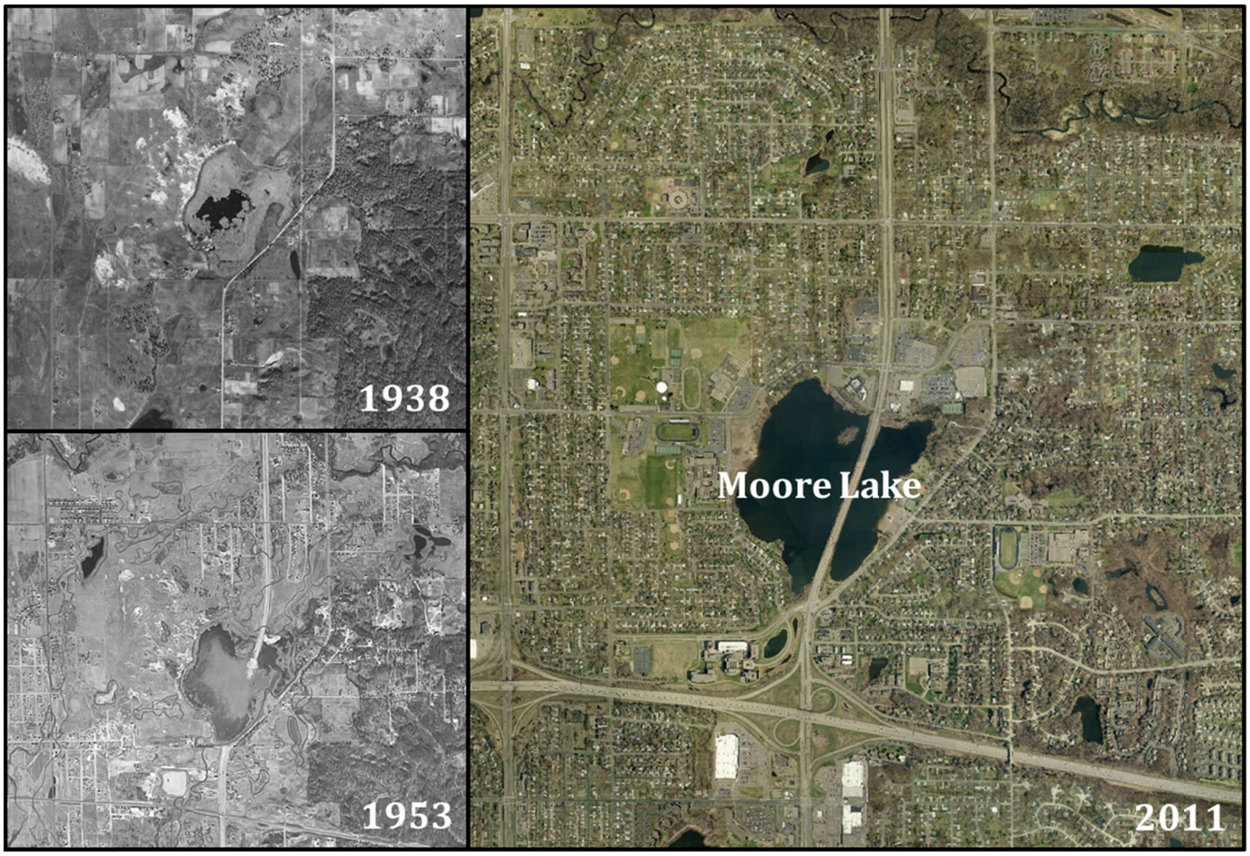


Moore Lake
Stormwater Retrofit Analysis

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

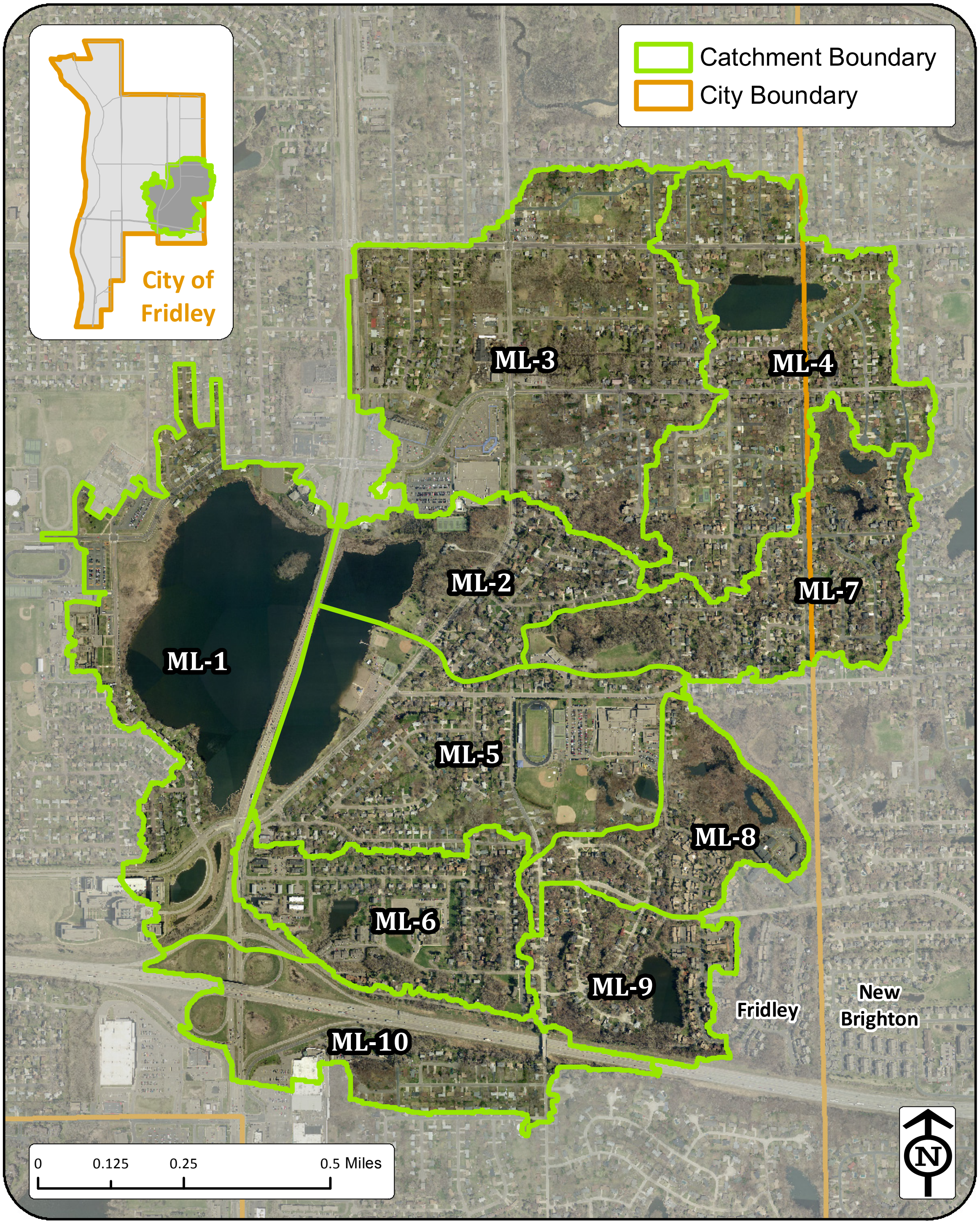
RICE CREEK WATERSHED DISTRICT

May 2013

Cover photos: Aerial photographs of Moore Lake from 1938, 1953, and 2011. The 1938 photograph shows the landscape prior to the construction of Highway 65 through the middle of Moore Lake, while the 1953 photograph shows partial completion of the highway through the northern part of the lake.

Contents

Map of stormwater catchments referred to in this report.



Executive Summary

This study provides recommendations for cost effectively improving treatment of stormwater from areas draining to Moore Lake (herein described as East and West Moore Lake when differentiating basins), which is located within the Rice Creek Watershed District in the City of Fridley. The lake is classified as a high priority water body by the Rice Creek Watershed District and is listed as a Tier II water body by the district. Tier II water bodies provide passive regional public recreation opportunities, and Moore Lake is used recreationally for swimming and fishing. Panfish are the primary sport fish sought by anglers, which also results in frequent ice fishing during the winter months.

East Moore Lake was added to the EPA's 303(d) list of impaired waters in 2002 for aquatic recreation due to excess nutrients. Years of water quality data have indicated high concentrations of phosphorus and chlorophyll a. Efforts to improve water quality within Moore Lake have resulted in a long history of lake and subwatershed activities. These have included numerous efforts within the subwatershed to treat stormwater runoff before it enters the lake as well as the installation of a plastic liner on the bottom of East Moore Lake to reduce sediment resuspension. The stormwater retrofits in this report will aid with alleviating existing water quality problems in Moore Lake.

East and West Moore Lakes are bisected by Highway 65 and are connected by a culvert under the highway. During periods of high water the lake outlets to the north via an outlet on the north side of West Moore Lake. The subwatershed consists of 936 acres (not including the lake area) and is dominated by medium density residential and commercial land uses. Of the 936 acre subwatershed, 659 acres are connected to Moore Lake via overland flow or stormwater infrastructure.

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 Moore Lake were delineated using available GIS subwatershed information and maps of stormwater conveyance features. Those areas were then divided into 10 smaller stormwater drainage areas, or catchments. For each catchment, modeling of stormwater volume and pollutants was completed using the software WinSLAMM. Base and existing conditions were modeled, including existing stormwater treatment practices. The total subwatershed analyzed for this project consisted of 936 acres. The 659 acres connected to Moore Lake contribute an estimated 395 acre feet of runoff, 392 pounds of phosphorus, and 83,112 pounds of total suspended solids each year.

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

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

- Maintenance of, or alterations to, existing stormwater treatment practices,
- Residential curb-cut rain gardens,
- New stormwater pond opportunities,
- Permeable pavement,
- Hydrodynamic separators, and
- Stormwater redirection.

If all of these practices were installed, significant pollution reduction could be accomplished. However, funding limitations and landowner interest makes this goal unlikely. 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.

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 (e.g. wet ponds) 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 potential projects. Potential projects are organized from most cost effective to least, based on cost per pound of total phosphorus 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 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.

Catchments 1 through 6: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
1	ML-5	New Wet Pond (East Moore Lake Park)	1	15.5	5972	0.0	$51,177	$700	$403	$155
2	ML-5	Residential Rain Gardens	5 - 20	5.0 - 15.1	1,425 - 4,221	3.5 - 10.3	$38,761 - $144,421	$375 - $1,500	$1,170 - $1,496	$333 - $418
3	ML-1	Residential Rain Gardens	1 - 5	1.1 - 4.1	307 - 1,158	0.8 - 2.8	$10,585 - $38,761	$75 - $375	$1,346 - $1,440	$388 - $407
4	ML-3	Residential Rain Gardens	5 - 15	3.3 - 8.1	721 - 1,822	3.4 - 8.2	$34,381 - $96,061	$375 - $1,125	$2,110 - $2,375	$461 - $534
5	ML-6	Residential Rain Gardens (downstream of pond)	3	1.9	508	1.2	$22,045	$225	$1,889	$505
6	ML-2	Residential Rain Gardens	3 - 10	1.9 - 5.0	422 - 1,127	2.0 - 4.9	$22,045 - $65,221	$225 - $750	$2,274 - $2,595	$505 - $585
7	ML-6	Rain Garden (Elementary School)	1	0.7 - 1.7	118 - 282	1.0 - 2.0	$10,446 - $27,396	$75	$3,073 - $3,586	$510 - $605
8	ML-4	Residential Rain Gardens	10 - 30	4.6 - 11.5	862 - 2,200	6.9 - 16.4	$65,221 - $188,581	$750 - $2,250	$3,392 - $3,880	$636 - $742
9	ML-6	Iron Enhanced Sand Filter Pond Modification	1	4.3	0	0.0	$48,252	$1,550	N/A	$735
10	ML-3	Pond Modification (Creekridge Park)	1	2.0	677	0.0	$32,109	$450	$2,246	$760
11	ML-6	Residential Rain Gardens (upstream of pond)	5 - 10	1.8 - 3.3	263 - 494	3.3 - 5.8	$34,381 - $65,221	$375 - $750	$5,783 - $5,919	$845 - $886
12	ML-1	Hydrodynamic Device (59th)	1	0.5 - 0.9	224 - 392	0.0	$18,252 - $46,752	$420	$3,900 - $5,047	$1,755 - $2,198
13	ML-1	Grass Swale (Church)	1	0.4	181	0.2	$14,896	$584	$5,970	$2,701
14	ML-3	New Wet Pond (Old Central Ave.)	1	2.0	657	0.0	$164,548	$450	$9,033	$2,967
15	ML-1	Hydrodynamic Device (58th)	1	0.3 - 0.5	113 - 199	0.0	$18,252 - $46,752	$420	$7,824 - $9,942	$3,071 - $3,957

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

Directly Connected Catchment (blue)

North Network (orange)

Catchments 1 through 6: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
16	ML-6	Hydrodynamic Device (Polk)	1	0.3 - 0..5	101 - 176	0.0	$18,252 - $46,752	$420	$8,774 - $11,241	$3,071 - $3,957
17	ML-2	Hydrodynamic Device	1	0.3 - 0.4	71 - 130	0.0	$18,252 - $46,752	$420	$11,270 - $15,218	$3,071 - $4,946
18	ML-2	New Wet Pond (East Moore Lake Park)	1	2.4	701	0.0	$223,244	$450	$11,257	$3,288
19	ML-1	Permeable Asphalt (Fridley High School)	1	1.9	632	1.7	$208,662	$476	$11,758	$3,911
20	ML-5	Permeable Asphalt (Totino Grace)	1	1.7	1,001	2.8	$219,552	$501	$7,812	$4,600
21	ML-1	Permeable Asphalt (Church)	1	1.0	615	1.7	$136,752	$311	$7,917	$4,869
22	ML-6	Permeable Asphalt (High Rise Residential 0.15 acre)	1	0.5	300	0.8	$68,968	$150	$8,164	$4,898
23	ML-6	Permeable Asphalt (High Rise Residential 0.1 acre)	1	0.3	200	0.6	$47,188	$100	$8,366	$5,577
24	ML-5	Grass Swale (East Moore Lake Park)	1	0.1	68	0.1	$7,464	$584	$12,247	$8,328
25	ML-3	New Wet Pond (Rice Creek Rd.)	1	0.6	251	0.0	$240,448	$450	$33,725	$14,108

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

Directly Connected Catchment (blue)

North Network (orange)

Catchment 8: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Retrofits within catchment 8 will benefit Innsbruck Nature Center. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
1	ML-8	Residential Rain Gardens	1 - 5	0.4 - 1.5	58 - 226	0.7 - 2.1	$9,709 - $34,381	$75 - $375	$6,315 - $6,873	$960 - $1,014

Disconnected Catchment (green)

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.

Methods

The methods section outlines general procedures used when analyzing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis, and project ranking. See Appendix A for a detailed description of the methods.

Catchment Profiles

The Moore Lake subwatershed was divided into stormwater catchments for the purpose of this analysis. See Appendix B for a guide to reading the 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 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

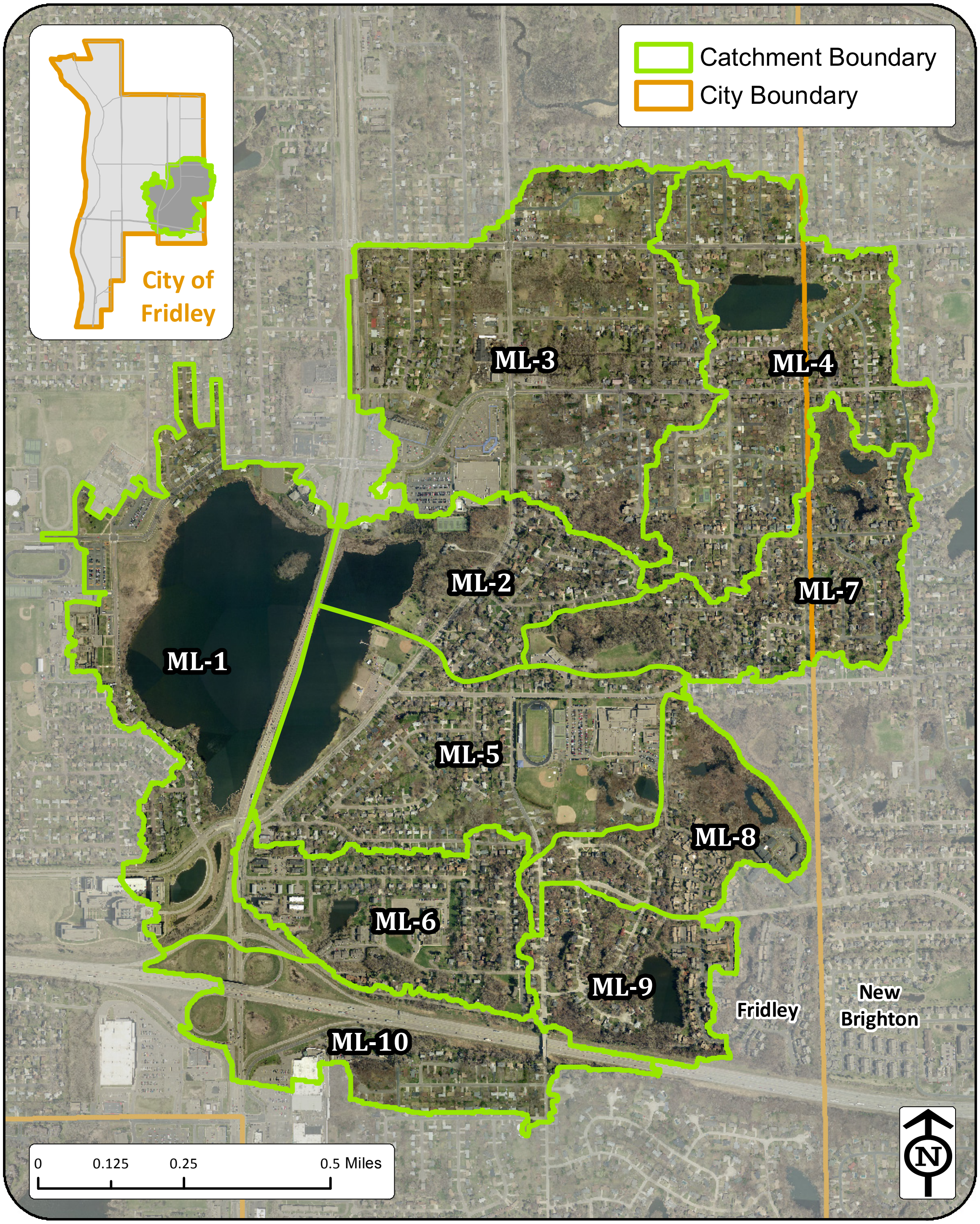
References

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.

Map of stormwater networks and catchment areas referred to in this report. Catchment profiles on the following pages provide additional detail.



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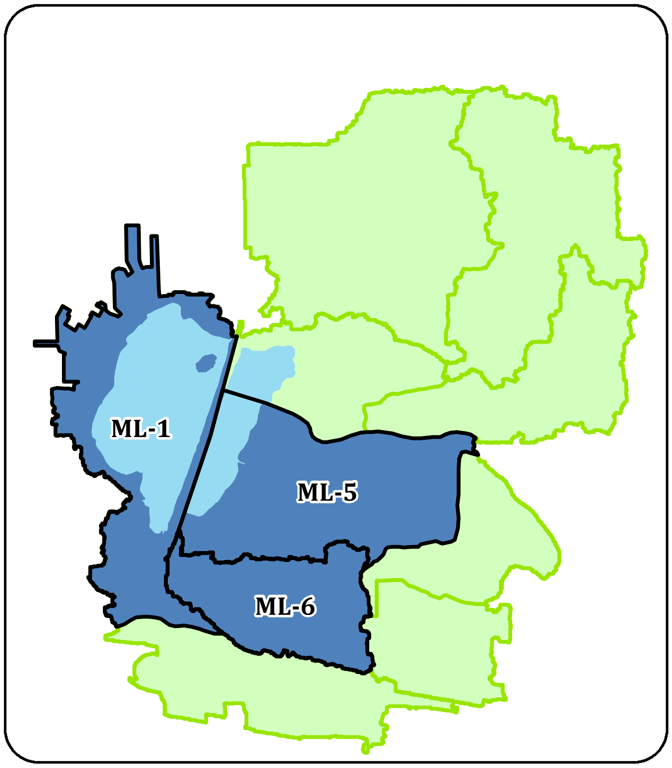
Section 1: Directly Connected Catchments

Existing Directly Connected Summary	
Acres	284
Dominant Land Cover	Residential
Parcels	610
TP (lbs/yr)	180.5
TSS (lbs/yr)	44,203
Volume (acre-feet/yr)	171.9

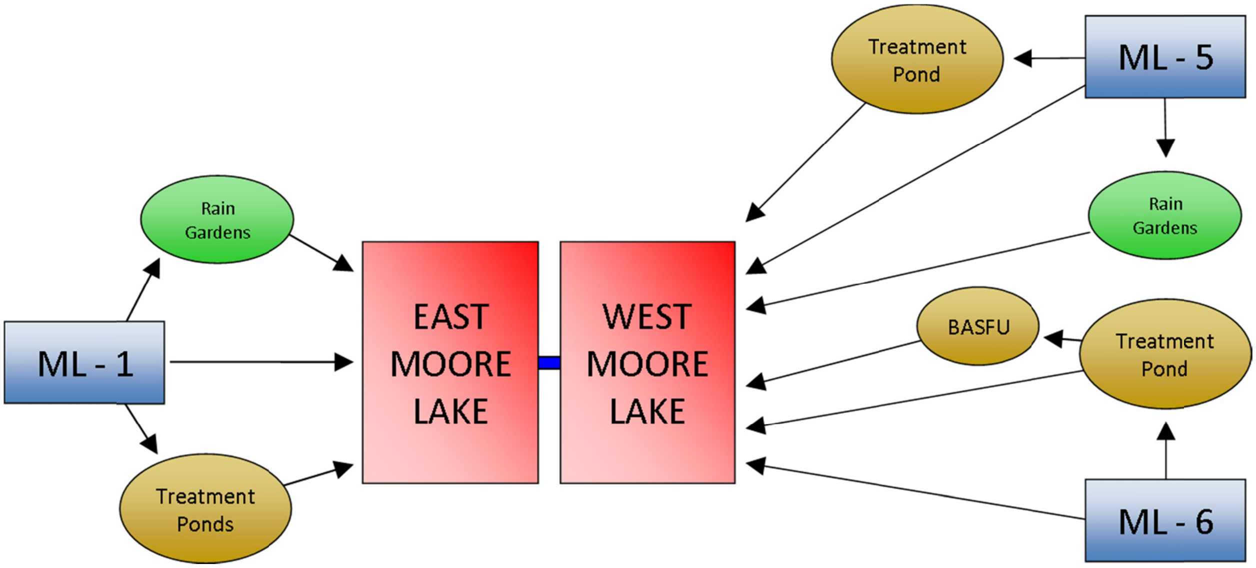


DIRECTLY CONNECTED CATCHMENTS

Catchment ID	Page
ML-1	12
ML-5	19
ML-6	27

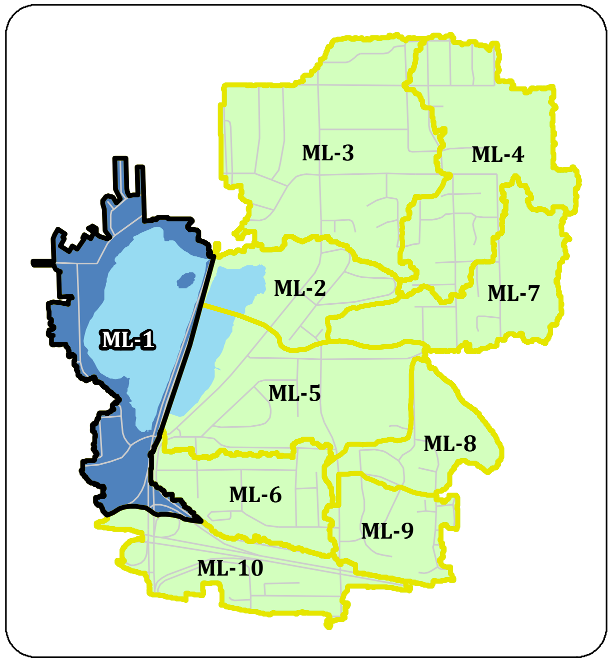
EXISTING TREATMENT

The image below represents a simplified flow network for the catchments that are directly connected to Moore Lake. Stormwater infrastructure throughout the directly connected catchments consists primarily of pipes. Existing stormwater treatment consists of several treatment ponds, curb-cut rain gardens, and street sweeping. In addition, a biologically activated soil filtration unit (BASFU) is located in catchment ML-6, though it is no longer functional.



Catchment ML-1

Existing Catchment Summary	
Acres	92
Dominant Land Cover	Residential
Parcels	129
TP (lbs/yr)	50.9
TSS (lbs/yr)	11,981
Volume (acre-feet/yr)	57.1



CATCHMENT DESCRIPTION

Catchment ML-1 consists of nine different land use types (freeway, institutional, medium density residential, multi-family residential, office park, open space, park, school, and open water). The area directly connected to West Moore Lake is encompassed within a relatively narrow fringe (0.1 – 0.2 miles wide) around the lake. It contains portions of the Fridley Middle School and Medtronic campuses and Moore Lake Park West. The entire catchment drains to West Moore Lake via stormwater infrastructure, and stormwater enters the lake through multiple inlets.

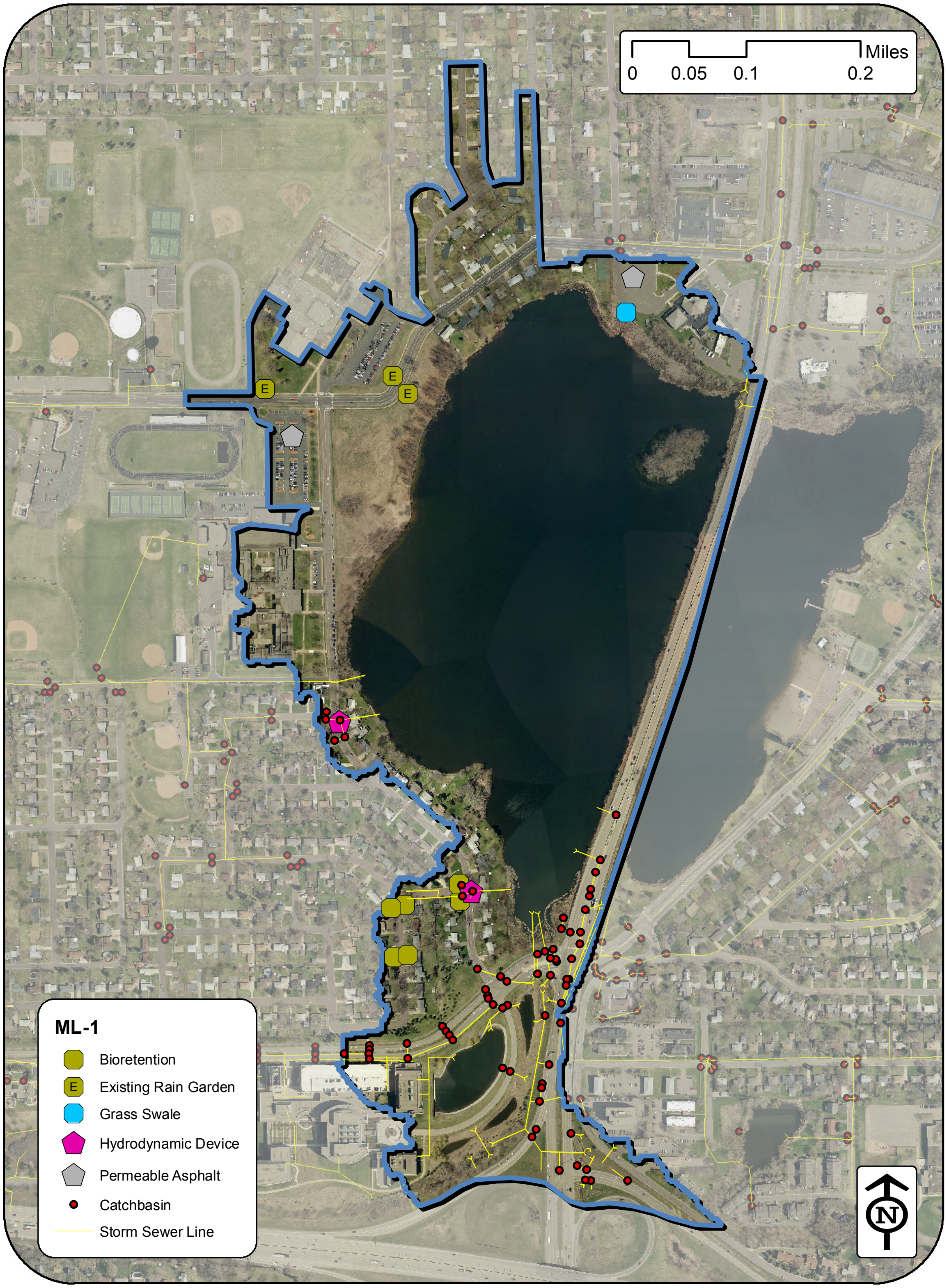
EXISTING STORMWATER TREATMENT

In addition to street sweeping by the City of Fridley, scattered stormwater treatment exists throughout catchment ML-1. The most substantial treatment exists on the Medtronic campus, which consists of three stormwater treatment ponds. Four curb-cut rain gardens also exist on the Fridley Middle School campus, which capture runoff from the campus as well as connected streets. The remaining untreated stormwater enters West Moore Lake via overland flow and more directed inlets such as stormwater pipes. The table below shows the base and existing conditions as well as how existing treatment practices within catchment ML-1 affect the stormwater volume and pollutant loads entering West Moore Lake.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	68.7	17.8	26%	**50.9**
	TSS (lb/yr)	18,856	6,875.0	36%	**11,981**
	Volume (acre-feet/yr)	66.5	9.4	14%	**57.1**
	Number of BMP's	8			
	BMP Size/Description	Medtronic ponds, Fridley Middle School rain gardens, street sweeping			

RETROFIT RECOMMENDATIONS



Project ID: ML-1 Residential Rain Gardens

Drainage Area – 21.7 acres
Location – Southwest corner of catchment ML-1 within residential land use
Property Ownership – Private
Description – Very little space is available for retrofits in this catchment. However, there are some opportunities to install curb-cut rain gardens to treat the residential land use (see Appendix C for design options). Six ideal rain garden locations were identified (see map), though more may exist. 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, 3, and 5 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 Treating Residential Land Use

	Cost/Removal Analysis	***Project ID***					
		1 Curb-Cut Rain Garden		**3 Curb-Cut Rain Gardens**		**5 Curb-Cut Rain Gardens**	
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	1.1	28%	2.7	30%	4.1	32%
	TSS (lb/yr)	307	38%	778	41%	1,158	43%
	Volume (acre-feet/yr)	0.8	15%	1.9	17%	2.8	18%
	Number of BMP's	1		3		5	
	BMP Size/Description	250	square feet	750	square feet	1,250	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	**Materials/Labor/Design**	$5,876		$17,628		$29,380	
	Promotion & Admin Costs	$4,709		$7,045		$9,381	
	Probable Project Cost	**$10,585**		**$24,673**		**$38,761**	
	Annual O&M	$75		$225		$375	
	30-yr Cost/lb-TP	**$389**		**$388**		**$407**	
	30-yr Cost/1,000lb-TSS	$1,394		$1,346		$1,440	

Project ID: ML-1 Grass Swale at St. Philip's Lutheran Church

Drainage Area – 2.0 acres
Location – Southwest corner of W Moore Lake Dr. and Highway 65 intersection
Property Ownership – Private
Description – St. Philip's Lutheran Church is located on the north side of West Moore Lake. The western side of the campus drains south through a curb-cut before entering West Moore Lake. Space is available to construct a vegetated swale that will treat stormwater before it enters the lake. Volume reduction and removal of TP and TSS are shown in the table below.

