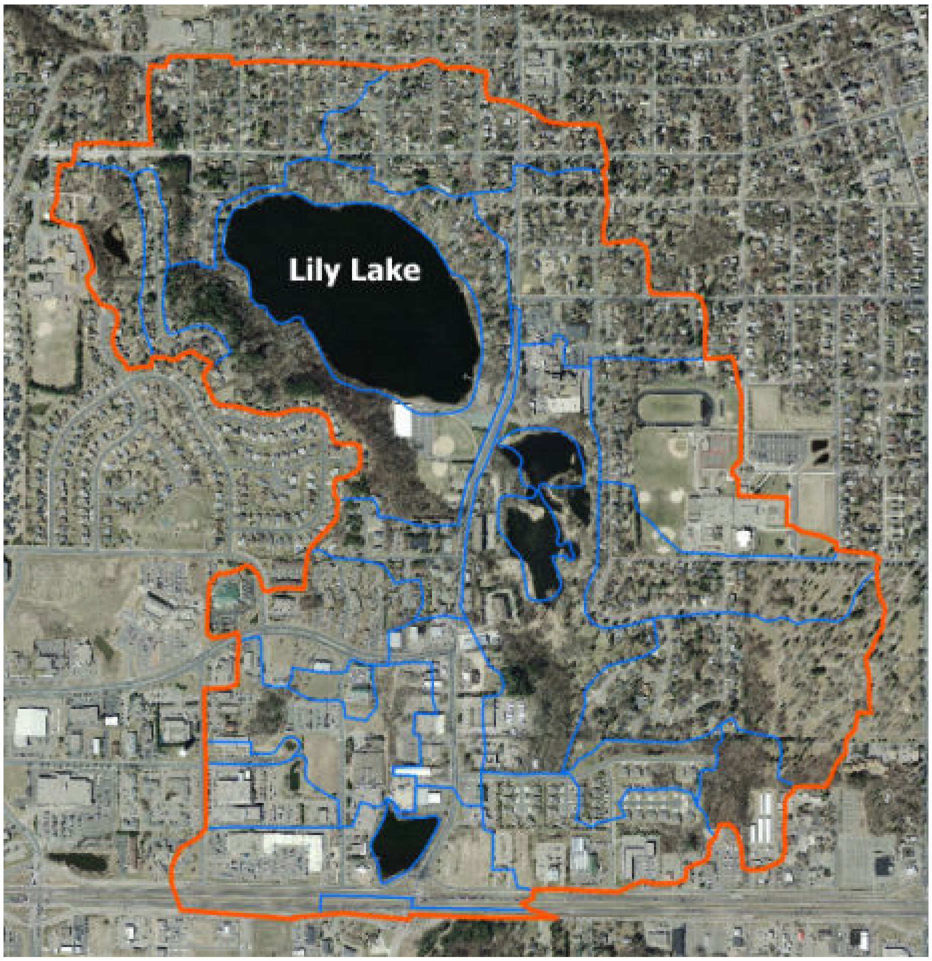
Lily Lake

Stormwater Retrofit Assessment



Prepared by:

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With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

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This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits that address the goals of the Local Governing Unit (LGU) and stakeholder partners. This document should be considered as *one part* of an overall watershed restoration plan including educational outreach, stream repair, riparian zone management, discharge prevention, upland native plant community restoration, and pollutant source control. The methods and analysis behind this document attempt to provide a sufficient level of detail to rapidly assess subwatersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology is appropriate for *initial assessment* applications. 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, agricultural and range land management, good housekeeping outreach and education, and others, within existing or future watershed restoration planning.

The assessment's background information is discussed followed by a summary of the assessment's results; the methods used and catchment profile sheets of selected sites for retrofit consideration. Lastly, the retrofit ranking criteria and results are discussed and source references are provided.

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 are then made between catchments to determine where best to initialize final retrofit design efforts and implement BMP projects. Site-specific design sets (driven by existing limitations of the landscape and its effect on design element selections) will need to be developed to determine a more refined estimate of the reported pollutant removal amounts reported in this report. This typically occurs after committed partnerships are developed for each specific target property for which BMPs are planned.

Executive Summary

The 22 catchments of the Lily Lake subwatershed, and their existing stormwater management practices, were analyzed for annual pollutant loading. Stormwater practice options were compared for each catchment, depending on specific site constraints and characteristics. Potential stormwater BMP retrofits were selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City of Stillwater and Middle St. Croix Watershed Management Organization (MSCWMO). Twelve of the 29 catchments were selected and modeled at various levels of treatment efficiency. These 12 catchments should be considered the "low-hanging-fruit" within the Lily Lake Subwatershed.

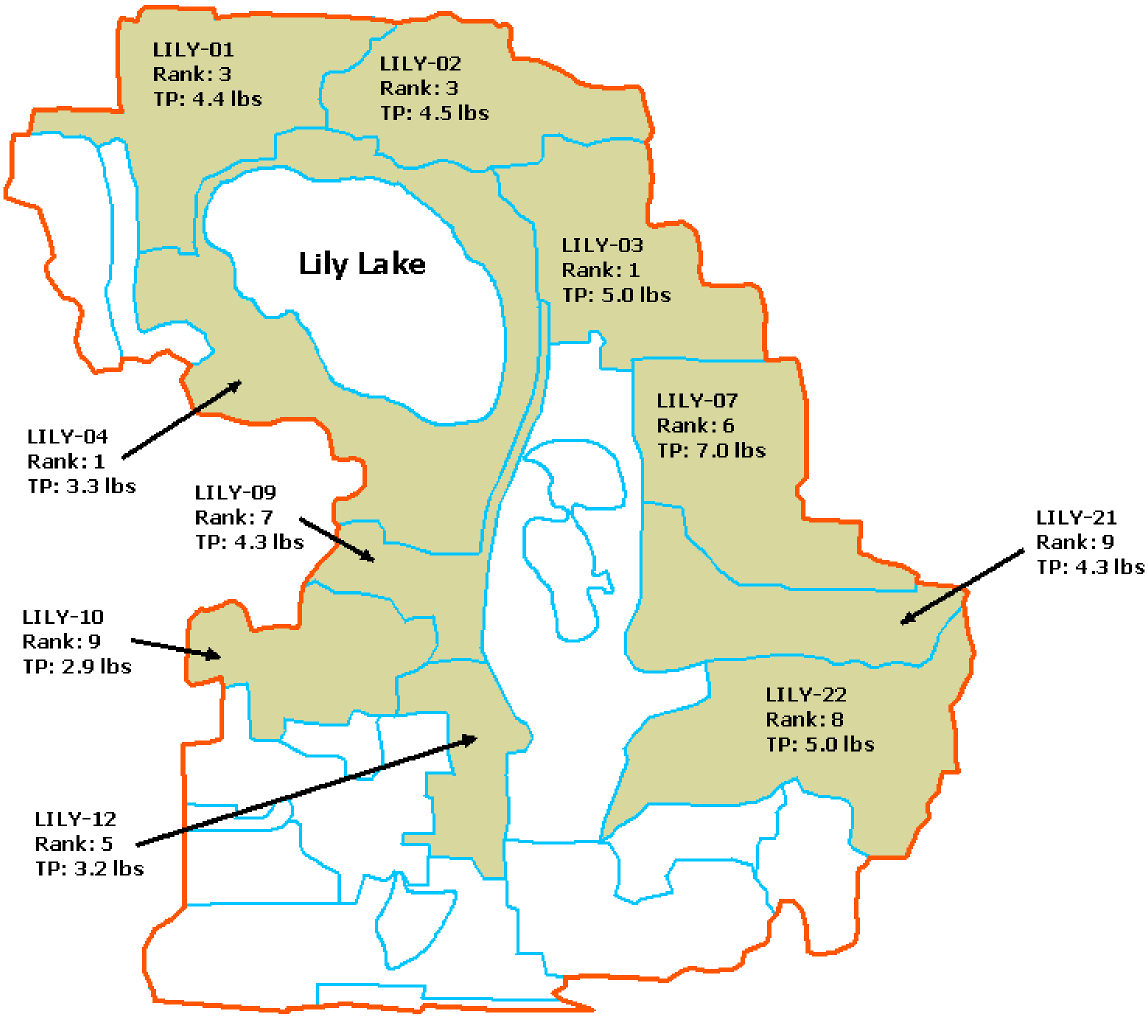
Lily Lake is demonstrating signs of eutrophication, driven by increased phosphorus loading from the contributing subwatershed (Wenck Associates, Inc., 2007). Total phosphorus (TP) is therefore the major target pollutant within the Lily Lake subwatershed. Reducing the annual TP loading to the lake by 145 pounds will allow the lake to meet desired TP concentrations. Treatment levels (percent reduction rates) listed below for retrofit projects that resulted in prohibitive BMP size/number or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal BMP location within the catchment and total BMP area. The recommended treatment levels/amounts summarized here are based on a subjective assessment of potential BMP installations, considering estimated public participation and site constraints. Recommended catchment rankings are based on a relative comparison of the cost per pound of phosphorus reduced over the life of the BMPs. A TP reduction of 93.9 pounds (65% of the target reduction) could be achieved for a total cost of $568,087 if recommended BMPs are installed within the top 12 ranked catchments according the table below.

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
LILY-03	B	1,244	10	5.0	4.0	$18,951	30	$313	1
LILY-04	B, PS, VS	773	10	3.3	2.9	$13,552	30	$313	1
LILY-02	B	1,124	10	4.5	3.7	$17,173	30	$315	3
LILY-01	B	1,100	10	4.4	3.6	$16,818	30	$315	3
LILY-12	B	797	10	3.2	2.5	$12,357	30	$316	5
LILY-07	B, VS	1,965	20	7.0	5.8	$22,283	30	$318	6
LILY-09	B	1,151	20	4.3	3.6	$17,573	30	$337	7
LILY-22	B	1,400	20	5.0	4.2	$21,267	30	$352	8
LILY-21	B	1,208	20	4.3	3.6	$18,417	30	$353	9
LILY-10	B, PS, F	713	10	2.9	2.4	$14,696	30	$353	9
[2]P13-W	WD	n/a	50	20	0	$130,000	15	$433	11
[2]P18-W	WD	n/a	50	30	0	$265,000	15	$589	12
TOTAL	-	-	-	**93.9**	**36.3**	**$568,087**	-	-	-

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc.)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = Wet Detention or wetland creation (new pond)

[1]Estimated overall costs include design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 30 years of operation and maintenance costs.

[2]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007



Top-Ranked Lily Lake Catchments and TP Removal Potential

About this Document

Document Overview

The Stormwater Retrofit Assessment is a subwatershed management tool used to prioritize stormwater BMP retrofit projects based on BMP performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four main sections that describe the general methods used, individual catchment profiles, a retrofit ranking for the subwatershed, and references used in the assessment protocol. The Appendices section provides additional information relevant to the assessment.

