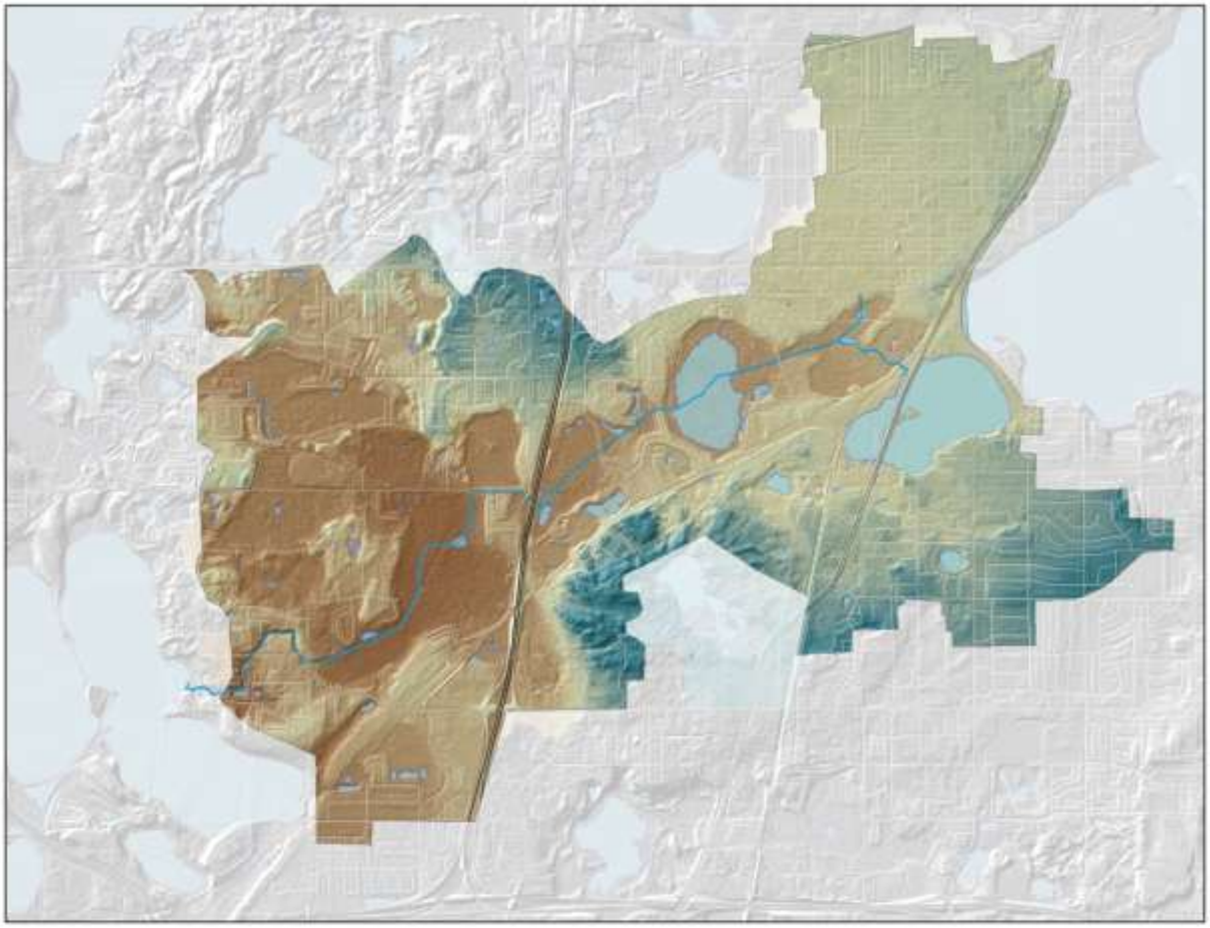
Lambert Creek Retrofit ID and Design Project



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for the

VADNAIS LAKE AREA WATERSHED MANAGEMENT ORGANIZATION

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 Vadnais Lake Area Watershed Management Organization (VLAWMO). 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 sub-watersheds of variable scales and land-uses to identify optimal locations for stormwater treatment. The time commitment required for this methodology was appropriate for *initial assessment* application. 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, 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 best management practices 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. 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 BMPs.

