Gilfillan Tamarack Wilkinson Subwatershed:

Urban Stormwater Retrofit Analysis

Prepared for the Vadnais Lake Area Water Management Organization by:
Ramsey Conservation District

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Prepared for the VLAWMO by:
Mike Goodnature, Ramsey Conservation District

VLAWMO Staff:

Stephanie McNamara
(Administrator)

Kristine Jenson
(Project Coordinator)

Brian Corcoran
(Water Resource Technician)

Vanessa Strong
(Education and Outreach Coordinator)

VLAWMO Board:

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VLAWMO
VADNAIS LAKE AREA WATER MANAGEMENT ORGANIZATION

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Abstract

This report details a relative subwatershed stormwater retrofit assessment recommending catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Vadnais Lake Area Water Management Organization (VLAWMO). No monitoring has been conducted in order to calibrate, verify, and/or validate the results. However, efforts were made to provide the most accurate and precise estimates for pollutant loading and reduction, along with estimated costs to reach these removal rates.

This report should be considered as one part of an overall watershed restoration plan that includes educational outreach, stream repair, riparian zone management, discharge prevention, upland native plant community restoration, and pollutant source control. The methods and analysis used attempt to provide sufficient detail to assess subwatersheds of variable scales and land uses, in order to identify optimal locations for stormwater treatment.

This report is a vital part of overall subwatershed restoration and should be considered in light of forecasting riparian and upland habitat restoration, pollutant hot-spot treatment, and educational outreach within existing or future development or watershed-restoration planning. The report includes background information, a summary of the assessment results, the methods used, catchment profile sheets of selected sites for retrofit consideration, and retrofit ranking results.

Results of this assessment are based on the development of catchment-specific conceptual stormwater treatment BMPs that either supplement existing stormwater infrastructure or provide quality and volume treatment where none currently exists. Relative comparisons were made between catchments to determine where best to initialize final retrofit design efforts. Site-specific design sets (driven by existing limitations of the landscape and the effect on design-element selection) will need to be developed to determine more refined estimates of pollutant removal amounts. This step typically occurs after identifying specific parcels for placement of BMPs.

VLAWMO
VADNAIS LAKE AREA WATER MANAGEMENT ORGANIZATION

Gilfillan Tamarack Wilkinson Subwatershed: Urban Stormwater Retrofit Analysis

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Introduction

The Gilfillan, Tamarack, Wilkinson (GTW) subwatershed is located in northeastern Ramsey County and southern Anoka County, MN (Figure 1.). The GTW subwatershed consists of mainly open space undeveloped land with a mix of low density residential land use. Commercial and industrial land use exists mainly along the Highway 35 corridor. Predevelopment, the land use consisted of mainly wet prairies and some hardwood forest. The soils in the areas where retrofit opportunities were found consist of mainly loamy fine sand, sandy loams, and urbanized soils. The chain of water features (Gilfillan, Black, Wilkinson, Amelia, Fish and Tamarack Lake) in this subwatershed are connected through a series of ditches, storm sewers, ponds and numerous wetlands. Within the chain, Wilkinson and Gilfillan Lakes are currently impaired for nutrients. TMDL studies of these lakes have been completed and are under review for approval. Both studies identified internal and external TP loading as causes for the nutrient impairments within these lakes. Implementation of water quality best management practices to reduce external TP within these catchment areas in attempt to meet the standards set forth in the TMDL and to improve water quality within the other lakes is what prompted this study.

This study identifies the most cost-effective opportunities to retrofit the stormwater conveyance system to improve water quality by reducing runoff volumes and TP levels. The methods used to complete this study were adapted from the Center for Watershed Protection. The methods include retrofit scoping, desktop analysis, a field investigation, treatment analysis/cost estimates of retrofits and an evaluation and ranking of the findings. The results of this study indentified the most cost effective retrofit location, type, and size to be installed given the contributing area within the Gilfillan, Wilkinson Lake and Wilkinson Stream catchments. The Amelia and Black Lake catchments were analyzed through the field reconnaissance process, but were excluded from further analysis within the study due to their current land use consisting of mainly open space and thus eliminating the need to implement retrofit water quality improvement practices. The five cathment area boundaries used for the study were taken from a previous study and provided by the VLAWMO. Figure 2 shows the lakes individual catchments and the study area highlighted in yellow. From the three cathments reviewed 24 retrofit opportunities were identified. The retrofit types proposed include mainly bioretention, dry swales containing native vegetation, and permeable asphalt.

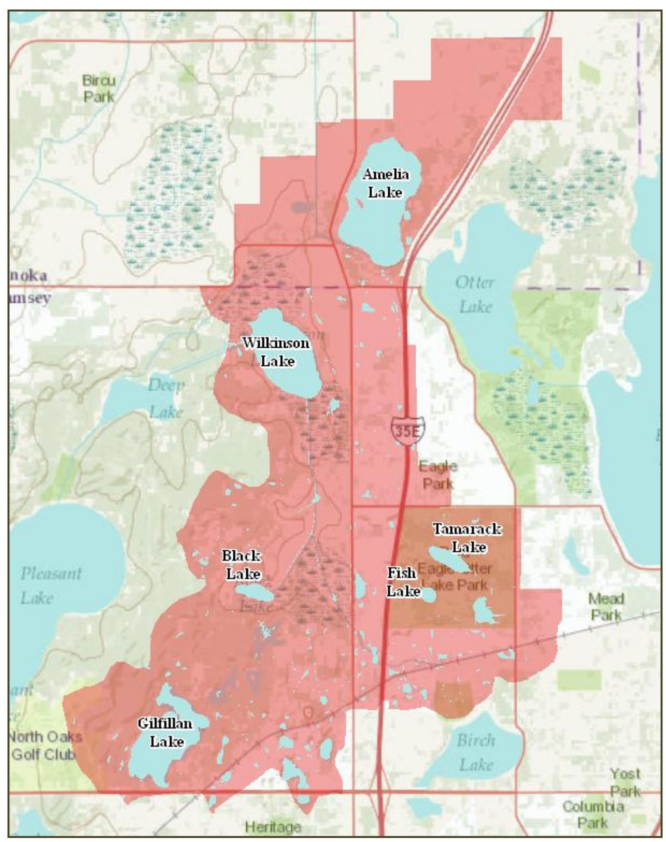

Figure 1. Location of subwatershed

Methods

Retrofit Scoping

Each cathment was analyzed using standard land use files in WinSLAMM software to determine a base load of TP. The WinSLAMM parameters and standard land use files used can be seen in Appendix A. These base loads were calculated so that it could be determined that catchments with a greater pollutant load could be considered first when deciding which identified retrofit practices to install. During the base load modeling current water quality practices were reviewed. Municipal practices such as street sweeping or unidentified inlet sumps were not taken in to consideration during the base load modeling. A limited number of small scale treatments, such as turf swales, were discovered during the field reconnaissance. Due to the unknown effectiveness to remove pollutants and maintenance schedule of the small scale best management practices they were not taken in to consideration as treatment in the base load modeling.