Project ID: ML-1 Permeable Asphalt at St. Philip's Lutheran Church

Drainage Area – 1.2 acres
Location – Southwest corner of W Moore Lake Dr. and Highway 65 intersection
Property Ownership – Private
Description – St. Philip's Lutheran Church is located on the north side of West Moore Lake. The western side of the campus drains south through a curb-cut before entering West Moore Lake. Stormwater runoff produced by the parking lot could be treated using permeable asphalt (see Appendix D for design options) prior to it entering the curb-cut. A detailed investigation of soils at the site would be necessary to determine acceptable infiltration capacity because of the close proximity to the lake and potentially high water table. Volume reduction and removal of TP and TSS are shown in the table below.

Church Parking Lot Grass Swale and Permeable Asphalt

	Cost/Removal Analysis	***Project ID***					
		130' Grass Swale		**0.3 acres Permeable Asphalt**			
		New trtmt	**Net %**	**New trtmt**	**Net %**		
Treatment	**TP (lb/yr)**	0.4	26%	1.0	27%		
	TSS (lb/yr)	181	37%	615	40%		
	Volume (acre-feet/yr)	0.2	14%	1.7	17%		
	Number of BMP's	1		1			
	BMP Size/Description	2,080	square feet	13,500	square feet		
	BMP Type	Dry Swale		Permeable Asphalt			
Cost	**Materials/Labor/Design**	$13,728		$135,000			
	Promotion & Admin Costs	$1,168		$1,752			
	Probable Project Cost	**$14,896**		**$136,752**			
	Annual O&M	$584		$311			
	30-yr Cost/lb-TP	**$2,701**		**$4,869**			
	30-yr Cost/1,000lb-TSS	$5,970		$7,917			

Project ID: ML-1 Permeable Asphalt at Fridley High School

Drainage Area – 1.9 acres

Location – Fridley High School parking lot west of W Moore Lake Dr.

Property Ownership – Private

Description – Fridley High School is located on the west side of W Moore Lake. Stormwater runoff from the parking lot that borders W Moore Lake Dr. could be treated using permeable asphalt (see Appendix D for design options) prior to it entering the curb-cut. A detailed investigation of soils at the site would be necessary to determine acceptable infiltration capacity because of the close proximity to the lake and potentially high water table. Volume reduction and removal of TP and TSS are shown in the table below.

Fridley High School Permeable Asphalt

	Cost/Removal Analysis	***Project ID***					
		0.475 acres Permeable Asphalt					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	1.9	29%				
	TSS (lb/yr)	632	40%				
	Volume (acre-feet/yr)	1.7	17%				
	Number of BMP's	1					
	BMP Size/Description	20,691	square feet				
	BMP Type	Permeable Asphalt					
Cost	**Materials/Labor/Design**	$206,910					
	Promotion & Admin Costs	$1,752					
	Probable Project Cost	**$208,662**					
	Annual O&M	$476					
	30-yr Cost/lb-TP	**$3,911**					
	30-yr Cost/1,000lb-TSS	$11,758					

Project ID: ML-1 Hydrodynamic Separator (near 59th Ave. NE)

Drainage Area – 9.2 acres

Location – Near intersection of W Moore Lake Dr. and 59th Ave NE.

Property Ownership – City of Fridley

Description – The confluence of multiple stormwater lines within catchment ML-1 near the intersection of W Moore Lake Dr. and 59th Ave. NE is a potential site for a hydrodynamic separator (see Appendix D for additional information). The structural best management practice uses hydrodynamic separation to remove particulate pollutants from stormwater and could be installed in place of an existing catch basin. Scenarios with 4, 6, and 8 foot diameter devices were analyzed to treat the residential and institutional land use. Removal of TP and TSS could be increased to the levels shown in the following table.

Hydrodynamic Separator (near 59th Ave. NE)

	Cost/Removal Analysis	***Project ID***					
		Hydrodynamic Separator		**Hydrodynamic Separator**		**Hydrodynamic Separator**	
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	0.9	27%	0.7	27%	0.5	27%
	TSS (lb/yr)	392	39%	315	38%	224	38%
	Volume (acre-feet/yr)	0.0	14%	0.0	14%	0.0	14%
	Number of BMP's	1		1		1	
	BMP Size/Description	8	foot diameter	6	foot diameter	4	foot diameter
	BMP Type	Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
Cost	**Materials/Labor/Design**	$45,000		$22,500		$16,500	
	Promotion & Admin Costs	$1,752		$1,752		$1,752	
	Probable Project Cost	**$46,752**		**$24,252**		**$18,252**	
	Annual O&M	$420		$420		$420	
	30-yr Cost/lb-TP	**$2,198**		**$1,755**		**$2,057**	
	30-yr Cost/1,000lb-TSS	$5,047		$3,900		$4,591	

Project ID: ML-1 Hydrodynamic Separator (near 58th Ave. NE)

Drainage Area – 6.4 acres

Location – Near intersection of W Moore Lake Dr. and 58th Ave NE.

Property Ownership – City of Fridley

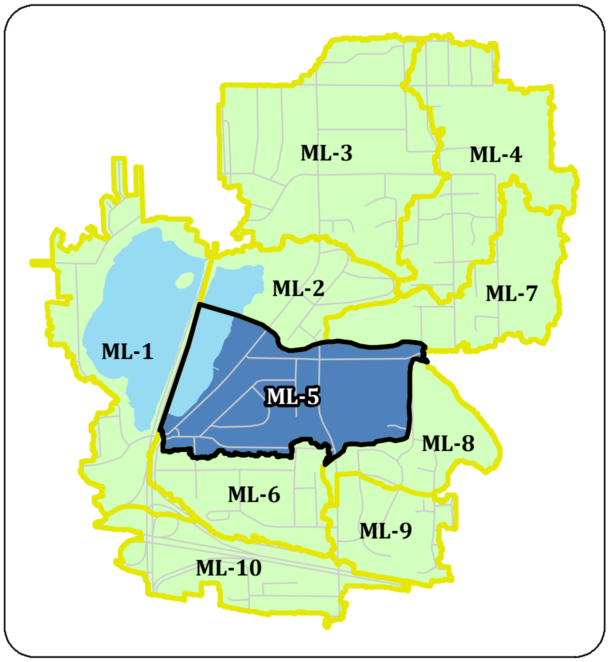
Description – The confluence of multiple stormwater lines within catchment ML-1 near the intersection of W Moore Lake Dr. and 59th Ave. NE is a potential site for a hydrodynamic separator (see Appendix D for additional information). The structural best management practice uses hydrodynamic separation to remove particulate pollutants from stormwater and could be installed in place of an existing catch basin. Scenarios with 4, 6, and 8 foot diameter devices were analyzed to treat the residential land use. Volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

Hydrodynamic Separator (near 58th Ave. NE)

	Cost/Removal Analysis	Project ID					
		Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.5	27%	0.4	26%	0.3	26%
	TSS (lb/yr)	199	38%	157	37%	113	37%
	Volume (acre-feet/yr)	0.0	14%	0.0	14%	0.0	14%
	Number of BMP's	1		1			
	BMP Size/Description	8	foot diameter	6	foot diameter	4	foot diameter
	BMP Type	Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
Cost	Materials/Labor/Design	$45,000		$22,500		$16,500	
	Promotion & Admin Costs	$1,752		$1,752		$1,752	
	Probable Project Cost	**$46,752**		**$24,252**		**$18,252**	
	Annual O&M	$420		$420		$420	
	30-yr Cost/lb-TP	**$3,957**		**$3,071**		**$3,428**	
	30-yr Cost/1,000lb-TSS	$9,942		$7,824		$9,101	

Catchment ML-5

Existing Catchment Summary	
Acres	120
Dominant Land Cover	Residential, School
Parcels	245
TP (lbs/yr)	92.2
TSS (lbs/yr)	24,157
Volume (acre-feet/yr)	66.1



CATCHMENT DESCRIPTION

Catchment ML-5 consists of medium density residential, park land, open water, and school land uses. Most of the eastern half of the catchment is comprised of Totino Grace High School and its athletic fields and other associated structures, while the western half is primarily a residential neighborhood. Moore Lake Park and Beach occupies much of the shoreline along the lake.

EXISTING STORMWATER TREATMENT

Existing stormwater treatment within catchment ML-5 consists of rain gardens, stormwater treatment ponds on and nearby the Totino Grace High School campus, and street sweeping by the City of Fridley. Stormwater is generally conveyed from east to west into East Moore Lake via stormwater infrastructure. With the exception of one residential curb-cut rain garden, stormwater from the residential neighborhoods west of Totino Grace High School receives no treatment prior to entering East Moore Lake. The table below shows how existing treatment practices within catchment ML-5 affect the stormwater volume and pollutant loads entering East Moore Lake.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	105.5	13.3	13%	**92.2**
	TSS (lb/yr)	28,475	4,318.0	15%	**24,157**
	Volume (acre-feet/yr)	69.8	3.7	5%	**66.1**
	Number of BMP's	6			
	BMP Size/Description	Rain gardens, Totino Grace High School ponds, street sweeping			

RETROFIT RECOMMENDATIONS

Project ID: ML-5 Residential Rain Gardens

Drainage Area – 63.4 acres
Location – Throughout catchment ML-5 in residential land use
Property Ownership – Private
Description – The residential nature of this catchment makes it best suited to curb-cut rain gardens (see Appendix C for design options). Twenty nine ideal rain garden locations were identified (see map), though more exist. 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 5, 10, and 20 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 Treating Residential Land Use

	Cost/Removal Analysis	***Project ID***					
		5 Curb-Cut Rain Garden		**10 Curb-Cut Rain Gardens**		**20 Curb-Cut Rain Gardens**	
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	5.0	17%	9.0	21%	15.1	27%
	TSS (lb/yr)	1,425	20%	2,542	24%	4,221	30%
	Volume (acre-feet/yr)	3.5	10%	6.2	14%	10.3	20%
	Number of BMP's	5		10		20	
	BMP Size/Description	1,250	square feet	2,500	square feet	5,000	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	**Materials/Labor/Design**	$29,380		$58,760		$117,520	
	Promotion & Admin Costs	$9,381		$15,221		$26,901	
	Probable Project Cost	**$38,761**		**$73,981**		**$144,421**	
	Annual O&M	$375		$750		$1,500	
	30-yr Cost/lb-TP	**$333**		**$357**		**$418**	
	30-yr Cost/1,000lb-TSS	$1,170		$1,265		$1,496	

Project ID: ML-5 Permeable Asphalt at Totino Grace High School

Drainage Area – 2.0 acres
Location – Main parking lot on west side of Totino Grace High School
Property Ownership – Totino Grace High School
Description – Totino Grace High School is located on the eastern side of catchment ML-5. Stormwater runoff from the main parking lot could be treated using permeable asphalt (see Appendix D for design options) prior to it entering the stormwater infrastructure. Permeable asphalt is well suited to this area because of the large amount of impervious surface. Volume reduction and removal of TP and TSS are shown in the table below.

Totino Grace High School Permeable Asphalt

	Cost/Removal Analysis	Project ID					
		0.50 acres Permeable Asphalt					
		New trtmt	Net %				
Treatment	TP (lb/yr)	1.7	27%				
	TSS (lb/yr)	1,001	39%				
	Volume (acre-feet/yr)	2.8	18%				
	Number of BMP's	1					
	BMP Size/Description	21,780	square feet				
	BMP Type	Permeable Asphalt					
Cost	Materials/Labor/Design	$217,800					
	Promotion & Admin Costs	$1,752					
	Probable Project Cost	**$219,552**					
	Annual O&M	$501					
	30-yr Cost/lb-TP	**$4,600**					
	30-yr Cost/1,000lb-TSS	$7,812					

Project ID: ML-5 Hydrodynamic Separator (Hackman Ave. NE)

Drainage Area – 6.4 acres

Location – Near intersection of Hackman Ave. NE and Hackman Circle NE

Property Ownership – City of Fridley

Description – The confluence of multiple stormwater lines within catchment ML-5 near the intersection of Hackman Ave. NE and Hackman Circle NE is a potential site for a hydrodynamic separator (see Appendix D for additional information). The structural best management practice uses hydrodynamic separation to remove particulate pollutants from stormwater and could be installed in place of an existing catch basin. Scenarios with 4, 6, and 8 foot diameter devices were analyzed to treat the residential land use. Volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

Hydrodynamic Separator (Hackman Ave. NE)

	Cost/Removal Analysis	***Project ID***					
		Hydrodynamic Separator		**Hydrodynamic Separator**		**Hydrodynamic Separator**	
		New trtmt	**Net %**	**New trtmt**	**Net %**	**New trtmt**	**Net %**
Treatment	**TP (lb/yr)**	8.0	36%	7.9	36%	7.7	36%
	TSS (lb/yr)	3,401	52%	3,355	51%	3,304	51%
	Volume (acre-feet/yr)	0.0	14%	0.0	14%	0.0	14%
	Number of BMP's	1		1		1	
	BMP Size/Description	8	foot diameter	6	foot diameter	4	foot diameter
	BMP Type	Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
Cost	**Materials/Labor/Design**	$45,000		$22,500		$16,500	
	Promotion & Admin Costs	$1,752		$1,752		$1,752	
	Probable Project Cost	**$46,752**		**$24,252**		**$18,252**	
	Annual O&M	$420		$420		$420	
	30-yr Cost/lb-TP	**$247**		**$155**		**$134**	
	30-yr Cost/1,000lb-TSS	$582		$366		$311	

Project ID: ML-5 Grass Swale at East Moore Lake Park

Drainage Area – 0.64 acres
Location – Northwest corner of parking lot in East Moore Lake Park
Property Ownership – City of Fridley
Description – Portions of the main parking lot within East Moore Lake Park currently drain directly to Moore Lake without any stormwater treatment. The northern portion of the parking lot drains to the northwest into a paved swale that transports stormwater directly to the lake. Space is available to construct a vegetated swale that will treat stormwater before it enters the lake. Volume reduction and removal of TP and TSS are shown in the table below.

East Moore Lake Park Parking Lot Grass Swale

	Cost/Removal Analysis	***Project ID***					
		106' Grass Swale					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	0.1	13%				
	TSS (lb/yr)	68	15%				
	Volume (acre-feet/yr)	0.1	5%				
	Number of BMP's	1					
	BMP Size/Description	954	square feet				
	BMP Type	Dry Swale					
Cost	**Materials/Labor/Design**	$6,296					
	Promotion & Admin Costs	$1,168					
	Probable Project Cost	**$7,464**					
	Annual O&M	$584					
	30-yr Cost/lb-TP	**$8,328**					
	30-yr Cost/1,000lb-TSS	$12,247					

Project ID: ML-5 New Pond in East Moore Lake Park

Drainage Area – 101 acres

Location – South of the parking lot in East Moore Lake Park

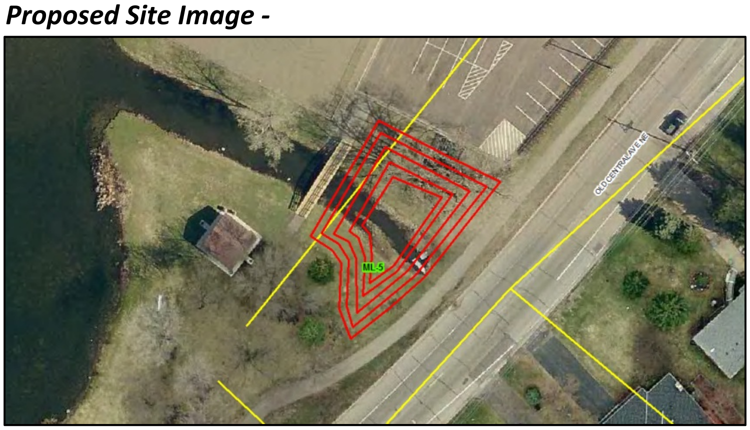
Property Ownership – City of Fridley

Description – Stormwater runoff currently generated within catchment ML-5 is primarily routed through stormwater infrastructure (101 of 120 acres) and outlets to Moore Lake within East Moore Lake Park untreated. Some space is available within the park to develop a wet pond that would serve as pretreatment for the runoff prior to it entering the lake. Additional engineering and feasibility analysis is required before the project could move forward. Removal of TP and TSS are shown in the table below.

East Moore Lake Park New Pond

	Cost/Removal Analysis	***Project ID***					
		New Pond - East Moore Lake Park					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	15.5	27%				
	TSS (lb/yr)	5,972	36%				
	Volume (acre-feet/yr)	0.0	5%				
	Number of BMP's	1					
	BMP Size/Description	522	cubic yards				
	BMP Type	Wet Pond					
Cost	**Materials/Labor/Design**	$45,337					
	Promotion & Admin Costs	$5,840					
	Probable Project Cost	**$51,177**					
	Annual O&M	$700					
	30-yr Cost/lb-TP	**$155**					
	30-yr Cost/1,000lb-TSS	$403					

Proposed Site Image -



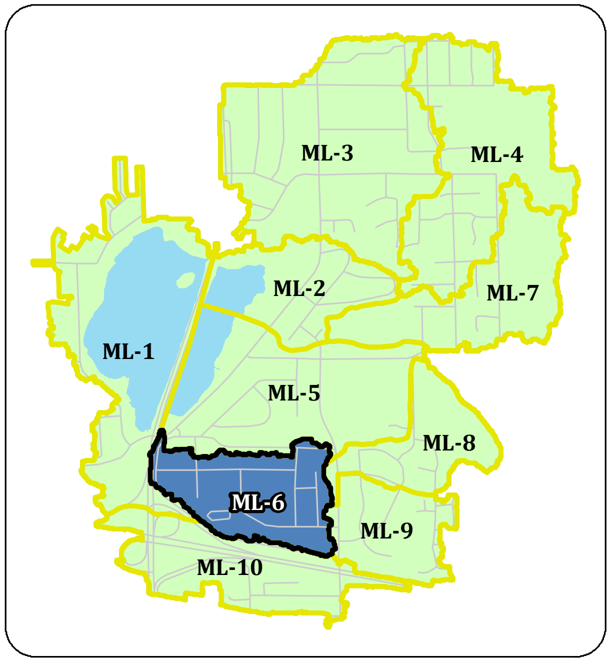
Additional Retrofit Considerations

If the retrofits proposed for this catchment are inadequate due to limited landowner participation or if additional treatment is desired, below is a list of other retrofits that could be used in this catchment. However, detailed model and cost estimates were not developed because the practices would be cost prohibitive or provide minimal pollutant reduction relative to the proposed retrofits for this catchment.

- Underground storage and reuse at Totino Grace High School

Catchment ML-6

Existing Catchment Summary	
Acres	72
Dominant Land Cover	Residential
Parcels	236
TP (lbs/yr)	37.4
TSS (lbs/yr)	8,065
Volume (acre-feet/yr)	48.7



CATCHMENT DESCRIPTION

Catchment ML-6 contains a wide range of land uses including medium density residential, multi-family residential, office park, and North Park Elementary School. The catchment is located north of I-694 and east of Central Avenue North.

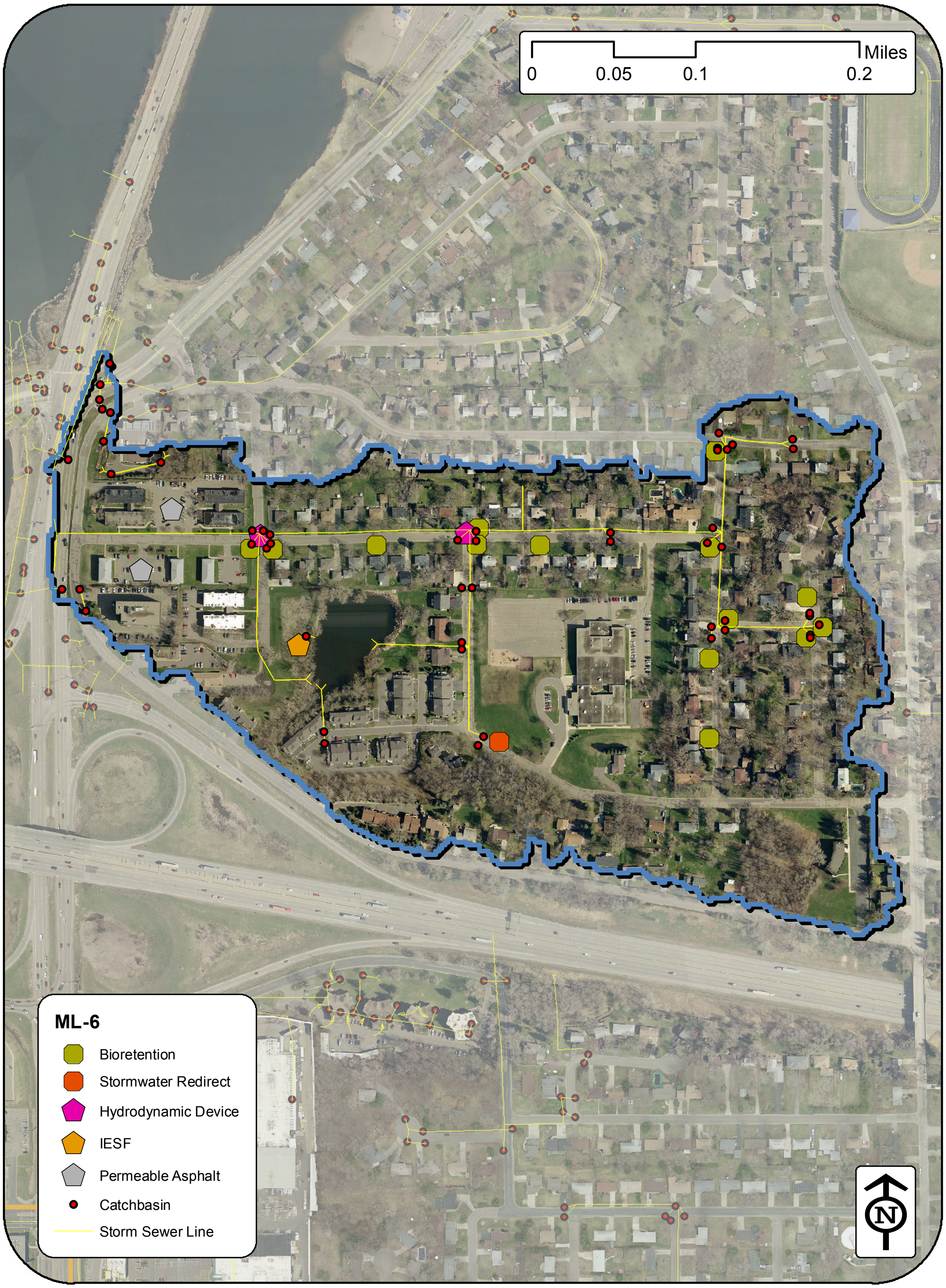
EXISTING STORMWATER TREATMENT

Existing stormwater treatment in catchment ML-6 consists of a large stormwater pond, a smaller pond that treats a portion of the Holiday gas station, and street sweeping by the City of Fridley. The large stormwater pond located near the center of the catchment treats stormwater from approximately 75% (55 acres) of catchment ML-6. A biologically activated soil filtration unit (BASFU) located on the west side of the pond was originally designed and constructed as additional treatment, but it has been disconnected for many years and therefore provides no current stormwater treatment. The table below shows how existing treatment practices within catchment ML-6 affect the stormwater volume and pollutant loads entering East Moore Lake.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	66.1	28.7	43%	**37.4**
	TSS (lb/yr)	18,009	9,944.0	55%	**8,065**
	Volume (acre-feet/yr)	49.2	0.5	1%	**48.7**
	Number of BMP's	3			
	BMP Size/Description	Holiday pond, pond, street sweeping			

RETROFIT RECOMMENDATIONS



Project ID: ML-6 Residential Rain Gardens Downstream of Existing Stormwater Pond

Drainage Area – 5.2 acres

Location – Downstream of stormwater treatment pond along Lynde Dr. NE

Property Ownership – Private

Description – The residential nature of this catchment makes it best suited to curb-cut rain gardens (see Appendix C for design options). Three ideal rain garden locations were identified (see map), though more may exist. The rain gardens downstream of the pond were modeled separately as to remove the treatment train effects associated with the existing stormwater treatment pond because stormwater treated by the proposed gardens is not currently treated by the pond. Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical landowner participation rates, a scenario with three rain gardens was 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

Residential Rain Gardens

	Cost/Removal Analysis	***Project ID***					
		3 Curb-Cut Rain Gardens					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	1.9	46%				
	TSS (lb/yr)	508	58%				
	Volume (acre-feet/yr)	1.2	3%				
	Number of BMP's	3					
	BMP Size/Description	750	square feet				
	BMP Type	Complex Bioretention					
Cost	**Materials/Labor/Design**	$15,000					
	Promotion & Admin Costs	$7,045					
	Probable Project Cost	**$22,045**					
	Annual O&M	$225					
	30-yr Cost/lb-TP	**$505**					
	30-yr Cost/1,000lb-TSS	$1,889					

Project ID: ML-6 Residential Rain Gardens Upstream of Existing Stormwater Pond

Drainage Area – 41.3 acres
Location – Upstream of stormwater treatment pond
Property Ownership – Private
Description – The residential nature of this catchment makes it best suited to curb-cut rain gardens (see Appendix C for design options). Eleven ideal rain garden locations were identified (see map), though more may exist. The rain gardens upstream of the pond were modeled separately as to represent the treatment train effects associated with the existing stormwater treatment pond. 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 5 and 10 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

Residential Rain Gardens

	Cost/Removal Analysis	***Project ID***					
		5 Curb-Cut Rain Gardens		**10 Curb-Cut Rain Gardens**			
		New trtmt	**Net %**	**New trtmt**	**Net %**		
Treatment	**TP (lb/yr)**	1.8	46%	3.3	48%		
	TSS (lb/yr)	263	57%	494	58%		
	Volume (acre-feet/yr)	3.3	8%	5.8	13%		
	Number of BMP's	5		10			
	BMP Size/Description	1,250	square feet	2,500	square feet		
	BMP Type	Complex Bioretention		Complex Bioretention			
Cost	**Materials/Labor/Design**	$25,000		$50,000			
	Promotion & Admin Costs	$9,381		$15,221			
	Probable Project Cost	**$34,381**		**$65,221**			
	Annual O&M	$375		$750			
	30-yr Cost/lb-TP	**$845**		**$886**			
	30-yr Cost/1,000lb-TSS	$5,783		$5,919			

Project ID: ML-6 Rain Garden at North Park Elementary School

Drainage Area – 5.0 acres

Location – South side of North Park Elementary School Campus

Property Ownership – North Park Elementary School

Description – Substantial open space exists on the south side of the North Park Elementary School campus along Regis Ln. NE (labeled stormwater redirect in the retrofit recommendations map). A curb-cut rain garden could be installed to treat stormwater runoff from 5 acres of residential land use. Three garden sizes (500 sq. ft., 1,000 sq. ft., and 2,000 sq. ft.) were analyzed to treat the contributing 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

North Park Elementary School Rain Garden

	Cost/Removal Analysis	Project ID					
		2,000 sq. ft. Curb-Cut Rain Gardens		1,000 sq. ft. Curb-Cut Rain Gardens		500 sq. ft. Curb-Cut Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	1.7	46%	1.2	45%	0.7	44%
	TSS (lb/yr)	282	57%	199	56%	118	56%
	Volume (acre-feet/yr)	2.0	5%	1.5	4%	1.0	3%
	Number of BMP's	1		1		1	
	BMP Size/Description	2,000	square feet	1,000	square feet	500	square feet
	BMP Type	Simple Bioretention		Simple Bioretention		Simple Bioretention	
Cost	Materials/Labor/Design	$24,476		$13,176		$7,526	
	Promotion & Admin Costs	$2,920		$2,920		$2,920	
	Probable Project Cost	**$27,396**		**$16,096**		**$10,446**	
	Annual O&M	$75		$75		$75	
	30-yr Cost/lb-TP	**$581**		**$510**		**$605**	
	30-yr Cost/1,000lb-TSS	$3,504		$3,073		$3,586	

Project ID: ML-6 Permeable Asphalt at High Rise Residential along Lynde Dr. NE

Drainage Area – 0.6 acres or 0.4 acres
Location – Main parking lots of high rise residential buildings along Lynde Dr. NE
Property Ownership – Private
Description – Two apartment complexes are located on either side of Lynde Dr. NE between Hillwind Rd. NE and Polk St. NE. Both parking lots could be treated using permeable asphalt (see Appendix D for design options) prior to it entering the stormwater infrastructure. Permeable asphalt is well suited to this area because of the large amount of impervious surface. Volume reduction and removal of TP and TSS are shown in the table below.

