Rice Lake Subwatershed Stormwater Retrofit Assessment

Prepared for the Rice Creek Watershed District by
The Anoka Conservation District

With Assistance From:
The Metropolitan Landscape Restoration Program

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(Revised January, 2010)

ANOKA CONSERVATION DISTRICT

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The Rice Creek Watershed District identified Rice Lake as a high priority water resource and contracted with the Anoka Conservation District to assess the subwatershed in the cities of Lino Lakes, Blaine and Circle Pines. The purpose of this project is to improve stormwater quality and reduce the volume of runoff entering the stormwater system from neighborhoods that most greatly contribute to the degradation of Rice Lake. The goal is to implement projects in a systematic way that maximizes the use of limited financial resources by identifying and prioritizing projects that provide the greatest amount of stormwater treatment per dollar spent. The Rice Lake subwatershed assessment resulted in a list of stormwater retrofit options which were ranked according to cost-effectiveness.

The process for assessing the Rice Lake subwatershed was modified from the Center for Watershed Protection's Urban Stormwater Retrofit Practices Manual 3 (2007). Due to the high nutrient load in Rice Lake, phosphorus was determined to be the target pollutant. Thirteen catchments were identified based on land cover, storm drainage and existing catchment information provided by the Rice Creek Watershed District. Those catchments were assessed for retrofit potential using GIS and field inspections. Some catchments were eliminated from consideration due to existing treatment or low pollutant generation, while others were found to be good candidates for retrofits. Though several sites were identified for specific projects, much of the watershed is highly developed residential land cover which is best suited for neighborhood rain garden retrofits.

A total of 12 retrofit projects were analyzed for cost and pollutant removal. Two of the projects are retrofits that implement BMPs on school properties and a third is a stormwater wetland project at Shenandoah Park that will require additional modeling to determine treatment efficiency. The remaining nine projects are groupings of neighborhood rain garden retrofits. Cost effectiveness of each project for varying levels of phosphorus reduction was analyzed and reflects the installed cost as well as long term operation and maintenance. The top five most cost-effective projects in terms of phosphorus reduction are:

1. RL-1: Centennial Campus Retrofit ($410/lb/yr)
2. RL-9: Rice Lake Elementary Retrofit ($450/lb/yr)
3. RL-6: Neighborhood Rain Garden Retrofit ($772/lb/yr)
4. RL-5: Neighborhood Rain Garden Retrofit ($819/lb/yr)
5. RL-13: Neighborhood Rain Garden Retrofit ($855/lb/yr)

A table summarizing the assessment results is on the following page.

Rice Lake Subwatershed Project Priorities

Highlighted rows in the table below indicate catchment/project areas directly connected to Rice Lake and could be considered a higher priority even though the cost per pound reduction is greater. Non-highlighted rows are projects serving areas where stormwater passes through already existing treatment or wetlands. All projects are assumed to have an operation and maintenance (O&M) term of 10 years.

Catchment	Retrofit Project	Number of BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Estimated Installation Cost	Installed Cost/lb TP Reduction	Annual O&M Cost per BMP	Estimated Term Cost/lb/yr (includes O&M)
RL-2*	Neighborhood Retrofit	23	30%	10.2	$93,541	$9,171	$75	$1,086
RL-2	Neighborhood Retrofit	48	50%	17.1	$193,841	$11,336	$75	$1,344
RL-3*	Neighborhood Retrofit	7	30%	3.3	$29,349	$8,894	$75	$1,048
RL-3	Neighborhood Retrofit	15	50%	4.8	$61,445	$11,172	$75	$1,322
RL-4*	Neighborhood Retrofit	5	30%	2.1	$21,325	$10,155	$75	$1,194
RL-4	Neighborhood Retrofit	9	50%	3.6	$37,373	$10,381	$75	$1,226
RL-5	Neighborhood Retrofit	19	10%	11.2	$77,493	$6,919	$75	$819
RL-5	Neighborhood Retrofit	69	30%	33.4	$278,093	$8,326	$75	$988
RL-5	Neighborhood Retrofit	143	50%	55.7	$574,981	$10,323	$75	$1,225
RL-6	Neighborhood Retrofit	14	10%	8.8	$57,433	$6,526	$75	$772
RL-6	Neighborhood Retrofit	52	30%	26.4	$209,889	$7,950	$75	$943
RL-6	Neighborhood Retrofit	110	50%	44	$442,585	$10,059	$75	$1,193
RL-6	Centennial Campus Retrofit	13	70%	11.3	$34,125	$3,020	$15-$300	$410
RL-6	Centennial Campus Retrofit	13	90%	14.5	$67,540	$4,652	$25-$500	$625
RL-8*	Neighborhood Retrofit	7	30%	3.3	$29,349	$8,894	$75	$1,048
RL-8	Neighborhood Retrofit	14	50%	5.5	$57,433	$10,442	$75	$1,235
RL-9	Rice Lake Elementary	6	50%	4.1	$12,150	$2,963	$100	$450
RL-9	Rice Lake Elementary	6	70%	5.4	$25,000	$4,340	$167	$650
RL-9	Rice Lake Elementary	6	90%	7.4	$55,150	$7,453	$334	$1,015

Rice Lake Subwatershed Project Priorities (continued)

Catchment	Retrofit Project	Number of BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Estimated Installation Cost	Installed Cost/lb TP Reduction	Annual O&M Cost per BMP	Estimated Term Cost/lb/yr (includes O&M)
RL-11	Neighborhood Retrofit	5	10%	2.7	$21,325	$7,898	$75	$929
RL-11	Neighborhood Retrofit	17	30%	8.1	$69,469	$8,576	$75	$1,015
RL-12	Neighborhood Retrofit	6	10%	3.4	$25,337	$7,452	$75	$878
RL-12	Neighborhood Retrofit	21	30%	9.4	$85,517	$8,552	$75	$1,013
RL-13	Neighborhood Retrofit	22	10%	12.4	$89,529	$7,220	$75	$855

* Slightly lower cost/lb was available for 10% TP reduction, but the resulting BMP size/number was too small to justify installation

Other potential projects that require additional modeling:

- Shenandoah Park stormwater wetland
- Culvert blocking on west side of Hodgson Road, south of Lake Drive
- Raising pond outlets to create more storage in residential areas south of Birch Street

There are many possible ways to prioritize projects, and the list provided is merely a starting point. Final project ranking for installation is the responsibility of the Rice Creek Watershed District and may include:

- Non-target pollutant reductions (TSS, volume, bacteria etc.)
- Project visibility
- Availability of funding
- Total project costs
- Educational value
- others

Document Overview

The Rice Lake subwatershed assessment is a tool to help prioritize stormwater retrofit projects by cost effectiveness in order to install BMPs where they will be most effective. This process helps to maximize the value of each dollar spent. The document is organized into catchment profiles which highlight a specific portion of the subwatershed.

Methods

The methods section outlines the general procedure used when assessing the Rice Lake subwatershed. It highlights retrofit scoping, the desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking.

Catchment Profiles

Each catchment profile is titled RL- # to coincide with the subwatershed name (Rice Lake) and an identification number. This code is referenced when comparing projects between catchments. If a site-specific project exists within a catchment, the project will be given a descriptive name in addition to the catchment code. Information found in each catchment profile is described below.

Catchment Summary/Description

Within the catchment profiles is a location map and table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant load. A brief description of the land cover, stormwater infrastructure and any other important general information is also described here.

Retrofit Recommendation

The recommendation section will describe the retrofit(s) selected for the catchment area and provide a description of why the specific retrofit was chosen. If no retrofit is recommended for a catchment area, an explanation is provided.

Cost/Treatment Analysis

Within the cost/treatment analysis section is a summary table of amount of treatment needed to achieve different levels of phosphorus reduction. Corresponding reductions of TSS are also included. Cost estimates are created to match the different levels of treatment and leads to the estimated cost per pound value used to prioritize projects. A separate table includes some of the important modeling inputs used.

Site Selection
This section highlights properties/areas suitable for retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for retrofits are identified here.

Retrofit Ranking
Retrofit ranking takes into account all of the information gathered during the assessment process to create a prioritized project list. The list is sorted by cost per pound of phosphorus treated for each project. The cost per pound treatment value is for the installed cost and does not include long term operation and maintenance.

Selection of Subwatershed
Before the subwatershed assessment can begin, a process of identifying a high priority water body as a target needs to take place. Many factors need to be 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 should be supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data) to ensure the assessment will be successful.

Subwatershed Assessment Methods
The process used for assessing the Rice Lake subwatershed is outlined below and was modified from the Center for Watershed Protection's Urban Stormwater Retrofit Practices Manual 3 (Schueler, 2007).

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 (filtration, detention, infiltration) and retrofit performance criteria.

Step 2: Desktop Retrofit Analysis
The desktop analysis involves scanning the subwatershed for potential retrofit sites. Accurate GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers to have include: 5-foot or finer topography, hydrology, watershed/subwatershed boundaries, parcel boundaries, high resolution aerial photography and the storm drainage infrastructure. The following table highlights some important features to look for and the associated potential retrofit project.

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

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through the desktop search, a field investigation is conducted to evaluate each site. During the investigation, the drainage area and stormwater infrastructure mapping data is verified. Site constraints are assessed to determine the most feasible retrofit options as well as eliminate other sites from consideration. The field investigation might also reveal additional potential retrofit sites that may have gone unnoticed during the desktop search.

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

The most feasible projects are taken to the design phase. Concepts are developed that take into account available space, site constraints and the subwatershed treatment objectives. Projects that involve complex stormwater treatment interactions or pose a risk for upstream flooding may require the assistance of an engineer. Designs include a cost estimate and estimate of pollution reduction so projects can be prioritized.

A P8 treatment model is created for each site that estimates pollution or volume reduction. The treatment model can also be used to properly size BMP's to meet the restoration objectives. The P8 model uses conservative estimates for runoff coefficients, infiltration rates and directly/indirectly connected impervious surfaces. Because the model produces conservative estimates of pollutant reduction, installed retrofits will likely outperform the model predictions. Post-construction monitoring is needed for the most accurate treatment analysis. Modeling did not take into account any existing stormwater treatment or other BMPs such as street sweeping. The following table outlines some of the model inputs and how they are determined.

Determining P8 Model Inputs	
P8 Parameter	**Method for Determining Value**
Total Area	GIS mapping.
Pervious Area Curve Number	Values from the USDA Urban Hydrology for Small Watersheds TR-55 (1986). A composite curve number was found based on proportion of hydrologic soil group and associated curve numbers for open space in fair condition (grass cover 50%-75%).
Directly Connected Impervious Fraction	Calculated using GIS to measure the amount of rooftop, driveway and street area directly connected to the storm system. Estimates calculated from one area can be used in other areas with similar land cover.
Indirectly Connected Impervious Fraction	Wisconsin urban watershed data (Panuska, 1998) provided in the P8 manual is used as a basis for this number. It is adjusted slightly based on the difference between the table value and calculated value of the directly connected impervious fraction.
Precipitation/Temperature Data	Rainfall and temperature recordings from 1959 were used as a representation of an average year.
Hydraulic Conductivity	A composite hydraulic conductivity rate is developed for each catchment area based on the average conductivity rate of the low and high bulk density rates by USDA soil texture class (Rawls et. al, 1998). Wet soils where practices will not be installed may be omitted.

Cost Estimates

Estimates for site-specific projects are calculated on a case-by-case basis. However, estimates for residential curb-cut raingardens are more easily calculated since standardized designs can be applied in a variety of situations. Estimated costs associated with installing residential curb-cut rain gardens included materials, labor, design finalization as well as promotion and administration costs. Materials and labor for installing a single curb-cut rain garden was averaged to be $3,500. The expected range for such a practice may be between $2,500 and $5,000 depending on how much in-kind labor is included, plant container sizes, inclusion of retaining walls and types as well as other considerations. Appendix A has more information on specific design features. Though detailed construction plans are included with this report, modifications of the concepts to account for site specific constraints (sidewalks, utilities, trees etc.) will be required. It was estimated that approximately six hours would be required to finalize a curb-cut raingarden design to fit site specific constraints. Anoka Conservation District's rate for a Metro Conservation District Landscape Restoration Specialist ($67/hr) was used to estimate the cost of finalizing designs.

Promotion and administration costs were estimated by calculating the hours required using the formula h=25+2(n-1) where *h= estimated hours* and *n=number of rain gardens*. The value of 25 accounts for the time required to conduct promotion and administration activities for the first rain garden. Many of the activities will require very little additional time for each additional rain garden. Promotion and administration estimates were calculated at the Anoka Conservation District's rate for a Technician and includes the following tasks:

- Outreach/Promotion
- Education
- Landowner agreements
- Cost share assistance
- Permits
- Contractor RFP
- Pre-bid meeting
- Pre-construction meeting
- Construction oversight
- Planting assistance

Step 5: Evaluation and Ranking

The final step in the subwatershed assessment is to conduct a cost-benefit analysis for each potential project. This is typically done by developing a cost per unit of treatment achieved. The treatment unit will likely be the pollutant of concern determined in step 1. Once the cost-benefit analysis is complete for each project, the projects can be ranked by cost-effectiveness.

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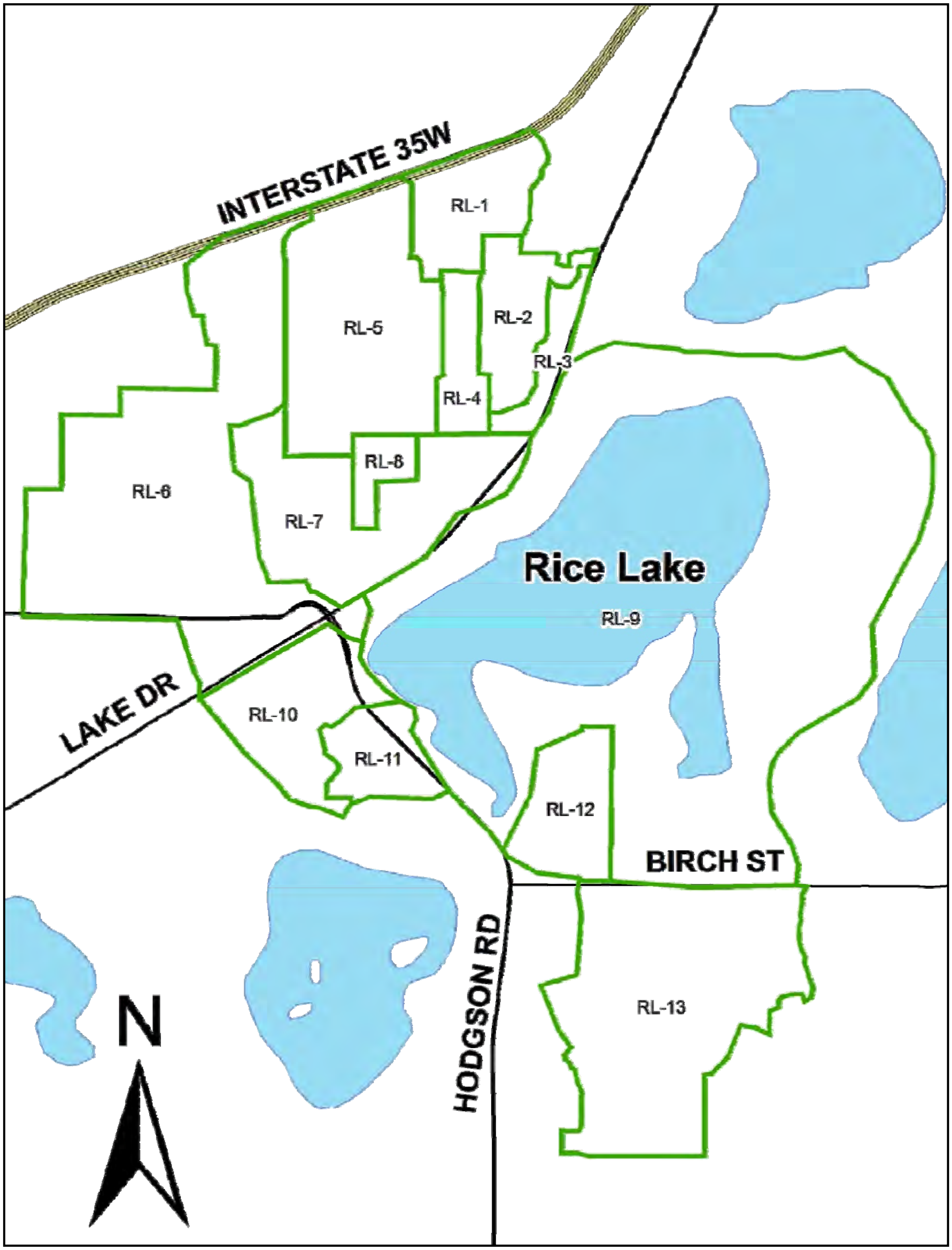
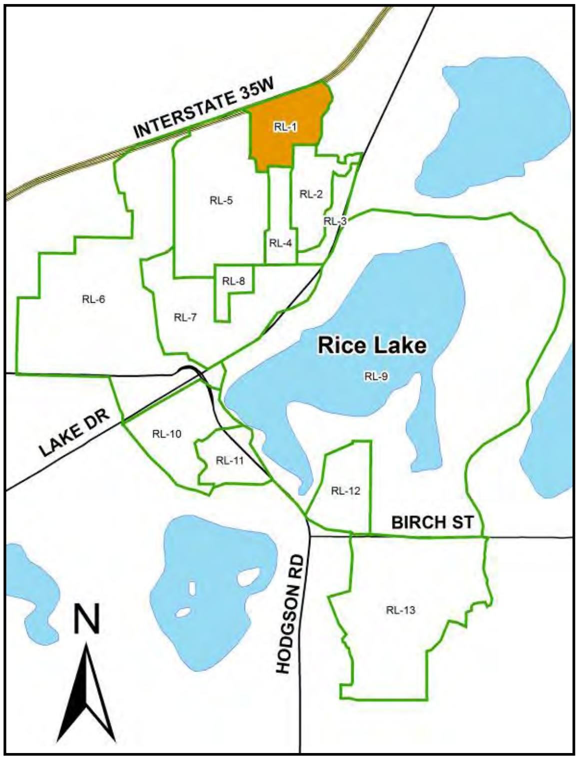
The map below shows the catchment areas assessed for stormwater retrofits and outlined in the following pages.



CATCHMENT PROFILE: RL-1

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	65
Dominant Land Cover	Turf grass
Parcels	18
TSS (lb/yr)	4,118
TP (lb/yr)	13.0
Volume (acre-feet/yr)	11.0



Description:

RL-1 is located in the north border of the Rice Lake subwatershed. The majority of the catchment area is turf grass athletic fields, but it also consists of residential development and part of the Centennial Middle School property. Runoff from Centennial Middle school is being treated by a stormwater pond, and most of the remainder of the catchment drains to a dry pond facility on Elm Street.

Retrofit Recommendation:

The majority of stormwater in this catchment is already receiving some form of treatment. In addition, the sandy soils in the area have a high infiltration rate which reduces the amount of runoff generated by the mainly pervious landscape. No retrofit projects are recommended in this catchment.

Treatment Analysis:

Model Inputs:

Parameter	Input
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.06
Directly Connected Impervious Fraction	0.08

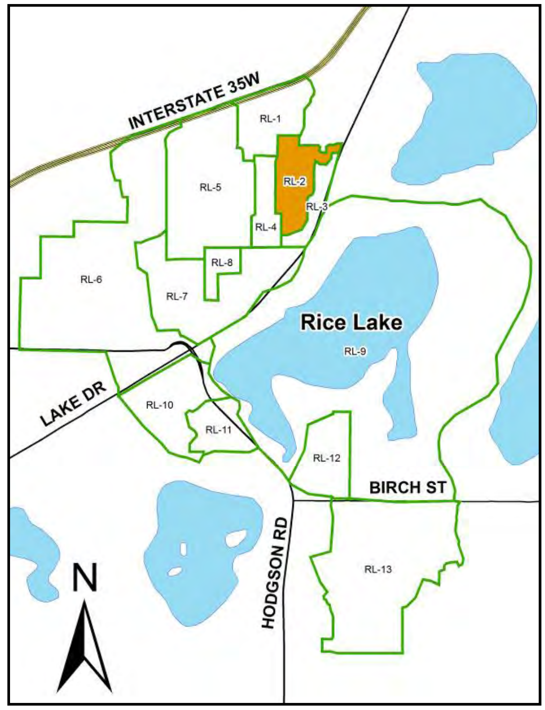
CATCHMENT PROFILE: RL-1

Rice Lake Subwatershed Assessment

CATCHMENT PROFILE: RL-2

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	54
Dominant Land Cover	Residential, ¼ acre lots
Parcels	126
TSS (lb/yr)	10,748
TP (lb/yr)	34.1
Volume (acre-feet/yr)	29.0



Description:

RL-2 is located in the northeast portion of the Rice Lake subwatershed. The majority of the catchment area is quarter-acre residential lots in the Wenzel Farms development. Current stormwater infrastructure includes catch basins and three outfalls that empty into a large wetland complex to the west of Rice Lake.

Retrofit Recommendation:

This highly developed catchment area is best suited for curb-cut rain garden retrofits. Positioning the rain gardens uphill from the catch basins will capture stormwater runoff before it enters the storm system.

