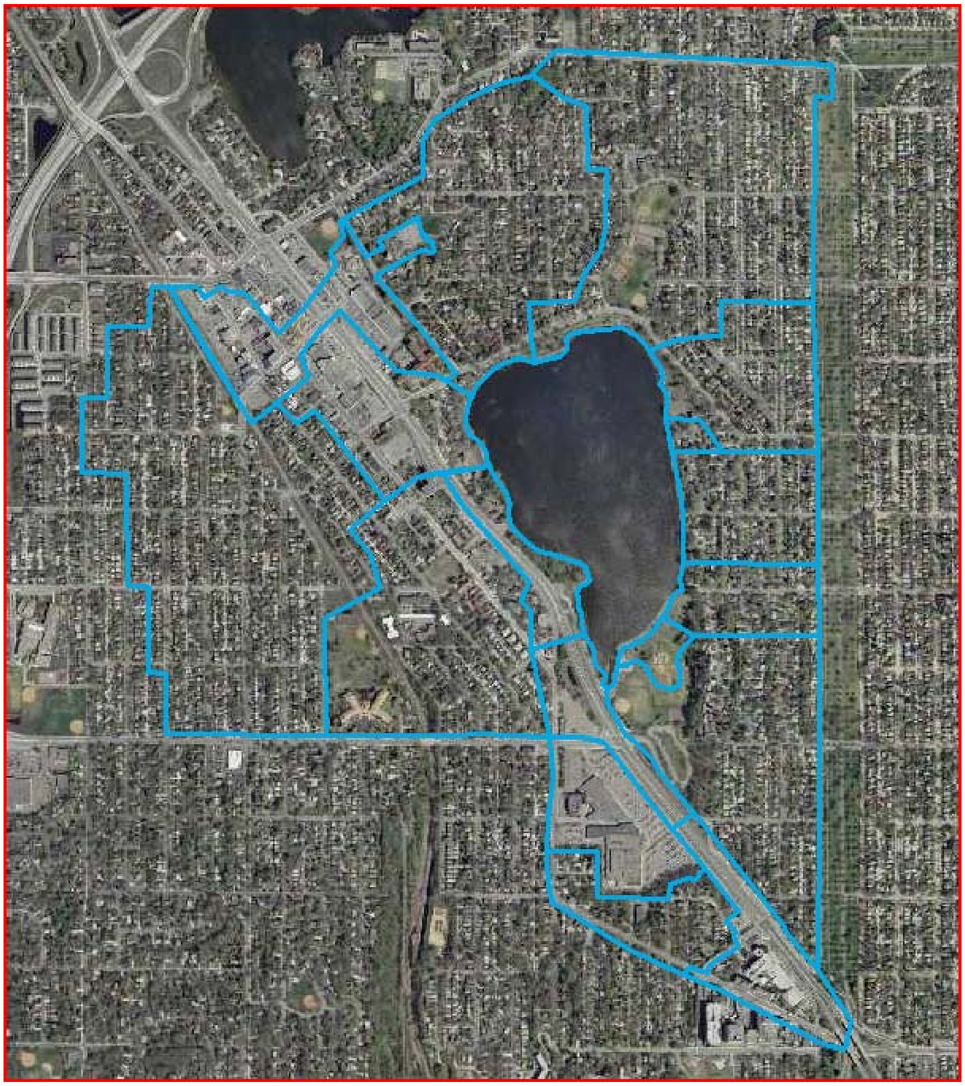
Crystal Lake: Stormwater Retrofit Assessment



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With assistance from:

THE METRO CONSERVATION DISTRICTS

for the

City of Robbinsdale and the Shingle Creek WMO

This report details a rapid stormwater retrofit assessment for Crystal Lake. 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.

The methods and analysis supporting this document provide a sufficient level of detail to rapidly assess sub-watersheds of variable scales and land-uses. The assessment identifies optimal locations for stormwater treatment. All efforts were made to provide the most accurate and precise estimates for pollutant loading and reduction along with estimated costs to achieve the reductions. The time commitment required for this methodology is appropriate for *initial assessment* applications. No monitoring was conducted in order to calibrate, verify and/or validate these results.

Results of this assessment are based on the development of catchment-specific *conceptual* stormwater treatment best management practices. These practices 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 focus final retrofit design efforts. Final, 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 here-in. This typically occurs after the procurement of committed partnerships relative to each specific target parcel slated for the placement of Best Management Practices (BMPs).

This document should be considered as *one part* of an overall watershed restoration plan. An overall plan would include components such as educational outreach, stream repair, riparian zone management, discharge prevention, upland native plant community restoration, and pollutant source control. This report should be considered regarding potential riparian and upland habitat restoration, pollutant hot-spot treatment, good housekeeping practices and environmental education identified within an existing or future watershed restoration plan.

Contents

Executive Summary

Crystal Lake in Robbinsdale, Minnesota has been designated by the State of Minnesota as an Impaired Water that does not meet state water quality standards. A Total Maximum Daily Load (TMDL) study completed in 2008 concluded that the amount of phosphorus, or load, from the subwatershed that drains to Crystal Lake must be reduced by just over 300 pounds per year to meet state standards. That TMDL identified a number of actions that could be taken to meet this reduction, including retrofitting the subwatershed with small water treatment practices.

The goal of this study is to identify and prioritize retrofit treatment practices. Seventeen catchments, and their existing stormwater management practices, were analyzed for annual pollutant loading. Stormwater practice options were compared, for each catchment, given their specific site constraints and characteristics. A stormwater practice was selected by weighing cost, ease of installation and maintenance and ability to serve multiple functions identified by the City and Watershed Management Organization. Ten of the 17 catchments were selected and modeled at various levels of treatment efficiencies. These catchments should be considered the “low-hanging-fruit” within the Crystal Lake Subwatershed. Two existing pond modification analysis results from a previous study are also included and highly recommended.

The following table summarizes the assessment results. Treatment levels (percent removal rates) for retrofit projects that resulted in a prohibitive BMP size, or number, or were too expensive to justify installation are not included. Reported treatment levels are dependent upon optimal siting and sizing. The recommended treatment levels/amounts summarized here are based on a subjective assessment of what can realistically be implemented considering anticipated public participation and site constraints.

			Overall Catchment Treatment					
Catchment or Pond ID	Retro Type	*Qty of BMPs	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/yr[2]
16c	PM	1	43	5.3	0	$5,500	30	$318
18c	B	5	10	5.0	84.7	$20,625	30	$332
16r	B	6	10	5.9	97.5	$24,225	30	$334
19	B	2	10	2.2	32.1	$9,775	30	$336
23	B	8	10	7.8	0	$35,350	30	$343
18r	B	11	10	9.7	170.1	$41,575	30	$356
26	B	2	10	1.2	0	$6,850	30	$378
17	B	10	10	7.8	113.6	$36,525	30	$387
22	B	2	10	1.8	0	$10,200	30	$397
32e	B	6	10	4.3	56.3	$23,500	30	$444

**Number of 250 sq-ft (at overflow elevation) equivalents – live storage or treatment volumes vary*

B = Bioretention (infiltration and/or filtration) (modeled as 250 sq-ft each at overflow elevation)

PM = Pond Modification (Iron-enhanced sand filter bench) – this BMP is actually 1 practice 200 sq-ft in size

[1]Estimated “Overall Cost” includes design, contracted soil core sampling, materials, contracted labor, promotion and administrative costs (including outreach, education, contracts, grants, etc), pre-construction meetings, installation oversight and 1 year of operation and maintenance costs.

[2]“Total Est. Term Cost” includes Overall Cost plus 30 years of maintenance and is divided by 30 years of TP treatment.

About this Document

Document Overview

This Subwatershed Stormwater Retrofit Assessment is a watershed management tool to help prioritize stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent.

This document is organized into four major sections that describe the general methods used, individual catchment profiles, a resulting retrofit ranking for the subwatershed and references used in this assessment protocol. In some cases, and 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 general procedures used when assessing the subwatershed. It overviews the processes of retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking. Project-specific details of each process 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.

Retrofit Profiles

Each retrofit profile is labeled with a unique ID coincide with the subwatershed name as designated by the City. This ID is referenced when comparing projects across the subwatershed. Information found in each catchment profile is described below.

Catchment Summary/Description

Within the catchment profiles is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant load (and other pollutants and volumes as specified by the LGU). Also, a table of the principal modeling parameters and values is reported. A brief description of the land cover, stormwater infrastructure and any other important general information is also described here.

Retrofit Recommendation

The recommendation section describes the conceptual BMP retrofit(s) selected for the catchment area and provides a description of why the specific retrofit(s) 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 retrofit projects. Additional field inspections will be required to verify project feasibility, but the most ideal locations for retrofits are identified here.

Retrofit Ranking

Retrofit ranking takes into account all of the information gathered during the assessment process to create a prioritized project list. The list is sorted by cost per pound of phosphorus treated for each project for the duration of one 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, and the list provided is merely a starting point. Final project ranking for installation may include:

- Non-target pollutant reductions
- Project visibility
- Availability of funding
- Total project costs
- Educational value
- Others

References

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

Appendices

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

Methods

Selection of Subwatershed

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.

Subwatershed Assessment Methods

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

Step 1: Retrofit Scoping

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

Crystal Lake Subwatershed Scoping

As Crystal Lake is an Impaired Water for excess nutrients, pollutants of concern for this subwatershed were identified as TP, TSS, and Volume. Chlorides were beyond the scope of this study.

Step 2: Desktop Retrofit Analysis

The desktop analysis involves computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identifies areas that don't need to be assessed because of existing stormwater infrastructure. Accurate GIS data are extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the storm drainage infrastructure. Each catchment is initially investigated for several land position opportunities that are conducive to stormwater retrofitting (Table 1).

Table 1 - Subwatershed Metrics and Potential Retrofit Project Site/Catchment	
Screening Metric	**Potential Retrofit Project**
Existing Ponds	Add storage and/or improve water quality by excavating pond bottom, modifying riser, raising embankment, and/or modifying flow routing.
Open Space	New regional treatment (pond, bioretention).
Roadway Culverts	Add wetland or extended detention water quality treatment upstream.
Outfalls	Split flows or add storage below outfalls if open space is available.
Conveyance system	Add or improve performance of existing swales, ditches and non-perennial streams.
Large Impervious Areas (campuses, commercial, parking)	Stormwater treatment on site or in nearby open spaces.
Neighborhoods	Utilize right of way, roadside ditches or curb-cut raingardens or filtering systems to treat stormwater before it enters storm drain network.

Crystal Lake Desktop Assessment

In this assessment, each catchment was initially defined using the newest delineations provided by the WMO. Each catchment was subdivided into up into unique cover types first defined by Met Council 2005 Land Use data and truthed against current aerial photography. For the sake of determining fractions of indirectly and directly connected impervious cover, a conversion of Met Council data was made into Standard Land Use codes provided within WINSLAMM literature and the resulting impervious fractions were then looked up in the P8 Help file for each. For cases were there was no one-to-one conversion between code sets, and to truth the one-to-one codes, aerial photography was used to either assign, change or confirm the land use code designation (Table 2). In all cases, many land use types (codes) defined the catchments. To determine appropriate coefficients for imperviousness, we calculated area-weighted acreages by multiplying acreage of unique cover by the look-up coefficients (Table 3), summing each and dividing the results by the total catchment area (Table 4). All results were visually truthed against aerial photography for cover type classification and estimated percent of indirect and directly connected impervious surfaces.

All catchments were modeled for estimated loading of TP, TSS and ac-ft of runoff based on area of unique land use, assumed condition and type of pervious areas via TR55 CN methodology and, then, including existing stormwater conveyance and treatment. For catchments with existing ponds or other treatment, city-provided data was used to construct the existing stormwater practice within P8 to estimate it annual treatment potential. In some cases (catchments 20, 24, 25, 29, 32W-C, R and I), either no significant potential was located, significant treatment was already provided relative to the remainder of the Subwatershed, the property nearly exclusively is owned by the state or county or conditions were simply too difficult for retrofitting.

