City of Cambridge
Stormwater Retrofit Assessment

Prepared by:

ANOKA CONSERVATION DISTRICT

With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

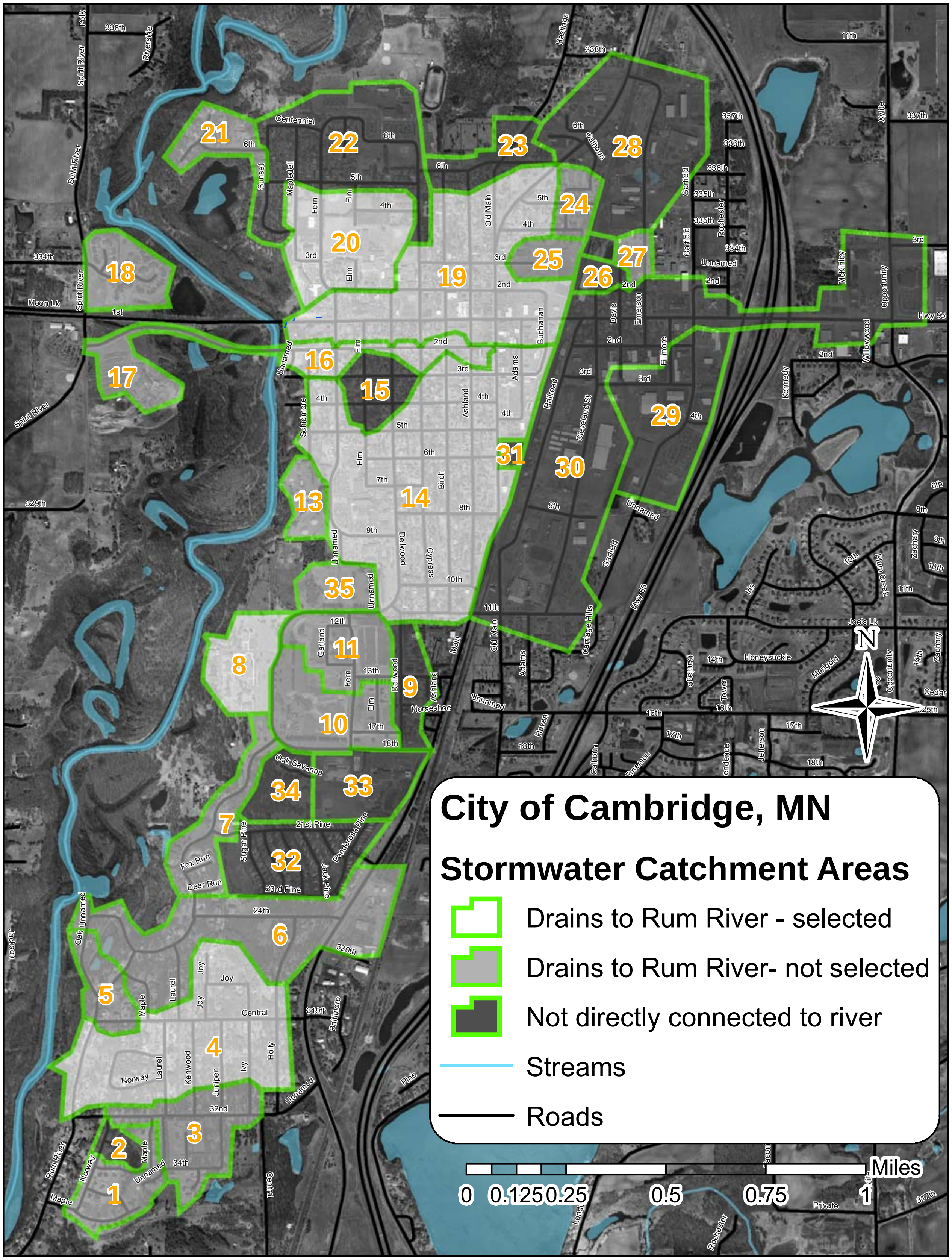
CITY OF CAMBRIDGE, MINNESOTA

Partial funding provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

Cover photo: The City of Cambridge's stormwater outfall into the Rum River from catchment 19, which includes the Highway 95 corridor west of the railroad tracks. The photo shows flows immediately following a 0.31-inch rainfall over 25 minutes.

Contents

Map of stormwater catchment areas referred to in this report.



Executive Summary

This study provides recommendations for cost effectively improving treatment of stormwater from the City of Cambridge before it is discharged into the Rum River. The Rum River is highly regarded for its recreational qualities and scenic nature. While not all parts of the City of Cambridge discharge to the Rum River, those that do are generally older areas built before modern-day stormwater treatment requirements. Many of these areas pipe stormwater to the river with little or no treatment, and have noticeably poor water quality. The volumes of stormwater are also problematic, sometimes overwhelming the system and leading to street flooding. This stormwater assessment systematically examined areas of the City draining to the Rum River, investigated ways to improve stormwater treatment, and prioritized these opportunities by cost-effectiveness.

The approaches in this report are often termed "stormwater retrofitting." This refers to adding stormwater treatment to an already built-up area. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. That approach neglects to consider how much pollution is removed per dollar spent. In this stormwater assessment we estimated both costs and pollutant reductions, and used them to calculate cost effectiveness of each possible project.

We dissected the western half of the City into 34 stormwater drainage areas, or "catchments." This list was narrowed to six by excluding catchments not draining to the Rum River, catchments with already-existing stormwater treatment, and catchments where little or no opportunity for stormwater retrofitting was identified. The six selected catchments included downtown business areas, schools, and several large residential neighborhoods. For each catchment, we modeled stormwater volume and pollutants using the software WinSLAMM. First, we modeled existing conditions. Then we modeled possible stormwater retrofits to estimate reductions in volume, total phosphorus (TP), and total suspended solids (TSS). Finally, we estimated the cost of each retrofit project. Projects were ranked by cost effectiveness.

A variety of stormwater retrofit approaches were identified. In residential areas, networks of strategically-placed rain gardens that accept road runoff are often favored. In some school and church areas, existing pipe alignments and land availability lent themselves to larger infiltration basins. In other places, practices such as swales were already in place but under-utilized. Small modifications to these existing practices can yield substantially larger areas served. In commercial and downtown areas we did not favor infiltration practices because of higher toxic pollutant levels from these land use types and because much of this area is within the City's Drinking Water Supply Management Area. Instead, filtration techniques such as underground sand filters and stormwater tree pits were considered.

This report provides conceptual sketches or photos of stormwater retrofitting projects that are recommended. The intent is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. This typically occurs after committed partnerships are formed to install the project.

The table below summarizes the assessment results. Stormwater retrofit projects are grouped into tiers from most cost effective to least, using cost per pound of phosphorus removed. The benefits of each project were estimated as if that project were installed alone with no other projects upstream of it in the same catchment. 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 table below.

An additional recommendation not included in the table below is to *reduce* downtown street sweeping frequency. Currently street sweeping in downtown areas is done every-other-week. We modeled this schedule versus a monthly sweeping schedule. We assumed only a vacuum-assisted sweeper was used. The pollutant removals gained by every-other-week sweeping are relatively small, and do not justify the costs. The dollars saved by this decrease in downtown street sweeping would yield greater pollutant reductions if spent on other recommended stormwater projects. The present street sweeping schedule for all other areas of the city (2x spring, 2x fall) seems appropriate.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness.

Tier 1 Retrofit Recommendations ($0-$500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 14	Residential Rain Gardens	1	8.6	4,076	8	$26,960	$157
Catchment 8*	Residential Rain Gardens	2	6.9	4,052	5.9	$26,960	$195
Catchment 19	Grandview Swale	2	3.2	1,696	3.8	$10,580	$199
Catchment 19	Residential Rain Gardens	3	11.7	5,420	10.4	$52,100	$226
Catchment 8*	Street Disconnects	1	0.9	844	2.5	$1,900	$311
Catchment 20	School Rain Garden	1	14.1	7,430	15.1	$43,520	$328
Catchment 16	Residential Rain Gardens	2	2.4	1,138	2.2	$18,580	$378
Catchment 4	Residential Rain Gardens	2	3.9	2,046	2.2	$31,150	$401
Total			51.7	26,702	50.1	$211,750	

*Pollution reduction benefits for some projects within the same catchment cannot be added together because they treat the same source areas.

Tier 2 Retrofit Recommendations ($501-$1,500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 20	Church Rain Garden	2	5.3	3,247	6.4	$46,720	$810
Catchment 14	Hospital Rain Garden	1	1.3	1,109	2.3	$20,255	$1,281
Total			6.6	4,356	8.7	$66,975	

Tier 3 Retrofit Recommendations (>$1,500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 16	Stormwater Tree Pits	3	0.7	293	0	$51,050	$3,195
Catchment 19*	Perimeter Sand Filters	2	0.9	584	0	$37,140	$3,322
Catchment 19*	Stormwater Tree Pits	1	1.1	449	0	$81,680	$3,323
Catchment 19*	Permeable Asphalt	1	0.6	491	1.1	$150,094	$8,744
Total			≥1.3*	≥742*	≥0*	≥$88,190*	

*Pollution reduction benefits for some projects within the same catchment cannot be added together because they treat the same source areas.

About this Document

This Stormwater Retrofit Assessment 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 four major sections, plus appendices. Each section is described below.

Methods

The methods section outlines general procedures used when assessing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking.

Catchment Profiles

The City was divided into stormwater catchments for the purpose of this assessment. Each catchment was given a unique ID number. For each catchment, the following information is detailed:

Catchment Description

Within the catchment profiles 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 here. 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.

Retrofits Considered but Rejected

Retrofits that were examined, but deemed unfeasible or impractical are highlighted in this section.

Retrofit Ranking

This section ranks retrofit stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by cost per pound of phosphorus treated for each project for a duration of 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 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 assessment protocol utilized in this analysis.

Appendices

This section provides supplemental information and/or data used at various points along the assessment protocol.

Methods

Selection of Subwatershed

Many factors are considered when choosing which subwatershed to assess 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. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly. For some communities a stormwater assessment complements their MS4 stormwater permit. The focus is always on a high priority waterbody.

For this assessment, portions of the City of Cambridge, Minnesota which drain directly to the Rum River were chosen for study. The Rum River is regarded highly for its recreational qualities and scenic nature. While not all parts of the City of Cambridge discharge to the Rum River, those that do are generally older areas built before modern-day stormwater treatment requirements. Many of these areas pipe stormwater to the river with little or no treatment and have noticeably poor water quality. These same areas have a high percentage of land surfaces that are impervious, with pavement or rooftops that generation large volumes of runoff water and recurring street flooding.

Downtown Cambridge – A high percentage of surfaces are both impervious (pavement, roofs) and within land uses that generate high pollutant loads. Because these areas were built before modern-day stormwater treatment technologies and requirements, treatment before discharge into the Rum River is limited.

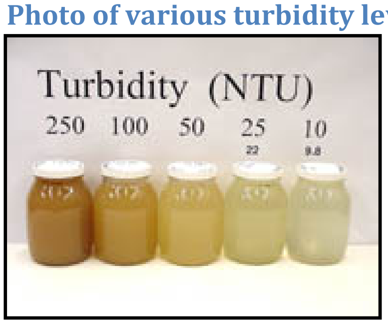
Water quality data supports selecting potions of the City of Cambridge for a stormwater retrofitting assessment, particularly those areas draining directly to the Rum River. Results of water quality testing done at the outfalls of major stormwater pipes into the Rum River are provided in the table below. Generally, the water was brown and turbid and occasionally had an oily sheen. Turbidity readings ranged from 36 to 249 NTU, with an average of 107. As a reference, the State of Minnesota water quality standard for rivers and streams is that turbidity should not exceed 25 NTU in more than 3 samples and 10% of all samples. Other parameters, such as metals, were not measured at the stormwater outfalls but were likely elevated. It is apparent that improved stormwater quality in the City will be significantly beneficial to the Rum River.

Turbid Stormwater – The outfall of catchment 14 into the Rum River following a 0.34-inch rainfall that fell in the preceding 25 minutes on August 13, 2010.

Results of water quality testing done at selected stormwater pipe outfalls in the City of Cambridge.

Catchment #	Date	Time	Turbidity (NTU)	TSS (mg/L)	TP (mg/L)	Rain total at sampling time (in)	Rain duration at sampling time (min)
4	7/27/2010	20:15	38			0.48	60
4	9/23/2010	12:05	36			0.29	110
8	9/23/2010	11:55	41			0.27	100
14	7/27/2010	19:40	163	21	0.152	0.38	40
14	8/13/2010	16:55	249	134	0.274	0.35	25
14	9/23/2010	11:45	119			0.27	90
19	7/27/2010	19:25	133	8	0.152	0.31	25
19	8/13/2010	16:45	65	33	0.081	0.35	25
19	9/23/2010	11:30	116			0.27	75
Average			107	49	0.165	0.33	61

Photo of various turbidity levels (source: North Carolina State University).



Subwatershed Assessment Methods

The process used for this assessment is outlined below 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 included 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 district staff 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 assess in large subwatersheds, a focus area may be determined.

In this assessment, the focus area began as all portion of Cambridge west of the railroad tracks. Generally, this captured all areas draining to the Rum River. We divided this area into 34 catchments using a combination of stormwater infrastructure maps and observed topography. In areas where topography seemed flat, catchments were delineated by observing the direction of water flow during rainfall. Catchments not draining to the Rum River were excluded. The focus area was further narrowed in later parts of the study to exclude those areas where significant stormwater treatment exists or no reasonable retrofit opportunities were identified. Targeted pollutants were phosphorus and suspended solids. Volume reductions are also sought to alleviate strain on the stormwater system in downtown areas which is sometimes overwhelmed, resulting in street flooding.

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 assessed because of existing stormwater infrastructure. 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 storm drainage infrastructure (with invert elevations).

For this assessment, GIS layers of stormwater infrastructure were obtained from the City of Cambridge. High-resolution aerial photography and parcel boundaries were available from Isanti County. Unfortunately, fine topography data was not available.

Desktop retrofit analysis features to look for and associated 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.**

Feature	Potential Retrofit Project
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 or curb-cut raingardens or filtering systems to treat stormwater before it 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 sol, 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 passing it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost 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 raingardens, 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 City'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 suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

Project pollutant removal estimates were obtained 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.

A "base" model was created which estimated pollutant loading from each catchment in its present-day state. To accurately model the land uses in each catchment, we delineated each land use in each catchment using ArcGIS, and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and converting to "sand" soils to account for the sandy soils in the City of Cambridge. For catchments with multiple standard land use files, these were combined using the software's batch processing capability. 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 ArcGIS, and adjusting the model acreages if needed. For example, we used ArcGIS to measure flat roofs in a school land use and compared that to the model's standard land use file's expected acreages of flat roofs. Generally, little adjustment was needed.

Once the "base" model was created, each proposed stormwater treatment practice was added to the 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.

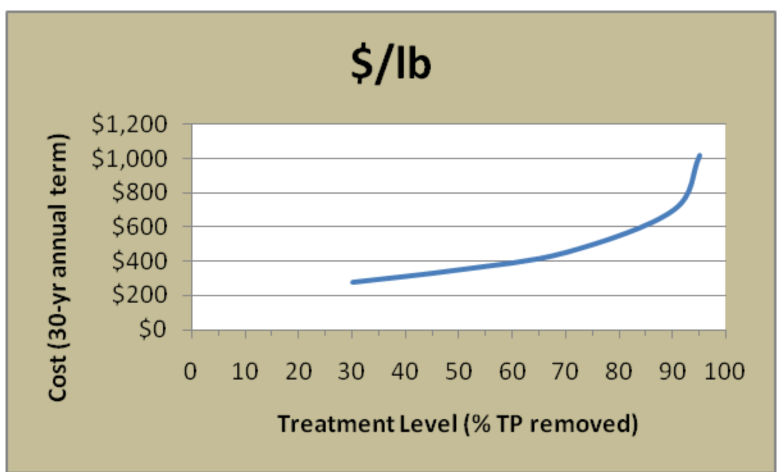
WinSLAMM stormwater computer model inputs

General WinSLAMM Model Inputs	
Parameter	**File/Method**
Land use acreage	ArcGIS
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

Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 30-year period. In cases, such as rain gardens, where promotion to landowners is important, 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 on-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 assessment, 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 City 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. Projects were grouped into tiers from most to least cost effective. Only projects that seem 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. The City may wish to revise the recommended level based on water quality goals, finances, or public opinion.

Catchment Profiles

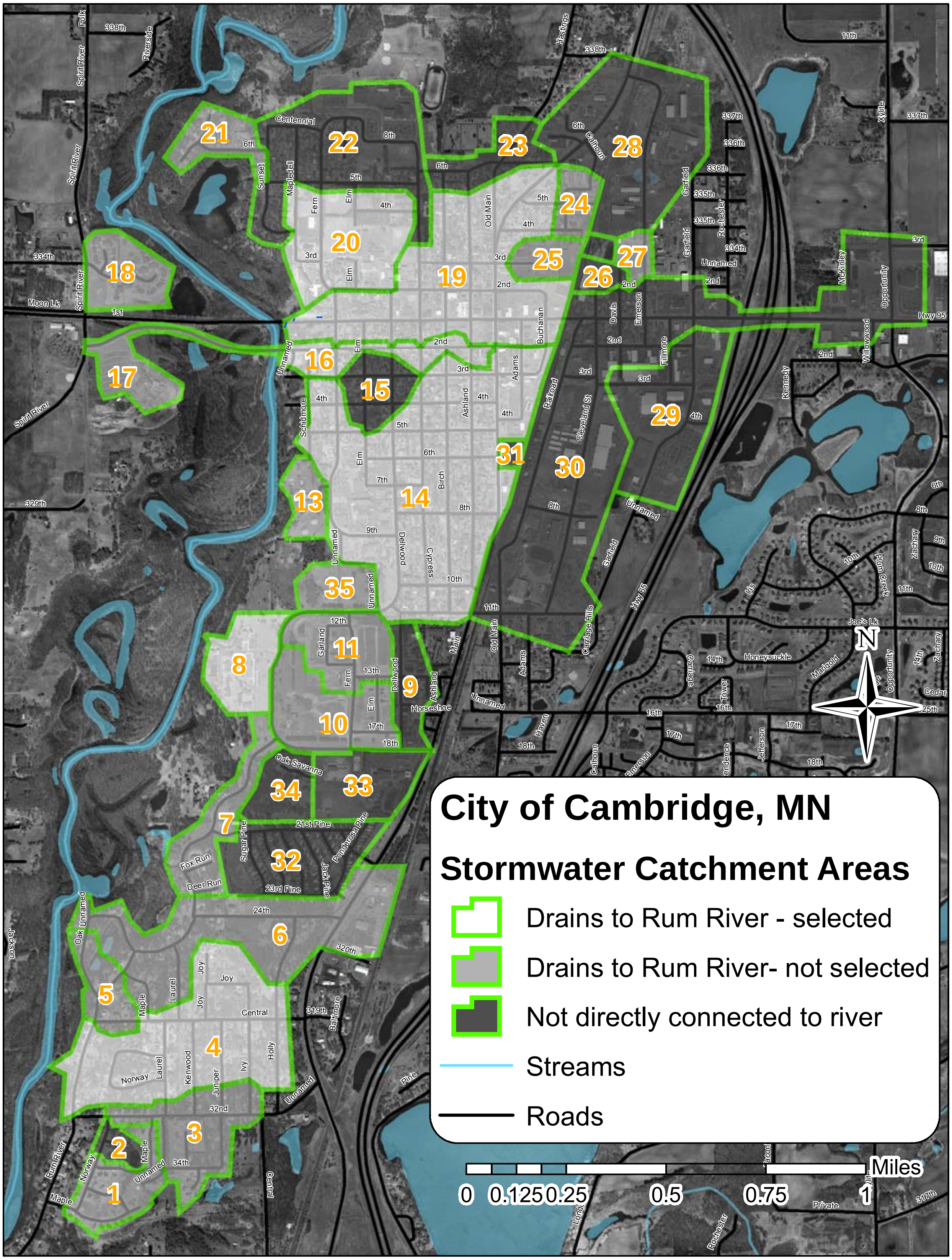
The following pages provide information for each stormwater catchment area we analyzed. Each catchment profile includes:

- Summary of existing conditions, including estimated pollutant export to the Rum River.
- Map of the catchment
- Recommended stormwater retrofits, pollutant reductions, and costs
- Retrofits considered but rejected

Catchment profiles are provided only for those six catchments selected as highest priority. Please refer to the catchment map earlier in this report. Some of the catchments that were not selected do not drain to the Rum River, and no projects in these areas should be considered for Rum River improvement. Other catchments were not selected because significant stormwater treatment exists or no reasonable retrofit opportunities were identified.

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

Map of stormwater catchment areas referred to in this report. A catchment profile for each selected catchment is on the following pages.