Treatment Analysis:

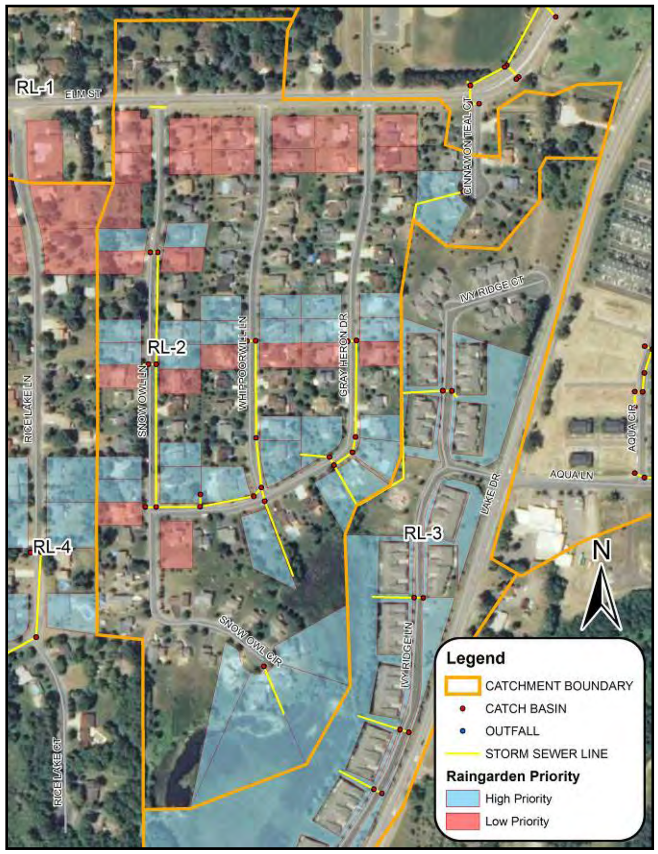
The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	8,941	7,297	5,387	2,831
TSS Reduction (%)	83%	68%	50%	26%
TP Reduction (lb/yr)	23.9	17.1	10.2	3.4
Volume Reduction (acre-feet/yr)	19.7	14.7	9.4	3.2
Volume Reduction (%)	68%	51%	32%	11%
Live Storage Volume (cubic feet)	8,712	4,791	2,257	620
Rain gardens Needed	87	48	23	6
Materials/Labor	$304,500	$168,000	$80,500	$21,000
Design Finalization	$34,974	$19,296	$9,246	$2,412
Promotion & Administration Costs	$10,835	$6,545	$3,795	$1,925
Total Project Cost	$350,309	$193,841	$93,541	$25,337
Cost/lb Phosphorus	$14,657	$11,336	$9,171	$7,452
Annual O&M	$6,525	$3,600	$1,725	$450
Term Cost/lb/yr (10 yr)	$1,739	$1,344	$1,086	$878

Model Inputs:

Parameter	Input
Pervious Curve Number	55
Indirectly Connected Impervious Fraction	0.12
Directly Connected Impervious Fraction	0.25
Hydraulic Conductivity	3.21 in/hr

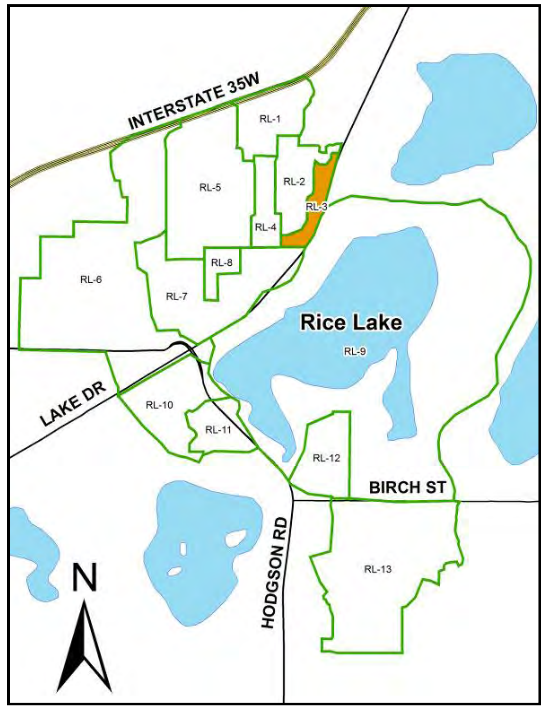
Site Selection:
In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, in which case adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.



CATCHMENT PROFILE: RL-3

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	26
Dominant Land Cover	Row-style Condos
Parcels	75
TSS (lb/yr)	3,479
TP (lb/yr)	11.1
Volume (acre-feet/yr)	9.5



Description:

RL-3 is located in the north east portion of the Rice Lake subwatershed. The catchment area contains the Wenzel Farms development of row-style condos. Current stormwater infrastructure includes catch basins and outfalls that empty into a large wetland complex that flows into Rice Lake.

Retrofit Recommendation:

Curb-cut rain gardens are the best option for treating stormwater in this catchment area. The small park in the condo development was considered as a possible retrofit site to treat stormwater from a pipe that empties into the wetland next to the park, but the elevation of the pipe was too low for this option.

Treatment Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	2,892	2,356	1,734	905
TSS Reduction (%)	83%	68%	50%	26%
TP Reduction (lb/yr)	7.8	5.5	3.3	1.1
Volume Reduction (acre-feet/yr)	6.5	4.8	3.1	1.1
Volume Reduction (%)	68%	51%	33%	12%
Live Storage Volume (cubic feet)	2,700	1,481	707	196
Rain gardens Needed	27	15	7	2
Materials/Labor	$94,500	$52,500	$24,500	$7,000
Design Finalization	$10,854	$6,030	$2,814	$804
Promotion, Oversight & Admin Costs	$4,235	$2,915	$2,035	$1,485
Total Project Cost	$109,589	$61,445	$29,349	$9,289
Cost/lb Phosphorus	$14,050	$11,172	$8,894	$8,445
Annual O&M	$2,025	$1,125	$525	$150
Term Cost/lb/yr (10 yr)	$1,665	$1,322	$1,048	$981

Model Inputs:

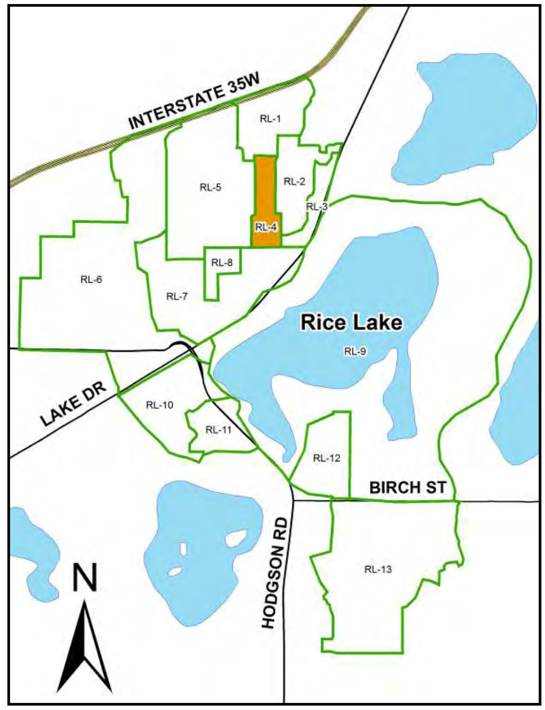
Parameter	Input
Pervious Curve Number	52
Indirectly Connected Impervious Fraction	0.20
Directly Connected Impervious Fraction	0.17
Hydraulic Conductivity	3.51 in/hr

Site Selection:
In order to maximize the treatment potential of each rain garden, they should be installed next to catch basins in the open space available between units. Areas near the high point in the road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. There are larger amounts of open space between some of the condo units, which could allow for the installation of larger rain gardens and reduce the overall number needed. This option could significantly reduce the cost of the project. Lack of landowner participation and additional site constraints may eliminate some properties from consideration, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.

CATCHMENT PROFILE: RL-4

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	34
Dominant Land Cover	Residential ½-1 acre lots
Parcels	28
TSS (lb/yr)	2,241
TP (lb/yr)	7.1
Volume (acre-feet/yr)	6.0



Description:

RL-4 is a small catchment located in the north east portion of the Rice Lake subwatershed. The catchment area contains the Ulmer's Rice Lake Addition development of single family homes. Current stormwater infrastructure includes catch basins that outfall at one point into a large wetland complex that flows into Rice Lake.

Retrofit Recommendation:

Curb-cut rain gardens are the best option for treating stormwater in this catchment area. The catchment area is fully developed and the large lots and sandy soils are well suited for rain gardens.

Treatment Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	1,858	1,509	1,104	567
TSS Reduction (%)	83%	67%	49%	25%
TP Reduction (lb/yr)	5.0	3.6	2.1	0.7
Volume Reduction (acre-feet/yr)	4.2	3.1	2.0	0.7
Volume Reduction (%)	70%	52%	33%	12%
Live Storage Volume (cubic feet)	1,612	871	423	118
Rain gardens Needed	16	9	5	1
Materials/Labor	$56,000	$31,500	$17,500	$3,500
Design Finalization	$6,432	$3,618	$2,010	$402
Promotion & Administration Costs	$3,025	$2,255	$1,815	$1,375
Total Project Cost	$65,457	$37,373	$21,325	$5,277
Cost/lb Phosphorus	$13,091	$10,381	$10,155	$7,539
Annual O&M	$1,200	$675	$375	$75
Term Cost/lb/yr (10yr)	$1,549	$1,226	$1,194	$861

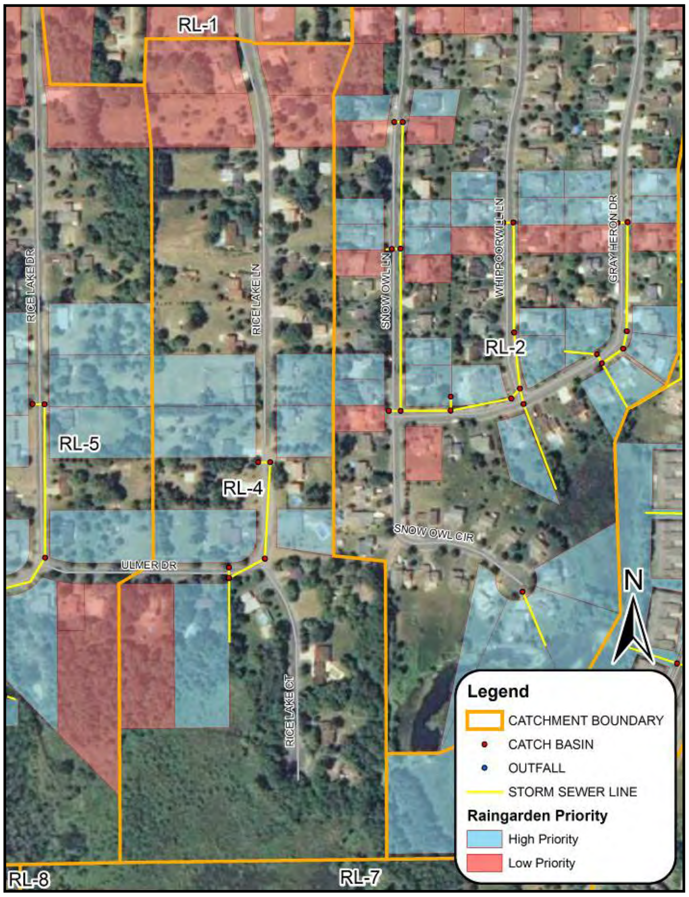
CATCHMENT PROFILE: RL-4

Rice Lake Subwatershed Assessment

Model Inputs:

Parameter	Input
Pervious Curve Number	50
Indirectly Connected Impervious Fraction	0.11
Directly Connected Impervious Fraction	0.08
Hydraulic Conductivity	4.11 in/hr

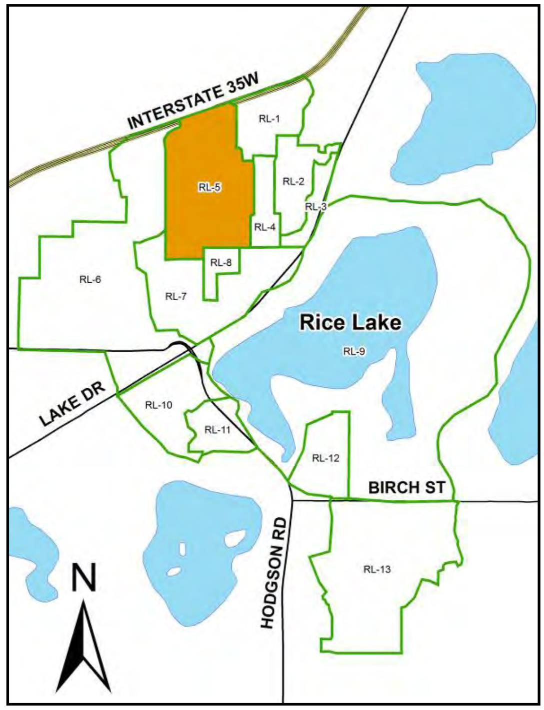
Site Selection:
In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.



CATCHMENT PROFILE: RL-5

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	177
Dominant Land Cover	Residential, ¼ acre lots
Parcels	290
TSS (lb/yr)	35,097
TP (lb/yr)	111.4
Volume (acre-feet/yr)	94.7



Description:

RL-5 is located in the north central portion of the Rice Lake subwatershed. The catchment area contains several developments of single family homes, St. Joseph's Church and the Willow Ponds development of townhomes. The townhome development has existing stormwater treatment ponds. Stormwater infrastructure in the single family residential area is a system of catch basins and stormwater piping that empties into a large wetland complex that flows into the lake.

Retrofit Recommendation:

Curb-cut rain gardens are the best option for treating stormwater in the residential neighborhoods. St. Joseph's Church was assessed for retrofit potential, but the combination of sandy soils some existing stormwater management that reduces the property's connectivity to the stormwater system eliminated it from retrofit consideration.

Treatment Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	29,128	23,693	17,376	8,984
TSS Reduction (%)	83%	68%	50%	26%
TP Reduction (lb/yr)	78.0	55.7	33.4	11.2
Volume Reduction (acre-feet/yr)	64.9	48.6	31.2	10.8
Volume Reduction (%)	69%	51%	33%	11%
Live Storage Volume (cubic feet)	26,136	14,314	6,826	1,869
Rain gardens Needed	262	143	69	19
Materials/Labor	$917,000	$500,500	$241,500	$66,500
Design Finalization	$105,324	$57,486	$27,738	$7,638
Promotion & Administration Costs	$30,085	$16,995	$8,855	$3,355

CATCHMENT PROFILE: RL-5

Rice Lake Subwatershed Assessment

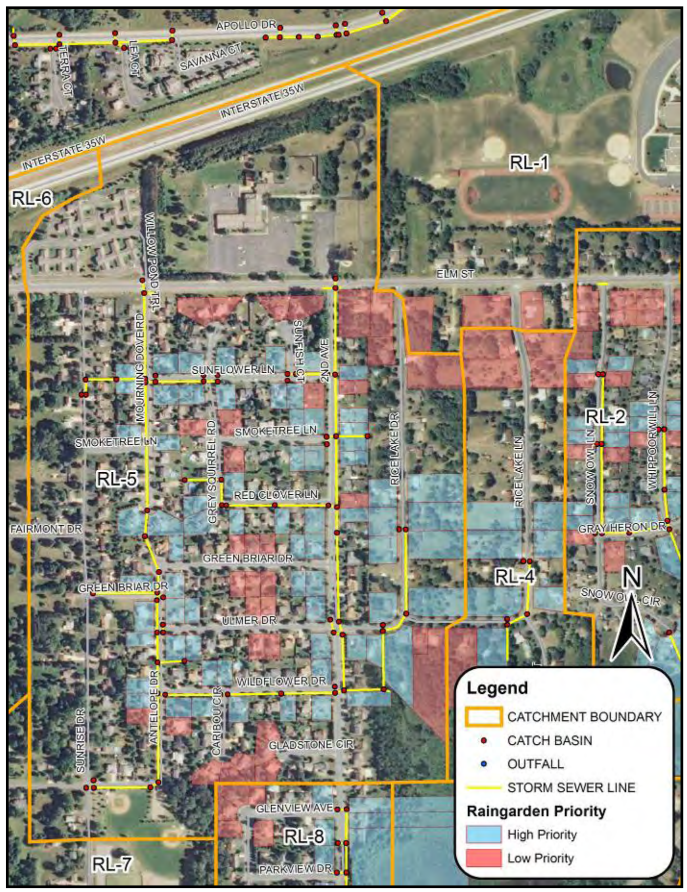
Total Project Cost	$1,052,409	$574,981	$278,093	$77,493
Cost/lb Phosphorus	$13,492	$10,323	$8,326	$6,919
Annual O&M	$19,650	$10,725	$5,175	$1,425
Term Cost/lb/yr (10 yr)	$1,601	$1,225	$988	$819

Model Inputs:

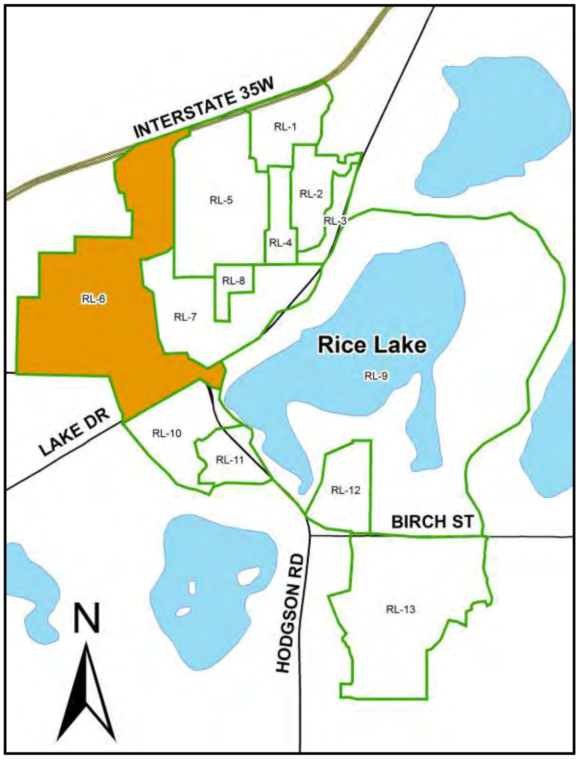
Parameter	**Input**
Pervious Curve Number	53
Indirectly Connected Impervious Fraction	0.13
Directly Connected Impervious Fraction	0.25
Hydraulic Conductivity	3.84 in/hr

Site Selection:

In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.



Catchment Summary	
Acres	349
Dominant Land Cover	Residential, ¼-1 acre lots
Parcels	477
TSS (lb/yr)	27,783
TP (lb/yr)	88.0
Volume (acre-feet/yr)	74.5



Description:

RL-6 is located in the north central portion of the Rice Lake subwatershed. The catchment area contains several developments of single family homes, the Centennial High School Campus, and a small portion of a residential area in Circle Pines. A network of catch basins and stormwater pipe drains the catchment area, including the school property, and outfalls at one location directly into Rice Lake. The development on the east side of the catchment area has no stormwater infrastructure, but a lack of curbs and the sandy soils allow for a significant amount of infiltration on-site.

Retrofit Recommendation:

1. Curb-cut rain gardens are the best option for treating stormwater in the residential neighborhoods.
2. The Centennial High School facility was assessed for “campus” retrofit potential, and the results can be found on page 13.

PROJECT 1: Rain Gardens

Treatment Analysis:

The analysis below is for curb-cut rain gardens only. Centennial High School and portions of neighborhoods not directly connected to stormwater infrastructure were not taken into consideration during modeling.

Model Inputs:

Parameter	Input
Pervious Curve Number	40
Indirectly Connected Impervious Fraction	0.12
Directly Connected Impervious Fraction	0.20
Hydraulic Conductivity	4.12 in/hr

CATCHMENT PROFILE: RL-6

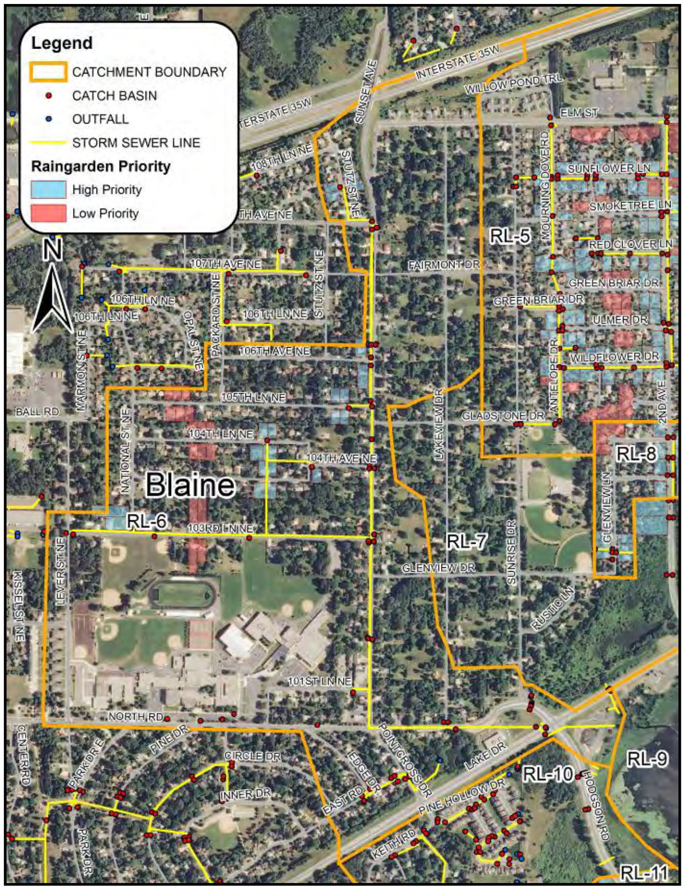
Rice Lake Subwatershed Assessment

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	23,039	18,712	13,675	7,021
TSS Reduction (%)	83%	67%	49%	25%
TP Reduction (lb/yr)	61.6	44.0	26.4	8.8
Volume Reduction (acre-feet/yr)	51.1	38.3	24.7	8.6
Volume Reduction (%)	69%	51%	33%	12%
Live Storage Volume (cubic feet)	20,059	10,973	5,210	1,420
Rain gardens Needed	201	110	52	14
Materials/Labor	$703,500	$385,000	$182,000	$49,000
Design Finalization	$80,802	$44,220	$20,904	$5,628
Promotion & Administration Costs	$23,375	$13,365	$6,985	$2,805
Total Project Cost	$807,677	$442,585	$209,889	$57,433
Cost/lb Phosphorus	$13,112	$10,059	$7,950	$6,526
Annual O&M	$15,075	$8,250	$3,900	$1,050
Term Cost/lb/yr (10 yr)	$1556	$1,193	$943	$772

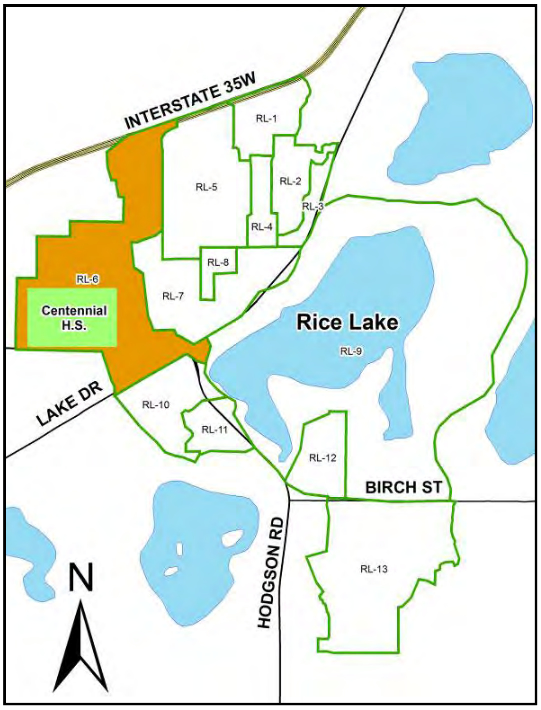
Site Selection:

In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.