Contents

Executive Summary

Thirty three 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 Watershed Management Organization. Nine of the 33 catchments were selected and modeled at various levels of treatment efficiencies. These catchments should be considered the "low-hanging-fruit" within the Lambert Creek Subwatershed.

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 expected to be installed considering expected public participation and site constraints.

Catchment or Pond ID	Retro Type	Qty of 100 ft^3 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]
LC7-1	B, PS, WD	23	10	9.0	7.0	$31,654	30	$310
LC5-4	B, PM, WD	19	30	6.2	5.2	$26,360	30	$373
LC10-3	B, F, PS, VS	37	10	15.0	12.2	$51,082	30	$301
LC10-4	B	25	10	10.0	8.2	$34,319	30	$302
LC7-3	B. PM, VS	23	10	8.3	6.0	$31,633	30	$335
LC8-3	B. PM, VS	14	10	5.5	4.4	$19,320	30	$307
LC10-2	B, PS	93	30	30.2	25.5	$126,980	30	$373
LC10-5	B	30	30	10.0	8.4	$41,841	30	$369
LC10-1	B, PS, VS	26	30	8.6	7.2	$36,471	30	$374

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc)
IR = Impervious [cover] Reduction
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = New [wet] Detention or Wetland creation
[1] Estimated [1]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 1 year of operation and maintenance costs
[2]Overall cost plus thrity years of maintenance divided by thirty years.

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

When applicable, each retrofit profile is labeled with a unique ID to coincide with the subwatershed name (e.g., LC7-1 for Lambert Creek Catchment 7-1). 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 included determining the objectives of the retrofits (volume reduction, target pollutant etc) and the level of treatment desired. It involved meeting with watershed district staff to determine the issues in the subwatershed. This step helped to define preferred retrofit treatment options and retrofit performance criteria.

Lambert Creek Subwatershed Scoping

Numerous studies and water quality data collected by the Saint Paul Regional Water Service (SPRWS) and the VLAWMO have shown that Total Phosphorus (TP) is a major concern within Lambert Creek. Therefore, TP was identified as the target pollutant of concern for this subwatershed.

Step 2: Desktop Retrofit Analysis

The desktop analysis involved computer-based scanning of the subwatershed for potential retrofit catchments and/or specific sites. This step also identified areas that didn't need to be assessed because of existing stormwater infrastructure. Accurate GIS data was extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers included: 2-foot or finer topography, hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the storm drainage infrastructure (with invert elevations). 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 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.

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

Step 4: Treatment Analysis/Cost Estimates

Treatment analysis

Sites most likely to be conducive to addressing the LGU goals and appeared to be simple-to-moderate in design/install/maintenance considerations were chosen for a cost/benefit analysis in order to relatively compare catchments/sites. Treatment concepts were developed taking into account site constraints and the subwatershed treatment objectives. Projects involving complex stormwater treatment interactions or pose a risk for upstream flooding will 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.

Modeling of the sites was done by using P8 modeling software. Sediment loading files were 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 was also used to properly size BMPs to meet restoration objectives.

The following table lists the parameter inputs required by the P8 software:

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.**

Lambert Creek Treatment Analysis

P8 was used to model catchments to asses for current pollutant loads and a hypothetical BMP at an outfall was created to capture runoff. The BMP was sized from the 10-95% 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. 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.

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

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)	**$4.21/sq ft**
Extended Detention	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
Wet Pond	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
Stormwater Wetland	$5.00	$1000/acre	30	[3]$2800/acre	$210 (3 visits)	**$5.09/sq ft**
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	$4.00	[2]$25/150 sq ft	30	$280/100 sq ft	$210	**$6.97/sq ft**

Disconnect Raingardens					(3 visits)	
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 Bioretention (incl. engineered soils, under-drains, curb cuts, forebays, 3-5 ft retaining walls)	$16.00	$0.75/sq ft	30	[4]$1400/1000 sq ft	$210 (3 visits)	**$18.15/sq ft**
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**