High Rise Residential Permeable Asphalt

	Cost/Removal Analysis	*Project ID*					
		Permeable Asphalt - 0.15 acre		Permeable Asphalt - 0.1 acre			
		New trtmt	Net %	New trtmt	Net %		
Treatment	TP (lb/yr)	0.5	44%	0.3	44%		
	TSS (lb/yr)	300	57%	200	56%		
	Volume (acre-feet/yr)	0.8	3%	0.6	2%		
	Number of BMP's	1		1			
	BMP Size/Description	6,534	square feet	4,356	square feet		
	BMP Type	Permeable Asphalt		Permeable Asphalt			
Cost	Materials/Labor/Design	$67,216		$45,436			
	Promotion & Admin Costs	$1,752		$1,752			
	Probable Project Cost	**$68,968**		**$47,188**			
	Annual O&M	$150		$100			
	30-yr Cost/lb-TP	**$4,898**		**$5,577**			
	30-yr Cost/1,000lb-TSS	$8,164		$8,366			

Project ID: ML-6 Hydrodynamic Separator (Polk St. NE)

Drainage Area – 5.2 acres

Location – Near intersection of Polk St. NE and Lynde Dr. NE

Property Ownership – City of Fridley

Description – The confluence of multiple stormwater lines within catchment ML-6 near the intersection of Polk St. NE and Lynde Dr. NE is a potential site for a hydrodynamic separator (see Appendix D for additional information). The structural best management practice uses hydrodynamic separation to remove particulate pollutants from stormwater and could be installed in place of an existing catch basin. Scenarios with 4, 6, and 8 foot diameter devices were analyzed to treat the residential land use. Removal of TP and TSS could be increased to the levels shown in the following table.

Hydrodynamic Separator (Polk St. NE)

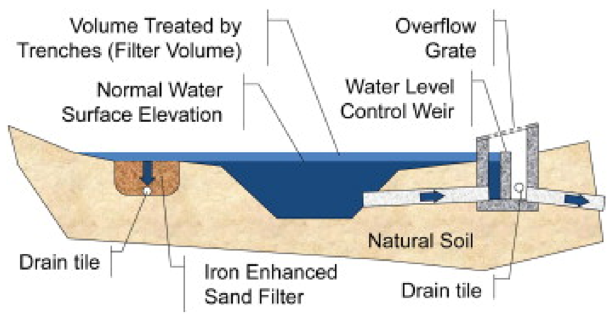
	Cost/Removal Analysis	*Project ID*					
		Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.5	44%	0.4	44%	0.3	44%
	TSS (lb/yr)	176	56%	140	56%	101	56%
	Volume (acre-feet/yr)	0.0	1%	0.0	1%	0.0	1%
	Number of BMP's	1		1		1	
	BMP Size/Description	8	foot diameter	6	foot diameter	4	foot diameter
	BMP Type	Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
Cost	Materials/Labor/Design	$45,000		$22,500		$16,500	
	Promotion & Admin Costs	$1,752		$1,752		$1,752	
	Probable Project Cost	**$46,752**		**$24,252**		**$18,252**	
	Annual O&M	$420		$420		$420	
	30-yr Cost/lb-TP	**$3,957**		**$3,071**		**$3,428**	
	30-yr Cost/1,000lb-TSS	$11,241		$8,774		$10,182	

Project ID: ML-6 Iron enhanced sand filter for existing pond

Drainage Area – 54.6 acres
Location – West side of wet detention pond located in the center of catchment ML-6
Property Ownership – City of Fridley
Description – Retrofitting the existing wet pond with an iron enhanced sand filter along the eastern edge of the pond would increase the pond's efficiency at removing dissolved phosphorus (Erickson & Gulliver 2010). A significant percentage of phosphorus in stormwater is dissolved (30% - 45%).

The iron enhanced sand filter would be installed at an elevation slightly above the normal water level of the pond so that following a storm event the increase in depth of the pond would be first diverted to the iron enhanced sand filter. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet (see schematic below). Large storm events that overwhelm the iron enhanced sand filter's capacity would exit the pond via the existing outlet.

Based on available space and the relatively large contributing drainage area, a 230 foot long by 100 foot wide by 2 foot deep filter with one foot of live storage above the iron enhanced sand filter was modeled. Network-wide volume and pollutant removal are shown in the table below. Please note that the iron enhanced sand filter would need to be an engineered project.



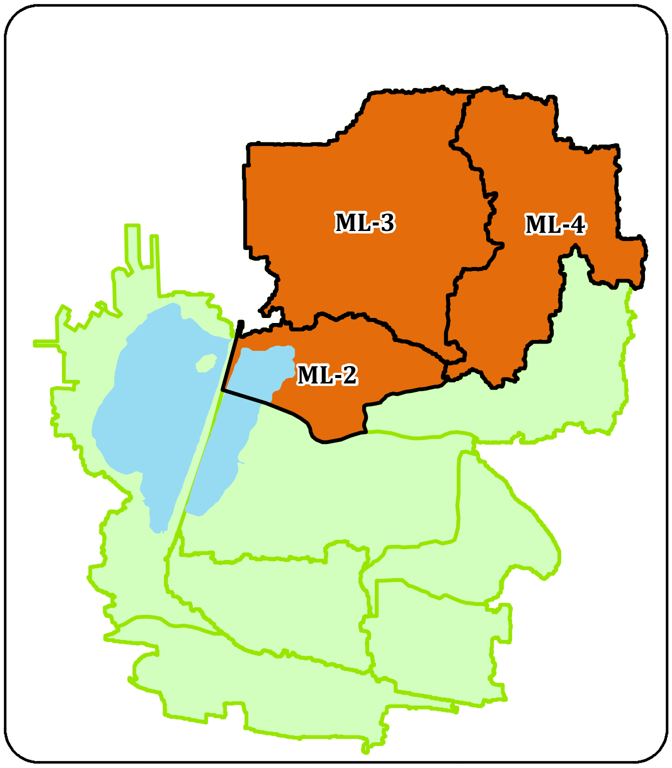
(Erickson & Gulliver 2010)

Iron Enhanced Sand Filter

	Cost/Removal Analysis	Project ID					
		IESF					
		New trtmt	Net %				
Treatment	TP (lb/yr)	4.3	50%				
	TSS (lb/yr)	0	55%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	1					
	BMP Size/Description	230	linear feet				
	BMP Type	Perimeter Iron Enhanced Sand Filter					
Cost	Materials/Labor/Design	$46,500					
	Promotion & Admin Costs	$1,752					
	Probable Project Cost	**$48,252**					
	Annual O&M	$1,550					
	30-yr Cost/lb-TP	**$735**					
	30-yr Cost/1,000lb-TSS	N/A					

Section 2: North Network

Existing Network Summary	
Acres	375
Dominant Land Cover	Residential, Park, Commercial
Parcels	922
TP (lbs/yr)	211.9
TSS (lbs/yr)	38,909
Volume (acre-feet/yr)	223.5

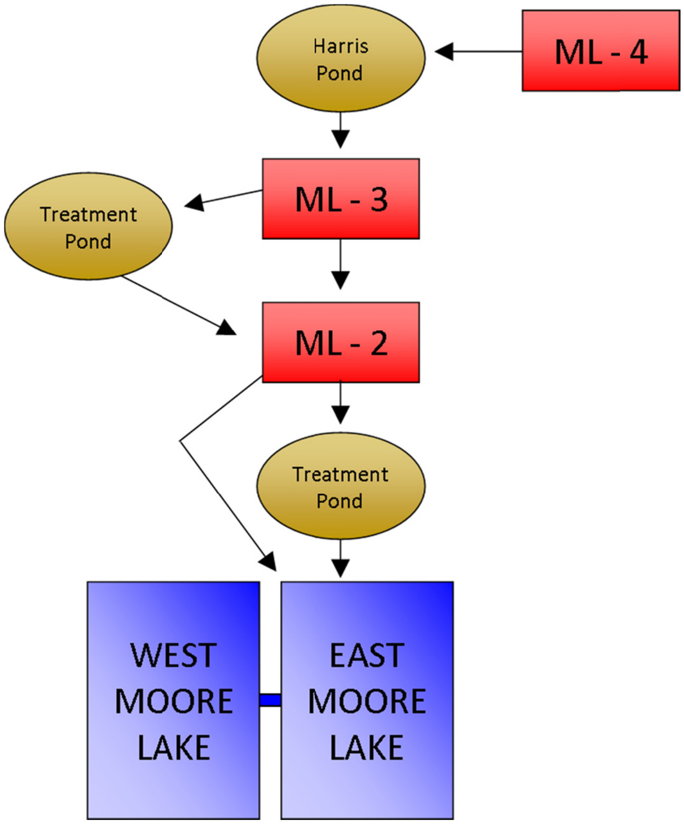


NETWORK CATCHMENTS

Catchment ID	Page
ML-2	36
ML-3	41
ML-4	47

EXISTING NETWORK TREATMENT

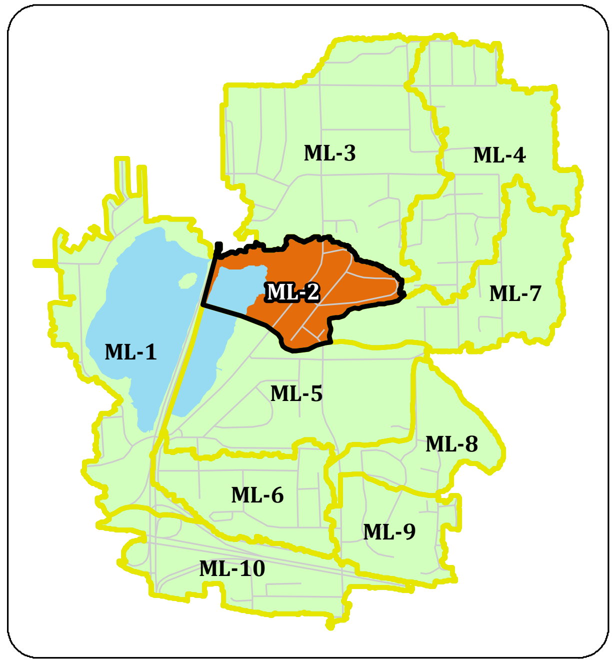
The image to the right represents a simplified flow network for the catchments within the North Network connected to East Moore Lake. Stormwater infrastructure throughout the connected catchments consists of pipes and open channel ditches. Existing stormwater treatment consists of several treatment ponds and street sweeping. The combination of these existing treatment practices results in a 36% TP reduction relative to base conditions. Connected catchments will only have network level reductions reported in the catchment profile because those reductions most accurately reflect the benefit to Moore Lake and the true cost effectiveness of each project.



Catchment ML-2

Existing Catchment Summary*	
Acres	58
Dominant Land Cover	Residential, Park
Parcels	130
TP (lbs/yr)	42.5
TSS (lbs/yr)	10,090
Volume (acre-feet/yr)	24.5

**Excludes network-wide treatment practices*



CATCHMENT DESCRIPTION

Catchment ML-2 consists of five different land use types (freeway, medium density residential, open space, park, and open water). The catchment drains directly to East Moore Lake and is positioned on the northeast side of the lake. Residential land use is approximately 70% of the total area, while Moore Lake Park represents 24% of the area.

EXISTING STORMWATER TREATMENT

In addition to street sweeping by the City of Fridley, the majority of stormwater generated from the residential land use in catchment ML-2 passes through a treatment pond located on the north side of the lake. The pond is undersized because it receives stormwater from catchments ML-2, ML-3, and ML-4 (approximately 374 acres). Most of Moore Lake Park enters the lake untreated. The table below shows the network-wide base and existing conditions. The network-wide table shows how existing treatment practices within catchment ML-2 affect the stormwater volume and pollutant load in East Moore Lake.

Network-Wide Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	332.3	120.4	36%	**211.9**
	TSS (lb/yr)	85,347	46,438.0	54%	**38,909**
	Volume (acre-feet/yr)	226.1	2.6	1%	**223.5**
	Number of BMP's	9			
	BMP Size/Description	Ponds, rain garden, exfiltration pipe, street sweeping			

RETROFIT RECOMMENDATIONS

Project ID: ML-2 Residential Rain Gardens

Drainage Area – 28 acres
Location – East of Old Central Ave. NE, predominantly along Woody Ln. NE
Property Ownership – Private
Description – The residential land use within this catchment is well suited for curb-cut rain gardens (see Appendix C for design options). Ten ideal rain garden locations were identified (see map), though more exist. 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 3, 5, and 10 rain gardens were analyzed to treat the residential land use. Network-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

Rain Gardens Treating Single Family, Medium Density Residential Land Use (Network-Wide)

	Cost/Removal Analysis	Project ID: 3 - Curb-Cut Rain Gardens		5 - Curb-Cut Rain Gardens		10 - Curb-Cut Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	1.9	37%	3.0	37%	5.0	38%
	TSS (lb/yr)	422	55%	657	55%	1,127	56%
	Volume (acre-feet/yr)	2.0	2%	3.0	2%	4.9	3%
	Number of BMP's	3		5		10	
	BMP Size/Description	750	square feet	1,250	square feet	2,500	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$15,000		$25,000		$50,000	
	Promotion & Admin Costs	$7,045		$9,381		$15,221	
	Probable Project Cost	**$22,045**		**$34,381**		**$65,221**	
	Annual O&M	$225		$375		$750	
	30-yr Cost/lb-TP	**$505**		**$507**		**$585**	
	30-yr Cost/1,000lb-TSS	$2,274		$2,315		$2,595	

Project ID: ML-2 Hydrodynamic Separator (Old Central Ave. NE)

Drainage Area – 17 acres

Location – Old Central Ave. NE near East Moore Lake Park

Property Ownership – City of Fridley

Description – The confluence of multiple stormwater lines within catchment ML-2 along Old Central Ave. NE near East Moore Lake Park is a potential site for a hydrodynamic separator (see Appendix D for additional information). The structural best management practice uses hydrodynamic separation to remove particulate pollutants from stormwater and could be installed in place of an existing catch basin. Scenarios with 4, 6, and 8 foot diameter devices were analyzed to treat the residential land use. Volume reduction and removal of TP and TSS could be increased to the levels shown in the following table.

Hydrodynamic Separator

	Cost/Removal Analysis	*Project ID*					
		Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.4	36%	0.4	36%	0.3	36%
	TSS (lb/yr)	130	55%	109	55%	71	54%
	Volume (acre-feet/yr)	0.0	1%	0.0	1%	0.0	1%
	Number of BMP's	1		1		1	
	BMP Size/Description	8	foot diameter	6	foot diameter	4	foot diameter
	BMP Type	Hydrodynamic Separator		Hydrodynamic Separator		Hydrodynamic Separator	
Cost	Materials/Labor/Design	$45,000		$22,500		$16,500	
	Promotion & Admin Costs	$1,752		$1,752		$1,752	
	Probable Project Cost	**$46,752**		**$24,252**		**$18,252**	
	Annual O&M	$420		$420		$420	
	30-yr Cost/lb-TP	**$4,946**		**$3,071**		**$3,428**	
	30-yr Cost/1,000lb-TSS	$15,218		$11,270		$14,485	

Project ID: ML-2 New Pond

Drainage Area – 17 acres

Location – West of Old Central Ave. NE near Woody Ln. NE

Property Ownership – City of Fridley

Description – Substantial open space exists west of Old Central Ave. NE near Woody Ln. NE. The property is owned by the City of Fridley and presents an opportunity for a new stormwater wet pond. Redirection of existing stormwater lines to the new pond is an option to provide additional treatment to the residential land use within catchment ML-2.

Analysis was completed for excavating the pond to provide four feet of ponding. Due to the existing topography within the proposed pond area, significant excavation is required to achieve the desired ponding depth. The network-wide modeled annual TP removal is only 2.4 pounds because most of the phosphorus is already treated by the existing pond on the north side of East Moore Lake. Additional engineering and feasibility analysis is required before the project could move forward. Network-wide removal of TSS and TP could be increased to the levels shown in the following table.

New Pond

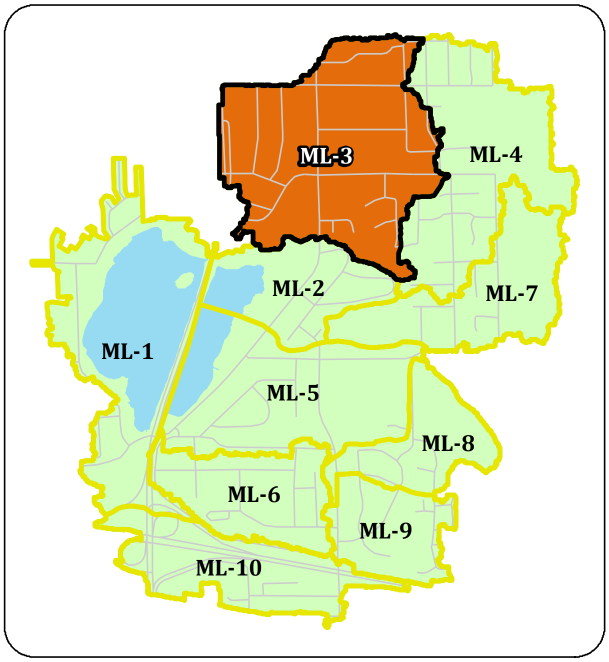
	Cost/Removal Analysis	***Project ID***					
		New Pond in East Moore Lake Park					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	2.4	37%				
	TSS (lb/yr)	701	55%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	1					
	BMP Size/Description	8,878	cubic yards				
	BMP Type	Wet Pond					
Cost	**Materials/Labor/Design**	$217,404					
	Promotion & Admin Costs	$5,840					
	Probable Project Cost	**$223,244**					
	Annual O&M	$450					
	30-yr Cost/lb-TP	**$3,288**					
	30-yr Cost/1,000lb-TSS	$11,257					

Proposed Site Image -

Catchment ML-3

Existing Catchment Summary*	
Acres	186
Dominant Land Cover	Residential, Commercial
Parcels	374
TP (lbs/yr)	146.2
TSS (lbs/yr)	42,912
Volume (acre-feet/yr)	123.4

**Excludes network-wide treatment practices*



CATCHMENT DESCRIPTION

Catchment ML-3 consists of 7 different land use types (freeway, office park, open space, park, commercial, high-rise residential and medium density residential). The catchment drains into the northeast corner of East Moore Lake. Medium density residential makes up 66% of the catchment and strip commercial makes up another 14%.

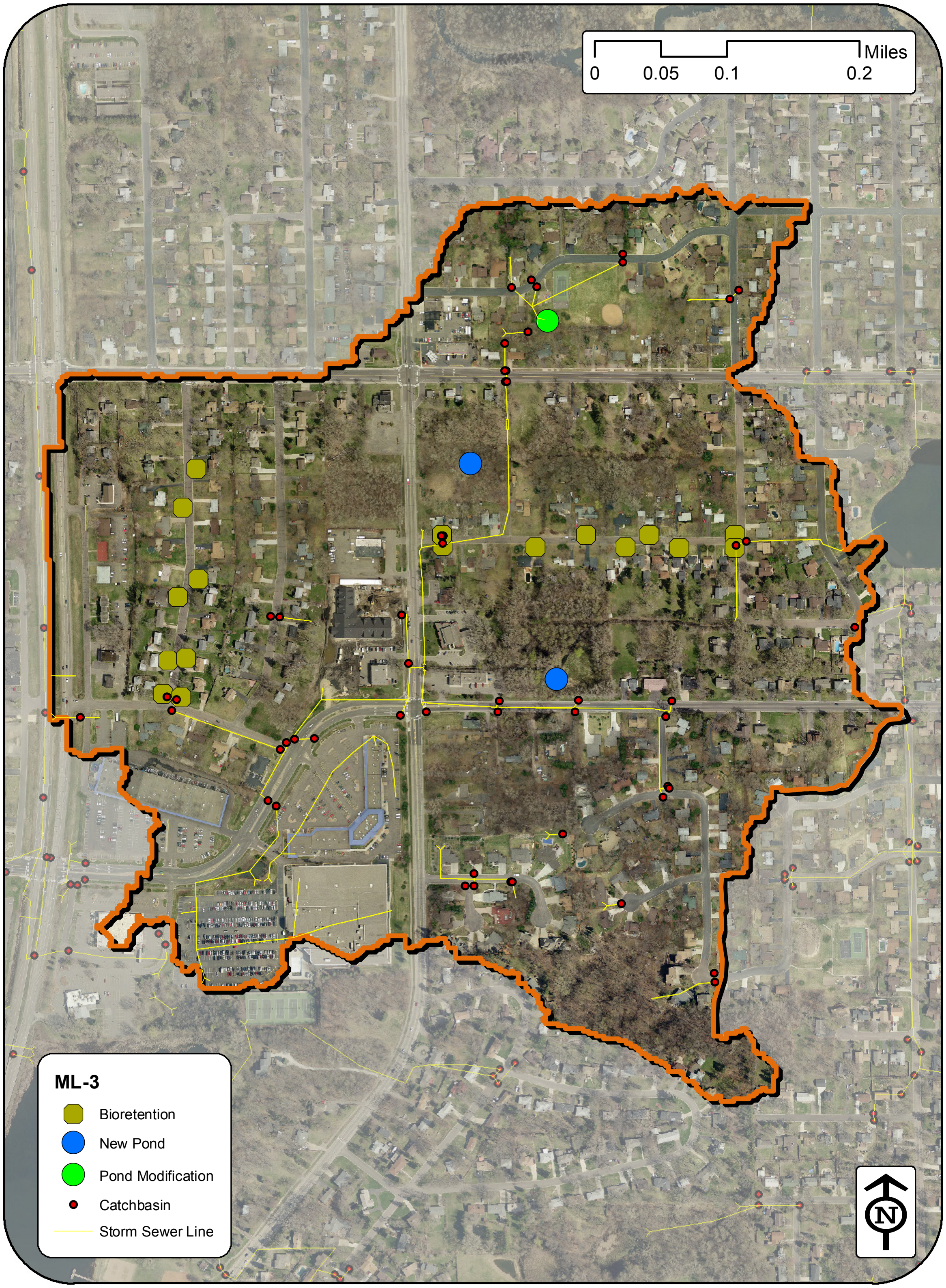
EXISTING STORMWATER TREATMENT

Existing stormwater treatment in ML-3 consists of multiple treatment ponds and street sweeping by the City of Fridley. Site specific stormwater treatment ponds exist near Lifetime Fitness and the Landmark of Fridley. In addition, a pond located in Creekridge Park provides treatment of stormwater for approximately nine acres of residential and park land use. An exfiltration pipe to promote infiltration exists downstream of the Creekridge Park pond. However, its condition is unknown. All water from catchment ML-3 is treated by the pond on the north side of East Moore Lake located in catchment ML-2, though it is undersized for the contributing drainage area. The network-wide table shows how existing treatment practices within catchment ML-3 affect the stormwater volume and pollutant load in East Moore Lake.

Network-Wide Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	332.3	120.4	36%	**211.9**
	TSS (lb/yr)	85,347	46,438.0	54%	**38,909**
	Volume (acre-feet/yr)	226.1	2.6	1%	**223.5**
	Number of BMP's	9			
	BMP Size/Description	Ponds, rain garden, exfiltration pipe, street sweeping			

RETROFIT RECOMMENDATIONS



Project ID: ML-3 Residential Rain Gardens

Drainage Area – 57 acres
Location – Throughout residential land use within catchment ML-3
Property Ownership – Private
Description – The residential land use within this catchment is well suited for curb-cut rain gardens (see Appendix C for design options). Seventeen ideal rain garden locations were identified (see map), though more may exist. 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 5, 10, and 15 rain gardens were analyzed to treat the residential land use. Network-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

Rain Gardens Treating Single Family, Medium Density Residential Land Use (Network-Wide)

	Existing Conditions	*Project ID*					
		5 - Curb-Cut Rain Gardens		10 - Curb-Cut Rain Gardens		15 - Curb-Cut Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	3.3	37%	5.9	38%	8.1	39%
	TSS (lb/yr)	721	55%	1,317	56%	1,822	57%
	Volume (acre-feet/yr)	3.4	3%	6.1	4%	8.2	5%
	Number of BMP's	5		10		15	
	BMP Size/Description	1,250	square feet	2,500	square feet	3,750	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$25,000		$50,000		$75,000	
	Promotion & Admin Costs	$9,381		$15,221		$21,061	
	Probable Project Cost	**$34,381**		**$65,221**		**$96,061**	
	Annual O&M	$375		$750		$1,125	
	30-yr Cost/lb-TP	**$461**		**$496**		**$534**	
	30-yr Cost/1,000lb-TSS	$2,110		$2,220		$2,375	

Project ID: ML-3 New Pond East of Old Central Ave. NE

Drainage Area – 28 acres

Location – East of Old Central Ave. NE and south of Mississippi St. NE

Property Ownership – Private

Description – Substantial open space exists east of Old Central Ave. NE just south of Mississippi St. NE. The property is privately owned, but presents an opportunity for a new stormwater wet pond. Redirection of an existing stormwater line to the new pond is an option to provide additional treatment to the residential land use within catchment ML-3.

Analysis was completed for excavating the pond to provide six feet of ponding. The tax value of the property ($47,600) was included in the cost estimate because the property is currently privately owned. The network-wide modeled annual TP removal is only 2.0 pounds because most of the phosphorus is already treated by the existing pond on the north side of East Moore Lake. Additional engineering and feasibility analysis is required before the project could move forward. Network-wide removal of TSS and TP could be increased to the levels shown in the following table.

New Pond

		Project ID					
	Existing Conditions	New Pond East of Old Central Ave.					
		New trtmt	Net %				
Treatment	TP (lb/yr)	2.0	37%				
	TSS (lb/yr)	657	55%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	1					
	BMP Size/Description	3,647	cubic yards				
	BMP Type	Wet Pond					
Cost	Materials/Labor/Design	$158,708					
	Promotion & Admin Costs	$5,840					
	Probable Project Cost	**$164,548**					
	Annual O&M	$450					
	30-yr Cost/lb-TP	**$2,967**					
	30-yr Cost/1,000lb-TSS	$9,033					

Proposed Site Image -

Project ID: ML-3 New Pond North of Rice Creek Rd.

Drainage Area – 131 acres

Location – North of Rice Creek Rd. and east of Old Central Ave. NE

Property Ownership – City of Fridley

Description – City owned lots exist on the north side of Rice Creek Rd. and present an opportunity for a new stormwater wet pond that would treat runoff from portions of ML-3 and all of ML-4 if the existing ditch was routed into the proposed pond.

Analysis was completed for excavating the pond to provide six feet of ponding. The network-wide modeled annual TP removal is only 0.6 pounds because most of the phosphorus is already treated by the existing pond on the north side of East Moore Lake. In addition, Harris Pond provides significant treatment of all land use within ML-4. Additional engineering and feasibility analysis is required before the project could move forward. Network-wide removal of TSS and TP could be increased to the levels shown in the following table.