PROJECT 2: Centennial High School

Project Site Summary	
Acres (leading to BMPs)	Variable depending on # of BMPs implemented
Dominant Land Cover	Parking lots and roof tops



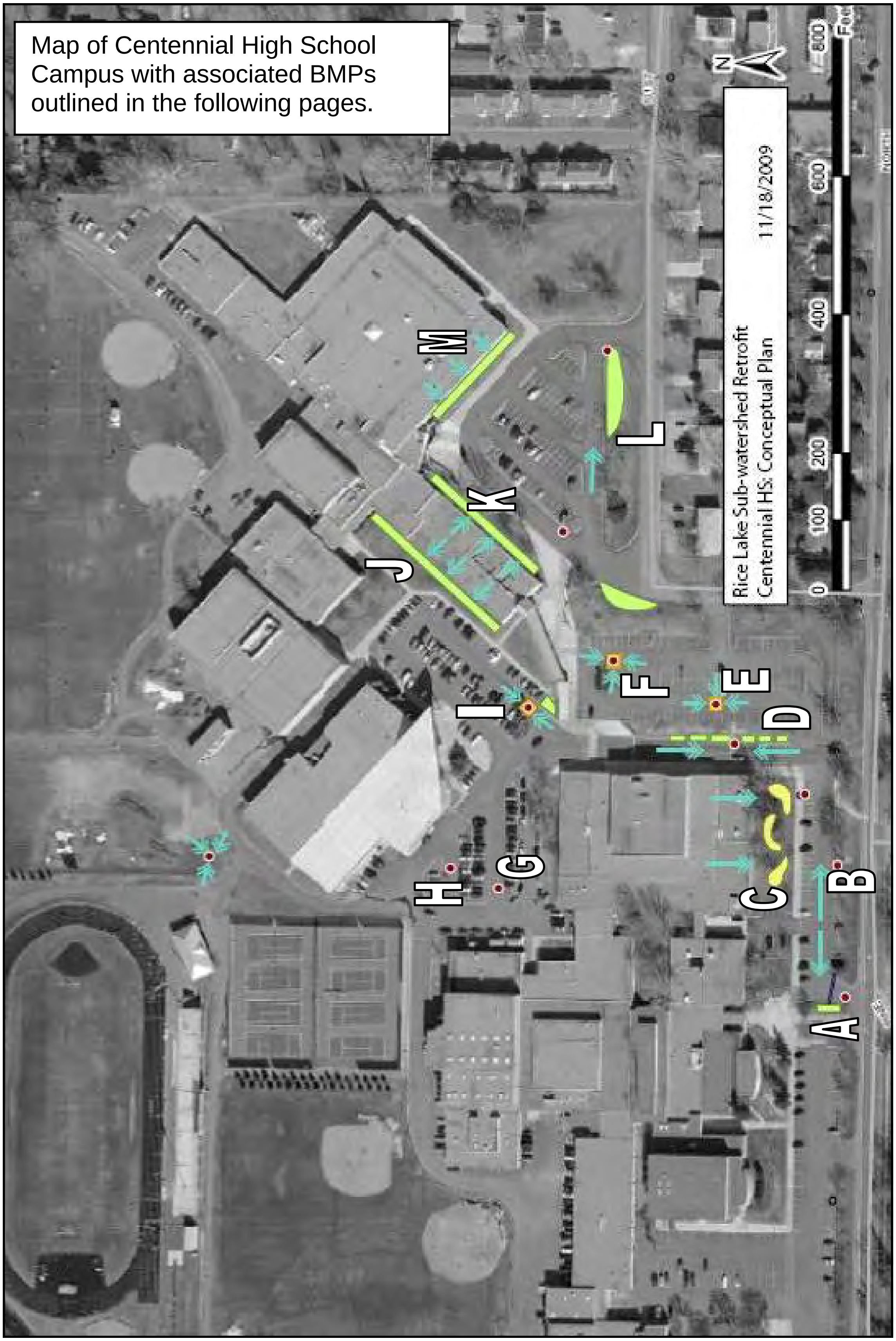
Description:
This school is a complex campus of several buildings, parking lots and recreational fields. Catch basins occur both along gutter lines and within driving lanes or parking stalls within the parking lots. It appears that most, or all, of the buildings' roof tops drain internally via rain leader pipes day-lighting 2 feet from the base of building walls or via downspouts leading from the roof top.

Retrofit Recommendation:
We recommend three forms of stormwater retrofits for Centennial High School.

1. Curb-cut rain gardens: Where catch basins occur along curb lines, curb-cut, offline rain gardens can be placed in turf areas adjacent to parking lots or driving lanes.

2. Permeable asphalt: In areas where catch basins occur within the parking lots themselves, 20-foot by 20-foot to 40-foot by 40-foot "patches" of permeable asphalt can be installed, replacing impermeable asphalt surrounding the catch basins. A border edging of concrete apron should frame in the patch so that when the impervious area of the parking lot is repaved in the future, the permeable areas will not be affected. In most areas, it will make more sense to simply extend a section of permeable pavement from one curb line to the other for ease of paving in the future.

3. Rain-leader disconnect rain gardens: Rain-leader disconnect rain gardens can be placed within landscaped/turf areas to reduce the volume of water reaching the parking lots. They should be placed as closely to the parking lots or sidewalks as possible (as opposed to close to the downspouts) so as to capture organic material, sediment and nutrients from the lawn areas between buildings and parking lots given turf's high concentrations of these pollutants



Map of Centennial High School Campus with associated BMPs outlined in the following pages.

Treatment/Cost Analysis:
The following tables summarize the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that BMP's are placed in ideal locations and optimally designed to capture and treat the maximum amount of stormwater. Analysis was stopped at the 70% reduction level as smaller BMP sizing is inappropriate either for construction or aesthetic purposes.

Most school projects incorporate a large amount of in-kind labor to facilitate environmental lesson plans. Although there is little-to-no opportunity for this in the permeable patch areas outlined in this assessment, there is ample opportunity for this option in the raingarden work. In an attempt to accommodate this, we have made a best-estimate of the financial impacts on installation and maintenance costs associated with raingardens, resulting in rather low 10-yr term cost/lb treatment value. Estimates for contracted labor include project grading, pavement work, materials acquisition and staging. Pricing estimates assume in-kind labor from the school for finish grading, edging, the installation of mulch, and planting. Maintenance of gardens is assumed to be partially contracted. Maintenance of permeable patches is assumed to be 2-vacuum sweeps per year by a contractor at reported rates of $\$0.05/ft^2$ (based on billing for maintenance at Ramsey-Washington Metro Watershed District's permeable pavement parking lot). Pricing for sweeping assumes that all "patches" are installed and maintained on the same visit by the contractor.

ALL PROJECTS

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	4896	4218
TSS Reduction (%)	1257	1081
TP Reduction (lb/yr)	14.52	11.3
Volume Reduction (ac-ft/yr)	11.85	9.5
Treatment Volume (cubic feet)	8515	4305
Project Cost	$67,540	$34,125
Cost/lb Phosphorus	$4,652	$3,020
Annual O&M	$2,290	$1,200
Term Cost/lb/yr (10 yr)	$625	$410

A-CURB-CUT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	96.9	83.4
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	0.29	0.2
Volume Reduction (ac-ft/yr)	0.23	0.18
Live Storage Volume (cubic feet)	170	85
Project Cost (~$\$12/ft^2$)[1]	$2,040	$1,020
Cost/lb Phosphorus	$7,035	$5,100
Annual O&M	$100	$50
Term Cost/lb/yr (10 yr)	$1,050	$760

[1]Requires the installation of a trench drain across entry

B-CURB CUT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	120.68	103.9
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	0.36	0.3
Volume Reduction (ac-ft/yr)	0.29	0.23
Live Storage Volume (cubic feet)	210	105
Project Cost (~$8/ft^2)[2]	$1,680	$840
Cost/lb Phosphorus	$4,670	$2,800
Annual O&M	$100	$50
Term Cost/lb/yr (10 yr)	$745	$450

[2]Estimated cost of curb cut rain garden without under-drains

C-RAIN LEADER DISCONNECT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	492.91	424.2
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	1.46	1.1
Volume Reduction (ac-ft/yr)	1.19	0.93
Live Storage Volume (cubic feet)	840	430
Project Cost (~$6/ft^2)[3]	$5,040	$2,580
Cost/lb Phosphorus	$3,450	$2,345
Annual O&M	$400	$200
Term Cost/lb/yr (10 yr)	$620	$420

[3]Estimated cost of rain leader disconnect rain garden

D-CURB-CUT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	390.93	336.4
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	1.16	0.9
Volume Reduction (ac-ft/yr)	0.94	0.74
Live Storage Volume (cubic feet)	650	340
Project Cost (~$8/ft^2)[2]	$5,200	$2,720
Cost/lb Phosphorus	$4,480	$3,020
Annual O&M	$350	$175
Term Cost/lb/yr (10 yr)	$750	$500

[2]Estimated cost of curb cut rain garden without under-drains

E-PERMEABLE PATCH

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	492.56	423.9
TSS Reduction (%)	96.6	83.1
TP Reduction (lb/yr)	1.46	1.1
Volume Reduction (ac-ft/yr)	1.19	0.94
Live Storage Volume (cubic feet)	870	440
Project Cost (~$9/ft^2)[4]	$7,830	$3,960
Cost/lb Phosphorus	$5,360	$3,600
Annual O&M	$45	$25
Term Cost/lb/yr (10 yr)	$570	$385

[4]Estimated cost of replacing impervious asphalt and base with permeable system and apron edge

F- PERMEABLE PATCH

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	333.92	292.3
TSS Reduction (%)	96.7	83.1
TP Reduction (lb/yr)	1.01	0.8
Volume Reduction (ac-ft/yr)	0.82	0.65
Live Storage Volume (cubic feet)	605	305
Project Cost (~$9/ft^2)[4]	$5,450	$2,745
Cost/lb Phosphorus	$5,340	$3,430
Annual O&M	$30	$15
Term Cost/lb/yr (10 yr)	$570	$365

[4]Estimated cost of replacing impervious asphalt and base with permeable system and apron edge

G- PERMEABLE PATCH

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	679.39	584.7
TSS Reduction (%)	96.6	83.1
TP Reduction (lb/yr)	2.01	1.6
Volume Reduction (ac-ft/yr)	1.65	1.29
Live Storage Volume (cubic feet)	1200	600
Project Cost (~$9/ft^2)[4]	$10,800	$5,400
Cost/lb Phosphorus	$5,370	$3,375
Annual O&M	$60	$30
Term Cost/lb/yr (10 yr)	$570	$360

[4]Estimated cost of replacing impervious asphalt and base with permeable system and apron edge

H- PERMEABLE PATCH

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	322.94	277.7
TSS Reduction (%)	96.6	83.1
TP Reduction (lb/yr)	0.96	0.7
Volume Reduction (ac-ft/yr)	0.78	0.61
Live Storage Volume (cubic feet)	580	290
Project Cost (~$9/ft^2)[4]	$5,220	$2,610
Cost/lb Phosphorus	$5,440	$3,730
Annual O&M	$25	$15
Term Cost/lb/yr (10 yr)	$570	$400

[4]Estimated cost of replacing impervious asphalt and base with permeable system and apron edge

I- PERMEABLE PATCH

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	283.17	243.6
TSS Reduction (%)	96.6	83.1
TP Reduction (lb/yr)	0.84	0.7
Volume Reduction (ac-ft/yr)	0.69	0.54
Live Storage Volume (cubic feet)	500	250
Project Cost (~$9/ft^2)[4]	$4,500	$2,250
Cost/lb Phosphorus	$5,360	$3,215
Annual O&M	$30	$15
Term Cost/lb/yr (10 yr)	$575	$345

[4]Estimated cost of replacing impervious asphalt and base with permeable system and apron edge

J-RAIN LEADER DISCONNECT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	203.96	175.5
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	0.60	0.5
Volume Reduction (ac-ft/yr)	0.49	0.39
Live Storage Volume (cubic feet)	350	180
Project Cost (~$6/ft^2)[3]	$2,100	$1,080
Cost/lb Phosphorus	$3,500	$2,160
Annual O&M	$175	$100
Term Cost/lb/yr (10 yr)	$645	$420

[3]Estimated cost of rain leader disconnect rain garden

K-RAIN LEADER DISCONNECT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	203.96	175.5
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	0.60	0.5
Volume Reduction (ac-ft/yr)	0.49	0.39
Live Storage Volume (cubic feet)	350	180
Project Cost (~$6/ft^2)[3]	$2,100	$1,080
Cost/lb Phosphorus	$3,500	$2,160
Annual O&M	$175	$100
Term Cost/lb/yr (10 yr)	$645	$420

[3]Estimated cost of rain leader disconnect rain garden

L-CURB-CUT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	713.88	614.4
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	2.11	1.6
Volume Reduction (ac-ft/yr)	1.73	1.35
Live Storage Volume (cubic feet)	1220	620
Project Cost (~$8/ft^2)[2]	$9,760	$4,960
Cost/lb Phosphorus	$4,630	$3,100
Annual O&M	$300	$300
Term Cost/lb/yr (10 yr)	$605	$500

[2]Estimated cost of curb cut rain garden without under-drains

M-RAIN LEADER DISCONNECT RAIN GARDEN

	90% TP Reduction	70% TP Reduction
TSS Reduction (lb/yr)	560.90	482.7
TSS Reduction (%)	96.7	83.2
TP Reduction (lb/yr)	1.66	1.3
Volume Reduction (ac-ft/yr)	1.36	1.06
Live Storage Volume (cubic feet)	970	480
Project Cost (~$6/ft^2)[3]	$5,820	$2,880
Cost/lb Phosphorus	$3,500	$2,215
Annual O&M	$500	$250
Term Cost/lb/yr (10 yr)	$655	$415

[3]Estimated cost of rain leader disconnect rain garden

Model Inputs:

Parameter	Input
Directly Connected Impervious	100%
Mean Design Infiltration Rate	3.39 in/hr

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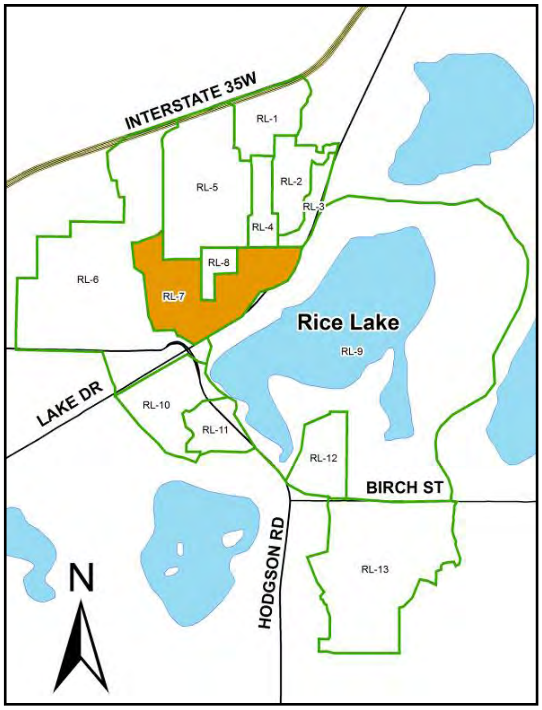
CATCHMENT PROFILE: RL-7

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	145
Dominant Land Cover	Residential, ½-1 acre, park, wetland
Parcels	95
TSS (lb/yr)	5,432
TP (lb/yr)	17.2
Volume (acre-feet/yr)	14.6



Description:

RL-7 is located west of Rice Lake. The catchment area is made up of mainly ¾ acre lots, Sunrise Park and a large wetland. Current stormwater infrastructure in this catchment is minimal.

Retrofit Recommendation:

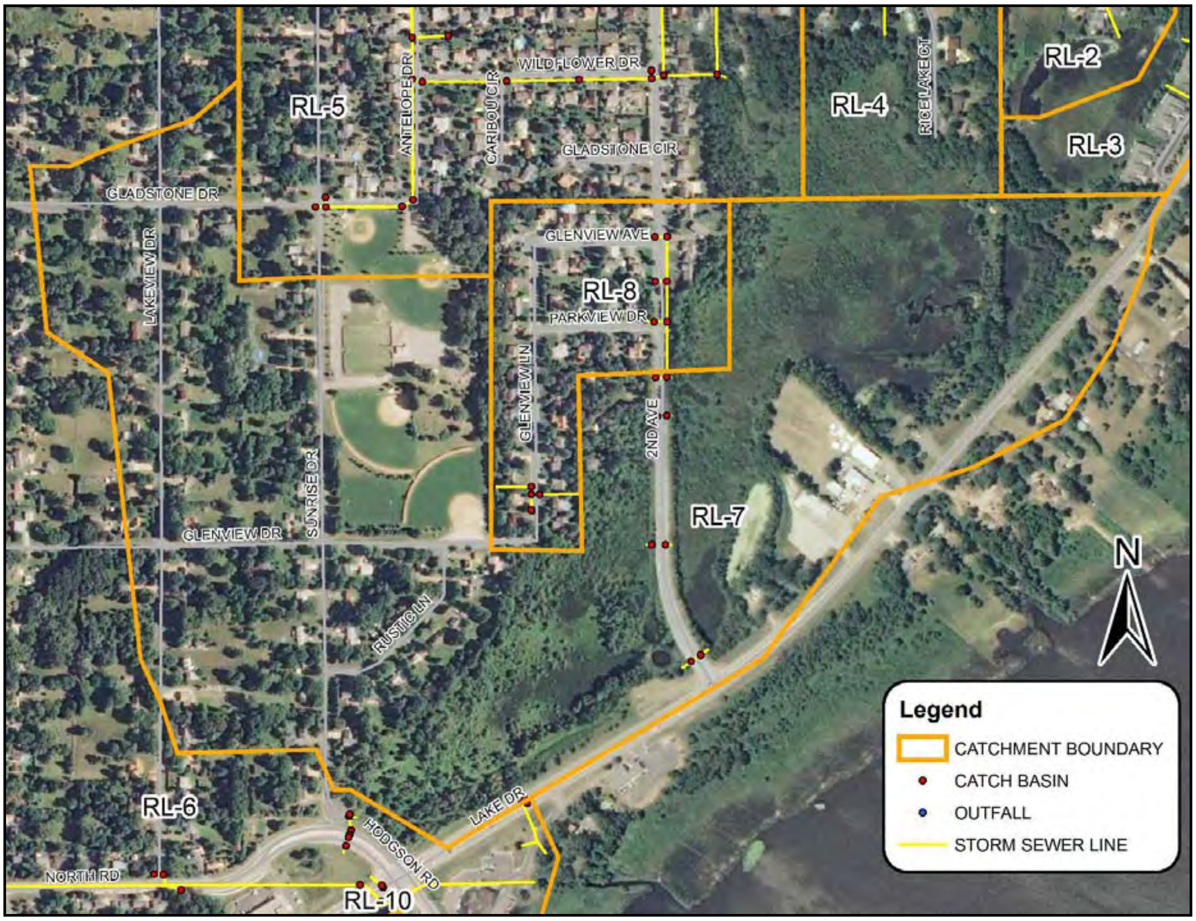
The residential development does not have any stormwater infrastructure or curbs. Due to the sandy soils present in the area, a majority of stormwater likely soaks into the ground rather than producing runoff that would make it to the lake. No retrofits are recommended in this catchment.