Under each section and subsection, project-specific information relevant to that portion of the assessment is provided with an ***Italicized Heading***.

Methods

The Methods section outlines the general procedures used when assessing the subwatershed. It details the processes of retrofit scoping, desktop analysis, retrofit field reconnaissance investigation, cost/treatment analysis, and catchment ranking. The project-specific details of each procedure are defined if different from the general standard procedures.

NOTE: the financial, technical, current landscape/stormwater system, and timeframe limits and needs are highly variable from subwatershed to subwatershed. This assessment uses some, or all, of the methods described herein.

Catchment Profiles

Each catchment profile is labeled with a unique ID to coincide with the catchment name (e.g., LILY-08 for Lily Lake catchment number 8). This catchment ID is referenced when comparing results across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within each Catchment Summary/Description section is a table that summarizes basic information including catchment size, current land cover, land ownership, and estimated annual pollutant load (target pollutant(s) are specified by the LGU). A table of the principal modeling parameters and values is also reported. A brief description of the land cover, stormwater infrastructure and any other important general information is described.

Retrofit Recommendation

The Retrofit Recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why each specific retrofit option was chosen.

Cost/Treatment Analysis

A summary table provides for the direct comparison of the expected amount of treatment, within a catchment, that can be expected per invested dollar. In addition, the results of each catchment can be cross-referenced to optimize available capitol budgets vs. load reduction goals.

Site Selection

A rendered aerial photograph highlights properties/areas suitable for BMP retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for BMP project installations are identified here.

Catchment Ranking

Catchment ranking takes into account all of the information gathered during the assessment process to create a prioritized catchment list. The list is sorted by the cost per pound of phosphorus treated within each catchment for the duration of the maintenance term (conservative estimate of BMP effective life). The final cost per pound treatment value includes installation and maintenance costs. There are many possible ways to prioritize projects within catchments, and the list provided is merely a starting point. Final catchment ranking for installation may include:

- Total amount of pollutant removal
- Non-target pollutant reductions
- BMP project visibility
- Availability of funding
- Total project costs
- Educational value

References

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

Appendices

The Appendices section provides supplemental information and/or data used during the assessment protocol.

Methods

Selection of Subwatershed

Before the subwatershed stormwater assessment begins, a process of identifying a high priority water body as a target takes place. Many factors are considered when choosing which subwatershed to assess for stormwater retrofits. Water quality monitoring data, non-degradation report modeling, and TMDL studies are just a few of the resources available to help determine which water bodies are a priority. Assessments supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the assessment also rank highly.

In areas without clearly defined studies, such as TMDL or officially listed water bodies of concern, or where little or no monitoring data exist, metrics are used to score subwatersheds against each other. In large subwatersheds (e.g., greater than 2500 acres), a similar metric scoring is used to identify areas of concern, or focus areas, for a more detailed assessment. This methodology was slightly modified from Manual 2 of the *Urban Stormwater Retrofit Practices* series.

Description of Lily Lake and the Contributing Subwatershed

Lily Lake has a surface area of 35.9 acres, average depth of 18 feet, and an ordinary high water level of 844.8 feet. The lake is located within the City of Stillwater in the northeastern suburban Twin Cities metropolitan area. The Lily Lake subwatershed encompasses approximately 567 acres. Major land uses include approximately 60% residential (single or multi-family) and 10% industrial. The lake drains to Lake McKusick, which ultimately discharges to the St. Croix River. Stormwater is conveyed through a network of storm sewers, channels, and ponds. Much of the development within the subwatershed occurred prior to implementation of regulations requiring stormwater treatment, so there are several areas where minimal treatment of runoff occurs before entering the lake. The most significant phosphorus source (93% of total loading) to Lily Lake is from the contributing watershed. (*City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007)

Washington Conservation District monitors Lily Lake for total phosphorus, chlorophyll-a, Secchi disk depth (transparency), and other parameters. The lake is listed as impaired for nutrients on the Minnesota Pollution Control Agency's Impaired Waters List and currently shows no statistically significant trend (increasing or decreasing) for average total phosphorus (*MSCWMO 2009 Water Monitoring Report*, Washington Conservation District, 2010).

Phosphorus was chosen as the target pollutant of this assessment to address the lake impairment. The direct drainage area (contributing subwatershed) was chosen as the focus of this assessment. This direct drainage area contributes 93% of the phosphorus load to Lily Lake. The only other significant phosphorus source to Lily Lake is atmospheric deposition (7%). The Wenck plan sets a reduction goal of 145 pounds of phosphorus from the direct drainage area for Lily Lake. When achieved, this reduction will allow Lily Lake to meet the MPCA's standard TP concentration of 40 µg/L for deep lakes.

Subwatershed Assessment Methods

The process used for this assessment is outlined below and was modified from the Center for Watershed Protection's *Urban Stormwater Retrofit Practices,* Manuals 2 and 3 (Schueler, 2005, 2007). Locally relevant design considerations were also included into the process (*Minnesota Stormwater Manual*).

Step 1: Retrofit Scoping

Retrofit scoping includes determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involves meeting with local stormwater managers, city staff, and watershed staff to determine the issues in the subwatershed. This step also helps to define preferred retrofit treatment options and retrofit performance criteria. In order to create a manageable area to assess in large subwatersheds, a smaller focus area may be determined.

Lily Lake Subwatershed Scoping

Pollutants of concern for this subwatershed were identified as TP, TSS, and volume. Goals of the MSCWMO, WCD, and City of Stillwater were considered as well the results of the *City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake*, Wenck Associates, Inc., October 2007.

Step 2: Desktop Retrofit Analysis

Desktop retrofit analysis involves computer-based scanning of the subwatershed for potential BMP retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate and current GIS data is extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography, and storm drainage infrastructure (with invert elevations and flow direction). The following table highlights some important features to look for and the associated potential retrofit project.

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

Step 3: Retrofit Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site. 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 to eliminate sites from consideration. The field investigation revealed additional retrofit opportunities that would have gone unnoticed during the desktop search.

The following stormwater BMPs were considered for each catchment/site:

Stormwater Treated Options for Retrofitting		
Area Treated	**Best Management Practice**	**Potential Retrofit Project**
5-500 acres	Extended Detention	**12-24 hr detention of stormwater with portions drying out between events (preferred over Wet Ponds). May include multiple cells, infiltration benches, sand/peat/iron filter outlets, and modified choker outlet features.**
	Wet Ponds	**Permanent pool of standing water with new water displacing pooled water from previous event.**
	Wetlands	**Depression less than 3 feet deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.**
0.1-5 acres	Bioretention	**Use of native sol, soil microbe, and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof.**
	Filtering	**Filters runoff through engineered media and passes it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost, and iron.**
	Infiltration	**A trench or sump that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering the infiltration area.**
	Swales	**A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.**
	Other	**On-site, source-disconnect practices such as rain-leader raingardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells and permeable pavements.**

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely address pollutant reduction goals and those that may have simple design/install/maintenance considerations are chosen for a cost/benefit analysis that relatively compares catchments/sites. Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions and those that may pose a risk for upstream flooding require the assistance of a professional engineer. Conceptual designs at this phase of the design process include cost and pollution reduction estimates. Reported treatment levels are dependent upon optimal site selection and sizing.

Modeling of the site is done by one or more methods such as with P8, WINSLAMM or simple spreadsheet methods using the Rational Method. Event mean concentrations or sediment loading files (depending on data availability and model selection) are used for each catchment/site to estimate relative pollution loading of the existing conditions. The site's conceptual BMP design is modeled to then estimate varying levels of treatment by sizing and design element. This treatment model can also be used to properly size BMPs to meet LGU restoration objectives.

General P8 Model Inputs	
Parameter	**Method for Determining Value**
Total Area	**Source/Criteria**
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 are omitted from composite calculations.**
Particle/Pollutant	**The default NURP50 particle file was used.**
Sweeping Efficiency	**Unless otherwise noted, street sweeping was not accounted for.**

Lily Lake Treatment Analysis

For the Lily Lake treatment analysis, each catchment (and each relevant parcel within them) was first assessed for BMP applicability given specific site constraints and soil types. Pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, project visibility, existing landscape maintenance, available space, and other site-specific factors dictated the selection of one or more potential BMPs for each site.

P8 was used to model catchments and a hypothetical BMP located at its outfall. The BMP was sized from the 10-50% treatment size and results were tabulated in the Catchment Profile section of this document.

Cost Estimates

Each resulting BMP (by percent TP-removal dictated sizing) was then assigned estimated design, installation and first-year establishment-related maintenance costs given its total cubic feet of treatment. In cases where live storage was 1 foot deep, this number roughly related to square feet of BMP coverage. An annual cost/TP-removed for each treatment level was then calculated for the life of each BMP that includes promotional, administrative and life cycle operations, and maintenance costs.

The following table provides the BMP cost estimates used to assist in cost analysis:

Average BMP Cost Estimates						
BMP	**Median Inst. Cost (\$/ft^2)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost (\$70/hr)**	**Installation Oversight Cost (\$70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Pond Retrofits	\$3.00	\$500/ac	30	[1]40% above construction	\$210 (3 visits)	**\$4.21/ft^2**
Extended Detention	\$5.00	\$1000/ac	30	[1]\$2800/ac	\$210 (3 visits)	**\$12.02*(ft^3^0.75)**
Wet Pond	\$5.00	\$1000/ac	30	[1]\$2800/ac	\$210 (3 visits)	**\$277.89*(ft^3^0.553)**
Stormwater Wetland	\$5.00	\$1000/ac	30	[1]\$2800/ac	\$210 (3 visits)	**\$4,800*(DA ac^0.484)**
Dry Swale	\$3.00	\$0.75/ft^2	30	\$280/100 ft^2	\$210 (3 visits)	**\$6.60/ft^2**
Water Quality Swale[4]	\$12.00	\$0.75/ft^2	30	\$1120/1000 ft^2	\$210 (3 visits)	**\$13.90/ft^2**
Cisterns	\$15.00	[3]\$100	30	NA	\$210 (3 visits)	**\$16.00/ft^2**
French Drain/Dry Well	\$12.00	[3]\$100	30	20% above construction	\$210 (3 visits)	**\$15.00/ft^2**
Infiltration Basin (turf)	\$15.00	\$2000/ac	30	\$1120/ac	\$210 (3 visits)	**\$15.10/ft^2**
Rain Barrels	\$25.00	[3]\$25	30	NA	\$210 (3 visits)	**\$25.00/ft^2**