Catchment 4

Catchment Summary	
Acres	93.5
Dominant Land Cover	Residential
Parcels	181
Volume (acre-feet/yr)	9.8
TP (lb/yr)	15.7
TSS (lb/yr)	8,121

CATCHMENT DESCRIPTION

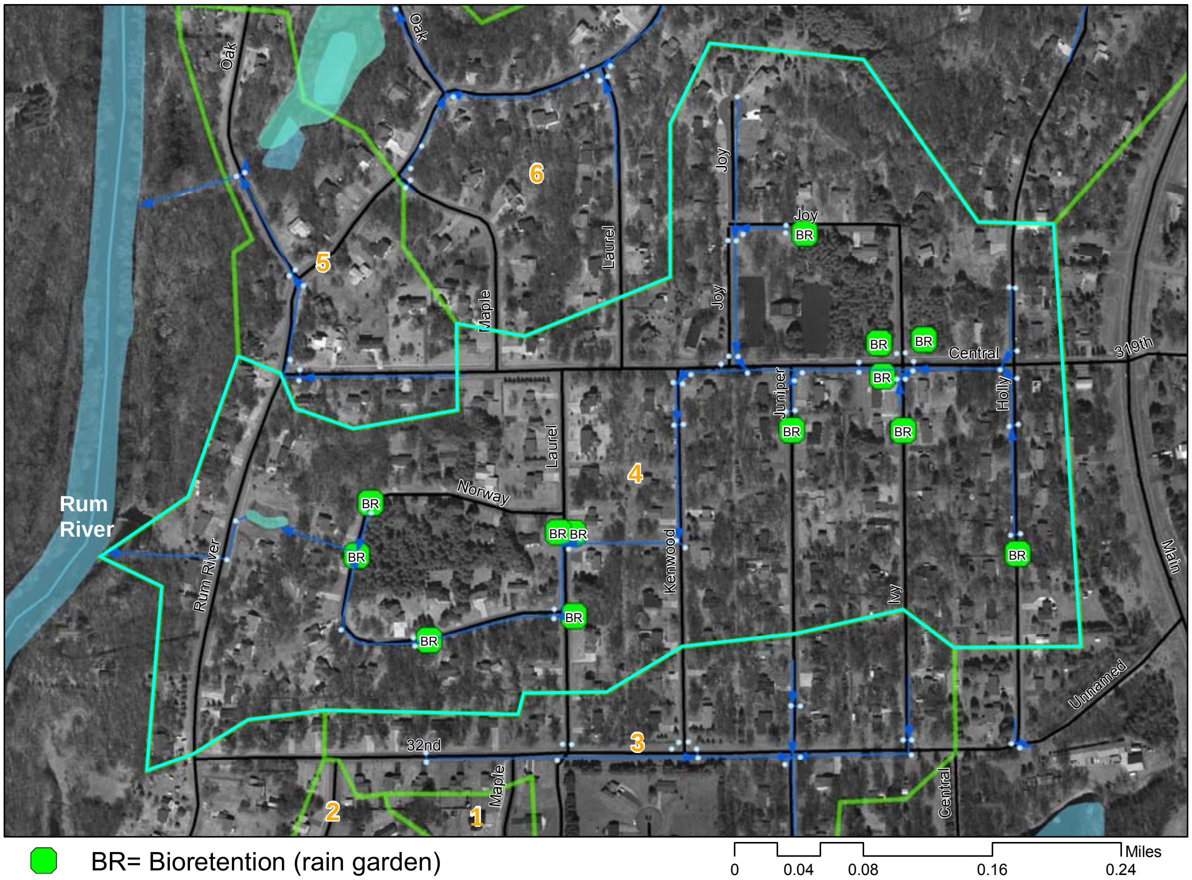
This catchment is comprised of primarily medium density, single-family residential development. It also includes the campus of Joy Lutheran Church and a few acres of city-owned open space.

EXISTING STORMWATER TREATMENT

Nearly all drainage in this catchment passes through a 0.2 acre pond at East Rum River Drive, near the outfall into the Rum River. Aside from street sweeping, this pond is the only stormwater treatment in the catchment, but it is working well. The pond infiltrates water rapidly, and dries completely between most storms. It's location at the bottom of the catchment and high infiltration rate help this otherwise small basin achieve significant pollutant removals. Model estimates of pollutant removals by the street sweeping were 14% of TSS and TP. Street sweeping and the pond together achieve an estimated 65-68% pollutant reduction and 75% volume reduction (see table below).

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	49.7	34.0	68%	**15.7**
	TSS (lb/yr)	23,355	15,234	65%	**8,121**
	Volume (acre-feet/yr)	38.5	28.7	75%	**9.8**
	Number of BMP's	2			
	BMP Size/Description	Outfall pond + Street sweeping			

RETROFIT RECOMMENDATIONS



Network of rain gardens - The residential nature of this catchment makes it best suited to residential, curb-cut rain gardens (see appendix B for design options). 13 ideal rain garden locations were identified (see map). Generally, ideal rain garden locations are immediately up-gradient of a catch basin serving a large area. Considering typical landowner willingness rates we analyzed scenarios where 5, 7, and 9 rain gardens were installed (levels 1, 2, and 3 in the table below). At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown the table below. The cost per pound of phosphorus removed is lowest if seven rain gardens are installed.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	2.5	73%	3.9	76%	4.2	77%
	TSS (lb/yr)	1,339	71%	2,046	74%	2,178	75%
	Volume (acre-feet/yr)	1.4	78%	2.2	80%	2.7	81%
	Number of BMP's	5		7		9	
	BMP Size/Description	1,250 sq ft		1,750 sq ft		2,250 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$20,460		$28,560		$36,660	
	Promotion & Admin Costs	$2,310		$2,590		$2,870	
	Total Project Cost	$22,770		$31,150		$39,530	
	Annual O&M	$375		$525		$675	
	Term Cost/lb/yr (30 yr)	**$454**		**$401**		**$471**	

RETROFITS CONSIDERED BUT REJECTED

East Rum River Drive pond - Alteration of the existing outfall pond at East Rum River Drive was considered. Given space constraints, little expansion, excavation, or outlet modification is possible. The pond filled only during larger rain storms. We observed that infiltration rates in this pond were high and the pond dried quickly after rain. This rapid infiltration is evidenced by stands of giant ragweed within the basin; this plant that does not tolerate standing water. While periodic excavation of accumulated sediment may be warranted, alteration of this pond seems unwarranted and impractical. It should be noted that maintenance is needed to the crumbling inlet.

Catchment 8

Existing Catchment Summary	
Acres	25.2
Dominant Land Cover	Institutional
Parcels	1
Volume (acre-feet/yr)	18.8
TP (lb/yr)	20.1
TSS (lb/yr)	11,527

DESCRIPTION

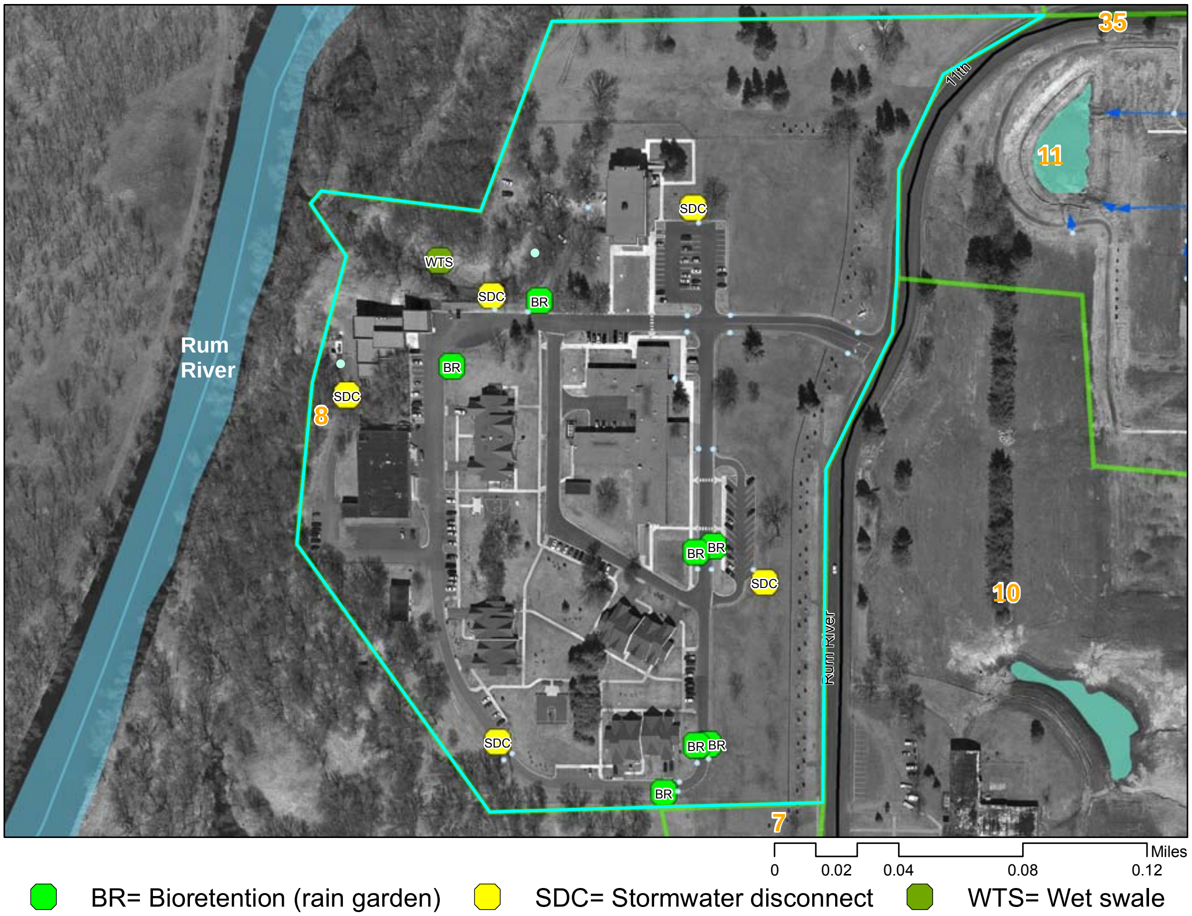
This catchment is the Minnesota Extended Treatment Options (METO) campus. This state-owned property includes office, maintenance, and residential buildings as well as parking. While the property is served by curb-and-gutter stormwater systems, maps of pipes and outfalls could not be found despite attempts to obtain them from property maintenance staff and managers. Most catch basin locations were identified during this study, and are shown on the map below. Based on field observations, it is clear that all drainage is to the Rum River.

EXISTING STORMWATER TREATMENT

There are no existing stormwater treatment practices. Existing pollutant loading from this catchment to the Rum River are shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	20.1	0.0	0%	**20.1**
	TSS (lb/yr)	11,527	0	0%	**11,527**
	Volume (acre-feet/yr)	18.8	0.0	0%	**18.8**
	Number of BMP's	0			
	BMP Size/Description	NA			

RETROFIT RECOMMENDATIONS



<u>Rain gardens</u> – The campus provides several ideal opportunities for curb-cut rain gardens (see appendix B for design options). The fact that a single owner manages the entire area simplifies logistics. Seven locations for rain gardens were identified (see map). All are immediately up-gradient of catch basins and in areas were unused green space would allow construction of the basin.

Example curb-cut rain garden location.

Understanding that site constrains, such as buried utilities, can limit the number of suitable sites we analyzed scenarios where 4, 6, and 8 rain gardens were installed. At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown the table below. The cost per pound of phosphorus removed is also listed in the table, and ranges from $173-210, which is low.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	5.3	26%	6.9	34%	8.5	42%
	TSS (lb/yr)	3,115	27%	4,052	35%	4,938	43%
	Volume (acre-feet/yr)	3.6	19%	5.9	31%	7.3	39%
	Number of BMP's	4		6		8	
	BMP Size/Description	1,000 sq ft		1,500 sq ft		2,000 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$16,410		$24,510		$32,610	
	Promotion & Admin Costs	$2,170		$2,450		$2,730	
	Total Project Cost	$18,580		$26,960		$35,340	
	Annual O&M	$300		$450		$600	
	Term Cost/lb/yr (30 yr)	**$173**		**$195**		**$210**	

<u>Stormwater street disconnects</u> – Stormwater disconnecting is the practice of routing stormwater onto permeable surfaces, such as lawn, instead of into catch basins. There are five promising locations for stormwater disconnects. Each would be accomplished by installing a curb-cut immediately up-gradient of an existing catch basin and doing some minor re-grading with erosion protection. In each case the water would be directed to unused open space. This is similar to a curb-cut rain garden approach, except that large areas of available space and sandy soils make creating a basin to contain and infiltrate the water unnecessary.

We analyzed a scenario where four disconnects were installed. At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown the table below. The cost per pound of phosphorus removed is $311/year.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	0.9	4%				
	TSS (lb/yr)	844	7%				
	Volume (acre-feet/yr)	2.5	13%				
	Number of BMP's	4					
	BMP Size/Description	40	linear feet				
	BMP Type	Curb-Cut					
Cost	Materials/Labor/Design	$1,200					
	Promotion & Admin Costs	$700					
	Total Project Cost	$1,900					
	Annual O&M	$210					
	Term Cost/lb/yr (30 yr)	**$311**					

Wet Swale – The northern part of the METO property contains what may be an ideal stormwater retrofit opportunity – modification of an existing swale – but not enough information exists to analyze it. The swale runs from the recreation building westward to the river. Based on conversations with maintenance crews, it was built in the early 2000's to address gully erosion. No construction plans were available. Today, the swale "stair-steps" down to the river. However, only one catch basin is directed to it. All other water runs into a pipe underneath the swale, bypassing the treatment capacity of the swale. The pipe should be day-lighted at the top of the swale if at all possible. Cost per pound of pollutant removed by the retrofit should be low given that the practice is already built in a way ideal for water quality treatment.

Catchment 14

Existing Catchment Summary	
Acres	169.0
Dominant Land Cover	Residential, Hospital
Parcels	386
Volume (acre-feet/yr)	112.6
TP (lb/yr)	99.1
TSS (lb/yr)	53,599

DESCRIPTION

This is the largest Cambridge catchment analyzed. It is comprised of the hospital and medium density, single-family residential development. The entire area is served by curb-and-gutter stormwater systems that drain to a single outlet into the Rum River near Fifth Avenue South.

EXISTING STORMWATER TREATMENT

The only functioning stormwater treatment practice in this catchment is street sweeping. A small residential rain garden exists near the corner of 8th Avenue South and Ashland Street, however it is clogged and in need of maintenance. Existing pollutant loading from this catchment to the Rum River, after street sweeping, are shown in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	114.4	15.2	13%	**99.2**
	TSS (lb/yr)	61,153	7,554	12%	**53,599**
	Volume (acre-feet/yr)	112.6	0.0	0%	**112.6**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS

<u>Hospital rain garden</u> –

A single, well-positioned rain garden site on hospital property was found (see appendix B for design options). The location is on the southwest corner of the hospital grounds, just south of a garage. A horseshoe court and lawn currently occupy the site. A catch basin adjacent to this location receives all runoff from parking lots to the north (but south of the emergency room entrance). It also receives some runoff from parking lots to the east. In all, approximately 1.9 acres of parking lot runoff can be treated by diverting water from the catch basin to a large rain garden. For modeling purposes, the proposed rain garden was sized at 1650 sq ft and 1.25 feet deep. This is approximately six times larger than most residential rain gardens. Estimated pollutant removals and costs are shown below.

Location of potential hospital rain garden (circled).

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	1.3	14%				
	TSS (lb/yr)	1,109	14%				
	Volume (acre-feet/yr)	2.3	2%				
	Number of BMP's	1-Hospital Rain Garden					
	BMP Size/Description	1,650 sq ft					
	BMP Type	Simple Bioretention					
Cost	Materials/Labor/Design	$18,855					
	Promotion & Admin Costs	$1,400					
	Total Project Cost	$20,255					
	Annual O&M	$990					
	Term Cost/lb/yr (30 yr)	**$1,281**					

Residential Rain gardens –
The fully-built-out nature of this catchment makes residential rain gardens one of the few practical retrofits (see appendix B for design options). Nine possible sites have been identified (see map above), however most of these have not been field verified. Of particular challenge in this catchment is the abundance of sidewalks, which make rain garden placement more difficult. In those situations the garden might be placed in the boulevard or water might be diverted under the sidewalk to a rain garden in the yard.

Understanding that site constraints and landowner willingness limit the number of suitable sites we analyzed scenarios where 6, 10, and 14 rain gardens were installed. At these three levels of treatment, catchment-wide removal of TSS and TP could be increased to the levels shown the table below. The cost per pound of phosphorus removed is also listed in the table, and ranges from $157-178, which is quite low.

It is important to note that the northern half of this catchment is in the city's Drinking Water Supply Management Area (DWSMA). No infiltration from stormwater "hotspots" (filling stations, industrial storage, etc) should occur. Infiltration of water from residential areas is less concerning, but caution should still be exercised.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	8.6	21%	13.1	25%	17.3	28%
	TSS (lb/yr)	4,076	19%	6,163	22%	8,088	26%
	Volume (acre-feet/yr)	8.0	7%	12.1	11%	15.7	14%
	Number of BMP's	6		10		14	
	BMP Size/Description	1,500 sq ft		2,500 sq ft		3,500 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$24,510		$40,710		$56,910	
	Promotion & Admin Costs	$2,450		$3,010		$3,570	
	Total Project Cost	$26,960		$43,720		$60,480	
	Annual O&M	$450		$750		$1,050	
	Term Cost/lb/yr (30 yr)	**$157**		**$168**		**$178**	

Catchment 16

Existing Catchment Summary	
Acres	20.2
Dominant Land Cover	Residential, Commercial
Parcels	88
Volume (acre-feet/yr)	18.8
TP (lb/yr)	18.4
TSS (lb/yr)	10,693

DESCRIPTION

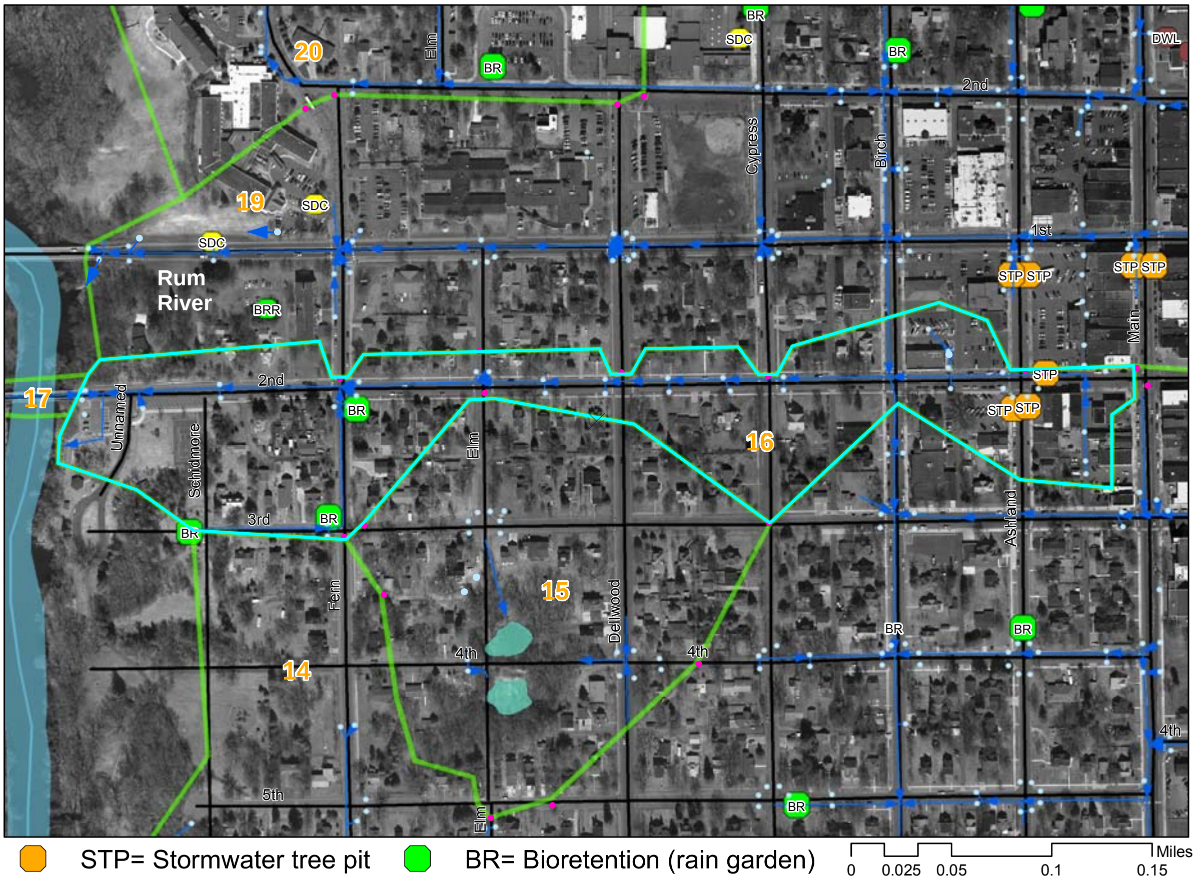
Catchment 16 is a narrow band that runs from Main Street westward along 2nd Avenue South. The west end of this catchment is part of downtown, and is mostly impervious surfaces. Other portions are residential. It discharges to the Rum River within the city park.

EXISTING STORMWATER TREATMENT

The only stormwater treatment practice in this catchment is street sweeping. Street sweeping removes approximately 7% of TSS, 8% of TP, and has no impact on the volume of runoff (see table below).

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	20.1	1.7	8%	**18.4**
	TSS (lb/yr)	11,527	834	7%	**10,693**
	Volume (acre-feet/yr)	18.8	0.0	0%	**18.8**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS



Residential rain gardens - Sites for stormwater treatment are few in this small catchment. Impervious surfaces already consume a large portion of the landscape and almost no large unoccupied spaces remain. Rain gardens are a go-to tool in these circumstances (see appendix B for design options). Only three possible rain garden sites were found, and there may be challenges at each due to sidewalks and topography. Cost estimates take these challenges into account.

We analyzed scenarios where 2 and 4 rain gardens were installed (level 1 and 2 in the table below). Catchment-wide removal of TSS and TP could be increased to the levels shown the table below.

Stormwater tree pits – Stormwater tree pits are a curbside stormwater filtration system. Stormwater is diverted into an underground box containing engineered soils and an underdrain. The boxes are planted with tree species typically used in urban settings. Pollutants are removed as water infiltrates through the soil media while the underdrain captures the treated water and returns it to the city stormwater conveyance system. Open-bottom tree pits, which allow some infiltration to the ground, are not recommended in drinking water recharge areas. Tree pits are often proprietary, and carry considerable expense. Tree pits are suitable from urbanized landscapes where space is extremely limited. See appendix A for a more detailed description of stormwater tree pits.

In catchment 16 tree pits would be best suited to the downtown areas. In many instances they would replace existing sidewalk trees. The city anticipates the need to replace these trees relatively soon, which could be a great opportunity to implement the tree pits. Three locations have been identified for stormwater tree pit placement (see map above). Each is immediately up-gradient of a catch basin. Approximately 1.36 acres of impervious surfaces drain to these points. Each 6x6' tree pit can treat 0.27-0.29 ac (from Filterra brand). Therefore approximately five 6x6' tree pits, or equivalently larger pits, would be needed in order to treat the entire area.

It is typically most cost-effective to order and install multiple tree pits. Therefore, we analyzed a scenario where a total of five tree pits would be installed simultaneously. The three highest priority locations were identified. At some locations, two pits or one double-sized pit may be needed. Installation of tree pits is shown as "level 3" treatment in the table below. It is worth noting that stormwater tree pits are also a proposed retrofit for catchment 19; simultaneous installations in both catchments would likely carry some cost savings.