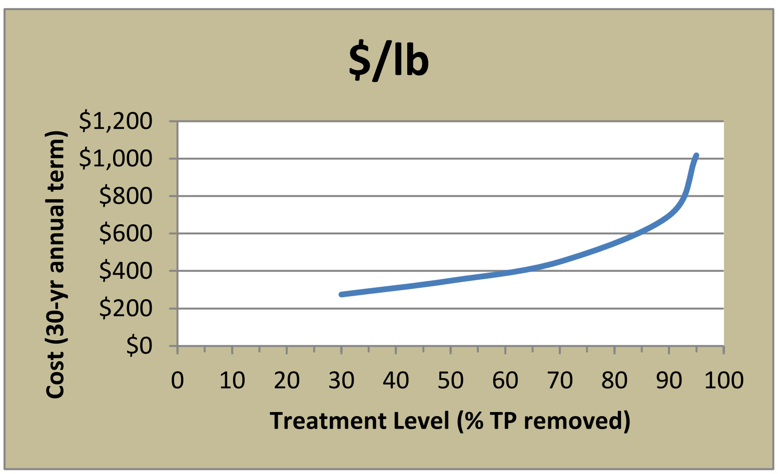
[1]Likely going to require a licensed, contacted engineer.
[2]Assumed landowner, not contractor, will maintain.
[3]LRP would only design off-line systems not requiring an engineer. For all projects requiring an engineer, assume engineering costs to be 40% above construction costs.
[4]If multiple projects 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.

Lambert Creek Cost Analysis

For the Lambert Creek 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), as 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.



Lambert Creek Evaluation and Ranking

In the Lambert Creek evaluation and ranking, the recommended level of treatment for each catchment, as reported in the Executive Summary table, was chosen by selecting the level of treatment expected to get 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, moving up one level of treatment (as described in the Catchment Profile tables) should then be selected.

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.

Lambert Creek Catchment Profiles

For development of the Lambert Creek catchment profile section, 10 out of 33 catchments were selected as the first-tier areas for stormwater retrofit efforts. Those catchments contributing lower TP levels, receiving modern stormwater pond treatment, or in some cases 2 levels of treatment, were not modeled or further analyzed in this assessment. It is recommended that after these initial catchments are built out past the 10-30% reduction levels that other catchments with direct discharge (2-4, 3, 4, 5-5, 8-1, 8-2, 8-3, 8-4, 9-2, 9-3, 9-4) be modeled and then subsequently those with some form of existing treatment and their storm water networks be modeled.

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 10% treatment level, or, in other words, establishing enough bmp's to equal 1,100 ft^3 of live storage.

	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

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7-1

Catchment Summary	
Acres	87
Dominant Land Cover	Industrial
Parcels	67
Volume (acre-feet/yr)	77.0
TP (lb/yr)	90.1
TSS (lb/yr)	28316.5

Model Inputs	
Parameter	**Input**
Pervious Curve Number	63.31
Indirectly connected Impervious Fraction	0.05
Directly Connected Impervious Fraction	0.42
Hydraulic Conductivity (in/hr)	1.19

DESCRIPTION

This catchment is comprised of primarily commercial and industrial land use and contributes an average of 1.03 Total Phosphorus (lb) per Acre per Year (TP/Acre/Yr). Analysis shows that this catchment contributes the most TP/Acre/Yr second to catchment 9-2 which empties into Goose Lake before entering Lambert Creek. This catchment drains through a series of storm sewer pipes that carry storm water south discharging into Lambert Creek near Centerville road and County road F.