Average BMP Cost Estimates						
BMP	**Median Inst. Cost ($/ft²)**	**Marginal Annual Maintenance Cost (contracted)**	**O&M Term**	**Design Cost ($70/hr)**	**Installation Oversight Cost ($70/hr)**	**Total Installation Cost (Includes design & 1-yr maintenance)**
Structural Sand Filter (including peat, compost, iron amendments, or similar) [4]	$20.00	$250/25 ln ft	30	$300/25 ln ft	$210 (3 visits)	**$21.50/ft²**
Impervious Cover Conversion	$20.00	$500/ac	30	$1120/ac	$210 (3 visits)	**$20.10/ft²**
Stormwater Planter	$27.00	$0.75/ft²	30	20% above construction	$210 (3 visits)	**$32.20/ft²**
Rain Leader Disconnect Raingardens	$4.00	$0.25/ft²	30	[2]$280/100 ft²	$210 (3 visits)	**$7.00/ft²**
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/ft²	30	[2]$1120/1000 ft²	$210 (3 visits)	**$11.30/ft²**
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, but no retaining walls)	$12.00	$0.75/ft²	30	[2]$1120/1000 ft²	$210 (3 visits)	**$13.90/ft²**
Complex Bioretention (same as MCB, but with 1.5 to 2.5 ft partial perimeter walls)	$14.00	$0.75/ft²	30	[2]$1400/1000 ft²	$210 (3 visits)	**$16.20/ft²**

Average BMP Cost Estimates						
BMP	Median Inst. Cost ($/ft^2)	Marginal Annual Maintenance Cost (contracted)	O&M Term	Design Cost ($70/hr)	Installation Oversight Cost ($70/hr)	Total Installation Cost (Includes design & 1-yr maintenance)
Highly Complex Bioretention (same as CB, but with 2.5 to 5 ft partial perimeter walls or complete walls)	$18.00	$0.75/ft^2	30	[2]$1400/1000ft^2	$210 (3 visits)	**$19.90/ft^2**
Underground Sand Filter	$65.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$91.75/ft^2**
Stormwater Tree Pits	$70.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$98.75/ft^2**
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Asphalt (granite base)	$10.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$14.00/ft^2**
Permeable Concrete (granite base)	$12.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$17.55/ft^2**
Permeable Pavers (granite base)	$25.00	$0.75/ft^2	30	[1]40% above construction	$210 (3 visits)	**$35.75/ft^2**
Extensive Green Roof	$225.00	$500/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$315.50/ft^2**
Intensive Green Roof	$360.00	$750/1000 ft^2	30	[1]40% above construction	$210 (3 visits)	**$504.75/ft^2**

[1]May require a professional engineer. Assume engineering costs to be 40% above construction costs

[2]If multiple projects are slated, such as in a neighborhood retrofit, a design packet with templates and standard layouts, element elevations and components, planting plans and cross sections can be generalized, design costs can be reduced.

[3]Not included in total installation cost (minimal).

[4]Assumed to be 15 feet in width.

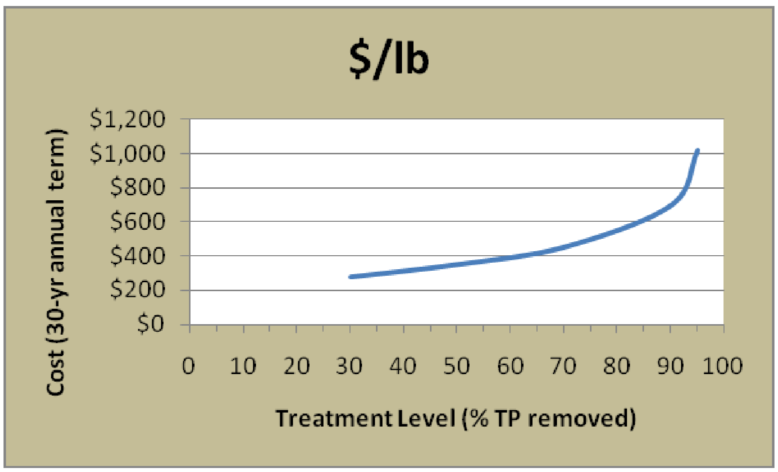
Lily Lake Cost Analysis

For the Lily Lake cost analysis, promotion and administration for each commercial/public property was estimated using a non-linear formula dependent on the surface area of BMPs, as the labor associated with outreach, education and administrative tasks typically are reduced with scale. Annual Operation & Maintenance referred to the ft^2 estimates provided in the preceding table. In cases were multiple BMP types were prescribed for an individual site, both the estimated installation and maintenance-weighted means by ft^2 of BMP were used to produce cost/benefit estimates.

Step 5: Evaluation and Ranking

The results of each site were analyzed for cost/treatment to prescribe the most cost-efficient level of treatment.

Example chart showing total phosphorus treatment vs. cost:



Lily Lake Evaluation and Ranking

In the Lily Lake evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the expected level of treatment considering public buy-in and above a minimal amount needed to justify crew mobilization and outreach efforts to the area. Should the cumulative expected load reduction of the recommended catchment treatment levels not meet LGU goals, a higher level of treatment (as described in the Catchment Profile tables) should be selected. The maps associated with each catchment show potential BMP locations as determined by field review. To meet treatment level goals for a catchment, a minimum percentage of potential BMPs (equaling or exceeding the "BMP Surface Area") must be installed within that catchment.

Catchment Profiles

The following pages provide catchment-specific information that was analyzed for stormwater BMP retrofit treatment at various levels. The recommended level of treatment reported in the Ranking Table is determined by weighing the cost-efficiency vs. site specific limitations about what is truly practical in terms of likelihood of being granted access to optimal BMP site locations, expected public buy-in (partnership), and crew mobilization in relation to BMP spatial grouping.

For development of the Lily Lake catchment profile section, 10 out of 22 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments receiving modern stormwater pond treatment, or in some cases 2 or more levels of treatment, were not modeled or further analyzed in this assessment.

LILY-01

Term Cost Rank = #3

Catchment Summary	
Acres	36.6
Dominant Land Cover	Residential
Parcels	128
Volume (acre-feet/yr)	37.4
TP (lb/yr)	43.7
TSS (lb/yr)	13,737.5

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.49
Hydraulic Conductivity (in/hr)	1.35

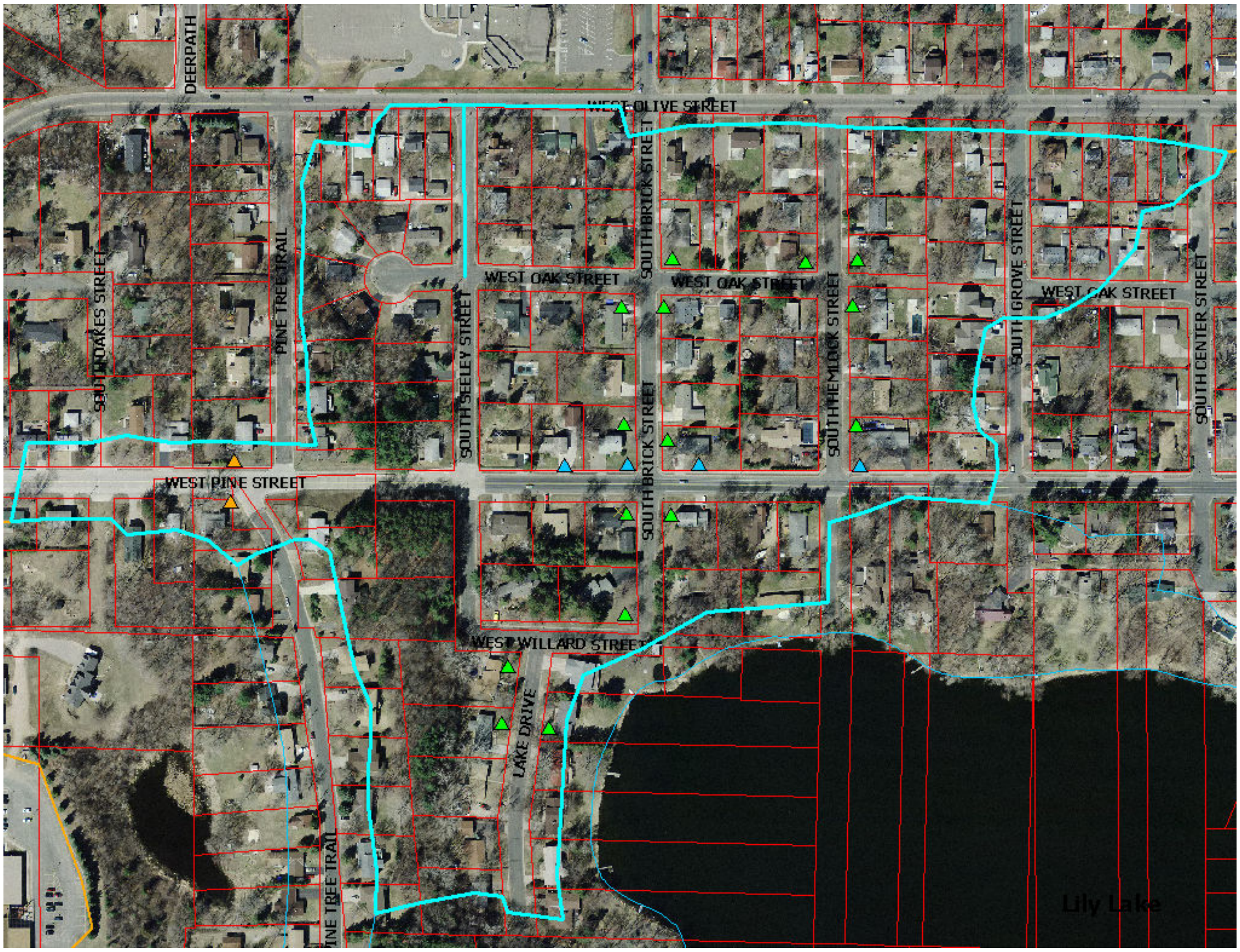
DESCRIPTION

This catchment is comprised of primarily medium-density single-family residential properties. Runoff is collected in the existing storm sewer system and discharged to the lake with little or no water quality treatment.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

A curb cut raingarden initiative within this neighborhood would work well for achieving the desired TP reduction. There are also areas where street bump-outs and curb cut box planters would be the preferred option.



Curb Cut Bioretention   Curb Cut Box Planter   Bump Out

	Cost/Benefit Analysis	***Percent TP Reduction Level***		
		30	**20**	**10**
Treatment	**TP Reduction (lb/yr)**	13.1	8.7	4.4
	TSS Reduction (lb/yr)	7,217	5,794	3,952
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	10.9	7.3	3.6
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	4,080	2,450	1,100
Costs	**Materials/Labor/Design**	$61,200	$36,750	$16,500
	Promotion & Admin Costs	$122	$177	$318
	Total Project Cost	$61,322	$36,927	$16,818
	Annual O&M	$3,060	$1,838	$825
	Term Cost/lb/yr (30 yr)	$390	$353	$315

LILY-02

Term Cost Rank = #3

Catchment Summary	
Acres	29.8
Dominant Land Cover	Residential
Parcels	129
Volume (acre-feet/yr)	38.4
TP (lb/yr)	45.0
TSS (lb/yr)	14,151.2

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.62
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment is comprised of primarily medium density, single-family residential development. Two existing curb cut raingardens exist (Intersection of Owens and Pine Streets). Runoff is collected in the existing storm sewer system and discharged to the lake with little or no water quality treatment.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

This catchment appears to be ideal for a neighborhood BMP retrofit effort. Although the 10% TP reduction level was chosen for the executive summary, the 20% level is also feasible. The term cost/lb/yr at the 20% level is $351, compared to $315 at the 10% level.