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	1.6	16%	2.4	22%	0.7	12%
	TSS (lb/yr)	742	14%	1,138	18%	293	10%
	Volume (acre-feet/yr)	1.4	8%	2.2	12%	0.0	0%
	Number of BMP's	2		4		5 - treating 1.36 acres	
	BMP Size/Description	500 sq ft		1,000 sq ft		5 units	
	BMP Type	Complex Bioretention		Complex Bioretention		Stormwater Tree Pits	
Cost	Materials/Labor/Design	$8,310		$16,410		$50,000	
	Promotion & Admin Costs	$1,890		$2,170		$1,050	
	Total Project Cost	$10,200		$18,580		$51,050	
	Annual O&M	$150		$300		$500	
	Term Cost/lb/yr (30 yr)	$310		$378		$3,195	

Catchment 19

Existing Catchment Summary	
Acres	99.5
Dominant Land Cover	Commercial, Residential
Parcels	326
Volume (acre-feet/yr)	87.8
TP (lb/yr)	70.5
TSS (lb/yr)	39,603

DESCRIPTION

Catchment 19 encompasses most of downtown, the highway 95 corridor west of downtown, and residential areas to the north. This catchment is of particular importance because of high percentages of impervious surfaces, land uses that have higher pollutant concentrations, and an aging infrastructure that is undersized, creating street flooding.

EXISTING STORMWATER TREATMENT

There are three existing stormwater treatment practices in catchment 19.

1. Street sweeping - Street sweeping occurs twice in the spring and twice in fall, except that downtown areas are swept every-other week. This practice removes approximately 12% of TSS and TP, but has no impact on runoff volumes.

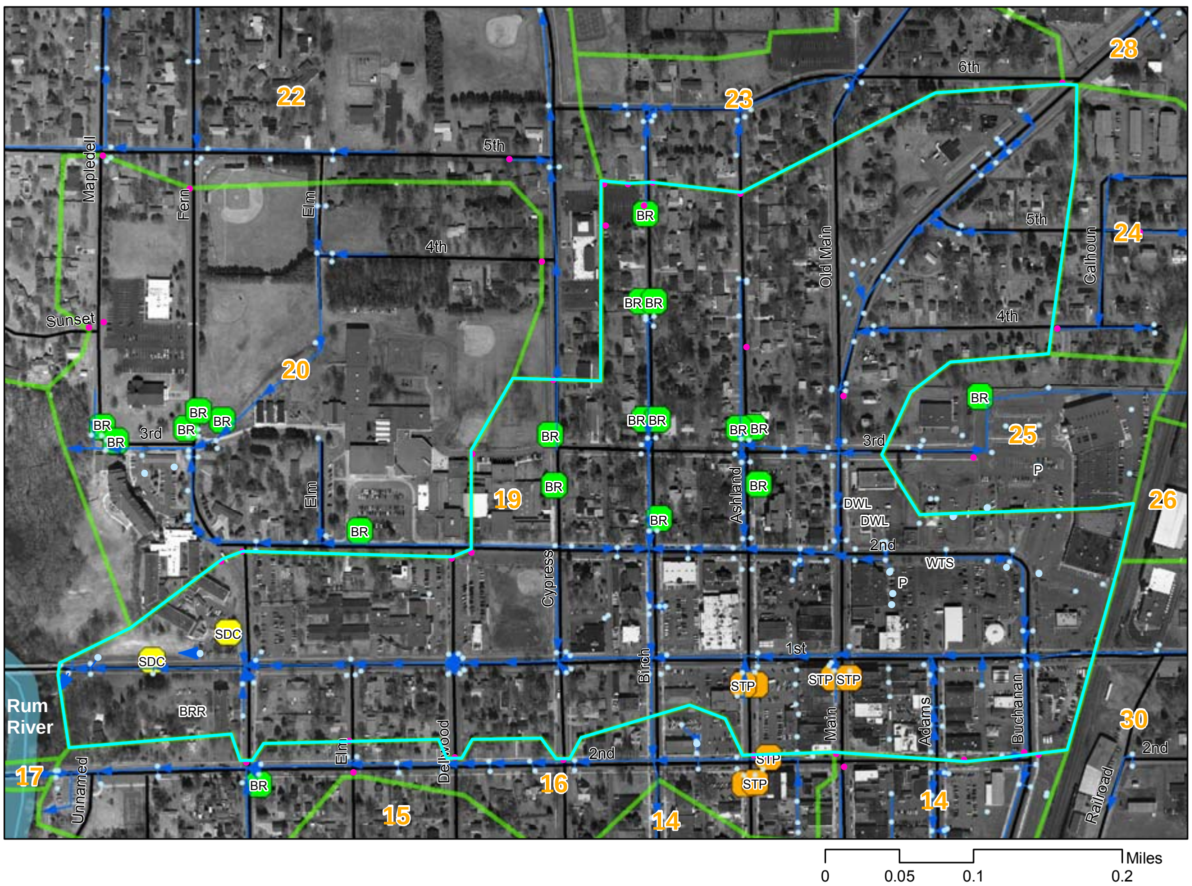
2. EDA apartments rain garden – The local Economic Development Authority owns an apartment complex on the west side of the catchment. Its parking lot is retrofitted with a rain garden. This rain garden is not draining properly, as evidenced by the presence of standing water and growth of cattails in the basin's bottom. Despite this issue and only serving a small parking lot, this rain garden provides some value, removing 0.1% to 0.2% of the entire catchment's TSS and TP.

3. Swale at Grandview Christian Homes - A large swale is present on the south side of Grandview Christian Home. It is on the north side of Highway 95. Presently, it is maintained as mowed lawn. There is a single inlet at the top of the swale and single outlet at the bottom. Presently, 0.15 acres of directly connected asphalt parking lot (Grandview visitor parking) is the only impervious surface runoff directed to this large swale. Approximately 0.47 acres of rooftop, sidewalks, and lawn also drain to it. As is, it removes an estimated 0.6% of the catchment's TSS and TP.

The sum of benefits from the existing stormwater treatment is in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	81.1	10.5	13%	**70.5**
	TSS (lb/yr)	45,335	5,732	13%	**39,603**
	Volume (acre-feet/yr)	88.5	0.7	1%	**87.8**
	Number of BMP's	3			
	BMP Size/Description	Street Sweeping + EDA apartments rain garden + Christian Home Swale Treating 0.62 acres			

RETROFIT RECOMMENDATIONS



STP= Stormwater tree pit SDC= Stormwater disconnect BR= Bioretention (rain garden)

Decrease downtown street sweeping frequency – We considered the possibility that the current every-other-week sweeping schedule for downtown areas was too frequent to yield cost-effective benefits. We compared it to a scenario where sweeping occurred monthly (half as frequent). The every-other week sweeping schedule reduces TSS by an estimated 5,369 lbs (12%) and TP by 9.89 lbs (12%). By comparison, our model estimates a monthly schedule reduces TSS by an estimated 5,202 lbs (11.5%) and TP by 9.69 lbs (12%). This analysis includes only the downtown areas in catchment 19, not those small portions in catchment 16. The model estimates suggest the city should consider reducing downtown street sweeping frequency. Those dollars would likely yield greater pollutant reductions if spent on other stormwater practices outlined in this report.

Residential rain gardens -
There are a few good sites for curb cut rain gardens in the commercial areas of catchment 19, but more opportunities exist in the residential areas (see appendix B for design options). Nine possible rain garden sites were identified (see map above). Generally, ideal sites are immediately up-gradient of a catch basin that serves a large drainage area. We analyzed scenarios where 5, 10, and 12 rain gardens were installed. Each rain garden was assumed to be 250 sq ft and one foot deep. Catchment-wide removal of TSS and TP could be increased to the levels shown the table below.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	6.5	21%	10.8	26%	11.7	27%
	TSS (lb/yr)	3,028	19%	5,004	24%	5,420	25%
	Volume (acre-feet/yr)	5.8	7%	9.5	12%	10.4	13%
	Number of BMP's	5		10		12	
	BMP Size/Description	1,250 sq ft		2,500 sq ft		3,000 sq ft	
	BMP Type	Complex Bioretention		Complex Bioretention		Complex Bioretention	
Cost	Materials/Labor/Design	$20,460		$40,710		$48,810	
	Promotion & Admin Costs	$2,310		$3,010		$3,290	
	Total Project Cost	$22,770		$43,720		$52,100	
	Annual O&M	$375		$750		$900	
	Term Cost/lb/yr (30 yr)	$175		$205		$226	

Permeable asphalt in downtown parking lots - Downtown areas include several expansive parking lots. Such large parking lots generate large volumes of runoff and contribute to pollutant loading to the river. Some areas of downtown experience occasional street flooding. At the same time, local businesses prefer not to convert existing parking into a stormwater treatment device. We considered that permeable pavement could replace some of the traditional pavement to reduce stormwater volumes and provide water quality treatment.

We modeled scenarios where 0.73 acres (approx 10%), 1.46 acres (20%), and 2.18 acres (30%) of downtown parking lots were treated by permeable asphalt. Generally, permeable pavements can treat water from an area of impervious surface three times the size of the permeable pavement. Therefore, the area of permeable pavement needed to treat the acreages mentioned above are 0.24 acres, 0.39 acres, and 0.73 acres, respectively. Our models did include maintenance, such as restorative vacuuming of the pavement annually. See appendix A for more details on the design of permeable pavements. Catchment-wide removal of volume and pollutants could be increased to the levels shown the table below.

It is notable that the proposed areas for permeable pavement are in the city's Drinking Water Supply Management Area (DWSMA). Infiltration of stormwater in this area should be done with great caution. No runoff from stormwater pollutant hotspots onto the permeable pavement should occur. Placing the permeable pavement where it will receive run-on from rooftops should be the first choice. As a second choice it could be placed where it will receive little run-on from the busiest parking areas and driving lanes, which carry the highest pollutant loads and are most frequently sanded in winter. These higher-pollutant areas are better suited to sand filter retrofits (discussed below). Lastly, permeable pavement should be placed only in areas draining directly to the Rum River (for example, not at City Hall parking, which is just outside of catchment 19).

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	0.6	14%	1.2	14%	1.8	15%
	TSS (lb/yr)	491	14%	983	15%	1,473	16%
	Volume (acre-feet/yr)	1.1	2%	2.1	3%	3.2	4%
	Number of BMP's	Treating 0.73 acres parking (10%)		Treating 1.46 acres parking (20%)		Treating 2.18 acres parking (30%)	
	BMP Size/Description	10,571	sq ft	21,141	sq ft	31,697	sq ft
	BMP Type	Permeable Asphalt		Permeable Asphalt		Permeable Asphalt	
Cost	Materials/Labor/Design	$147,994		$295,974		$443,758	
	Promotion & Admin Costs	$2,100		$2,800		$3,500	
	Total Project Cost	$150,094		$298,774		$447,258	
	Annual O&M	$243		$486		$729	
	Term Cost/lb/yr (30 yr)	$8,744		$8,633		$8,592	

Perimeter sand filters in downtown parking lots – As discussed above for permeable pavement, a challenge in downtown parking lots is to install practices that address stormwater without consuming parking spaces. Permeable pavement and sand filters are two options. Sand filters have the advantages of consuming no parking and being effective in the removal of pollutants. Because they do not infiltrate water, they are ideal for use in drinking water protection areas. Their weakness is that they do not reduce volume, and therefore would not alleviate street flooding. See appendix A for more details on the design of perimeter sand filters.

The pollutant removal numbers presented below assume the sand filters are enhanced by addition of iron filings to the filter media. Iron filings substantially improve removal of dissolved phosphorus. A significant portion of phosphorus in stormwater is dissolved.

We modeled scenarios where 0.73 acres (approx 10%), 1.46 acres (20%), and 2.18 acres (30%) of downtown parking lots were treated by perimeter sand filters. Generally, 100 linear feet of perimeter sand filter (as designed in Appendix B) can treat water from 1 acre of impervious surfaces. Catchment-wide removal of pollutants could be increased to the levels shown the table below.

	Cost/Benefit Analysis	*Network Treatment By BMP*					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	0.4	13%	0.9	14%	1.3	15%
	TSS (lb/yr)	294	13%	584	14%	875	15%
	Volume (acre-feet/yr)	0.0	1%	0.0	1%	0.0	1%
	Number of BMP's	Treating 0.73 acres parking (10%)		Treating 1.46 acres parking (20%)		Treating 2.18 acres parking (30%)	
	BMP Size/Description	73	linear feet	146	linear feet	218	linear feet
	BMP Type	Perimeter Sand Filter		Perimeter Sand Filter		Perimeter Sand Filter	
Cost	Materials/Labor/Design	$17,520		$35,040		$52,320	
	Promotion & Admin Costs	$1,400		$2,100		$2,800	
	Total Project Cost	$18,920		$37,140		$55,120	
	Annual O&M	$876		$1,752		$2,616	
	Term Cost/lb/yr (30 yr)	**$3,504**		**$3,322**		**$3,426**	

Stormwater tree pits – Stormwater tree pits are a curbside stormwater filtration system. Stormwater is diverted into an underground box containing engineered soils and an underdrain. The boxes are planted with tree species typically used in urban settings. Pollutants are removed as water infiltrates through the soil media while the underdrain captures the treated water and returns it to the city stormwater conveyance system. Open-bottom tree pits, which allow some infiltration to the ground, are not recommended in drinking water recharge areas. Tree pits are often proprietary, and carry considerable expense. Tree pits are suitable from urbanized landscapes where space is extremely limited. See appendix A for a more detailed description of stormwater tree pits.

In catchment 19 tree pits would be best suited to the downtown areas. They would, in many instances, replace existing sidewalk trees. The city anticipates the need to replace these trees in coming years.

Four ideal locations have been identified for stormwater tree pit placement, and other acceptable locations may also exist (see map above). Each ideal location is immediately up-gradient of a catch basin. While a 6x6' pit size is most common, these accommodate a commercial drainage area of 0.27-0.29 ac (from Filterra brand). The drainage areas for the four identified sites is approximately double this, requiring the tree pits be installed two in a row or double-sized (12x6'). Therefore, we considered a scenario where eight, tree pits are installed. Catchment-wide removal of pollutants could be increased to the levels shown the table below.

It is typically most cost-effective to order and install multiple tree pits simultaneously. Therefore, we assumed all four tree pit locations are installed. It is worth noting that stormwater tree pits are also a proposed retrofit for catchment 16; simultaneous installations in both catchments would likely carry some savings.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New	Net %	New	Net %	New	Net %
Treatment	TP (lb/yr)	1.1	14%	1.3	15%	1.6	15%
	TSS (lb/yr)	449	14%	561	14%	673	14%
	Volume (acre-feet/yr)	0.0	1%	0.0	1%	0.0	1%
	Number of BMP's	2.2 acres treated		2.8 acres treated		3.4 acres treated	
	BMP Size/Description	8 units		10 units		12 units	
	BMP Type	Stormwater Tree Pits		Stormwater Tree Pits		Stormwater Tree Pits	
Cost	Materials/Labor/Design	$80,000		$100,000		$120,000	
	Promotion & Admin Costs	$1,680		$2,240		$2,520	
	Total Project Cost	$81,680		$102,240		$122,520	
	Annual O&M	$800		$1,000		$1,200	
	Term Cost/lb/yr (30 yr)	$3,323		$3,339		$3,344	

<u>Diversion of greater drainage into Grandview swale</u> - One of the already-existing stormwater treatment practices in catchment 19 is a swale on the north side of Highway 95 on the Grandview Christian Home

property. Currently, only water from the 20-stall Grandview visitor parking lot is directed into this swale, in addition to other flows from roofs and lawns totaling approximately 0.62 acres. The swale's capacity for stormwater treatment is much greater. Given that this is an already-constructed practice, diverting more water to it is an attractive opportunity. We examined two scenarios.

In the first scenario (level 1 in the table below), a catch basin is replaced with a splitter, diverting a total of approximately 1.84 acres of runoff into the swale (see map below). The catch basin in question is on the north side of Highway 95 approximately mid-way down the swale. Presently, any water flowing down the curb and into this catch basin goes south to the stormwater main under the Highway 95 centerline, then directly to the Rum River. A splitter installed at or up-gradient of the catch basin could divert an appropriate amount of curbside flow into the swale. It would be preferable to intercept the curbside water near the top of the swale, so it benefits from the full length of the swale. The sketches in Appendix A are based upon the splitter concept at this location.

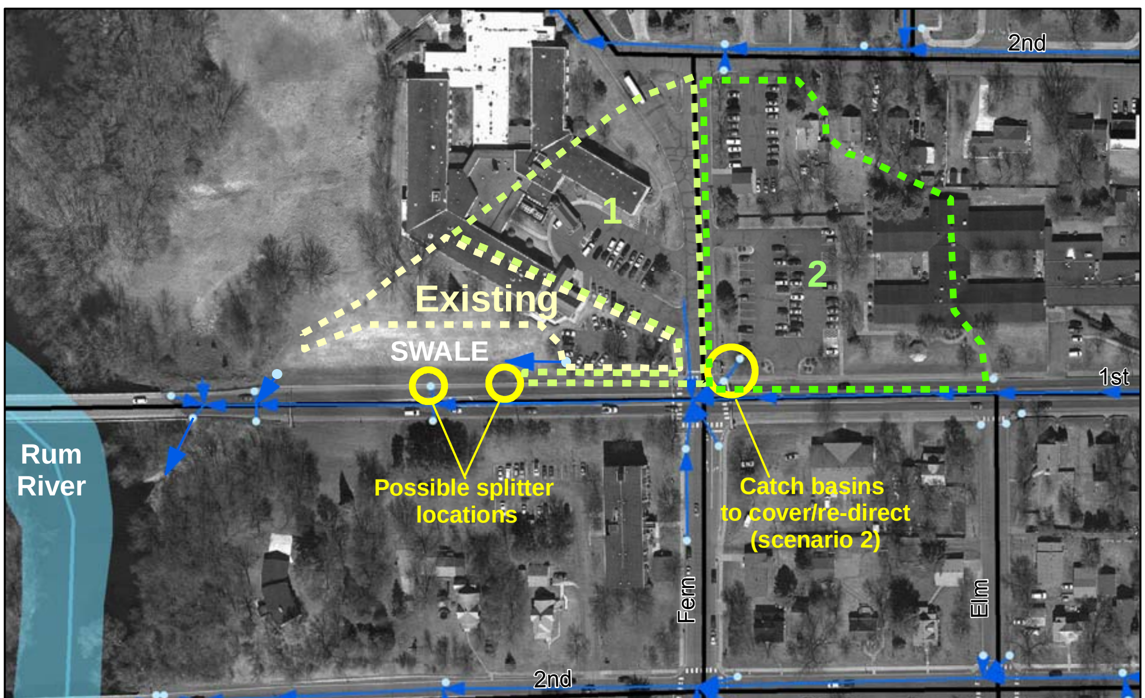
The second scenario builds upon the first. It includes the same splitter, but also the diversion of more acreage to the Highway 95 curbside, where stormwater would be delivered to the splitter and swale. We estimate that runoff from a total of 4.86 acres could reach the splitter. This would be accomplished by covering existing upstream catch basins and installing curb-cuts as needed to allow the water to reach the north side of Highway 95 (see map below).

Under scenario 2 (level 2 in table), the most notable opportunity to expand drainage to the swale is in the nursing home parking lot on the east side of Fern Street and North side of Highway 95. Here, a single catch basin in the southwest corner of the parking lot collects all runoff and delivers it to the underground stormwater main. This catch basin could be covered and the parking lot curb cut to allow the water to escape to Highway 95. This would require diverting the water across or under the sidewalk, but this seems feasible. An adjacent street catch basin would also need to be covered.

It is worth noting that if use of the swale increases, management of it should change. Presently it is managed as manicured lawn, complete with chemical treatments. The chemical treatments should be discontinued to ensure these chemicals are not washed into the river. Taller mowing heights would benefit swale function.

Catchment-wide removal of pollutants could be increased to the levels shown the table below.

Cost/Benefit Analysis		Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	1.0	14%	3.2	17%		
	TSS (lb/yr)	544	14%	1,696	16%		
	Volume (acre-feet/yr)	1.1	2%	3.8	5%		
	Number of BMP's	Swale treating 1.84 acres		Swale treating 4.87 acres			
	BMP Size/Description	New catch basin with splitter		New catch basin + curb cuts + catch basin covers			
	BMP Type	Dry Swale		Dry Swale			
Cost	Materials/Labor/Design	$7,300		$8,900			
	Promotion & Admin Costs	$1,120		$1,680			
	Total Project Cost	$8,420		$10,580			
	Annual O&M	$210		$280			
	Term Cost/lb/yr (30 yr)	**$486**		**$199**			



Map indicates the locations of possible swale retrofits. The area labeled “existing” approximates the current drainage area to the swale. The areas labeled “1” and “2” are the approximate drainage areas to the swale under scenarios one and two described in the text. Blue lines are stormwater mains and blue dots are catch basins.

RETROFITS CONSIDERED BUT REJECTED

Increase downtown street sweeping schedule – We modeled a scenario in which catchment 19 downtown areas were swept every week instead of the current every-other-week schedule. Doubling the sweeping frequency reduced TSS by 547 lbs (1.4%) and TP by 0.86 lbs (1.2%). It seemed unrealistic to expect this to be cost-effective and the idea was abandoned.

Increase residential street sweeping schedule – We modeled a scenario in which catchment 19 residential areas were swept every week instead of the current every-other-week schedule. Doubling the sweeping frequency reduced TSS by 550 lbs (1.4%) and TP by 1.27 lbs (1.8%). It seemed unrealistic to expect this to be cost-effective and the idea was abandoned.

Catchment 20

Existing Catchment Summary	
Acres	48.9
Dominant Land Cover	School, Church, Residential
Parcels	56
Volume (acre-feet/yr)	35.4
TP (lb/yr)	34.3
TSS (lb/yr)	18,624

DESCRIPTION

This catchment includes the primary and middle schools, Christ the King Catholic Church, and some small residential areas. Minor street flooding occurs occasionally, most notably on Fern Street next to the Catholic Church.