Table 2 – Land Use Classification			
WINSLAMM CODE	**MET COUNCIL CODE**		
COMMERCIAL			
SCOM	120	142	143
SHOP	120	142	143
OFPK	130		
CDT	120	142	143
INDUSTRIAL			
MI	151	153	203
LI	151		
INSTITUTINOL			
SCH	160		
INST	160		
HOSP	160		
OTHER URBAN LAND USES			
PARK	170	173	
OSUD	210		
CEM	160		
FREEWAY LAND USES			
FREE	201	202	
RESIDENTIAL			
HDRNA	113		
HDRWA	113		
MDRNA	113		
MDRWA	113		
LDR	113		
DUP	113		
MFRNA	114		
HRR	115		
MOBH	116		
SUB	113	111	112

Table 3 – Determination of Impervious Fractions			
	Weighted P8 Impervious Coefficients		
WINSLAMM CODE	**Total Pervious**	**Total Indirect Conn.**	**Total Directly Conn.**
Cemetery	0.874	0.007	0.12
Commercial Downtown	0.046	0.001	0.953
Duplex	0.609	0.121	0.271
HD Res. with Alleys	0.481	0.138	0.381
HD Res. No alleys	0.469	0.131	0.399
High Rise Res.	0.356	0.012	0.632
Hospital	0.231	0.006	0.763
Institutional - Fair C & G	0.364	0.036	0.6
LT Industrial	0.205	0.088	0.707
LD Residential	0.796	0.079	0.126
MD Residential no alleys	0.622	0.135	0.242
MD Residential with alleys	0.589	0.169	0.242
MD Industrial	0.167	0.208	0.625
Mobile Homes	0.502	0.011	0.487
Multi-Fam. Res. No alleys	0.462	0.063	0.474
Office Park	0.263	0.006	0.731
Urban Open Space	0.951	0	0.049
Parks	0.856	0.041	0.103
Schools	0.421	0.014	0.565
Shopping Ctr.	0.083	0	0.917
Strip Commercial	0.079	0.014	0.907
Rural Residential / Suburban	0.904	0.04	0.056

Table 4 - Impervious Acres and Coefficients by Catchment

Catch.	113 = MDRNA		114 = DWP		115 = HRR		120 = COMM		141 = MFRNA		151 = LTIND		160 = INST		170 = PARK		SUM (ACRES)		Total Imperv (ac)	Total Pervi (ac)	Total (ac)	Area-weighted Coefficient		
	INDIR (0.169)	*DIR (0.242)*	*INDIR (0.121)*	*DIR (0.271)*	*INDIR (0.012)*	*DIR (0.632)*	*INDIR (0.001)*	*DIR (0.953)*	*INDIR (0.063)*	*DIR (0.474)*	*INDIR (0.088)*	*DIR (0.707)*	*INDIR (0.042)*	*DIR (0.658)*	*INDIR (0.041)*	*DIR (0.103)*	*INDIR*	*DIR*				INDIR	DIR	PER
16C	0.05	0.07	0.00	0.00	0.04	1.96	0.02	14.53	0.09	0.65	0.12	0.97	0.45	6.98	0.03	0.06	0.78	25.22	26.00	6.60	32.60	0.024	0.774	0.202
16R	12.23	17.51	0.48	1.08	0.00	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.08	0.20	0.50	12.92	19.23	32.14	49.25	81.39	0.159	0.236	0.605
17	14.60	20.90	0.39	0.87	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.10	1.52	0.68	1.71	15.76	25.12	40.88	67.77	108.65	0.145	0.231	0.624
18C	1.33	1.91	0.00	0.00	0.05	2.45	0.01	12.95	0.04	0.29	0.00	0.00	0.21	3.32	0.02	0.06	1.66	20.98	22.65	9.88	32.52	0.051	0.645	0.304
18R	21.34	30.55	0.62	1.38	0.00	0.07	0.00	0.34	0.00	0.00	0.00	0.02	0.05	0.77	0.10	0.25	22.11	33.39	55.50	80.56	136.06	0.162	0.245	0.592
19	5.59	8.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.17	5.66	8.18	13.83	21.07	34.91	0.162	0.234	0.604
20	0.39	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.56	0.95	1.38	2.33	0.168	0.240	0.592
22	4.21	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.14	4.26	6.16	10.42	15.85	26.27	0.162	0.234	0.603
23	4.47	6.40	0.56	1.26	0.21	11.19	0.01	6.70	0.17	1.24	0.05	0.41	0.16	2.49	0.31	0.78	5.94	30.48	36.42	35.84	72.26	0.082	0.422	0.496
24	0.75	1.07	0.14	0.32	0.00	0.14	0.00	1.52	0.01	0.06	0.00	0.00	0.00	0.00	0.24	0.61	1.15	3.72	4.86	9.43	14.29	0.080	0.260	0.660
*25**	0.19	0.27	0.02	0.05	0.00	0.01	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.11	1.24	11.20	12.45	3.11	15.56	0.080	0.720	0.200
26	2.61	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.19	2.69	3.93	6.63	10.70	17.33	0.155	0.227	0.618
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.47	0.19	0.47	0.65	3.87	4.52	0.041	0.103	0.856
32E	8.45	12.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	1.62	9.10	13.72	22.82	44.74	67.56	0.135	0.203	0.662
32WC	0.09	0.13	0.00	0.01	0.00	0.00	0.02	23.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	23.50	23.62	1.47	25.09	0.005	0.937	0.059
*32WI**	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.02	0.14	0.36	5.65	0.00	0.00	1.92	17.24	19.15	3.38	22.53	0.085	0.765	0.150
32WR	3.01	4.31	0.07	0.16	0.02	0.83	0.00	0.06	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	3.10	5.37	8.47	11.32	19.78	0.157	0.271	0.572
																	88.97	248.47	337.44	376.21	713.65			

Acreage by Catchment

*Catchment results were determined innacurate via classification approach and reassigned coefficients via visual inspection of aerial photography

See Appendix for description of WINSLAMM standard land use codes

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 (Table 5) as well as eliminate sites from consideration. The field investigation may have also revealed additional retrofit opportunities that could have gone unnoticed during the desktop search.

Table 5 - 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). Mau include multiple cell design, infiltration benches, sand/peat/iron filter outlets and modified choker outlet features.
	Wet Ponds	Permanent pool of standing water with new water displacing pooled water from previous event.
	Wetlands	Depression less than 1-meter deep and designed to emulate wetland ecological functions. Residence times of several days to weeks. Best constructed off-line with low-flow bypass.
0.1-5 acres	Bioretention	Use of native soil, soil microbe and plant processes to treat, evapotranspirate, and/or infiltrate stormwater runoff. Facilities can either be fully infiltrating, fully filtering or a combination thereof
	Filtering	Filter runoff through engineered media and passing it through an under-drain. May consist of a combination of sand, soil, compost, peat, compost and iron.
	Infiltration	A trench or sump that is rock-filled with no outlet that receives runoff. Stormwater is passed through a conveyance and pretreatment system before entering infiltration area.
	Swales	A series of vegetated, open channel practices that can be designed to filter and/or infiltrate runoff.
	Other	On-site, source-disconnect practices such as rain-leader raingardens, rain barrels, green roofs, cisterns, stormwater planters, dry wells or permeable pavements.

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Treatment concepts are developed taking into account site constraints and the subwatershed treatment objectives. Practices involving complex stormwater treatment interactions or that pose a risk for upstream flooding require the assistance of a certified engineer. Conceptual designs, at this phase of the design process, include a cost estimate and estimate of pollution reduction. Reported treatment levels are dependent upon optimal site selection and sizing. The cost benefit analyses are developed for practices within catchments that produce significant loads and where site constraints are deemed manageable. The cost benefit analyses are used to compare the cost-effectiveness of practices and sites.

Modeling of the site is done by one or more methods such as 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 parameters. This treatment model can also be used to properly size BMPs to meet LGU restoration objectives.

Table 6 - General P8 Model Inputs used in the Crystal Lake Assessment

Parameter	Method for Determining Value
Pervious Area Curve Number	County soils survey data was used to determine the distribution of soil types across the subwatershed. Area-weighted curve numbers for each catchment were calculated.
Directly Connected Impervious Fraction	Determined through classification of existing land use data into WINSLAMM codes which served as look-up class for coefficients in P8 Help files.
Indirectly Connected Impervious Fraction	Determined through classification of existing land use data into WINSLAMM codes which served as look-up class for coefficients in P8 Help files.
Precipitation/Temperature Data	Rainfall and temperature recordings from the Crystal Lake airport were used for the duration of the record (1998-2008).
Hydraulic Conductivity	Estimated hydraulic capacity of soils located in areas to be considered for treatment were derived from comparison of County Soils data and NRCS Web Soil Survey published data for limiting soils layers. Estimates took low-end published values and limited maximum capacity for the fastest soils to 2-in/hr and make the assumption that all sub soils will be adequately decompacted during construction. It is imperative to understand that actual soils boring data should be used when designing site-specific practices. For engineered soils, set to 2.5-in/hr
Particle/Pollutant	The default NURP50 particle file was used.
P0%-Removal efficiency	For filtering Bioretention or tree pits with pipes, set to 65%; for Iron-enhanced Sand Filters, set to 85%
Sweeping Efficiency	Unless otherwise noted, street sweeping was not accounted for.

Crystal Lake Treatment Analysis

For the Crystal Lake treatment analysis, each catchment, and each parcel within them, was first assessed for BMP "family" type applicability given specific site constraints and soil types. Parameters included pedestrian and car traffic flow, parking needs, snow storage areas, obvious utility locations, existing landscaping, surface water runoff flow, and project visibility. Additional factors include "cues of care" in relation to existing landscape maintenance such as, available space and other constraints. Consideration of these 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 typically sized from the 10-30% 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 ft^3 of treatment (Table 7). In cases where live storage was 1-ft, this number roughly related to ft^2 of coverage. An annual cost/TP-removed for each treatment level was then calculated for the life-cycle of said BMP which included promotional, administrative and life-cycle operations and maintenance costs.

Table 7 -Average BMP Cost Estimates

BMP	Median Inst. Cost ($/sq ft)	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/acre	30	[1]40% above construction	$210 (3 visits)	Design-dependent
Extended Detention	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	Drainage Area-dependent calculation
Wet Pond	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	"
Stormwater Wetland	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	"
Water Quality Swale[6]	$12.00	$250/100 ln ft	30	$1120/100 ln ft	$210 (3 visits)	$12.91/sq ft
Cisterns	$15.00	[5]$100	30	NA	$210 (3 visits)	$15.00/sq ft
French Drain/Dry Well	$12.00	[5]$100	30	20% above construction	$210 (3 visits)	$14.40/sq ft
Infiltration Basin	$15.00	$500/acre	30	$1120/acre	$210 (3 visits)	$15.04/sq ft
Rain Barrels	$25.00	[5]$25	30	NA	$210 (3 visits)	$25.00/sq ft
Structural Sand Filter (including peat, compost, iron amendments, or similar) [6]	$20.00	$250/25 ln ft	30	$300/25 ln ft	$210 (3 visits)	$21.47/sq ft
Impervious Cover Conversion	$20.00	$500/acre	30	$1120/acre	$210 (3 visits)	$20.04/sq ft
Stormwater Planter	$27.00	$50/100 sq ft	30	20% above construction	$210 (3 visits)	$32.90/sq ft
Rain Leader Disconnect Raingardens	$4.00	[2]$25/150 sq ft	30	$280/100 sq ft	$210 (3 visits)	$6.97/sq ft
Simple Bioretention (no engineered soils or under-drains, but w/curb cuts and forebays)	$10.00	$0.75/sq ft	30	$840/1000 sq ft	$210 (3 visits)	$11.59/sq ft
Moderate Bioretention (incl. engineered soils, under-drains, curb cuts, no retaining walls)	$12.00	$0.75/sq ft	30	$1120/1000 sq ft	$210 (3 visits)	$13.87/sq ft
Moderately Complex Bioretention (incl. engineered soils, under-drains, curb cuts, forebays , 2-3 ft retaining walls)	$14.00	$0.75/sq ft	30	$1250/1000 sq ft	$210 (3 visits)	$16.00/sq ft
Highly Complex	$16.00	$0.75/sq ft	30	[4]$1400/1000 sq ft	$210	$18.15/sq ft

Bioretention (incl. engineered soils, under-drains, curb cuts, forebays, 3-5 ft retaining walls)					(3 visits)	
Underground Sand Filter	$65.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$91.75/sq ft
Stormwater Tree Pits	$70.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$98.75/sq ft
Grass/Gravel Permeable Pavement (sand base)	$12.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$17.55/sq ft
Permeable Asphalt (granite base)	$10.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$14.00/sq ft
Permeable Concrete (granite base)	$12.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$17.55/sq ft
Permeable Pavers (granite base)	$25.00	$0.75/sq ft	30	[1]40% above construction	$210 (3 visits)	$35.75/sq ft
Extensive Green Roof	$225.00	$500/1000 sq ft	30	[1]40% above construction	$210 (3 visits)	$315.50/sq ft
Intensive Green Roof	$360.00	$750/1000 sq ft	30	[1]40% above construction	$210 (3 visits)	$504.75/sq ft

[1]Likely going to require a licensed, contacted engineer.

[2]Assumed landowner, not contractor, will maintain.

[3]LRP would only design off-line systems not requiring an engineer. For all projects requiring an engineer, assume engineering costs to be 40% above construction costs.

[4]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.

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

[5]Assumed to be 15 feet in width.

Crystal Lake Cost Analysis

For the Crystal Lake cost analysis, promotion and administration for each commercial/public property was estimated using a non-linear formula dependent on total number of 100 ft^3 treatment cells (BMPs). The labor associated with outreach, education and administrative tasks typically see savings with scale. Annual O & M 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.

Subwatershed Overview

The following illustrations describe the Crystal Lake subwatershed and its makeup.