Treatment Analysis:

Model Inputs:

Parameter	Input
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.09
Directly Connected Impervious Fraction	0.07

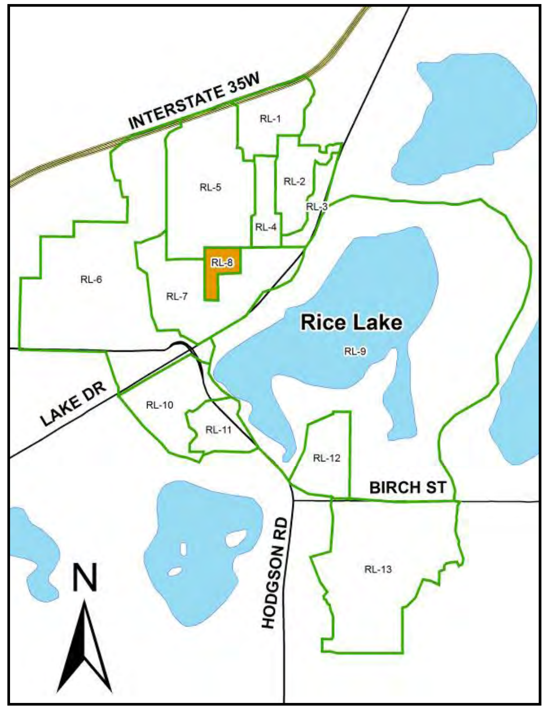
No Retrofits are recommended in the RL-7 catchment.



CATCHMENT PROFILE: RL-8

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	20
Dominant Land Cover	Residential, ¼-1/3 acre lots
Parcels	44
TSS (lb/yr)	3,456
TP (lb/yr)	11.0
Volume (acre-feet/yr)	9.3



Description:

RL-8 is a small catchment located west of Rice Lake. The catchment area contains the Parkview Estates development of single family homes. Current stormwater infrastructure consists of catch basins and pipe that empties into a large wetland complex and eventually flows into Rice Lake.

Retrofit Recommendation:

Curb-cut rain gardens are the best option for treating stormwater in the residential neighborhood.

Treatment Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	2,864	2,326	1,700	872
TSS Reduction (%)	83%	67%	49%	25%
TP Reduction (lb/yr)	7.7	5.5	3.3	1.1
Volume Reduction (acre-feet/yr)	6.4	4.8	3.1	1.1
Volume Reduction (%)	69%	52%	33%	12%
Live Storage Volume (cubic feet)	2,483	1,350	645	176
Rain gardens Needed	25	14	7	2
Materials/Labor	$87,500	$49,000	$24,500	$7,000
Design Finalization	$10,050	$5,628	$2,814	$804
Promotion & Administration Costs	$4,015	$2,805	$2,035	$1,485
Total Project Cost	$101,565	$57,433	$29,349	$9,289
Cost/lb Phosphorus	$13,190	$10,442	$8,894	$8,445
Annual O&M	$1,875	$1,050	$525	$150
Term Cost/lb/yr (10 yr)	$1,563	$1,235	$1,048	$981

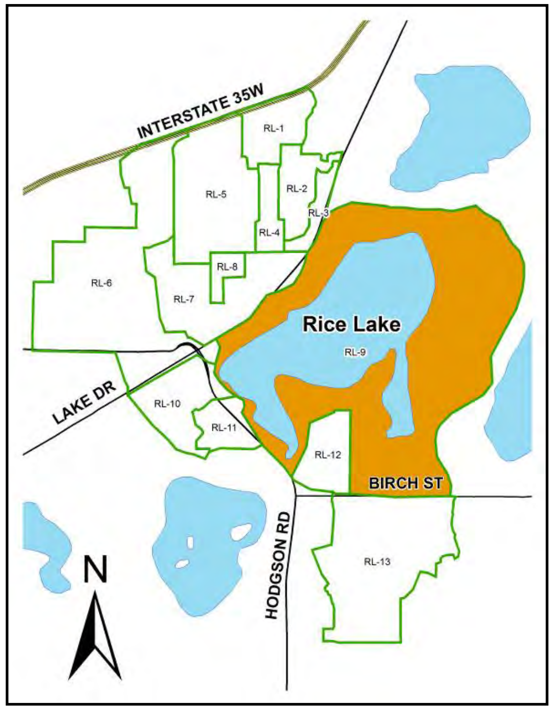
Model Inputs:

Parameter	Input
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.12
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity	4.16 in/hr

Site Selection:

In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.

Catchment Summary	
Acres	992
Dominant Land Cover	Lake
Parcels	90
TSS (lb/yr)	13,588
TP (lb/yr)	43.1
Volume (acre-feet/yr)	36.4



Description:

RL-9 is Rice Lake and the land immediately adjacent to it. The catchment contains shoreland, Rice Lake Elementary and part of Chominix Golf Course. There is very little stormwater infrastructure other than outfalls draining to the lake.

Retrofit Recommendation:

There are retrofit opportunities available at Rice Lake Elementary, which has the largest area of impervious surface in the catchment. The next section highlights the potential retrofit projects.

Treatment Analysis:

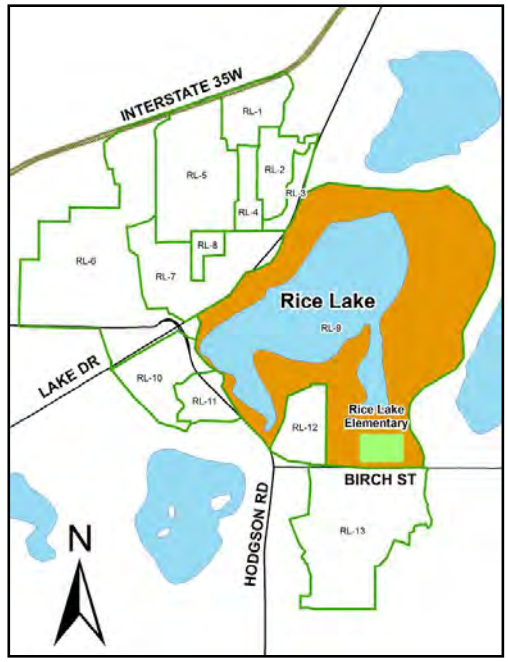
Model Inputs:

Parameter	Input
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.00
Directly Connected Impervious Fraction	0.03

RL-1
RL-2
RL-3
RL-4
RL-5
RL-6
RL-7
RL-8
RL-9
RL-10
RL-11
RL-12
RL-13
N
Legend
CATCHMENT BOUNDARY
CATCH BASIN
OUTFALL
STORM SEWER LINE

PROJECT SITE: Rice Lake Elementary School

Project Summary	
Acres (leading to BMPs)	6.43
Dominant Land Cover	Turf and parking lot
TSS (lb/yr)	2552
TP (lb/yr)	8.2

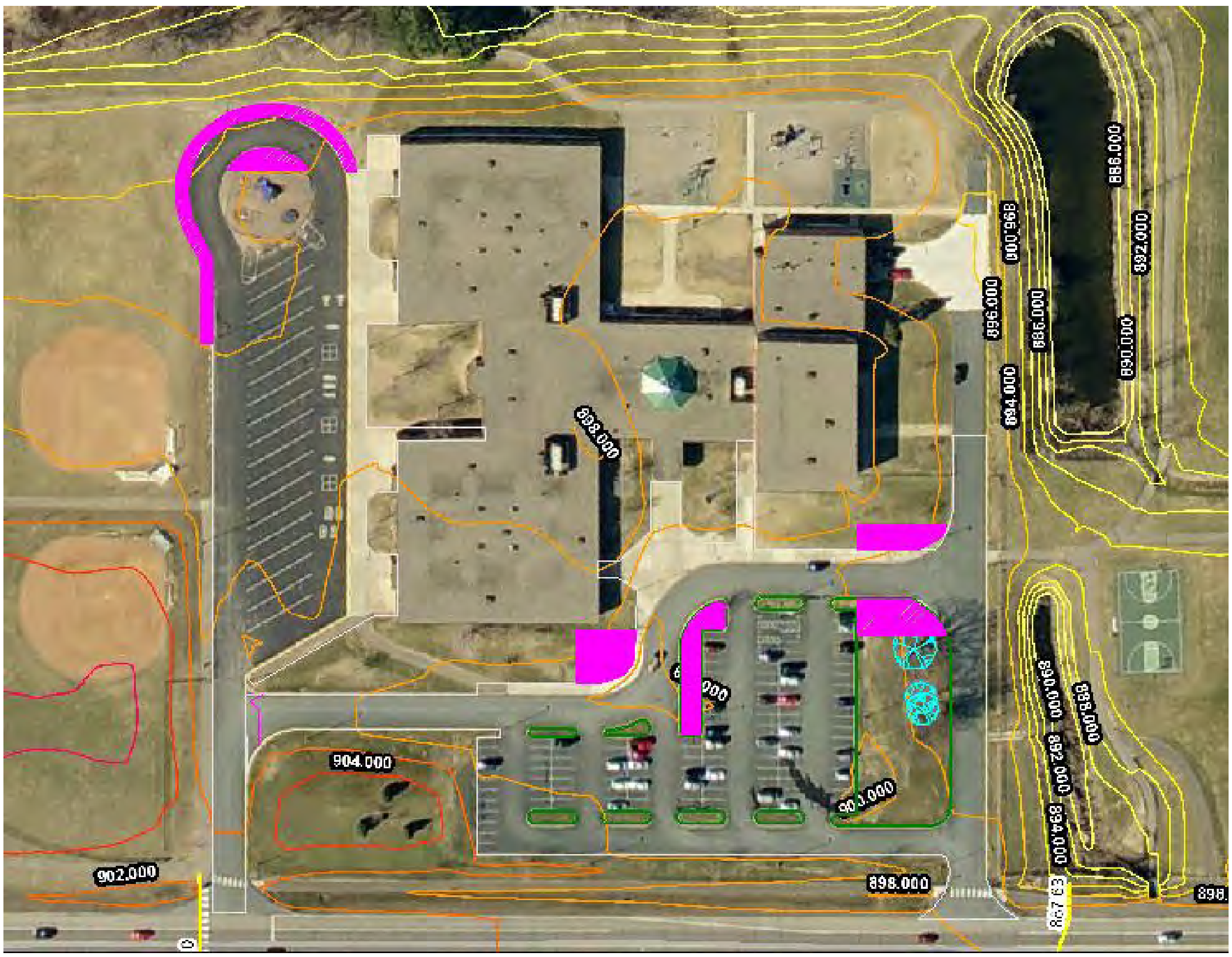


Description:
The school was built in 1992 with primary roof-top runoff being directly connected to existing storm water ponds immediately east of building. Parking lots drain via catch basins to the ponds and/or possibly to wetland fringe of Rice Lake (stormwater routing in the western parking lot was undetermined). Existing ponds treat runoff from neighborhoods south of Birch Street. It appears that as much as 4 feet of bounce may occur within the pond system with the northern overflow being overtopped during any significant rain event (northern cell appears to maintain its elevation directly under the outlet elevation with the exception of evaporative losses).

Retrofit Recommendation:
Two forms of volume and pollutant-reducing storm water retrofit practices, or BMP alterations, have been identified for this site.

1. Pond Modifications: Simple modifications to the existing storm pond system can be made. Although further analysis is required, the possibility exists for simple outlet modification of the two-pond system to treat volume, rate and quality of storm water runoff via raising outlet structures and/or reducing their diameter (detailed hydrologic and hydraulic assessment need to be undertaken to ensure the applicability of this approach in terms of backwater flooding of upstream systems). Another potential modification to consider is the construction of infiltration benches ringing either/both ponds either independently or in conjunction with the outlet modifications. Adding infiltration capacity to the system's abstraction of volume will greatly increase its quality and volume functions provided infiltration occurs below outlets and enough space is available to provide significant surface area. Given the complex connection to the existing storm water infrastructure upstream, no further cost/benefit analysis is provided herein for these pond modifications.

2. Infiltration: There are six locations within the parking lot where infiltration can be used to partially disconnect the parking lot from the lake thereby reducing the volume of water reaching the pond system and also increase the quality of the lots' effluent. All but one catch basin in the lot system is located along the gutter line, as opposed to within driving lanes. In addition, very little landscaping or utilities exist in turf areas adjacent to the lot and the catch basins, nor are there any significant grades or anthropomorphic features within potential infiltration areas that would limit rain garden placement. Therefore, infiltration facilities in the form of simple curb-cut rain gardens are a relatively easy and cost-effective fit for this site.



Areas in pink, above, show potential rain garden locations that will treat nearly all of the parking lot surface before discharge to the ponds shown to the school building's east. Locations were based on proximity to catch basins located along curb lines and will require retrofitting new curb at entry points to the cells. The illustration does not define final shape, size or extent of rain garden areas.

Treatment/Cost Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that BMP's are placed in ideal locations and optimally designed to capture and treat the maximum amount of stormwater.

Most school projects incorporate a large amount of in-kind labor to facilitate environmental lesson plans. There is ample opportunity for this option in the proposed raingarden work. In an attempt to accommodate this, we have made a best-estimate of the financial impacts on installation and maintenance costs associated with raingardens, resulting in rather low 10-yr term cost/lb treatment value. Estimates for contracted labor include project grading, materials acquisition and staging. Pricing estimates assume in-kind labor from the school for finish grading, edging, the installation of mulch, and planting. Maintenance of gardens is assumed to be partially contracted.

	90% TP Reduction	**70% TP Reduction**	**50% TP Reduction**
TSS Reduction (lb/yr)	2452	2105	1707
TSS Reduction (%)	96.10	82.50	66.90
TP Reduction (lb/yr)	7.40	5.76	4.10
Volume Reduction (ac-ft/yr)	6.9	5.4	4.1
Live Storage Volume (cubic feet)	5515	2254	1215
Rain gardens Needed (1-ft deep)	6 (~5515 ft^2 combined)	6 (~2254 ft^2 combined)	6 (~1215 ft^2 combined)
Project Cost (~$10/$ft^2$)	$55,150	$25,000	$12,150
Cost/lb Phosphorus	$7,453	$4,340	$2,963
Annual O&M	$2000	$1000	$600
Term Cost/lb/yr (10 yr)	$1015	$650	$450

Model Inputs:

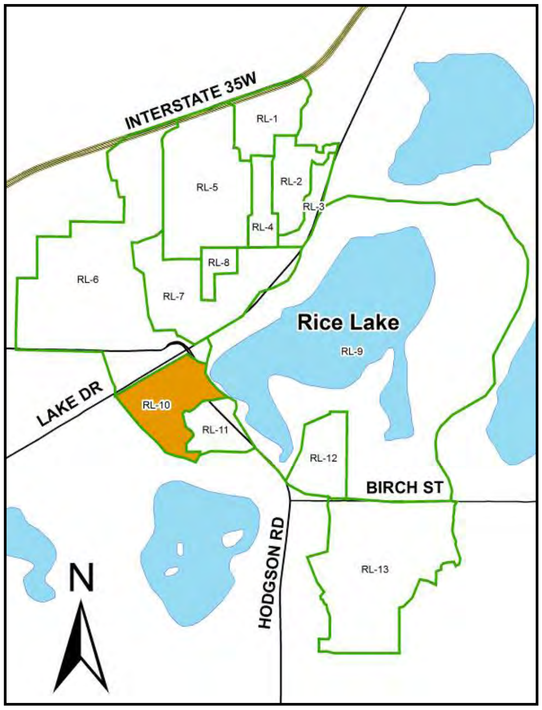
Parameter	**Input**
Pervious Curve Number	49
Directly Connected Impervious	60%
Mean Design Infiltration Rate	3.39 in/hr

(Intentionally Blank)

CATCHMENT PROFILE: RL-10

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	85
Dominant Land Cover	Residential, 1/8-1/3 acre lots
Parcels	125
TSS (lb/yr)	8,121
TP (lb/yr)	25.9
Volume (acre-feet/yr)	22.2



Description:

RL-10 makes up a portion of the west border of the Rice Lake subwatershed. The catchment area contains the Pine Hollow development of detached townhomes, the Circle Pines Part 2 East development of single family homes and wetland area. The townhomes have existing stormwater treatment ponds and stormwater infrastructure in the single family residential area is discharged to a wetland area. There are three culverts that connect the wetland area to Rice Lake under Hodgson Road.

Retrofit Recommendation:

Due to the existing stormwater infrastructure and treatment provided by routing stormwater through the wetland area, no retrofits are recommended. Raising the culvert elevations could allow additional treatment within the wetland area. However, the gains would not likely be significant, and the potential for upstream flooding would have to be assessed.

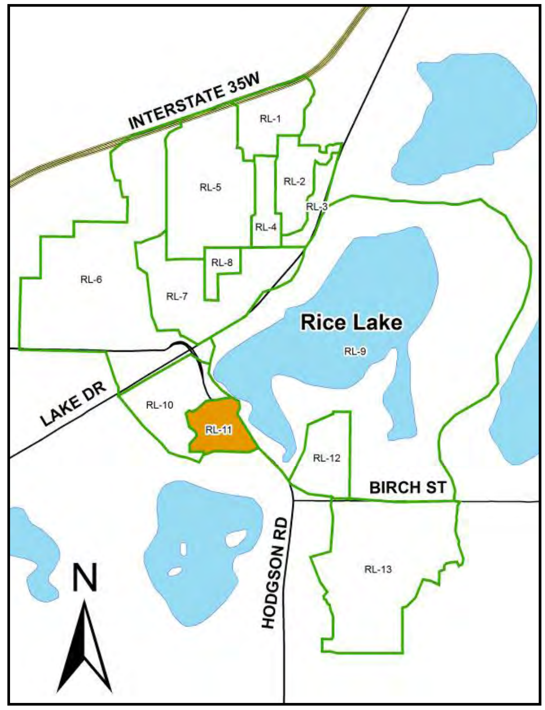
Treatment Analysis:

Model Inputs:

Parameter	Input
Pervious Curve Number	59
Indirectly Connected Impervious Fraction	0.06
Directly Connected Impervious Fraction	0.12

No retrofits are recommended in the RL-10 catchment.

Catchment Summary	
Acres	43
Dominant Land Cover	Residential, ¼ acre lots
Parcels	96
TSS (lb/yr)	8,566
TP (lb/yr)	27.1
Volume (acre-feet/yr)	23.0



Description:
RL-11 is located south west of Rice Lake. The catchment area contains the Rice Lake Estates development of single family homes. Stormwater in the area is captured in catch basins that either drain directly into Rice Lake under Hodgson Road, or empty into a small ponding facility connected to a ditch that flows into the lake.

Retrofit Recommendation:
Curb-cut rain gardens are the best option for treating stormwater in this residential neighborhood. Positioning the rain gardens uphill from the catch basins will capture stormwater runoff before it enters the storm system.

Treatment Analysis:
The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	7,106	5,775	4,220	2,174
TSS Reduction (%)	83%	67%	49%	25%
TP Reduction (lb/yr)	19.0	13.6	8.1	2.7
Volume Reduction (acre-feet/yr)	15.7	11.8	7.6	2.6
Volume Reduction (%)	68%	51%	33%	11%
Live Storage Volume (cubic feet)	6,229	3,441	1,623	443
Rain gardens Needed	63	35	17	5
Materials/Labor	$220,500	$122,500	$59,500	$17,500
Design Finalization	$25,326	$14,070	$6,834	$2,010
Promotion & Administration Costs	$8,195	$5,115	$3,135	$1,815
Total Project Cost	$254,021	$141,685	$69,469	$21,325
Cost/lb Phosphorus	$13,370	$10,418	$8,576	$7,898
Annual O&M	$4,725	$2,625	$1,275	$375
Term Cost/lb/yr (10 yr)	$1,586	$1,235	$1,015	$929

Model Inputs:

Parameter	Input
Pervious Curve Number	40
Indirectly Connected Impervious Fraction	0.13
Directly Connected Impervious Fraction	0.25
Hydraulic Conductivity	4.01 in/hr

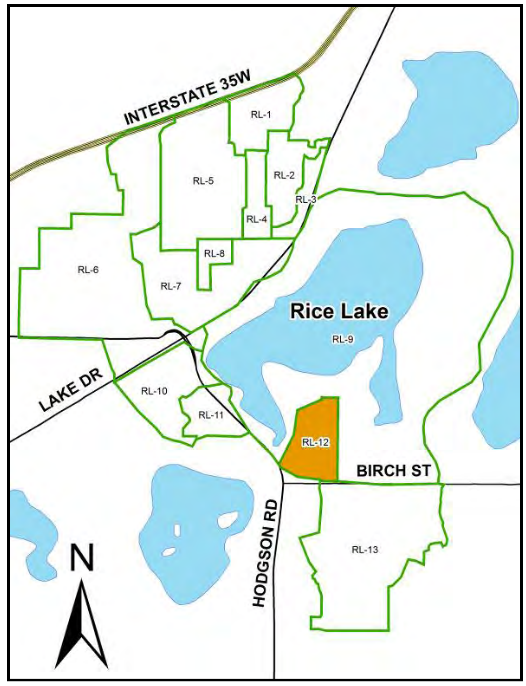
Site Selection:

Since part of the catchment area receives some treatment from a small pond, emphasis should be placed on implementing projects closest to the catch basins that outfall directly into the lake. In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.

CATCHMENT PROFILE: RL-12

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	61
Dominant Land Cover	Residential, ¼-½ acre lots
Parcels	104
TSS (lb/yr)	10,547
TP (lb/yr)	33.4
Volume (acre-feet/yr)	28.3



Description:

RL-12 is located on the south side of Rice Lake. The catchment area contains the Spirit Hills development on the west side and Shenandoah development on the east side of the catchment. The majority of stormwater in the Spirit Hills development is captured in catch basins that empty into a centralized stormwater pond, while the Shenandoah development discharges directly into the lake.

Retrofit Recommendation:

Curb-cut rain gardens are the best option for treating stormwater in this residential neighborhood. Positioning the rain gardens uphill from the catch basins will capture stormwater runoff before it enters the storm system.