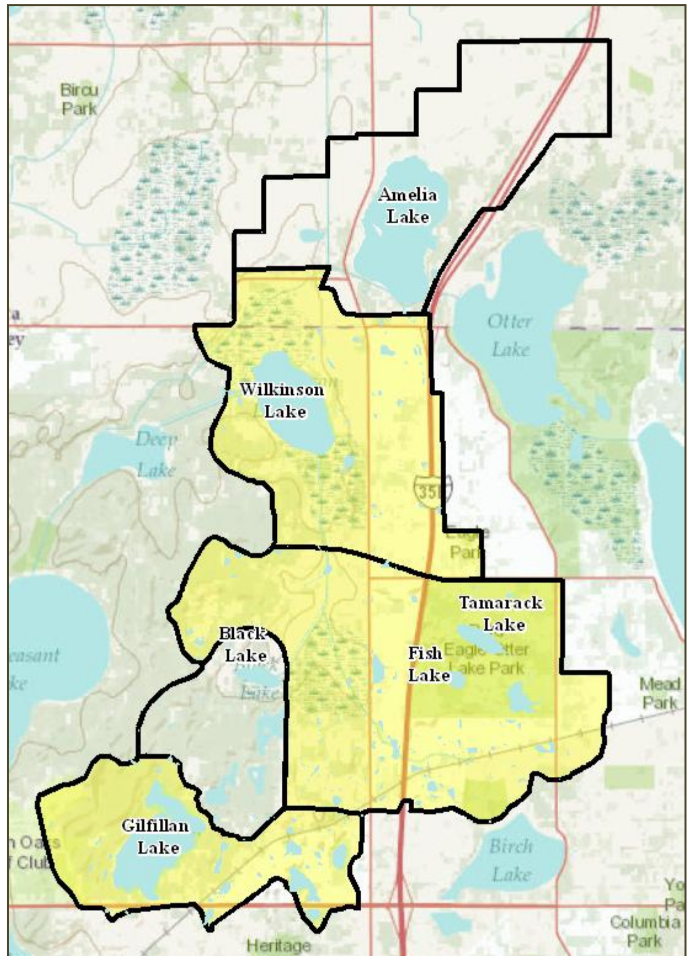

Figure 2. Lake drainage areas and study area in yellow

Larger regional treatments consist of numerous natural and man-made ponding and wetland systems. These features are assumed to have the ability to remove a percentage of TP before it enters the target waters, however, it was determined that the whole watershed be assessed and that many of the natural regional features were in need of protection as well as the lakes. In addition to this, current water quality sampling data was lacking for all regional treatment features which otherwise could have been used to calibrate the model. With this in mind each catchment was modeled as a whole and TP reduction through any series of regional treatment before it entered the lakes was not take in to consideration, which equates for the high number of TP pound base loads for each catchment. However, all steps used to calculate the base load modeling were done to create an even playing field for all the catchments modeled. Although the pollutant base loads may be higher than reality the same parameters were used in the modeling so that an overall precise comparison could be made between the catchments. More accurate and precise pollutant loads for each retrofit opportunity found within the drainage areas were calculated and discussed below in the Treatment Analysis/Cost Estimates.

Desktop Retrofit Analysis

A desktop search for potential retrofit locations was conducted for each of the three drainage areas to identify potential retrofit opportunities before completing a field reconnaissance. GIS layers including topography, hydrology, soils, watershed/subwatershed boundaries, parcel info/boundaries, high-resolution aerial photography and the storm drainage infrastructure data were reviewed to determine potential retrofit placement. Several factors and key locations were considered during the desktop analyses that are conducive to retrofitting opportunities. These included areas well known for contributing increased polluted runoff (gas stations, sites with large impervious areas, storage facilities, etc.), public land (due to ease of cooperation during the installation process) and areas slated for redevelopment. Redevelopment was reviewed because of the cost savings when installing retrofits in conjunction with other construction. Efforts were put forth discussing future redevelopment projects with VLAWMO contacts and reviewing cities website information for future construction plans. From what was determined there were no future construction projects within the drainage areas that would be conducive to retrofitting BMPs.

Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through the desktop search, a field investigation was conducted to evaluate each site. During the investigation, the drainage area and stormwater infrastructure mapping data were verified. Site constraints were assessed to determine the most feasible retrofit options as well as eliminate sites from consideration. The field investigation also revealed many additional retrofit opportunities that went unnoticed during the desktop search.

Treatment Analysis/Cost Estimates

Retrofit Neighborshed Delineation

After the retrofit sites were identified each of their individual drainage areas or “neighborsheds,” consisting of runoff from surrounding streets, buildings, parking lots, and landscaped areas, etc., were delineated using drainage data gathered in the field and GIS contour data. See an example in Figure 3. This information, in conjunction with the NRCS soil survey data, was used to model the pollutant loads from each of the sites. Each of the source areas acreage was manually entered in to the WinSLAMM program under the appropriate land use type of which the site fell within. To maintain consistency all file data used in WInSLAMM, listed in Appendix A, was the same for each site modeled and street sweeping was not take into consideration in addition to the retrofit being modeled.

Retrofit Modeling & Sizing

The retrofit type and dimensions, conducive to the landscape and size of each neighborshed, was then chosen and incorporated in to the model to determine its capability to reduce TP. The retrofit types identified include: simple bioretention, moderately complex bioretention, complex bioretntion, dry swales, or permeable asphalt. The majority of residential bioretention BMPs modeled were all sized at 250 square feet. The soil type determined which type of bioretention cell could be installed for each location.

Figure 3. An example neighborshed and the source areas that are entered in to WinSLAMM

Retrofit Types

Bioretention: The bioretention referred to in this report, also referred to as curb cut rain gardens, takes stormwater runoff off line for treatment and utilizes the current stormwater conveyance system for overflow. Depending on the soil type at the location being constructed the bioretention basins consist of a depression utilizing native soils for infiltration or replacing current soil with an engineered soil and native vegetation plantings more conducive to infiltration. At some sites, an underdrain with connection to the existing storm sewer system may be needed if infiltration capability is limited by underlying soils or if infiltration cannot be allowed due to soil compaction or other conditions. It is important to properly design and install the engineered soils so that the bioretention basins take no less than 24 hours to drain but no more than 48 hours. The bioretention basins fell within the categories, listed below, depending on where the site was located within the landscape.

- Simple Bioretention - includes native vegetation, a curb cut and forebay, but no engineered soils or under-drains. May include a retaining wall if grade is steep.

- Moderately Complex Bioretention - includes native vegetation, engineered soils, a curb cut, forebay and underdrain, and no retaining walls.

- Complex Bioretention - is the same as the MCB, but with 1.5-2.5 ft partial perimeter walls.

Dry Swales: the dry swales referred to in this report are shallow channels consisting of native vegetation which treat and convey stormwater runoff and are considered dry swales that do not hold water. The dry swales were modeled as if the current storm water conveyance system was re-graded to form a shallow channel approximately 8-15 feet wide. The soil would then be deeply ripped and planted with native grasses such as switch grass, prairie cord grass and little and big bluestem. Check dams could also be installed inexpensively within the vegetated swales for additional treatment. Check dams were not modeled within this report.

Permeable Asphalt: The permeable asphalt referred to in this report consists of porous asphalt with an underlying aggregate bedding and filter media. The permeable asphalt was modeled using an underdrain once the runoff was filtered through the engineered complex.

A schematic of the retrofit types and example modeling parameters used within WinSLAMM of each retrofit type can be seen in Appendix B.

Retrofit Cost Estimates

Each retrofit identified was then assigned an estimated materials, design, and installation costs given its ft^2 of treatment. These cost estimates were derived from The Center of Watershed Protection manuals and recent installation costs provided by personal contacts. A unit promotion and admin costs were calculated with a total project cost and annual maintenance. A 30 year term cost/TP-removed for each retrofit was then calculated for the life-cycle of that retrofit, which was calculated from the total cost + (30 year * annual maintenance) / (30 year * TP (lb/yr)).

Results

Catchment Comparison

The three catchments and their total TP base loads are listed in the table below. It is estimated that the Wilkinson Stream catchment is producing the most TP load overall at 681.20 lbs TP per year and the Gilfillan catchment is producing the most TP (lbs)/acre/year at 0.70. This information is suggested to be used in prioritizing which catchments should be considered first when efforts are put forth in installing the associated identified retrofits.

Drainage Area	Total TP (lbs)/ Year	Acres	TP (lbs)/Acre/Year
Gilfillan	344.60	493.26	0.70
Wilkinson Lake	428.40	910.68	0.47
Wilkinson Stream	681.20	1398.49	0.49

Catchment Profiles

The following pages provide catchment-specific information including a catchment summary and description. Each profile includes a catchment summary table showing the size of the catchment (acres) and the volume, and TP load estimates coming from the catchment. A table of individual retrofit types within the catchment and their levels of treatment is also included. This table shows the information listed below for each individual retrofit opportunity proposed. A map of retrofit locations and types is also provided in the catchment profile. More detailed retrofit locations can be seen on the large overview map and can be viewed digitally in ArcGIS with the ESRI shapefile, both provided with this report. The shapefile provides detailed retrofit locations and associated retrofit attributes.