Diagram 1 – Catchments

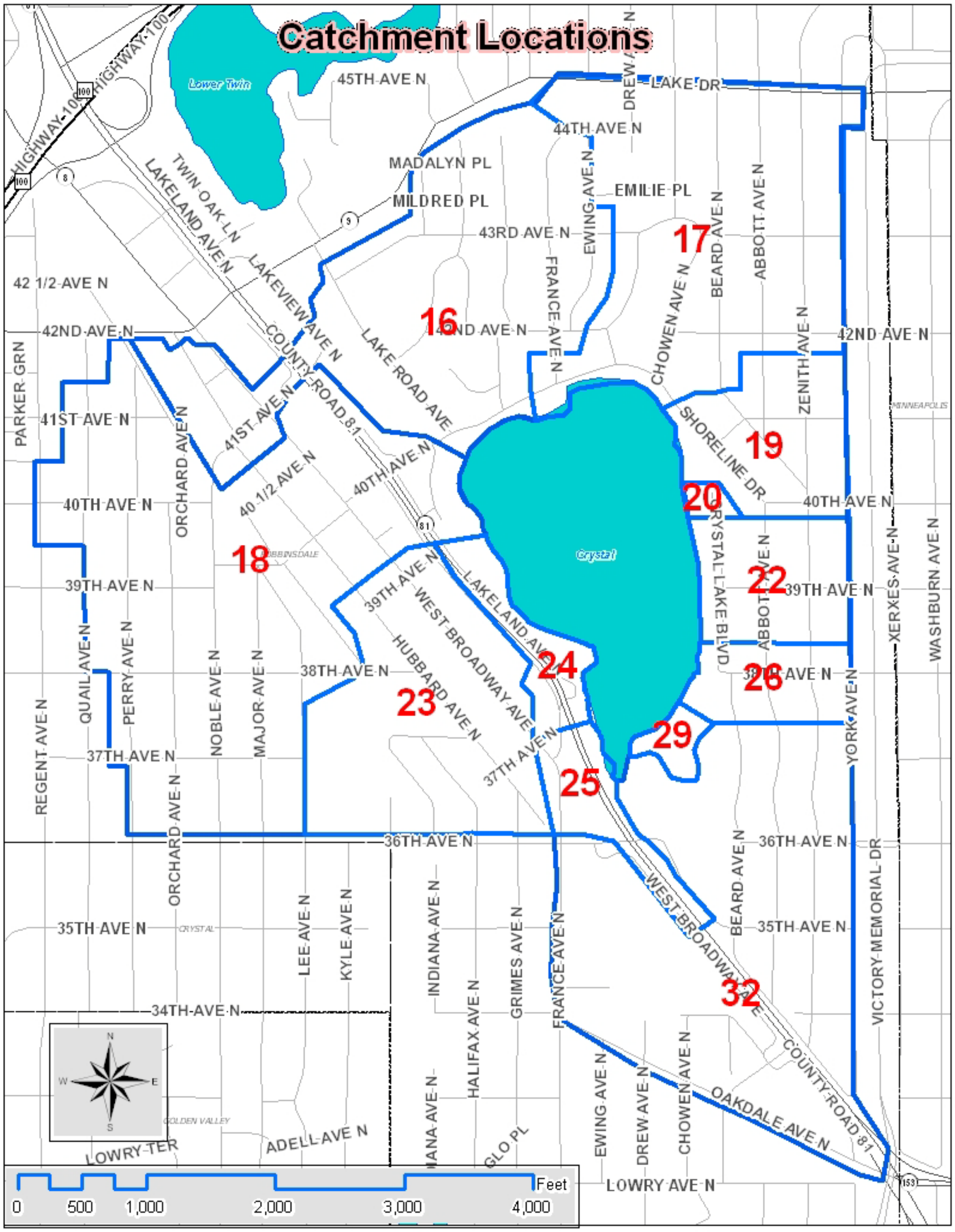


Diagram 2 – Storm-sewer network in Crystal Lake subwatershed

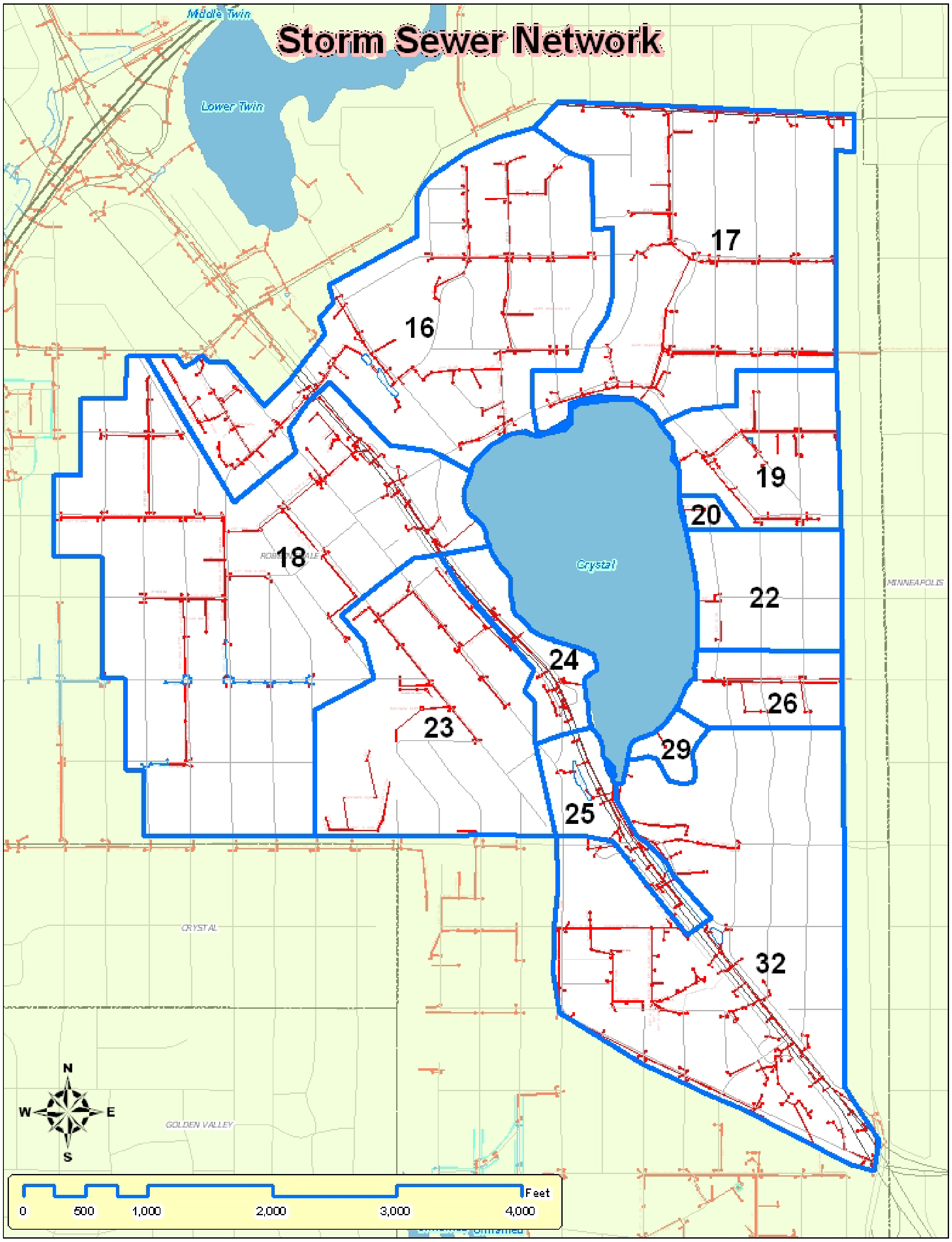


Diagram 3 – Land Use (Met Council 2005)

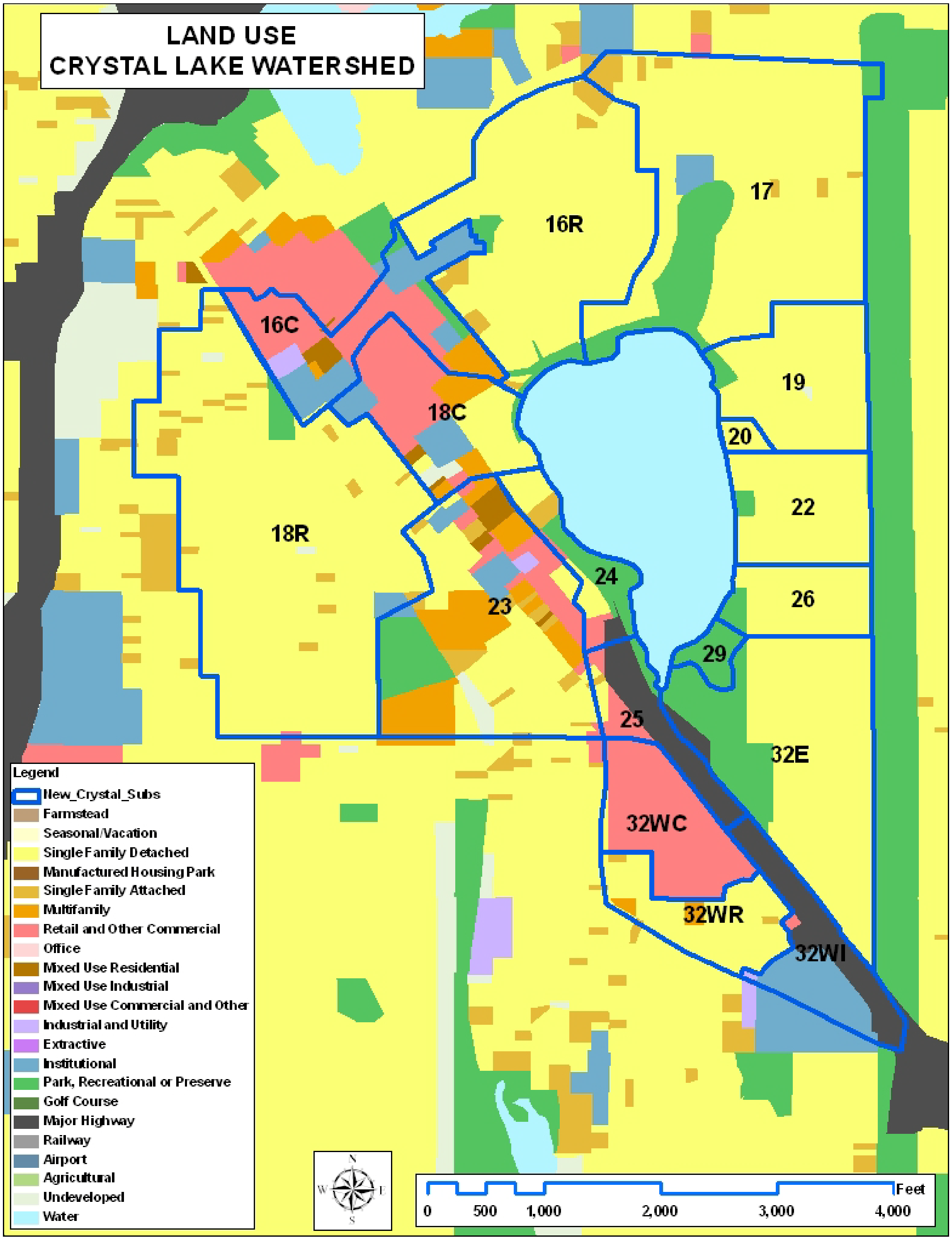
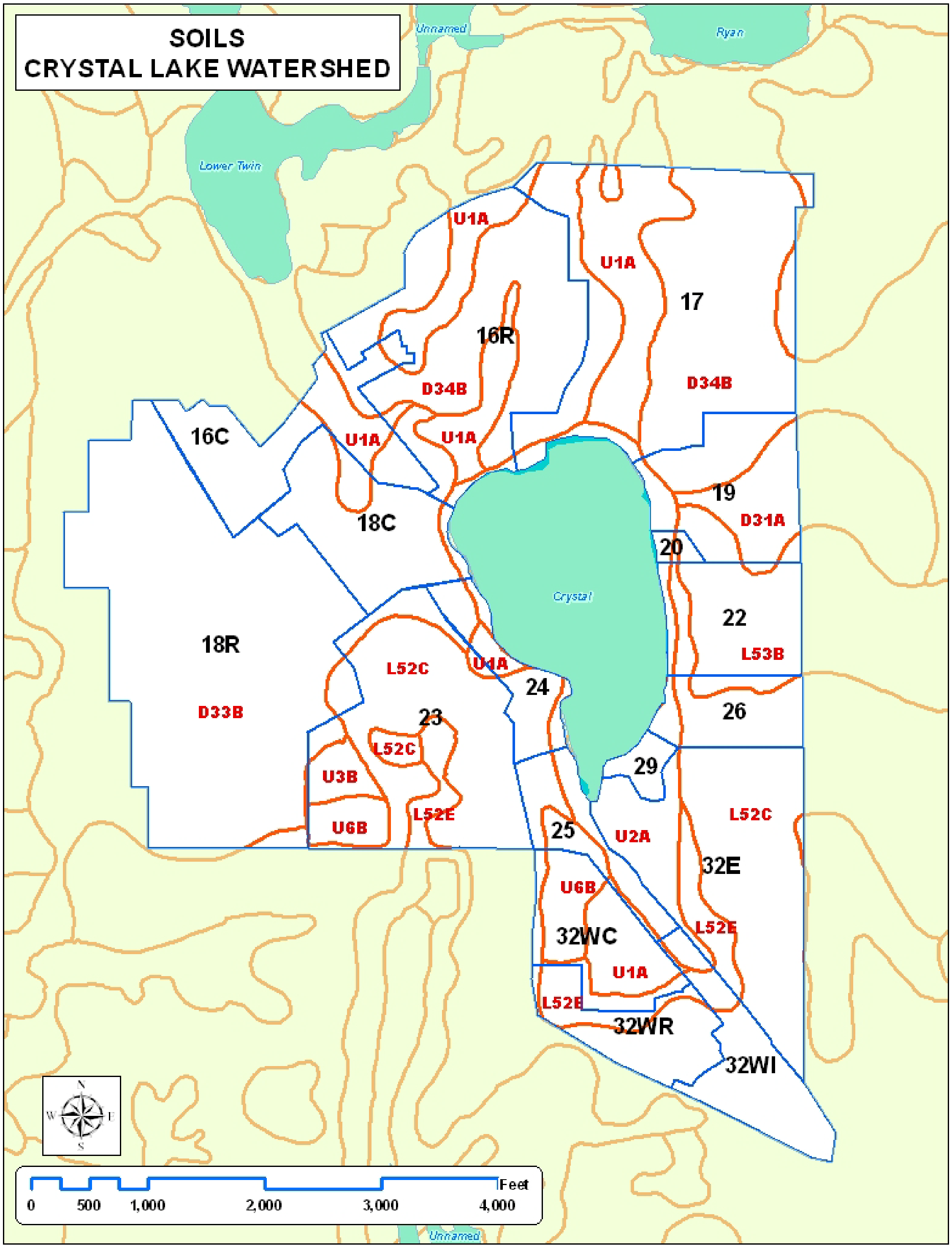


Diagram 4 – Soils distribution for the Crystal Lake subwatershed



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 regarding access to optimal BMP site locations, expected public buy-in (partnerships) and crew mobilization in relation to BMP spatial grouping

Each Catchment Profile includes a table showing the data relevant to various levels of treatment. The recommended treatment level (or expected success in establishing a certain amount of practices in the catchment) is highlighted. The table below is an example of such a table recommending the 43% treatment level to be achieved by modifying the existing pond with an enhanced iron sand filter. If the decision is made to move to the next level of treatment, by adding approximately 28 12’ X 6’ Tree Pits, then the expected treatment increases yet its value potentially decreases relative to other treatment levels found within other catchments in the study.