Treatment Analysis:

The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	8,752	7,117	5,210	2,687
TSS Reduction (%)	83%	68%	49%	26%
TP Reduction (lb/yr)	23.4	16.7	10.0	3.4
Volume Reduction (acre-feet/yr)	19.4	14.5	9.4	3.3
Volume Reduction (%)	69%	51%	33%	12%
Live Storage Volume (cubic feet)	7,797	4,269	2,024	553
Rain gardens Needed	78	43	21	6
Materials/Labor	$273,000	$150,500	$73,500	$21,000
Design Finalization	$31,356	$17,286	$8,442	$2,412
Promotion & Administration Costs	$9,845	$5,995	$3,575	$1,925
Total Project Cost	$314,201	$173,781	$85,517	$25,337
Cost/lb Phosphorus	$13,427	$10,406	$8,552	$7,452
Annual O&M	$5,850	$3,225	$1,575	$450
Term Cost/lb/yr (10 yr)	$1,593	$1,234	$1,013	$878

Model Inputs:

Parameter	Input
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.12
Directly Connected Impervious Fraction	0.22
Infiltration Rate	3.93 in/hr

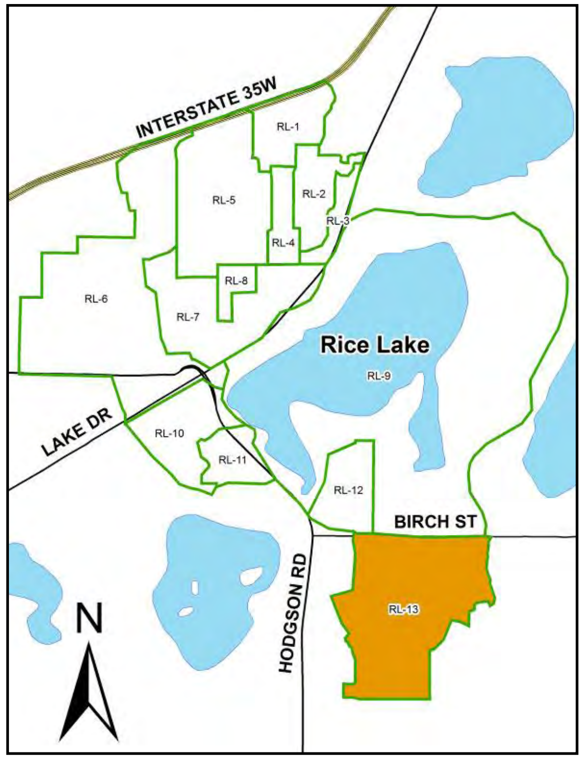
Site Selection:

Since stormwater in the Spirit Hills development is being partially treated by a pond and the Shenandoah development discharges directly into the lake, properties in the Shenandoah development should be a higher priority. In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties can be pursued. See appendix A for curb-cut rain garden site considerations and designs.

CATCHMENT PROFILE: RL-13

Rice Lake Subwatershed Assessment

Catchment Summary	
Acres	249
Dominant Land Cover	Residential, ¼-½ acre lots
Parcels	455
TSS (lb/yr)	39,066
TP (lb/yr)	123.8
Volume (acre-feet/yr)	105.0



Description:
RL-13 is located on the south side of Rice Lake. The catchment area contains several developments of single family homes. Stormwater management in the catchment area is comprised of a complex network of catch basins, pipes, ditches and ponds.

Retrofit Recommendation:
Three retrofit possibilities exist in this area:

1. Curb-cut rain gardens: The best option for treating stormwater in the residential neighborhoods is with curb-cut rain gardens. Positioning the rain gardens uphill from the catch basins will capture stormwater runoff before it enters ponds, and may improve the ponds' ability to treat stormwater by increasing the residency time.

2. Shenandoah Park: Treatment of ditch water running through the park can be accomplished by creating a stormwater wetland facility in the unused portion of the park. Flows from the ditch greater than base conditions could be diverted to the facility and treated. In addition, the facility could improve the aesthetics of the park and provide educational opportunities to the public and students at nearby Rice Lake Elementary. See page 37 for more project details.

3. Pond Modifications: Another retrofit opportunity involves modifying the elevations of the inlets/outlets of the ponds in the catchment area to provide additional treatment at a low cost. They could also be assessed for maintenance that could provide additional storage volume. Due to the interconnectivity of the system and the risk of upland flooding, pond modifications should be assessed by an engineer.

PROJECT 1: Rain Gardens

Treatment Analysis:

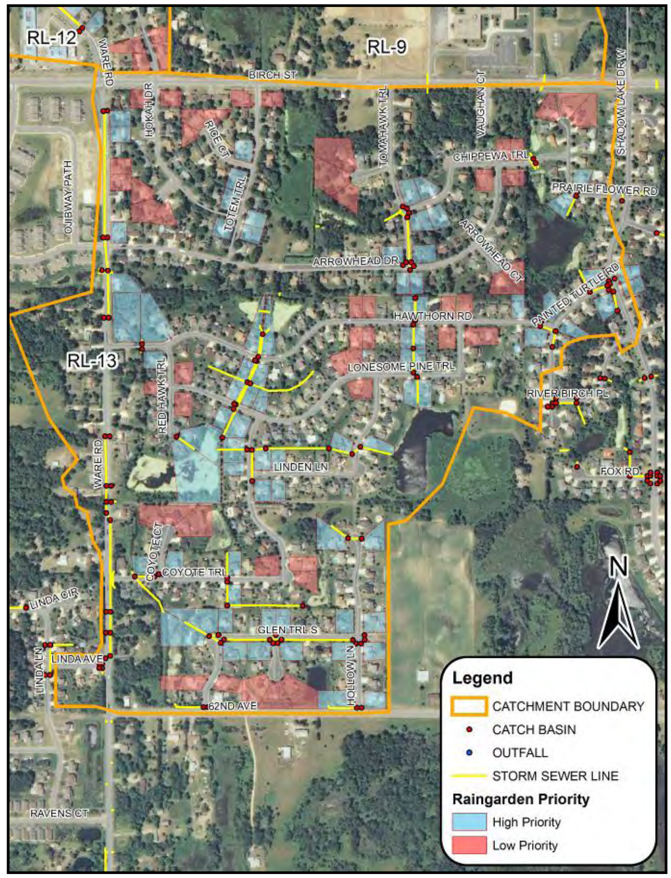
The following table summarizes the amount of treatment needed to achieve different levels of phosphorus reduction. Reductions assume that rain gardens are placed in ideal locations to capture the maximum amount of stormwater.

	70% TP Reduction	50% TP Reduction	30% TP Reduction	10% TP Reduction
TSS Reduction (lb/yr)	32,477	26,480	19,508	10,193
TSS Reduction (%)	83%	68%	50%	26%
TP Reduction (lb/yr)	86.7	61.9	37.2	12.4
Volume Reduction (acre-feet/yr)	71.5	53.4	34.1	11.7
Volume Reduction (%)	68%	51%	32%	11%
Live Storage Volume (cubic feet)	30,511	16,734	7,995	2,187
Rain gardens Needed	305	168	80	22
Materials/Labor	$1,067,500	$588,000	$280,000	$77,000
Design Finalization	$122,610	$67,536	$32,160	$8,844
Promotion & Administration Costs	$34,815	$19,745	$10,065	$3,685
Total Project Cost	$1,224,925	$675,281	$322,225	$89,529
Cost/lb Phosphorus	$14,128	$10,909	$8,622	$7,220
Annual O&M	$22,875	$12,600	$6,000	$1,650
Term Cost/lb/yr (10 yr)	$1,677	$1,294	$1,027	$855

Model Inputs:

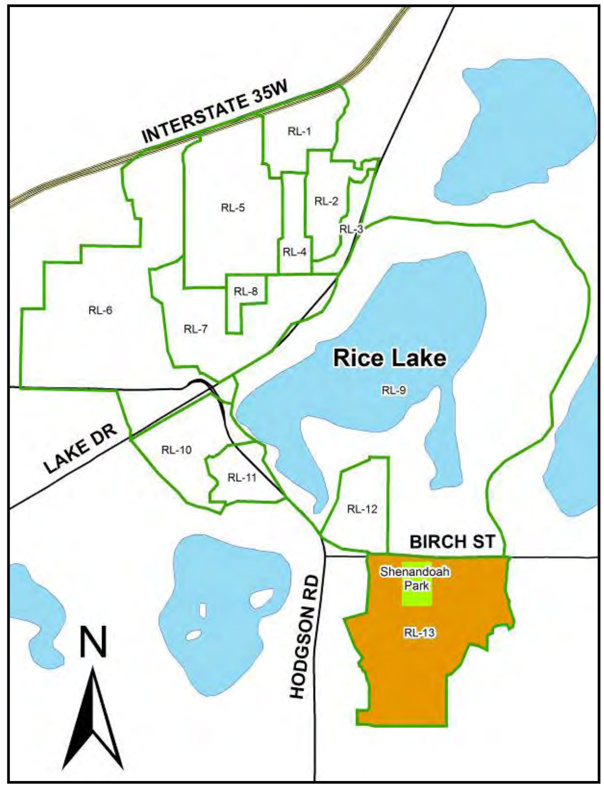
Parameter	**Input**
Pervious Curve Number	49
Indirectly Connected Impervious Fraction	0.12
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity	3.39 in/hr

Site Selection:
In order to maximize the treatment potential of each rain garden, properties furthest "downhill" or near a catch basin should be targeted as high priority sites. Properties near the high point in a road or immediately downhill from a catch basin are low priority because they will be less likely to intercept large amounts of stormwater. The following map highlights high and low priority properties. Properties not highlighted can be targeted for rain garden retrofits if additional treatment is desired. Lack of landowner participation and additional site constraints may eliminate some high priority properties, and adjacent upstream properties should be pursued. See appendix A for curb-cut rain garden site considerations and designs.



PROJECT 2: Shenandoah Park

Project Site Summary	
Dominant Land Cover	Residential
TSS (lb/yr)	(Additional modeling needed)
TP (lb/yr)	(Additional modeling needed)
Volume (acre-feet/yr)	(Additional modeling needed)

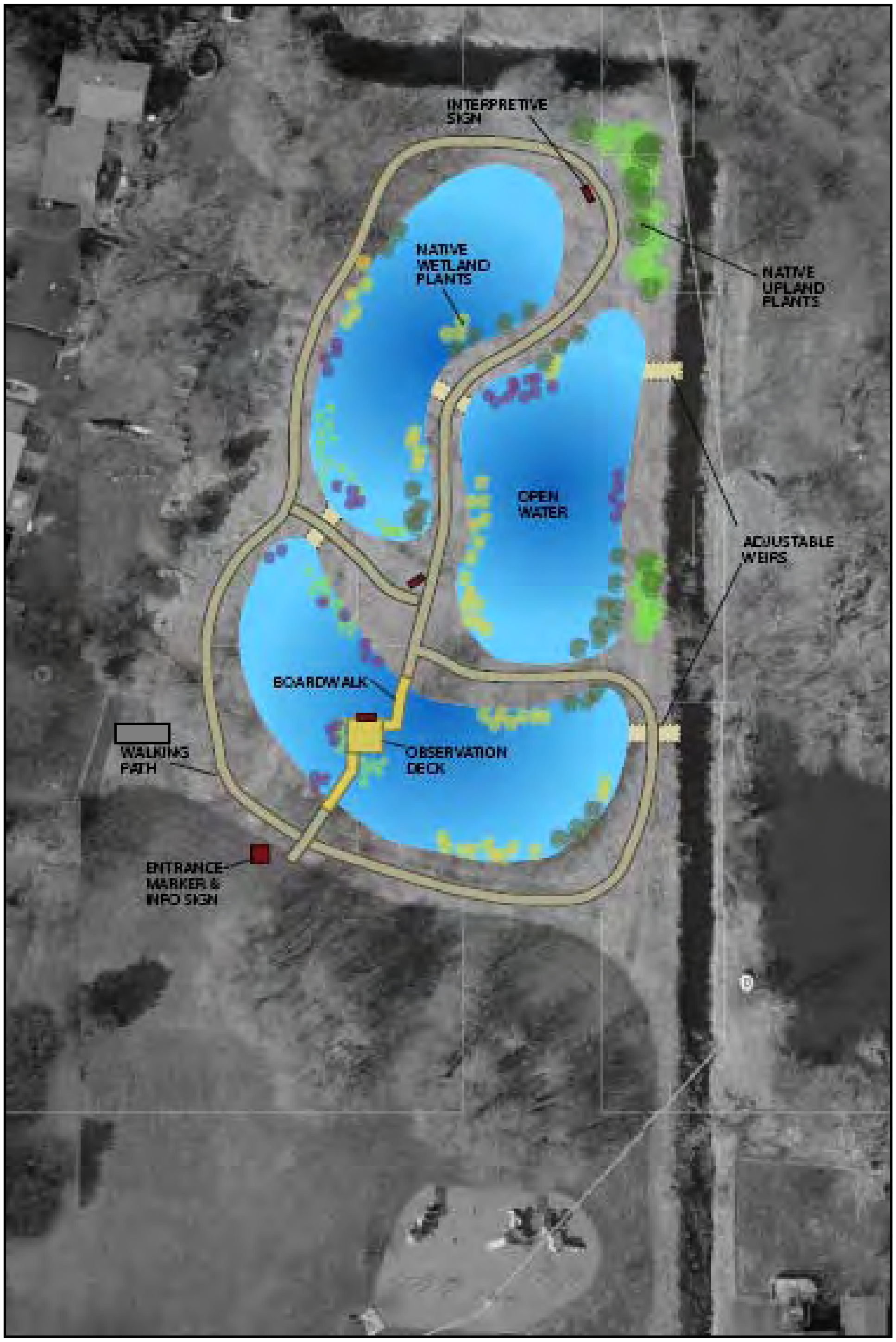


Description:
The park is located immediately adjacent to a drainage ditch that drains a large area of residential properties to the south. The park is divided into a public space and playground area in its southern half, and what appears to be a drained wetland in its northern half, given the presence of hydric soils (rapid assessment only) and persistent vegetation cues.

Retrofit Options:
Restoration of the apparently drained wetland can provide several benefits including water quality treatment, rate control, habitat values, potential wetland credit for the city and public educational and aesthetic benefits. We envision a 3-celled wetland complex, hydrologically connected to the ditch via 2 adjustable weirs (customized floatable system) located along the existing ditch channel and with culverts between cells. Recharge of the wetland will be achieved during medium-to-high ditch flow events and evapotranspiration will drive drawdown. A secondary component of the design will include the provision of effective public interfaces that convey information regarding watershed ecology and human's place within it. This will include a circuit pathway, node points for educational interaction and potentially a short section of boardwalk over open water.

Treatment/Cost Analysis:
The following table summarizes estimated pollutant load reductions based on the MN Stormwater Manual.

	Pollutant Removal Potential	Est. Cost
COST AS DESIGNED		$70,000-$80,000
TSS	75%	
TP/TN	40%/30%	
METALS	40%	
BACTERIA	80%	
HYDROCARBONS	85%	



Concept Layout

A multiple-celled wetland restoration design that draws and treats residential runoff from neighborhoods to the south. Self-adjusting weir (floats located on wetland side of weir adjust to wetland ponding elevation) are located along the ditch. Culverts will connect the 3 cells together with weirs only being used along ditch.

Retrofit Project Prioritization:
A total of 12 retrofit projects were analyzed for cost and pollutant removal. Two of the projects are retrofits that implement BMPs on school properties and a third is a stormwater wetland project at Shenandoah Park that will require additional modeling to determine treatment efficiency. The remaining nine projects are groupings of neighborhood rain garden retrofits. Cost effectiveness of each project for varying levels of phosphorus reduction was analyzed and reflects the installed cost as well as long term operation and maintenance. The top five most cost-effective projects in terms of phosphorus reduction are:

1. RL-1: Centennial Campus Retrofit ($410/lb/yr)
2. RL-9: Rice Lake Elementary Retrofit ($450/lb/yr)
3. RL-6: Neighborhood Rain Garden Retrofit ($772/lb/yr)
4. RL-5: Neighborhood Rain Garden Retrofit ($819/lb/yr)
5. RL-13: Neighborhood Rain Garden Retrofit ($855/lb/yr)

Rice Lake Subwatershed Project Priorities
Highlighted rows in the table below indicate catchment/project areas directly connected to Rice Lake and could be considered a higher priority even though the cost per pound reduction is greater. Non-highlighted rows are projects serving areas where stormwater passes through already existing treatment or wetlands. All projects are assumed to have an operation and maintenance (O&M) term of 10 years.

Catchment	Retrofit Project	Number of BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Estimated Installation Cost	Installed Cost/lb TP Reduction	Annual O&M Cost per BMP	Estimated Term Cost/lb/yr (includes O&M)
RL-2*	Neighborhood Retrofit	23	30%	10.2	$93,541	$9,171	$75	$1,086
RL-2	Neighborhood Retrofit	48	50%	17.1	$193,841	$11,336	$75	$1,344
RL-3*	Neighborhood Retrofit	7	30%	3.3	$29,349	$8,894	$75	$1,048
RL-3	Neighborhood Retrofit	15	50%	4.8	$61,445	$11,172	$75	$1,322
RL-4*	Neighborhood Retrofit	5	30%	2.1	$21,325	$10,155	$75	$1,194
RL-4	Neighborhood Retrofit	9	50%	3.6	$37,373	$10,381	$75	$1,226
RL-5	Neighborhood Retrofit	19	10%	11.2	$77,493	$6,919	$75	$819
RL-5	Neighborhood Retrofit	69	30%	33.4	$278,093	$8,326	$75	$988
RL-5	Neighborhood Retrofit	143	50%	55.7	$574,981	$10,323	$75	$1,225

Rice Lake Subwatershed Project Priorities (continued)

Catchment	Retrofit Project	Number of BMPs	TP Reduction (%)	TP Reduction (lb/yr)	Estimated Installation Cost	Installed Cost/lb TP Reduction	Annual O&M Cost per BMP	Estimated Term Cost/lb/yr (includes O&M)
RL-6	Neighborhood Retrofit	14	10%	8.8	$57,433	$6,526	$75	$772
RL-6	Neighborhood Retrofit	52	30%	26.4	$209,889	$7,950	$75	$943
RL-6	Neighborhood Retrofit	110	50%	44	$442,585	$10,059	$75	$1,193
RL-6	Centennial Campus Retrofit	13	70%	11.3	$34,125	$3,020	$15-$300	$410
RL-6	Centennial Campus Retrofit	13	90%	14.5	$67,540	$4,652	$25-$500	$625
RL-8*	Neighborhood Retrofit	7	30%	3.3	$29,349	$8,894	$75	$1,048
RL-8	Neighborhood Retrofit	14	50%	5.5	$57,433	$10,442	$75	$1,235
RL-9	Rice Lake Elementary	6	50%	4.1	$12,150	$2,963	$100	$450
RL-9	Rice Lake Elementary	6	70%	5.4	$25,000	$4,340	$167	$650
RL-9	Rice Lake Elementary	6	90%	7.4	$55,150	$7,453	$334	$1,015
RL-11	Neighborhood Retrofit	5	10%	2.7	$21,325	$7,898	$75	$929
RL-11	Neighborhood Retrofit	17	30%	8.1	$69,469	$8,576	$75	$1,015
RL-12	Neighborhood Retrofit	6	10%	3.4	$25,337	$7,452	$75	$878
RL-12	Neighborhood Retrofit	21	30%	9.4	$85,517	$8,552	$75	$1,013
RL-13	Neighborhood Retrofit	22	10%	12.4	$89,529	$7,220	$75	$855

* Slightly lower cost/lb was available for 10% TP reduction, but the resulting BMP size/number was too small to justify installation

Other potential projects that require additional modeling:

- Shenandoah Park stormwater wetland (RL-13)
- Raising pond outlets or inspecting for maintenance issues that could lead to additional stormwater storage in residential areas south of Birch Street (RL-13)
- Culvert blocking on west side of Hodgson Road, south of Lake Drive (RL-10)

Panuska, J. 1998. “Drainage System Connectedness for Urban Areas”. Memo. Wisconsin Dept of Natural Resources. Madison, WI.

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

USDA. 1986. Urban Hydrology for Small Watersheds TR-55. Second Edition. Washington, DC.