- Catchment
- Site ID – a unique site ID number within the individual catchment
- TP – the Total Phosphorus reduced by the retrofit (lbs/year)
- TSS – the Total Suspended Solids reduced by the retrofit (lbs/year)
- Volume – the volume of water runoff reduced (cubic feet/year)
- Size – proposed size of retrofit and the size used to model (square feet)

- BMP Type – type of retrofit proposed at that site
- Materials/Labor/Design – cost estimates of materials, labor, and design
- Unit Promotion & Administrative Costs – admin costs associated with the installation of retrofits (*100 cu ft unit cost)
- Total Project Cost (**Typical Raingarden maintenance costs)
- Annual Operation & Maintenance Cost
- Term Cost – Cost/ TP removed (lbs)/30 year life cycle – retrofits are ranked from lowest to highest buy this number in each table.

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Gilfillan

DESCRIPTION

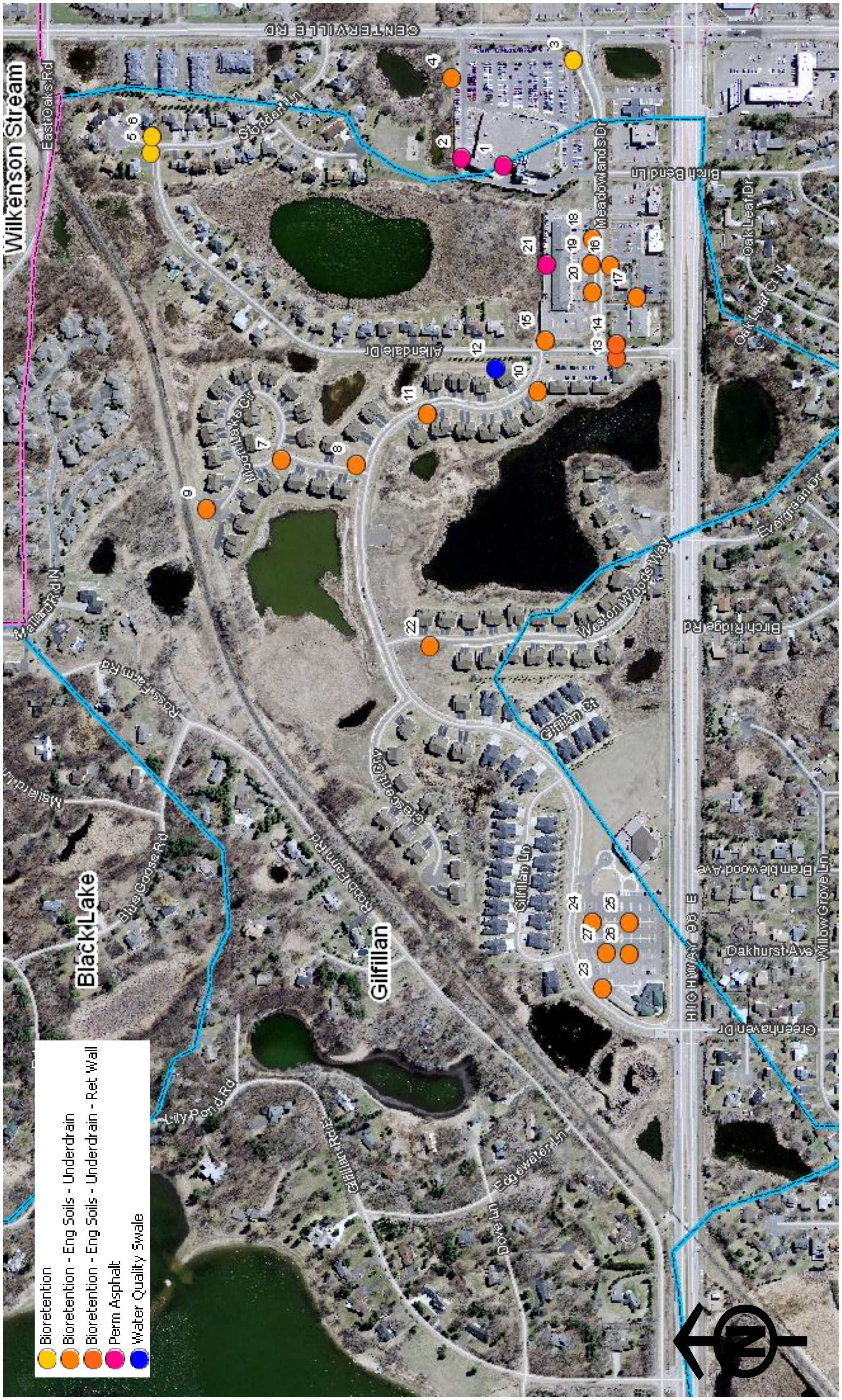
Existing Catchment Summary	
Acres	493.26
TP (lbs/yr)	344.60
TP(lbs)/Acre/Yr	0.70

This catchment is comprised of primarily low density residential single family housing units on multiple acre lots. The eastern one third of the catchment consists of multifamily residential housing and commercial land use mix. A series of wetlands and stormwater ponds exist within this catchment provide some open space buffers. The majority of the soils are classified as sandy loam with some soils comprised of the udorthents complex which would both allow for bioretention with engineered soils and an underdrain, if found to not be compacted or polluted. Fine sandy loam soil was also identified within the catchment which would allow for simple bioretention.

RETROFIT RECOMMENDATION

All of the retrofit locations were identified on the east side of the Gilfillan catchment, within the more urban area consisting of residential duplexes and commercial complexes, and include bioretention, dry swale and permeable asphalt. Sites identified were all on private land so cooperation of landowners will be required during the planning and installation of projects. As assumed bioretention basins capturing runoff more from roads combined with larger drainage areas were at the top of the list for installation. Twelve individual bioretention cells and 4 sites with multiple bioretention cell clusters were identified. The potential to install a water quality swale (dry swale) to capture runoff from a large grassy area and roof tops of several duplexes was identified in a current swale consisting of eroding turf grass. Options for permeable asphalt were identified in paved parking lot locations consisting of larger drainage areas with limited space for bioretention. If removing parking space/pavement to replace with bioretention is an option at these locations the bioretention would be a more efficient cost effective retrofit alternative than the permeable asphalt. Site ID location 1,2,3,4 was a combination of the permeable asphalt and bioretention sites that were identified on the Cub Foods complex. These clusters were also modeled individually to compare options. It is suggested that retrofits proposed be considered from the top of the list down also taking in to account overall ease of installation. If all retrofit opportunities are installed 8.88 lbs of TP would be removed from the catchment resulting in a 2.5% decrease from the base load at an initial total project cost of $168,632.

Catchment	Site ID	TP (lb/yr)	TSS (lb/yr)	Volume (cubic-feet/yr)	Size (sq ft)	BMP Type	Materials/Labor/Design	Unit Promotion & Admin Costs*	Total Project Cost**	Annual O&M	Term Cost/lb/yr (30 yr)
GF	7	0.80	338.97	5042.80	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$498.95
GF	8	0.79	298.40	8339.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$504.08
GF	5 & 6	0.90	324.90	21747.00	500	Simple Bioretention	$6,210.00	$564.81	$9,034.06	$375.00	$754.03
GF	22	0.44	230.50	10098.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$893.89
GF	3 & 4	1.28	732.00	61736.00	1000	Simple Bioretention	$12,210.00	$340.76	$15,617.64	$750.00	$990.33
GF	13	0.39	267.02	7842.00	250	Complex Bioretnetion	$4,710.00	$936.17	$7,050.43	$187.50	$1,074.42
GF	14	0.39	272.58	6367.00	250	Complex Bioretnetion	$4,710.00	$936.17	$7,050.43	$187.50	$1,077.43
GF	10	0.34	129.40	10093.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,183.78
GF	9	0.33	132.39	8497.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,204.59
GF	11	0.32	125.50	9684.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,236.82
GF	1,2,3,4	1.90	1408.10	96812.00	2000	Permeable and Bioretention	$26,420.00	$205.59	$30,531.80	$1,500.00	$1,327.91
GF	24-27	0.78	508.00	42797.00	1000	Moderately Complex Bioretention	$15,210.00	$340.76	$18,617.64	$750.00	$1,763.95
GF	17	0.19	120.80	10479.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$2,097.70
GF	15	0.19	120.10	10450.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$2,125.74
GF	1 & 2	0.61	676.10	35076.00	1000	Permeable Asphalt	$14,210.00	$340.76	$17,617.64	$750.00	$2,181.49
GF	18, 19, 20	0.43	283.10	24443.00	750	Moderately Complex Bioretention	$11,460.00	$420.27	$14,612.06	$562.50	$2,439.16
GF	16	0.13	93.37	8188.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$3,043.75
GF	21	0.22	210.50	13547.00	500	Permeable Asphalt	$7,210.00	$564.81	$10,034.06	$375.00	$3,232.20
GF	12	0.25	71.98	9192.00	800	Dry Sw ale	$5,490.00	$400.96	$8,697.68	$600.00	$3,559.69
GF	23	0.11	73.18	7037.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$3,767.19