		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	**Base Loading**	**Treatment***	***Network Treatment By BMP***					
				Level 1		**Level 2**		**Level 3**	
Treatment	**Existing BMP performance (%TP)**		**34%**	**New**	**Net %**	**New**	**Net %**	**New**	**Net %**
	TP (lb/yr)	58.8	19.9	5.3	43%	10.1	51%	NA	
	TSS (lb/yr)	17185	11975	698	74%	1260	77%	NA	
	Volume (acre-feet/yr)	771.40	0.00	0.00	0%		0%	NA	
	Square feet of practice (or, CU FT of storage for WP, ED, SW)	26000		2000		1440			
Marginal Costs	**BMP Type**	Wet Pond		Pond Retrofits		Stormwater Tree Pits			
	Materials/Labor/Design			$5,000		$144,210			
	Unit Promotion & Admin Costs			$500		$2,416			
	Total Project Cost			$5,500		$179,006			
	Annual O&M			$1,500		$1,080			
	Term Cost/lb/yr (30 yr)			$318		$698			

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Crystal Lake 16-C

Existing Catchment Summary*	
Acres	33.0
Dominant Land Cover	COMM
Volume (acre-feet/yr)	771.4
TP (lb/yr)	58.8
TSS (lb/yr)	17185

*Before existing treatment

Model Inputs	
Parameter	**Input**
Pervious Curve Number	73
Indirectly Connected Impervious Fraction	0.02
Directly Connected Impervious Fraction	0.77
Hydraulic Conductivity (in/hr)	1.11

DESCRIPTION

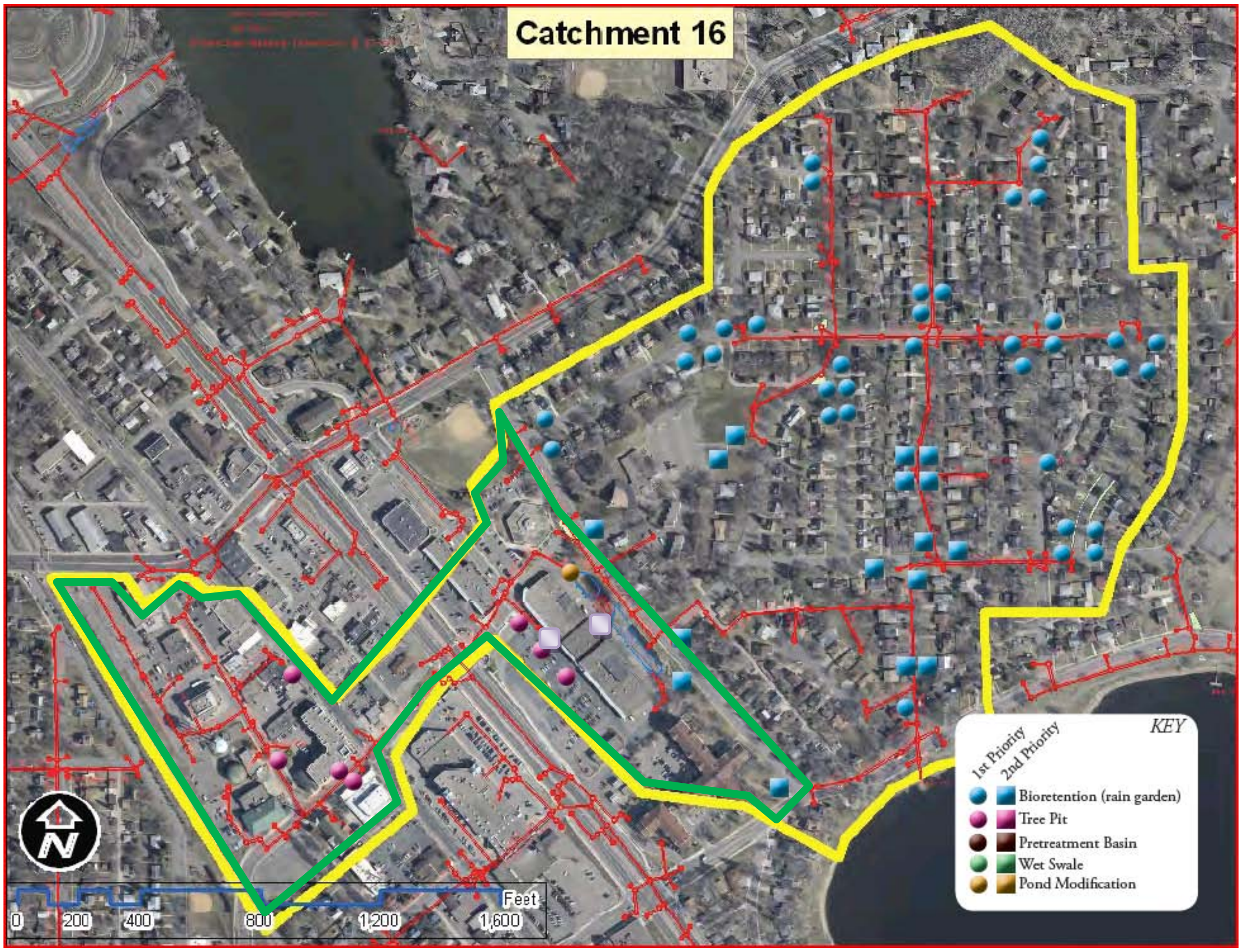
This catchment is comprised of primarily commercial with some institutional land use interspersed. Existing boulevard trees are reaching life-capacity along major roadways. The relatively high level of impervious cover had provided little space to retrofit stormwater practices. A two-celled detention pond (known as “Nummer Pond”) treats the area on its eastern terminus.

RETROFIT RECOMMENDATION

Due to the very tight working conditions within this particular catchment, it is recommended that the existing detention pond be retrofitted with an iron-enhanced sand filter. The iron-enhanced sand filter could be located at the outlet and consist of a 50 foot long, 4 foot wide bench as per Saint Anthony Falls/Prior Lake design specifications. Essentially this practice entails digging a 2 foot deep trench, lining the trench with EPDM, installing a drain tile along the length of the practice, and backfilling with iron-enhanced sand. The outlet is core-drilled into the riser or, in this case, the outlet culvert. We estimate that its performance, as modeled here, is on the conservative side.

An additional area to consider as a sort of pond modification would be a refurbishing design of the low area currently being used primarily as surface conveyance of parking lot runoff along the east side of City Hall. Deep ripping and amending of soils, in concert with the raisign of the outlet structure and/or adding an iron-enhanced sand filter, may be a viable option on public land for moving this catchment up a notch in treatment with relatively low costs.

For treatment levels beyond this, tree pits located within parking lots or in boulevard areas (at new locations or when replacing boulevard trees, for instance) is an option within this catchment, although not without substantial expense. In this rather highly impervious an tight catchment, however, it is the most likely option for added treatment beyond the pond modification described here.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment*	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		34%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	58.8	19.9	5.3	43%	10.1	51%	NA	
	TSS (lb/yr)	17185	11975	698	74%	1260	77%	NA	
	Volume (acre-feet/yr)	771.40	0.00	0.00	0%		0%	NA	
	Square feet of practice	26000		2000		1440			
Marginal Costs	BMP Type	Wet Pond		Pond Retrofits		Stormwater Tree Pits			
	Materials/Labor/Design			$5,000		$144,210			
	Admin Costs			$500		$2,416			
	Total Project Cost			$5,500		$146,626			
	Annual O&M			$1,500		$1,080			
	Term Cost/lb/yr (30 yr)			$318		$591			

Crvstal Lake 16-R

Existing Catchment Summary	
Acres	81.0
Dominant Land Cover	RES
Parcels	
Volume (acre-feet/yr)	840.6
TP (lb/yr)	59.5
TSS (lb/yr)	16717

Model Inputs	
Parameter	**Input**
Pervious Curve Number	73
Indirectly Connected Impervious Fraction	0.159
Directly Connected Impervious Fraction	0.236
Primary Site Hydraulic Conductivity (in/hr)	2.00

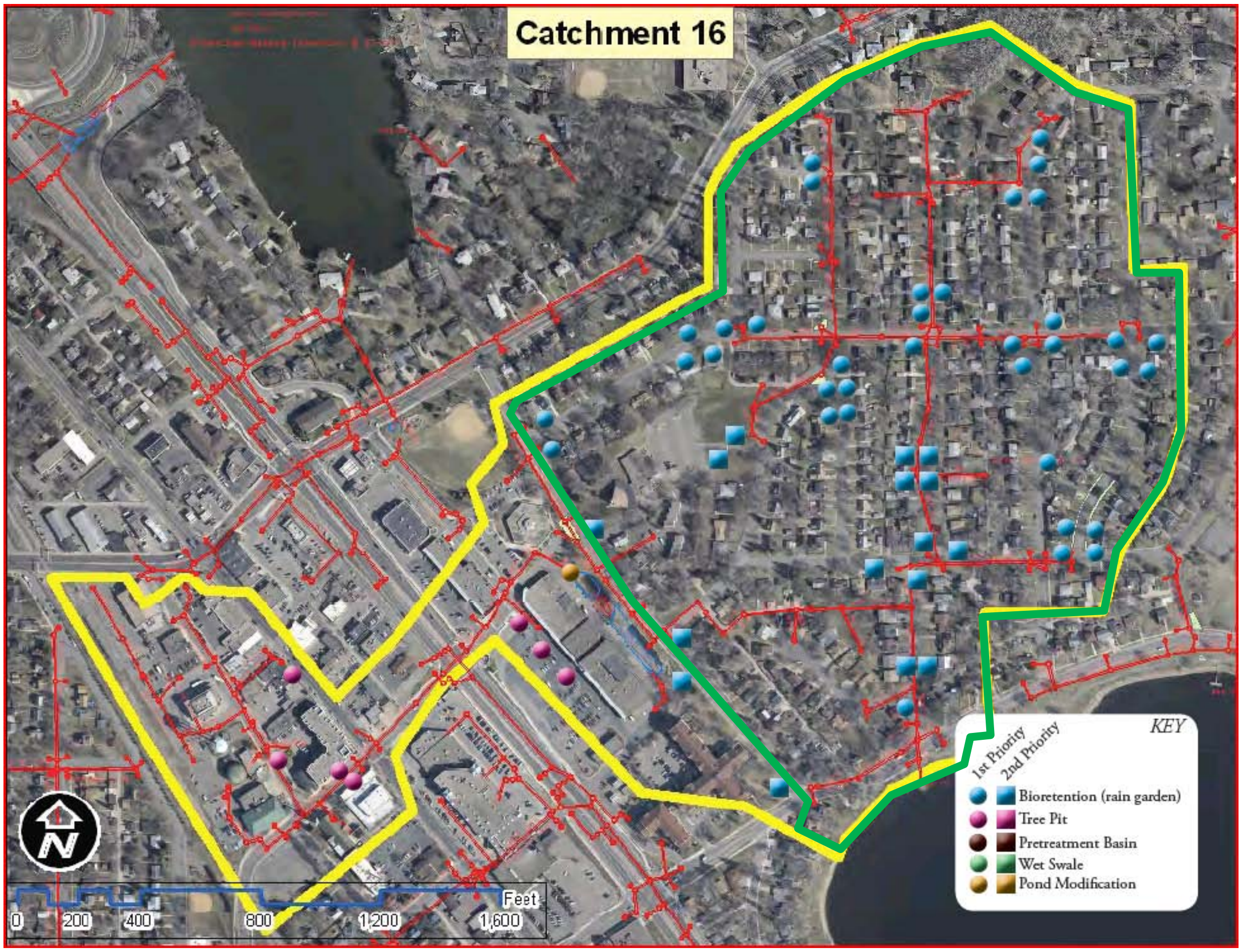
DESCRIPTION

This catchment is comprised of primarily medium density residential land use. Little alley cover exists.

