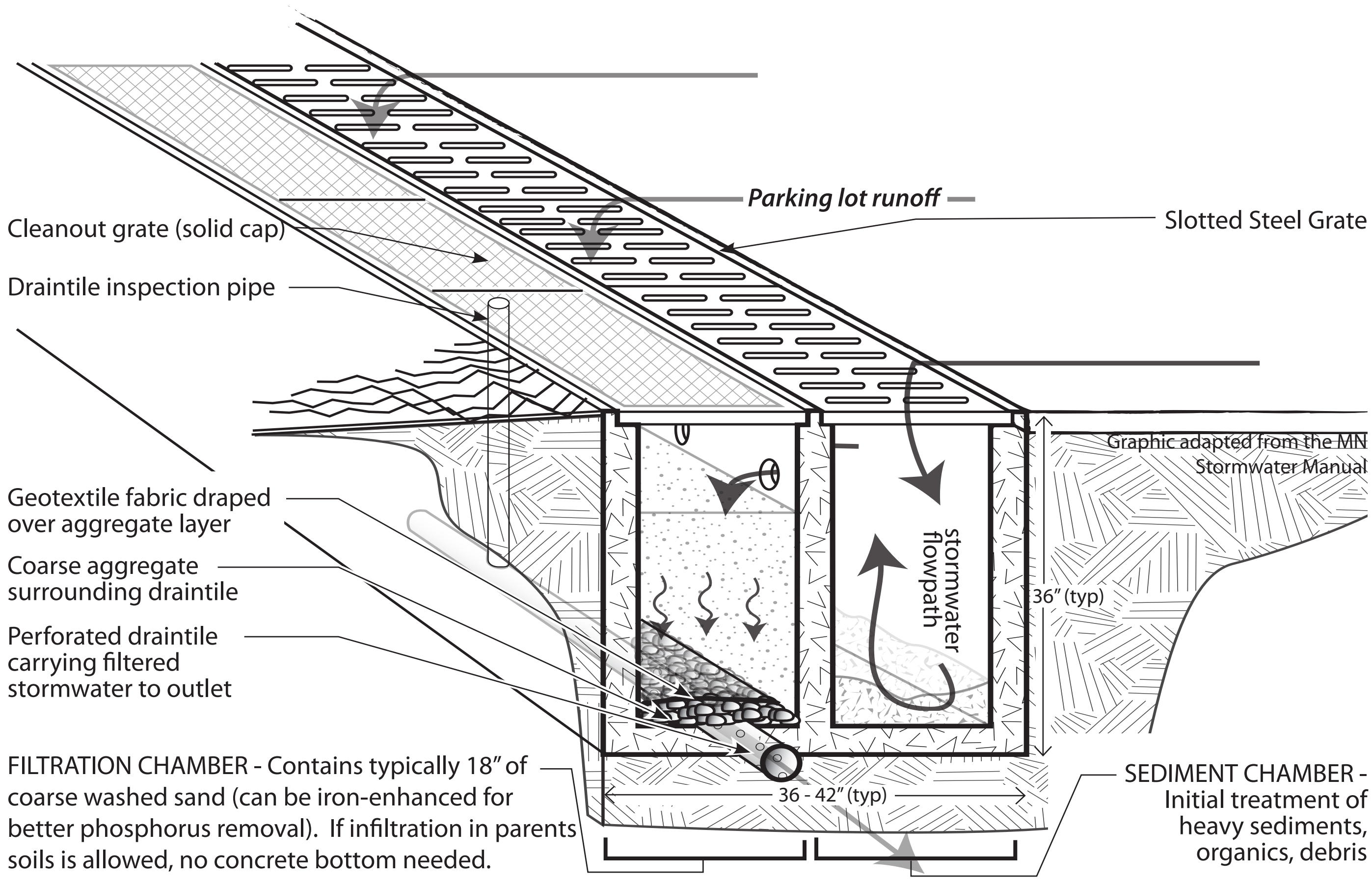

Sand filter inspection, Iowa Stormwater Partnership

BENEFITS:
- Great for adjacent to large impervious areas like parking lots
- Remove up to 90 percent of total suspended solids, 55 percent of total phosphorous, and 35 percent of total nitrogen
- Can effectively treat hot-spot runoff
- Consume small amounts of land