New Pond

		Project ID					
	Existing Conditions	**New Pond North of Rice Creek Rd.**					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	0.6	36%				
	TSS (lb/yr)	251	55%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	1					
	BMP Size/Description	11,037	cubic yards				
	BMP Type	Wet Pond					
Cost	**Materials/Labor/Design**	$234,608					
	Promotion & Admin Costs	$5,840					
	Probable Project Cost	**$240,448**					
	Annual O&M	$450					
	30-yr Cost/lb-TP	**$14,108**					
	30-yr Cost/1,000lb-TSS	$33,725					

Proposed Site Image -

Project ID: ML-3 Pond Modification in Creekridge Park

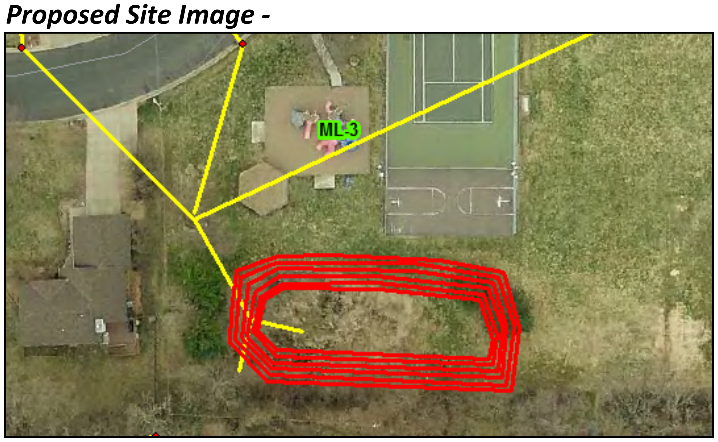
Drainage Area – 9 acres
Location – Existing pond within Creekridge Park
Property Ownership – City of Fridley
Description – The existing stormwater pond within Creekridge Park currently provides little treatment because of a shallow ponding depth and small size. Some potential exists for additional excavation to increase ponding depth and overall size.

Analysis was completed for excavating the pond to provide three feet of ponding and expand the footprint of the pond. The network-wide modeled annual TP removal is only 2.0 pounds because most of the phosphorus is already treated by the existing pond on the north side of East Moore Lake. Additional engineering and feasibility analysis is required before the project could move forward. Network-wide removal of TSS and TP could be increased to the levels shown in the following table.

Pond Modification

	Existing Conditions	*Project ID*					
		Pond Modification in Creekridge Park					
		New trtmt	**Net %**				
Treatment	**TP (lb/yr)**	2.0	37%				
	TSS (lb/yr)	677	55%				
	Volume (acre-feet/yr)	0.0	1%				
	Number of BMP's	1					
	BMP Size/Description	861	cubic yards				
	BMP Type	Wet Pond					
Cost	**Materials/Labor/Design**	$26,269					
	Promotion & Admin Costs	$5,840					
	Probable Project Cost	**$32,109**					
	Annual O&M	$450					
	30-yr Cost/lb-TP	**$760**					
	30-yr Cost/1,000lb-TSS	$2,246					

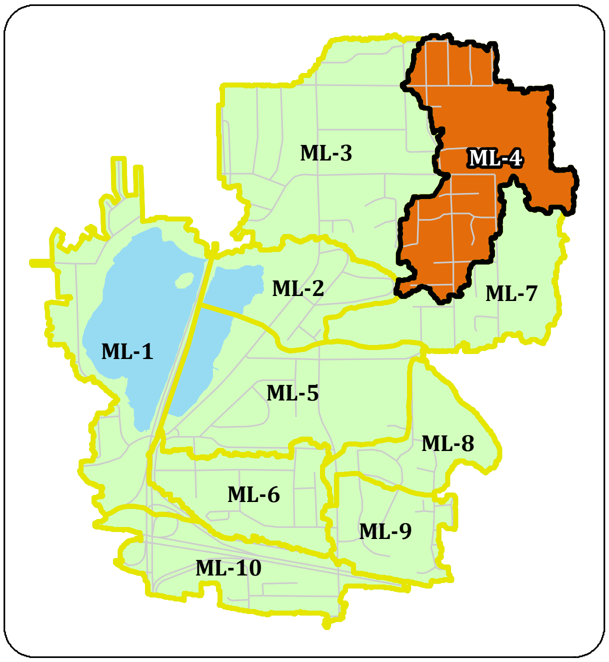
Proposed Site Image -



Catchment ML-4

Existing Catchment Summary*	
Acres	131
Dominant Land Cover	Residential
Parcels	418
TP (lbs/yr)	64.6
TSS (lbs/yr)	2,490
Volume (acre-feet/yr)	75.5

**Excludes network-wide treatment practices*



CATCHMENT DESCRIPTION

Catchment ML-4 is predominantly medium density residential land use (88%). Other land uses present in the catchment are park, office park, and open water. The majority of the catchment lies in the city of Fridley, but the eastern third crosses into New Brighton.

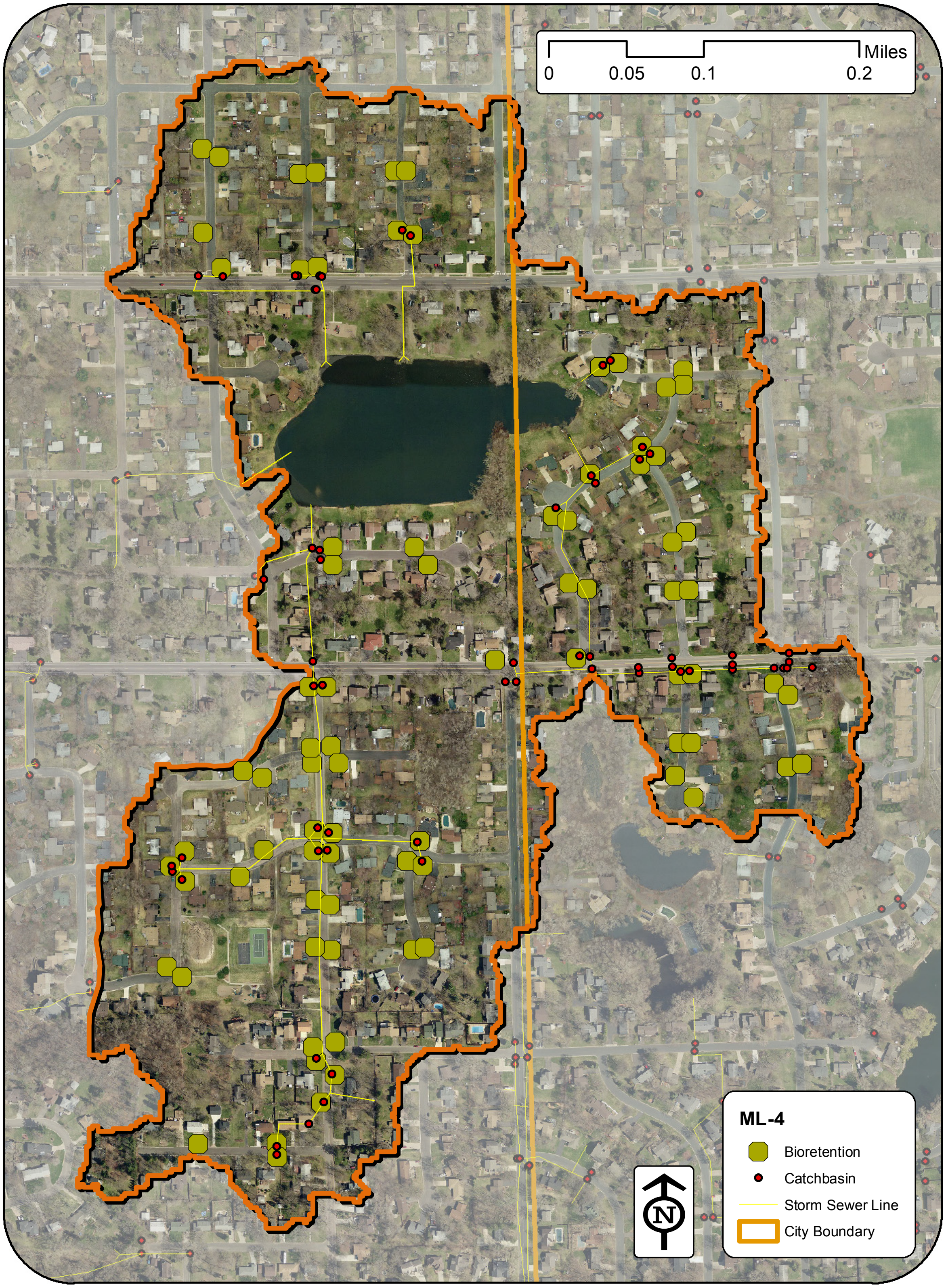
EXISTING STORMWATER TREATMENT

All stormwater from catchment ML-4 passes through Harris Pond, which essentially functions as a large stormwater treatment pond. The City of Fridley also conducts street sweeping throughout catchment ML-4. Finally, all water from catchment ML-4 is also treated by the pond on the north side of East Moore Lake located in catchment ML-2, though it is undersized for the contributing drainage area. The network-wide table below shows how existing treatment practices within catchment ML-4 affect the stormwater volume and pollutant load to East Moore Lake.

Network-Wide Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	332.3	120.4	36%	**211.9**
	TSS (lb/yr)	85,347	46,438.0	54%	**38,909**
	Volume (acre-feet/yr)	226.1	2.6	1%	**223.5**
	Number of BMP's	9			
	BMP Size/Description	Ponds, rain garden, exfiltration pipe, street sweeping			

RETROFIT RECOMMENDATIONS



Project ID: ML-4 Residential Rain Gardens

Drainage Area – 115.6 acres
Location – Throughout the residential land use in ML-4
Property Ownership – Private
Description – The residential nature of this catchment makes it best suited to curb-cut rain gardens (see Appendix C for design options). Eighty one ideal rain garden locations were identified (see map), though more may exist. 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 10, 20, and 30 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

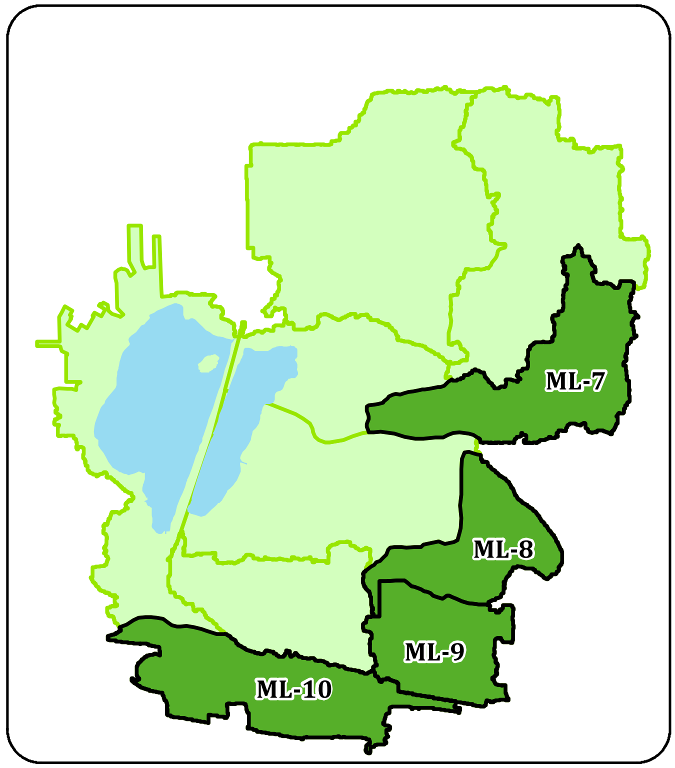
Residential Rain Gardens

	Cost/Removal Analysis	*Project ID*					
		10 - Curb-Cut Rain Gardens		20 - Curb-Cut Rain Gardens		30 - Curb-Cut Rain Gardens	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	4.6	38%	8.4	39%	11.5	40%
	TSS (lb/yr)	862	55%	1,605	56%	2,200	57%
	Volume (acre-feet/yr)	6.9	4%	12.2	7%	16.4	8%
	Number of BMP's	10		20		30	
	BMP Size/Description	2,500	square feet	5,000	square feet	7,500	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$50,000		$100,000		$150,000	
	Promotion & Admin Costs	$15,221		$26,901		$38,581	
	Probable Project Cost	**$65,221**		**$126,901**		**$188,581**	
	Annual O&M	$750		$1,500		$2,250	
	30-yr Cost/lb-TP	**$636**		**$682**		**$742**	
	30-yr Cost/1,000lb-TSS	$3,392		$3,570		$3,880	

Section 3: Disconnected Catchments

Existing Network Summary	
Acres	277
Dominant Land Cover	Residential
Parcels	1,251
TP (lbs/yr)	N/A
TSS (lbs/yr)	N/A
Volume (acre-feet/yr)	N/A

Catchment ID	Page
ML-7	51
ML-8	53
ML-9	56
ML-10	58

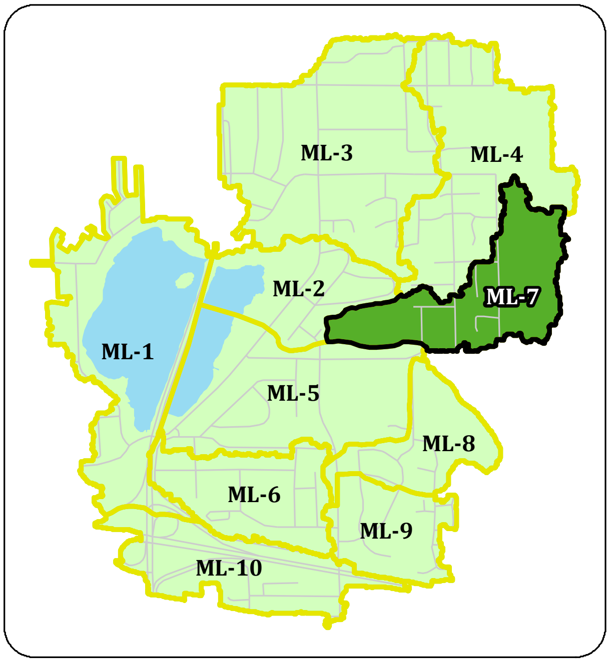


EXISTING TREATMENT

Catchments in this section were found to have no connection to Moore Lake. Therefore, no formal analyses were completed for the included catchments, with the exception of ML-8 because Innsbruck Nature Center was deemed a resource of interest.

Catchment ML-7

Existing Catchment Summary	
Acres	88
Dominant Land Cover	Residential, Open Space
Parcels	264
TP (lbs/yr)	N/A
TSS (lbs/yr)	N/A
Volume (acre-feet/yr)	N/A



CATCHMENT DESCRIPTION

Catchment ML-7 is comprised primarily of medium density, residential land use (80%). There is also a sizeable area of open space on the far western lobe of the catchment. Other land uses present include school, multi-family residential, and open water. Approximately half of the Islamic Center of Minnesota campus is located in catchment ML-7.

EXISTING STORMWATER TREATMENT

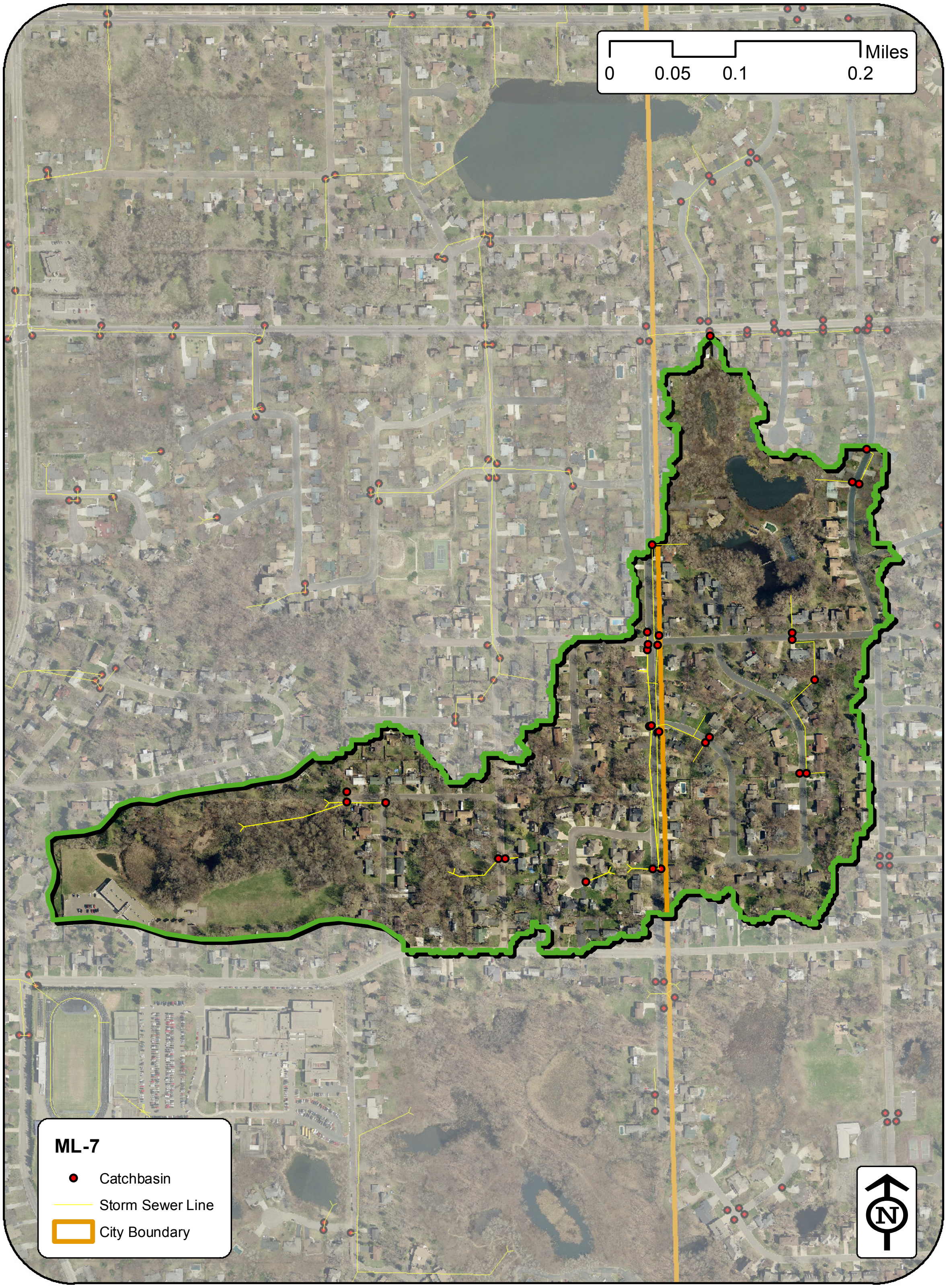
All stormwater in this catchment is directed to isolated stormwater ponds or wetland areas with no regular connection to Moore Lake. However, excessive precipitation has resulted in documented overflow near the far western lobe into catchment ML-2.

Stormwater east of Stinson Blvd. is conveyed north to existing ponds on the north side of 18th St. NW. The west side of Stinson Blvd. drains to the wetland complex behind the Islamic Center of Minnesota as well as several isolated low lying areas.

RETROFIT RECOMMENDATIONS

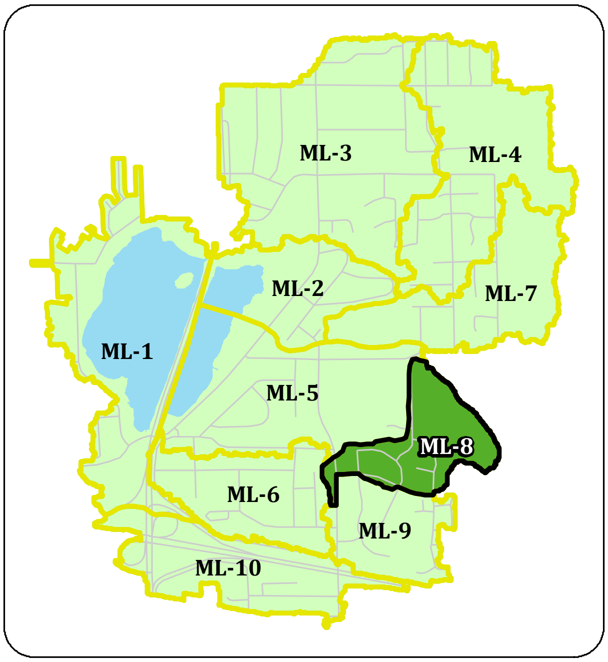
Due to the lack of connection to Moore Lake, no retrofits were recommended.

RETROFIT RECOMMENDATIONS



Catchment ML-8

Existing Catchment Summary	
Acres	54
Dominant Land Cover	Residential, Open Space
Parcels	695
TP (lbs/yr)	33.5
TSS (lbs/yr)	8,180
Volume (acre-feet/yr)	28.8



CATCHMENT DESCRIPTION

Catchment ML-8 consists of a wide variety of land uses. The western half is primarily medium density residential while the eastern half is a mix of multi-family residential, hi-rise residential, open space, and parkland. The catchment includes portions of Innsbruck Nature Center.

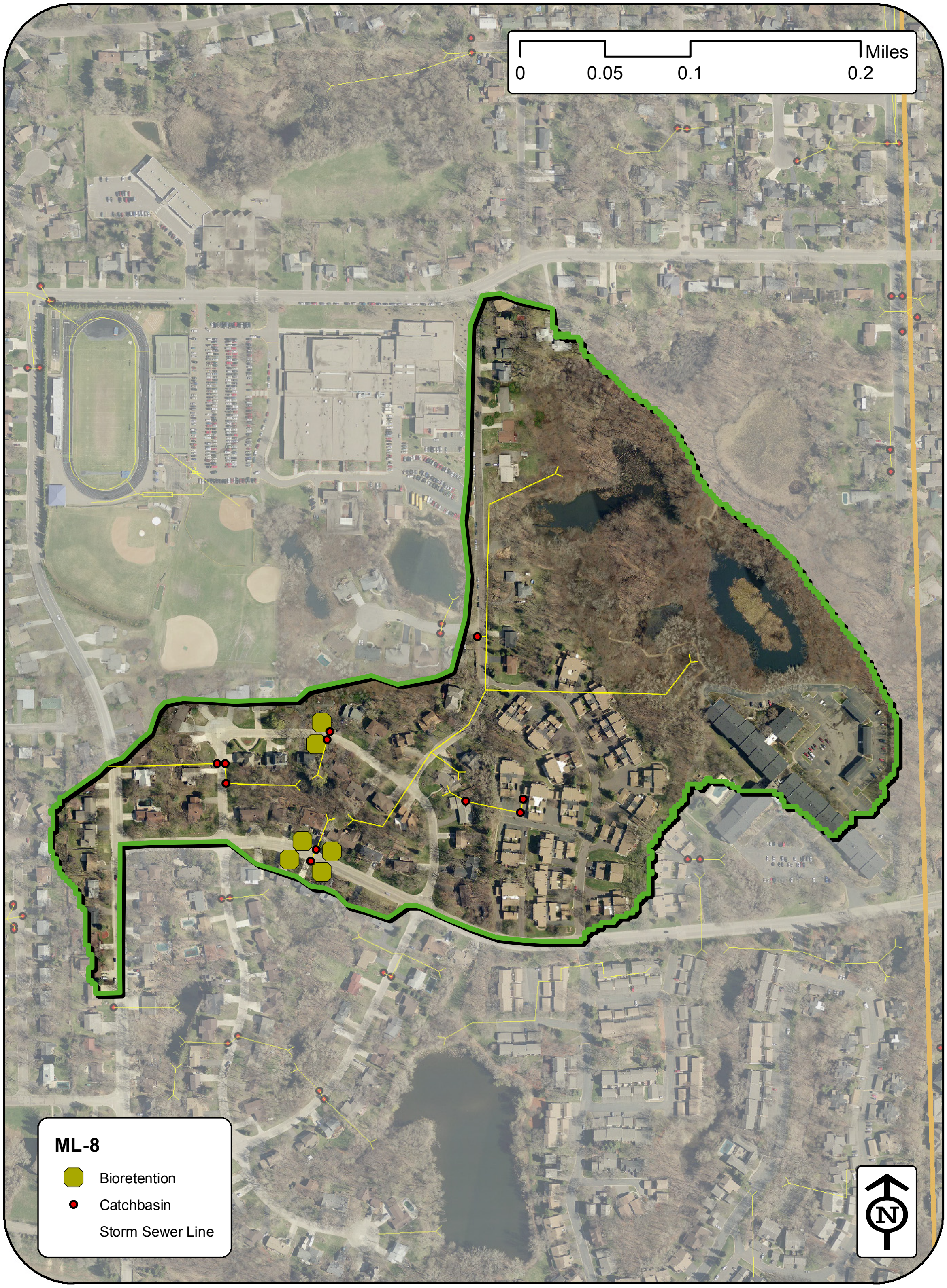
EXISTING STORMWATER TREATMENT

Innsbruck Nature Center was identified as a resource of interest. Therefore, modeling and retrofit recommendations for this catchment were completed even though it is disconnected from Moore Lake. Nevertheless, the stormwater ultimately enters the wetland complex located on the Innsbruck Nature Center campus and additional treatment was desired. Existing stormwater treatment practices within catchment ML-8 primarily consist of outlets in wetland areas and street sweeping by the City of Fridley. The table below shows how existing treatment practices within catchment ML-8 affect the stormwater volume and pollutant load to the Innsbruck Nature Center.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	39.1	5.6	14%	**33.5**
	TSS (lb/yr)	10,305	2,125.0	21%	**8,180**
	Volume (acre-feet/yr)	28.8	0.0	0%	**28.8**
	Number of BMP's	2			
	BMP Size/Description	Pond, street sweeping			

RETROFIT RECOMMENDATIONS



Project ID: ML-8 Residential Rain Gardens

Drainage Area – 9.6 acres
Location – Throughout catchment ML-8 in residential land use
Property Ownership – Private
Description – The residential nature of this catchment makes it best suited to curb-cut rain gardens (see Appendix C for design options). Six ideal rain garden locations were identified (see map), though more may exist. 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, 3, and 5 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

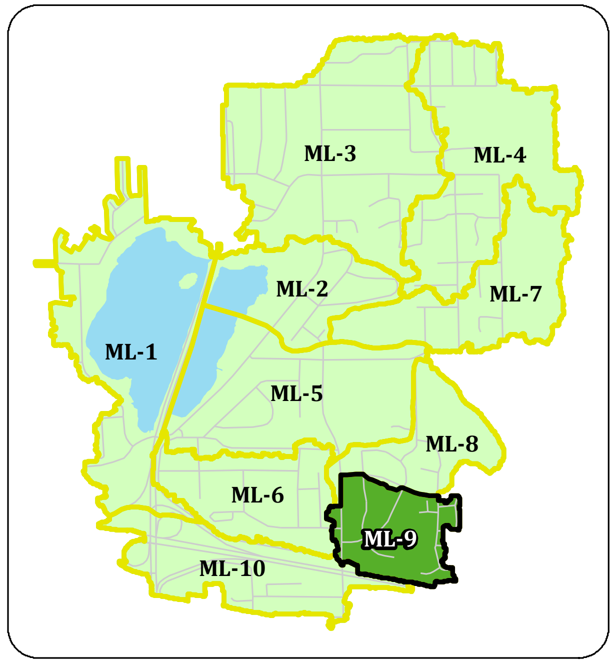
During rain

Curb-Cut Rain Gardens Treating Residential Land Use

	Cost/Removal Analysis	Project ID					
		1 - Curb-Cut Rain Garden		3 - Curb-Cut Rain Garden		5 - Curb-Cut Rain Garden	
		New trtmt	Net %	New trtmt	Net %	New trtmt	Net %
Treatment	TP (lb/yr)	0.4	15%	1.0	17%	1.5	18%
	TSS (lb/yr)	58	21%	152	22%	226	23%
	Volume (acre-feet/yr)	0.7	2%	1.5	5%	2.1	7%
	Number of BMP's	1		3		5	
	BMP Size/Description	250	square feet	750	square feet	1,250	square feet
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$5,000		$15,000		$25,000	
	Promotion & Admin Costs	$4,709		$7,045		$9,381	
	Probable Project Cost	**$9,709**		**$22,045**		**$34,381**	
	Annual O&M	$75		$225		$375	
	30-yr Cost/lb-TP	**$997**		**$960**		**$1,014**	
	30-yr Cost/1,000lb-TSS	$6,873		$6,315		$6,730	

Catchment ML-9

Existing Catchment Summary	
Acres	53
Dominant Land Cover	Residential, Open Space
Parcels	192
TP (lbs/yr)	N/A
TSS (lbs/yr)	N/A
Volume (acre-feet/yr)	N/A



CATCHMENT DESCRIPTION

Nearly half of catchment ML-9 is composed of medium density residential and another quarter is multi-family residential. The last quarter is divided between freeway, open space, and open water land uses. ML-9 lies just north of I-694 on the eastern edge of the Moore Lake subwatershed.

EXISTING STORMWATER TREATMENT

All stormwater in this catchment is directed to isolated stormwater ponds, wetland areas, or Farr Lake with no connection to Moore Lake. The western most portion of the catchment flows to a stormwater pond that is connected via pipe to another treatment pond, which ultimately has a pipe connection to Farr Lake. Stormwater from the eastern side of the catchment enters Farr Lake directly.