EXISTING STORMWATER TREATMENT

The only existing stormwater treatment in catchment 20 is street sweeping. This practice removes approximately 9% of TSS and TP, but has no impact on the volume of runoff.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	TP (lb/yr)	37.5	3.2	9%	**34.3**
	TSS (lb/yr)	20,456	1,832	9%	**18,624**
	Volume (acre-feet/yr)	35.4	0.0	0%	**35.4**
	Number of BMP's	1			
	BMP Size/Description	Street Sweeping			

RETROFIT RECOMMENDATIONS

Rain Gardens at Primary School - Presently a long swale runs on the northwest side of the primary school playground, just south of baseball fields. Little surface flow over this swale occurs. It might be feasible to retrofit the bottom of this swale into a large rain garden.

There would be two potential inlets to the rain garden. First, there is an underground pipe running the swale's length that could be daylighted. This pipe carries runoff from neighborhoods the northeast as well as from some school roofs. Secondly, a curb cut inlet from Fern Street could be provided. The appropriate inlet location would be immediately up-gradient of existing catch basins (see map below). In addition to inlets other work would include minor re-grading, soil amendments, and plantings. Investigative work is needed to ensure daylighting the pipe is practical and soils will provide the desired infiltration rates. Because this practice is in-line with the stormwater conveyance system it should be designed by an engineer. Creation of this practice would need to be a cooperative venture with the school district.

Given it's proximity to the school playground, safety is an important consideration for this large rain garden. Generally, rain gardens are safer than stormwater ponds because there should be standing water for no more than 48 hours. In this case, additional precautions should be considered. The maximum depth of standing water should be shallow and controlled with the existing outlet culvert.

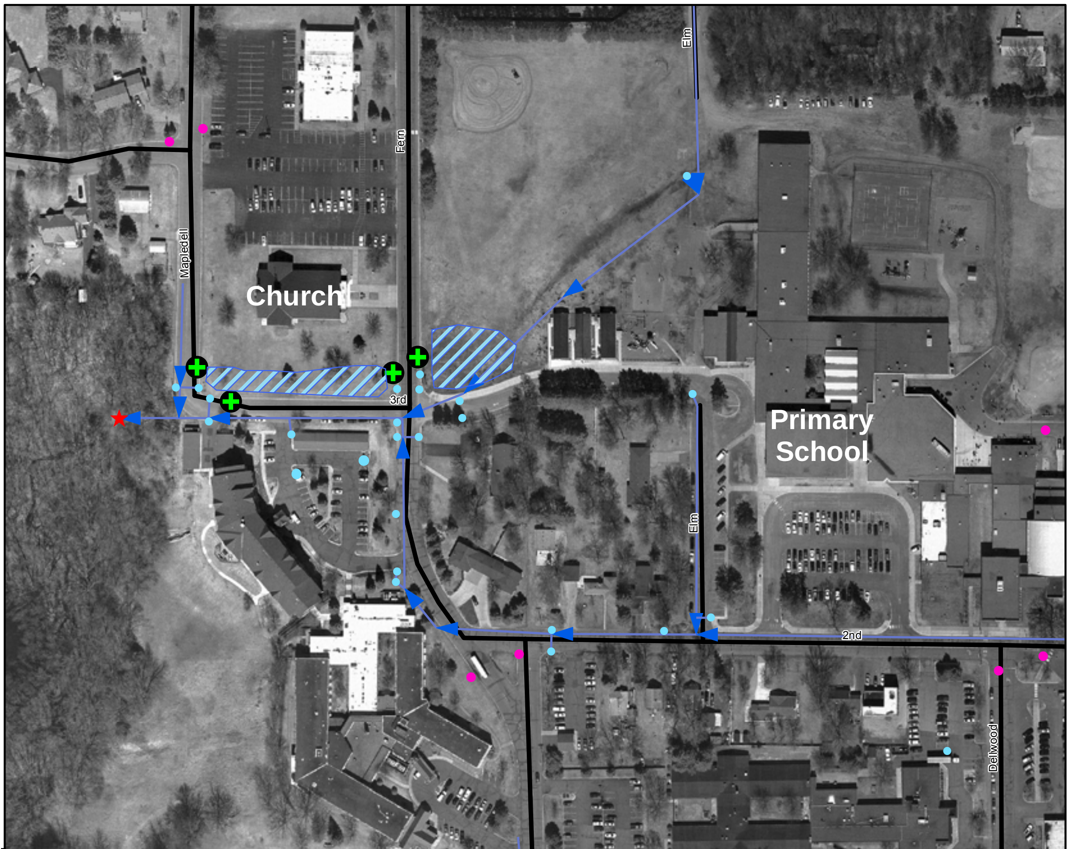
Ensuring rapid infiltration will be important. A border of shrubs or a fence should be considered to discourage entry.

Because of the large potential size of the basin (10,600 sq ft), this rain garden could treat much of the water draining to it. Considering only the area draining to it, 90% of TP would be removed, 87% of TSS, and 93% of volume. Treatment provided relative to the entire catchment is shown in the table below.

Rain Garden at Catholic Church - Christ the King Church is near the outfall of catchment 20 to the Rum River. The southern end of the property, just south of the church building, is lawn. A large rain garden at this position could treat runoff from three streets – 3rd Avenue North, Mapledell, and Fern Street. Three curb-cut inlets would be needed. Because of the slope of the ground, retaining walls would be necessary to create the basin. Creation of this practice would need to be a cooperative venture with the church.

Because of the potential size of the basin (9,120 sq ft), this rain garden could treat all of the water draining to it in a typical year. This means 100% removal of pollutants from the areas draining to this rain garden. Treatment provided relative to the entire catchment is shown in the table below.

	Cost/Benefit Analysis	Network Treatment By BMP					
		Level 1		Level 2		Level 3	
		New Trtmt	Net %	New Trtmt	Net %	New Trtmt	Net %
Treatment	TP (lb/yr)	14.1	46%	5.3	23%		
	TSS (lb/yr)	7,430	45%	3,247	25%		
	Volume (acre-feet/yr)	15.1	43%	6.4	18%		
	Number of BMP's	1-School Rain Garden		1-Church Rain Garden			
	BMP Size/Description	10,600 sq ft		9,120 sq ft			
	BMP Type	Moderately Complex Bioretention		Complex Bioretention			
Cost	Materials/Labor/Design	$42,400		$45,600			
	Promotion & Admin Costs	$1,120		$1,120			
	Total Project Cost	$43,520		$46,720			
	Annual O&M	$3,180		$2,736			
	Term Cost/lb/yr (30 yr)	$328		$810			



Map indicates the locations of possible rain gardens on school property and at Christ the King Catholic Church. Green plus symbols indicate inlet locations.

Retrofit Ranking

The table below summarizes the assessment results. Stormwater retrofit projects are grouped into tiers from most cost effective to least, using cost per pound of phosphorus removed. The benefits of each project were estimated if that project were installed alone, with no other projects upstream of it in the same catchment. The cost per pound of suspended sediment is also provided, but projects are not sorted by cost effectiveness at removing this pollutant. 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 table below.

An additional recommendation not included in the table below is to *reduce* downtown street sweeping frequency. Currently street sweeping in downtown areas is done every-other-week. We modeled this schedule versus a monthly sweeping schedule. We assumed only a vacuum-assisted sweeper was used. The pollutant removals gained by every-other-week sweeping are relatively small, and do not justify the costs. The dollars saved by this decrease in downtown street sweeping would yield greater pollutant reductions if spent on other recommended stormwater projects.

Summary of preferred stormwater retrofit opportunities ranked by cost-effectiveness.

Tier 1 Retrofit Recommendations ($0-$500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 14	Residential Rain Gardens	1	8.6	4,076	8	$26,960	$157
Catchment 8*	Residential Rain Gardens	2	6.9	4,052	5.9	$26,960	$195
Catchment 19	Grandview Swale	2	3.2	1,696	3.8	$10,580	$199
Catchment 19	Residential Rain Gardens	3	11.7	5,420	10.4	$52,100	$226
Catchment 8*	Street Disconnects	1	0.9	844	2.5	$1,900	$311
Catchment 20	School Rain Garden	1	14.1	7,430	15.1	$43,520	$328
Catchment 16	Residential Rain Gardens	2	2.4	1,138	2.2	$18,580	$378
Catchment 4	Residential Rain Gardens	2	3.9	2,046	2.2	$31,150	$401
Total			51.7	26,702	50.1	$211,750	

*Pollution reduction benefits for some projects within the same catchment cannot be added together because they treat the same source areas.

Tier 2 Retrofit Recommendations ($501-$1,500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 20	Church Rain Garden	2	5.3	3,247	6.4	$46,720	$810
Catchment 14	Hospital Rain Garden	1	1.3	1,109	2.3	$20,255	$1,281
Total			6.6	4,356	8.7	$66,975	

Tier 3 Retrofit Recommendations (>$1,500/lb TP/yr)

Catchment ID	Retrofit Type	Treatment Level (refer to catchment profile pages)	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Estimated Cost	Estimated cost/lb-TP/year (30-year)
Catchment 16	Stormwater Tree Pits	3	0.7	293	0	$51,050	$3,195
Catchment 19*	Perimeter Sand Filters	2	0.9	584	0	$37,140	$3,322
Catchment 19*	Stormwater Tree Pits	1	1.1	449	0	$81,680	$3,323
Catchment 19*	Permeable Asphalt	1	0.6	491	1.1	$150,094	$8,744
Total			≥1.3*	≥742*	≥0*	≥$88,190*	

*Pollution reduction benefits for some projects within the same catchment cannot be added together because they treat the same source areas.

References

Minnesota Stormwater Steering Committee. 2005. *Minnesota Stormwater Manual.* Minnesota Pollution Control Agency. St. Paul, MN.

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.

Schueler et. al. 2007. *Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection*. Ellicott City, MD.

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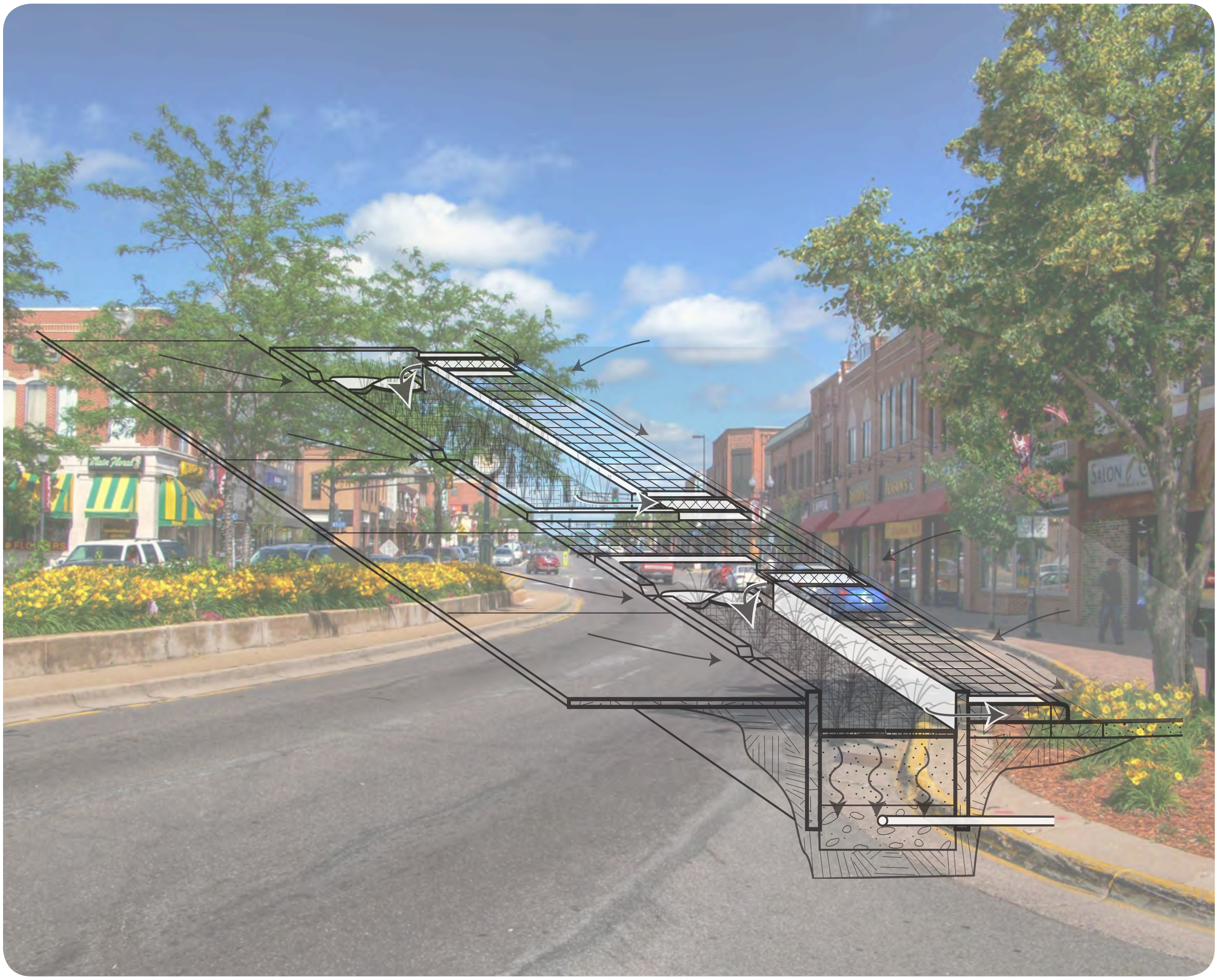
Appendix A – Retrofit Concept Designs

- Perimeter Sand Filters
- Tree Pit Filters
- Porous Pavement
- Flow Splitters
- Hydrodynamic Separators

Urban Stormwater Best Management Practices / Retrofit Concepts



ANOKA CONSERVATION DISTRICT

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.

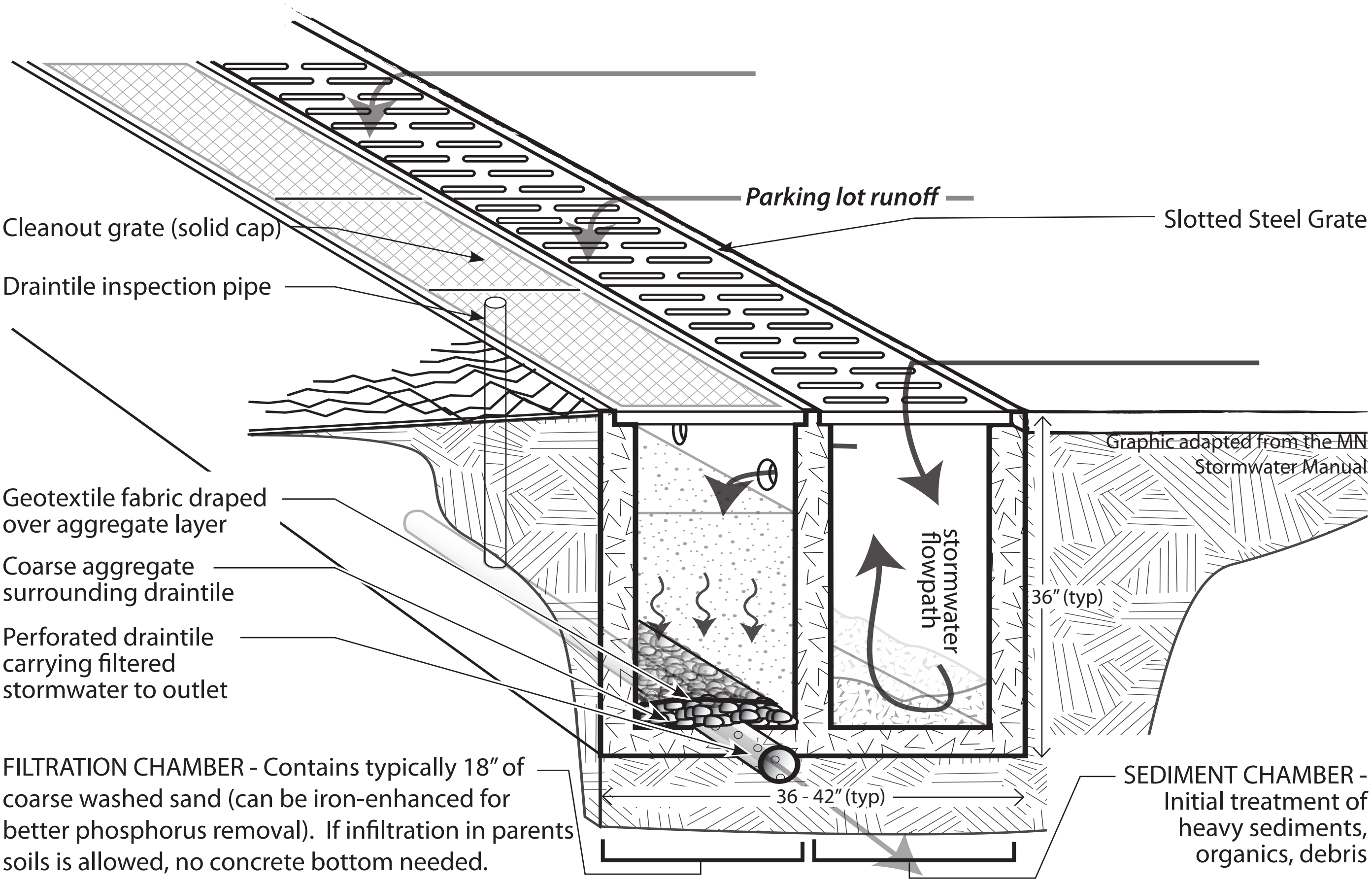

Sand filter inspection, Iowa Stormwater Partnership

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, nyc.org

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

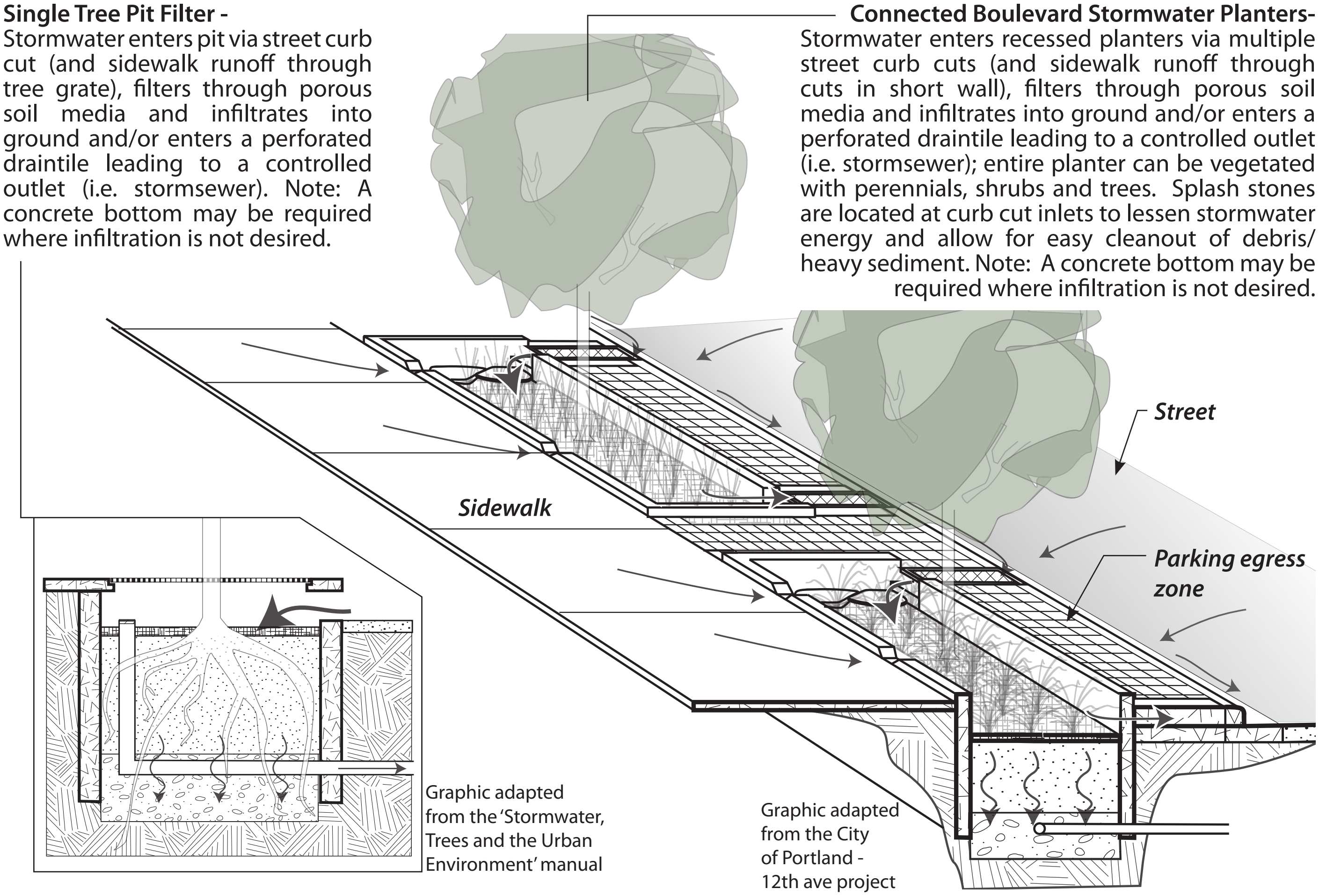
CONCERNS:
- Tree species will be limited to those that have salt tolerance and limited root aggression
- Regular inspections to prevent clogging & maintain function

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*

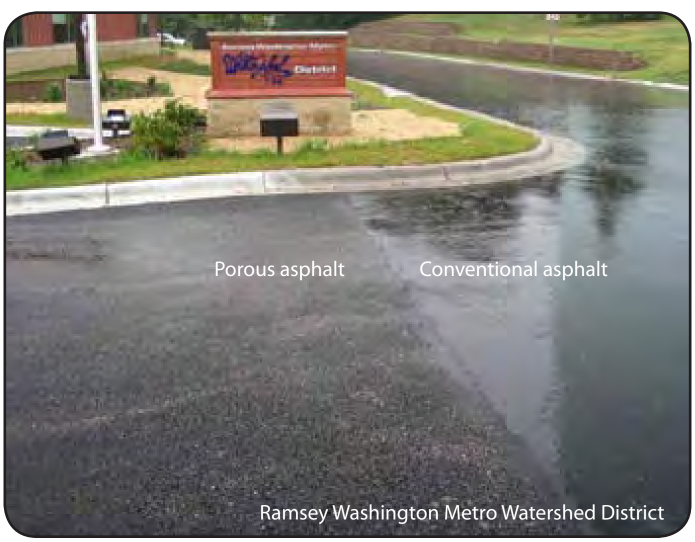
Porous pavements come in a wide array of materials - ***concrete, asphalt, pavers, and grid*** - with void spaces that allow water to percolate through the surface and reach a subsurface layer of coarse aggregate allowing stormwater to quickly drain into the ground. Porous pavements are ideally situated 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