Curb-Cut Rain Garden Guidebook

ANOKA COUNTY CURB-CUT RAINGARDENS

Photo: Barr Engineering

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

ANOKA CONSERVATION DISTRICT

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

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 1000 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 hieght within 16 feet of the curb
→ Retaining not needed

Property rises greater than 1 foot above the curb hieght within 16 feet of the curb
→ Retaining wall needed

2

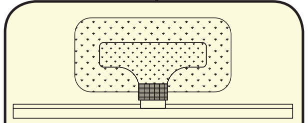
Retaining not needed:

- 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

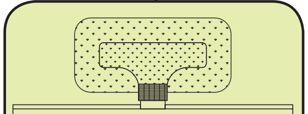
Retaining wall needed:

- 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

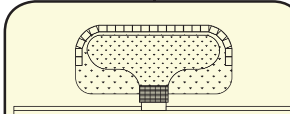
3



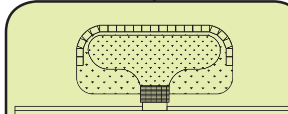
I. Rectangle
Sun, No Wall
pg. 8



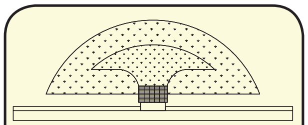
IV. Rectangle
Shade, No Wall
pg. 11



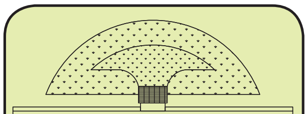
VII. Rectangle
Sun, with Wall
pg. 14



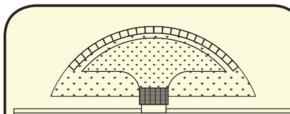
X. Rectangle
Shade, with Wall
pg. 17



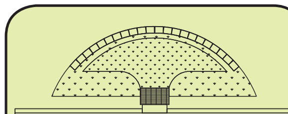
II. Arc
Sun, No Wall
pg. 9



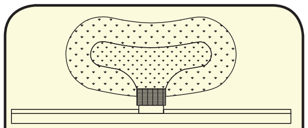
V. Arc
Shade, No Wall
pg. 12



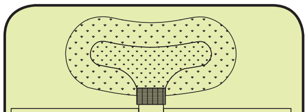
VIII. Arc
Sun, with Wall
pg. 15



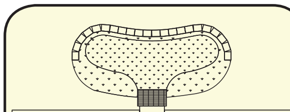
XI. Arc
Shade, with Wall
pg. 18



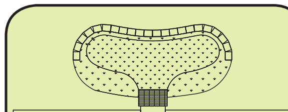
III. Curvilinear
Sun, No Wall
pg. 10



VI. Curvilinear
Shade, No Wall
pg. 13

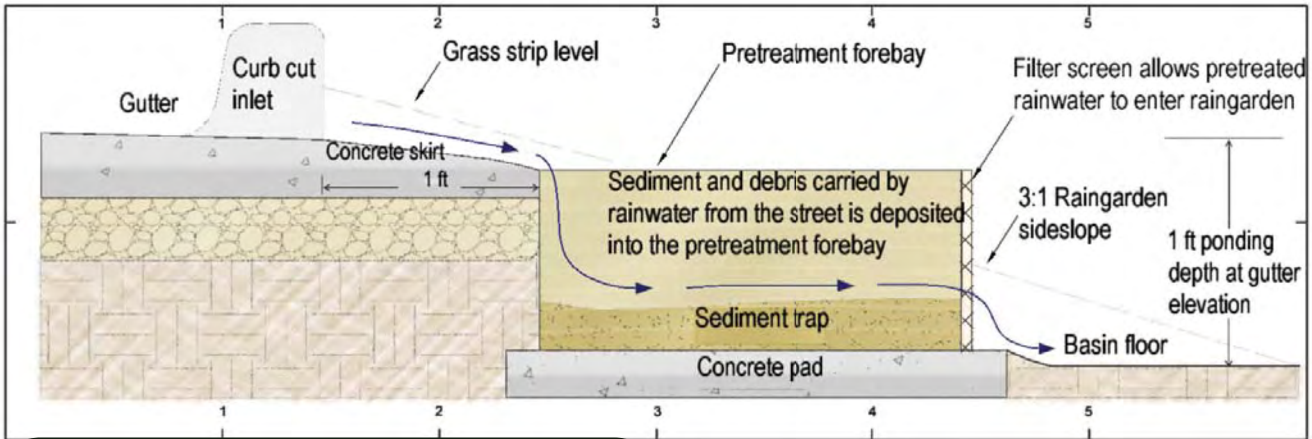


IX. Curvilinear
Sun, with Wall
pg. 16

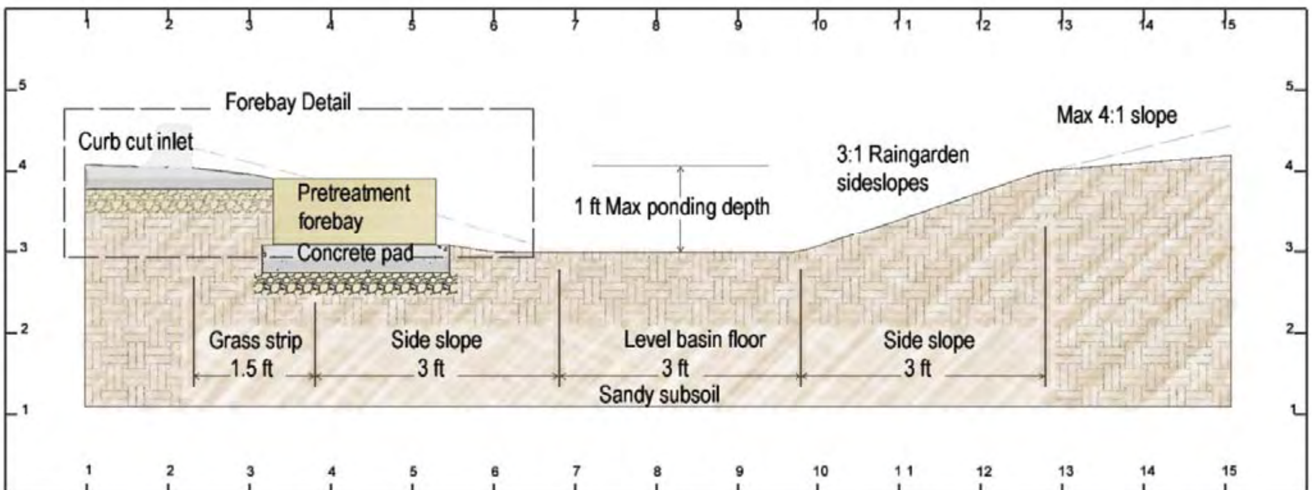


XII. Curvilinear
Shade, With Wall
pg. 19

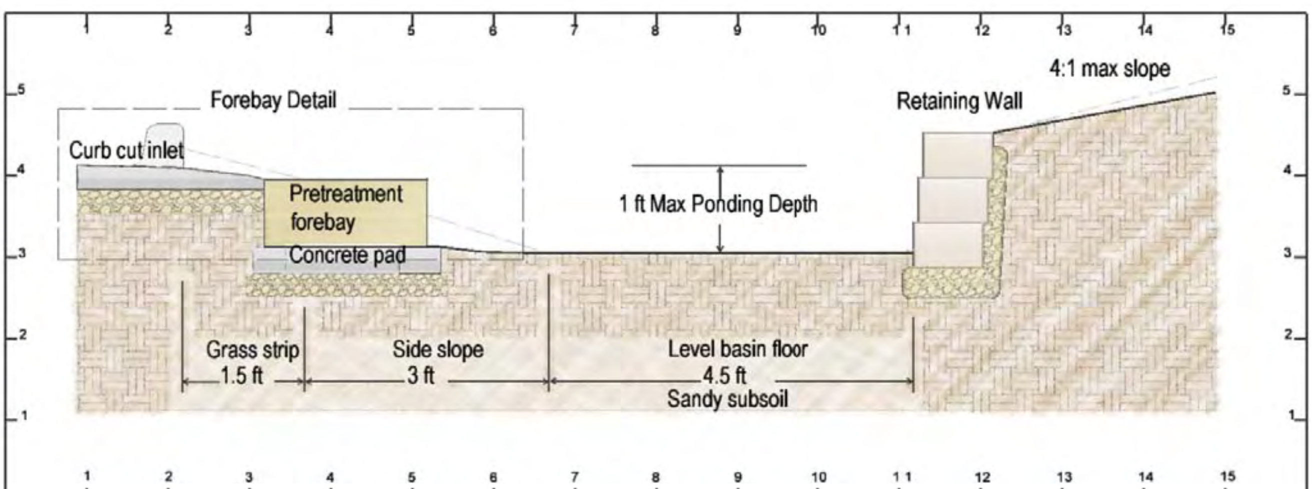
ANATOMY OF A CURB-CUT RAINGARDEN



PRETREATMENT FOREBAY

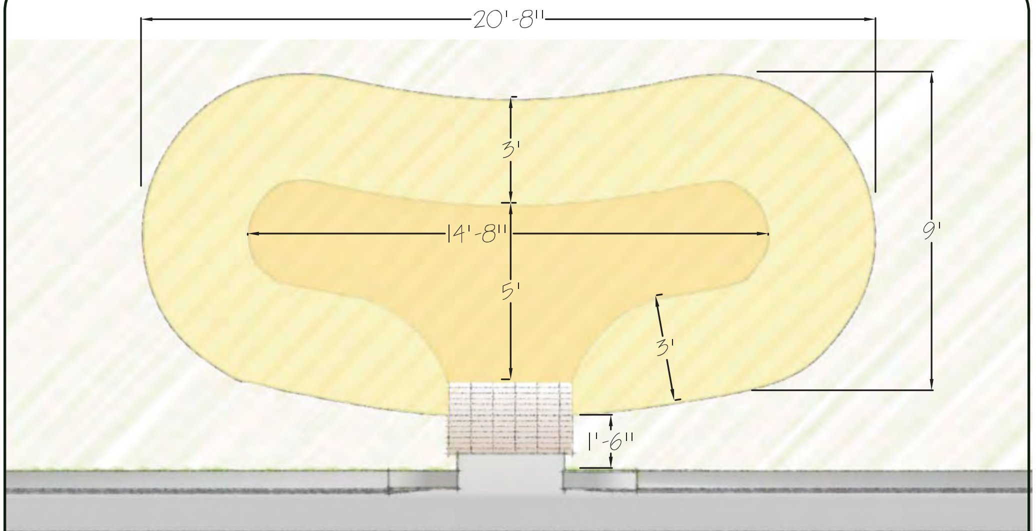


RAINGARDEN WITHOUT RETAINMENT

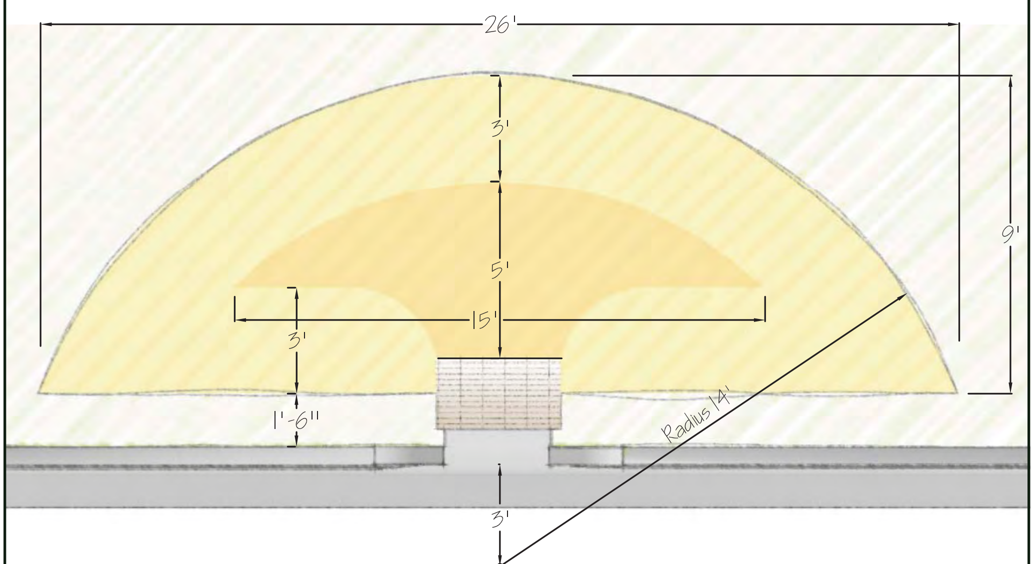


RAINGARDEN WITH RETAINING WALL

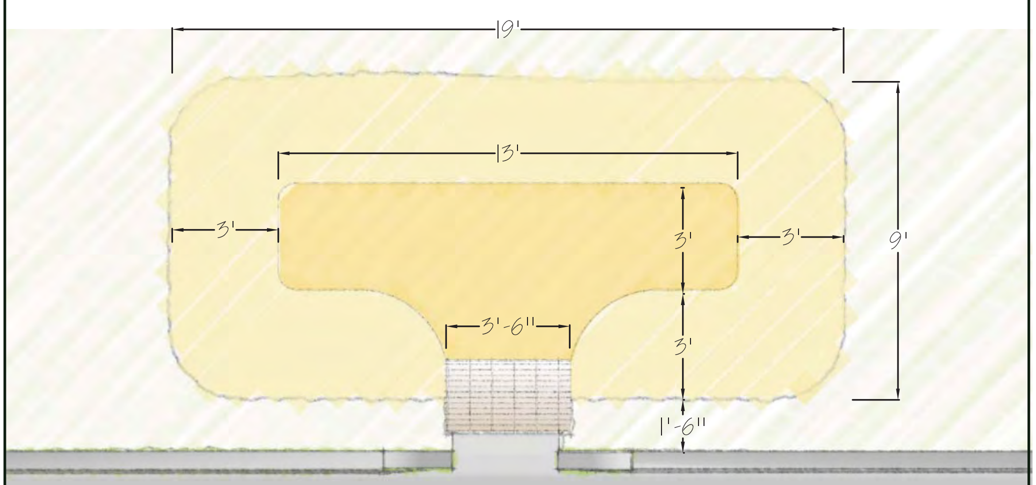
Raingarden Dimensions without a Retaining Wall



Curvilinear Garden



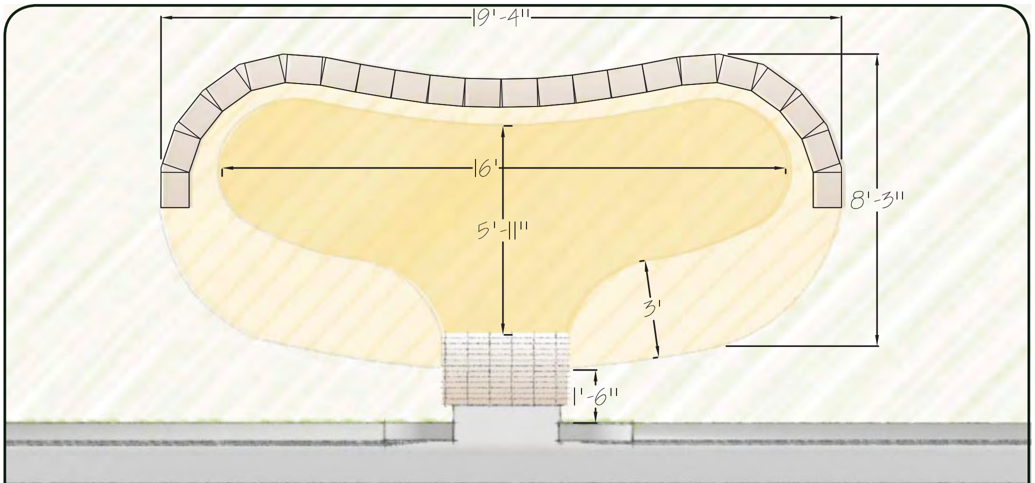
Arc Garden

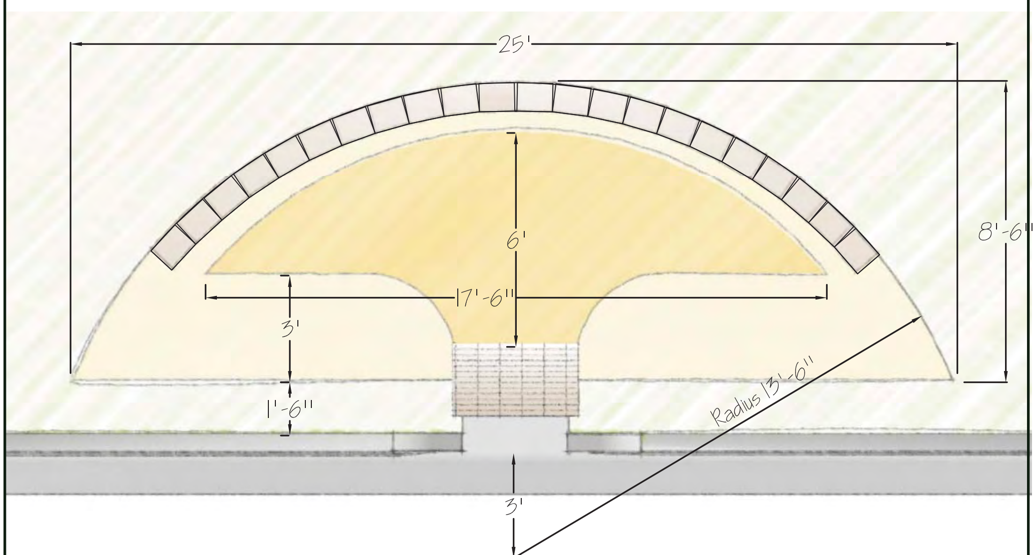


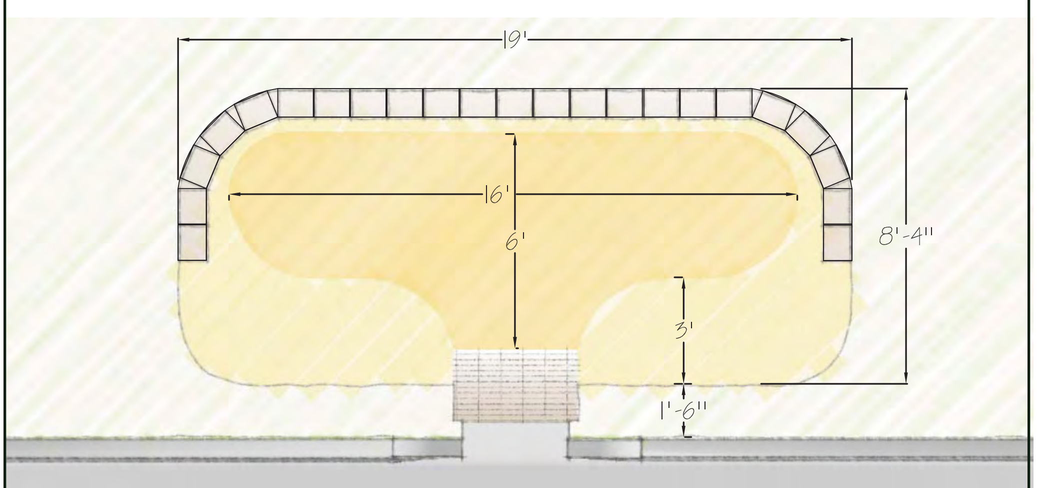
Rectangle Garden

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

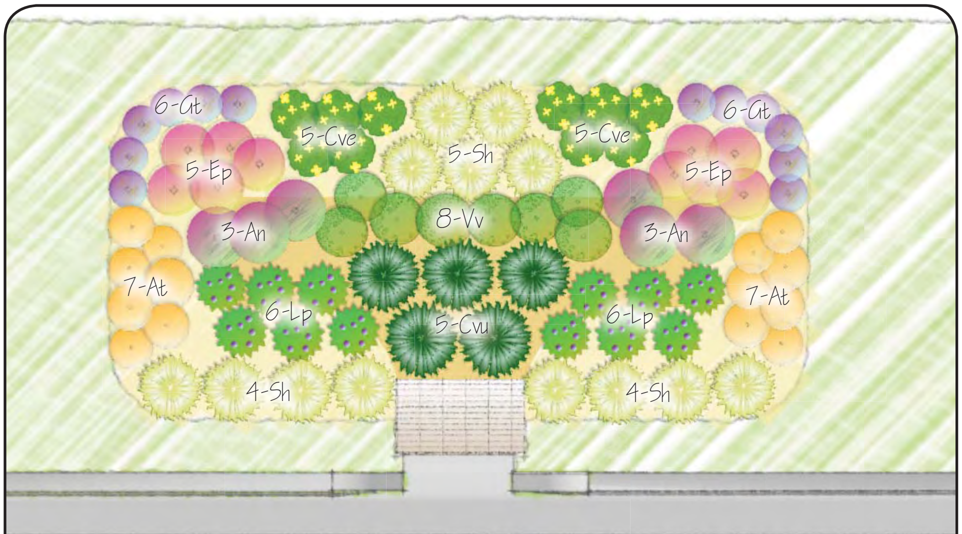




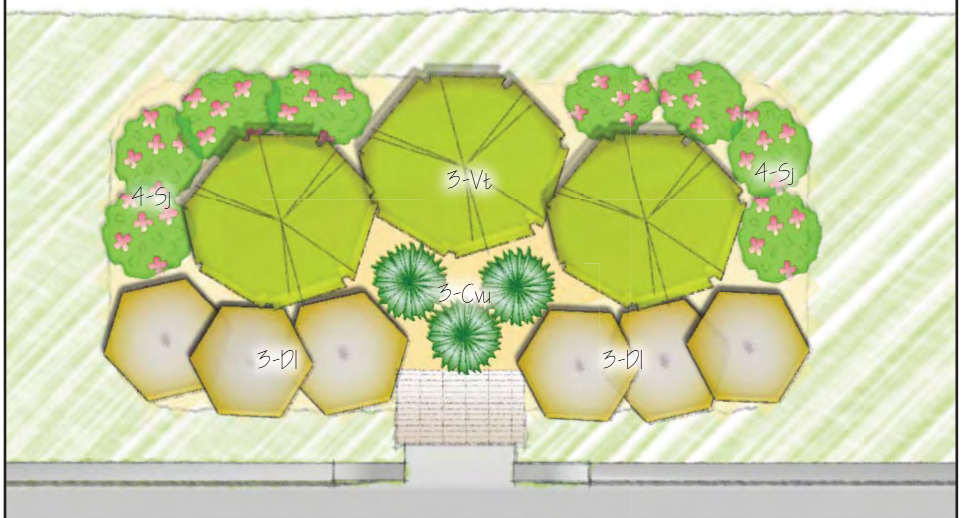


The dimensions given are the minimum dimensions needed to achieve the storage volume required by this stormwater retrofit program. The level basin floor needs to be set 1 foot below the gutter elevation. The entire planting area should be covered with 3 inches of shredded hardwood mulch.