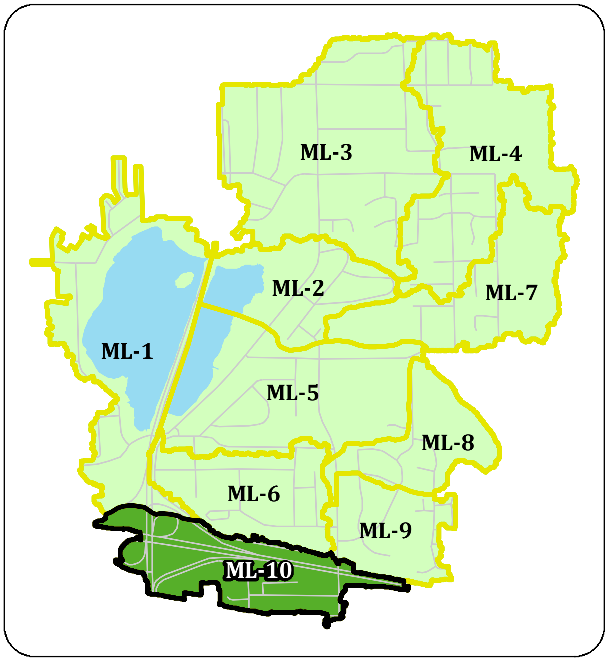
RETROFIT RECOMMENDATIONS

Due to the lack of connection to Moore Lake, no retrofits were recommended.

RETROFIT RECOMMENDATIONS

Catchment ML-10

Existing Catchment Summary	
Acres	82
Dominant Land Cover	Freeway, Residential
Parcels	100
TP (lbs/yr)	N/A
TSS (lbs/yr)	N/A
Volume (acre-feet/yr)	N/A



CATCHMENT DESCRIPTION

Catchment ML-10 is mostly comprised of I-694 but also contains part of a medium density residential neighborhood south of the freeway and a portion of the Menards store campus in the southwest corner.

EXISTING STORMWATER TREATMENT

All stormwater in this catchment is directed to isolated stormwater ponds or wetland areas with no connection to Moore Lake. The residential area near Skywood Ln. NE drains north to a large, isolated depression on the south side of I-694. Stormwater from the high-rise residential complex and Menards is directed west toward the treatment ponds at the I-694 and Central Ave. NE exchange.

RETROFIT RECOMMENDATIONS

Due to the lack of connection to Moore Lake, no retrofits were recommended.

RETROFIT RECOMMENDATIONS

Retrofit Ranking

The tables on the next pages summarize potential projects. Potential projects are organized from most cost effective to least, based on cost per pound of total phosphorus 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.

Catchments 1 through 6: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
1	ML-5	New Wet Pond (East Moore Lake Park)	1	15.5	5972	0.0	$51,177	$700	$403	$155
2	ML-5	Residential Rain Gardens	5 - 20	5.0 - 15.1	1,425 - 4,221	3.5 - 10.3	$38,761 - $144,421	$375 - $1,500	$1,170 - $1,496	$333 - $418
3	ML-1	Residential Rain Gardens	1 - 5	1.1 - 4.1	307 - 1,158	0.8 - 2.8	$10,585 - $38,761	$75 - $375	$1,346 - $1,440	$388 - $407
4	ML-3	Residential Rain Gardens	5 - 15	3.3 - 8.1	721 - 1,822	3.4 - 8.2	$34,381 - $96,061	$375 - $1,125	$2,110 - $2,375	$461 - $534
5	ML-6	Residential Rain Gardens (downstream of pond)	3	1.9	508	1.2	$22,045	$225	$1,889	$505
6	ML-2	Residential Rain Gardens	3 - 10	1.9 - 5.0	422 - 1,127	2.0 - 4.9	$22,045 - $65,221	$225 - $750	$2,274 - $2,595	$505 - $585
7	ML-6	Rain Garden (Elementary School)	1	0.7 - 1.7	118 - 282	1.0 - 2.0	$10,446 - $27,396	$75	$3,073 - $3,586	$510 - $605
8	ML-4	Residential Rain Gardens	10 - 30	4.6 - 11.5	862 - 2,200	6.9 - 16.4	$65,221 - $188,581	$750 - $2,250	$3,392 - $3,880	$636 - $742
9	ML-6	Iron Enhanced Sand Filter Pond Modification	1	4.3	0	0.0	$48,252	$1,550	N/A	$735
10	ML-3	Pond Modification (Creekridge Park)	1	2.0	677	0.0	$32,109	$450	$2,246	$760
11	ML-6	Residential Rain Gardens (upstream of pond)	5 - 10	1.8 - 3.3	263 - 494	3.3 - 5.8	$34,381 - $65,221	$375 - $750	$5,783 - $5,919	$845 - $886
12	ML-1	Hydrodynamic Device (59th)	1	0.5 - 0.9	224 - 392	0.0	$18,252 - $46,752	$420	$3,900 - $5,047	$1,755 - $2,198
13	ML-1	Grass Swale (Church)	1	0.4	181	0.2	$14,896	$584	$5,970	$2,701
14	ML-3	New Wet Pond (Old Central Ave.)	1	2.0	657	0.0	$164,548	$450	$9,033	$2,967
15	ML-1	Hydrodynamic Device (58th)	1	0.3 - 0.5	113 - 199	0.0	$18,252 - $46,752	$420	$7,824 - $9,942	$3,071 - $3,957

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

Directly Connected Catchment

North Network

Catchments 1 through 6: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
16	ML-6	Hydrodynamic Device (Polk)	1	0.3 - 0..5	101 - 176	0.0	$18,252 - $46,752	$420	$8,774 - $11,241	$3,071 - $3,957
17	ML-2	Hydrodynamic Device	1	0.3 - 0.4	71 - 130	0.0	$18,252 - $46,752	$420	$11,270 - $15,218	$3,071 - $4,946
18	ML-2	New Wet Pond (East Moore Lake Park)	1	2.4	701	0.0	$223,244	$450	$11,257	$3,288
19	ML-1	Permeable Asphalt (Fridley High School)	1	1.9	632	1.7	$208,662	$476	$11,758	$3,911
20	ML-5	Permeable Asphalt (Totino Grace)	1	1.7	1,001	2.8	$219,552	$501	$7,812	$4,600
21	ML-1	Permeable Asphalt (Church)	1	1.0	615	1.7	$136,752	$311	$7,917	$4,869
22	ML-6	Permeable Asphalt (High Rise Residential 0.15 acre)	1	0.5	300	0.8	$68,968	$150	$8,164	$4,898
23	ML-6	Permeable Asphalt (High Rise Residential 0.1 acre)	1	0.3	200	0.6	$47,188	$100	$8,366	$5,577
24	ML-5	Grass Swale (East Moore Lake Park)	1	0.1	68	0.1	$7,464	$584	$12,247	$8,328
25	ML-3	New Wet Pond (Rice Creek Rd.)	1	0.6	251	0.0	$240,448	$450	$33,725	$14,108

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

Directly Connected Catchment

North Network

Catchment 8: Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness with respect to total phosphorus (TP) reduction. Retrofits within catchment 8 will benefit Innsbruck Nature Center. Volume and total suspended solids (TSS) reductions are also shown. For more information on each project refer to the catchment profile pages in this report.

Project Rank	Catchment ID	Retrofit Type (refer to catchment profile pages for additional detail)	Projects Identified	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Total Project Cost	Estimated Annual Operations & Maintenance (2013 Dollars)	Estimated cost/ 1,000lb-TSS (30-year)	Estimated cost/ lb-TP (30-year)
1	ML-8	Residential Rain Gardens	1 - 5	0.4 - 1.5	58 - 226	0.7 - 2.1	$9,709 - $34,381	$75 - $375	$6,315 - $6,873	$960 - $1,014

Disconnected Catchment

References

Erickson, A.J. and J.S. Gulliver. 2010. Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus. University of Minnesota St. Anthony Falls Laboratory Engineering, Environmental and Geophysical Fluid Dynamics Project Report No. 549. Prepared for the City of Prior Lake, Prior Lake, MN.

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Schueler et. al. 2005. *Methods to Develop Restoration Plans for Small Urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

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Appendix A:
Methods

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Methods

Selection of Subwatershed

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

For this analysis, areas draining to Moore Lake were chosen for study. Moore Lake is a high priority because it is classified as a Tier II water body by the Rice Creek Watershed District and is used regularly for recreation. Moore Lake was added to the EPA's 303(d) list of impaired waters for excess nutrients in 2002. Years of water quality monitoring identified increased levels total phosphorus and chlorophyll a that exceeded state standards.

Stormwater runoff from impervious surfaces like pavement and roofs can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, other areas were built before modern-day stormwater treatment technologies and requirements or have undersized treatment devices.

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 focus area was all areas that drain to East and West Moore Lakes. Included are areas of residential, commercial, industrial, and institutional land uses. The subwatershed was divided into 10 catchments using a combination of existing subwatershed mapping data, stormwater infrastructure maps, and observed topography.

The targeted pollutant for this study was total phosphorus, though total suspended solids and volume were also modeled and reported. Total phosphorus (TP) was chosen as the primary target pollutant because long term water quality monitoring has identified elevated levels in East Moore Lake. Total suspended solids (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, watershed/subwatershed boundaries, 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.

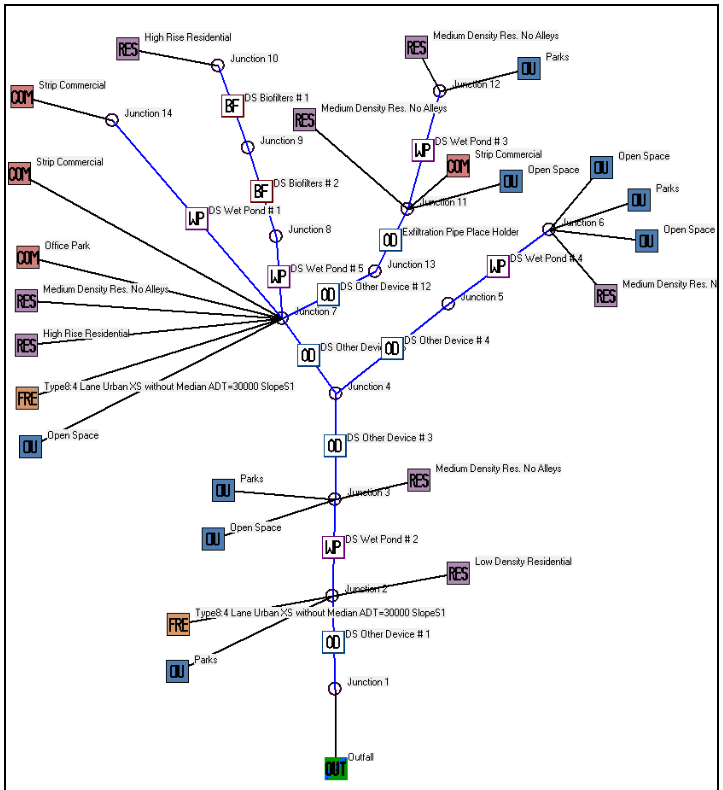
Stormwater Treatment Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over wet ponds). May include multiple cell design, infiltration 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 be conducive to addressing the cities' and watershed district's goals 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 phosphorus and total suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

Each proposed project's pollutant removals were estimated using the stormwater model WinSLAMM. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. 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. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.



WinSLAMM model schematic for the existing conditions of the North Network. Each colored square connected to a junction circle via a line represents a land cover type within a catchment (e.g. RES = residential, OU = other urban, COM = commercial, INS = institutional, IND = industrial, and FRE = freeway). All land cover types that collectively meet at a junction represent all land covers within a particular catchment. All water from catchments ML-2 through ML-4 is routed through "Wet Pond 2" prior to discharge into Moore Lake at the "Outfall."

The newest version of WinSLAMM (version 10), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis because of the unique connectivity amongst the catchments identified in the focus area under investigation. There are three areas where stormwater is routed through multiple catchments before being discharged to Moore Lake. This creates a network of stormwater treatment. Therefore, volume and pollutant loads to Moore Lake from any given catchment must take into consideration other treatment practices within the same network. The screen shot to the right displays the North Network of catchments used in this analysis to accurately model the effectiveness of the proposed BMP's while taking into account existing treatment from the pond on the north side of East Moore Lake (represented by "Wet Pond 2").

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 (all soils were modeled as silt in this analysis). 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. For certain source areas critical to our models we verified that model estimates were accurate by calculating actual acreages in ArcMap, and adjusting the model acreages if needed.

Once the "base" model was established, an "existing conditions" model was created by incorporating any existing stormwater treatment practices in the catchment. For example, street cleaning with mechanical or vacuum street sweepers, rain gardens, stormwater treatment ponds, and others were included in the "existing conditions" model if they were present in the catchment.

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.

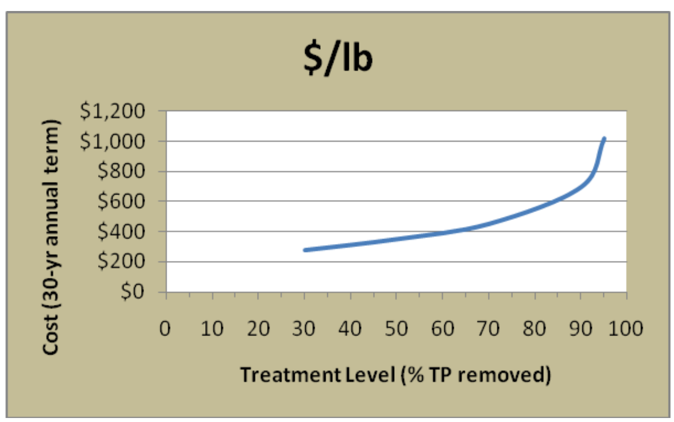
WinSLAMM stormwater computer model inputs

General 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.

Cost Estimates

All estimates were developed using 2013 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, the cities and watershed district 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 Moore 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:

<u>Base conditions</u> - Volume and pollutant loadings from the catchment landscape without any stormwater practices.

<u>Existing conditions</u> - Volume and pollutant loadings after already-existing stormwater practices are taken into account.

<u>Proposed conditions</u> - Volume and pollutant loadings after proposed stormwater retrofits.

Analyses were performed at one of two geographic scales, "catchment or network." They are defined as follows:

<u>Catchment level analyses</u> - Volume and pollutant loads exiting the catchment at the catchment boundary. There may be other stormwater practices existing or proposed farther downstream, but this analysis ignores them.

<u>Network level analyses</u> - Volume and pollutant loads that reach Moore Lake through a stormwater network. One stormwater network consisting of three catchments (North Network) was identified in the Moore Lake subwatershed. Network loading estimates will be much larger than loading estimates from any one catchment because it is the sum of multiple catchments that discharge at the same point into the lake, and might receive treatment from the same practice. This analysis takes into account stormwater treatment ponds that are in-line with the conveyance system and upstream of Moore Lake. Catchments within a stormwater network will only have network level reductions reported in the catchment profile, since those reductions most accurately reflect the true cost-effectiveness of each project.

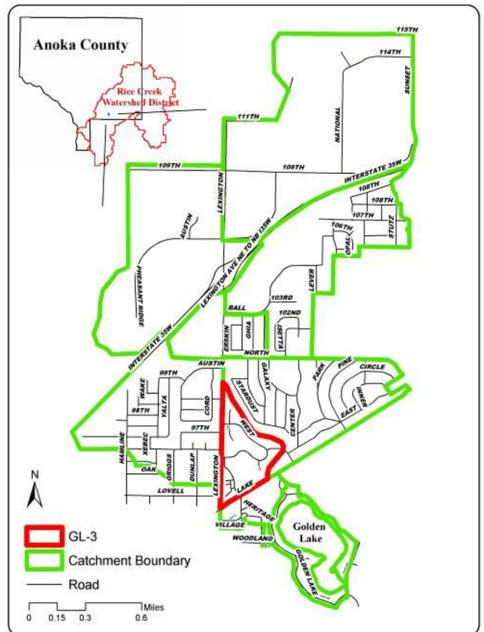
The pollutant load reduction for a single proposed stormwater retrofit will often be greater at the catchment level than at the network level. This is the result of existing treatment practices (such as a pond) located downstream that may have already been treating some of the pollutants being removed by a proposed project. For example, a proposed project may capture 10 pounds of phosphorus at the catchment level, but that doesn't necessarily mean 10 fewer pounds of phosphorus will reach the creek because some of that phosphorus might have been removed by a network pond downstream. Benefits of a proposed project within a network must be judged by their pollutant reductions and cost effectiveness at the network level.

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
Volume (acre-feet/yr)	18.37
TP (lb/yr)	25.00
TSS (lb/yr)	6461.00



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	TP (lb/yr)	25.2	0.2	1%	**25.0**
	TSS (lb/yr)	7,186	725.0	10%	**6,461**
	Volume (acre-feet/yr)	18.4	0.0	0%	**18.4**
	Number of BMP's	1			
	BMP Size/Description	Street cleaning, stormwater pond			

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).

Percent reductions by existing practices.

Pollutants and volume exiting the catchment after existing practices.

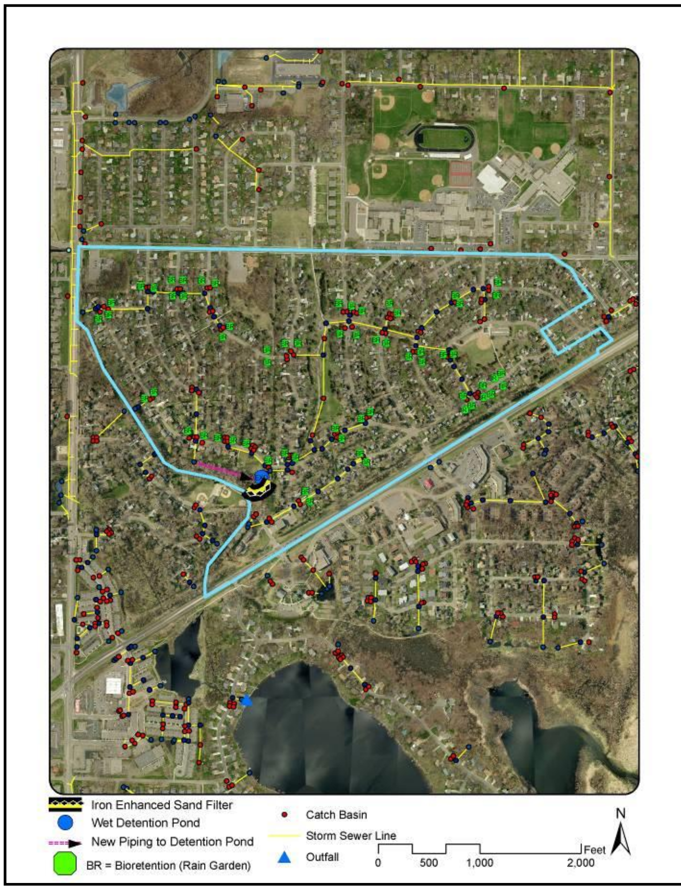
Network-level analysis of existing conditions.

Network-Wide Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	623.7	313.0	50%	**310.7**
	TSS (lb/yr)	216,101	124,172.0	57%	**91,929**
	Volume (acre-feet/yr)	494.5	0.0	0%	**494.5**
	Number of BMP's	All BMPs in catchment network			
	BMP Size/Description	Street cleaning and extended wet detention ponds just before outfall into target waterbody			

Same definitions as above, except here the numbers refer to pollutants and volumes discharged from the network collectively. The existing practices might include stormwater ponds that treat water from multiple catchments. These numbers reflect the cumulative impact of multiple catchments at the point they discharge to Coon Creek.

HOW TO READ THE CATCHMENT PROFILES



Map shows catchment boundaries, stormwater infrastructure, and the locations of proposed stormwater retrofits.

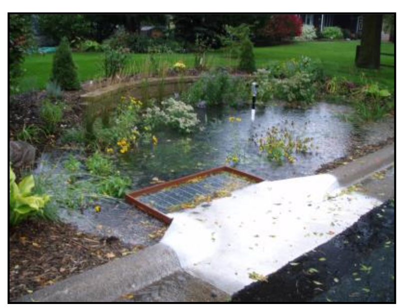
Proposed stormwater retrofits. The project ID number corresponds to this project's catchment and project type.

RETROFIT RECOMMENDATIONS

Project ID LCC-1 Residential RG's – Curb-Cut Rain Garden Network
Drainage Area – 33.7 acres
Location – 5 locations throughout residential area
Property Ownership – Private
Description – The residential land cover within this catchment is best suited to residential, curb-cut rain gardens (see Appendix B for design options). Seven optimal rain garden locations were identified (see map below). Generally, ideal curb-cut rain garden locations are immediately up-gradient of a catch basin serving a large drainage area. Considering typical land owner participation rates we analyzed a scenario where 5 rain gardens were installed in catchment GL-3. Volume and pollutant reductions resulting from the rain garden installations are highlighted in the tables below.

EXAMPLE Conceptual and example images –


Before rain


During rain

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: 6, 9, or 12 rain gardens, for example.

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

	Cost/Benefit Analysis	***Project ID***					
		6 Rain Gardens		**9 Rain Gardens**		**12 Rain Gardens**	
		New trtmt	**Net trtmt %**	**New trtmt**	**Net trtmt %**	**New trtmt**	**Net trtmt %**
Treatment	**TP (lb/yr)**	5.4	39%	6.8	43%	7.7	46%
	TSS (lb/yr)	1,684	41%	2,127	45%	2,408	48%
	Volume (acre-feet/yr)	4.2	33%	5.4	38%	6.1	41%
	Number of BMP's	6		9		12	
	BMP Size/Description	1,500 sq ft		2,250 sq ft		3,000 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	**Materials/Labor/Design**	$27,210		$40,710		$54,210	
	Promotion & Admin Costs	$2,450		$2,870		$3,290	
	Total Project Cost	$29,660		$43,580		$57,500	
	Annual O&M	$450		$675		$900	
	Term Cost/lb-TP	$855		$1,000		$1,170	
	Term Cost/1,000lb-TSS	**$266**		**$313**		**$364**	

Project installation cost estimation.

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

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

Compare cost effectiveness of various project "levels" in these rows for TP (2nd row from bottom) or TSS (bottom row) removal. Compare cost effectiveness numbers between projects to determine the best value.

HOW TO READ THE CATCHMENT PROFILES

EXAMPLE Network-Wide Cost/Benefit Analysis

	Cost/Benefit Analysis	Project ID					
		6 Rain Gardens		9 Rain Gardens		12 Rain Gardens	
		New trtmt	Net trtmt %	New trtmt	Net trtmt %	New trtmt	Net trtmt %
Treatment	TP (lb/yr)	5.4	39%	6.8	43%	7.7	46%
Treatment	TSS (lb/yr)	1,684	41%	2,127	45%	2,408	48%
Treatment	Volume (acre-feet/yr)	4.2	33%	5.4	38%	6.1	41%
Treatment	Number of BMP's	6		9		12	
Treatment	BMP Size/Description	1,500 sq ft		2,250 sq ft		3,000 sq ft	
Treatment	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$27,210		$40,710		$54,210	
Cost	Promotion & Admin Costs	$2,450		$2,870		$3,290	
Cost	Total Project Cost	$29,660		$43,580		$57,500	
Cost	Annual O&M	$450		$675		$900	
Cost	Term Cost/1,000lb-TSS/yr	$855		$1,000		$1,170	
Cost	Term Cost/lb-TP/yr	**$266**		**$363**		**$414**	

This table is the same as the previous catchment-level table, except it examines the costs and benefits of proposed stormwater retrofits at the network level. **This table should be used to compare projects in catchments located in the North Network because it represents volume and pollutant removals at the point where the water enters Moore Lake.**

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Appendix C:
Rain Garden Design Concepts

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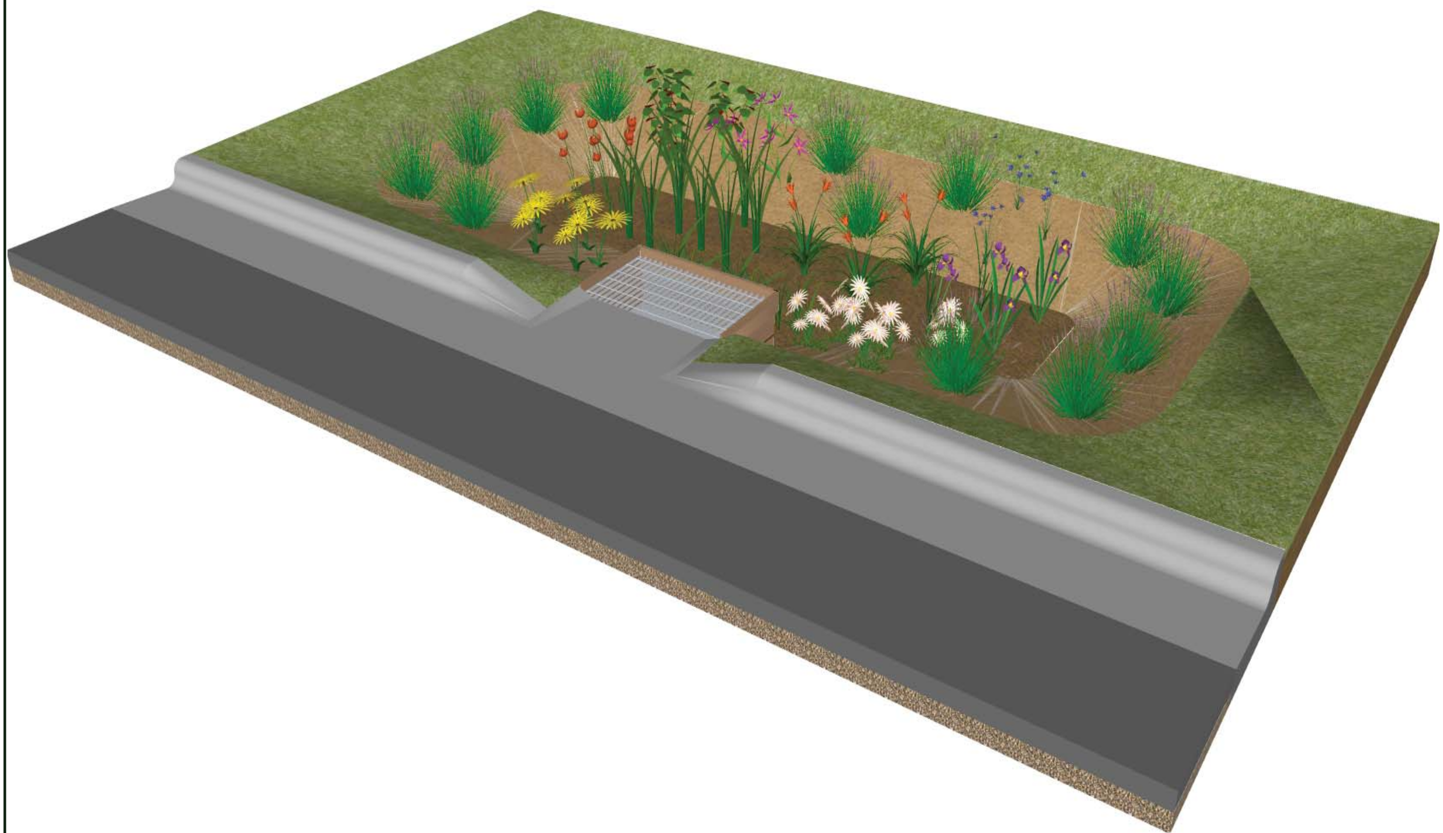
ANOKA COUNTY CURB-CUT RAINGARDENS



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.