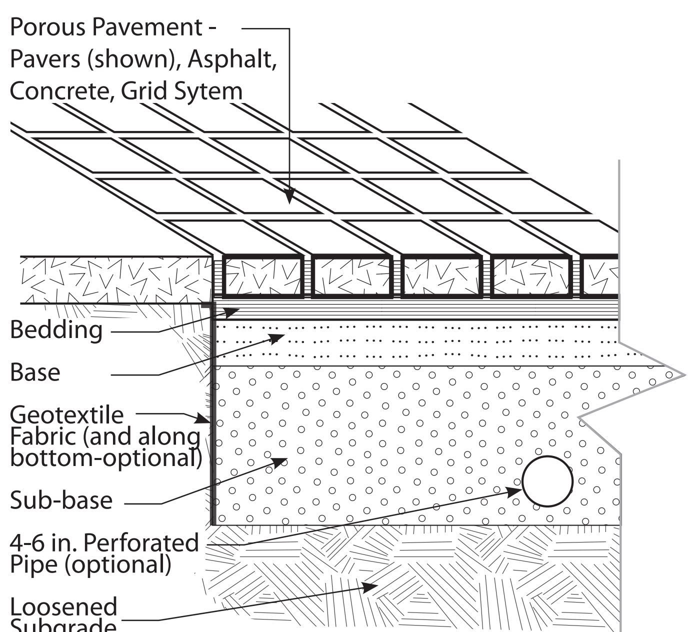
COST:
- Approximately $14 - $35 per cu ft storage depending on underlayment



Ramsey Washington Metro Watershed District


Permeable pavement in parking aisle, City of Portland

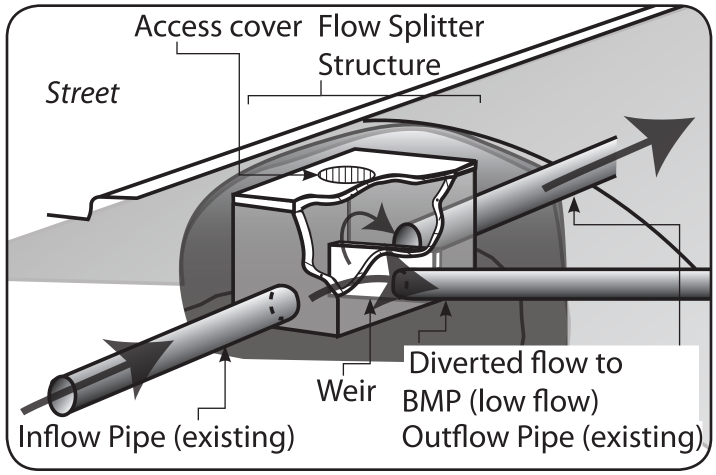

Permeable pavers, Minneapolis



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

CONCERNS:

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

RECOMMENDED DRAINAGE AREA:

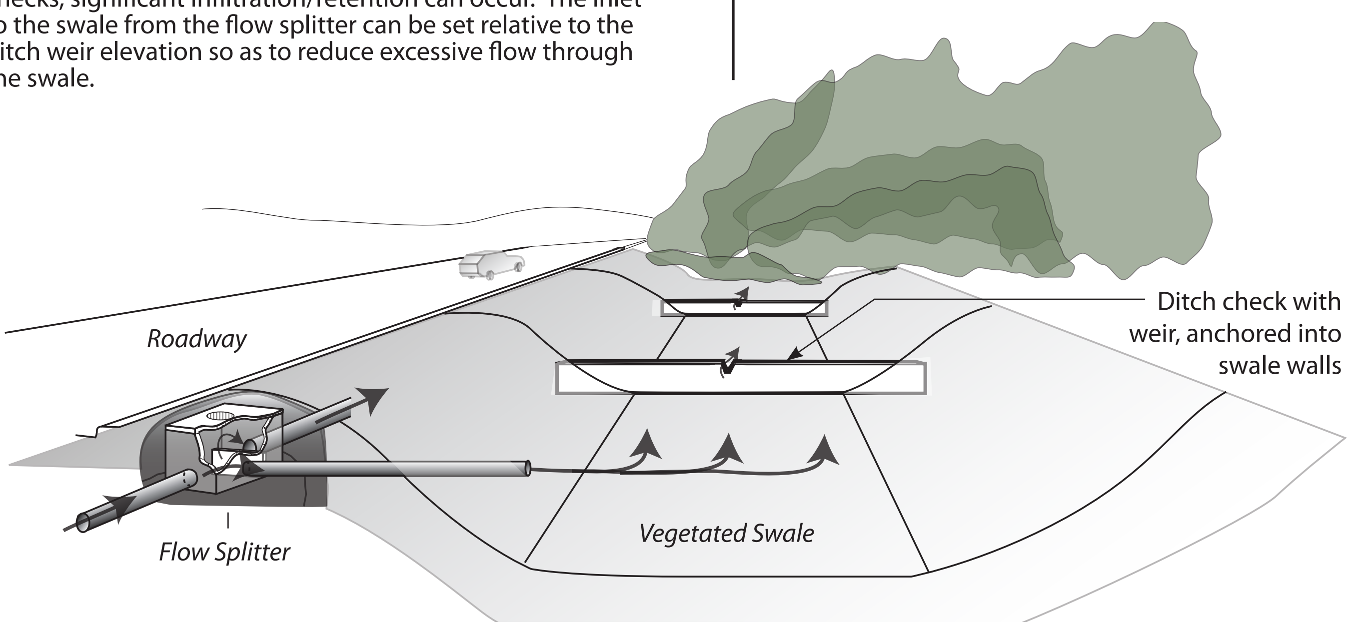
- Varies, pipe sizing can be scaled according to drainage area and capacity of Stormwater BMP that flow is diverted to

COST:

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

**Based on local sourcing, 2010*

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



Retrofit Concepts: Hydrodynamic Separators

Hydrodynamic 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:

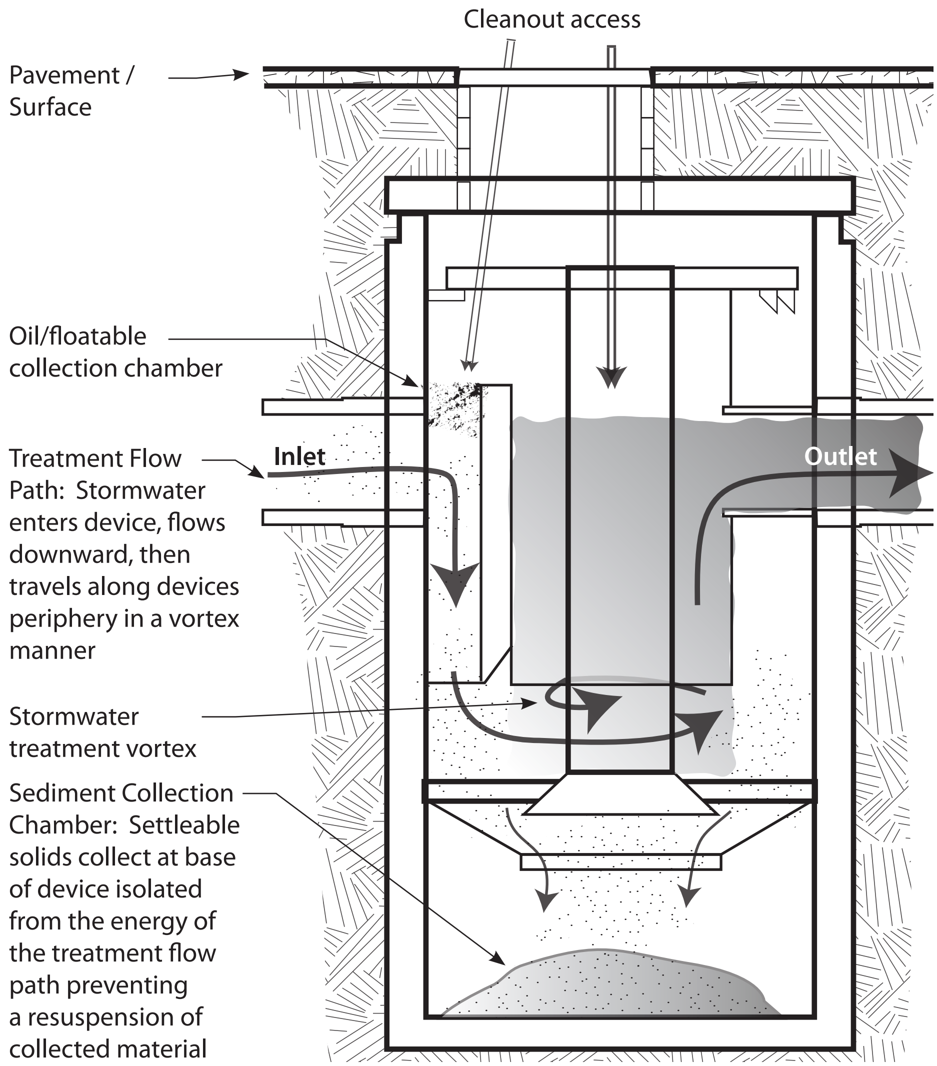
- A minimum annual vacuum removal of captured pollutants; however, required inspections every 6 months for the first year observing sedimentation and oil accumulation rates may determine more frequent visits are necessary
- High initial installation costs

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*

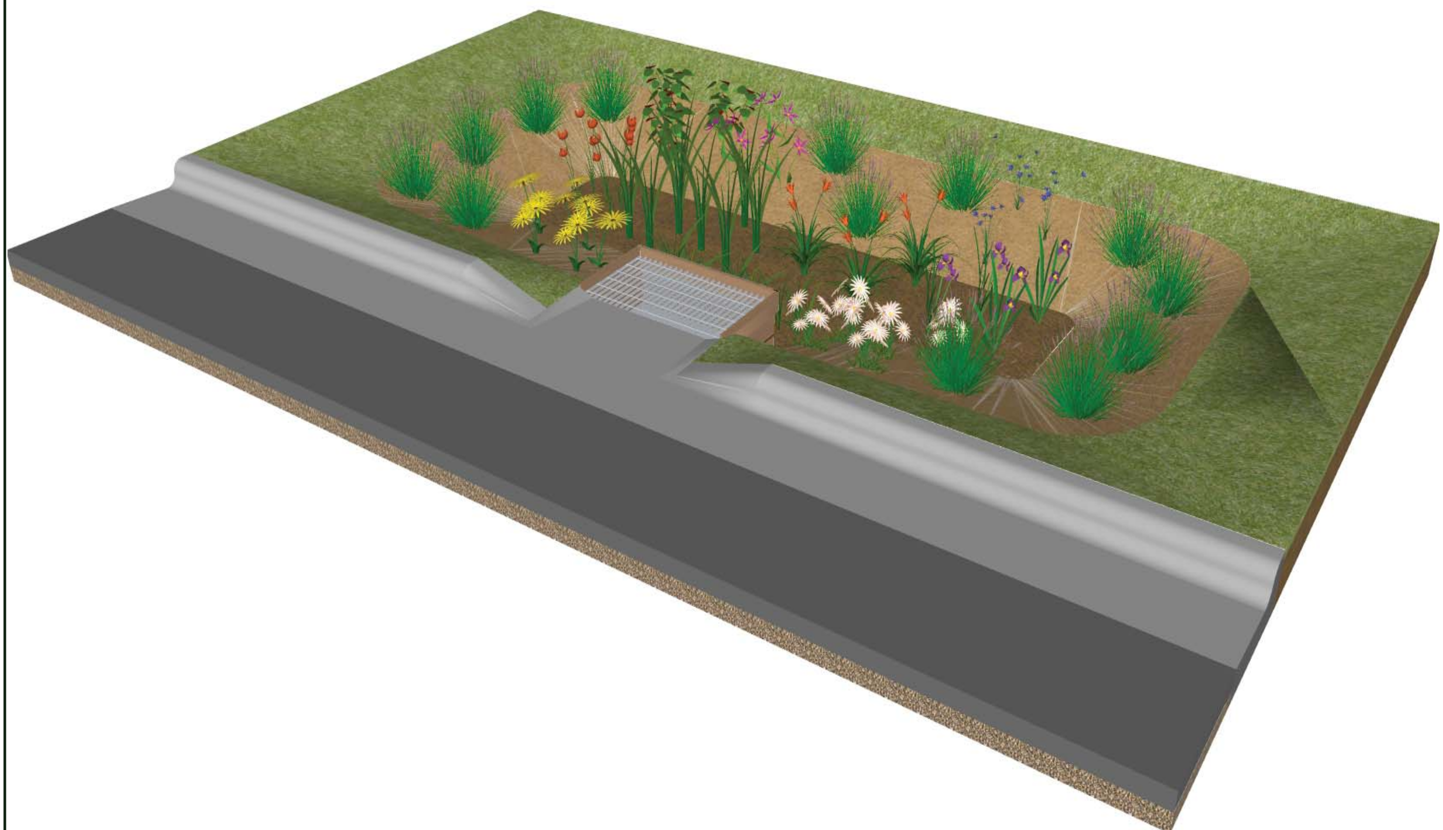


Base design source: *Dowstream Defender***

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

Appendix B – Rain Garden Concept Designs

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

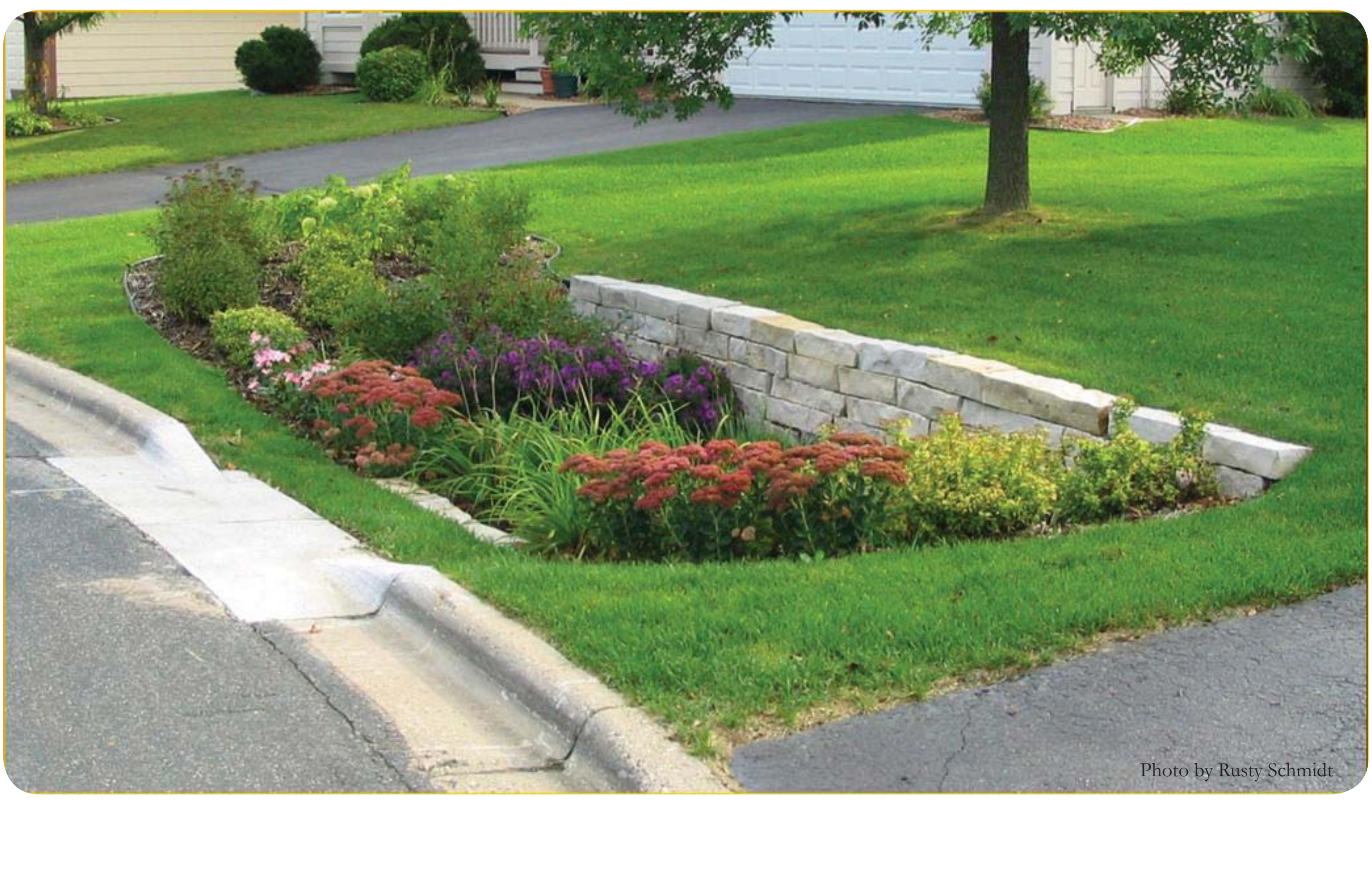


Photo by Rusty Schmidt

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

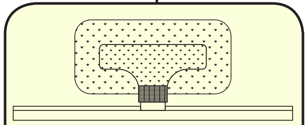
1

- 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**

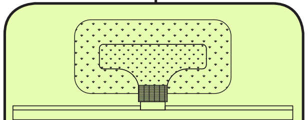
2

- Retaining not needed:
  - 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**
- Retaining wall needed:
  - 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**