I. Rectangle Garden - Sunny Site - No Retaining Wall



Flowering Perennial Garden



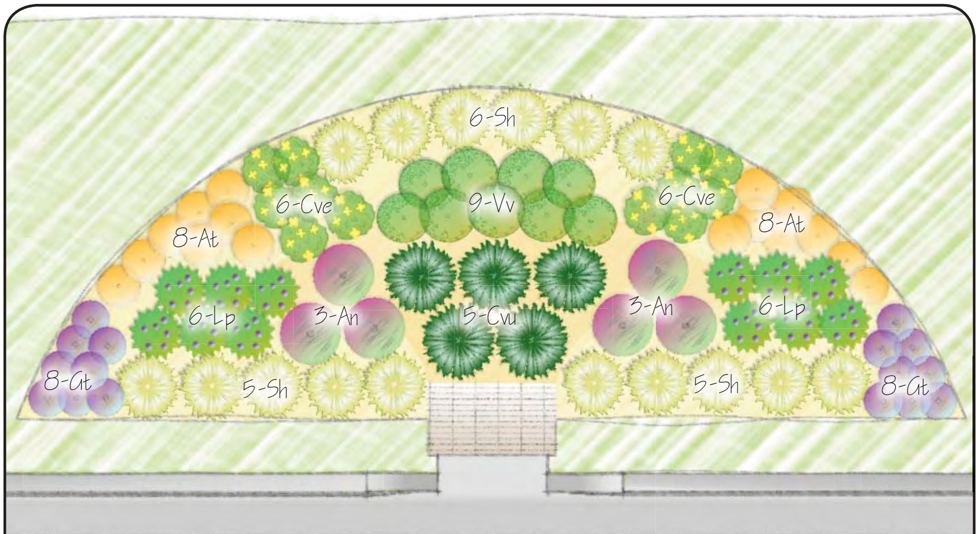
Shrub Garden

Mixed Shrub/Flower Garden

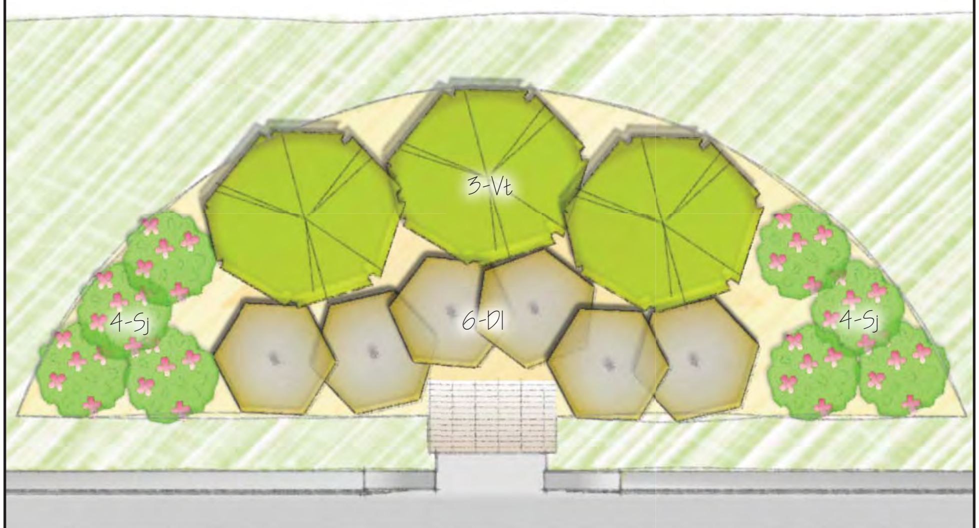
Plant Key

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



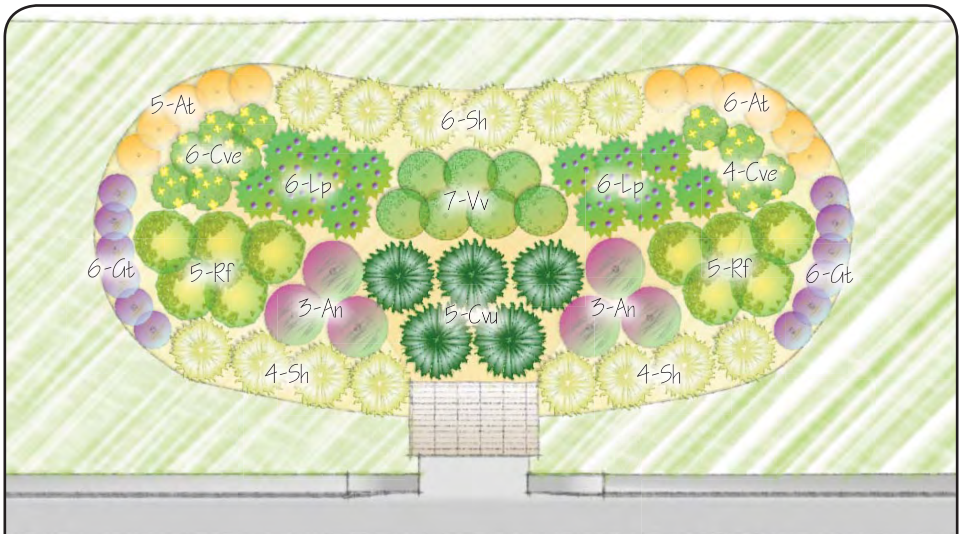
Shrub Garden

Mixed Shrub/Flower Garden

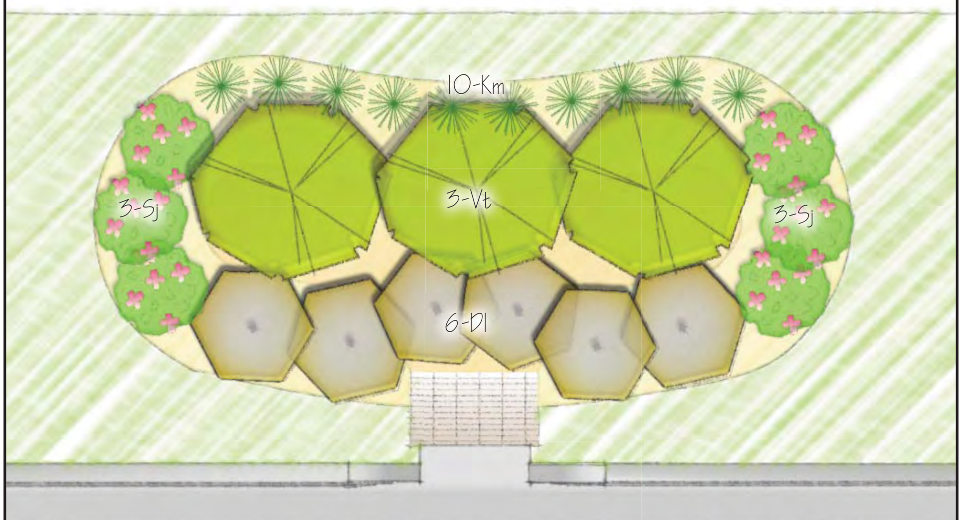
Plant Key

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



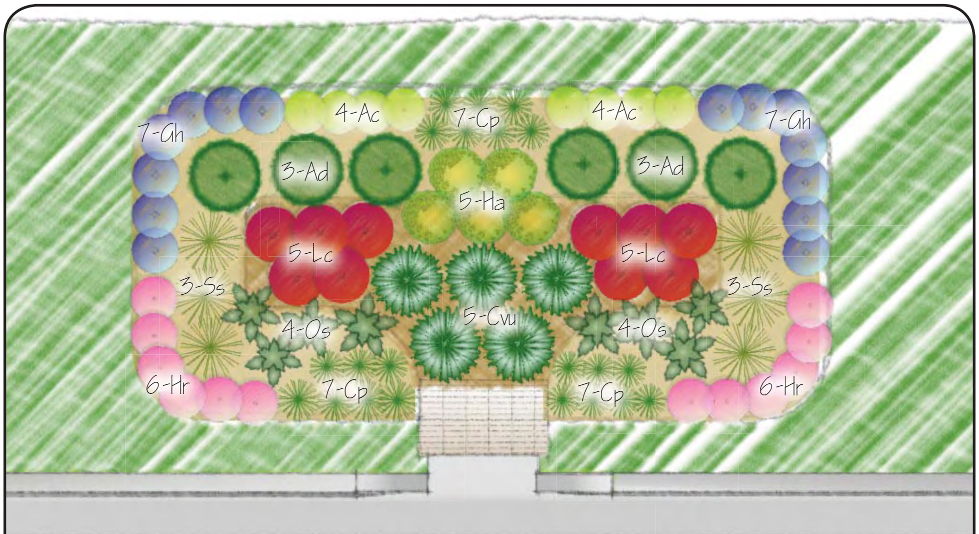
Shrub Garden

Mixed Shrub/Flower Garden

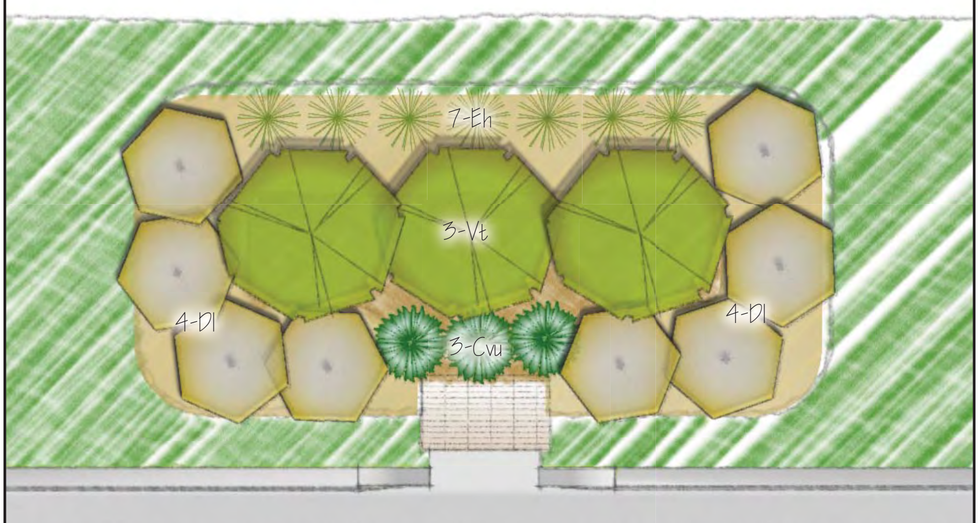
Plant Key

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'*

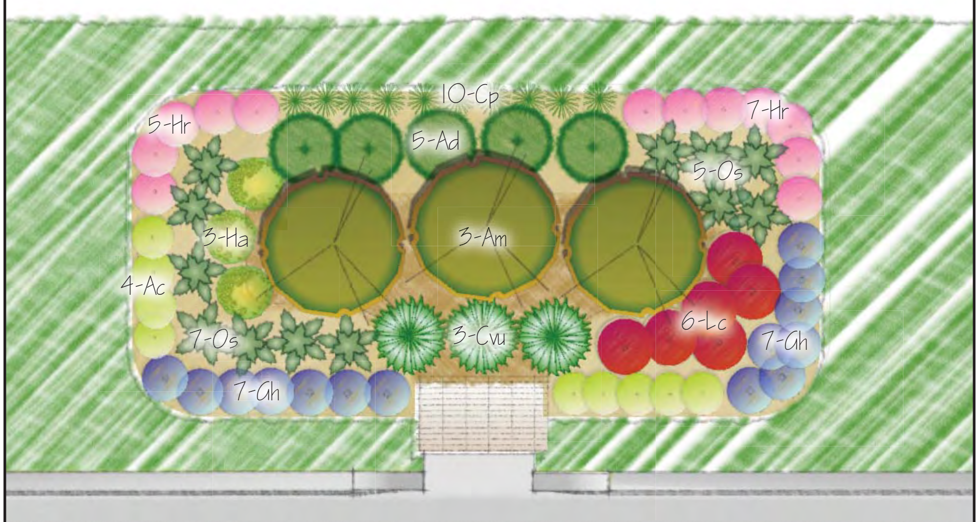
IV. Rectangle Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



Shrub Garden

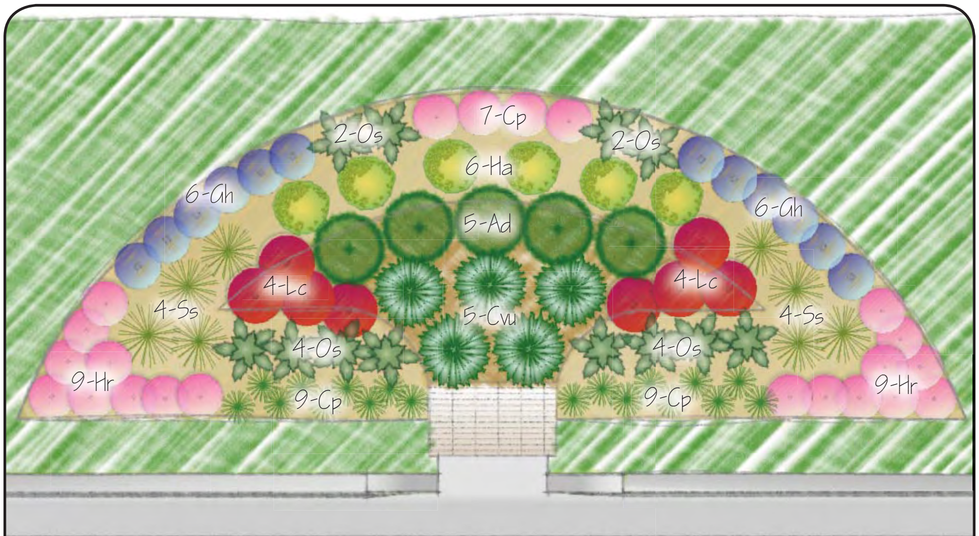


Mixed Shrub/Flower Garden

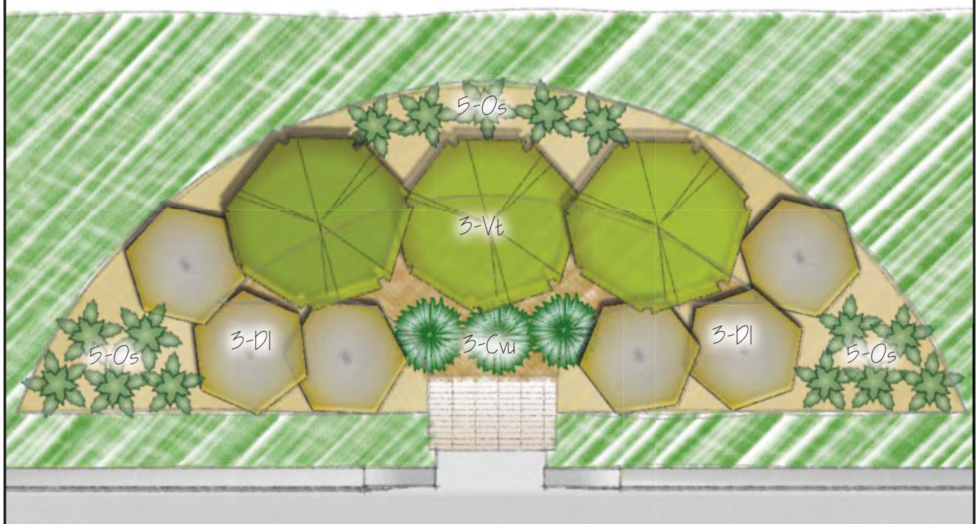
Plant Key

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*
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Gh	GERANIUM 'JOHNSON BLUE' *Geranium himalayense x pratense*
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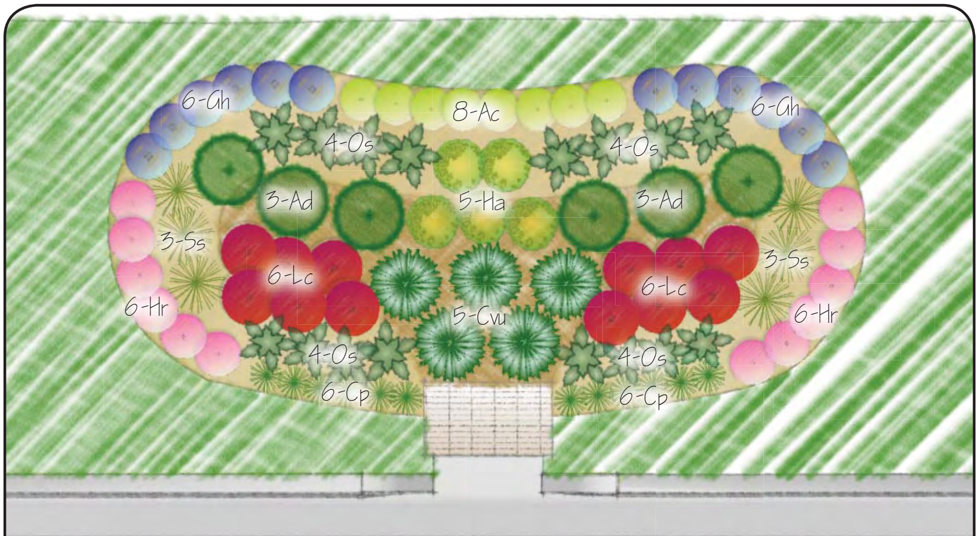
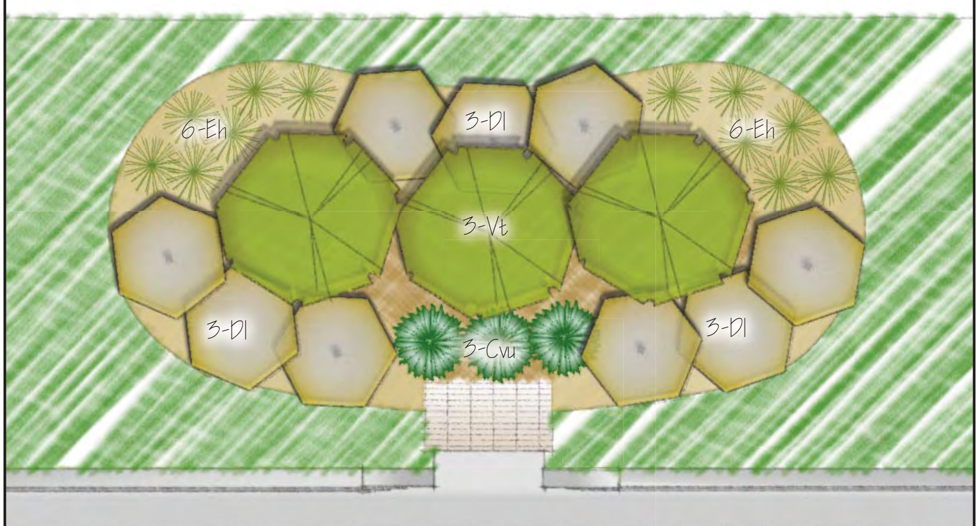
Hr	ALUMROOT *Heuchera richardsonii*
Lc	CARDINAL FLOWER *Lobelia cardinalis*
Os	SENSITIVE FERN *Onoclea sensibilis*
Vt	CRANBERRYBUSH VIBURNUM *Viburnum trilobum 'compactum'*

VI. Curvilinear Garden - Shady Site - No Retaining Wall



Flowering Perennial Garden



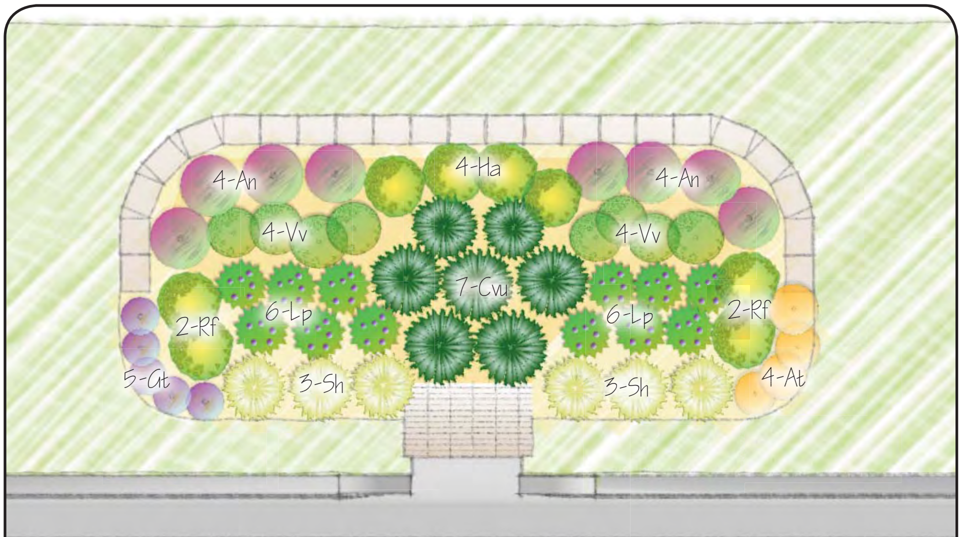
Shrub Garden

Mixed Shrub/Flower Garden

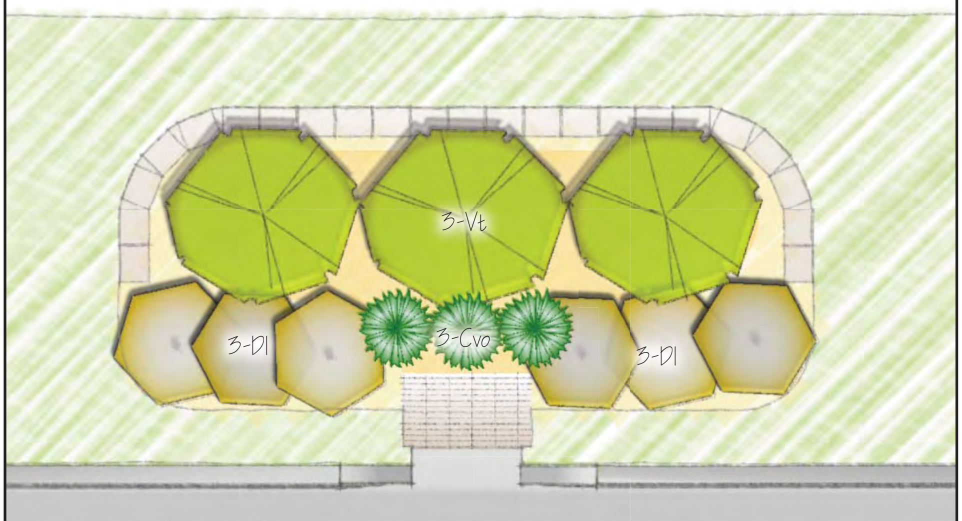
Plant Key

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

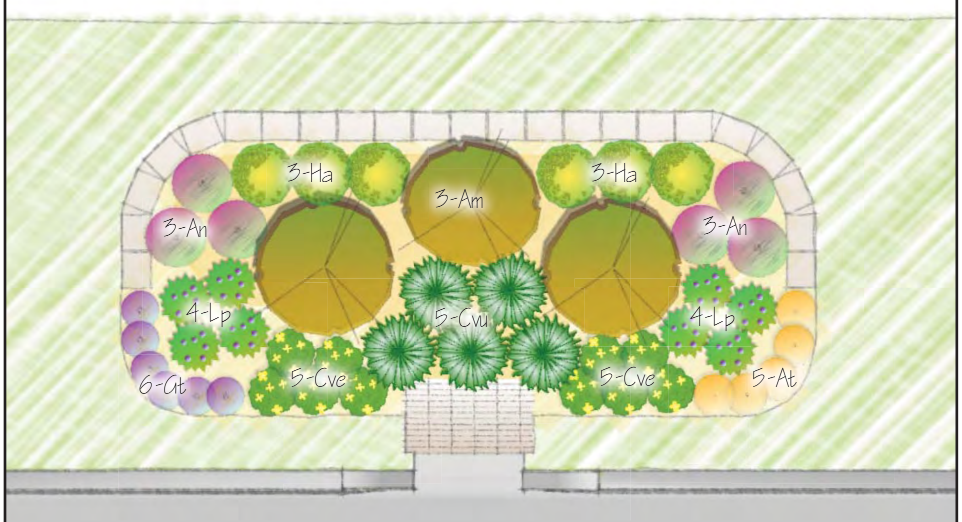
VII. Rectangle Ga rden - Sunny Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