RETROFIT RECOMMENDATION

Residential curb cut raingardens designed to be fully infiltrating (no engineered soils or underdrains), some with small and partial retaining walls, are recommended for the areas labeled as "1st Priority" on the catchment profile diagram at right. These areas are likely to have the best soils within the catchment and are situated ideally in relation to catch basins. In as such, this somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP. Soils should be amended with leaf compost and mulched with 3-in of shredded hardwood mulch.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity will assists the designer determine whether an underdrain and engineered soils are warranted.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	**Base Loading**	**Treatment**	***Network Treatment By BMP***					
				Level 1		**Level 2**		**Level 3***	
Treatment	**Existing BMP performance**		**0%**	**New**	**Net %**	**New**	**Net %**	**New**	**Net %**
	TP (lb/yr)	59.5		5.9	10%	11.9	20%	17.8	30%
	TSS (lb/yr)	16717		4470	27%	6552	39%	8210	49%
	Volume (acre-feet/yr)	840.60		97.50	12%	194.20	23%	285.00	34%
	Square feet of practice			1550		3820		6815	
Marginal Costs	**BMP Type**	No Treatment		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$21,755		$53,308		$94,939	
	Admin Costs			$2,478		$3,749		$5,426	
	Total Project Cost			$24,233		$57,057		$100,365	
	Annual O&M			$1,163		$2,865		$5,111	
	Term Cost/lb/yr (30 yr)			$334		$401		$475	

Crystal Lake 17

Existing Catchment Summary	
Acres	109.0
Dominant Land Cover	MDRA
Volume (acre-feet/yr)	1106.1
TP (lb/yr)	78.1
TSS (lb/yr)	21911

Model Inputs	
Parameter	**Input**
Pervious Curve Number	73
Indirectly Connected Impervious Fraction	0.145
Directly Connected Impervious Fraction	0.231
Hydraulic Conductivity (in/hr)	1.43

DESCRIPTION

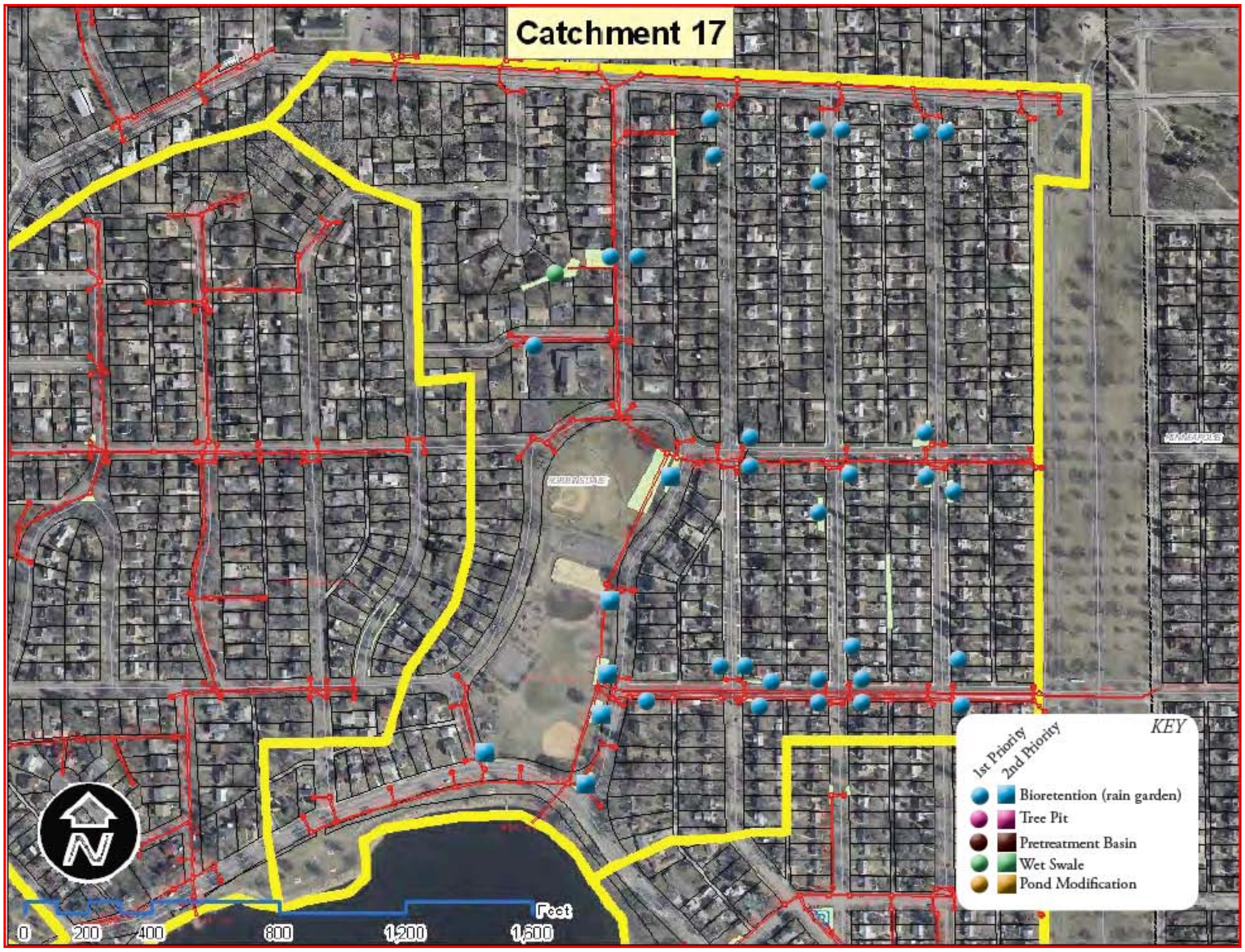
This catchment is comprised of primarily medium density residential land use. Alley cover exists.

RETROFIT RECOMMENDATION

Residential curb cut raingardens designed to be fully infiltrating (no engineered soils or underdrains), some with small and partial retaining walls, are recommended for the areas labeled as "1st Priority" on the catchment profile diagram at right. These areas are likely to have the best soils within the catchment and are situated ideally in relation to catch basins. In as such, this somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP. Soils should be amended with leaf compost and mulched with 3-in of shredded hardwood mulch.

Similarly, there are several opportunities located along the curb lines that define the City Park that could take runoff from the adjacent streets. For example, along the park's north eastern side a rather large open-space area is conducive to a curb cut bioretention cell as well as along the south-eastern and south-western perimeter.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer determine whether an underdrain and engineered soils are warranted.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	78.1		7.8	10%	15.6	20%	23.4	30%
	TSS (lb/yr)	21911		6115	28%	8806	40%	10945	50%
	Volume (acre-feet/yr)	1106.10		113.60	10%	232.00	21%	346.30	31%
	Square feet of practice			2400		5700		10200	
Marginal Costs	BMP Type	No Treatment		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$33,570		$79,440		$141,990	
	Admin Costs			$2,954		$4,802		$7,322	
	Total Project Cost			$36,524		$84,242		$149,312	
	Annual O&M			$1,800		$4,275		$7,650	
	Term Cost/lb/yr (30 yr)			$387		$454		$540	

Crvstal Lake 18-C

Existing Catchment Summary	
Acres	35.5
Dominant Land Cover	MDRA
Volume (acre-feet/yr)	655.9
TP (lb/yr)	49.6
TSS (lb/yr)	14427

Model Inputs	
Parameter	**Input**
Pervious Curve Number	71
Indirectly Connected Impervious Fraction	0.051
Directly Connected Impervious Fraction	0.645
Hydraulic Conductivity (in/hr)	2.00

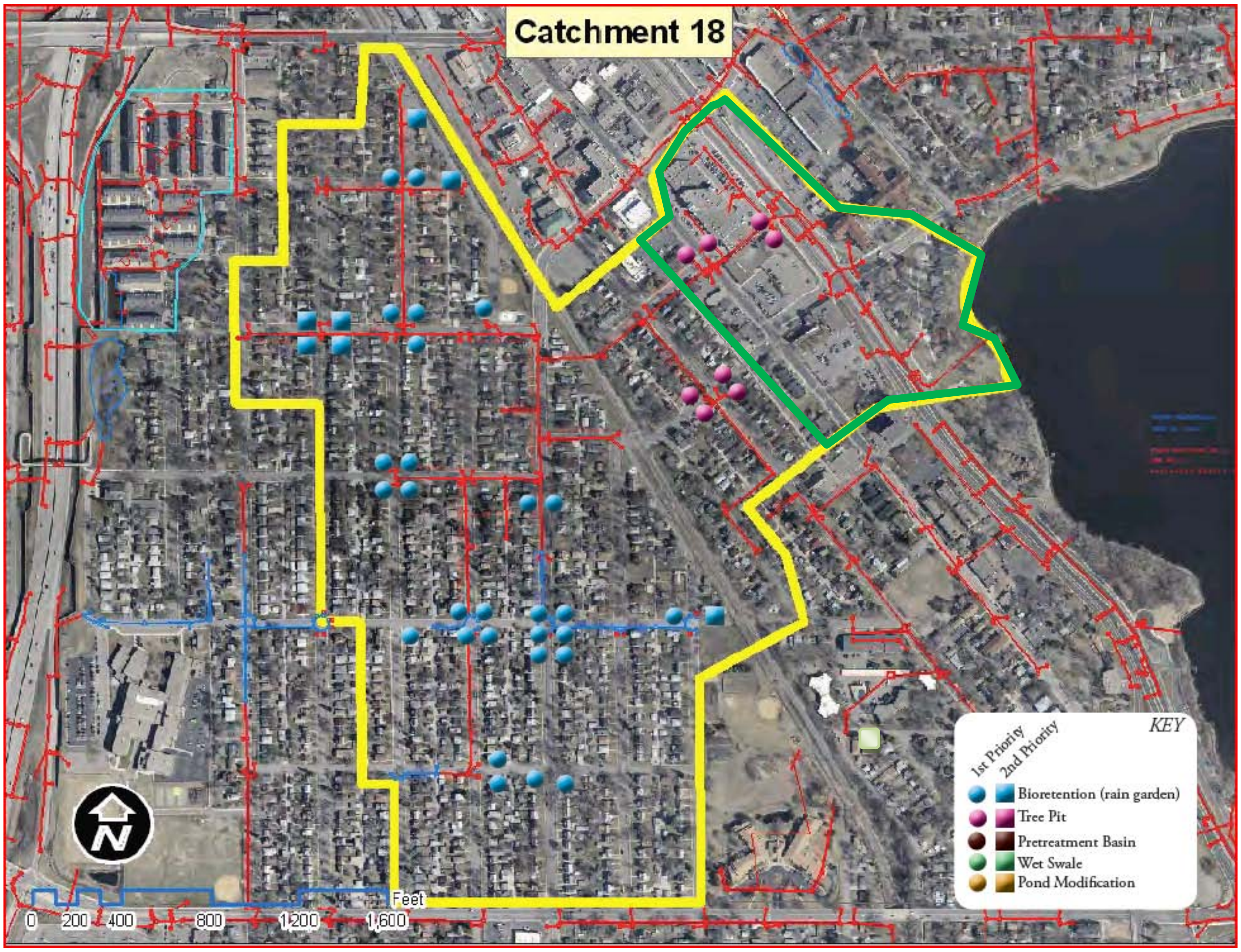
DESCRIPTION

This catchment is comprised of primarily commercial land uses. Existing boulevard trees are reaching life-capacity along major roadways. The relatively high level of impervious cover had provided little space to retrofit stormwater practices.

RETROFIT RECOMMENDATION

Due to the very tight working conditions within this particular catchment, it is recommended that stormwater tree planters/pits be designed, manufactured and installed by the City Public Works and Engineering departments. At this point, several commercial products are available for this BMP as well, but for the sake of cost estimates, we have assumed the City will likely choose to do this work in-house. Contact the City of St. Cloud's Engineering Department for and example of their design. We have modeled the tree planters without engineered soils and underdrains for this catchment given the likelihood of decent soils for infiltration.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	49.6		5.0	10%	9.9	20%	14.9	30%
	TSS (lb/yr)	14427		4215	29%	6115	42%	7600	53%
	Volume (acre-feet/yr)	655.90		84.70	13%	170.60	26%	252.00	38%
	Square feet of practice			1300		3200		5700	
Marginal Costs	BMP Type	No Treatment		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$18,280		$44,690		$79,440	
	Admin Costs			$2,338		$3,402		$4,802	
	Total Project Cost			$20,618		$48,092		$84,242	
	Annual O&M			$975		$2,400		$4,275	
	Term Cost/lb/yr (30 yr)			$332		$404		$475	

Crvstal Lake 18-R

Existing Catchment Summary	
Acres	136.1
Dominant Land Cover	MDRA
Volume (acre-feet/yr)	1363.1
TP (lb/yr)	96.4
TSS (lb/yr)	27084

Model Inputs	
Parameter	**Input**
Pervious Curve Number	69
Indirectly Connected Impervious Fraction	0.162
Directly Connected Impervious Fraction	0.245
Hydraulic Conductivity (in/hr)	2.00

DESCRIPTION

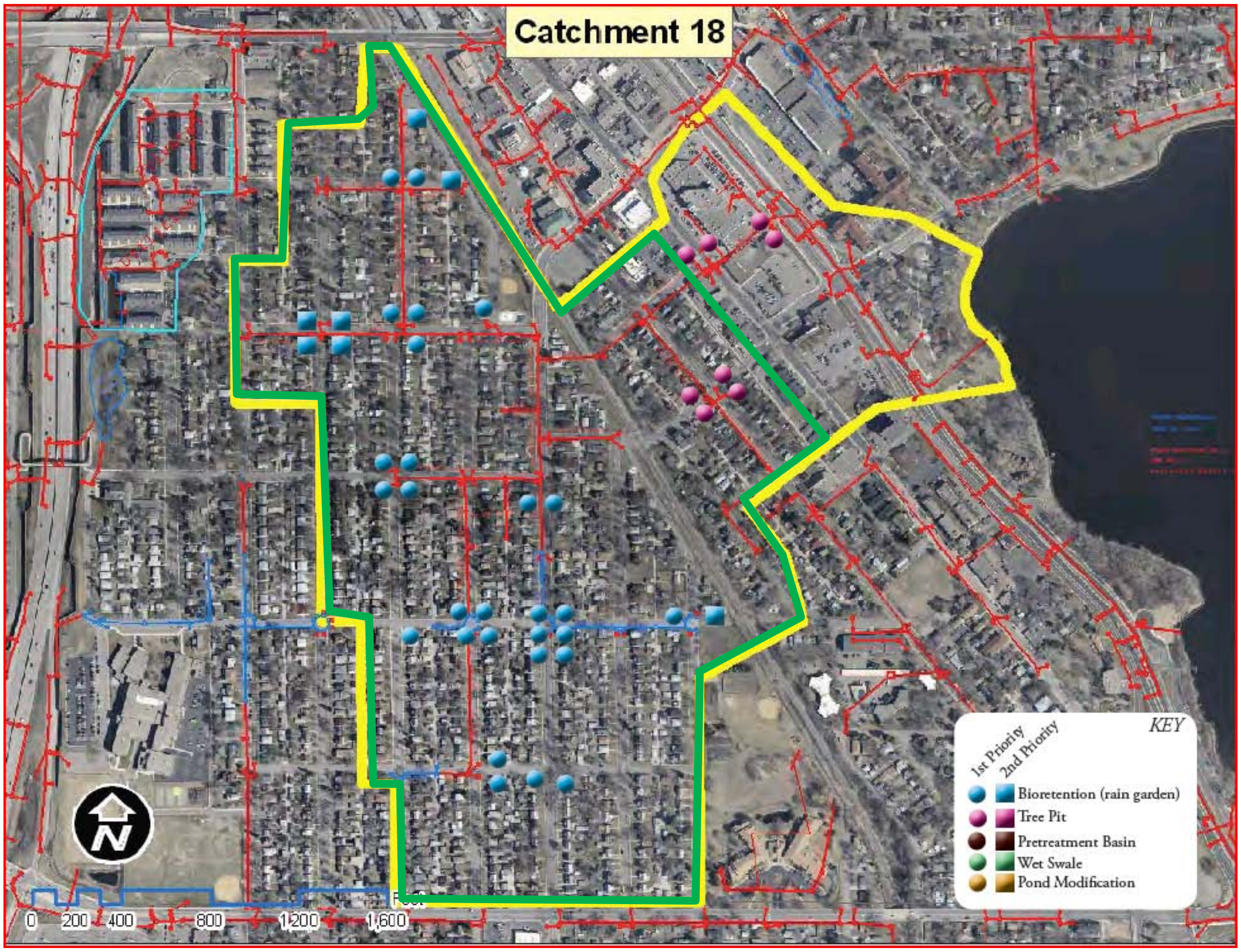
This catchment is comprised of primarily medium density residential land use. Alley cover exists.