Wilkenson Stream
Black Lake
Gilfillan
Bioretention
Bioretention - Eng Soils - Underdrain
Bioretention - Eng Soils - Underdrain - Ret Wall
Perm Asphalt
Water Quality Swale

Wilkinson Lake

DESCRIPTION

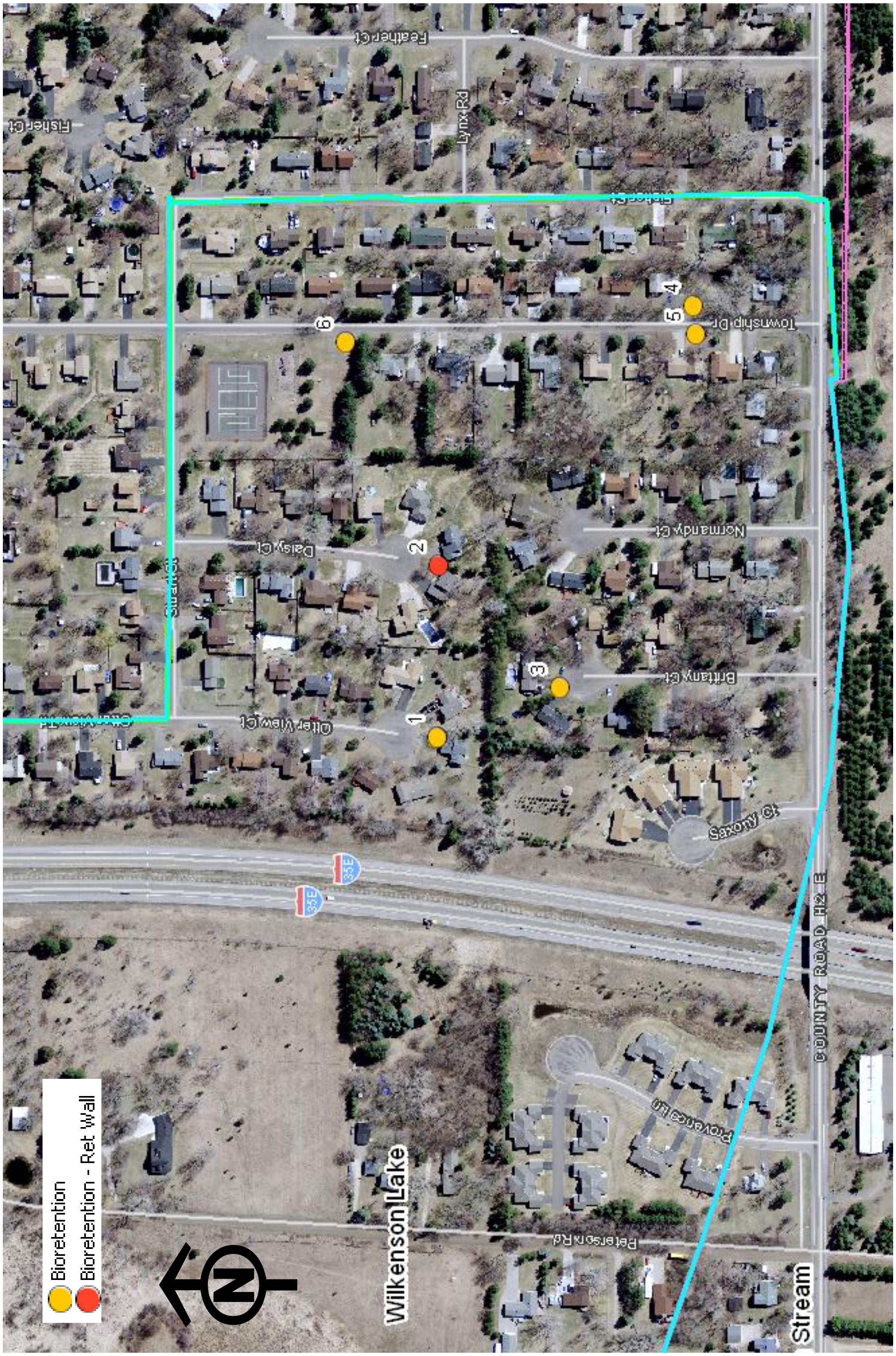
Over half of this catchment, mainly the west side, consists of open space. The eastern portion of the catchment along the 35E and Centerville Road corridor consists of low density residential single family housing, commercial and light industrial land use. A series of wetlands, ditches and stormwater ponds exist within this catchment, contributing runoff to Wilkinson Lake. The soils within the area where retrofit opportunities were identified consists of Zimmerman and Soderville loamy fine sand which would allow for simple bioretention if found to not be compacted or polluted.

Existing Catchment Summary	
Acres	910.68
TP (lbs/yr)	428.40
TP(lbs)/Acre/Yr	0.47

RETROFIT RECOMMENDATION

During the reconnaissance process it was found that the commercial/industrial area and townhomes located in the north east corner of the catchment were receiving adequate treatment before draining in to Wilkinson Lake. In addition, according to VLAWMO staff a storm sampler collecting water quality samples that drain from this area have also shown that the runoff is receiving treatment upstream before entering Wilkinson Lake. A neighborhood in the south east corner of the catchment was identified as a potential location for a cluster of six simple bioretention cells. This neighborhood receives little treatment before it drains in to a ditch system connected to the south east corner of the wetland complex attached to Wilkinson Lake. If all six bioretention cells are installed at around 250 square feet each it is calculated that 5.3 lbs of TP would be removed from the catchment resulting in a 1.2% decrease from the base load at an initial total project cost of $22,013.

Catchment	Site ID	TP (lb/yr)	TSS (lb/yr)	Volume (cubic-feet/yr)	Size (sq ft)	BMP Type	Materials/ Labor/Design	Unit Promotion & Admin Costs*	Total Project Cost**	Annual O&M	Term Cost/lb/yr (30 yr)
WL	1 - 6	5.30	1769.00	100497.00	1500	Simple Bioretention	$18,210.00	$253.56	$22,013.42	$1,125.00	$350.71


Bioretention
Bioretention - Ret Wall
N
Wilkenson Lake
Stream
COUNTY ROAD H2 E
35E
Feather Ct
Fisher Ct
Lynx Rd
Township Dr
Normandy Ct
Daisy Ct
Brittany Ct
Otter View Ct
Saxony Ct
Provence Ln
Peterson Rd
1
2
3
4
5
6

Wilkinson Stream

DESCRIPTION

A large portion of this catchment is comprised of open space consisting of lowlands, wetlands and buffers. The southern portion of the catchment consists of low to medium density residential single family housing, commercial and light industrial land use. A series of wetlands, ditches and stormwater ponds exist within this catchment, contributing runoff to Tamarack and Fish Lake. The soils within the area where retrofit opportunities were identified consist of Urban land-Zimmerman complex and Anoka and Lino loamy fine sand which would allow for simple bioretention complex if found to not be compacted or polluted.

Existing Catchment Summary	
Acres	1398.49
TP (lbs/yr)	681.20
TP(lbs)/Acre/Yr	0.49

RETROFIT RECOMMENDATION

Many stormwater ponds exist to capture runoff from sites around the 35E corridor within this catchment. Although the pond specifications were not modeled it is assumed that they are adequately sized to treat the runoff from these sites. If water quality monitoring in this area suggests otherwise these ponds should be assessed to determine if they should be cleaned or resized to increase capacity. Two areas in the north east corner of the catchment were found to have little treatment before entering ditch systems that are connected to the wetland complex attached to Tamarack and Fish Lakes. A cluster of eight bioretention cell locations were identified in the neighborhood along Lakeview Avenue and Hennessy Vis in the east corner of the catchment. Two locations to retrofit permeable asphalt were identified within a commercial warehouses parking lot. The runoff from this area was causiong noticeable erosion problems before it entered the ditch system. If all retrofits are installed within this catchment it is calculated that 7.63 lbs of TP would be removed from the catchment resulting in a 1.1% decrease from the base load at an initial total project cost of $45,939.