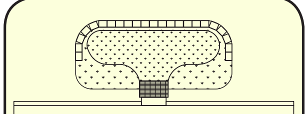
3



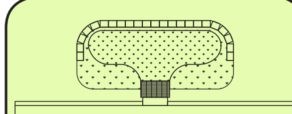
I. Rectangle
Sun, No Wall
pg. 8



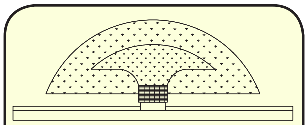
IV. Rectangle
Shade, No Wall
pg. 11



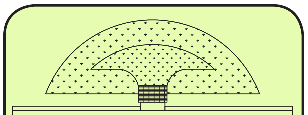
VII. Rectangle
Sun, with Wall
pg. 14



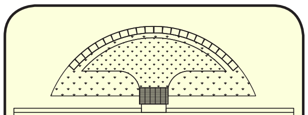
X. Rectangle
Shade, with Wall
pg. 17



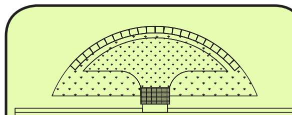
II. Arc
Sun, No Wall
pg. 9



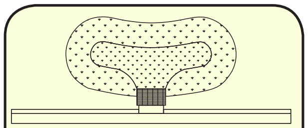
V. Arc
Shade, No Wall
pg. 12



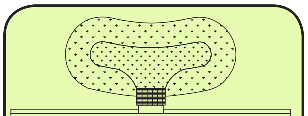
VIII. Arc
Sun, with Wall
pg. 15



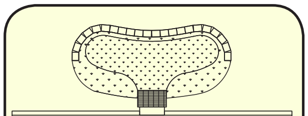
XI. Arc
Shade, with Wall
pg. 18



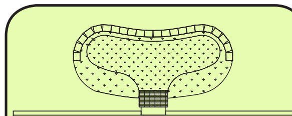
III. Curvilinear
Sun, No Wall
pg. 10



VI. Curvilinear
Shade, No Wall
pg. 13

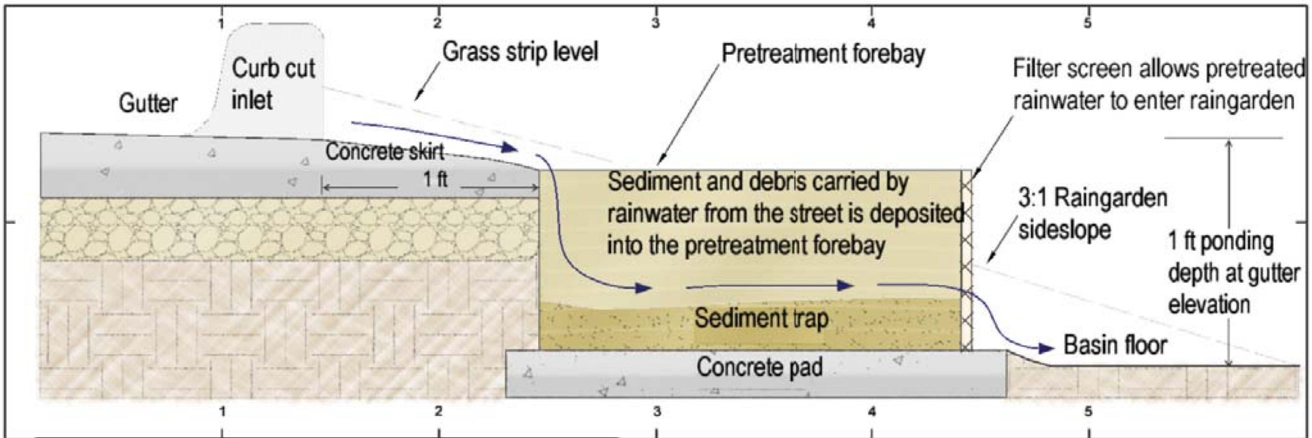


IX. Curvilinear
Sun, with Wall
pg. 16

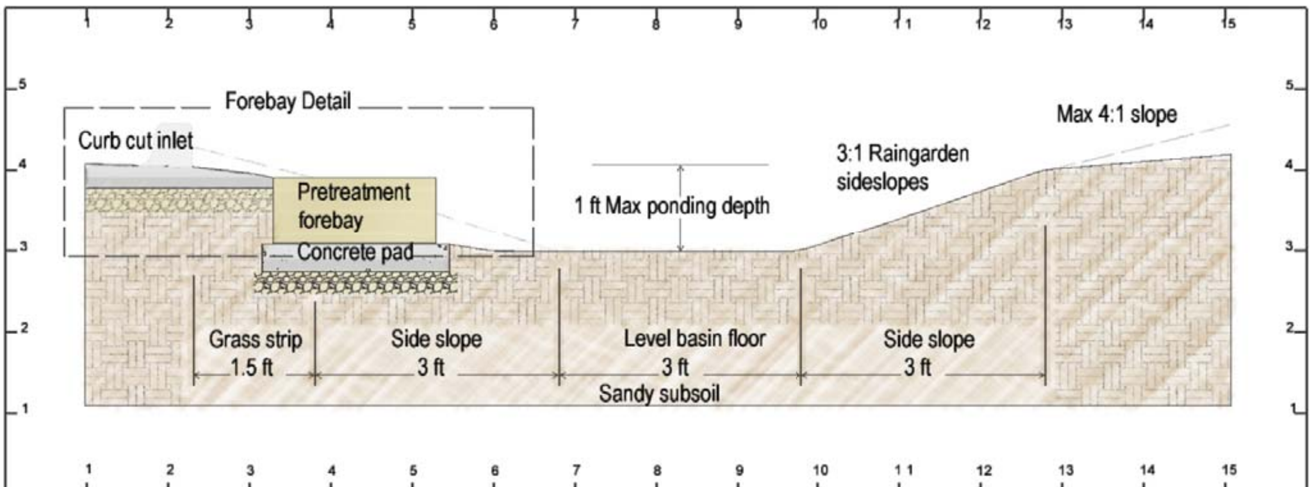


XII. Curvilinear
Shade, With Wall
pg. 19

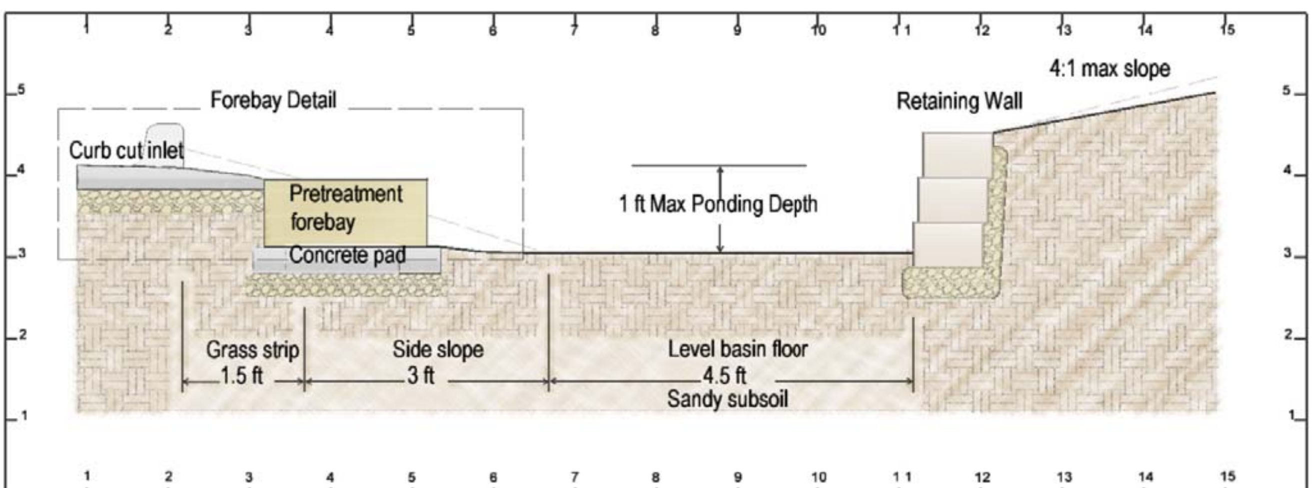
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

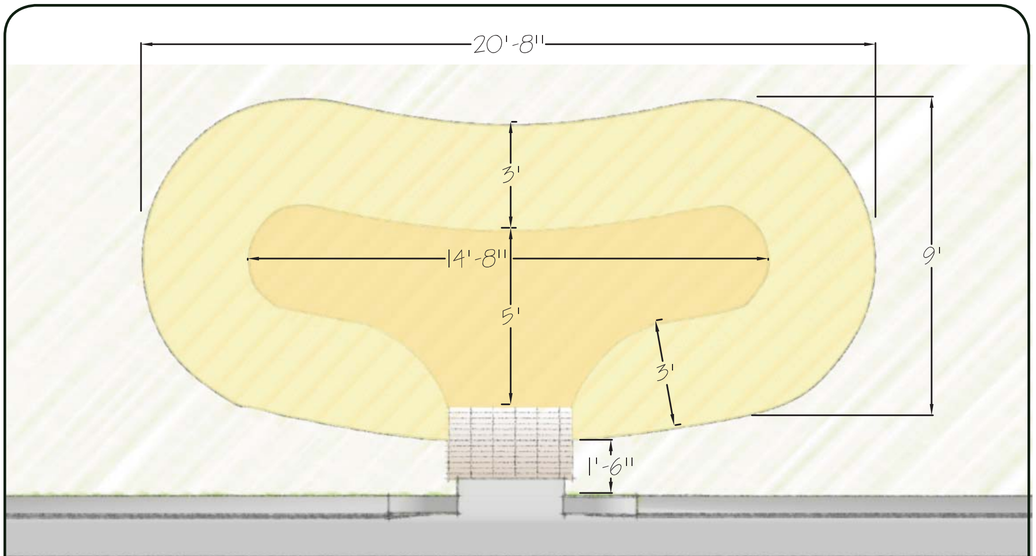


RAINGARDEN WITHOUT RETAINMENT

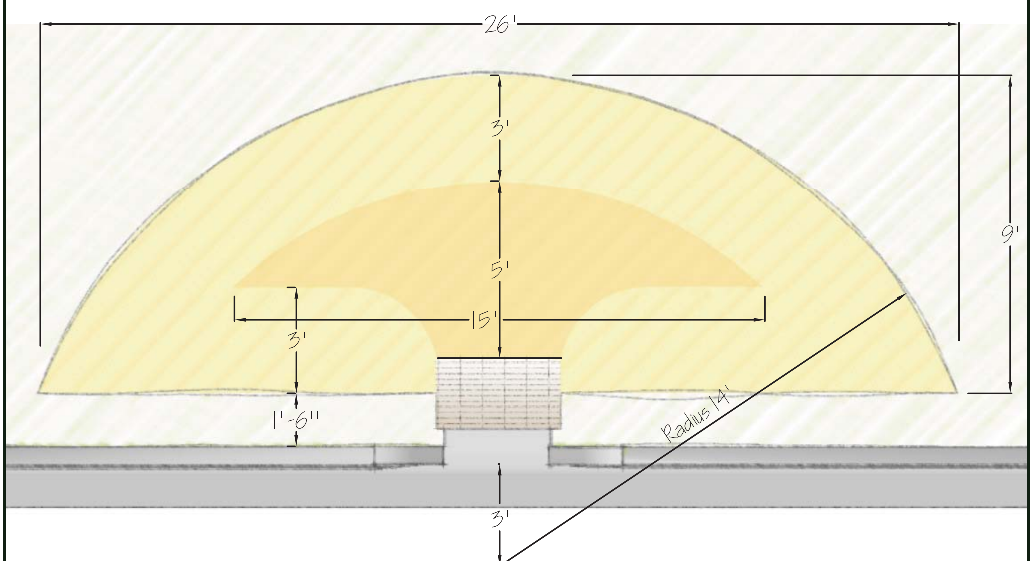


RAINGARDEN WITH RETAINING WALL

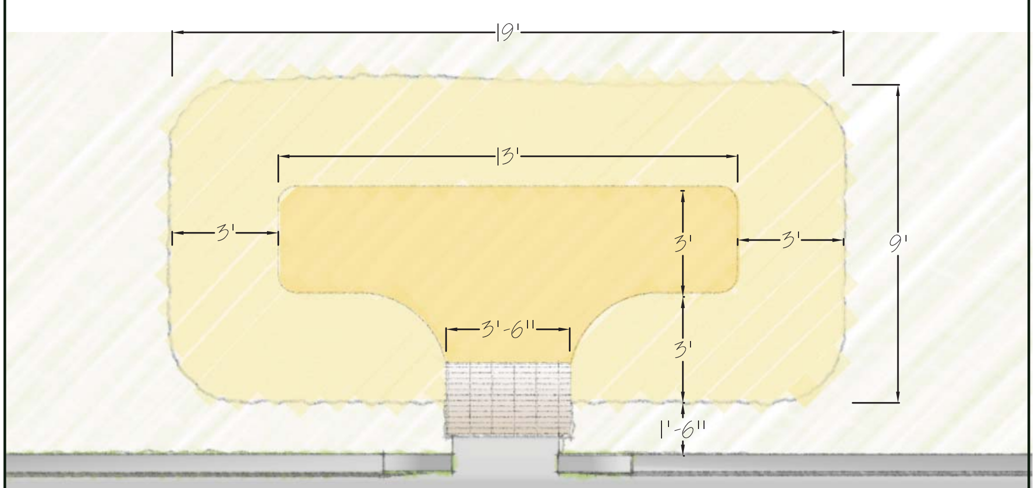
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



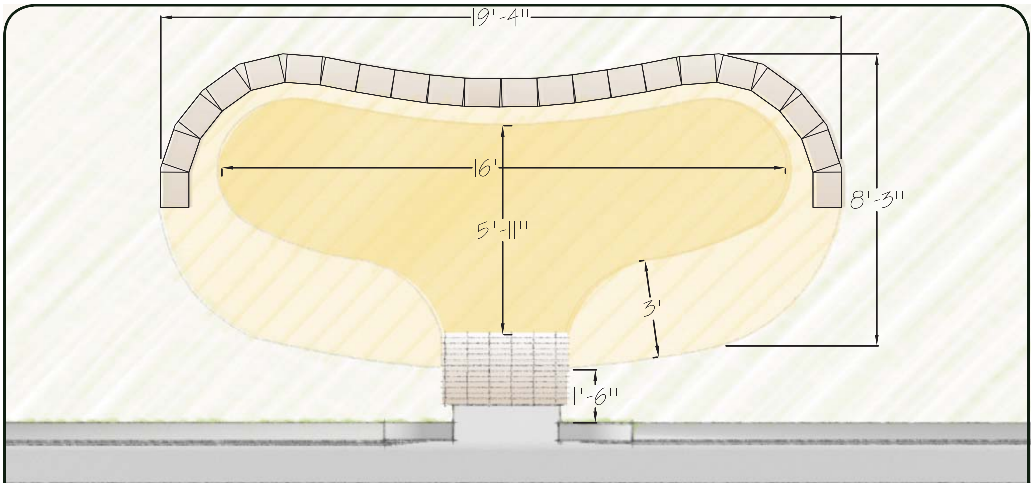
Arc Garden

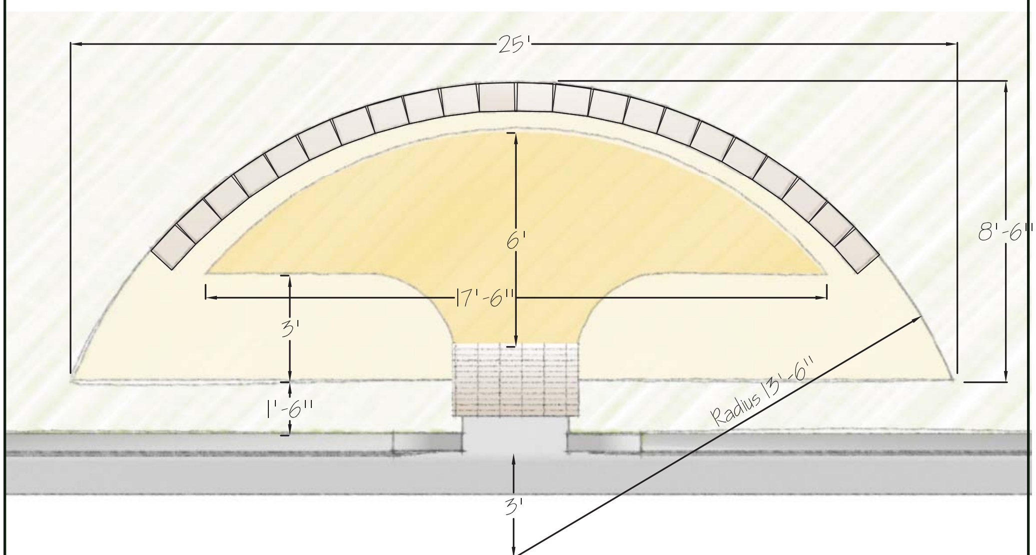


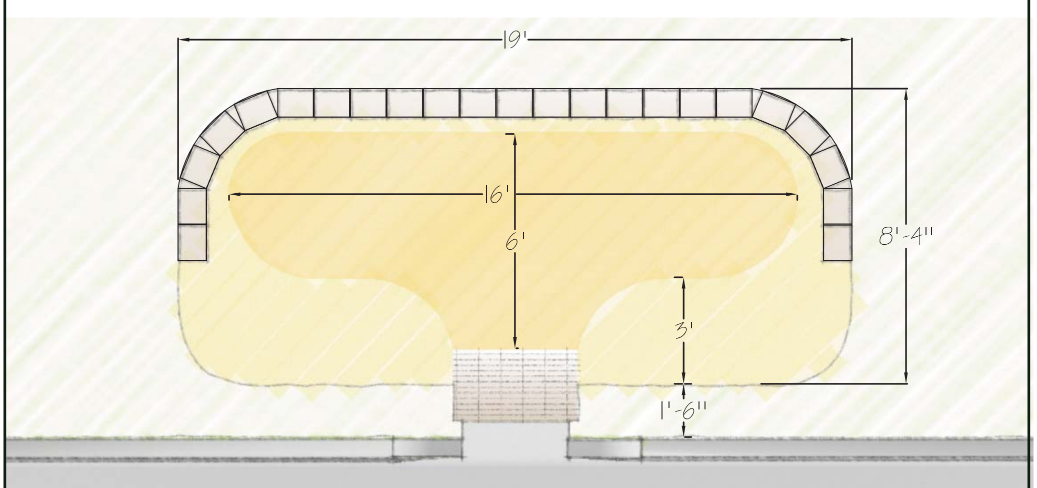
Rectangle Garden

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

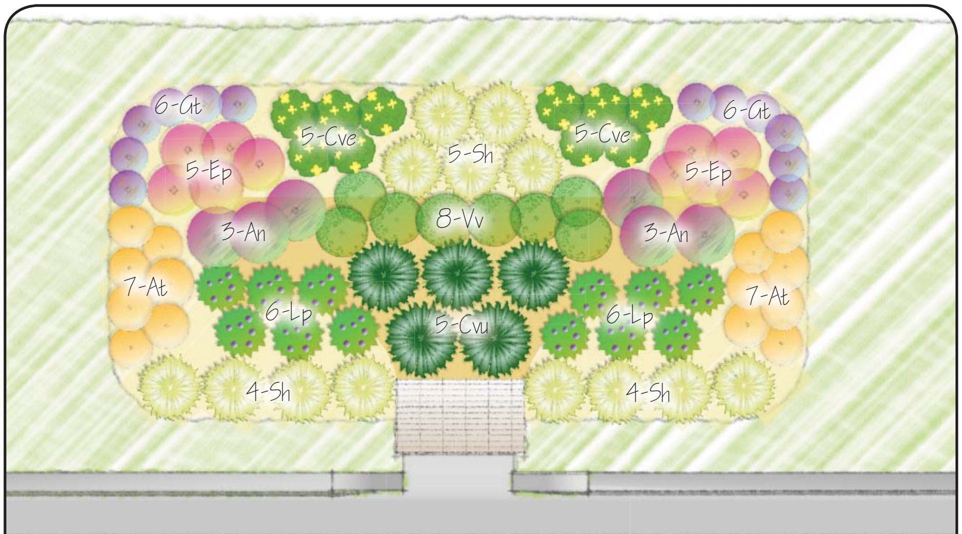




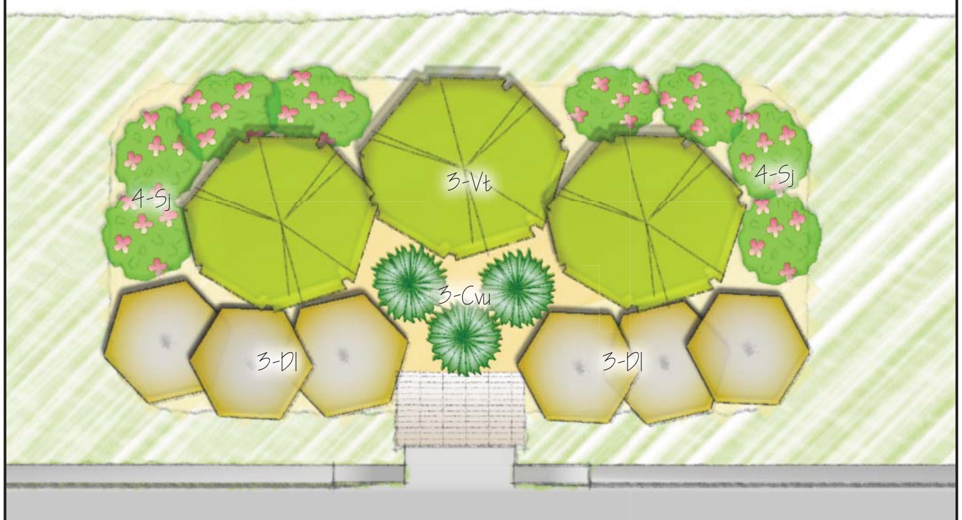


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

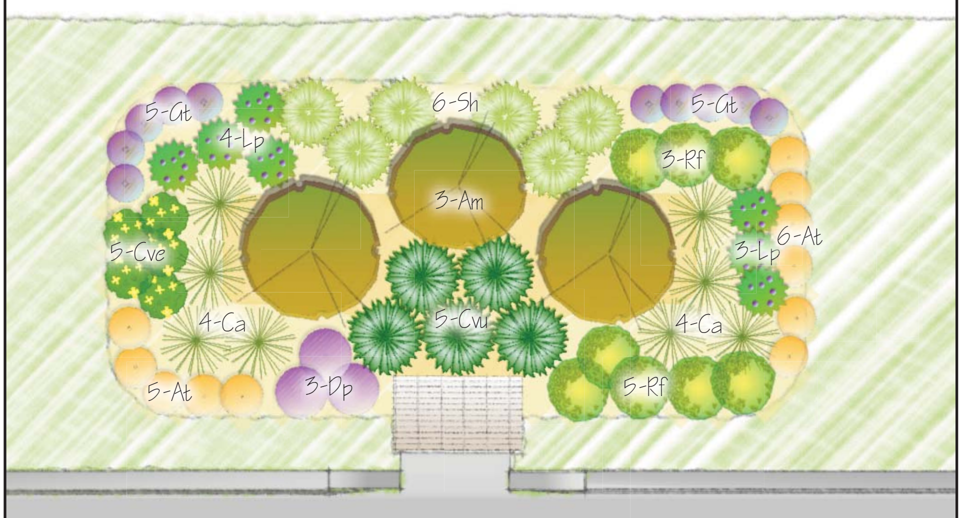
I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

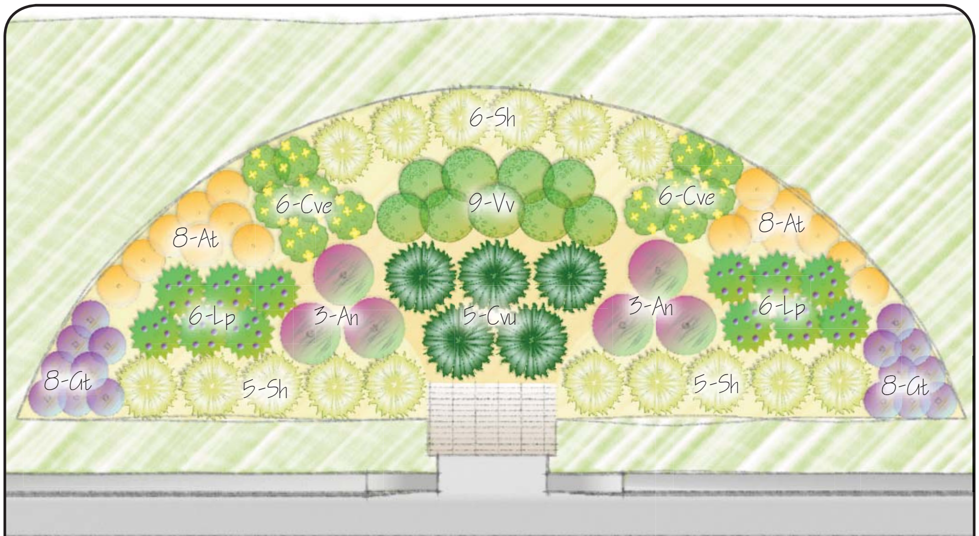


Mixed Shrub/Flower Garden

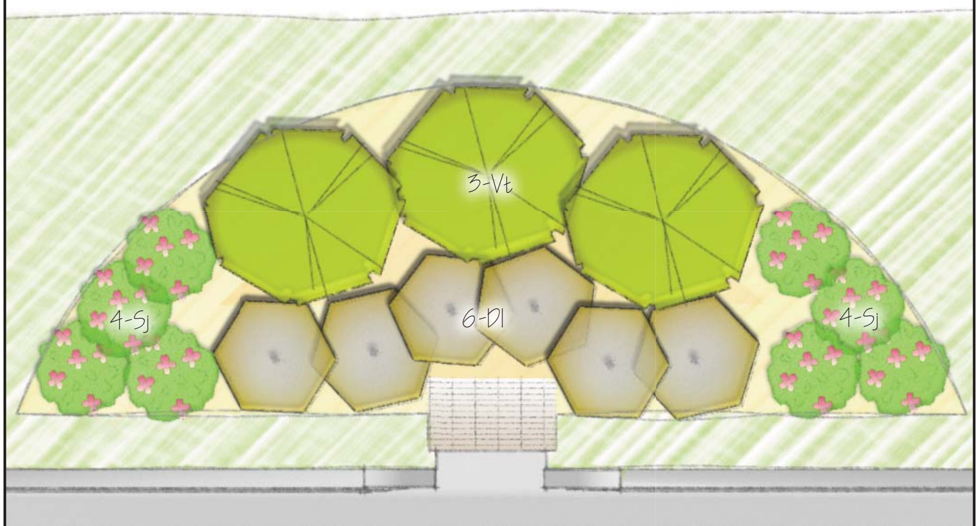
Plant Key

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'*

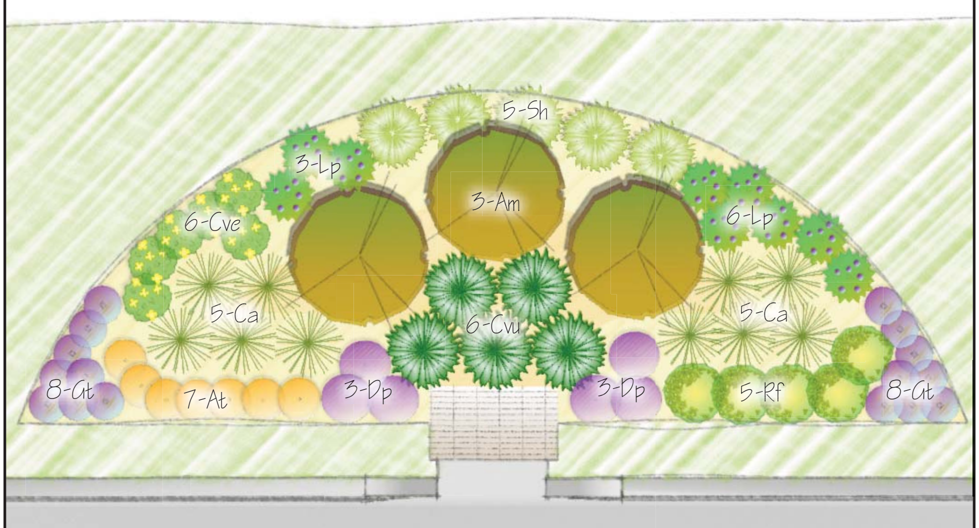
II. Arc Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