COST:
- Approximately $21.50 per cu ft of storage

CONCERNS:
- High maintenance burden (regular inspections for clogging, sand replacement, and removal of captured sediment)
- Not recommended for areas with high sediment content in stormwater or areas receiving significant clay/silt runoff
- Relatively costly

RECOMMENDED DRAINAGE AREA:
- Highly impervious sites up to 2 acres
- Approximately 100 linear feet treats 1 acre of impervious area



Retrofit Concepts: *Tree Pit Filter*

Stormwater tree pits consist of an underground structure and above ground plantings which collect and treat stormwater using bioretention. Although their structures differ, stormwater tree pits closely resemble traditional street trees and are perfect for urban streets where space is limited.


Tree Pit Filter, Green Infrastructure - Stormwater Department, nyc.gov

BENEFITS:
- Reduces runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Improves aesthetic appeal of streets and neighborhoods
- Provides shade to nearby buildings to reduce energy costs
- Requires limited space
- Simple to install
- Available in multiple sizes
- Eliminates watering and fertilizing needed by traditional street trees

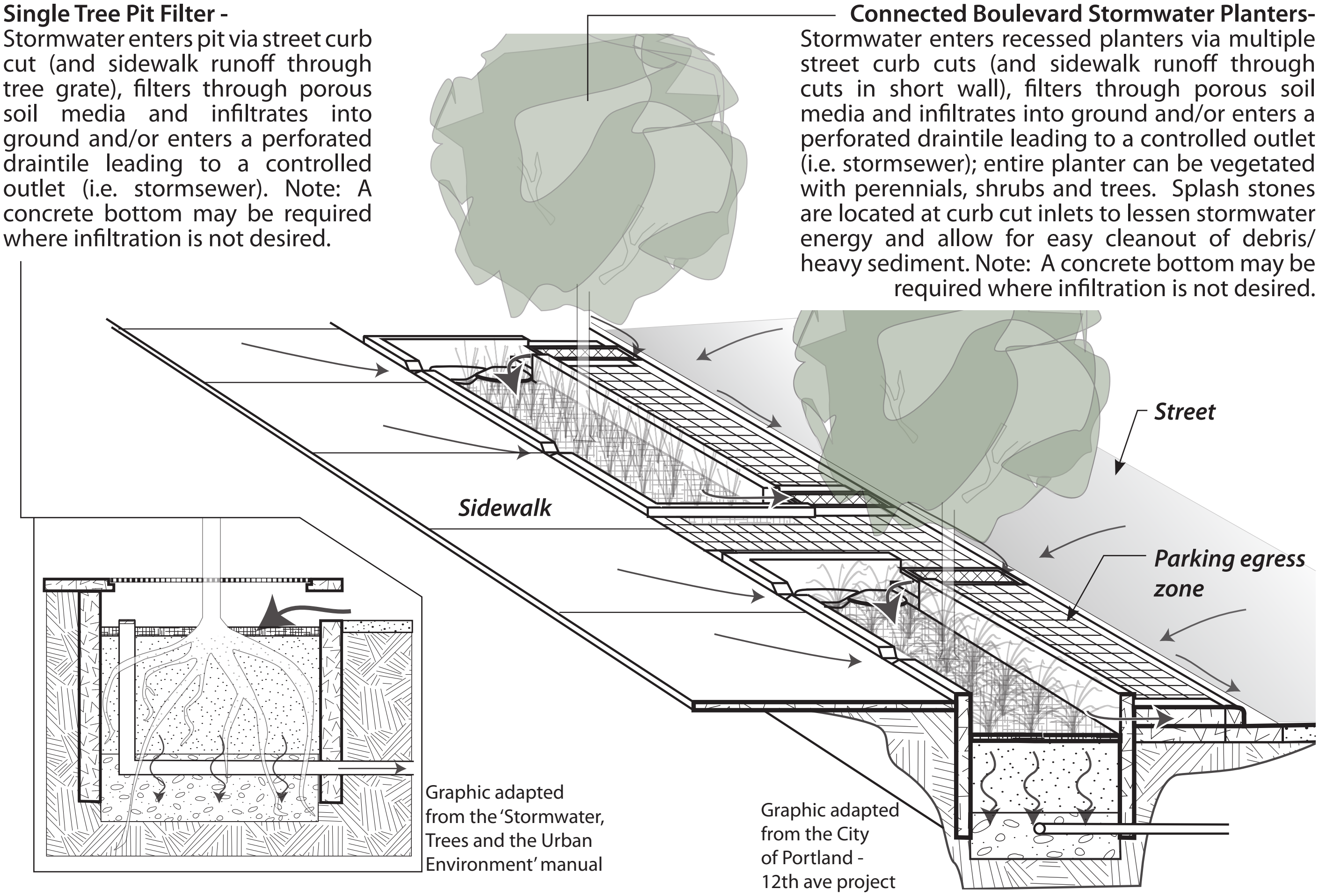
CONCERNS:
- Tree species will be limited to those that have salt tolerance and limited root aggression
- Regular inspections to prevent clogging & maintain function