Catchment	Site ID	TP (lb/yr)	TSS (lb/yr)	Volume (cubic-feet/yr)	Size (sq ft)	BMP Type	Materials/Labor/Design	Unit Promotion & Admin Costs*	Total Project Cost**	Annual O&M	Term Cost/lb/yr (30 yr)
WS	1 - 6	6.90	2316.00	132211.00	2000	Simple Bioretention	$24,210.00	$205.59	$28,321.80	$1,500.00	$354.21
WS	9, 10	0.73	956.90	39304.00	1000	Permeable Asphalt	$14,210.00	$340.76	$17,617.64	$750.00	$1,824.36


Bioretention
Perm Asphalt
N
STILLWATER ST
Cottage Ln
Seneca Trl
Cottage Ln
Lakeview Ave
Hennessy Vis
Garden Ln
1
2
3
4
5
6
7
8
9
10
Wilkenson Stream
OTTER LAKE RD
9th St
9TH

Overall Retrofit Results

In the list provided below are all of the retrofit opportunities ranked from lowest to highest term cost for every catchment within the Gilfillan Tamarack Wilkinson Subwatershed. From the three catchments studied within the watershed, 23 retrofit locations were identified.

Catchment	Site ID	TP (lb/yr)	TSS (lb/yr)	Volume (cubic-feet/yr)	Size (sq ft)	BMP Type	Materials/Labor/Design	Unit Promotion & Admin Costs*	Total Project Cost**	Annual O&M	Term Cost/lb/yr (30 yr)
WL	1 - 6	5.30	1769.00	100497.00	1500	Simple Bioretention	$18,210.00	$253.56	$22,013.42	$1,125.00	$350.71
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GF	7	0.80	338.97	5042.80	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$498.95
GF	8	0.79	298.40	8339.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$504.08
GF	5 & 6	0.90	324.90	21747.00	500	Simple Bioretention	$6,210.00	$564.81	$9,034.06	$375.00	$754.03
GF	22	0.44	230.50	10098.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$893.89
GF	3 & 4	1.28	732.00	61736.00	1000	Simple Bioretention	$12,210.00	$340.76	$15,617.64	$750.00	$990.33
GF	13	0.39	267.02	7842.00	250	Complex Bioretnetion	$4,710.00	$936.17	$7,050.43	$187.50	$1,074.42
GF	14	0.39	272.58	6367.00	250	Complex Bioretnetion	$4,710.00	$936.17	$7,050.43	$187.50	$1,077.43
GF	10	0.34	129.40	10093.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,183.78
GF	9	0.33	132.39	8497.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,204.59
GF	11	0.32	125.50	9684.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$1,236.82
GF	1,2,3,4	1.90	1408.10	96812.00	2000	Permeable and Bioretention	$26,420.00	$205.59	$30,531.80	$1,500.00	$1,327.91
GF	24-27	0.78	508.00	42797.00	1000	Moderately Complex Bioretention	$15,210.00	$340.76	$18,617.64	$750.00	$1,763.95

Table continued on page 20

Catchment	Site ID	TP (lb/yr)	TSS (lb/yr)	Volume (cubic-feet/yr)	Size (sq ft)	BMP Type	Materials/Labor/Design	Unit Promotion & Admin Costs*	Total Project Cost**	Annual O&M	Term Cost/lb/yr (30 yr)
WS	9, 10	0.73	956.90	39304.00	1000	Permeable Asphalt	$14,210.00	$340.76	$17,617.64	$750.00	$1,824.36
GF	17	0.19	120.80	10479.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$2,097.70
GF	15	0.19	120.10	10450.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$2,125.74
GF	1 & 2	0.61	676.10	35076.00	1000	Permeable Asphalt	$14,210.00	$340.76	$17,617.64	$750.00	$2,181.49
GF	18, 19, 20	0.43	283.10	24443.00	750	Moderately Complex Bioretention	$11,460.00	$420.27	$14,612.06	$562.50	$2,439.16
GF	16	0.13	93.37	8188.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$3,043.75
GF	21	0.22	210.50	13547.00	500	Permeable Asphalt	$7,210.00	$564.81	$10,034.06	$375.00	$3,232.20
GF	12	0.25	71.98	9192.00	800	Dry Swale	$5,490.00	$400.96	$8,697.68	$600.00	$3,559.69
GF	23	0.11	73.18	7037.00	250	Moderately Complex Bioretention	$3,960.00	$936.17	$6,300.43	$187.50	$3,767.19

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Appendix A.

WINSLAMM modeling parameters and files used in the assessment

File Name	Date Created/ Last Modified	Created By	Description
"CPZ:" These files contain the sediment particle size distributions developed from monitored data. The files area used in the evaluation of control practices that rely upon particle settling for pollution control.			
NURP.CPZ	5/16/88	Pitt/UA	Summarizes NURP outfall particle size data
"PPD" (Pollutant Probability Distribution) files describe the pollutant concentrations found in source areas.			
WI_GEO01.ppd	11/26/02	Horwatich/USGS	USGS/DNR pollutant probability distribution file from Wisconsin monitoring data.
"PRR" (Particulate Residue Reduction) files describe the fraction of total particulates that remains in the drainage system (curbs and gutters, grass swales, and storm drainage) after rain events end due to deposition. This fraction of the total particulates does not reach the outfall, so the outfall values are reduced by the fraction indicated in the .PRR file.			
WI_DLV01.prr	7/8/01	Horwatich/USGS	USGS/DNR particulate residue reduction file for the delivery system from Wisconsin monitoring data.
"RSV" (Runoff coefficient file). These coefficients, when multiplied by rain depths, land use source areas, and a conversion factor, determine the runoff volumes needed by WinSLAMM.			
WI_SL06 Dec06.rsv	12/18/06	Horwatich/USGS	USGS/DNR runoff volumetric coefficient file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0.
"STD" (Street Delivery File): These files describe the fraction of total particulates that are washed from the streets during rains, but are subsequently redeposited due to lack of energy in the flowing water.			
WI_Com Inst Indust Dec06.std	12/12/06	Horwatich/USGS	USGS/DNR street delivery file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0 for Industrial, Commercial and Institutional land uses.
WI_Res and Other Urban Dec06.std	12/07/06	Horwatich/USGS	USGS/DNR street delivery file from Wisconsin monitoring data. Use for all versions of WinSLAMM starting from v 9.2.0 for Residential and Other Urban land uses.
Freeway Dec06.std	7/12/05	Pitt/UA	Street delivery file developed to account for TSS reductions due to losses in a freeway delivery system based upon early USDOT research. Renamed Freeway.std
"PSC" (Particulate Solids Concentration): Values in this file, when multiplied by source area runoff volumes and a conversion factor, calculate particulate solids loadings (lbs).			
WI_AVG01.psc	11/26/02	Horwatich/USGS	USGS/DNR particulate solids concentration file from Wisconsin monitoring data.
"RAN" (Rain Files):			
MN Minneapolis 59.RAN	NA	NA	A n event-record of rainfall for the year 1959, considered as an average year, in the form of Start Date, Start Time, End Date, End Time and Rainfall (in inches).
Settings			
Parameter	**Description**		
Start/End Date	Defines the modeling period in reference to the rain file data. In this case, the entire one year period was selected (i.e., 01/02/59-12/28/59).		
Winter Season Range	Set to begin on November 7th and end on March 17th.		
Drainage System	Set to "Curb and gutter, valleys, or sealed swales in fair condition.		