▲ Curb Cut Bioretention ▲ Curb Cut Box Planter

	Cost/Benefit Analysis	***Percent TP Reduction Level***		
		30	**20**	**10**
Treatment	**TP Reduction (lb/yr)**	13.5	9.0	4.5
	TSS Reduction (lb/yr)	7,431	5,965	4,066
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	11.2	7.5	3.7
	Volume Reduction (%)	29%	20%	10%
	Live Storage Volume (cubic feet)	4,194	2,519	1,124
Costs	**Materials/Labor/Design**	$62,910	$37,785	$16,860
	Promotion & Admin Costs	$120	$174	$313
	Total Project Cost	$63,030	$37,959	$17,173
	Annual O&M	$3,146	$1,889	$843
	Term Cost/lb/yr (30 yr)	$389	$351	$315

LILY-03

Term Cost Rank = #1

Catchment Summary	
Acres	33.6
Dominant Land Cover	Residential
Parcels	113
Volume (acre-feet/yr)	42.6
TP (lb/yr)	49.9
TSS (lb/yr)	15,700.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.35

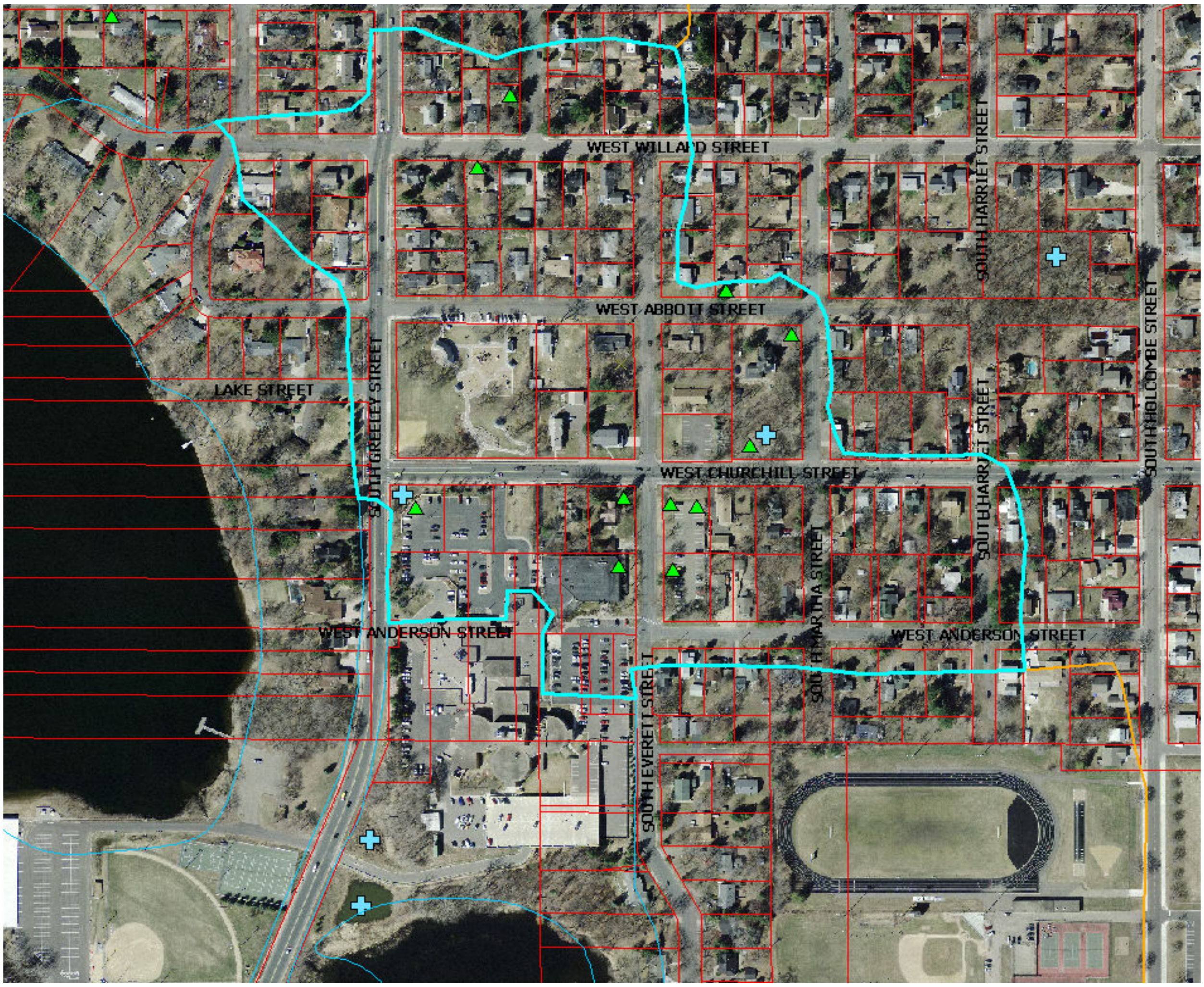
DESCRIPTION

This catchment is comprised of a mixture of medium-density residential development, institutional (one hospital campus), and open space (one large park). There are no constructed stormwater ponds within the catchment. There is one existing stormwater feature that treats water from a portion of the hospital site, although it is assumed to be under-functioning. Stormwater runoff from the rest of the catchment flows through the existing storm sewer system and into a wetland complex (Brick Pond, catchment Lily-08W) before discharging to Lily Lake. The catchment discharge point into Brick Pond and the outlet to Lily Lake are separated by less than 200 feet, creating a short-circuiting situation in which this stormwater likely does not receive much treatment in Brick Pond.

RETROFIT RECOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

Several features make this catchment very attractive for retrofitting. In a few locations, modification or additional bioretention surface area could easily be retrofitted into the existing practices to maximize efficiencies. In one location, it may be possible to daylight stormwater sewer lines to an existing major depression that would effectively treat (infiltrate and filter) approximately 1/6th of the catchment. Further investigation into this possibility is highly recommended.



Curb Cut Bioretention (including 2 existing pond retrofits)

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	15.0	10.0	5.0
	TSS Reduction (lb/yr)	8,245	6,618	4,500
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	12.5	8.3	4.0
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	4,654	2,795	1,244
Costs	Materials/Labor/Design	$69,810	$41,925	$18,660
	Promotion & Admin Costs	$111	$161	$291
	Total Project Cost	$69,921	$42,086	$18,951
	Annual O&M	$3,491	$2,096	$933
	Term Cost/lb/yr (30 yr)	$388	$350	$313

LILY-04

Term Cost Rank = #1

Catchment Summary	
Acres	56.9
Dominant Land Cover	Residential
Parcels	103
Volume (acre-feet/yr)	28.7
TP (lb/yr)	33.3
TSS (lb/yr)	10,460.6

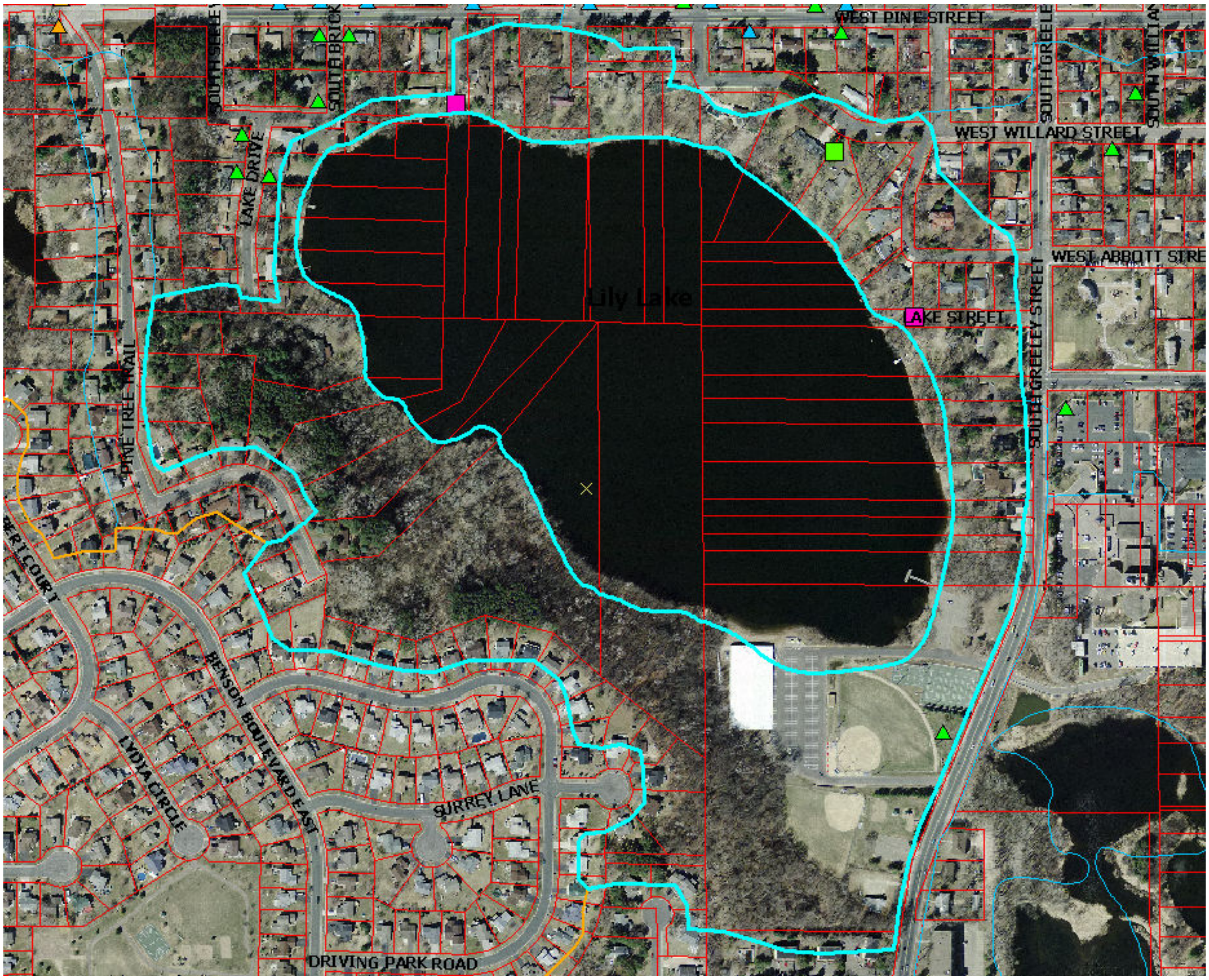
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.24
Hydraulic Conductivity (in/hr)	1.74

DESCRIPTION

This catchment is comprised of primarily low density, single-family residential development with direct drainage to Lily Lake. The catchment includes areas of open space and a City park. A small demonstration shoreline buffer BMP and pervious pavement section exists within the park, as well as a treatment swale that was required when the City repaved the parking lot.