RECOMMENDED DRAINAGE AREA:
- Optimum ratio at highy impervious sites is one 6' x 6' tree pit per .25 acres

COST:
- Approximately $98.75 per cu ft of storage

Single Tree Pit Filter -
Stormwater enters pit via street curb cut (and sidewalk runoff through tree grate), filters through porous soil media and infiltrates into ground and/or enters a perforated draintile leading to a controlled outlet (i.e. stormsewer). Note: A concrete bottom may be required where infiltration is not desired.

Connected Boulevard Stormwater Planters-
Stormwater enters recessed planters via multiple street curb cuts (and sidewalk runoff through cuts in short wall), filters through porous soil media and infiltrates into ground and/or enters a perforated draintile leading to a controlled outlet (i.e. stormsewer); entire planter can be vegetated with perennials, shrubs and trees. Splash stones are located at curb cut inlets to lessen stormwater energy and allow for easy cleanout of debris/ heavy sediment. Note: A concrete bottom may be required where infiltration is not desired.



Graphic adapted from the 'Stormwater, Trees and the Urban Environment' manual

Graphic adapted from the City of Portland - 12th ave project

Retrofit Concepts: *Porous Pavement*

Porous pavements come in a wide array of materials - ***concrete, asphalt, pavers, and grid*** - with void spaces that allow water to percolate through the surface and reach a subsurface layer of coarse aggregate allowing stormwater to quickly drain into the ground. Porous pavements are ideally situated in areas where soil type, seasonal water table and frost line levels allow for groundwater recharge. Porous pavements are typically used in low traffic areas and are well suited for use in parking lots, overflow areas, low traffic roads, residential driveways and pedestrian walkways. They can also be installed surrounding other stormwater management systems to provide overflow collection and infiltration.

BENEFITS:

- Reduces runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Reduces the need for traditional stormwater infrastructure
- Can improve aesthetic appeal of paved areas (pavers)
- Flexible for use in areas of various shapes and sizes
- Remove up to 80 percent of total phosphorous and total nitrogen
- Reduced Ice buildup on street

CONCERNS:

- Typically not suited for slopes greater than 5%
- Cost
- At minimum 2 vacuum sweepings per year
- Periodic replacement of fill material in joint spacing (pavers)
- Not suitable for areas generating a lot of sediment

RECOMMENDED DRAINAGE AREA:

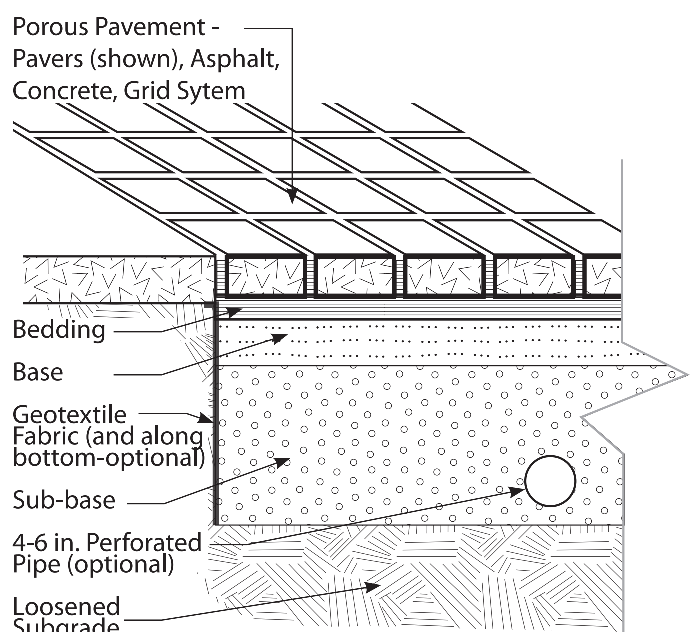
- Typically 3:1 (drainage area to porous pavement area) or less