WINSLAMM Standard Land Use Codes

RESIDENTIAL LAND USES

- High Density Residential without Alleys (HDRNA): Urban single family housing at a density of greater than 6 units/acre. Includes house, driveway, yards, sidewalks, and streets.
- High Density Residential with Alleys (HDRWA): Same as HDRNA, except alleys exist behind the houses.
- Medium Density Residential without Alleys (MDRNA): Same as HDRNA except the density is between 2 - 6 units/acre.
- Medium Density Residential with Alleys (MDRWA): Same as HDRWA, except alleys exists behind the houses.
- Low Density Residential (LDR): Same as HDRNA except the density is 0.7 to 2 units/acre.
- Duplexes (DUP): Housing having two separate units in a single building.
- Multiple Family Residential (MFRNA): Housing for three or more families, from 1 - 3 stories in height. Units may be adjoined up-and-down, side-by-side; or front-and-rear. Includes building, yard, parking lot, and driveways. Does not include alleys.
- High Rise Residential (HRR): Same MFRNA except buildings are High Rise Apartments; multiple family units 4 or more stories in height.
- Mobile Home Park (MOBH): A mobile home or trailer park, includes all vehicle homes, the yard, driveway, and office area.
- Suburban (SUB): Same as HDRNA except the density is between 0.2 and 0.6 units/acre.

COMMERCIAL LAND USES

- Strip Commercial (SCOM): Those buildings for which the primary function involves the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, courthouses, and fire and police stations. This category does not include buildings used for the manufacture of goods or warehouses. This land use includes the buildings, parking lots, and streets. This land use does not include nursery, tree farms, vehicle service areas, or lumber yards.
- Shopping Centers (SHOP): Commercial areas where the related parking lot is at least 2.5 times the area of the building roof area. Parking areas usually surrounds the buildings in this land use. This land use includes the buildings, parking lot, and streets.
- Office Parks (OFPK): Land use where non-retail business takes place. The buildings are usually multi storied buildings surrounded by larger areas of lawn and other landscaping. This land use includes the buildings, lawn, and road areas. Types of establishments that may be in this category includes: insurance offices, government buildings, and company headquarters.
- Commercial Downtown (CDT): Multi-story high-density area with minimal pervious area, and with retail, residential and office uses.

INDUSTRIAL LAND USES

- Medium Industrial (MI): This category includes businesses such as lumber yards, auto salvage yards, junk yards, grain elevators, agricultural coops, oil tank farms, coal and salt storage areas, slaughter houses, and areas for bulk storage of fertilizers.

- Non-Manufacturing (LI): Those buildings that are used for the storage and/or distribution of goods waiting further processing or sale to retailers. This category mostly includes warehouses, and wholesalers where all operations are conducted indoors, but with truck loading and transfer operations conducted outside.

INSTITUTIONAL LAND USES

- Education (SCH): Includes any public or private primary, secondary, or college educational institutional grounds. Includes buildings, playgrounds, athletic fields, roads, parking lots, and lawn areas.
- Miscellaneous Institutional (INST): Churches and large areas of institutional property not part of CST and CDT.
- Hospital (HOSP): Multi-story building surrounded by parking lots and some vegetated areas.

OTHER URBAN LAND USES

- Parks (PARK): Outdoor recreational areas including municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas.
- Undeveloped (OSUD): Lands that are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, urban fringe areas slated for development, greenways, and forest areas.
- Cemetery (CEM): This land use file covers cemeteries, and includes road frontage along the cemetery, and paved areas and buildings within the cemetery.

FREEWAY LAND USES

- Freeways (FREE): Limited access highways and the interchange areas, including any vegetated rights-of-ways.

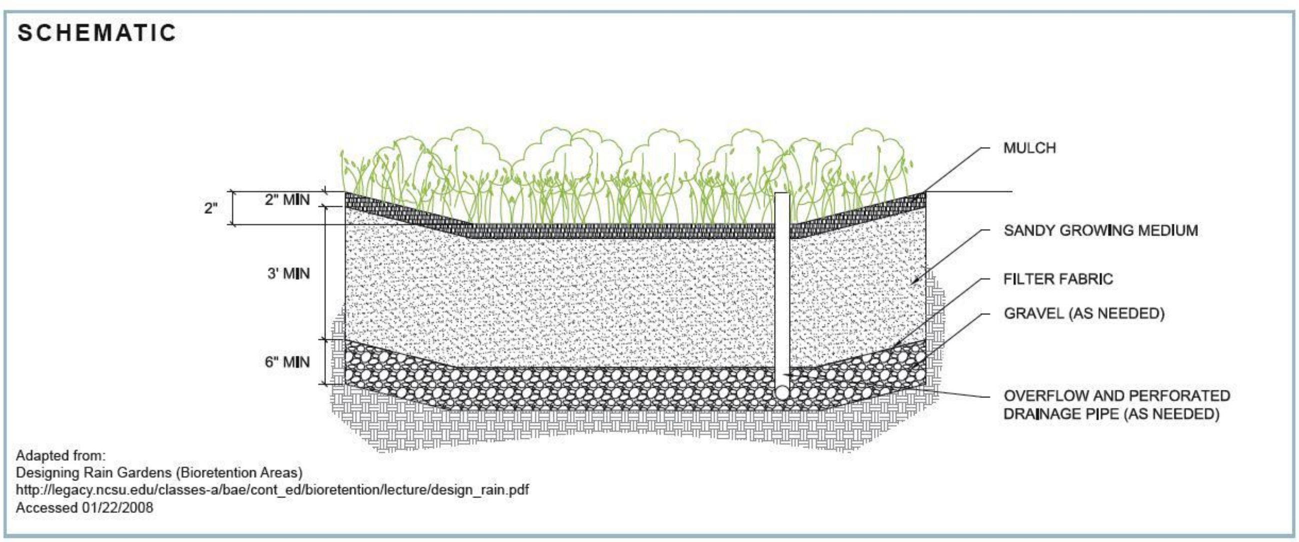
Appendix B.

Bioretention:

Curb cut raingarden, with 1.5-2ft perimeter wall, in a residential area.

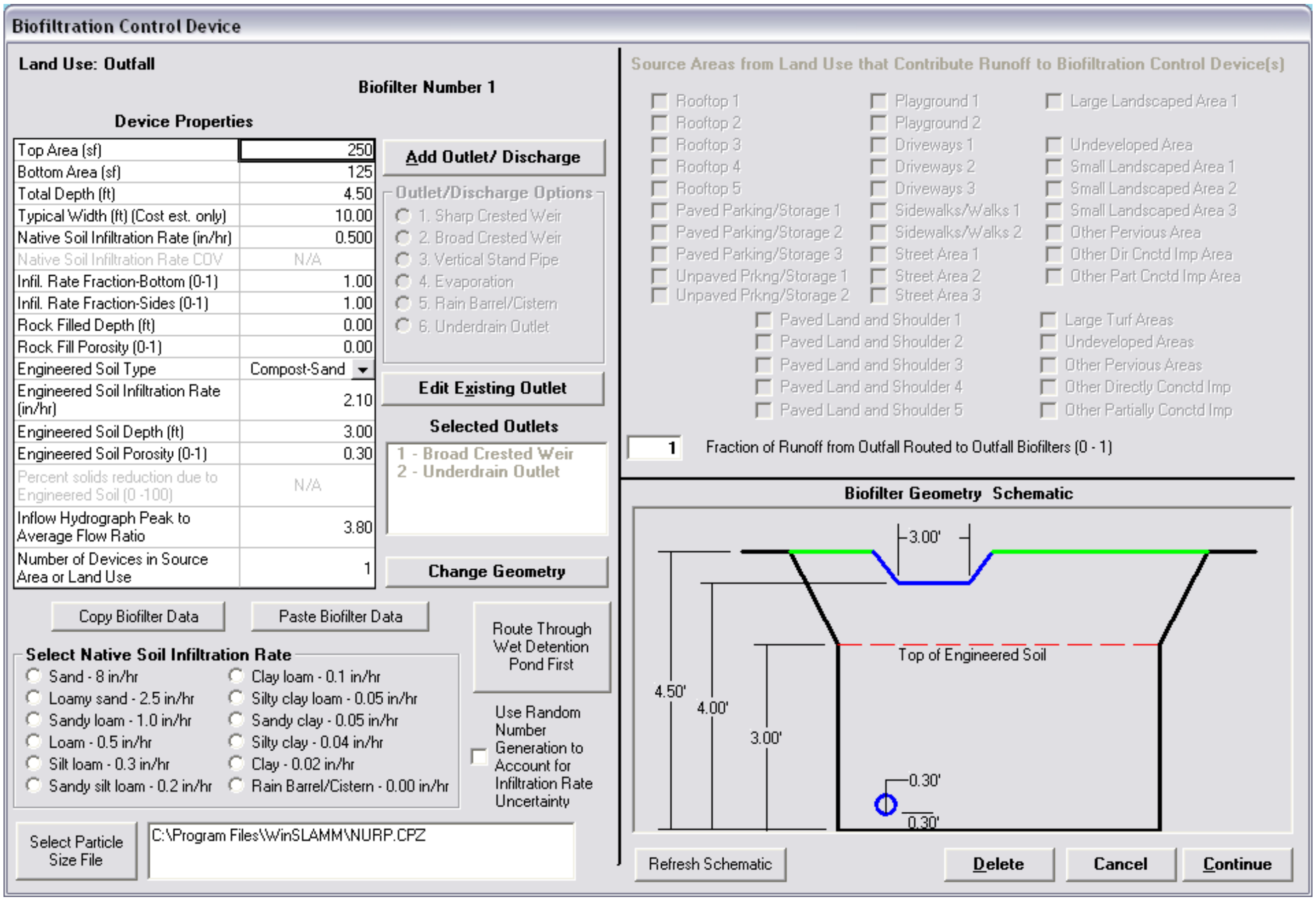
Photo Courtesy of Rusty Schmidt.