RETROFIT RECOMMENDATION

1st Tier Recommendation

Due to favorable soil types on site, a combination of bio-infiltration types is recommended for this catchment. Where soils are found to be less than favorable additional soil amendments or bio-retention cells should be utilized. The majority of these bio-infiltration cells will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. The boulevards in this area are wide and ideal for adequately sized bio-infiltration cells, however, where space is limited, such as in boulevards where sidewalk and curb lines define the useable space, we recommend poured concrete wall retainment to form "box planters" along the streetscape. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	*Percent TP Reduction Level*					
		95	**90**	**70**	**50**	**30**	**10**
Treatment	**TP Reduction (lb/yr)**	85.6	81	63.0	44.98	27.0	9.0
	TSS Reduction (lb/yr)	28106.4	27439.03	23,841	19736.9	14,959	8,197
	TSS Reduction (%)	99%	97%	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	72.7	65.91	49.8	36.1	22.1	7.0
	Volume Reduction (%)	94%	86%	65%	47%	29%	9%
	Live Storage Volume (cubic feet)	120825.5823	65888.76	32,097	17,778	8,695	2,308
Costs	**Materials/Labor/Design**	$1,631,145	$889,498	$433,303	$240,005	$117,377	$31,154
	Promotion & Admin Costs	$500	$500	$500	$500	$500	$500
	Total Project Cost	$1,631,645	$889,998	$433,803	$240,505	$117,877	$31,654
	Annual O&M	$90,619	$49,417	$24,072	$13,334	$6,521	$1,731
	Term Cost/lb/yr (30 yr)	$1,694	$976	$612	$475	$387	$310

Alternate best management practices that could be placed within catchment 7-1 include porous asphalt strips and a detention basin. South within catchment 7-1 is municipal owned land where an extended detention basin could be constructed. Pond construction would be complex and include day lighting a portion of the storm sewer system to flow into this basin. The design criteria for a storm water pond, according to The Minnesota Stormwater Manual, states that the permanent pool volume for a stormwater pond should be sized 1800 cubic feet per acre draining to the pond and have the appropriate sized live storage capacity which in conjunction could have the potential to remove 50% of the TP. Given the approximate watershed size flowing to this point estimated at 25 acres the permanent pool of the pond could be sized at 1666 cubic yards with a live storage area of approximately half of the permanent pool size estimated at 833 cubic yards. An estimated cost for the excavation of the pond is $49,980. This estimate does not include topsoil, seeding, blanket, fertilizer, outlet structure or forebay- which is recommended to be sized at 10% of the pond area recommended. It is recommended that the watershed district's engineer first model for this pond addition (i.e., depth, outlet elevation, etc.) for treatment and cost analysis before committing to bioretention.

5-4

Catchment Summary	
Acres	22
Dominant Land Cover	Medium Residential
Parcels	27
Volume (acre-feet/yr)	17.6
TP (lb/yr)	20.7
TSS (lb/yr)	6507.2

Model Inputs	
Parameter	**Input**
Pervious Curve Number	51
Indirectly connected Impervious Fraction	0.04
Directly Connected Impervious Fraction	0.38
Hydraulic Conductivity (in/hr)	1.38

DESCRIPTION

This catchment is comprised of medium density, single-family residential development, commercial and institutional development. The majority of runoff with in this catchment comes from County Road E. Ramsey County recently constructed a small depression on the southwest corner of Kohler and Centerville roads where the storm sewer is day lighted before entering a culvert and discharging into a channel which leads to a wetland that flows to Lambert Creek. The discharge from this catchment is contributing 20.7 lb of TP per year and creating erosion problems through a channel system that runs through an outdoor classroom west of a White Bear Lake public school.

RETROFIT RECOMMENDATION

1st Tier Recommendation

A major opportunity to divert stormwater from the small depression to an existing wetland exists south of the discharge point. This wetland is listed on the National Wetland Inventory and should be first reviewed by regulatory agencies to determine if an increased diversion of runoff to this wetland is possible. It is recommended secondly, that the watershed district's engineer model for the stormwater diversion to determine if the existing wetland can handle the excess runoff and to determine the total treatment and cost. After conducting a field reconnaissance of the system it is assumed that this diversion has the ability to treat the recommended level of TP reduction for far less money than other systems.