COST:

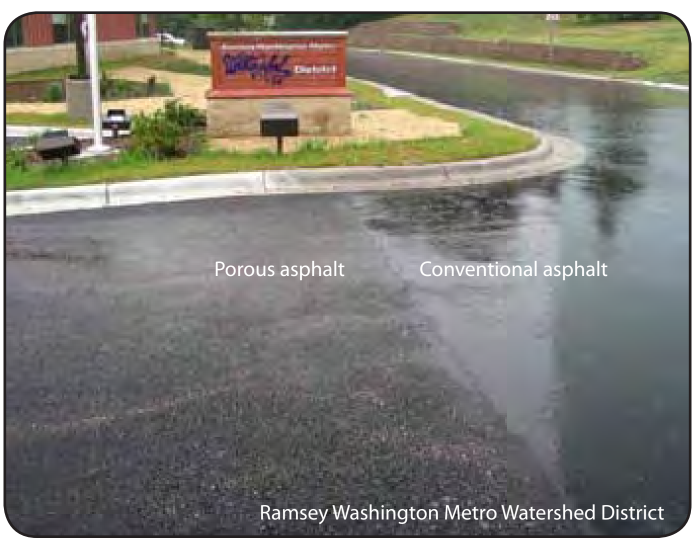
- Approximately $14 - $35 per cu ft storage depending on underlayment

Permeable pavement in parking aisle, City of Portland

Permeable pavers, Minneapolis



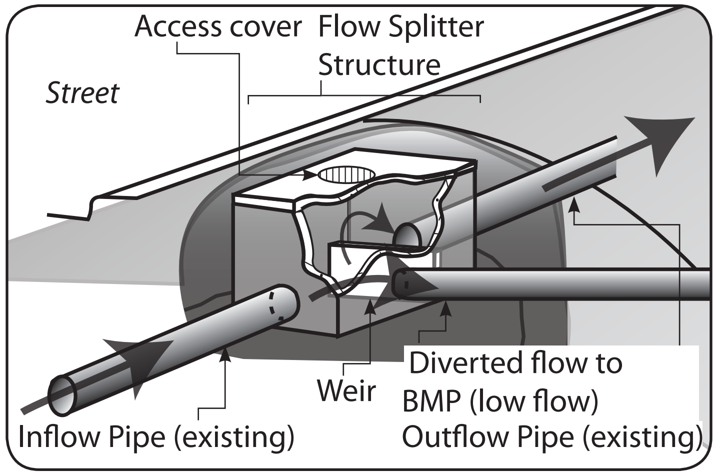
Graphic adapted from the Charles River Watershed Association - Information Sheet



Ramsey Washington Metro Watershed District

Retrofit Concepts: Flow Splitters

Flow splitters are stormsewer structures used to divert initial flows from stormsewer network out into a stormwater BMP such as constructed wetlands, detention ponds, infiltration basins, swales and various other filtration practices. During intense rain events excess stormwater travels over a weir, located in the flow splitter, and continues down pipe. Flow splitters are often designed to divert at least the 'first flush' into a BMP.



BENEFITS:

- Provides the ability to capture and treat otherwise untreated stormwater
- Allows high flows to bypass the connected stormwater BMPs thus reducing opportunities for erosion and re-suspension of sediment captured in the BMP systems
- Only periodic inspections are needed, with annual debris / sediment cleanout being sufficient

CONCERNS:

- Alone this practice does not reduce pollutants. It is a tool to divert appropriate flows into a water quality practice

RECOMMENDED DRAINAGE AREA:

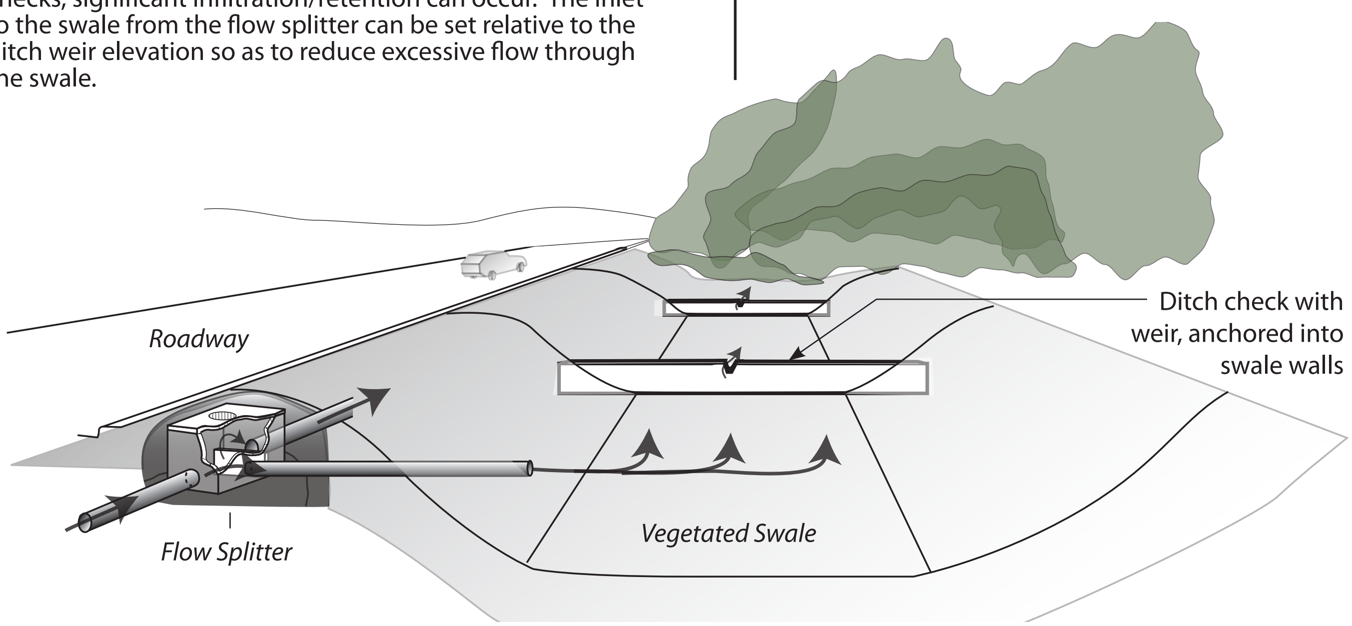
- Varies, pipe sizing can be scaled according to drainage area and capacity of Stormwater BMP that flow is diverted to

COST:

- Varies, the smallest typical structure to fit a weir is 48" diameter.
- Individual component costs of a 48" diameter structure*:
  1. Base slab ~ $250,
  2. Weir ~ $200 per vertical foot,
  3. Riser (side walls) ~ $130 per vertical foot,
  4. Cover slab (with opening) ~ $300,
  5. Metal casting (top grate, option) ~ $400
  6. Diverted flow pipe ~ $2 - $10 per linear foot (depends on material and diameter)

**Based on local sourcing, 2010*

Flow Splitter to Stormwater BMP -
Flow splitters can be used to divert runoff to a suite of stormwater Best Management Practices including a vegetated swale (shown) where filtration and, with ditch checks, significant infiltration/retention can occur. The inlet to the swale from the flow splitter can be set relative to the ditch weir elevation so as to reduce excessive flow through the swale.



Retrofit Concepts: Hydrodynamic Separators

***H**ydrodynamic Separator devices* are structural BMPs vary in size and function, but all use some form of filtration, settling, or hydrodynamic separation to remove particulate pollutants from overland or piped flow. They often replace traditional catch basins and look much the same from the surface. Below the surface is a series of baffles, chambers, and devices designed to capture pollutants. They generally remove coarse sediment, oil and grease, litter, and debris and are often employed in areas with high concentrations of pollutants in runoff (ultra urban and retrofit situations). They may serve as pre-treatment of stormwater runoff before it reaches other BMPs, such as infiltration systems. Manufacturers of the devices provide the internal design specifications and installation instructions.