Bioretention design



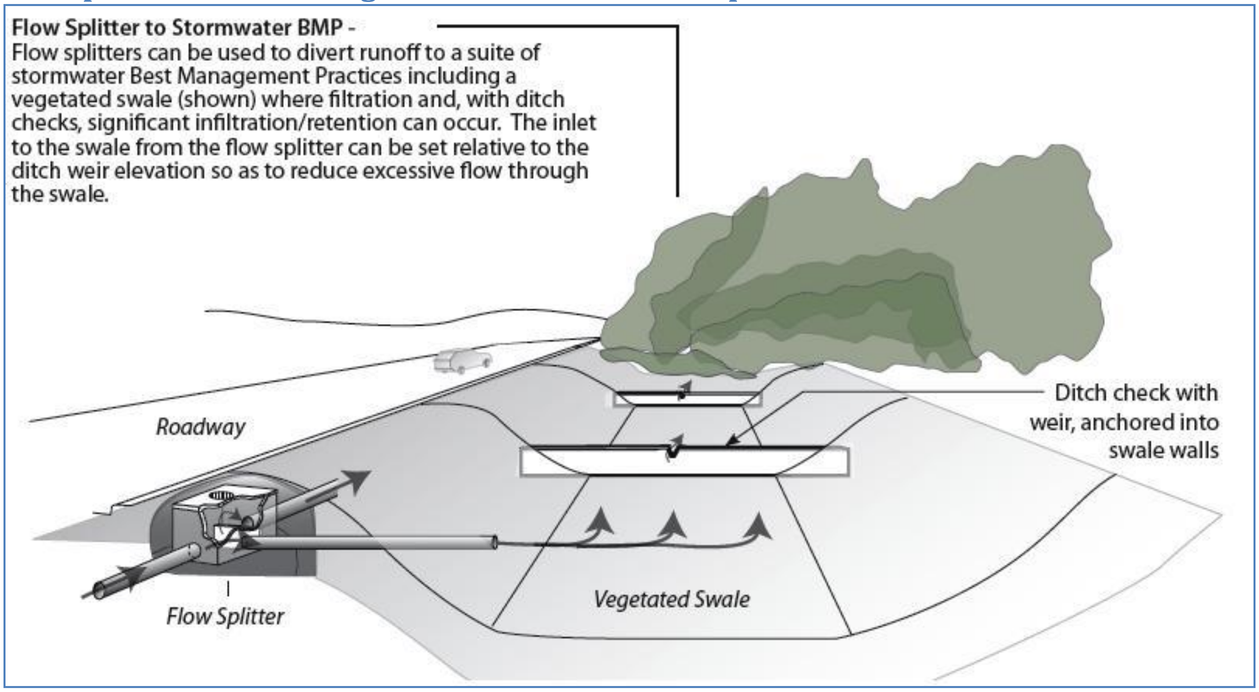
Graphic courtesy of Charles River Watershed Association, Weston, MA. www.charlesriver.org.

WinSLAMM Bioinfiltration Control Device parameters



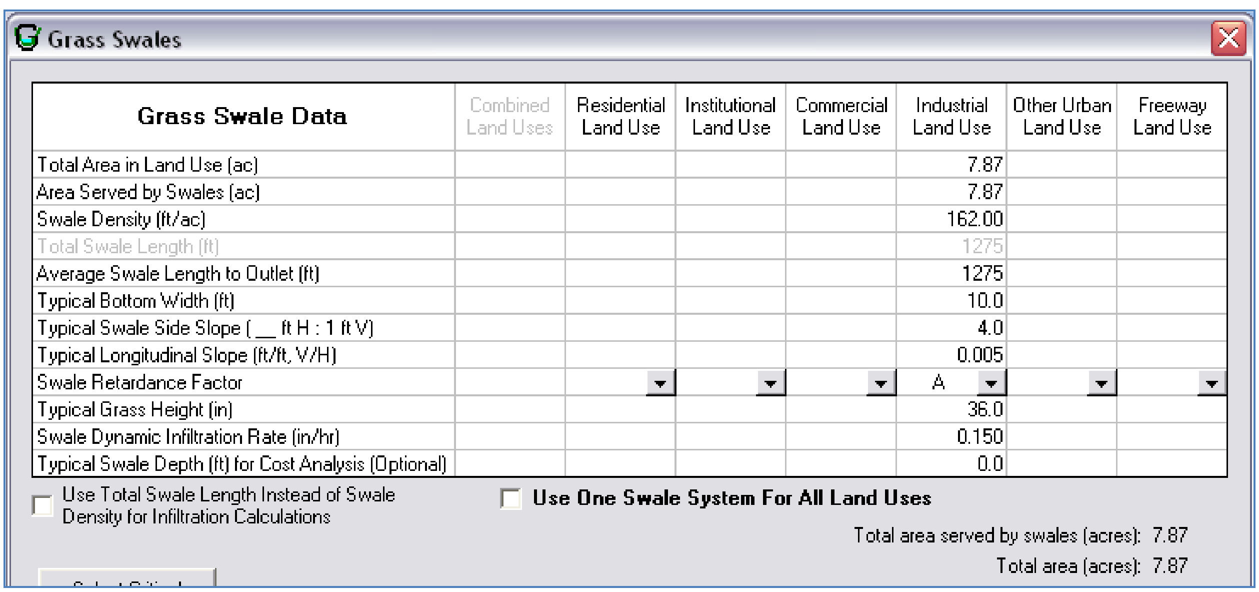
Dry Swales

Example schematic of vegetated swale with flow splitter



Graphic courtesy of Anoka Conservation District in Association with the Metropolitan Conservation Districts

WinSLAMM Grass Swales parameters



Grass Swales

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)					7.87		
Area Served by Swales (ac)					7.87		
Swale Density (ft/ac)					162.00		
Total Swale Length (ft)					1275		
Average Swale Length to Outlet (ft)					1275		
Typical Bottom Width (ft)					10.0		
Typical Swale Side Slope (__ ft H : 1 ft V)					4.0		
Typical Longitudinal Slope (ft/ft, V/H)					0.005		
Swale Retardance Factor					A		
Typical Grass Height (in)					36.0		
Swale Dynamic Infiltration Rate (in/hr)					0.150		
Typical Swale Depth (ft) for Cost Analysis (Optional)					0.0		