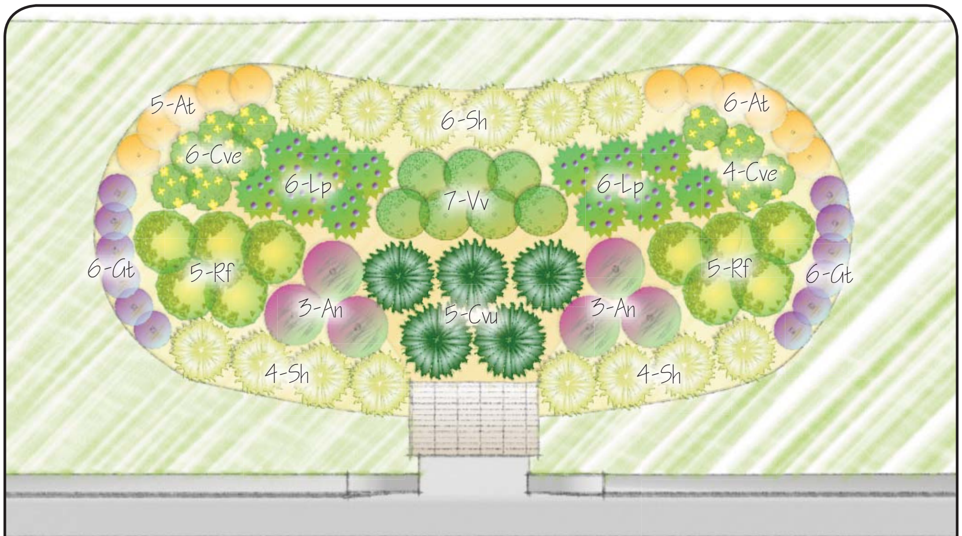


Mixed Shrub/Flower Garden

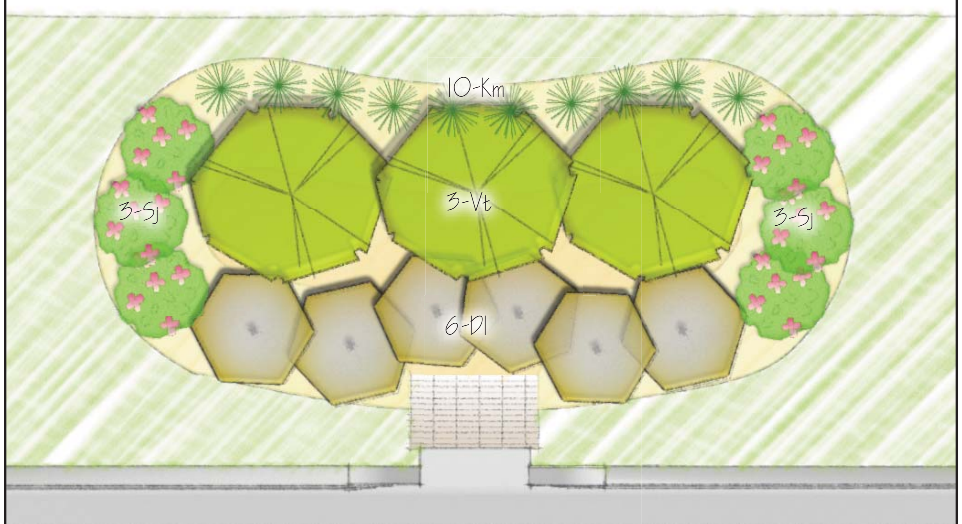
Plant Key

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'*

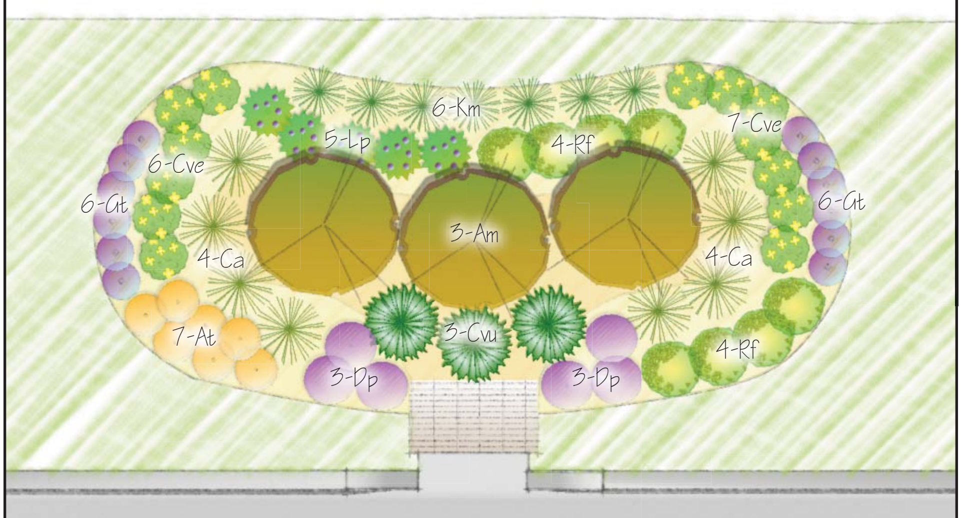
III. Curvilinear Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

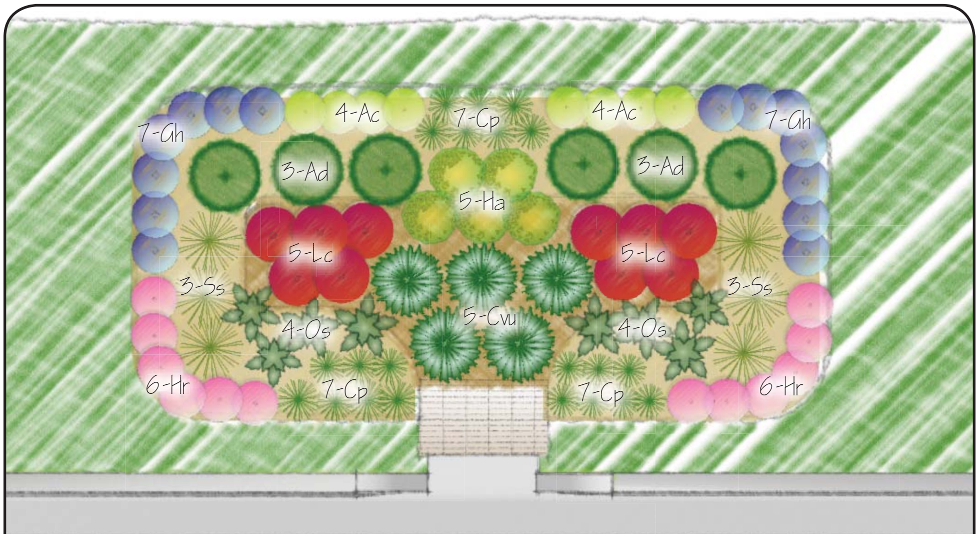


Mixed Shrub/Flower Garden

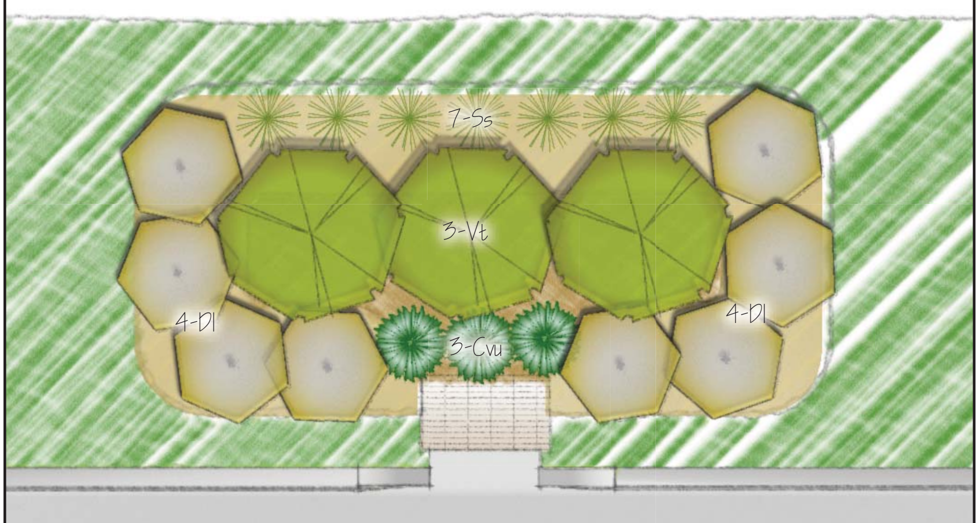
Plant Key

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'*

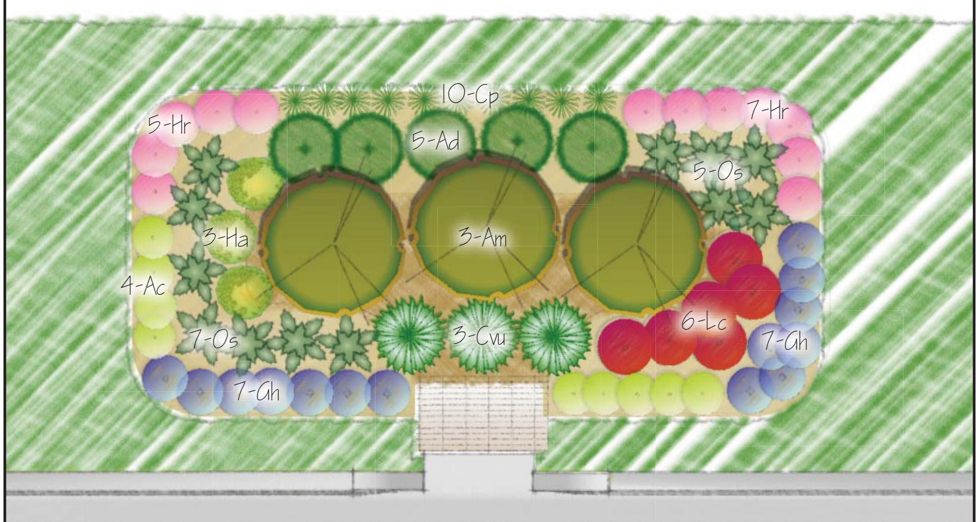
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

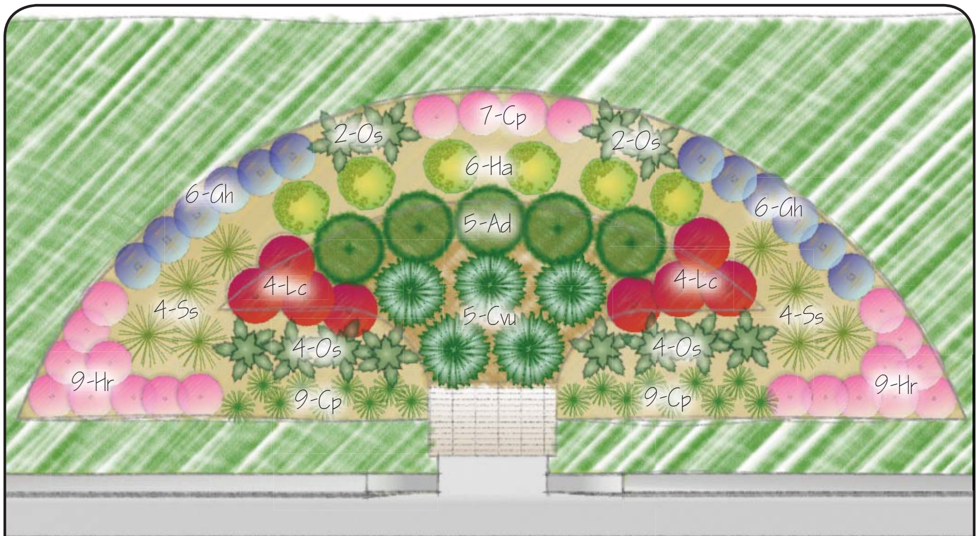


Mixed Shrub/Flower Garden

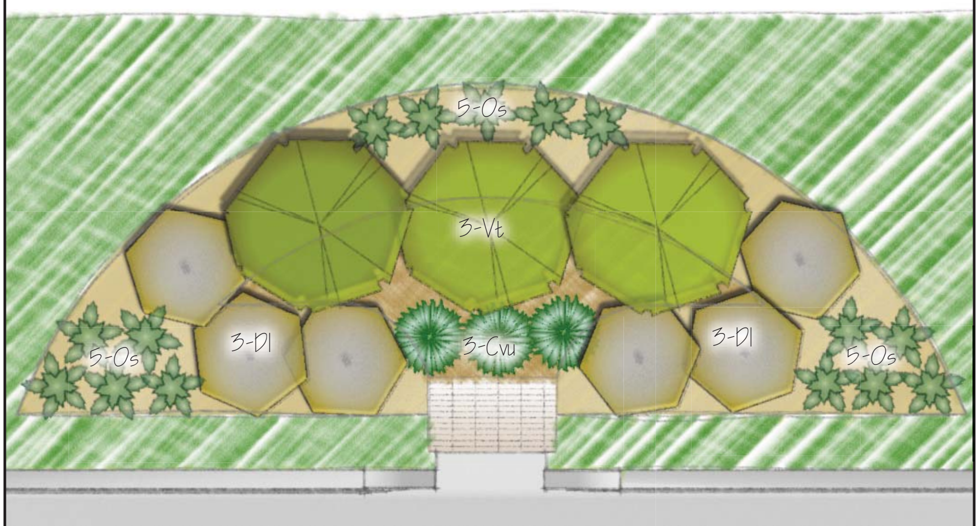
Plant Key

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



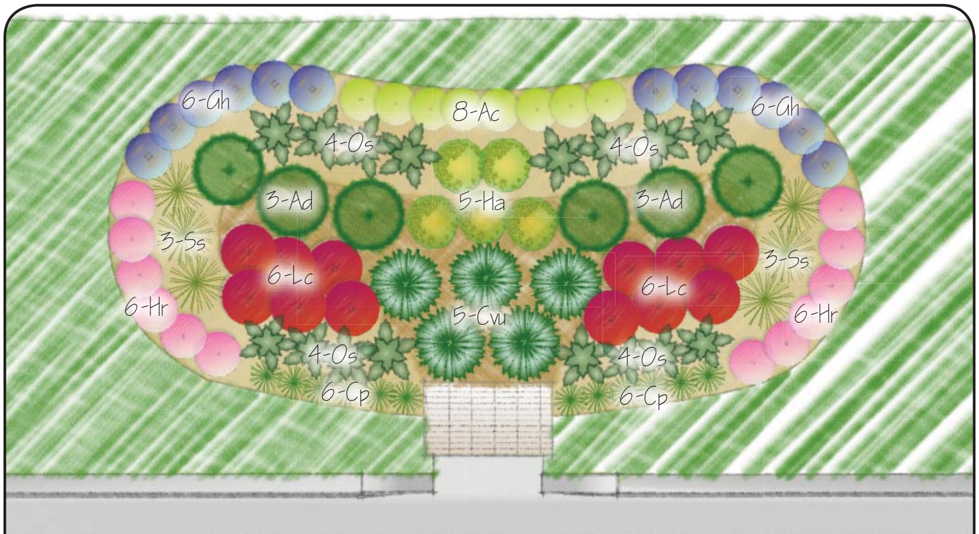
Shrub Garden

Mixed Shrub/Flower Garden

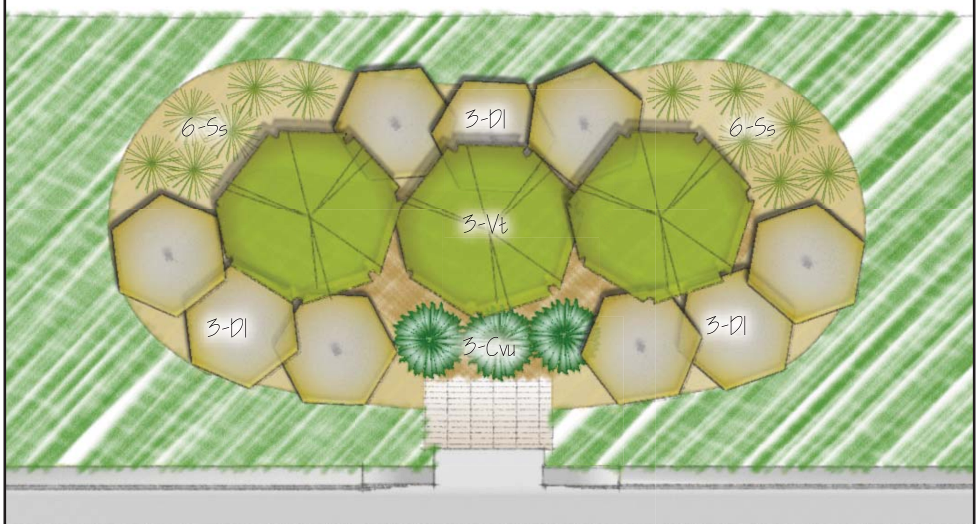
Plant Key

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

VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



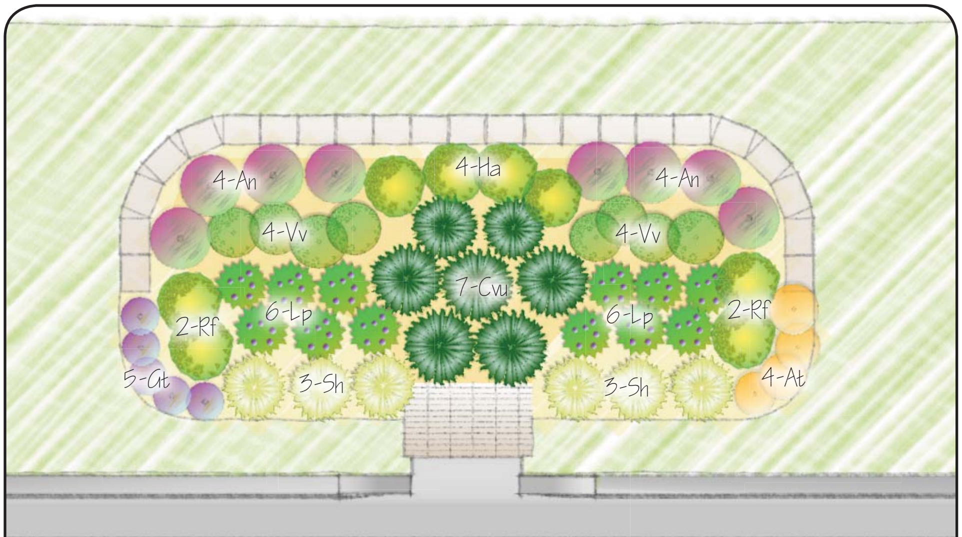
Shrub Garden

Mixed Shrub/Flower Garden

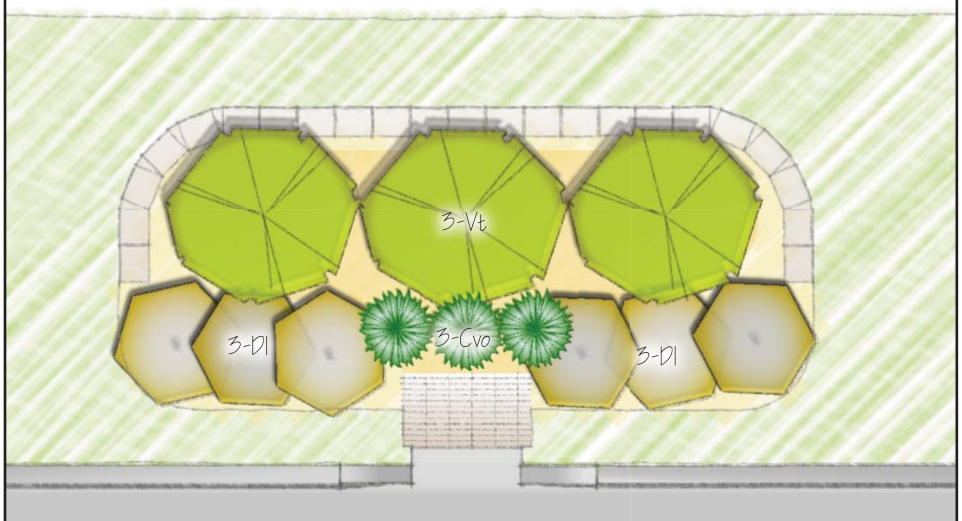
Plant Key

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

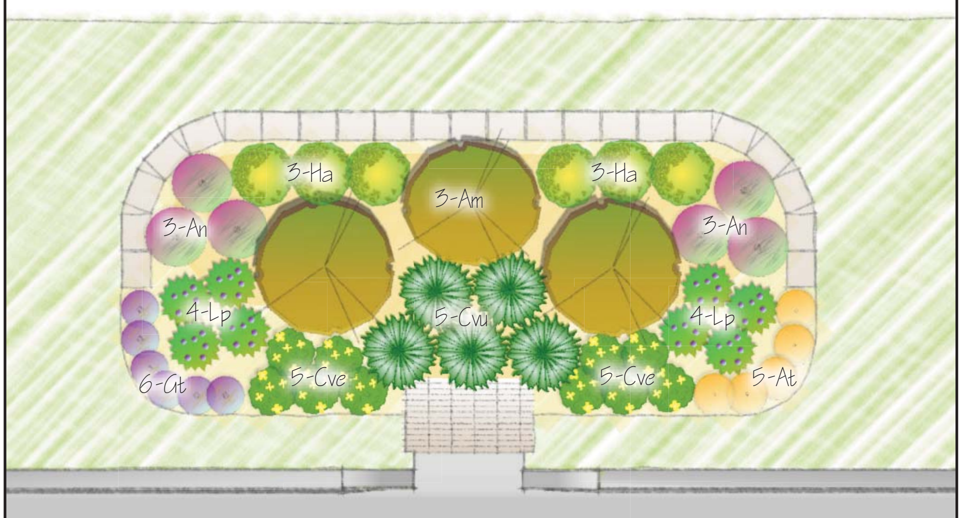
VII. Rectangle Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