RETROFIT RECOMMENDATION

Residential curb cut raingardens designed to be fully infiltrating (no engineered soils or underdrains), some with small and partial retaining walls, are recommended for the areas labeled as "1st Priority" on the catchment profile diagram at right. These areas are likely to have the best soils within the catchment and are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP. Soils should be amended with leaf compost and mulched with 3-in of shredded hardwood mulch.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.

Permeable alleys are not recommended by us at this time given their cost per annual unit of pollutant removed either when considering capacity or life-span costs.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	Network Treatment By BMP					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	96.4		9.7	10%	19.2	20%	28.9	30%
	TSS (lb/yr)	27084		7750	29%	11280	42%	14117	52%
	Volume (acre-feet/yr)	1363.10		170.10	12%	339.40	25%	496.50	36%
	Square feet of practice			2750		6750		12150	
Marginal Costs	BMP Type	No Treatment		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$38,435		$94,035		$169,095	
	Admin Costs			$3,150		$5,390		$8,414	
	Total Project Cost			$41,585		$99,425		$177,509	
	Annual O&M			$2,063		$5,063		$9,113	
	Term Cost/lb/yr (30 yr)			$356		$436		$520	

Crvstal Lake 19

Existing Catchment Summary*	
Acres	35.0
Dominant Land Cover	RES
Volume (acre-feet/yr)	315.4
TP (lb/yr)	22.2
TSS (lb/yr)	6227

Model Inputs	
Parameter	**Input**
Pervious Curve Number	63
Indirectly Connected Impervious Fraction	0.162
Directly Connected Impervious Fraction	0.234
Hydraulic Conductivity (in/hr)	2.00

*Before existing treatment (data provided insufficient to estimate existing treatment)

DESCRIPTION

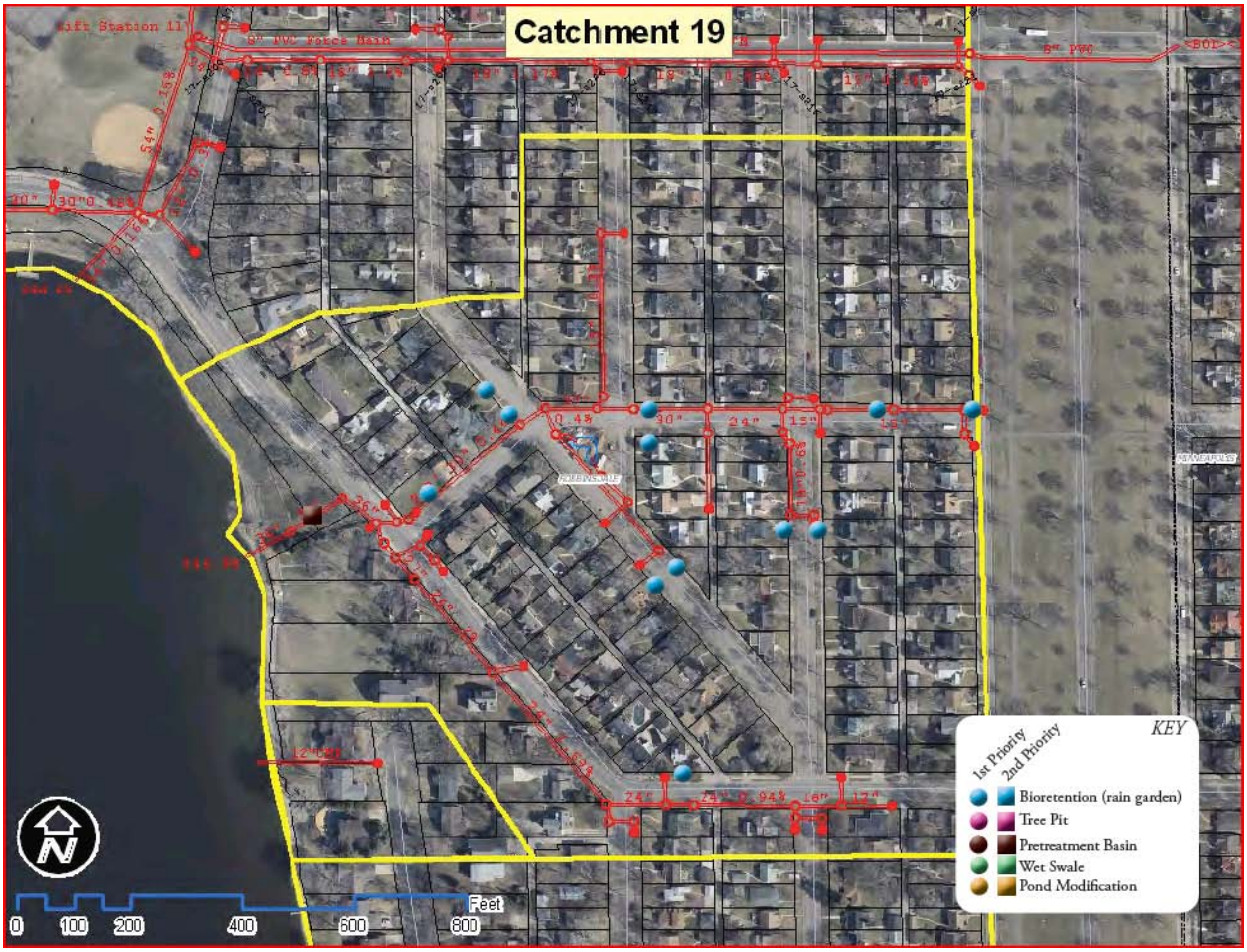
This catchment is comprised of primarily medium density residential land use. Alley cover exists. We were unable to model the expected treatment provided by the existing raingarden the City installed given the data provided to us. Most of the area is hilly in nature.

RETROFIT RECOMMENDATION

Residential curb cut raingardens designed to be fully infiltrating (no engineered soils or underdrains), some with small and partial retaining walls, are recommended for the areas labeled as "1st Priority" on the catchment profile diagram at right. These areas are likely to have the best soils within the catchment and are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. Care must to be taken to site BMP's on more level streets with shallow grades extending along street sides; moderate slopes leading away (or perpendicular from) streets are feasible with retraining wall up to 4 feet in nature but obviously more expensive. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP. Soils should be amended with leaf compost and mulched with 3-in of shredded hardwood mulch.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.

Permeable alleys are not recommended by us at this time given their cost per annual unit of pollutant removed either when considering capacity or life-span costs.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	**Base Loading**	**Treatment (undetermined)**	***Network Treatment By BMP***					
				Level 1		**Level 2**		**Level 3**	
Treatment	**Existing BMP performance**		**0%**	**New**	**Net %**	**New**	**Net %**	**New**	**Net %**
	TP (lb/yr)	22.2		2.2	10%	4.4	20%	6.7	30%
	TSS (lb/yr)	6227		1715	28%	2500	40%	3110	50%
	Volume (acre-feet/yr)	315.40		35.10	11%	70.30	22%	105.00	33%
	Square feet of practice			550		1320		2400	
Marginal Costs	**BMP Type**	Highly Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$7,855		$18,558		$33,570	
	Admin Costs			$1,918		$2,349		$2,954	
	Total Project Cost			$9,773		$20,907		$36,524	
	Annual O&M			$413		$990		$1,800	
	Term Cost/lb/yr (30 yr)			$336		$383		$450	

Crvstal Lake 22

Existing Catchment Summary	
Acres	26.3
Dominant Land Cover	RES
Volume (acre-feet/yr)	259.2
TP (lb/yr)	18.3
TSS (lb/yr)	5123

Model Inputs	
Parameter	**Input**
Pervious Curve Number	70
Indirectly Connected Impervious Fraction	0.162
Directly Connected Impervious Fraction	0.234
Hydraulic Conductivity (in/hr)	0.20
Engineered Soil HC (in/hr)	2.5

DESCRIPTION

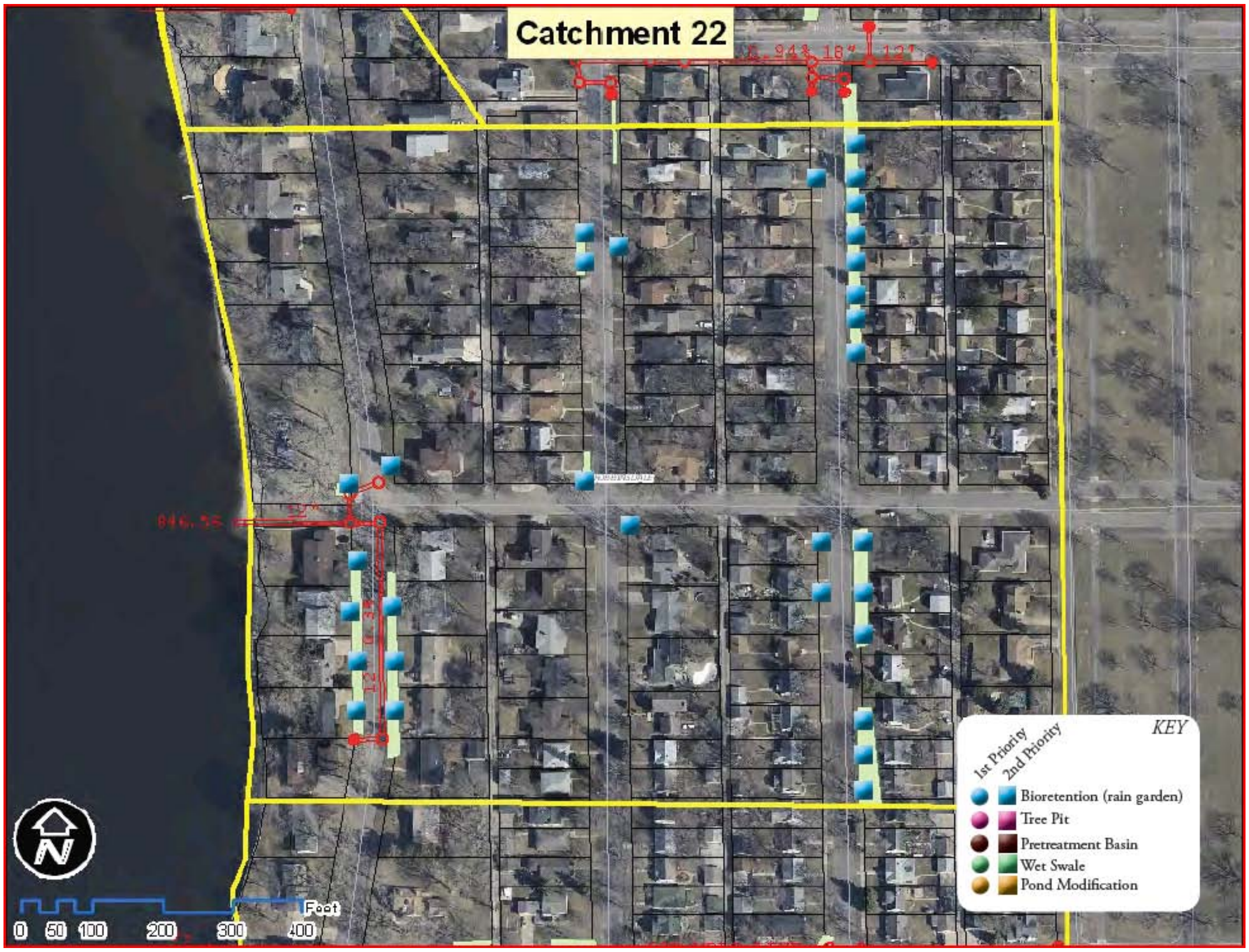
This catchment is comprised of primarily medium density residential land use. Alley cover exists.

RETROFIT RECOMMENDATION

Residential curb cut raingardens designed to be mostly filtering (with engineered soils and underdrains), most with medium-sized and partial retaining walls, are recommended for the areas labeled as "2nd Priority" on the catchment profile diagram at right. These areas are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. Care must be taken to site BMP's on more level streets with shallow grades extending along street sides. Moderate slopes leading away (or perpendicular from) streets is surmountable with retraining wall up to 4 feet in nature but obviously more expensive. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.