Southeast Michigan Stormwater LID case study

BENEFITS:

- Can be used in a variety of applications including retrofitting existing stormwater systems
- Subsurface device, consumes little to no land
- Removal of sediment, oils and other floatables

CONCERNS:

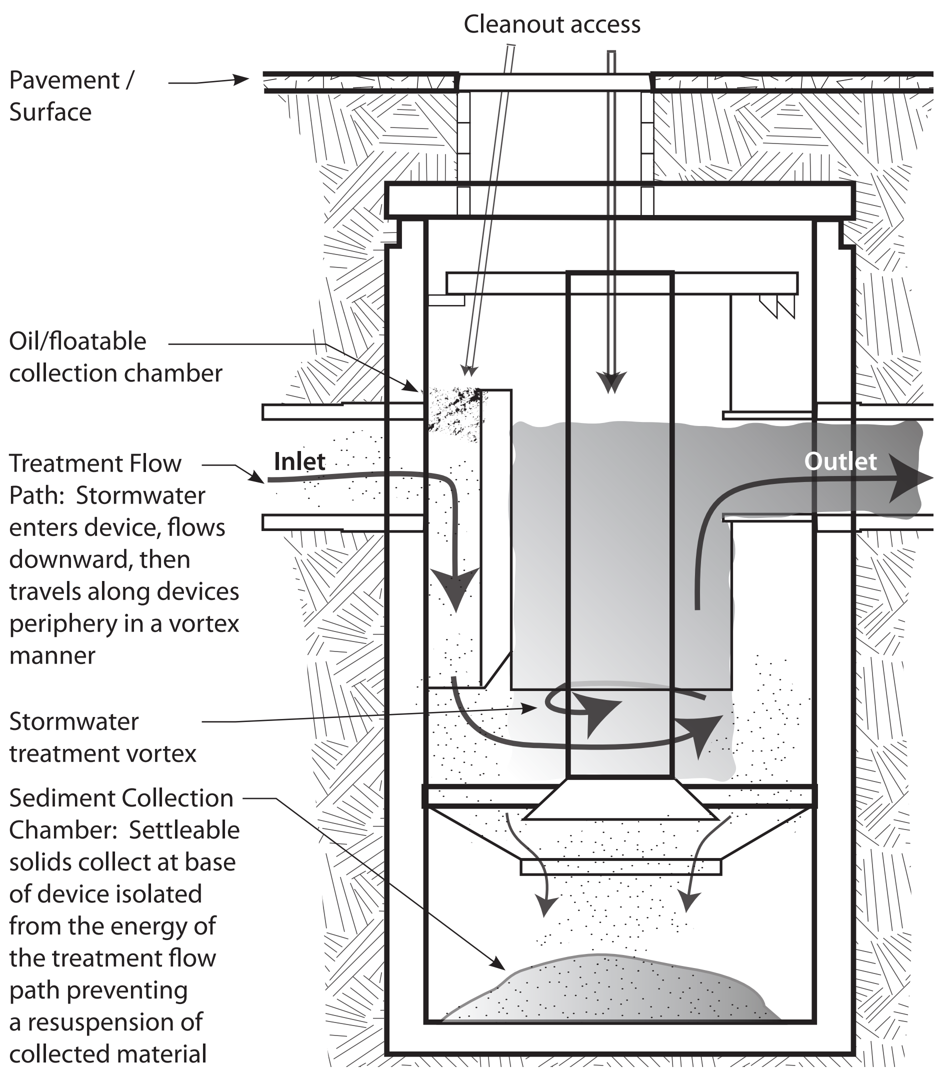
- A minimum annual vacuum removal of captured pollutants; however, required inspections every 6 months for the first year observing sedimentation and oil accumulation rates may determine more frequent visits are necessary
- High initial installation costs

RECOMMENDED DRAINAGE AREA:

- With a suite of scalable devices, drainage areas can range from a single parking lot up to 7 acres of predominently impervious surfaces (based on a standard 80% removal rate of total suspended solids on Stormceptor products**)

COST:

- Varies widely, from $2,300 to $40,000 depending on site characteristics including the amount of runoff (in cfs) required to be treated, the amount of land available, and any other treatment technologies that are presently being used. Often costs break down to approximately $9,000 per acre runoff treated*



Base design source: *Dowstream Defender***

**EPA Technology Fact Sheet*
***This mention does not constitute an endorsement of product*