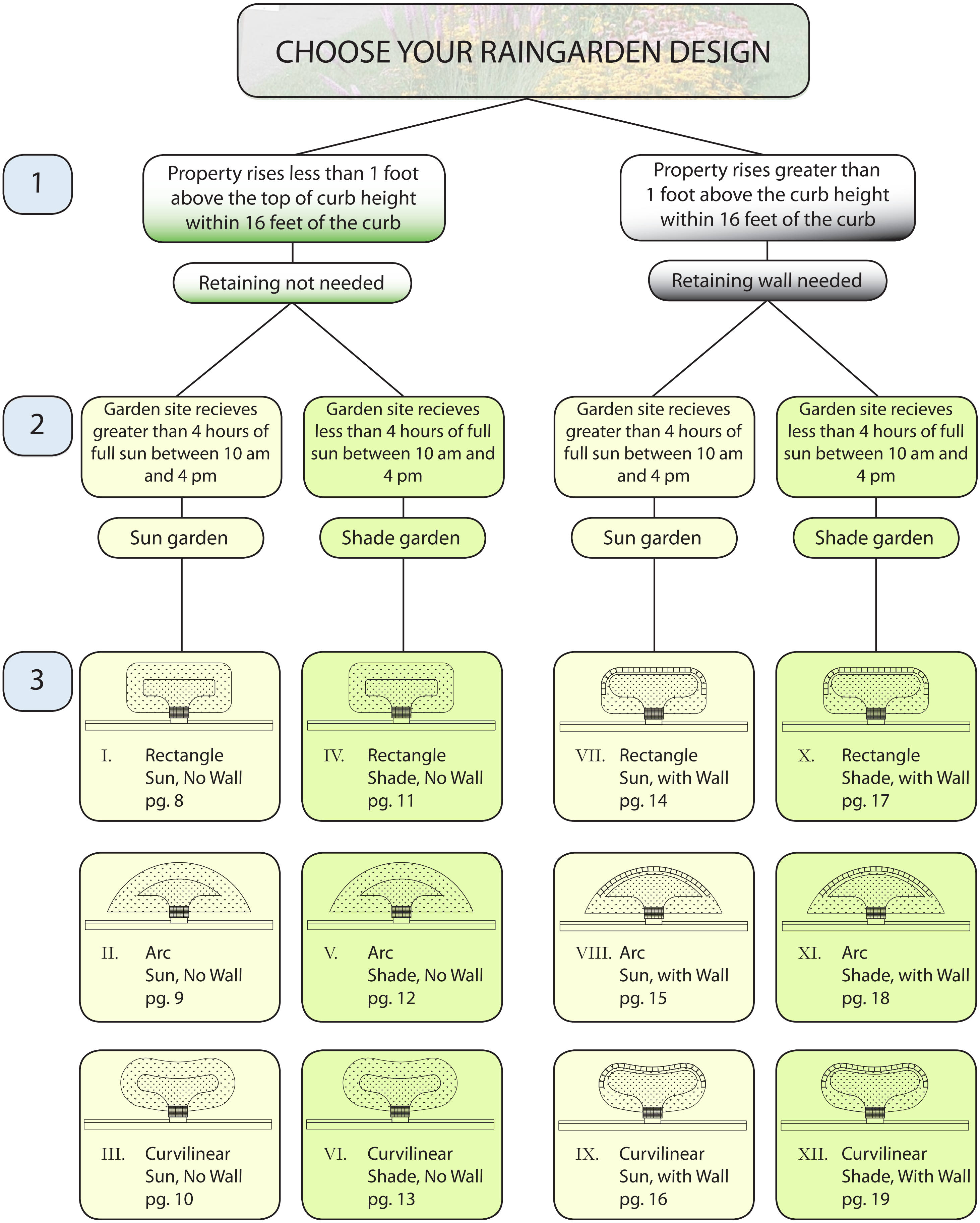
evapotranspiration: The transfer of liquid water from the earth's surface to atmospheric water vapor as result of transpiration by plants and evaporation by solar energy and diffusion. Evapotranspiration can constitute a significant water "loss" from a watershed.

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.

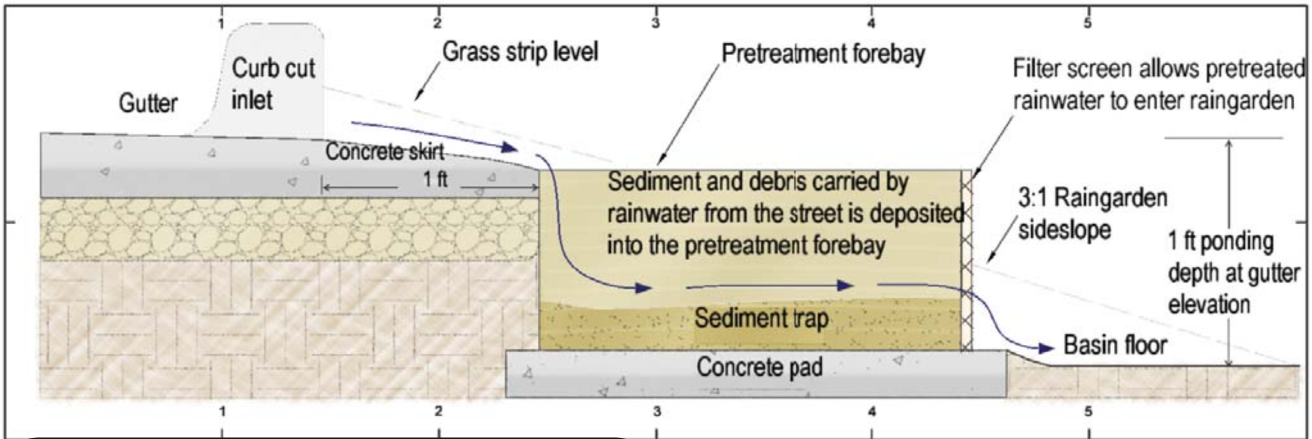
raingarden: A landscaped garden in a shallow depression that receives rainwater runoff from nearby impervious surfaces such as roofs, parking lots or streets. The purpose of a raingarden is to reduce peak runoff flows, increase groundwater recharge and improve water quality in our lakes, streams and 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.

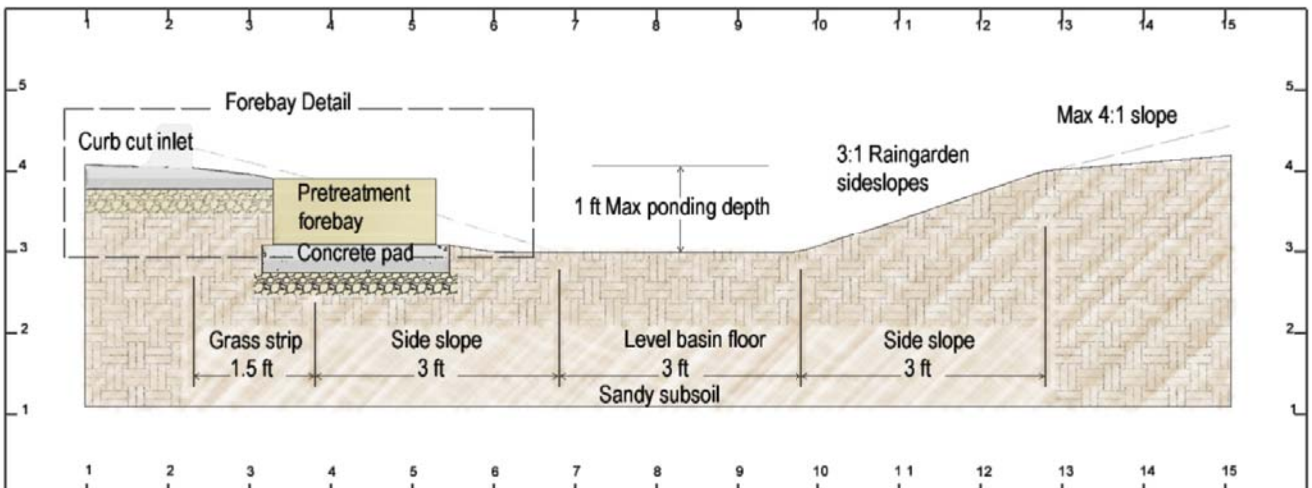


CHOOSE YOUR RAINGARDEN DESIGN
1
Property rises less than 1 foot above the top of curb height within 16 feet of the curb
Retaining not needed
Property rises greater than 1 foot above the curb height within 16 feet of the curb
Retaining wall needed
2
Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm
Sun garden
Garden site recieves less than 4 hours of full sun between 10 am and 4 pm
Shade garden
Garden site recieves greater than 4 hours of full sun between 10 am and 4 pm
Sun garden
Garden site recieves less than 4 hours of full sun between 10 am and 4 pm
Shade garden
3
I. Rectangle Sun, No Wall pg. 8
IV. Rectangle Shade, No Wall pg. 11
VII. Rectangle Sun, with Wall pg. 14
X. Rectangle Shade, with Wall pg. 17
II. Arc Sun, No Wall pg. 9
V. Arc Shade, No Wall pg. 12
VIII. Arc Sun, with Wall pg. 15
XI. Arc Shade, with Wall pg. 18
III. Curvilinear Sun, No Wall pg. 10
VI. Curvilinear Shade, No Wall pg. 13
IX. Curvilinear Sun, with Wall pg. 16
XII. Curvilinear Shade, With Wall pg. 19

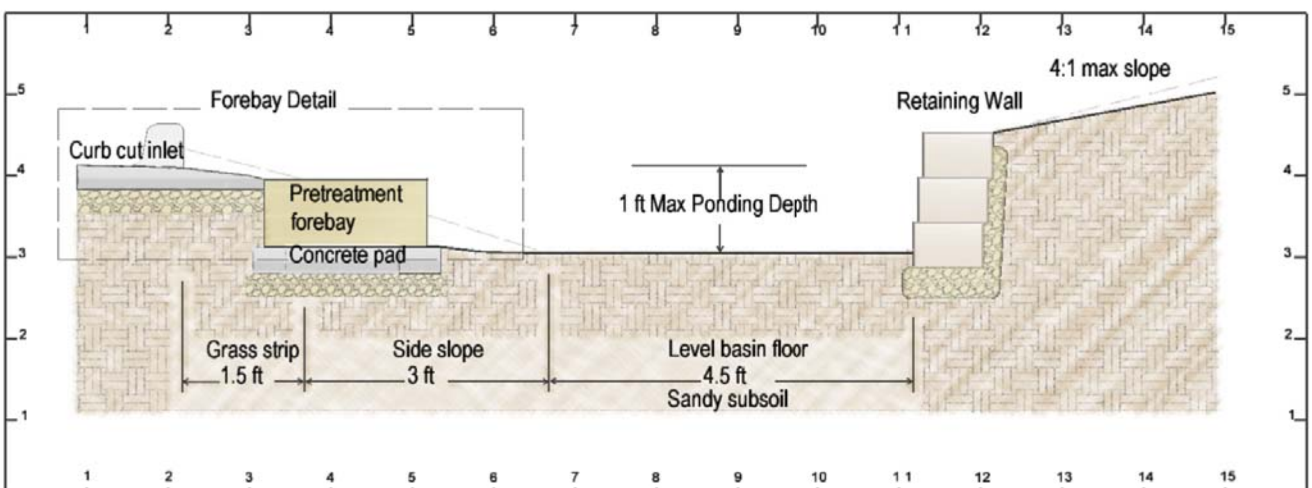
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

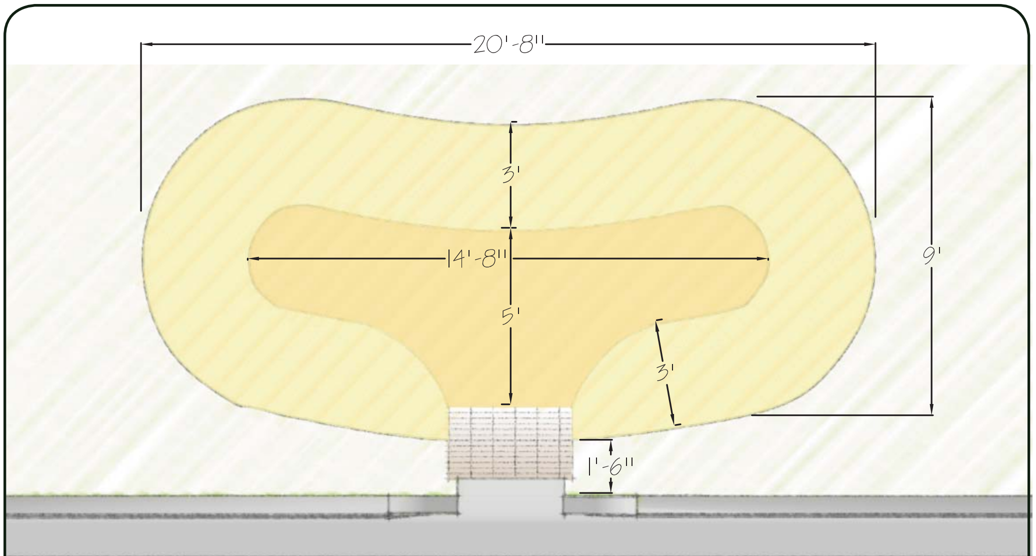


RAINGARDEN WITHOUT RETAINMENT

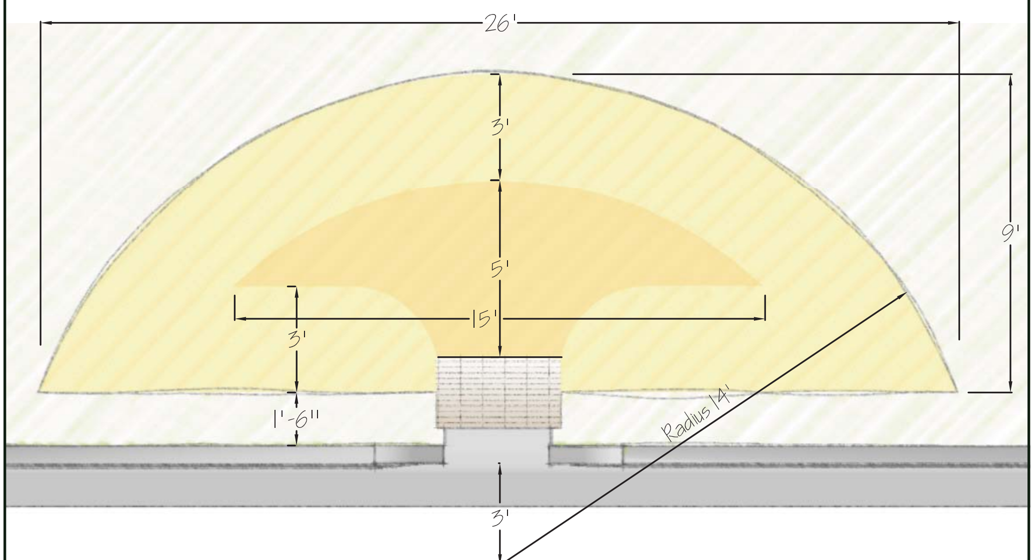


RAINGARDEN WITH RETAINING WALL

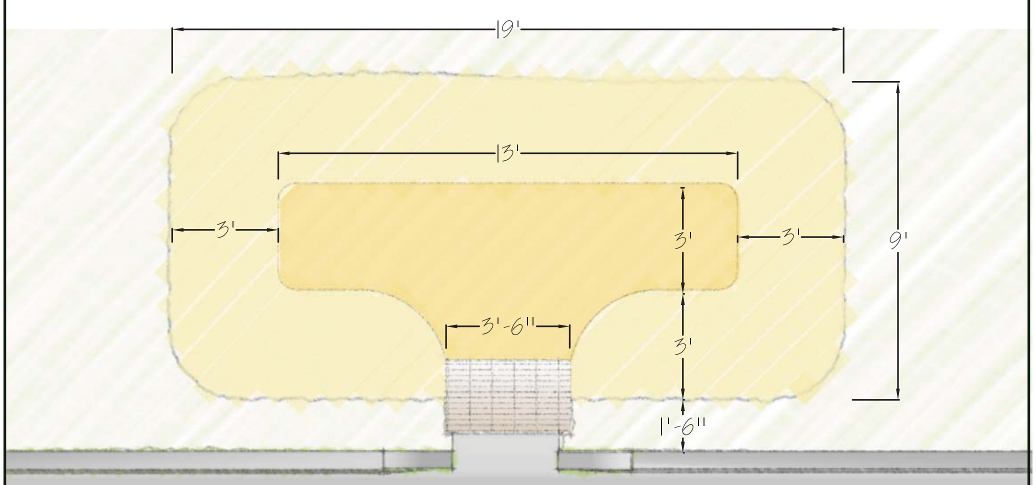
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



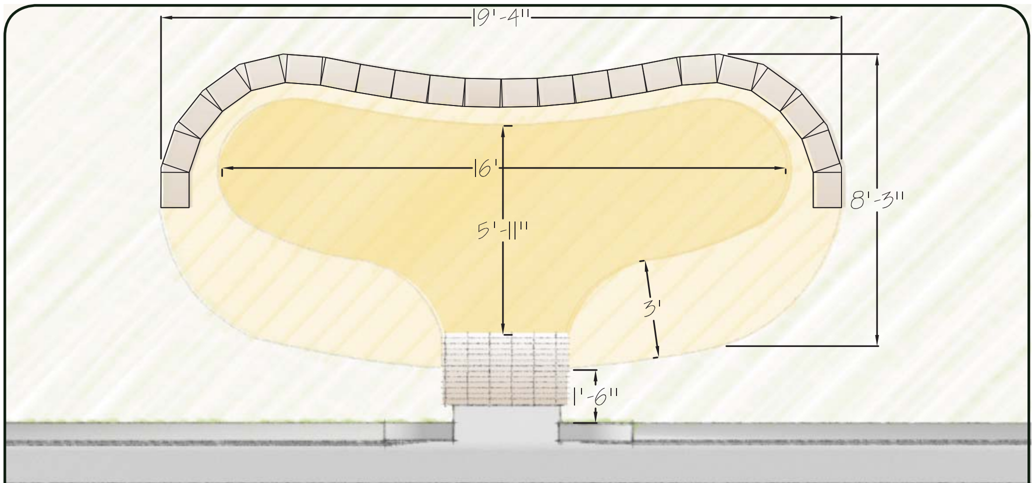
Arc Garden

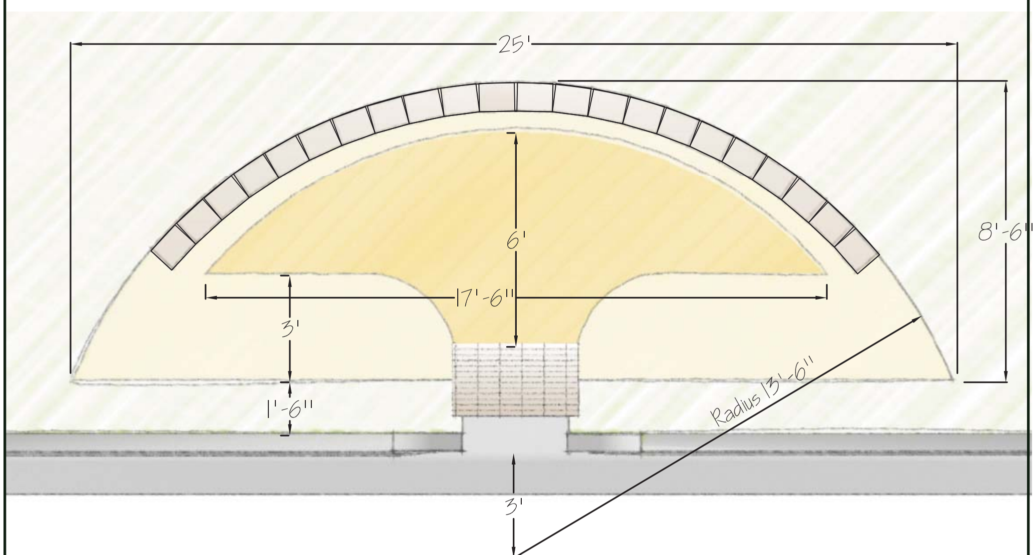


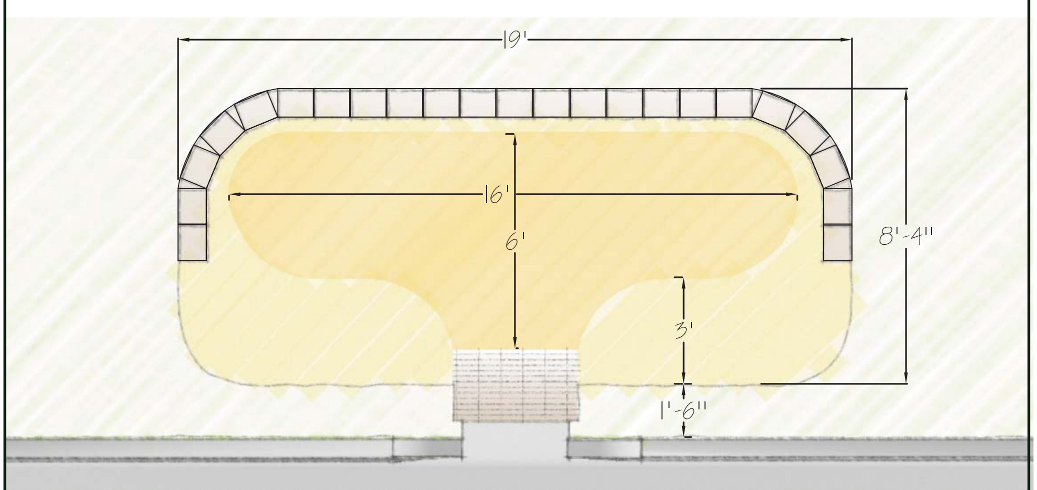
Rectangle Garden

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

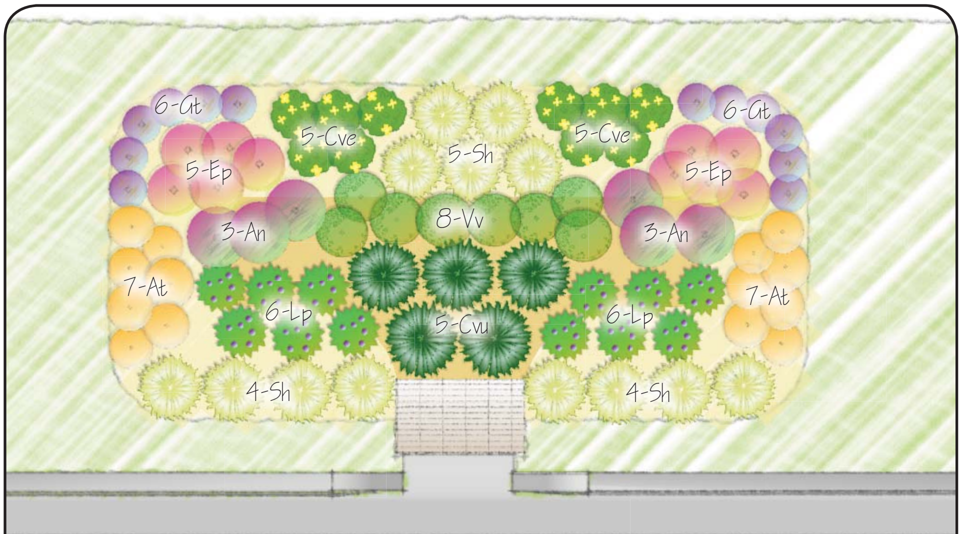




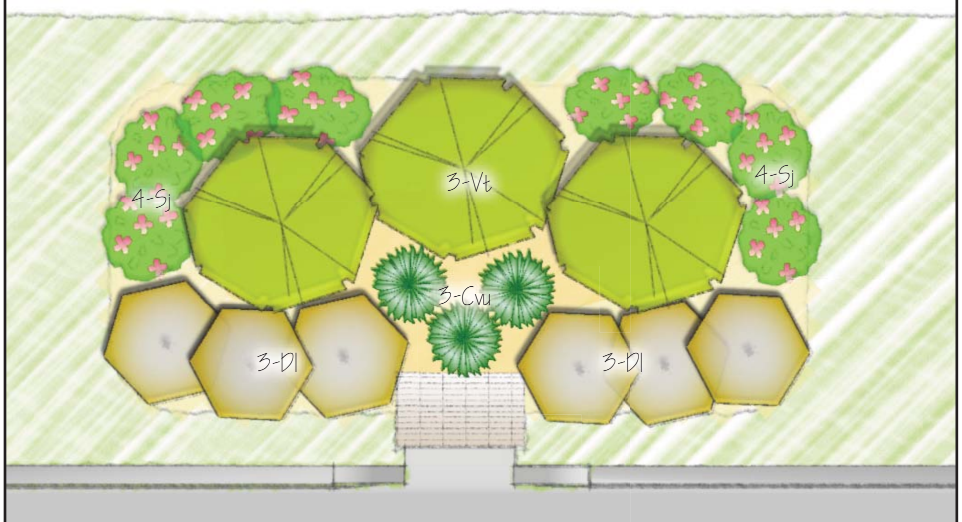


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

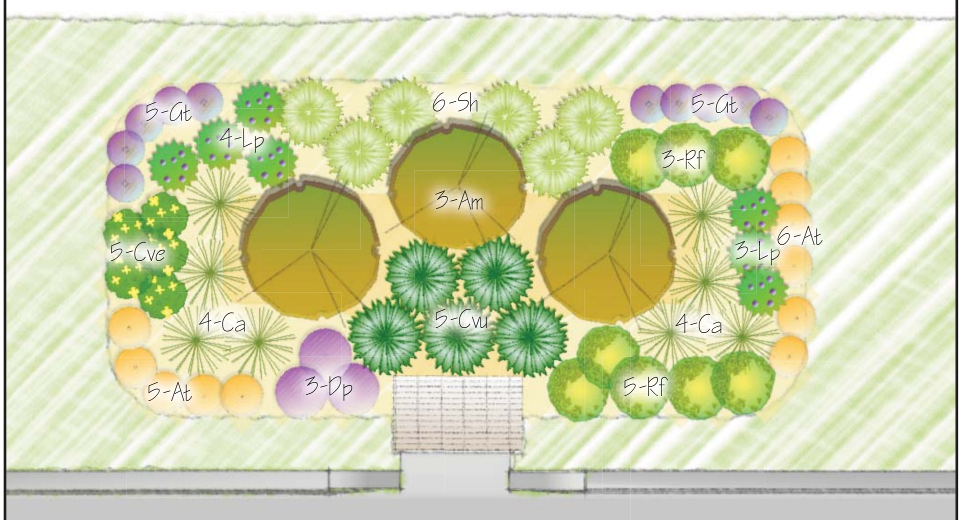
I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

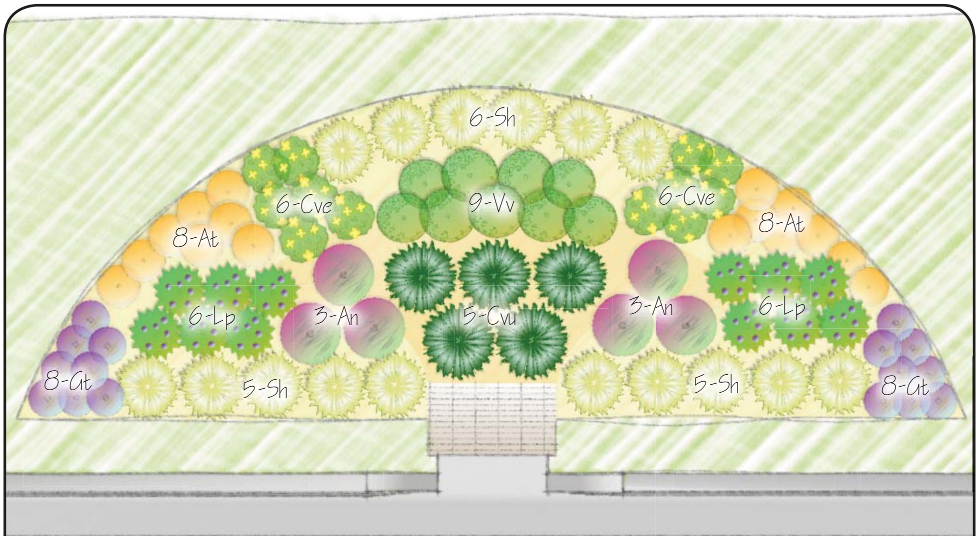


Mixed Shrub/Flower Garden

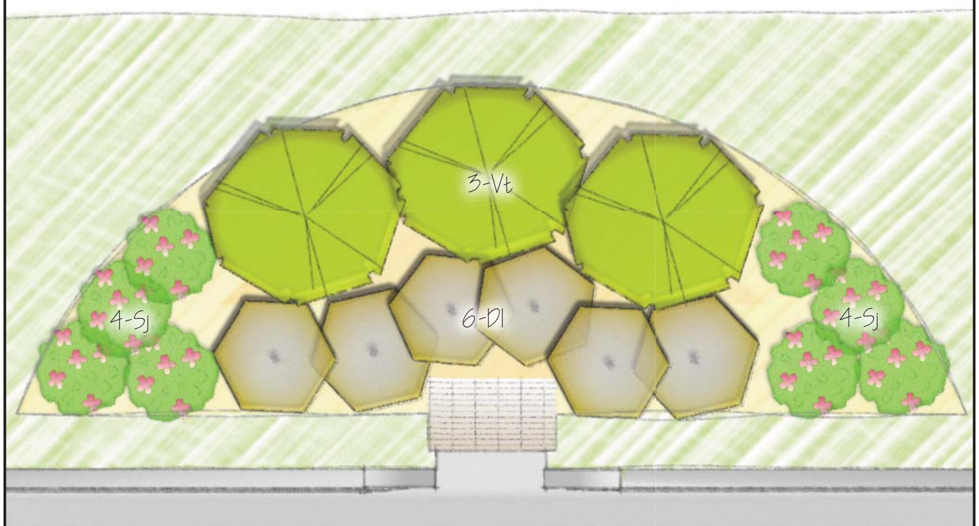
Plant Key

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'*

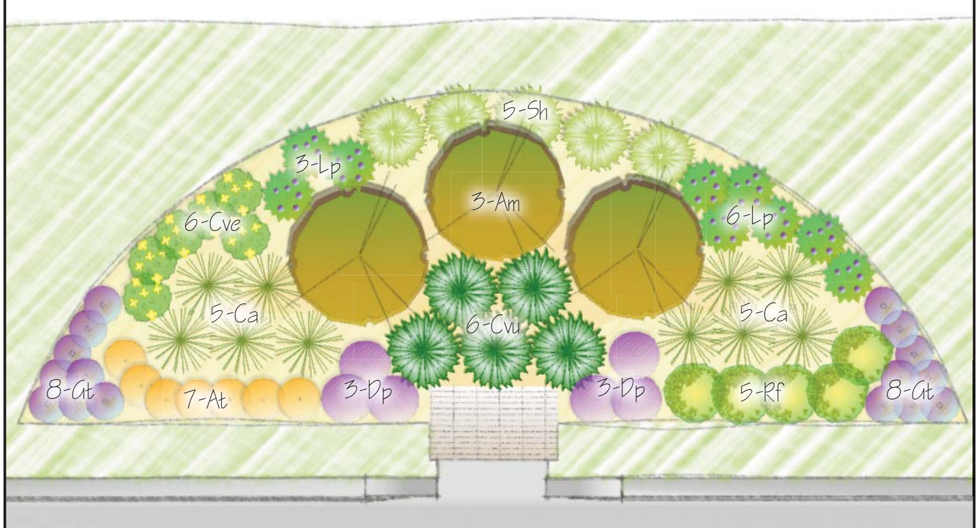
II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