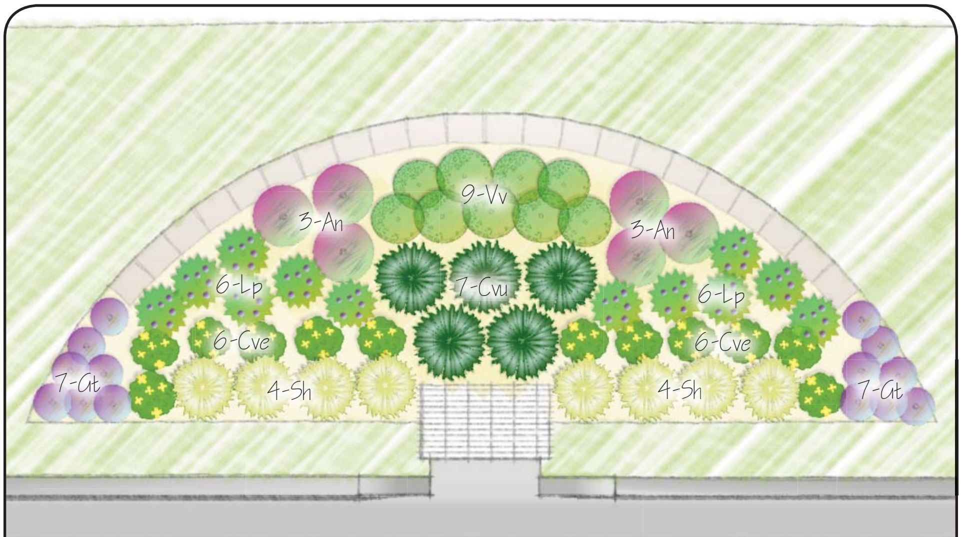


Mixed Shrub/Flower Garden

Plant Key

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

VIII. Arc Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden

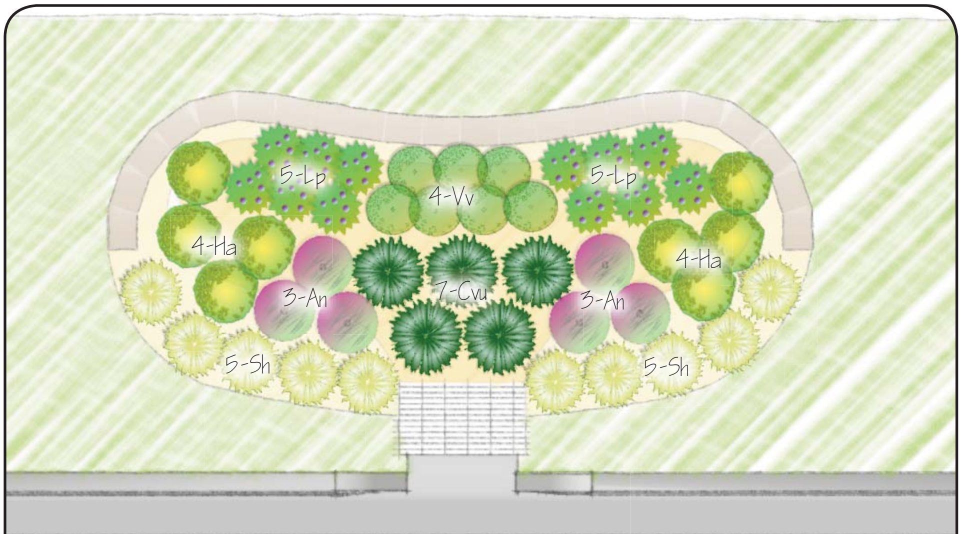
Shrub Garden

Mixed Shrub/Flower Garden

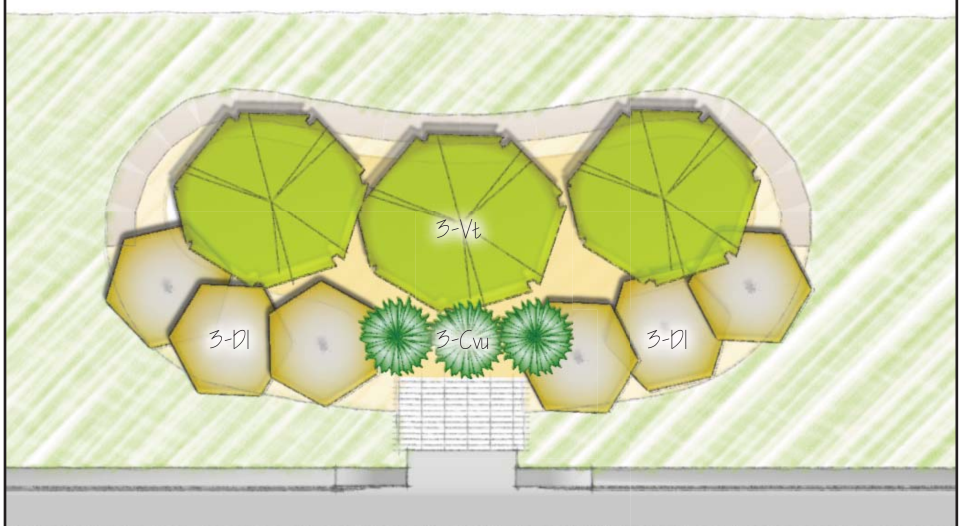
Plant Key

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*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Gt	PRAIRIE SMOKE *Geum trifolium*
Lp	PRAIRIE BLAZING STAR *Liatris pycnostachya*
Sj	DART'S RED SPIRAEA *Spiraea japonica*
Sh	PRAIRIE DROPSEED *Sporobolis heterolepsis*
Vv	CULVERS ROOT *Veronicastrum virginicum*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

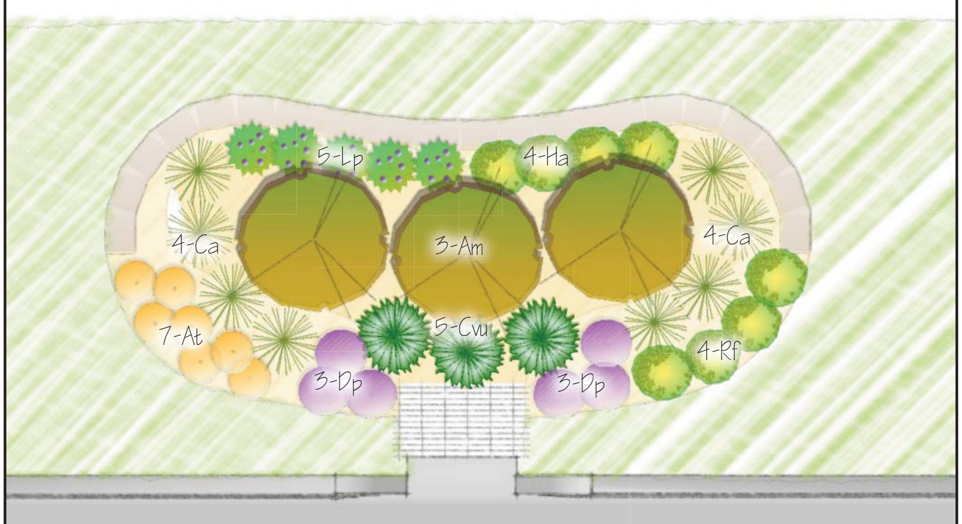
IX. Curvilinear Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden



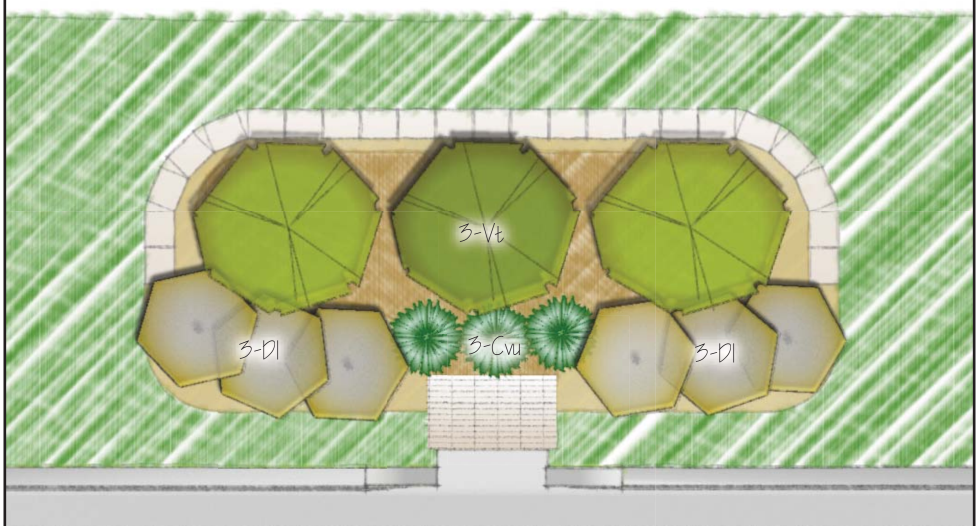
Mixed Shrub/Flower Garden

Plant Key

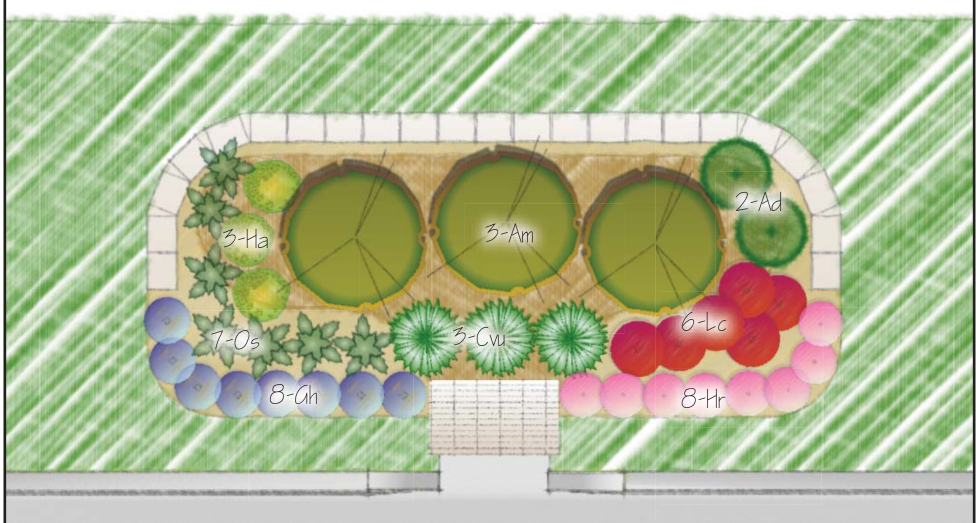
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*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

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

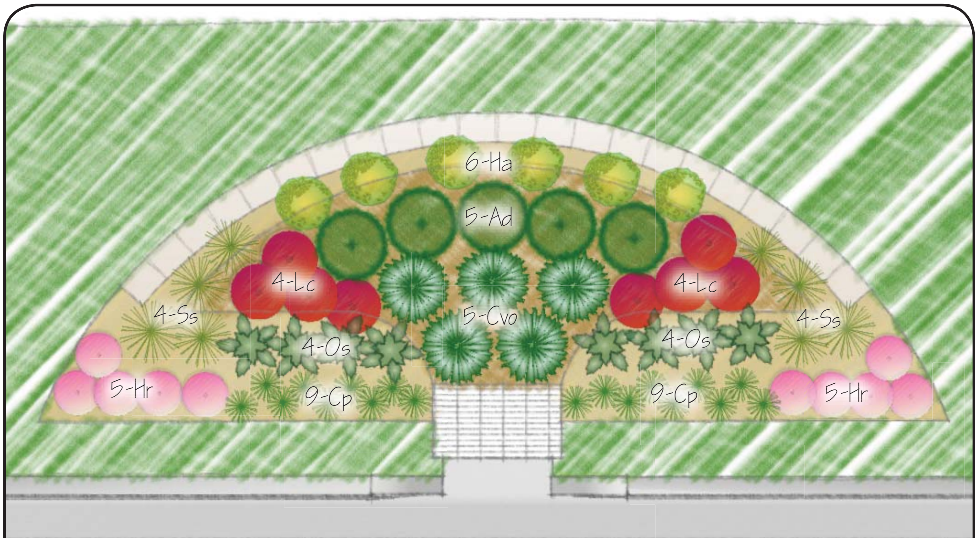


Mixed Shrub/Flower Garden

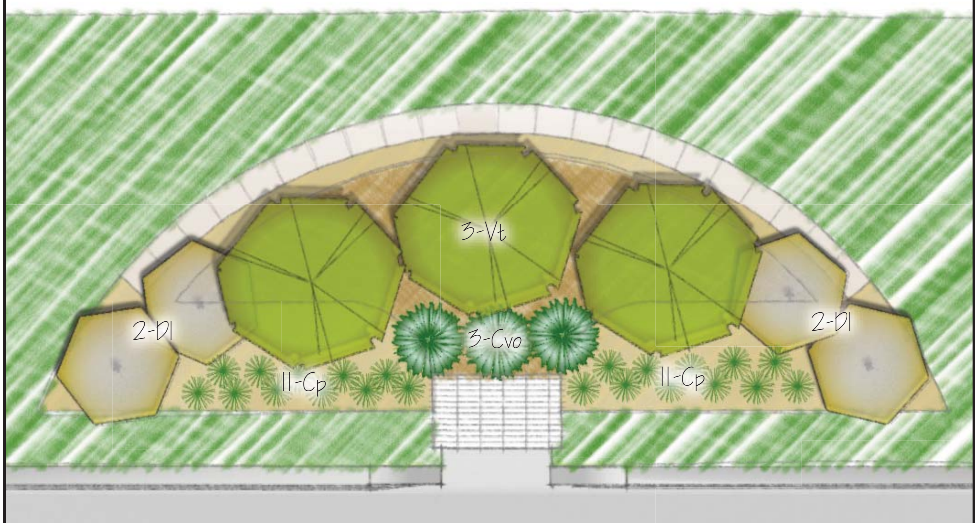
Plant Key

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

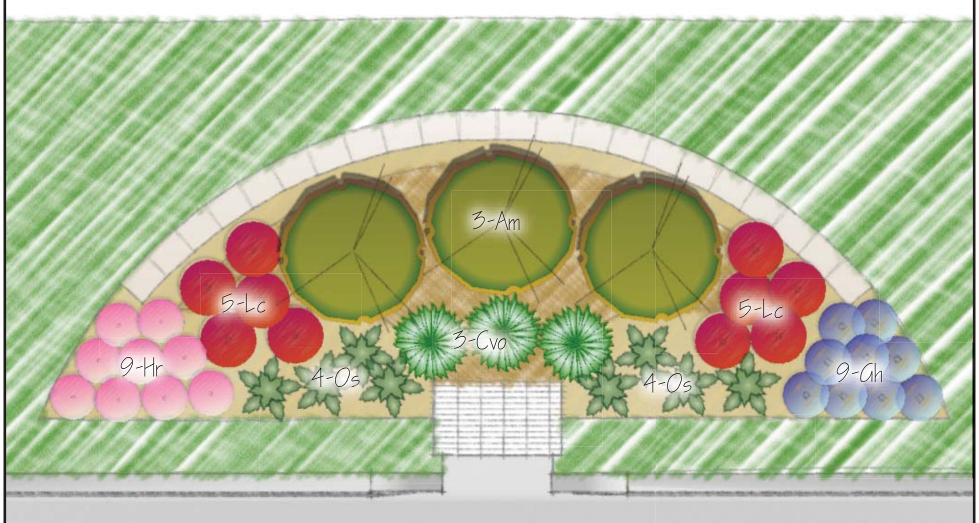
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

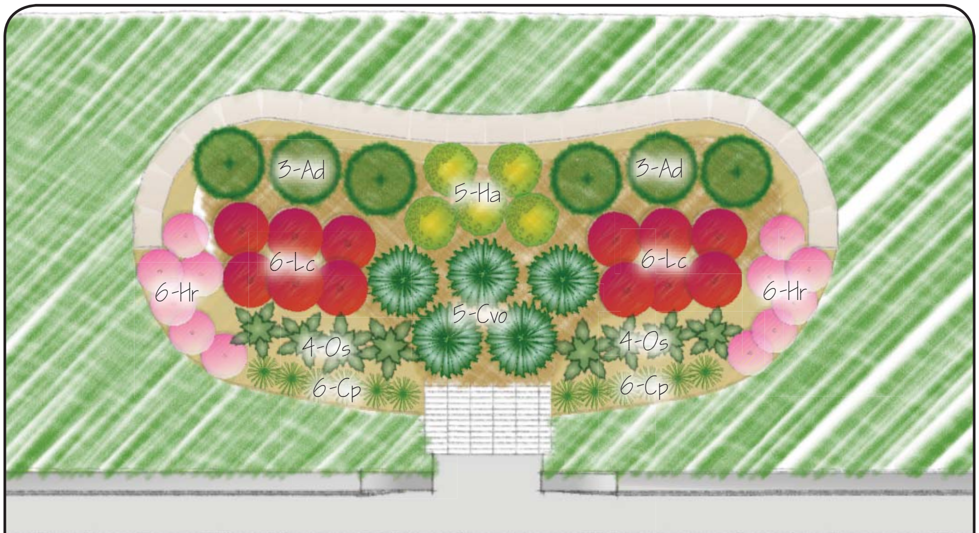


Mixed Shrub/Flower Garden

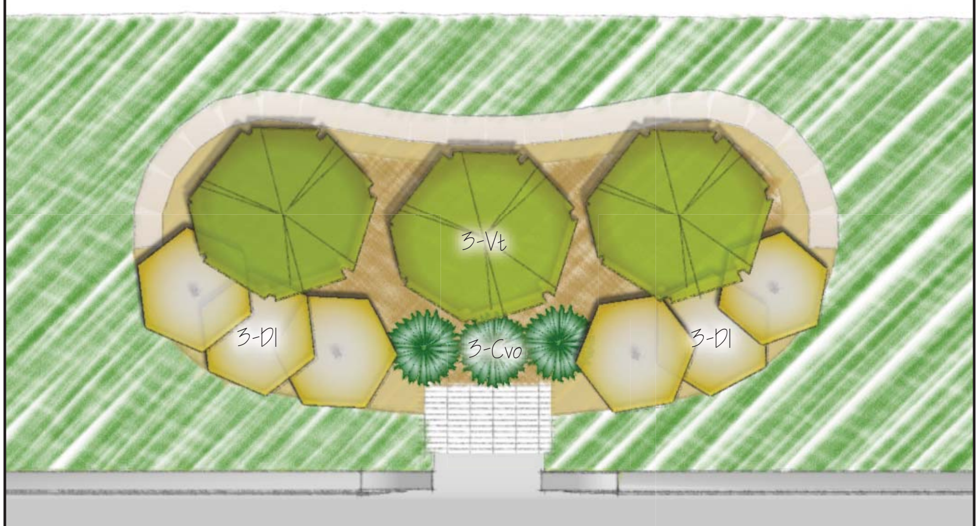
Plant Key

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

XII. Curvilinear Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

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

FLOWERING PERENNIAL
Plant pallette

CANADA ANEMONE
Anemone canadensis

GOAT'S BEARD
Aruncus diocius

BUTTERFLY MILKWEED
Asclepias tuberosa

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

COREOPSIS 'MOONBEAM'
Coreopsis verticillata 'Moonbeam'

PURPLE PRARIE CLOVER
Dalea purpurea

PURPLE CONEFLOWER
Echinacea purpurea

GERANIUM 'JOHNSON BLUE'
Geranium himalayense x pratense

PRAIRIE SMOKE
Geum trifolium

SNEEZEWEED
Helenium autumnale

ALUMROOT
Heuchera richardsonii

PRAIRIE BLAZING STAR
Liatris pycnostachya

CARDINAL FLOWER
Lobelia cardinalis

SENSITIVE FERN
Onoclea sensibilis

GOLDSTRUM BLACK-EYED SUSAN
Rudbeckia fulgida

CULVERS ROOT
Veronicastrum virginicum

SHRUB
Plant pallette

BLACK CHOKEBERRY
Aronia melonocarpa

DWARF BUSH HONEYSUCKLE
Diervilla lonicera

DART'S RED SPIRAEA
Spiraea japonica

CRANBERRYBUSH VIBURNUM
Viburnum trilobum 'compactum'

GRASSES
Plant pallette

KARL FORESTER GRASS
Calamagrostis acutifolia

PENNSYLVANIA SEDGE
Carex pennsylvanica

FOX SEDGE
Carex vulpinoidea

JUNE GRASS
Koeleria macrantha

LITTLE BLUESTEM
Schizachyrium scoparium

PRAIRIE DROPSEED
Sporobolis heterolepsis