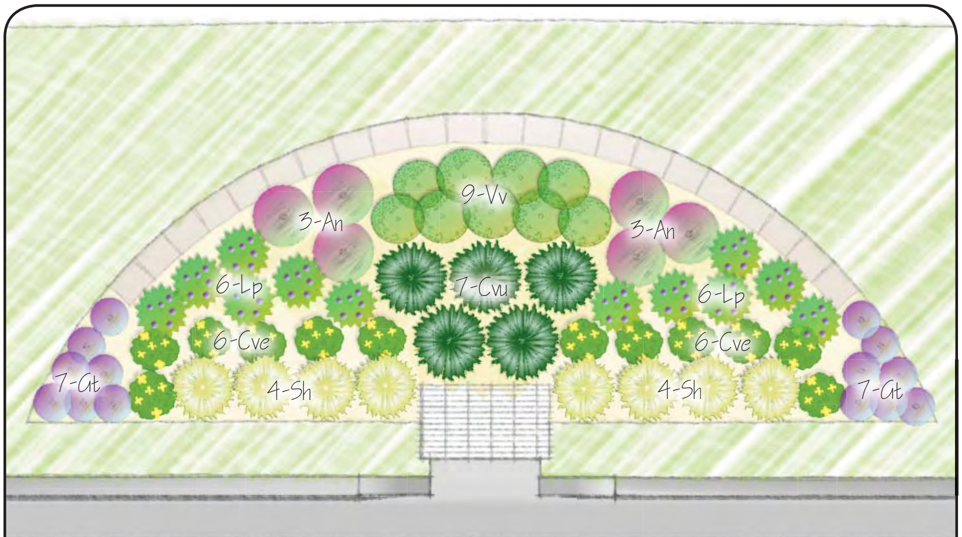


Mixed Shrub/Flower Garden

Plant Key

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

VIII. Arc Garden - Sunny Site - Retaining Wall



Flowering Perennial Garden

Shrub Garden

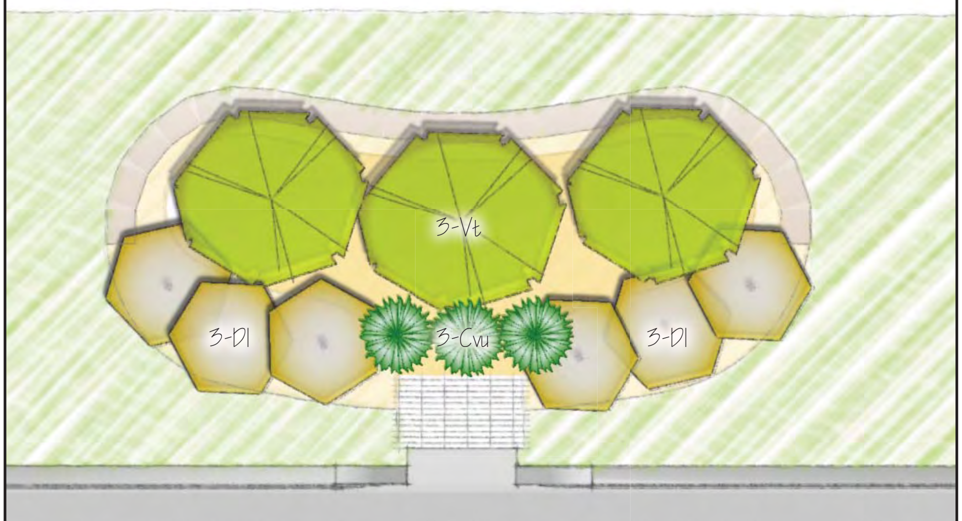
Mixed Shrub/Flower Garden

Plant Key

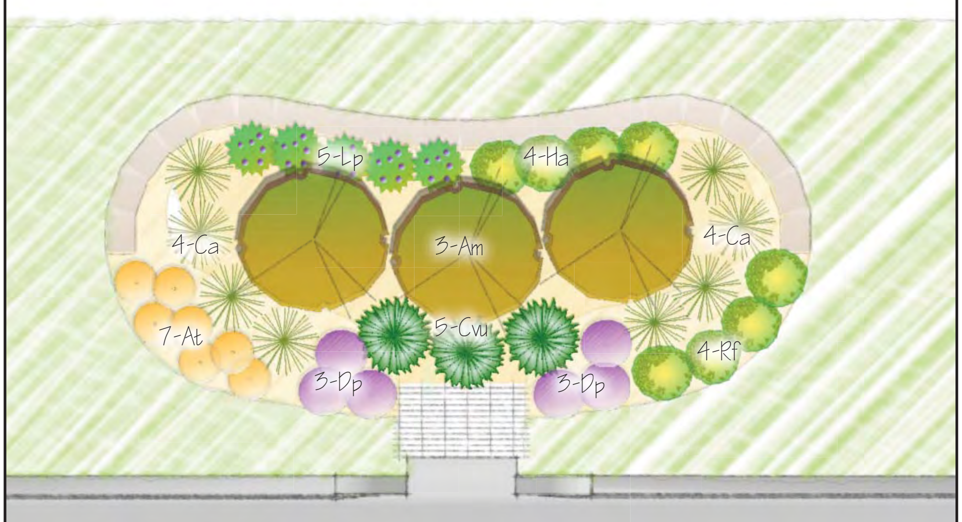
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Cve	COREOPSIS 'MOONBEAM' *Coreopsis verticillata 'Moonbeam'*
Dl	DWARF BUSH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

IX. Curvilinear Ga rden - Sunny Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden



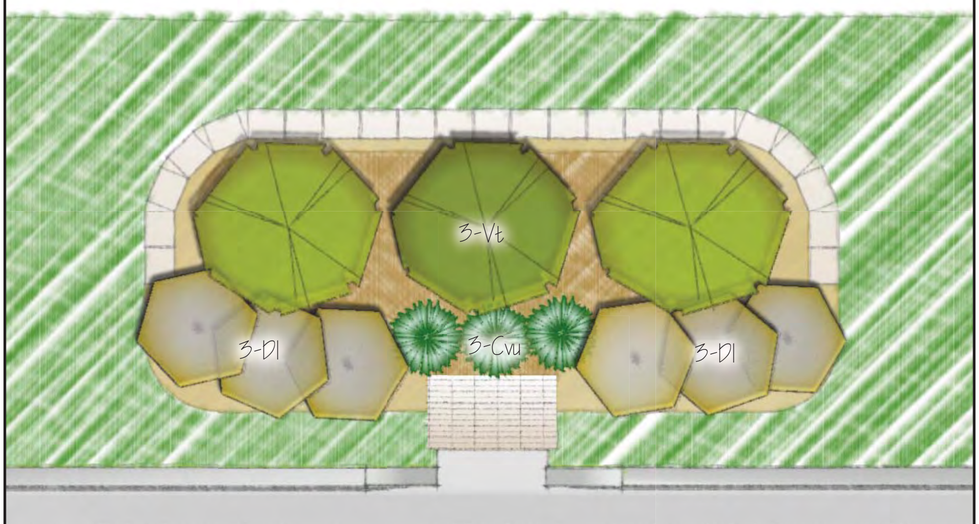
Mixed Shrub/Flower Garden

Plant Key

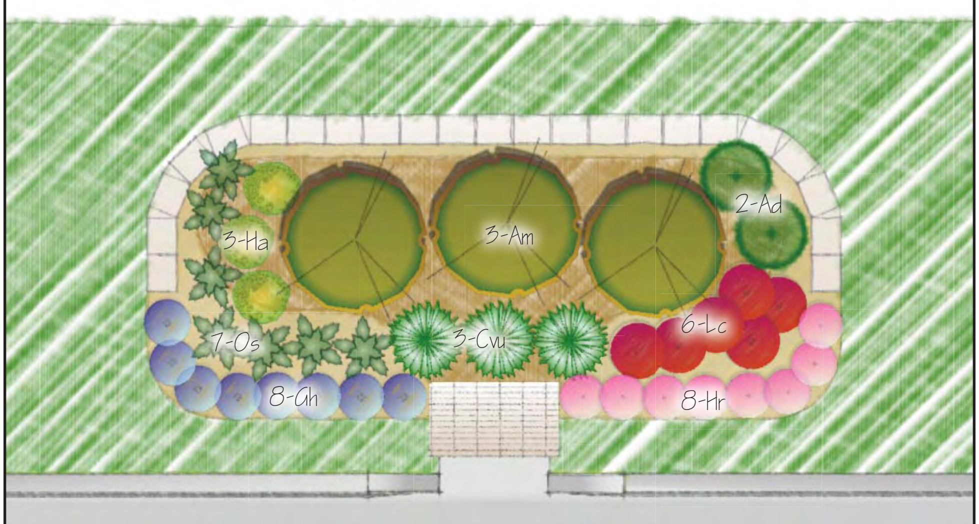
Am	BLACK CHOKEBERRY *Aronia melonocarpa*
At	BUTTERFLY MILKWEED *Asclepias tuberosa*
An	ASTER 'PURPLE DOME' *Aster novae-angliae 'Purple Dome'*
Ca	KARL FORESTER GRASS *Calamagrostis acutifolia*
Cvu	FOX SEDGE *Carex vulpinoidea*
Dl	DWARF BUSH HONEYSUCKLE *Diervilla lonicera*
Ha	SNEEZEWEED *Helenium autumnale*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

X. Rectangle Garden - Shady Site - Retaining Wall

Flowering Perennial Garden



Shrub Garden

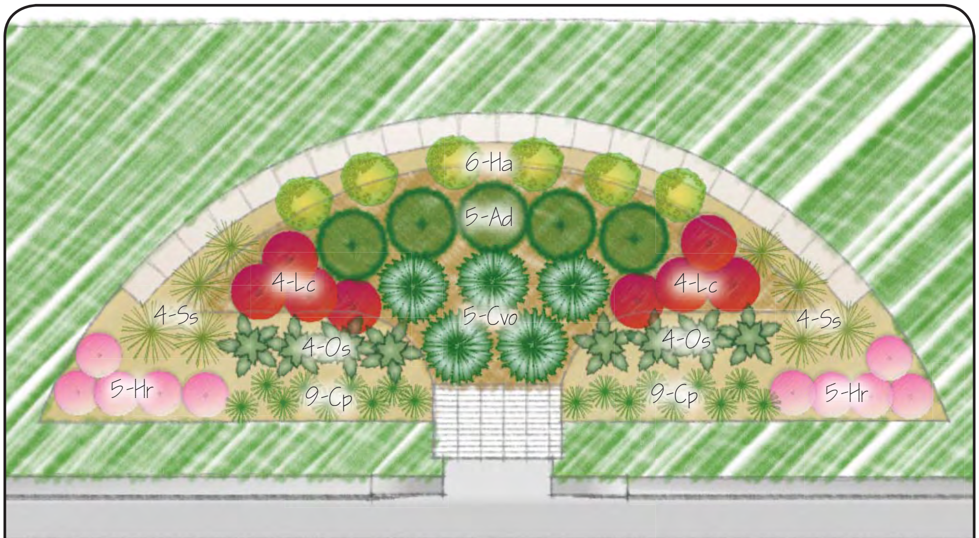


Mixed Shrub/Flower Garden

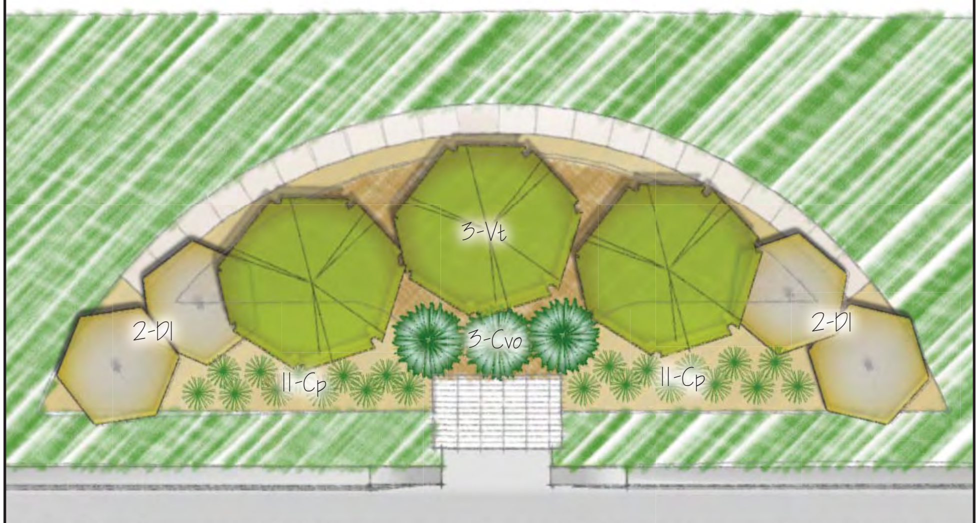
Plant Key

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

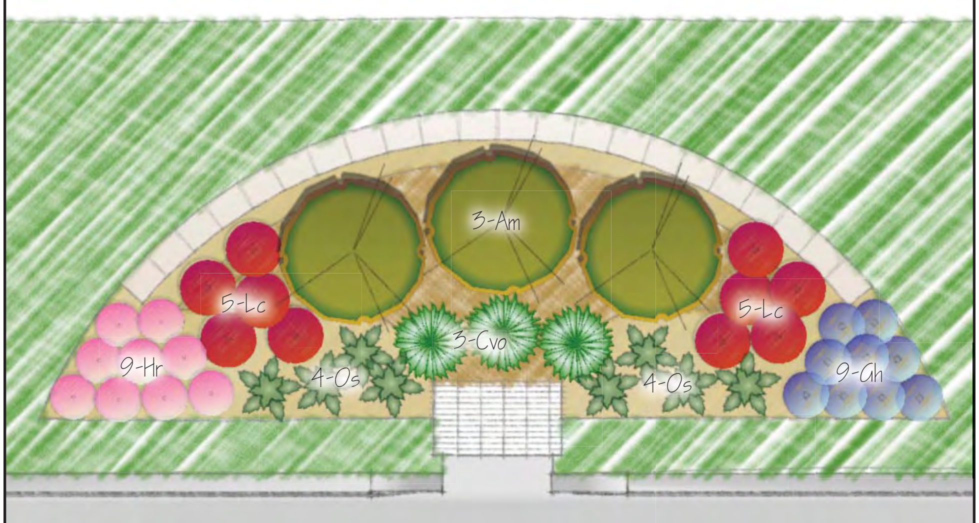
XI. Arc Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

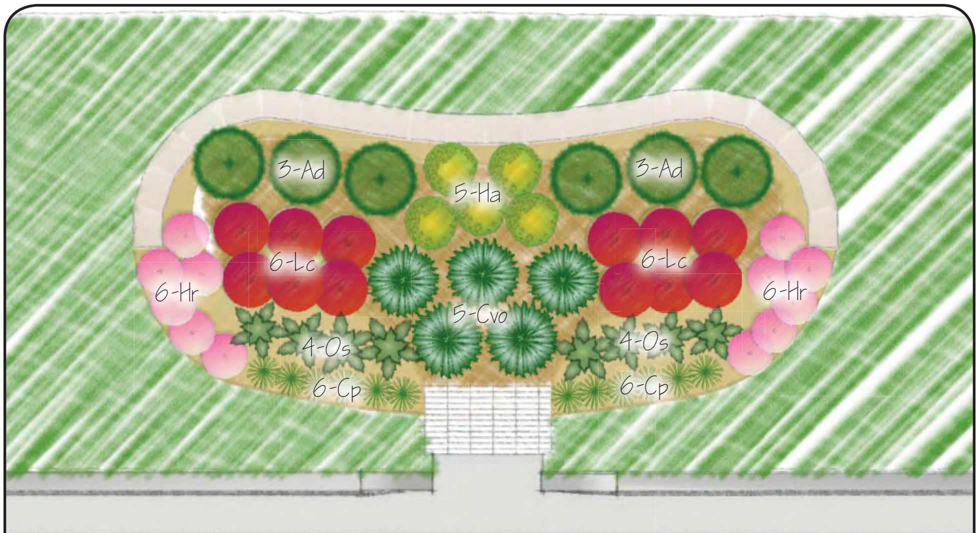


Mixed Shrub/Flower Garden

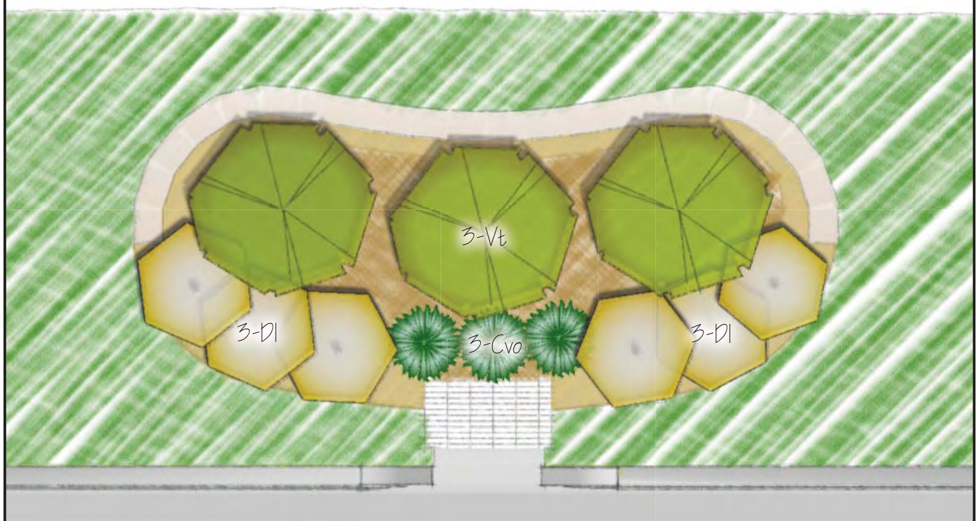
Plant Key

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

XII. Curvilinear Garden - Shady Site - Retaining Wall



Flowering Perennial Garden



Shrub Garden

Mixed Shrub/Flower Garden

Plant Key

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

FLOWERING PERENNIAL
Plant pallette

CANADA ANEMONE
Anemone canadensis

GOAT'S BEARD
Aruncus diocius

BUTTERFLY MILKWEED
Asclepias tuberosa

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

COREOPSIS 'MOONBEAM'
Coreopsis verticillata 'Moonbeam'

PURPLE PRARIE CLOVER
Dalea purpurea

PURPLE CONEFLOWER
Echinacea purpurea

GERANIUM 'JOHNSON BLUE'
Geranium himalayense x pratense

PRAIRIE SMOKE
Geum trifolium

SNEEZEWEED
Helenium autumnale

ALUMROOT
Heuchera richardsonii

PRAIRIE BLAZING STAR
Liatris pycnostachya

CARDINAL FLOWER
Lobelia cardinalis

SENSITIVE FERN
Onoclea sensibilis

GOLDSTRUM BLACK-EYED SUSAN
Rudbeckia fulgida

CULVERS ROOT
Veronicastrum virginicum

SHRUB
Plant pallette

BLACK CHOKEBERRY
Aronia melonocarpa

DWARF BUSH HONEYSUCKLE
Diervilla lonicera

DART'S RED SPIRAEA
Spiraea japonica

CRANBERRYBUSH VIBURNUM
Viburnum trilobum 'compactum'

GRASSES
Plant pallette

KARL FORESTER GRASS
Calamagrostis acutifolia

PENNSYLVANIA SEDGE
Carex pennsylvanica

FOX SEDGE
Carex vulpinoidea

JUNE GRASS
Koeleria macrantha

LITTLE BLUESTEM
Schizachyrium scoparium

PRAIRIE DROPSEED
Sporobolis heterolepsis