RETROFIT RECEOMMENDATION

The limited BMP opportunities available within this catchment need to be maximized. A combination of bioretention, dry swale and permeable surface retrofitting is recommended. Bioretention areas will be focused in the western half of the catchment and little to no retaining walls would be needed (*see* Lake Dr and the bottom of Brick St S). In two locations, with preference given to the Hemlock Street site, a permeable section of pavement could be installed at the end of a street to at least filter, if not infiltrate, runoff running down the impermeable street. In such cases, care should be made to accommodate the expected volume of both water and sediment entering the permeable system and it is recommended that some form of pre-treatment occur in concert with careful and limited application of sand during winter months. In addition, appropriately timed, and frequency, street sweeping will help reduce long-term maintenance "in-practice" for the permeable patch.



Curb Cut Bioretention | Swale | Permeable Patch

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	10.0	6.7	3.3
	TSS Reduction (lb/yr)	5,434	4,343	2,926
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	8.6	5.8	2.9
	Volume Reduction (%)	30%	20%	10%
	Live Storage Volume (cubic feet)	2,895	1,741	773
Costs	Materials/Labor/Design	$49,215	$29,597	$13,141
	Promotion & Admin Costs	$157	$227	$411
	Total Project Cost	$49,372	$29,824	$13,552
	Annual O&M	$2,171	$1,306	$580
	Term Cost/lb/yr (30 yr)	$382	$343	$313

LILY-07

Term Cost Rank = #6

Catchment Summary	
Acres	35.0
Dominant Land Cover	School
Parcels	44
Volume (acre-feet/yr)	30.0
TP (lb/yr)	35.0
TSS (lb/yr)	10,993.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.41
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

Recommended retrofit efforts focus on the school campus given the reduced amount of time needed for education and outreach and administrative costs in concert with the ease of installation (relatively flat and open conditions). In addition, it is highly likely that a fair amount of volunteer effort can be expected in such locations. Collectively, these attributes make the overall cost, and resulting efficiency, of stormwater bmp retrofits far less expensive than residential retrofitting.

Opportunities exist within and surrounding impervious areas such parking lots, sidewalks and between buildings and walkways in addition to a major opportunity to daylight a stormwater pipe servicing the entire campus. Some required BMPs have already been implemented as a result of an expansion and parking lot retrofit in 2008.

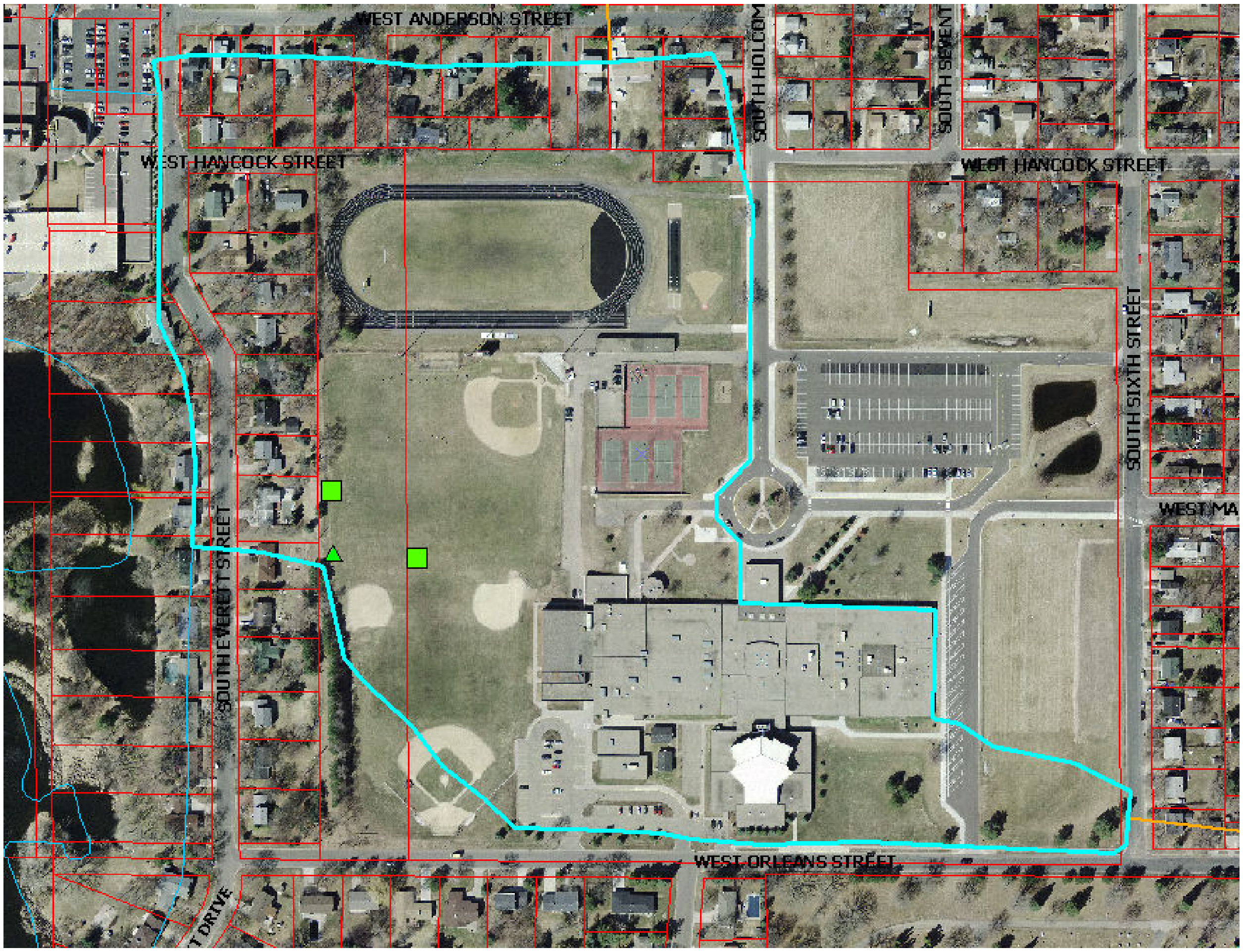
RETROFIT RECOMMENDATION

A combination of bioretention and dry swales servicing the entire campus via curb cut and stormwater pipe daylighting is possible on this campus. Bioretention located off the perimeters of parking lots and sidewalks is possible throughout the campus with no retaining walls needed. As with all other forms of infiltration, it is mandatory to include pretreatment in these designs.

A major opportunity to daylight a stormwater pipe for quality treatment exists on the western side of the property between the two ball fields. This pipe could be opened near the eastern limit of these fields, dumping into a pretreatment forebay. This forebay could then overflow to some combination of wet pond and dry swale system that then discharges to a bioretention cell(s). Emphasis on infiltration should be made with both filtered and overflow runoff being reintroduced to the existing pipe near the western terminus of the property. It is likely this system will need extensive excavation and careful surveying of the invert elevations of the pipe need to be made before committing to this design option.

This site has the ability to treat far beyond the recommended level of 20% TP reduction for far less money than other systems, but until some form of buy-in is expressed, in terms of project scale, a conservative treatment amount is reported here.

For the sake of estimating costs per volume of water treated, we approximated a ft^2 pricing as some marriage of each of these forms of stormwater practices.



▲ Curb Cut Bioretention ■ Swale

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	10.5	7.0	3.5
	TSS Reduction (lb/yr)	5,778	4,640	3,152
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	8.7	5.8	2.8
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	3,272	1,965	871
Costs	Materials/Labor/Design	$37,104	$22,283	$9,877
	Promotion & Admin Costs	$144	$208	$377
	Total Project Cost	$37,248	$22,491	$10,254
	Annual O&M	$2,454	$1,474	$653
	Term Cost/lb/yr (30 yr)	$352	$318	$284

LILY-09

Term Cost Rank = #7

Catchment Summary	
Acres	14.4
Dominant Land Cover	Commercial
Parcels	52
Volume (acre-feet/yr)	18.2
TP (lb/yr)	21.4
TSS (lb/yr)	6,727.4

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.61
Hydraulic Conductivity (in/hr)	1.55

DESCRIPTION

This catchment is comprised of primarily commercial buildings, medium-density multi-family residential properties, and a few single-family residences. It also includes a long section of Greeley Street running close to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.

▲ Curb Cut Bioretention ▲ Curb Cut Box Planter

	Cost/Benefit Analysis	***Percent TP Reduction Level***		
		30	**20**	**10**
Treatment	**TP Reduction (lb/yr)**	6.4	4.3	2.1
	TSS Reduction (lb/yr)	3,509	2,810	1,900
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	5.4	3.6	1.8
	Volume Reduction (%)	30%	20%	10%
	Live Storage Volume (cubic feet)	1,916	1,151	510
Costs	**Materials/Labor/Design**	$28,740	$17,265	$7,650
	Promotion & Admin Costs	$212	$308	$557
	Total Project Cost	$28,952	$17,573	$8,207
	Annual O&M	$1,437	$863	$383
	Term Cost/lb/yr (30 yr)	$375	$337	$312

LILY-10

Term Cost Rank = #9

Catchment Summary	
Acres	22.4
Dominant Land Cover	Residential
Parcels	24
Volume (acre-feet/yr)	25.1
TP (lb/yr)	29.4
TSS (lb/yr)	9,264.0

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.54
Hydraulic Conductivity (in/hr)	1.47