Permeable alleys are not recommended by us at this time given their cost per annual unit of pollutant removed either when considering capacity or life-span costs.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	18.3		1.8	10%	3.6	20%	5.5	30%
	TSS (lb/yr)	5123		1408	27%	2078	41%	2620	51%
	Volume (acre-feet/yr)	259.20		0.00	0%	0.00	0%	0.00	0%
	Square feet of practice			500		1200		2000	
Marginal Costs	BMP Type	No Treatment		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design			$8,310		$19,650		$32,610	
	Admin Costs			$1,890		$2,282		$2,730	
	Total Project Cost			$10,200		$21,932		$35,340	
	Annual O&M			$375		$900		$1,500	
	Term Cost/lb/yr (30 yr)			$397		$453		$487	

Crvstal Lake 23

Existing Catchment Summary	
Acres	72.3
Dominant Land Cover	RES/COM
Volume (acre-feet/yr)	1054.0
TP (lb/yr)	77.7
TSS (lb/yr)	22319

Model Inputs	
Parameter	**Input**
Pervious Curve Number	72
Indirectly Connected Impervious Fraction	0.082
Directly Connected Impervious Fraction	0.422
Hydraulic Conductivity (in/hr)	0.10
Engineered Soil HC (in/hr)	2.5

DESCRIPTION

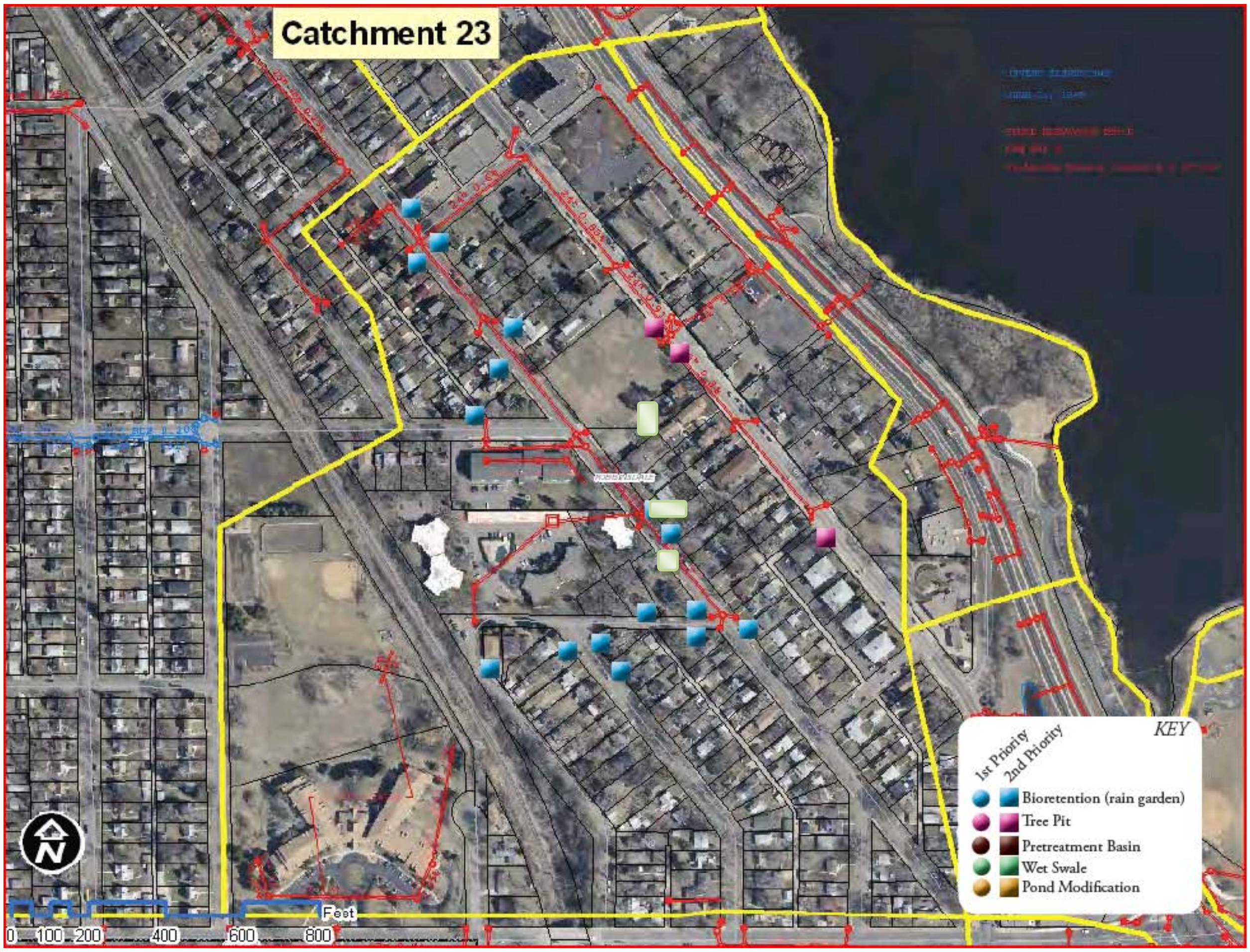
This catchment is comprised of primarily medium density residential and multi-family residential land uses along with various other, smaller contributing uses. Alley cover exists.

RETROFIT RECOMMENDATION

Curb cut raingardens designed to be mostly filtering (with engineered soils and underdrains), most with medium-sized and partial retaining walls, are recommended for the areas labeled as "2nd Priority" on the catchment profile diagram at right. These areas are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance. The actual performance of proposed/installed BMP's should try to emulate this pattern. Care must be taken to site BMP's on more level streets with shallow grades extending along street sides; moderate slopes leading away (or perpendicular from) streets is surmountable with retraining wall up to 4 feet in nature but obviously more expensive. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.

Permeable alleys are not recommended by us at this time given their cost per annual unit of pollutant removed either when considering capacity or life-span costs.



		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	77.7		7.8	10%	15.5	20%	23.3	30%
	TSS (lb/yr)	22319		6260	28%	9200	41%	11540	52%
	Volume (acre-feet/yr)	1054.00		0.00	0%	0.00	0%	0.00	0%
	Square feet of practice			2000		4750		8250	
Marginal Costs	BMP Type	No Treatment		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design			$32,610		$77,160		$133,860	
	Admin Costs			$2,730		$4,270		$6,230	
	Total Project Cost			$35,340		$81,430		$140,090	
	Annual O&M			$1,500		$3,563		$6,188	
	Term Cost/lb/yr (30 yr)			$343		$405		$466	

Crystal Lake 26

Existing Catchment Summary	
Acres	17.3
Dominant Land Cover	RES
Volume (acre-feet/yr)	169.5
TP (lb/yr)	11.9
TSS (lb/yr)	3341

Model Inputs	
Parameter	**Input**
Pervious Curve Number	71
Indirectly Connected Impervious Fraction	0.155
Directly Connected Impervious Fraction	0.227
Hydraulic Conductivity (in/hr)	0.30
Engineered Soil HC (in/hr)	2.5

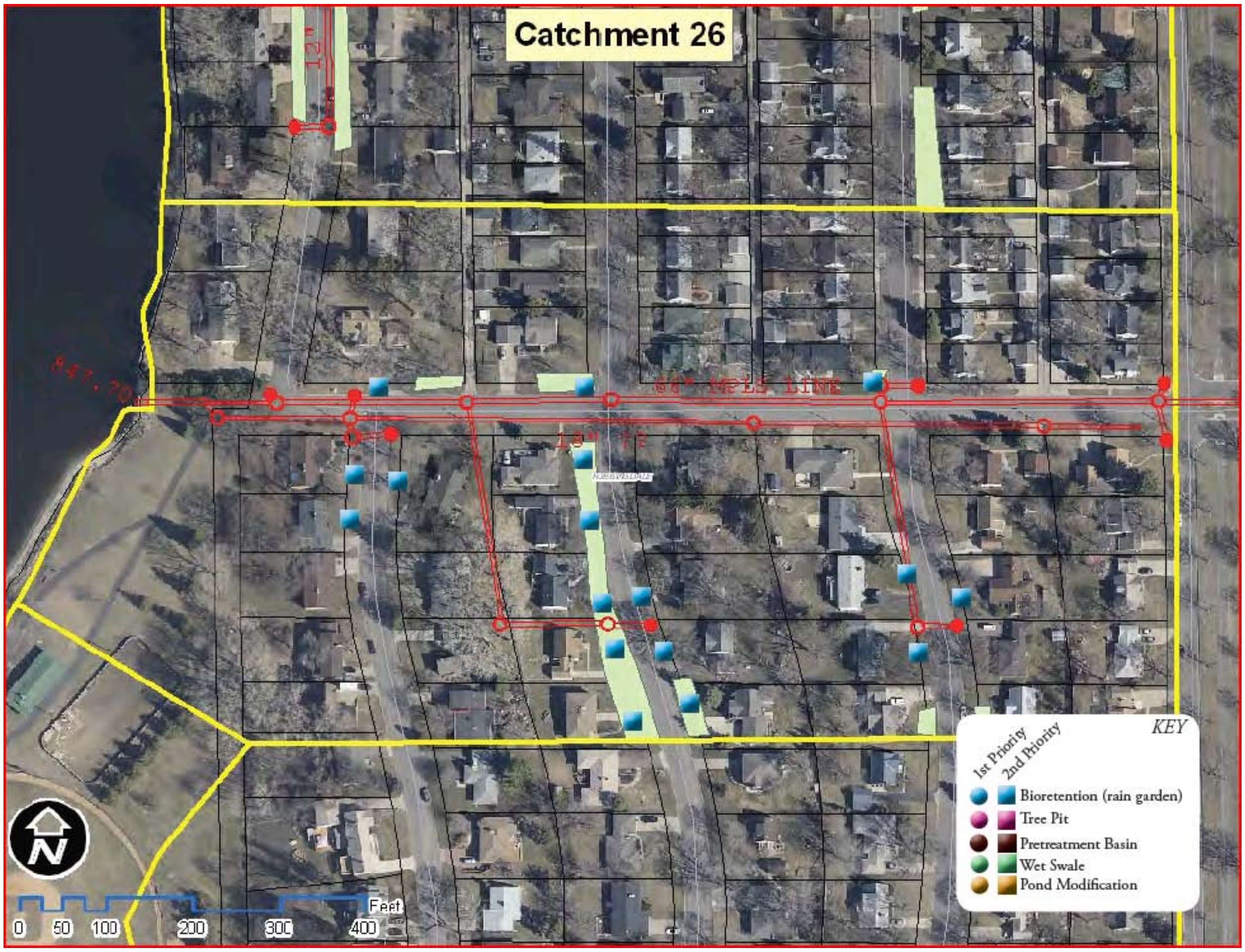
DESCRIPTION

This small catchment is comprised of primarily medium density residential.

RETROFIT RECOMMENDATION

Curb cut raingardens designed to be mostly filtering (with engineered soils and underdrains), most with medium-sized and partial retaining walls, are recommended for the areas labeled as "2nd Priority" on the catchment profile diagram at right. These areas are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. Care must be taken to site BMP's on more level streets with shallow grades extending along street sides; moderate slopes leading away (or perpendicular from) streets is surmountable with retraining wall up to 4 feet in nature but obviously more expensive. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.



	Cost/Benefit Analysis	EXISTING CONDITIONS Base Loading	EXISTING CONDITIONS Treatment	RETROFIT OPTIONS Network Treatment By BMP Level 1 New	Level 1 Net %	Level 2 New	Level 2 Net %	Level 3 New	Level 3 Net %
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	11.9		1.2	10%	2.4	20%	3.6	30%
	TSS (lb/yr)	3341		920	28%	1350	40%	1700	51%
	Volume (acre-feet/yr)	169.50		0.00	0%	0.00	0%	0.00	0%
	Square feet of practice			300		800		1375	
Marginal Costs	BMP Type	No Treatment		Complex Bioretention		Complex Bioretention		Complex Bioretention	
	Materials/Labor/Design			$5,070		$13,170		$22,485	
	Admin Costs			$1,778		$2,058		$2,380	
	Total Project Cost			$6,848		$15,228		$24,865	
	Annual O&M			$225		$600		$1,031	
	Term Cost/lb/yr (30 yr)			$378		$462		$517	

Crystal Lake 32E

Existing Catchment Summary	
Acres	67.6
Dominant Land Cover	RES
Volume (acre-feet/yr)	620.0
TP (lb/yr)	43.2
TSS (lb/yr)	12037

Model Inputs	
Parameter	**Input**
Pervious Curve Number	72
Indirectly Connected Impervious Fraction	0.135
Directly Connected Impervious Fraction	0.203
Hydraulic Conductivity (in/hr)	1.00

DESCRIPTION

This catchment is comprised of primarily medium density residential and multi-family residential land uses along with various other, smaller contributing uses. Alley cover exists.

RETROFIT RECOMMENDATION

Curb cut raingardens designed to be a combination of filtering and infiltrating (with engineered soils and a suspended underdrain), most with medium-sized and partial retaining walls, are recommended for the areas labeled as "2nd Priority" on the catchment profile diagram at right. We modeled this catchment's BMP costs out as an average design expecting that some BMP's will require engineered soils and underdrains while others won't. These areas are situated ideally in relation to catch basins. This somewhat spread out distribution of BMP's in the landscape will optimize each cell's performance and actual performance of proposed/installed BMP's should try to emulate this pattern. Care will need to be taken to site BMP's on more level streets with shallow grades extending along street sides; moderate slopes leading away (or perpendicular from) streets is surmountable with retraining wall up to 4 feet in nature but obviously more expensive. A pretreatment forebay similar to Anoka Conservation District's "Rain Guardian" is recommended to reduce maintenance over the long term, localize maintenance efforts and extend the lifespan of the BMP.

In 32W, the commercial/industrial portion of catchment 32 to the west, outreach to properties with potential for in-lot treatment will extend treatment beyond the initially-recommended levels reported here, but at significant cost, low buy-in expectations and relatively difficult siting conditions.