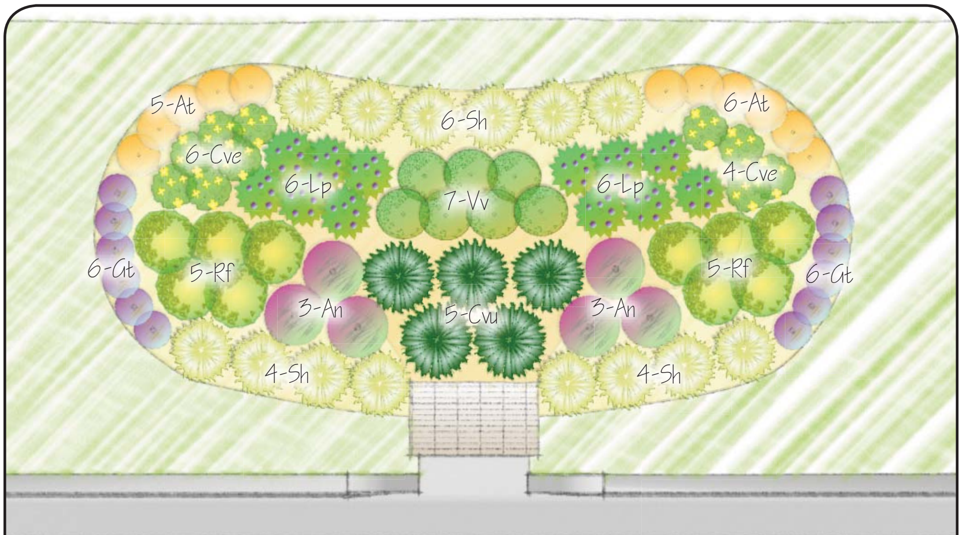


Mixed Shrub/Flower Garden

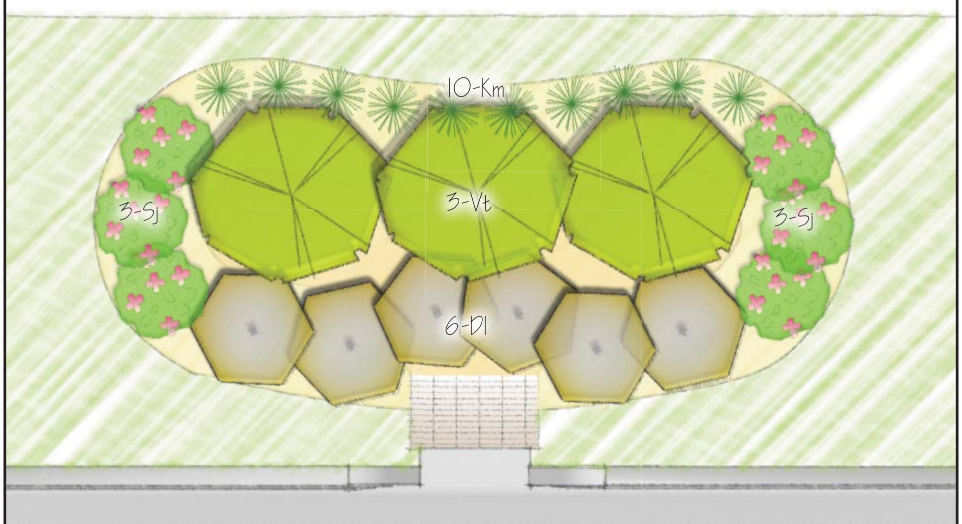
Plant Key

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'*

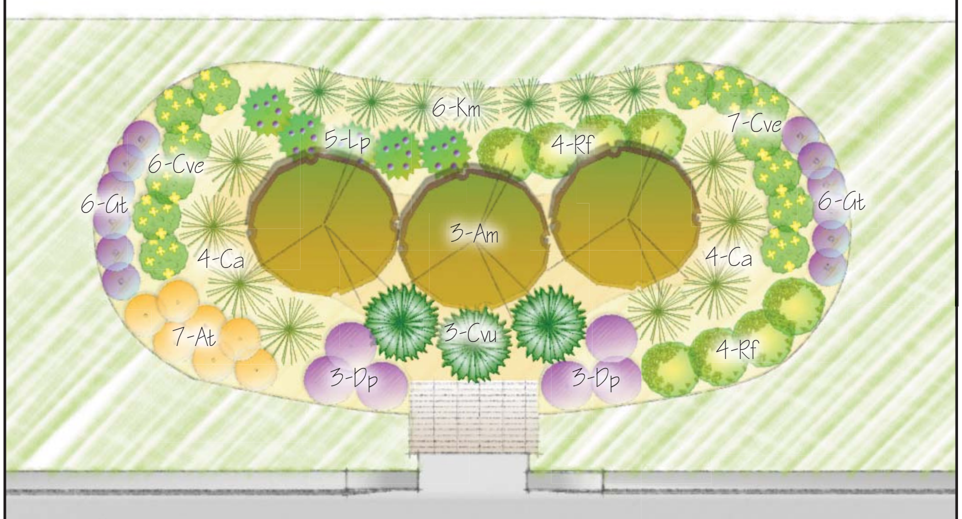
III. Curvilinear Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

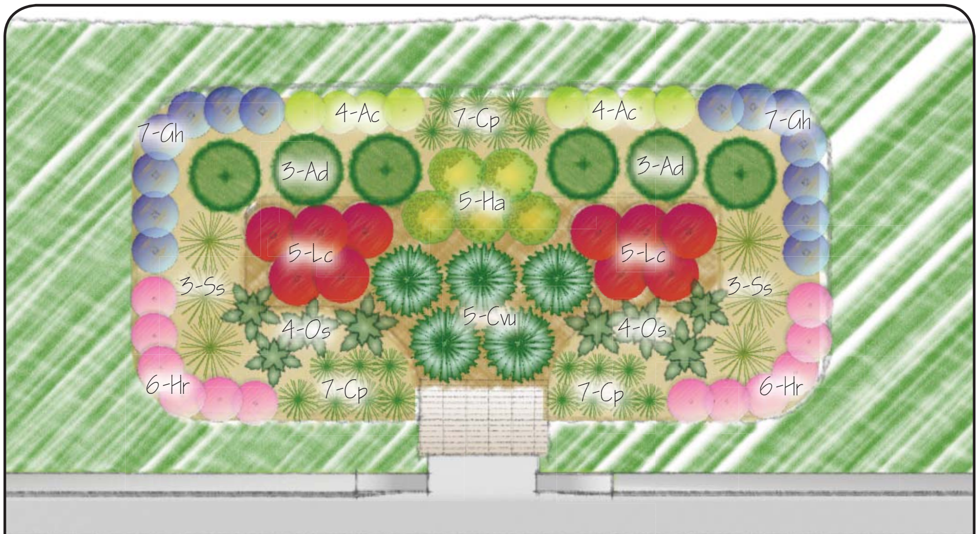


Mixed Shrub/Flower Garden

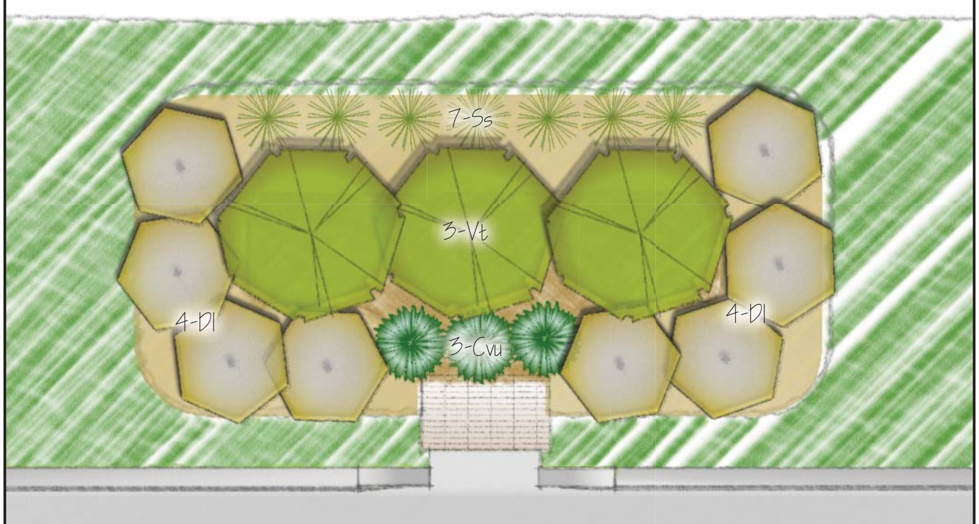
Plant Key

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'*

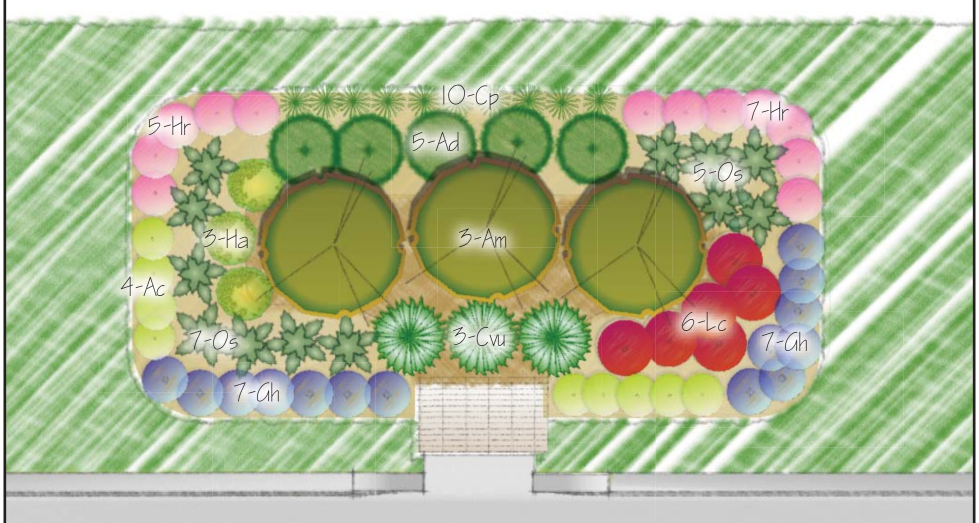
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

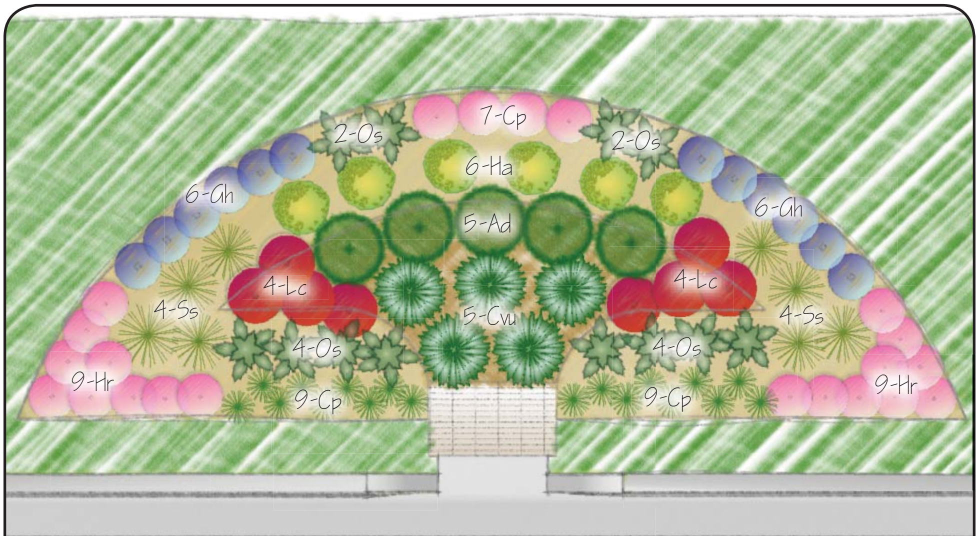


Mixed Shrub/Flower Garden

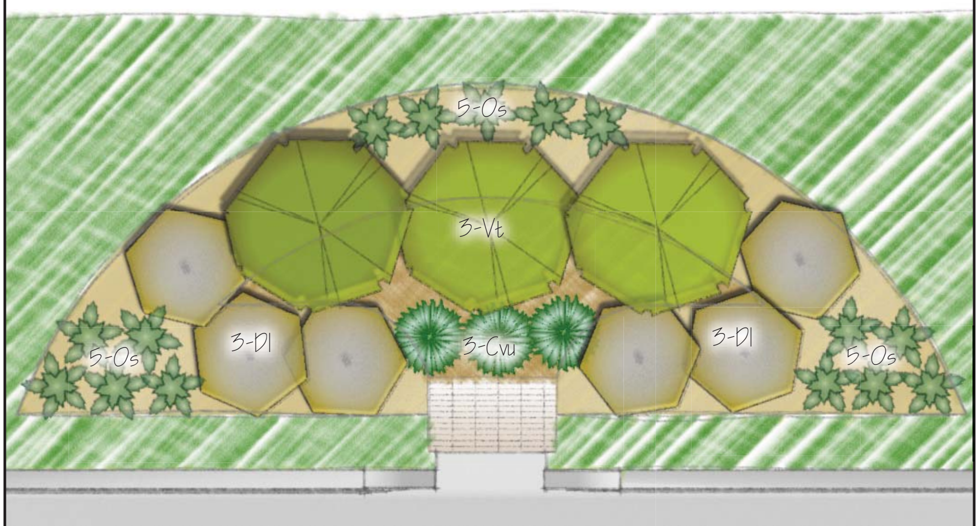
Plant Key

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

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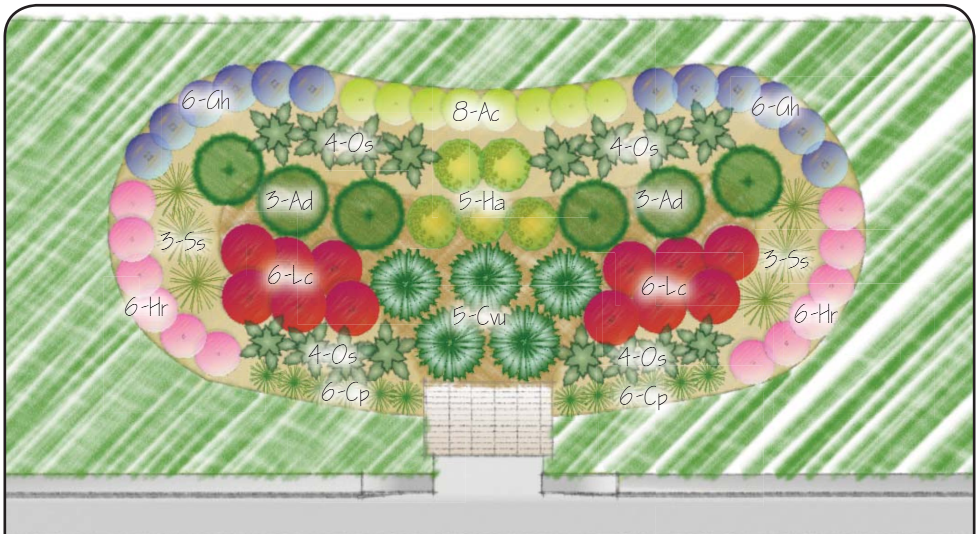
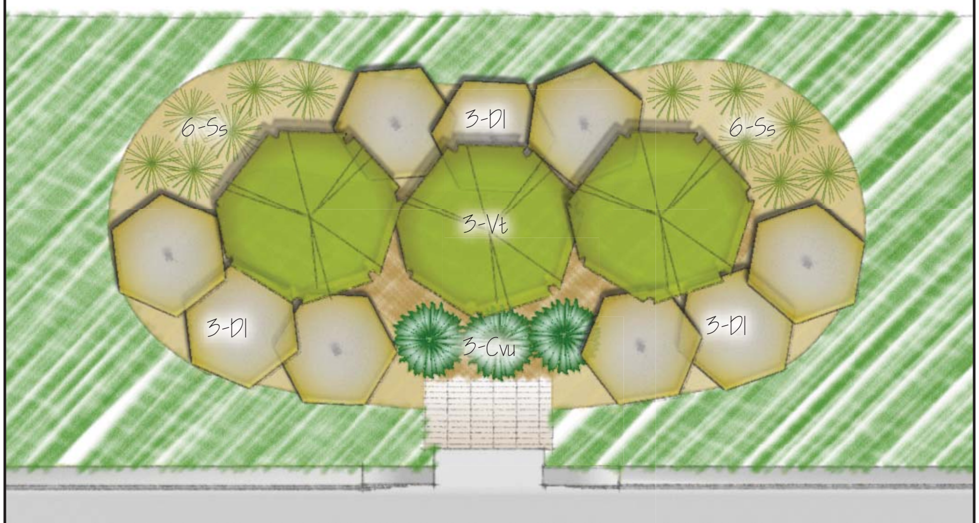
Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	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

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Ac	CANADA ANEMONE *Anemone canadensis*
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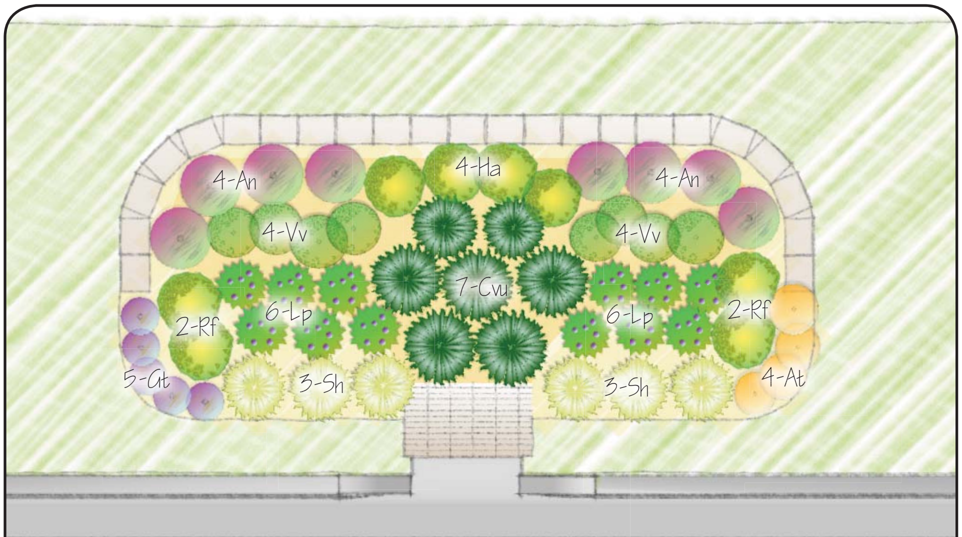
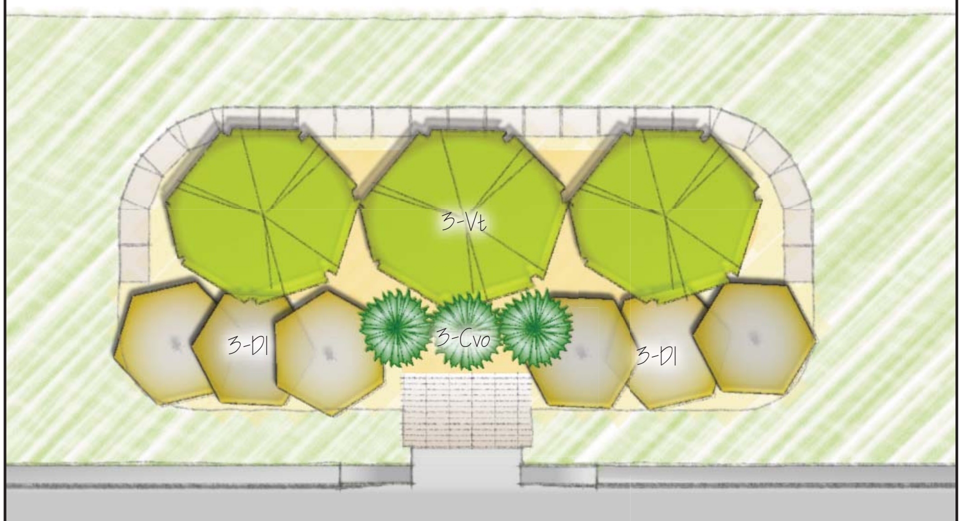
Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
Ha	SNEEZEWEED *Helenium autumnale*
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Ss	LITTLE BLUESTEM *Schizachyrium scoparium*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

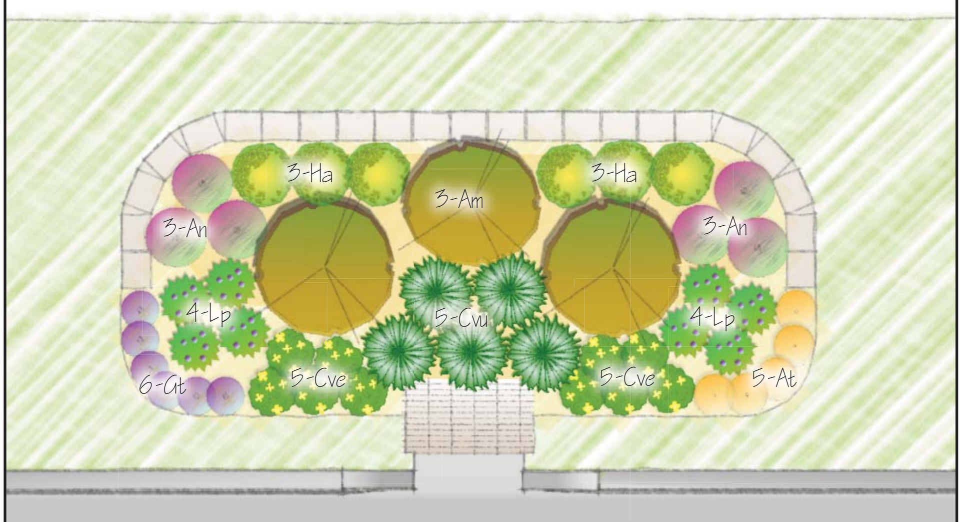
VII. Rectangle Garden - Sunny Site - Retaining Wall



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'*
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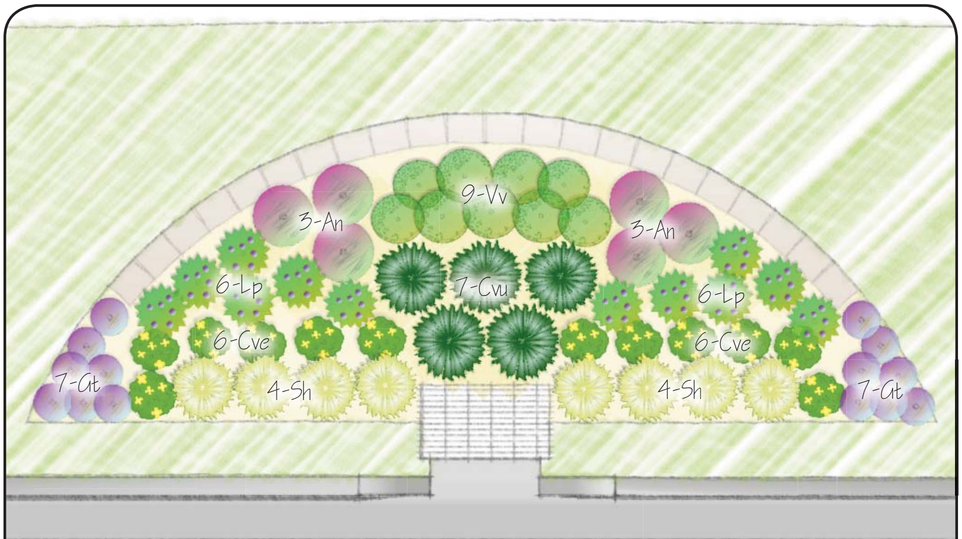
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Ha	SNEEZEWEED *Helenium autumnale*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Rf	GOLDSTRUM BLACK-EYED SUSAN *Rudbeckia fulgida*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Vronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

VIII. Arc Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden

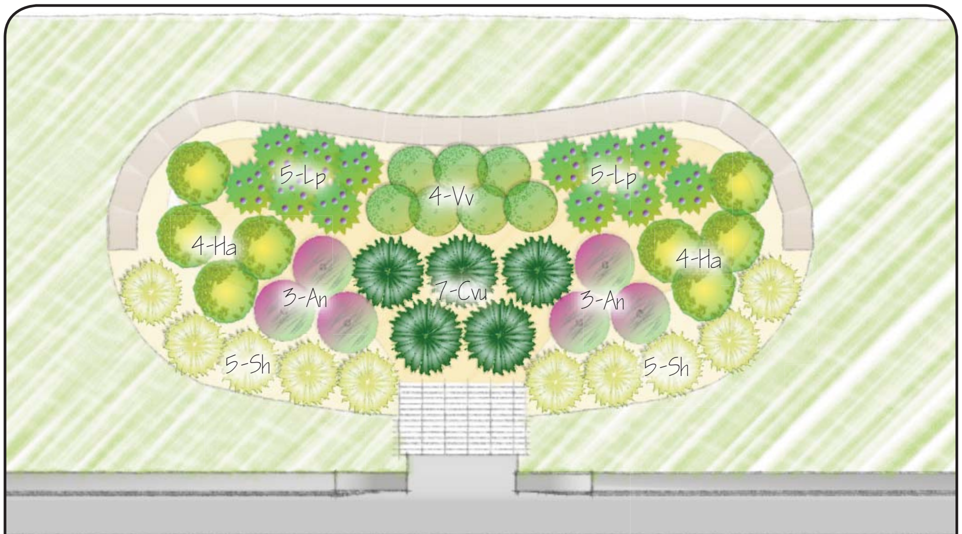
Shrub Garden

Mixed Shrub/Flower Garden

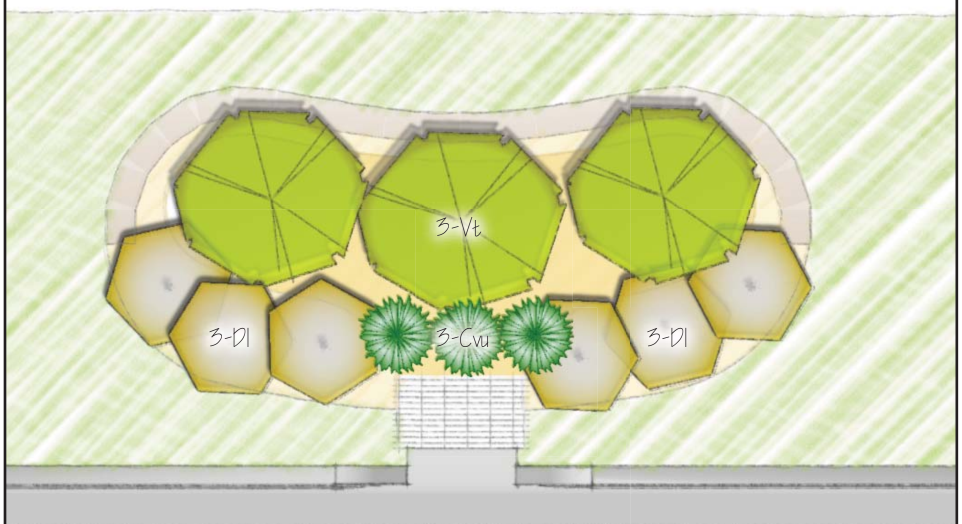
Plant Key

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'*

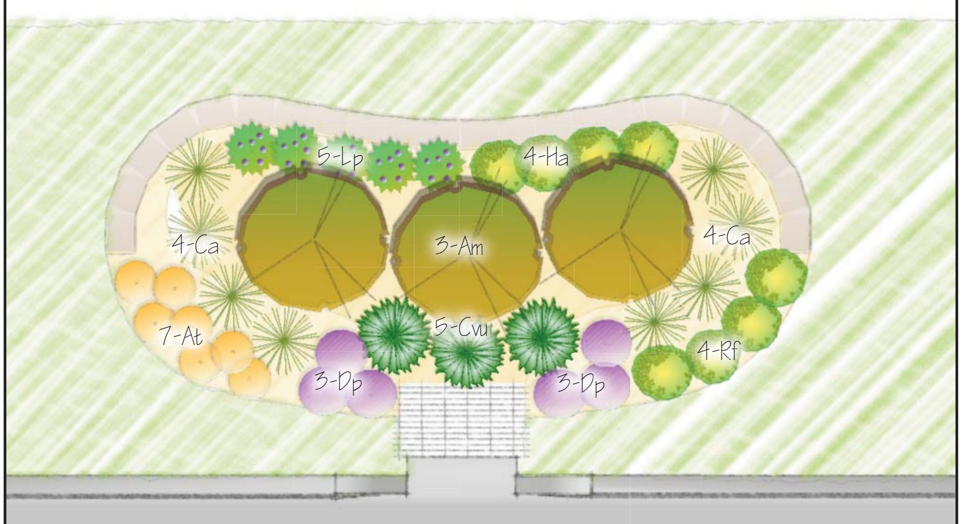
IX. Curvilinear Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