DESCRIPTION

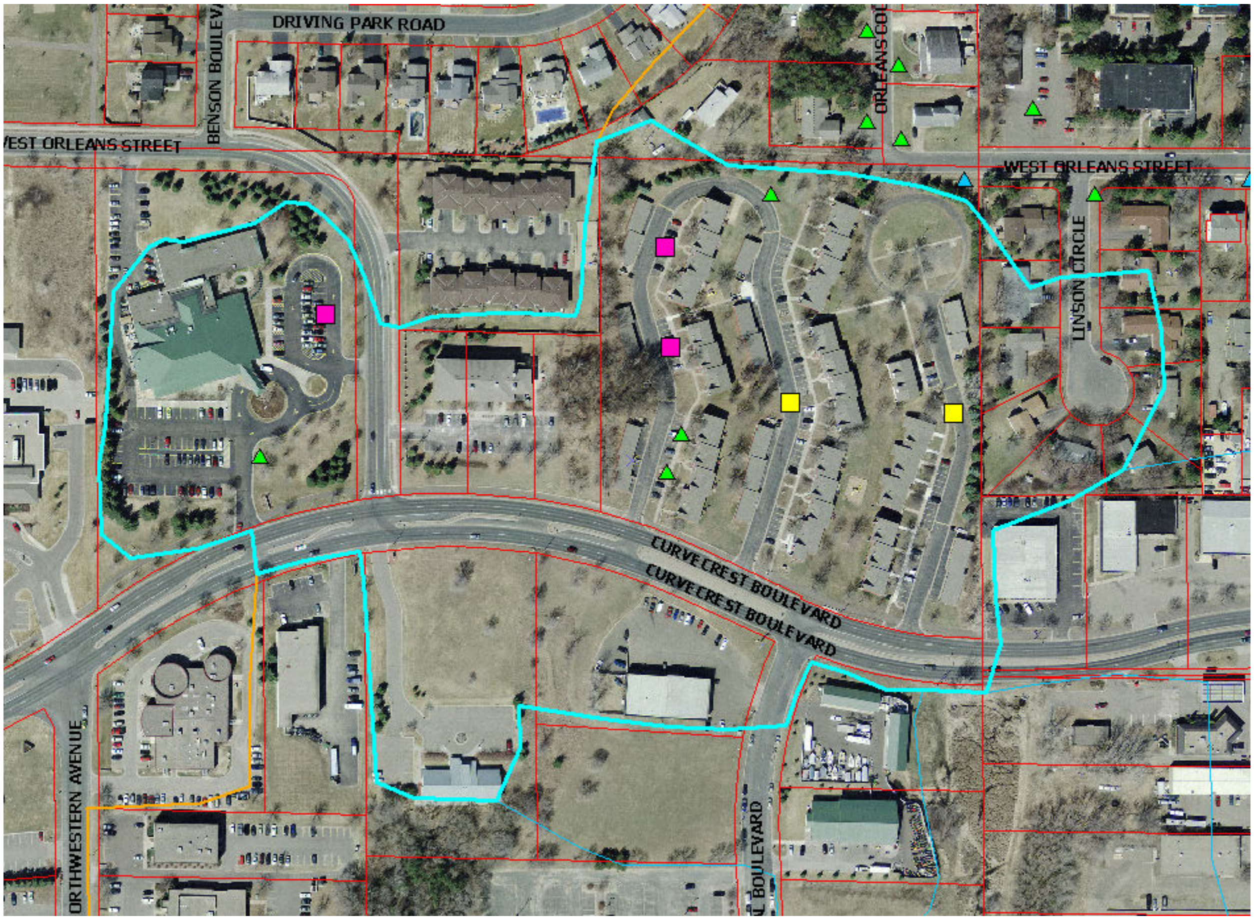
This catchment consists of medium-density multi-family residential areas with smaller areas of commercial properties. Runoff is collected in the existing storm sewer system and flows through one wet detention pond (somewhat short-circuited, but with sand infiltration treatment bench) before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention, infiltration curtains and permeable surface retrofitting is recommended for this catchment. A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. In several locations, no retainment would be needed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape.

In two parking locations a permeable section of pavement could be installed to at least filter, if not infiltrate, runoff running down the impermeable driving lanes and from buildings. In such cases, care should be made to accommodate the expected volume of both water and sediment entering the permeable system and it is recommended that some form of pre-treatment occur in concert with careful and limited application of sand during winter months. In addition, appropriately timed, and frequency, street sweeping will help reduce long-term maintenance “in-practice” for the permeable patch.

In a few locations, where neither permeable parking or bioretention is possible, the ribbon gutter could be replaced with a vertical sand filter and grate. Care will need to be taken to design some form of pretreatment, likely in the form of a two-stage channel. Investigation into a similar design, and its effectiveness and maintenance demands, at the U of MN’s Landscape Arboretum should be undertaken before committing to this option.



Curb Cut Bioretention   Permeable Surface   Infiltration Curtain

	Cost/Benefit Analysis	***Percent TP Reduction Level***		
		30	**20**	**10**
Treatment	**TP Reduction (lb/yr)**	8.8	5.9	2.9
	TSS Reduction (lb/yr)	4,845	3,883	2,630
	TSS Reduction (%)	52%	42%	28%
	Volume Reduction (acre-feet/yr)	7.4	5.0	2.4
	Volume Reduction (%)	29%	20%	10%
	Live Storage Volume (cubic feet)	2,680	1,610	713
Costs	**Materials/Labor/Design**	$5,360	$32,200	$14,260
	Promotion & Admin Costs	$166	$241	$436
	Total Project Cost	$5,526	$32,441	$14,696
	Annual O&M	$2,010	$1,208	$535
	Term Cost/lb/yr (30 yr)	$249	$388	$353

LILY-12

Term Cost Rank = #5

Catchment Summary	
Acres	15.2
Dominant Land Cover	Commercial
Parcels	25
Volume (acre-feet/yr)	27.1
TP (lb/yr)	31.8
TSS (lb/yr)	1,011.0

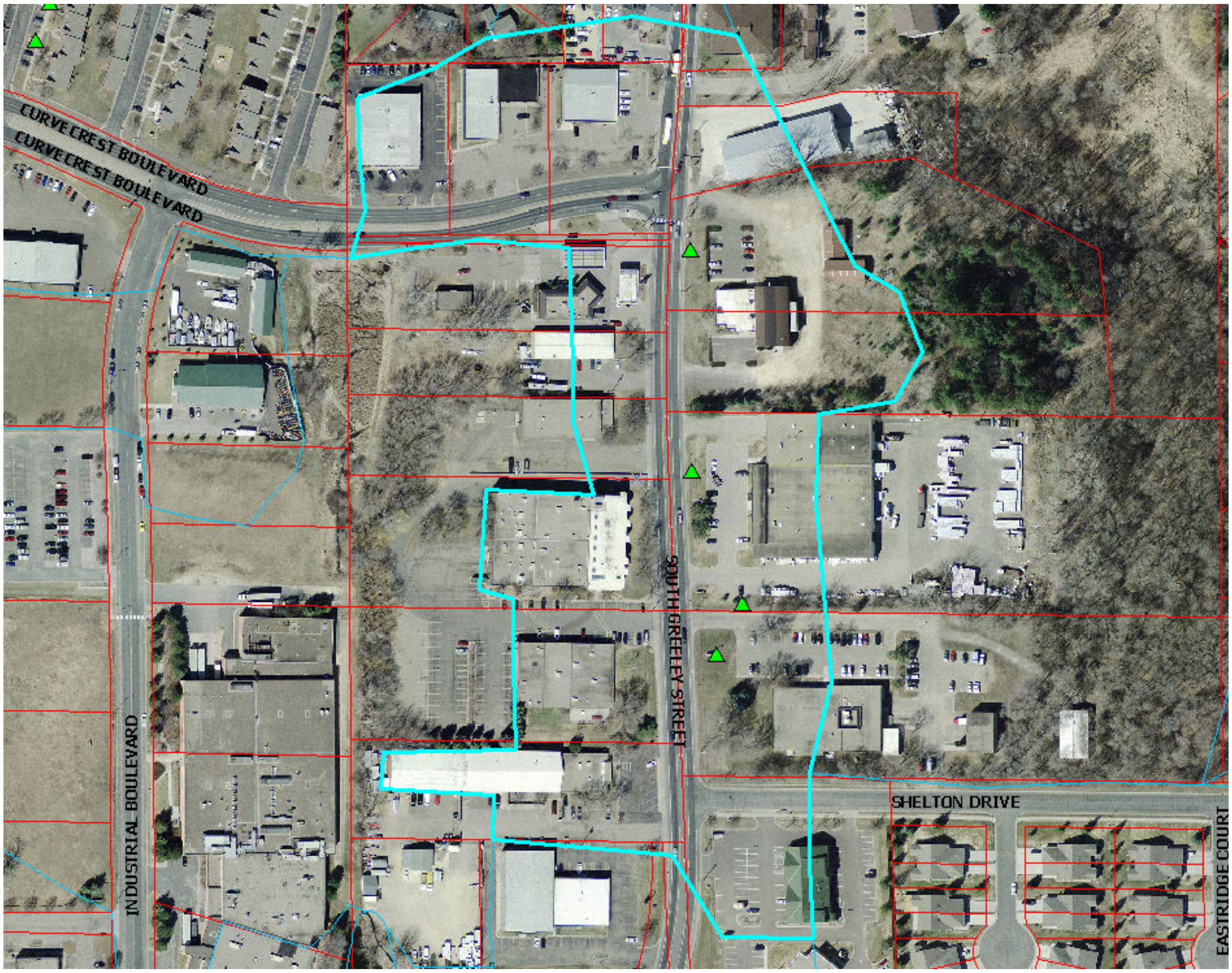
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.86
Hydraulic Conductivity (in/hr)	1.29

DESCRIPTION

This catchment consists of commercial properties and associated highly impervious fraction. Runoff is collected in the existing storm sewer system and flows through Brick Pond (catchment LILY-08W) before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	9.5	6.4	3.2
	TSS Reduction (lb/yr)	5,265	4,230	2,876
	TSS Reduction (%)	521%	418%	284%
	Volume Reduction (acre-feet/yr)	7.9	5.2	2.5
	Volume Reduction (%)	29%	19%	9%
	Live Storage Volume (cubic feet)	2,997	1,800	797
Costs	Materials/Labor/Design	$44,955	$27,000	$11,955
	Promotion & Admin Costs	$153	$222	$402
	Total Project Cost	$45,108	$27,222	$12,357
	Annual O&M	$2,248	$1,350	$598
	Term Cost/lb/yr (30 yr)	$395	$353	$316

LILY-21

Term Cost Rank = #9

Catchment Summary	
Acres	18.4
Dominant Land Cover	Residential
Parcels	56
Volume (acre-feet/yr)	18.4
TP (lb/yr)	21.5
TSS (lb/yr)	6,765.0