Use Total Swale Length Instead of Swale Density for Infiltration Calculations

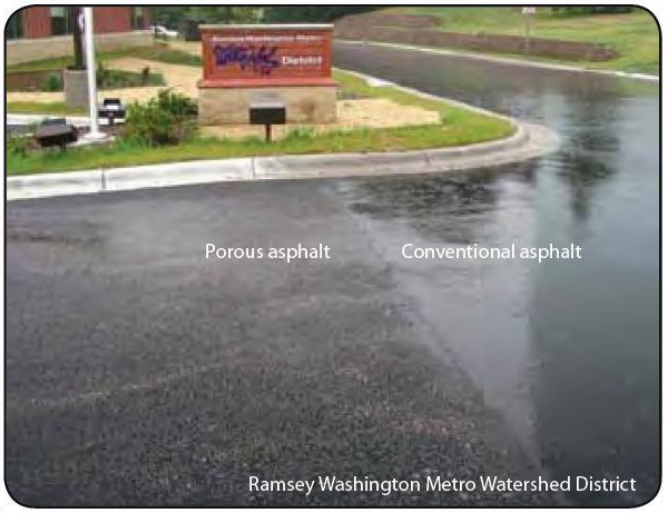
Use One Swale System For All Land Uses

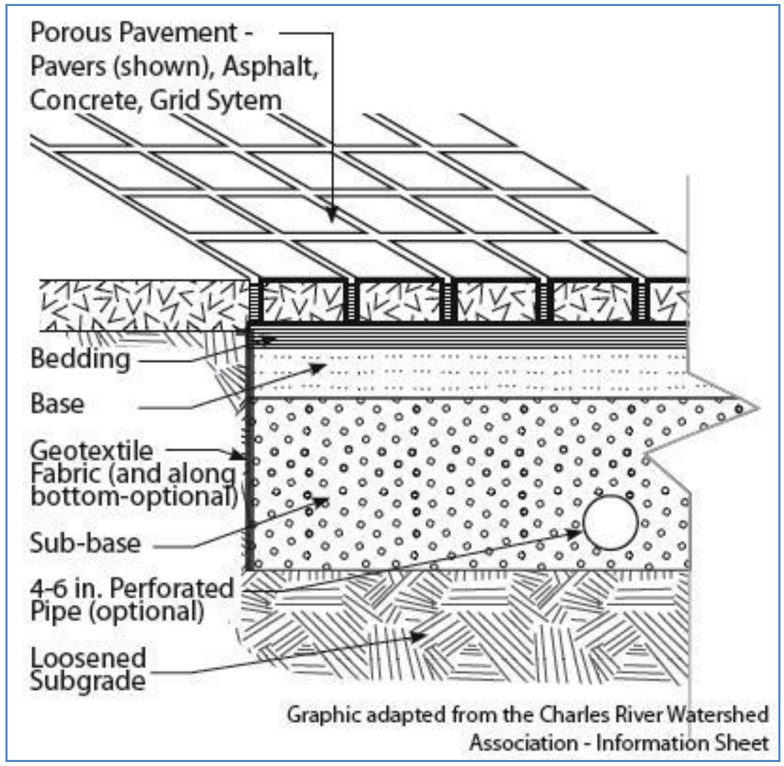
Total area served by swales (acres): 7.87

Total area (acres): 7.87

Permeable Asphalt

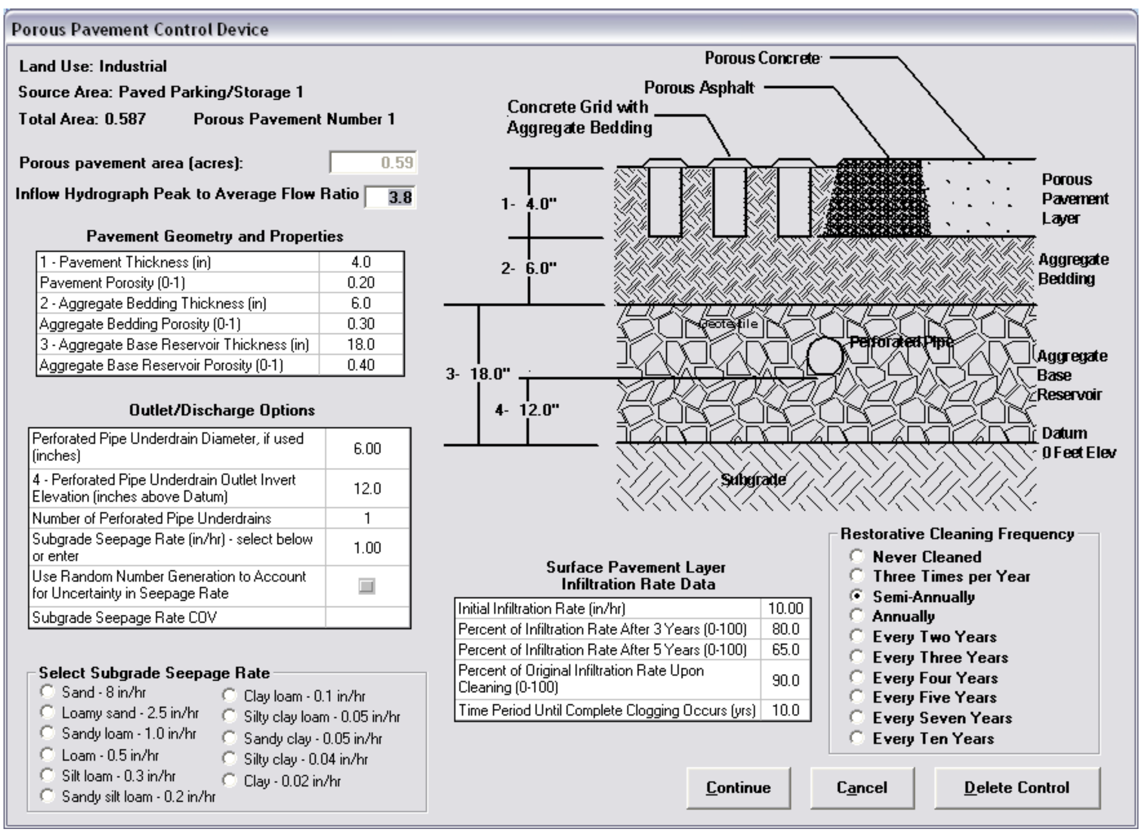
Example schematic & picture of permeable asphalt





Graphic courtesy of Anoka Conservation District in Association with the Metropolitan Conservation Districts

WinSLAMM Porous Pavement Control Device parameters



Porous Pavement Control Device

Land Use: Industrial
Source Area: Paved Parking/Storage 1
Total Area: 0.587 Porous Pavement Number 1

Porous pavement area (acres): 0.59
Inflow Hydrograph Peak to Average Flow Ratio 3.8

Pavement Geometry and Properties

1 - Pavement Thickness (in)	4.0
Pavement Porosity (0-1)	0.20
2 - Aggregate Bedding Thickness (in)	6.0
Aggregate Bedding Porosity (0-1)	0.30
3 - Aggregate Base Reservoir Thickness (in)	18.0
Aggregate Base Reservoir Porosity (0-1)	0.40

Outlet/Discharge Options

Perforated Pipe Underdrain Diameter, if used (inches)	6.00
4 - Perforated Pipe Underdrain Outlet Invert Elevation (inches above Datum)	12.0
Number of Perforated Pipe Underdrains	1
Subgrade Seepage Rate (in/hr) - select below or enter	1.00
Use Random Number Generation to Account for Uncertainty in Seepage Rate	
Subgrade Seepage Rate COV	

Select Subgrade Seepage Rate
- Sand - 8 in/hr
- Loamy sand - 2.5 in/hr
- Sandy loam - 1.0 in/hr
- Loam - 0.5 in/hr
- Silt loam - 0.3 in/hr
- Sandy silt loam - 0.2 in/hr
- Clay loam - 0.1 in/hr
- Silty clay loam - 0.05 in/hr
- Sandy clay - 0.05 in/hr
- Silty clay - 0.04 in/hr
- Clay - 0.02 in/hr

Surface Pavement Layer Infiltration Rate Data

Initial Infiltration Rate (in/hr)	10.00
Percent of Infiltration Rate After 3 Years (0-100)	80.0
Percent of Infiltration Rate After 5 Years (0-100)	65.0
Percent of Original Infiltration Rate Upon Cleaning (0-100)	90.0
Time Period Until Complete Clogging Occurs (yrs)	10.0

Restorative Cleaning Frequency
- Never Cleaned
- Three Times per Year
- Semi-Annually (selected)
- Annually
- Every Two Years
- Every Three Years
- Every Four Years
- Every Five Years
- Every Seven Years
- Every Ten Years

Continue | Cancel | Delete Control