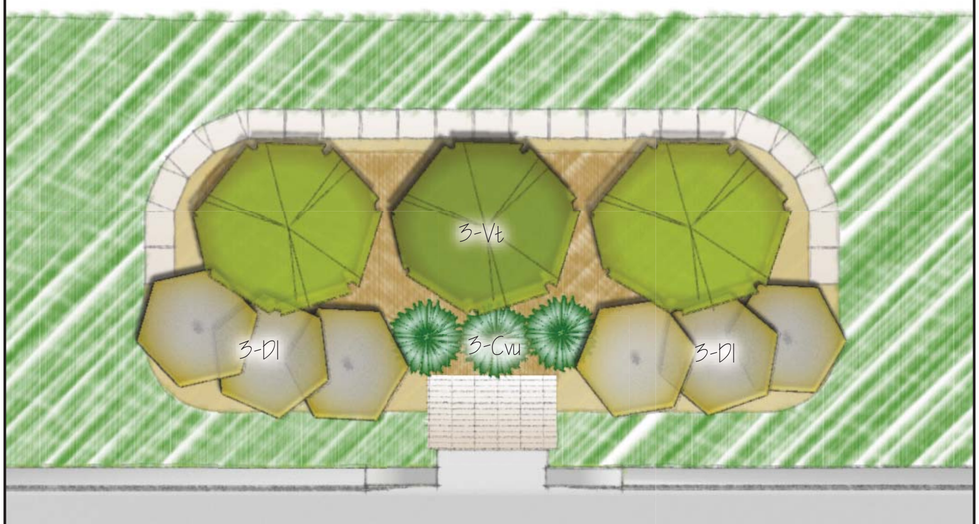
Mixed Shrub/Flower Garden

Plant Key

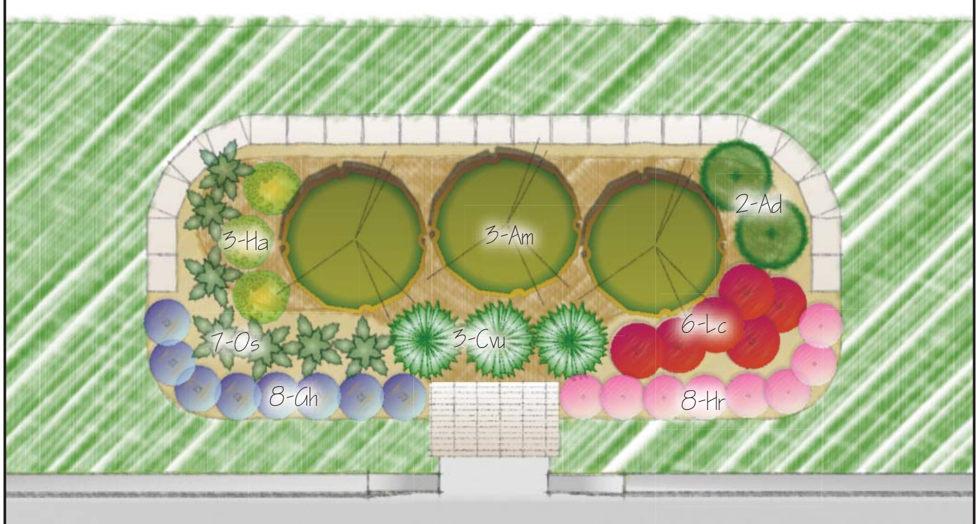
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*
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

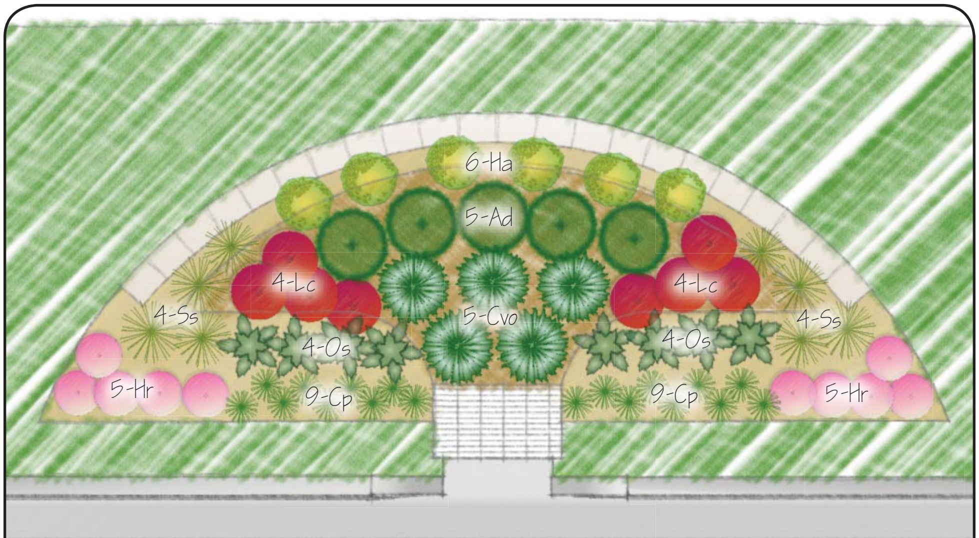


Mixed Shrub/Flower Garden

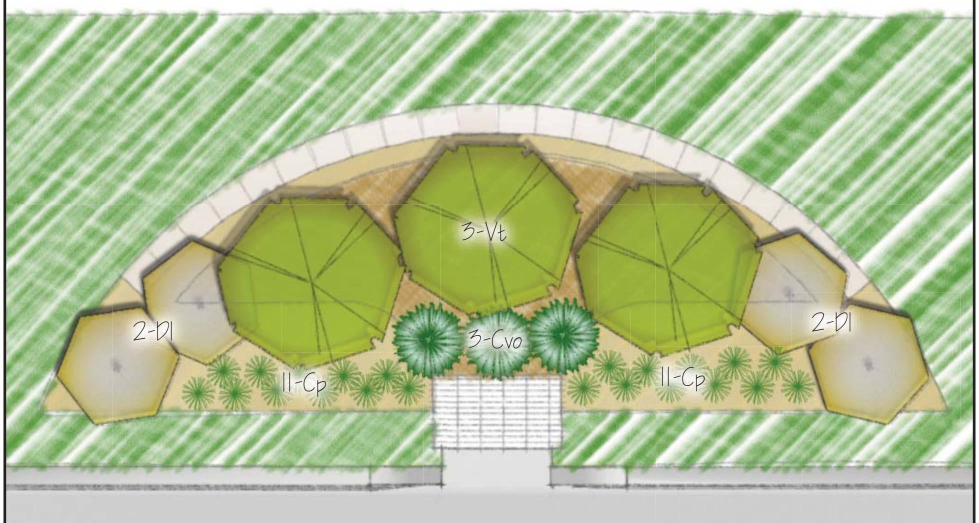
Plant Key

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'*

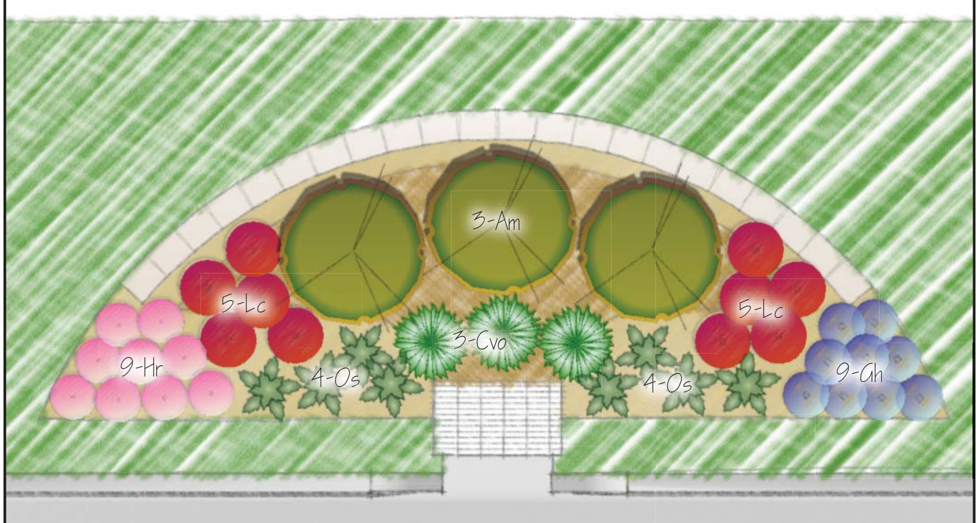
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



Mixed Shrub/Flower Garden

Plant Key

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Ad	GOAT'S BEARD *Aruncus diocius*
Cp	PENNSYLVANIA SEDGE *Carex pennsylvanica*
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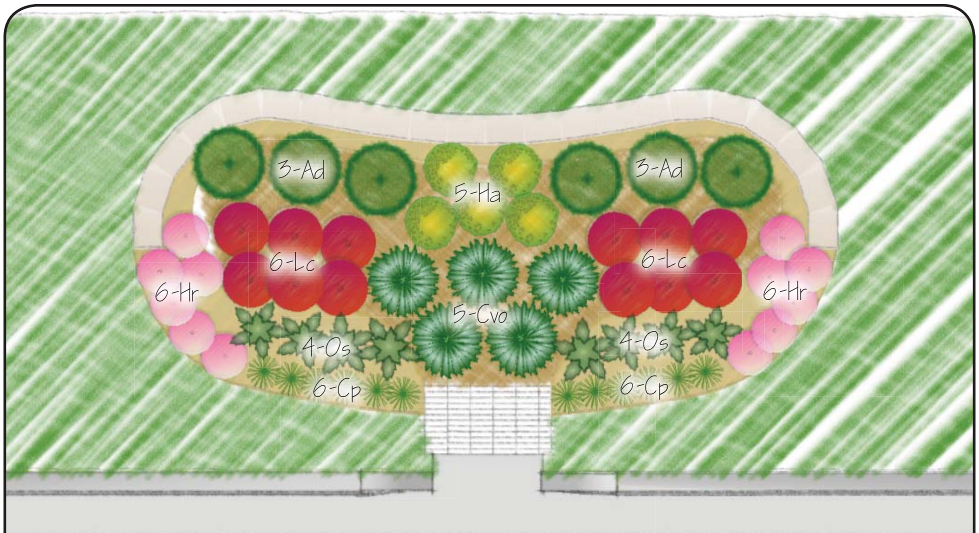
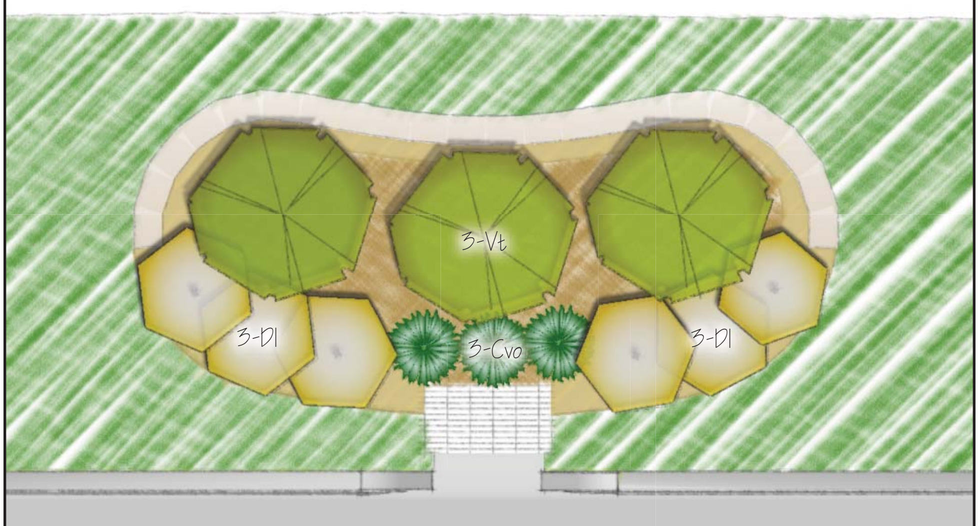
XII. Curvilinear Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

Am	BLACK CHOKEBERRY *Aronia melonocarpa*
Ad	GOAT'S BEARD *Aruncus diocius*
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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

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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.

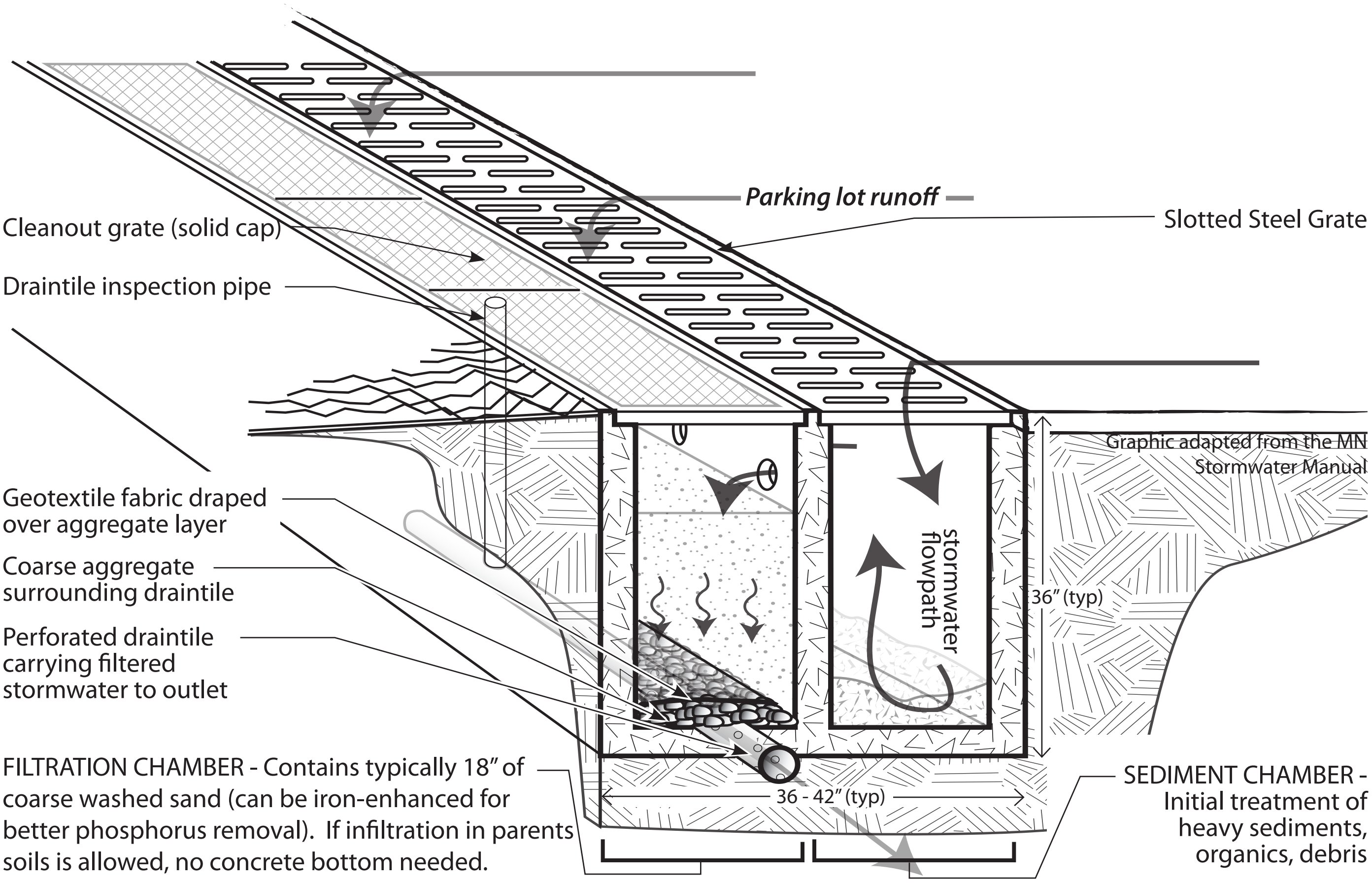

Sand filter inspection, Iowa Stormwater Partnership

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:

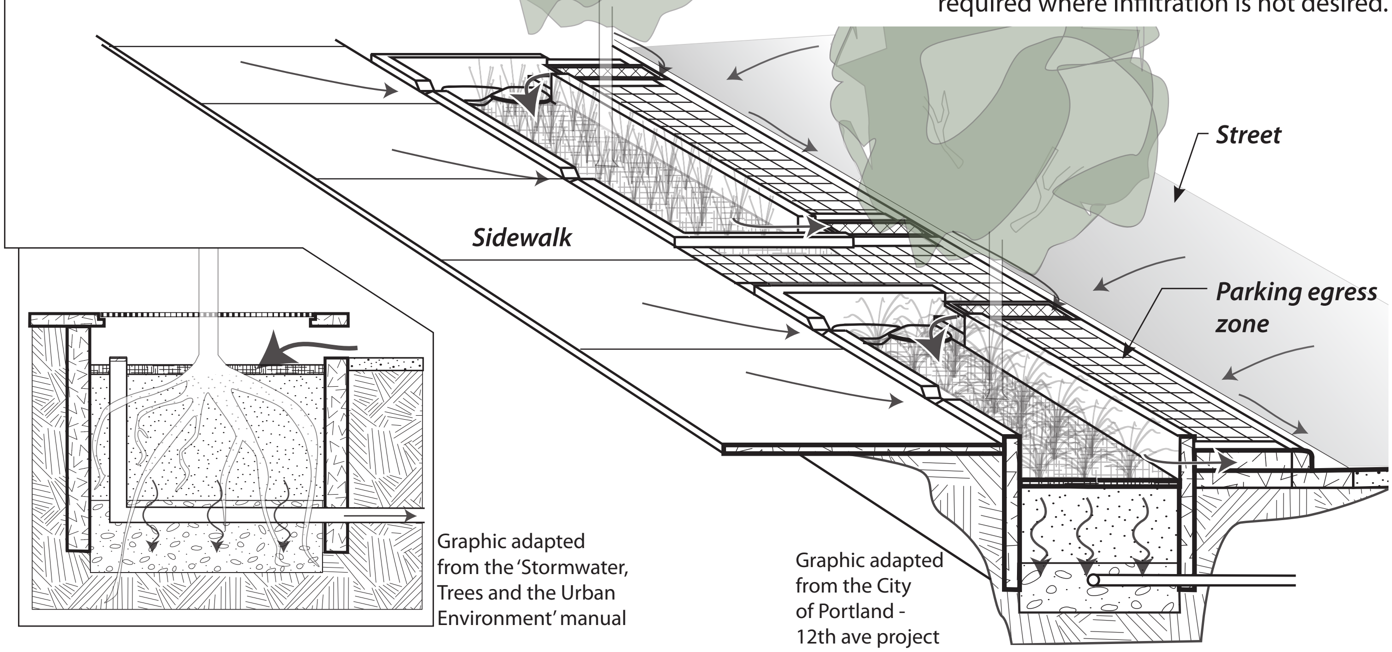
- Optimum ratio at highy impervious sites is one 6' x 6' tree pit per .25 acres

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

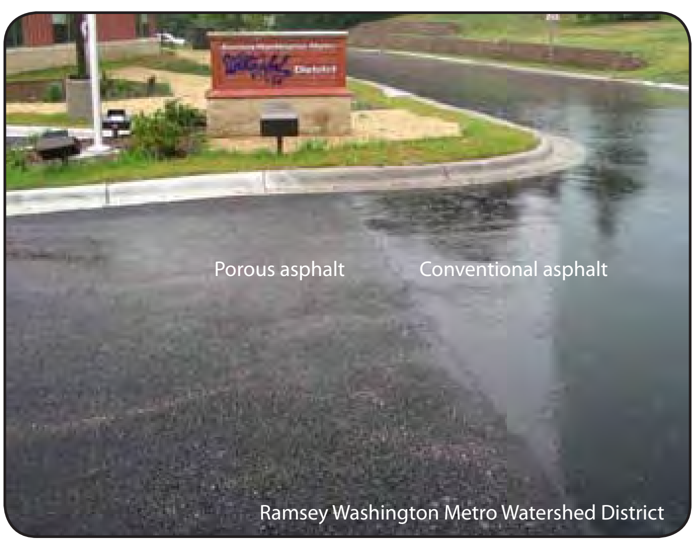
CONCERNS:
- Typically not suited for slopes greater than 5%
- Cost
- At minimum 2 vacuum sweepings per year
- Periodic replacement of fill material in joint spacing (pavers)
- Not suitable for areas generating a lot of sediment

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

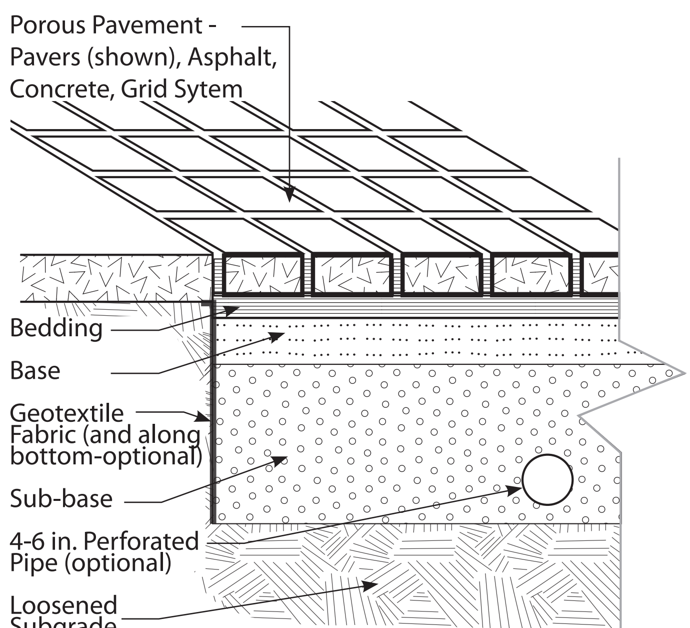
COST:
- Approximately $14 - $35 per cu ft storage depending on underlayment


Permeable pavement in parking aisle, City of Portland


Permeable pavers, Minneapolis



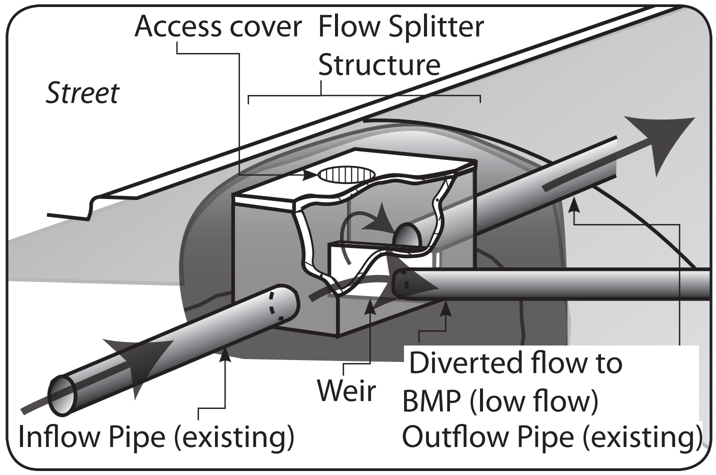
Ramsey Washington Metro Watershed District



Graphic adapted from the Charles River Watershed Association - Information Sheet

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

RECOMMENDED DRAINAGE AREA:

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

CONCERNS:

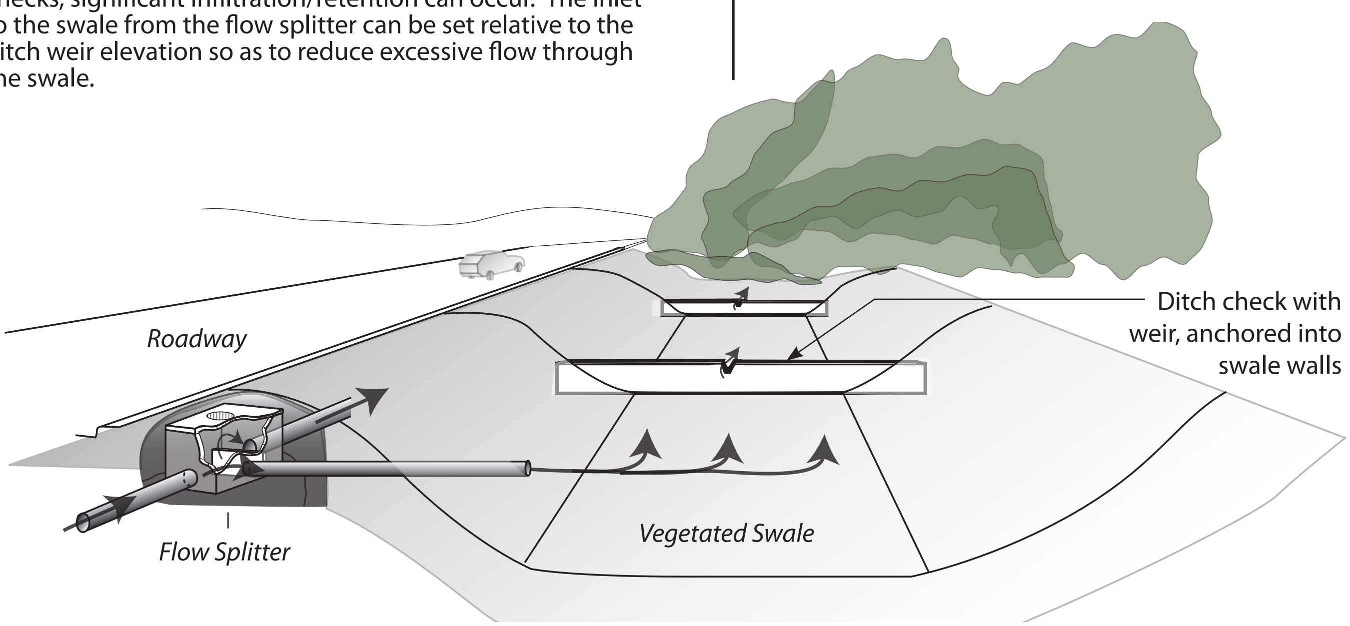
- Alone this practice does not reduce pollutants. It is a tool to divert appropriate flows into a water quality practice

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.

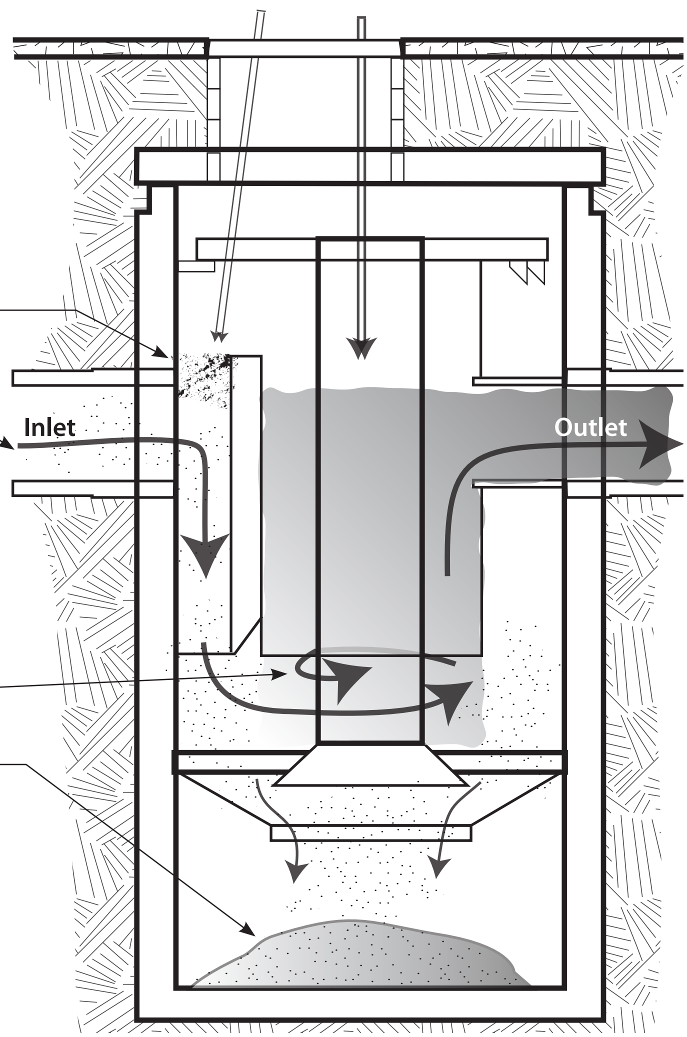

Southeast Michigan Stormwater LID case study

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*