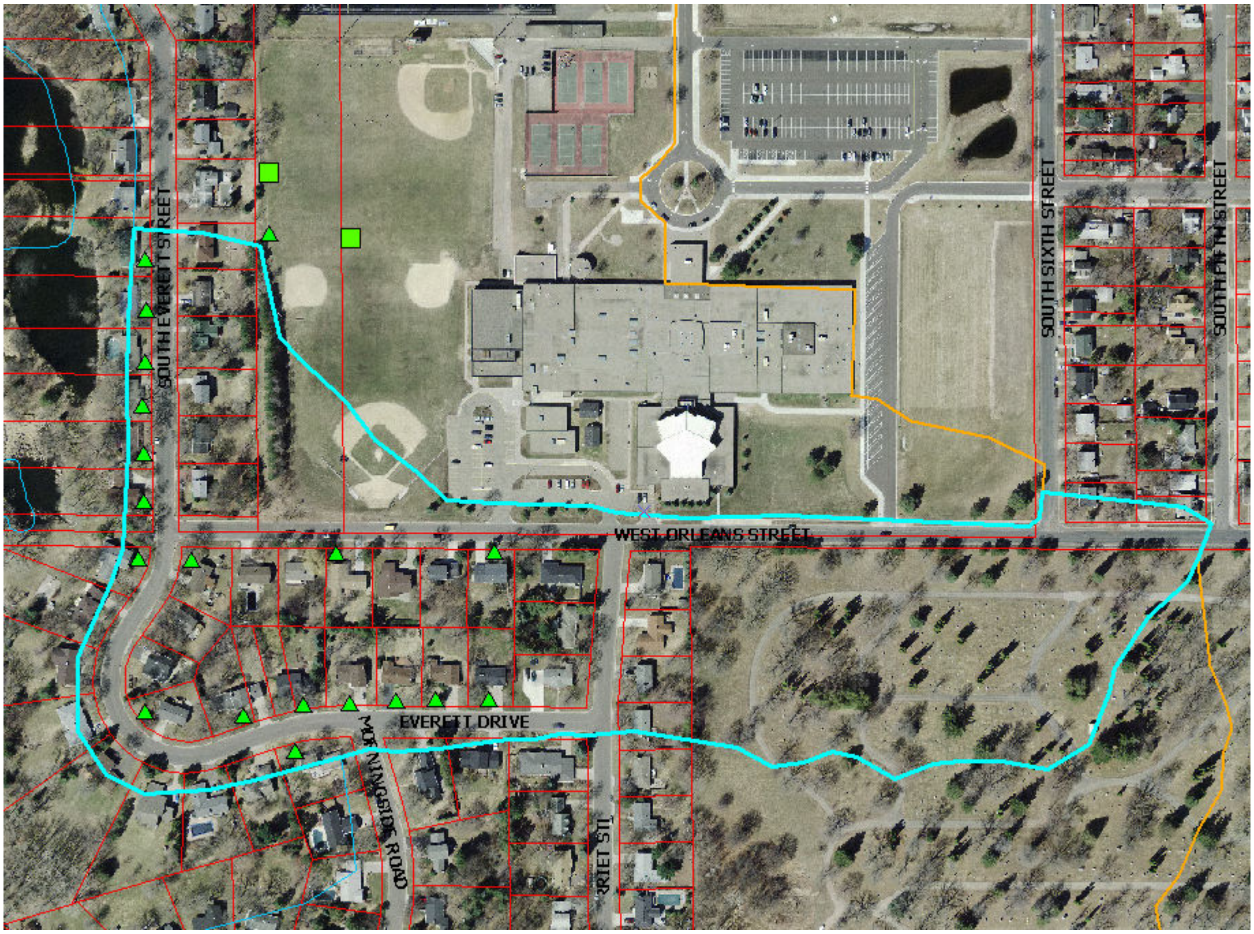
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.48
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment consists mainly of medium density single-family homes. The large cemetery in the eastern half of the catchment was excluded from this study. Runoff is collected in the existing storm sewer system and flows through Brick Pond before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	6.5	4.3	2.2
	TSS Reduction (lb/yr)	3,555	2,854	1,939
	TSS Reduction (%)	53%	42%	29%
	Volume Reduction (acre-feet/yr)	5.4	3.6	1.7
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	2,010	1,208	535
Costs	Materials/Labor/Design	$30,150	$18,120	$8,025
	Promotion & Admin Costs	$205	$297	$538
	Total Project Cost	$30,355	$18,417	$8,563
	Annual O&M	$1,508	$906	$401
	Term Cost/lb/yr (30 yr)	$388	$353	$312

LILY-22

Term Cost Rank = #8

Catchment Summary	
Acres	20.9
Dominant Land Cover	Residential
Parcels	55
Volume (acre-feet/yr)	21.4
TP (lb/yr)	25.0
TSS (lb/yr)	7,845.0

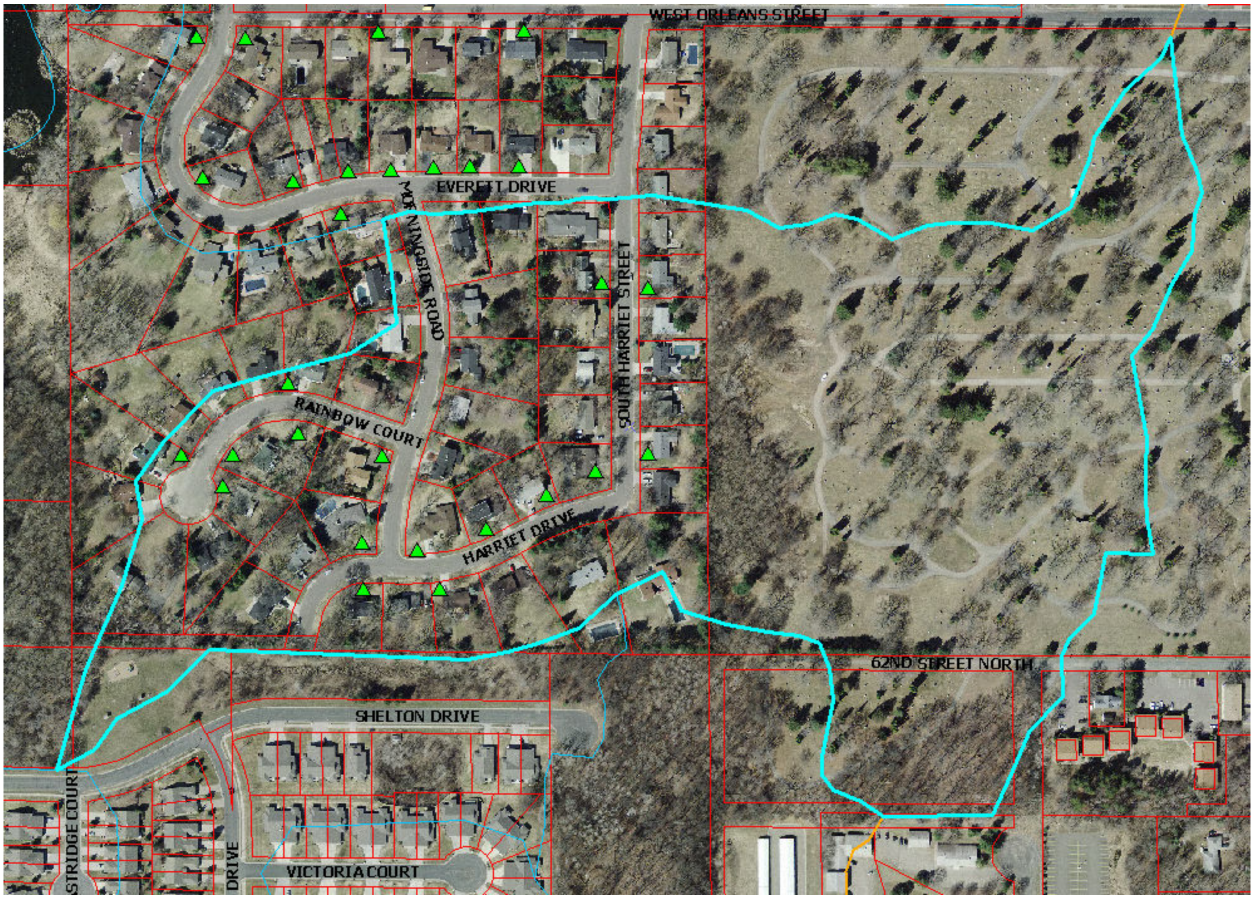
Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0
Directly Connected Impervious Fraction	0.49
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

This catchment consists mainly of medium density single-family homes. The large cemetery in the eastern half of the catchment was excluded from this study. Runoff is collected in the existing storm sewer system and flows through Brick Pond before discharging to Lily Lake.

RETROFIT RECEOMMENDATION

A combination of bioretention types is recommended for this catchment, all relying on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell; the main differences between the types of practices being the degree to which soil retainment is employed. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. Where space is limited, such as in boulevards where a sidewalk and curb line define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. In one location in this catchment, curb bump-outs with bioretention cells would work very well where other stormwater BMPs would be far more difficult to fit in and would reduce impervious surface cover on what appears, at first glance, to be superfluous.



Curb Cut Bioretention

	Cost/Benefit Analysis	Percent TP Reduction Level		
		30	20	10
Treatment	TP Reduction (lb/yr)	7.8	5.0	2.5
	TSS Reduction (lb/yr)	4,118	3,308	2,248
	TSS Reduction (%)	52%	42%	29%
	Volume Reduction (acre-feet/yr)	6.2	4.2	2.0
	Volume Reduction (%)	29%	20%	9%
	Live Storage Volume (cubic feet)	2,325	1,400	620
Costs	Materials/Labor/Design	$34,875	$21,000	$9,300
	Promotion & Admin Costs	$184	$267	$483
	Total Project Cost	$35,059	$21,267	$9,783
	Annual O&M	$1,744	$1,050	$465
	Term Cost/lb/yr (30 yr)	$373	$352	$316

Catchment Ranking

Catchment or Pond ID	Retro Type	BMP area (sq ft)	TP Reduction (%)	TP Reduction (lb/yr)	Volume Reduction (ac/ft/yr)	Overall Est. Cost[1]	O&M Term (years)	Total Est. Term Cost/lb-TP/30 yr	Rank
LILY-03	B	1,244	10	5.0	4.0	$18,951	30	$313	1
LILY-04	B, PS, VS	773	10	3.3	2.9	$13,552	30	$313	1
LILY-02	B	1,124	10	4.5	3.7	$17,173	30	$315	3
LILY-01	B	1,100	10	4.4	3.6	$16,818	30	$315	3
LILY-12	B	797	10	3.2	2.5	$12,357	30	$316	5
LILY-07	B, VS	1,965	20	7.0	5.8	$22,283	30	$318	6
LILY-09	B	1,151	20	4.3	3.6	$17,573	30	$337	7
LILY-22	B	1,400	20	5.0	4.2	$21,267	30	$352	8
LILY-21	B	1,208	20	4.3	3.6	$18,417	30	$353	9
LILY-10	B, PS, F	713	10	2.9	2.4	$14,696	30	$353	9
[2]P13-W	WD	n/a	50	20	0	$130,000	15	$433	11
[2]P18-W	WD	n/a	50	30	0	$265,000	15	$589	12
TOTAL	-	-	-	**93.9**	**36.3**	**$568,087**	-	-	-

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc.)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = Wet Detention or wetland creation (new pond)
[1]Estimated overall costs include design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 30 years of operation and maintenance costs.
[2]See "City of Stillwater Lake Management Plans – Lily Lake and McKusick Lake," Wenck Associates, Inc., October 2007

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Appendices

Appendix 1 – Catchments not included in Ranking Table

Catchments not included in ranking table were excluded for a number of reasons, mainly involving connectivity to the receiving water. After BMPs are installed within the priority catchments, it is recommended that the watershed revisit the entire subwatershed to determine other catchments that, while they may be conducive to retrofitting, were not considered a high priority for this report.