Actual hydraulic capacity will need to be estimated for each BMP proposed, preferably measured at each unique site, to be installed once property owners have committed to allowing the City to install infiltrating BMP's on their property. Measuring the hydraulic capacity assists the designer in determining whether an underdrain and engineered soils are warranted.

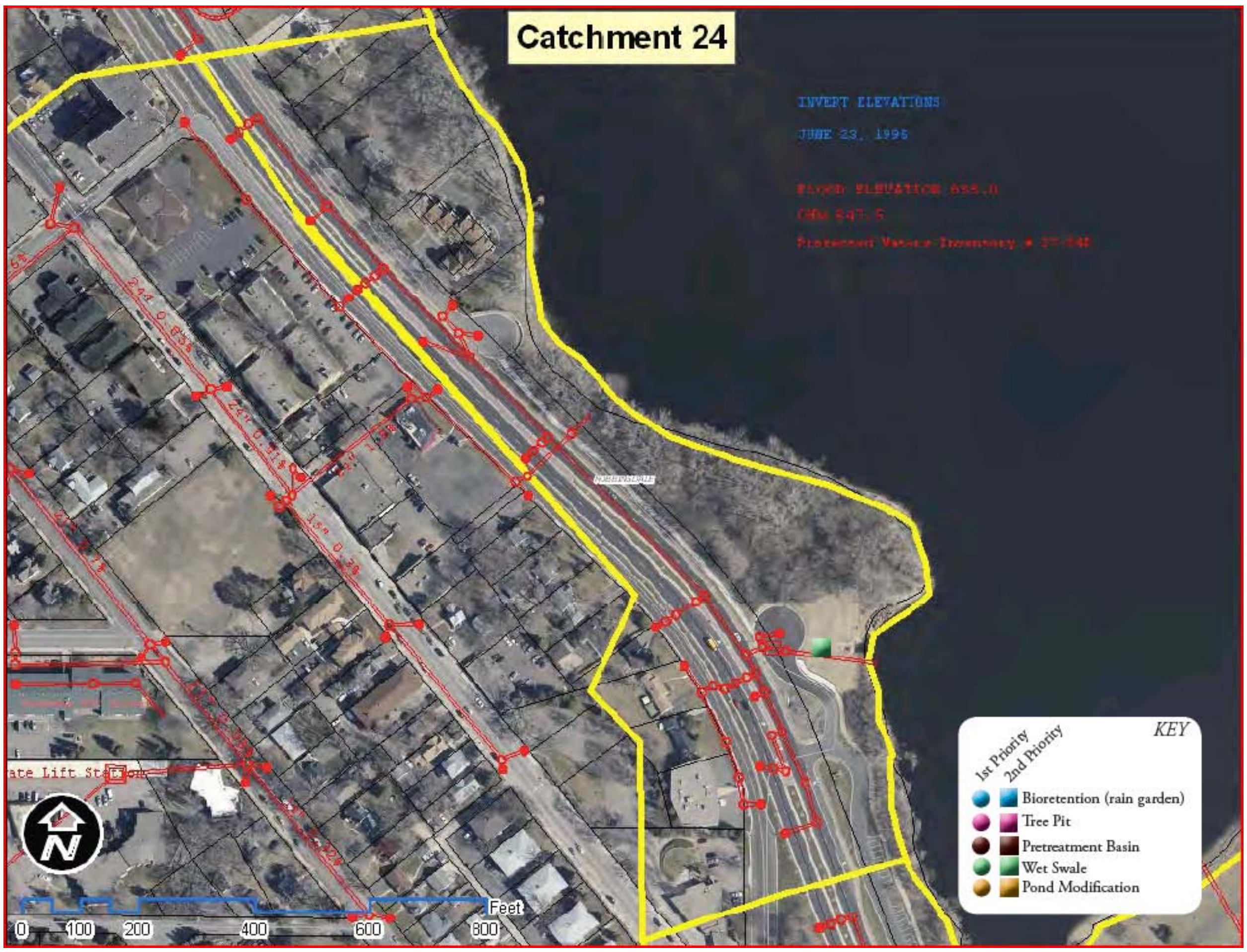
Permeable alleys are not recommended by us at this time given their cost per annual unit of pollutant removed either when considering capacity or life-span costs.

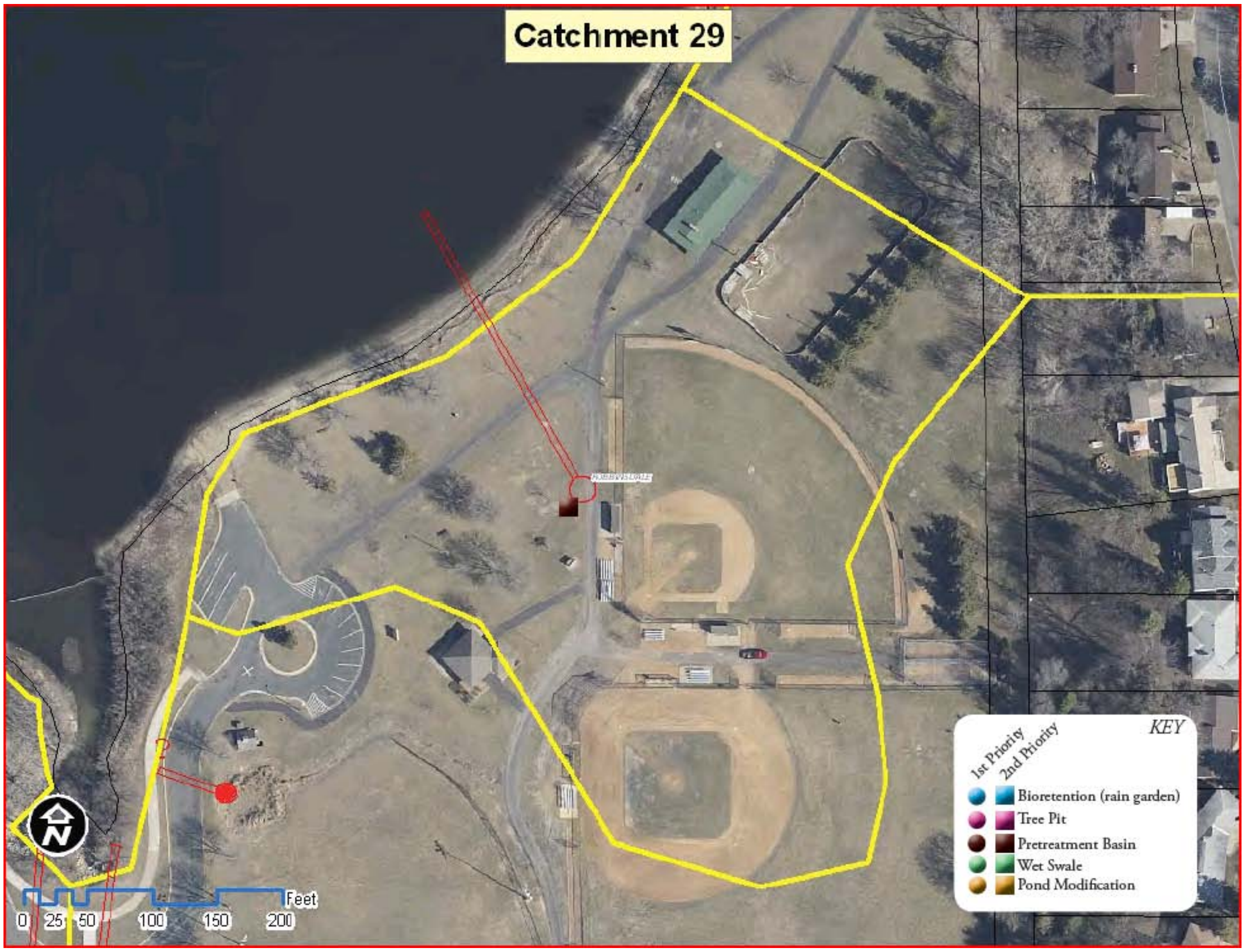

Catchments 32E & 32W
KEY
1st Priority
2nd Priority
Bioretention (rain garden)
Tree Pit
Pretreatment Basin
Wet Swale
Pond Modification
0 100 200 400 600 800
Feet

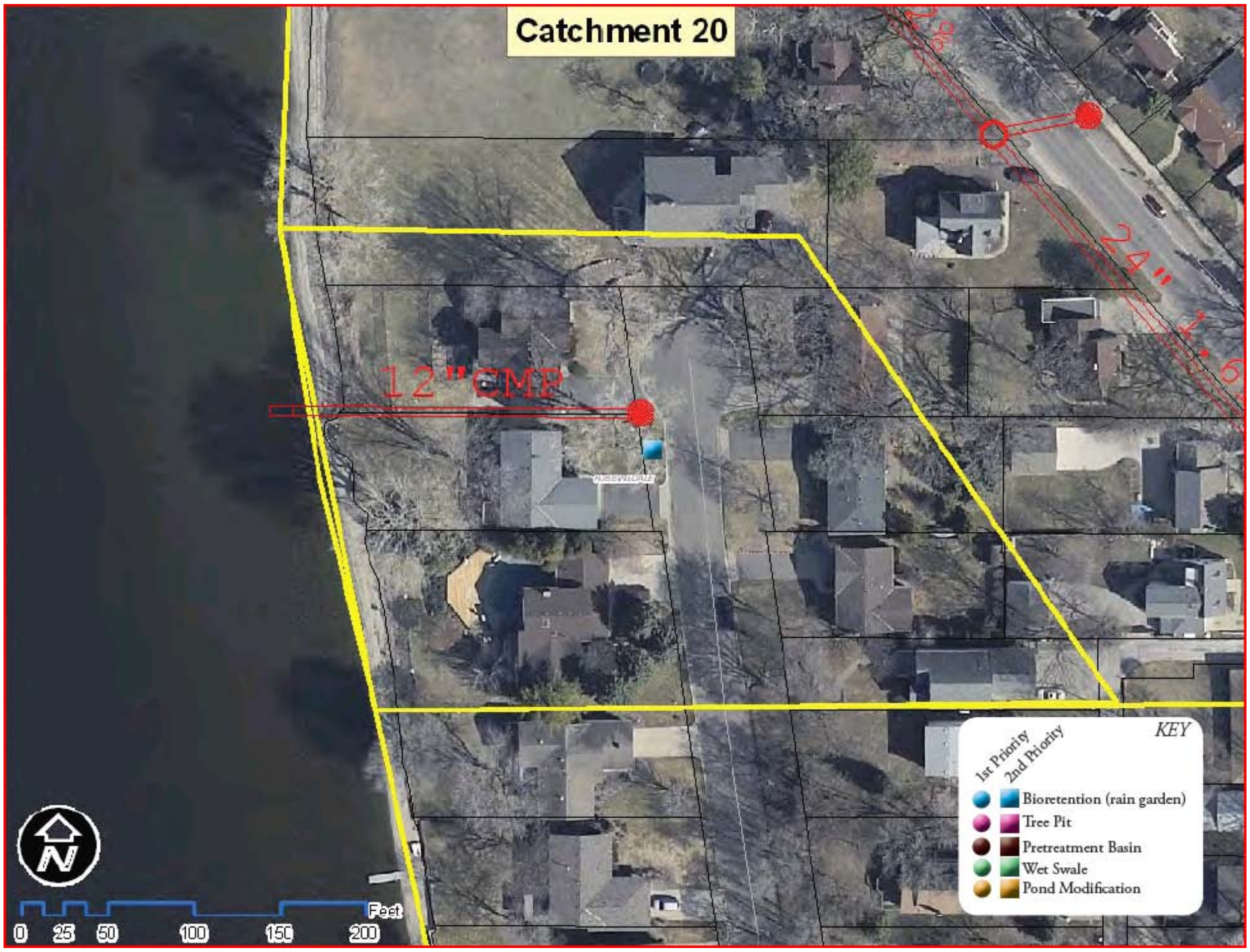
		EXISTING CONDITIONS		RETROFIT OPTIONS					
	Cost/Benefit Analysis	Base Loading	Treatment	*Network Treatment By BMP*					
				Level 1		Level 2		Level 3	
Treatment	Existing BMP performance		0%	New	Net %	New	Net %	New	Net %
	TP (lb/yr)	43.2		4.3	10%	8.6	20%	13.0	30%
	TSS (lb/yr)	12037		3522	29%	5000	42%	6180	51%
	Volume (acre-feet/yr)	620.00		56.30	9%	118.10	19%	180.00	29%
	Square feet of practice			1500		3720		6650	
Marginal Costs	BMP Type	No Treatment		Moderately Complex Bioretention		Moderately Complex Bioretention		Moderately Complex Bioretention	
	Materials/Labor/Design			$21,060		$51,918		$92,645	
	Admin Costs			$2,450		$3,693		$5,334	
	Total Project Cost			$23,510		$55,611		$97,979	
	Annual O&M			$1,125		$2,790		$4,988	
	Term Cost/lb/yr (30 yr)			$444		$540		$635	

Additional Sites for further analysis and consideration

At least 2 additional sites exist within the city where stormwater best management practices may be explored for retrofitting potential. These sites were not modeled in this study as one is located in what is presumed to be State land and the other lies within a city park where expected treatment values will likely not compete with those reported herein.




Catchment 29
KEY
1st Priority
2nd Priority
Bioretention (rain garden)
Tree Pit
Pretreatment Basin
Wet Swale
Pond Modification
Feet
0
25
50
100
150
200


Catchment 20
12" CMP
24"
KEY
1st Priority
2nd Priority
Bioretention (rain garden)
Tree Pit
Pretreatment Basin
Wet Swale
Pond Modification
N
0
25
50
100
150
200
Feet

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Appendix

Appendix 1—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.