Appendix 2 – Summary of Protocol

This protocol attempts to provide a sufficient level of detail to rapidly assess subwatersheds or catchments of variable scales and land uses. It provides the assessor defined project goals that aid in quickly narrowing down multiple potential sites to a point where the assessor can look critically at site-specific driven design options that affect, sometimes dramatically, BMP selection. We feel that the time commitment required for this methodology is appropriate for most initial assessment applications and has worked well thus far for the Lily Lake Assessment.

Appendix 3 – Definitions

The following terms are used throughout this document and define the basic terminology used to talk about watersheds and restoration. Many of the terms can have different meanings in different contexts, so it is imperative to define their use within this document.

Best Management Practice (BMP) – One of many different structural or non-structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, bioretention, and infiltration.

Bioretention – A soil and plant-based stormwater management BMP used to filter runoff.

Catchment – Land area within a subwatershed generally having a drainage area of 1 – 100 acres for urban areas, where all water drains to a particular point. Several catchments make up a subwatershed. The existing stormwater infrastructure helps to define a catchment; therefore it is critical to obtain accurate stormwater infrastructure mapping information (including, at a minimum, the location of inlets and pipes, flow direction, and outfall locations) before undertaking a stormwater assessment process.

Raingarden – A landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, roads, and parking lots.

Retrofit – The introduction of a new or improved stormwater management element where it either never existed or did not operate effectively.

Stormwater – Water that is generated by rainfall or snowmelt that causes runoff and is often routed into drain systems for treatment or conveyance.

Subwatershed – Land area within a watershed generally having a drainage area of more than 500 acres, where all water drains to a particular point. Several subwatersheds make up a watershed. An example would be the Lily Lake subwatershed, which is within the boundaries of the Middle St. Croix Water Management Organization (the watershed). Subwatersheds are entirely based on hydrologic conditions, not political boundaries.

Urban – Any watershed or subwatershed with more than 10% total impervious cover.

Watershed – Land area defined by topography, where all water drains to a particular point. Watershed drainage areas are large, ranging from 20 to 100 square miles or more, and are made up of several subwatersheds. There are currently 8 watersheds located either wholly or partially within Washington County, each defined along political boundaries that attempt to mimic hydrologic boundaries.

Appendix 4 – WCD Subwatershed Selection Process

The Washington Conservation District selected the Lily Lake/Lake McKusick subwatersheds for the MCD assessment program through a competitive process. Watershed organizations in Washington County were asked to nominate subwatersheds that were then scored on 5 equally weighted criteria (maximum of 5 points each). There were 7 nominations, of which 2 were chosen for assessments. The results were as follows:

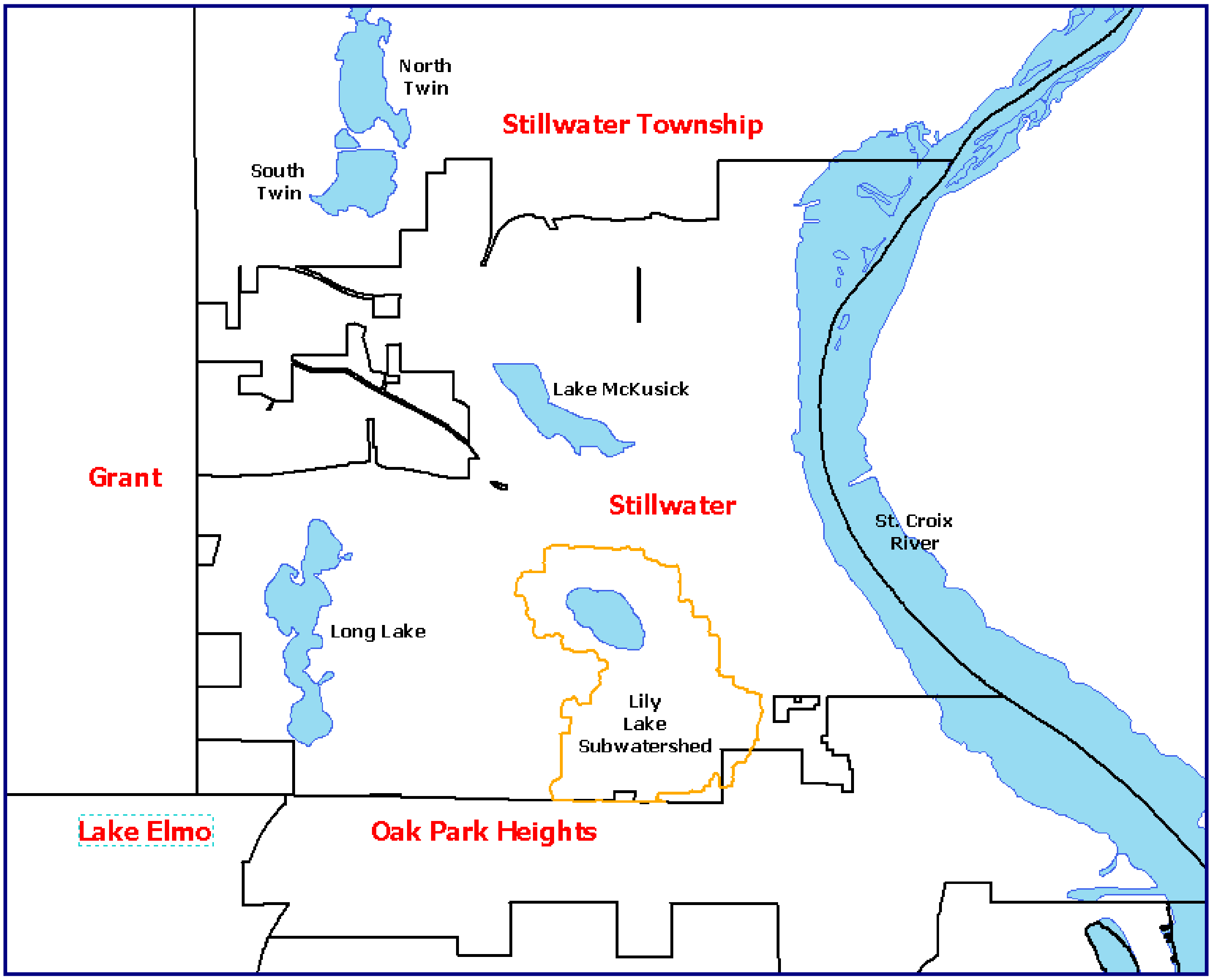
Organization	Subwatershed	C1	C2	C3	C4	C5	TOTAL
RWMWD	Carver Lake	5	5	5	5	5	**25**
MSCWMO	Lily/McKusick	5	5	5	5	5	**25**
VBWD	Raleigh Creek	5	5	5	5	3	23
SWWD	Markgrafs Lake	5	5	0	5	4	19
CLFLWD	CL04	5	5	2	2	4	18
RCWD	N. Clear Lake	5	3	2	0	4	15
RCWD	N. Mahtomedi	5	3	2	0	2	12

Criteria
C1 = urban/suburban
C2 = well-defined subwatershed boundary
C3 = water quality monitoring data
C4 = stormwater infrastructure mapping
C5 = drains to impaired or target water body

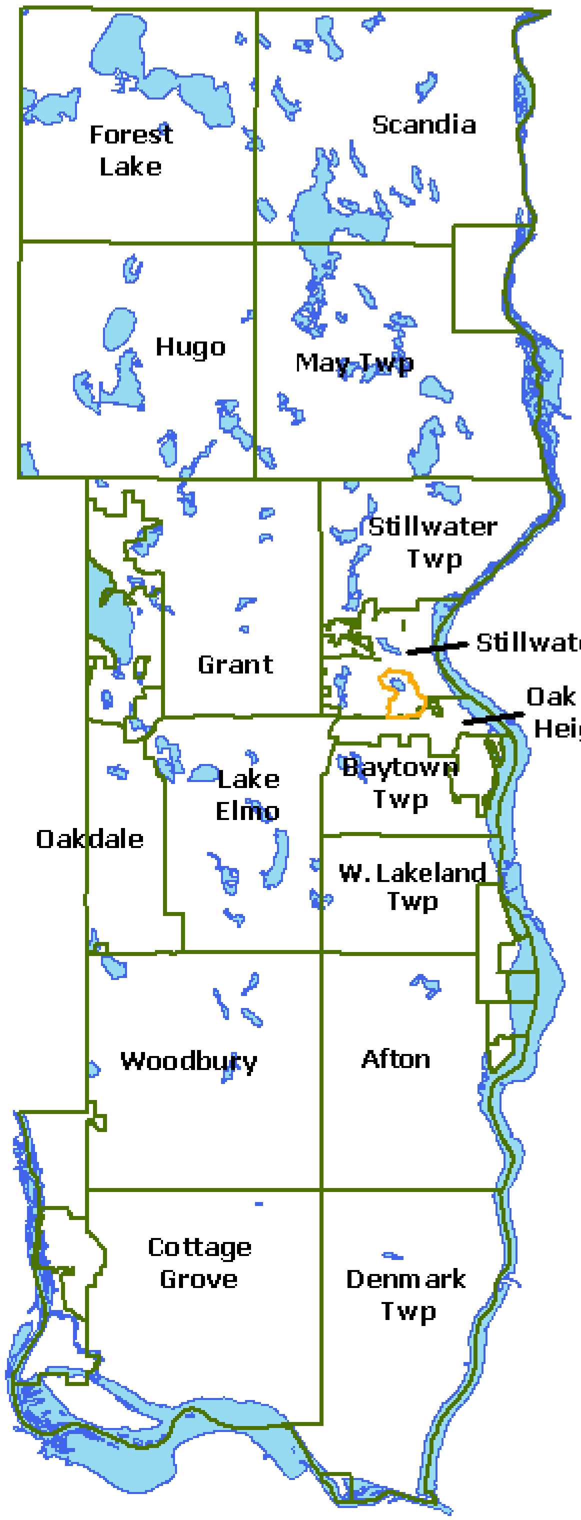
Appendix 5 – Subwatershed Maps

Lily Lake Subwatershed – Aerial Photo (2009)

Lily Lake Subwatershed – 22 Catchments (Priority Catchments are Shaded)



Location of the Lily Lake Subwatershed within Stillwater



Location of the Lily Lake Subwatershed within Washington County