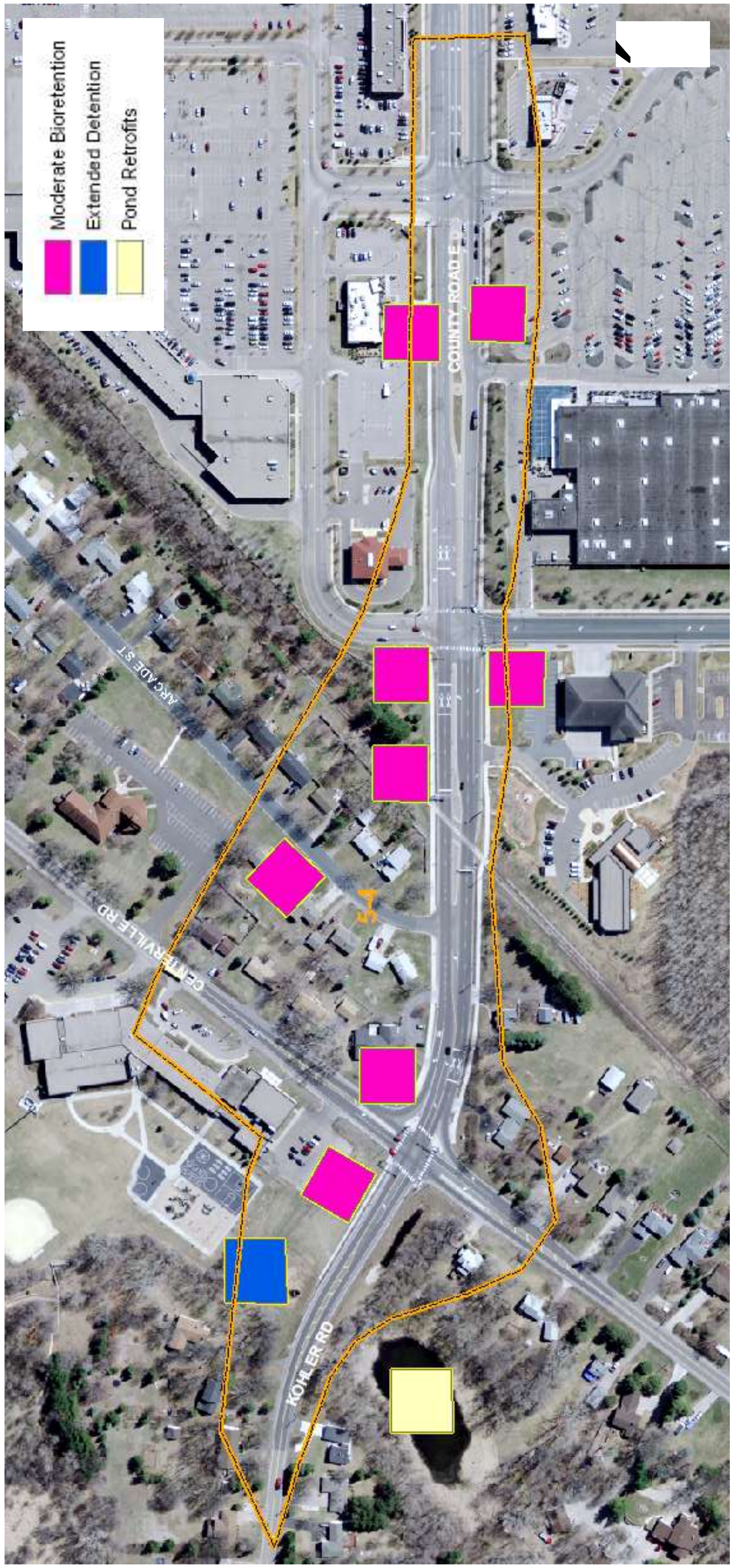
2nd Tier Recommendation

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 trench drains or poured concrete wall retainment to form "box planters" along the streetscape. In one location, south of the school, it may be possible to daylight stormwater sewer lines to the existing depression within the right of way that would effectively treat (infiltrate and filter) approximately 1/6th of the catchment. Further investigation into this possibility is highly recommended. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	Percent TP Reduction Level					
		95	90	70	50	30	10
Treatment	TP Reduction (lb/yr)	19.7	18.6	14.5	10.4	6.2	2.1
	TSS Reduction (lb/yr)	6,481	6,330	5,498	4,543	3,440	1,872
	TSS Reduction (%)	100%	97%	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	16.6	15.03	11.4	8.4	5.2	1.7
	Volume Reduction (%)	94%	85%	65%	48%	30%	10%
	Live Storage Volume (cubic feet)	26,090	14,418	7,025	3,899	1,916	516
Costs	Materials/Labor/Design	$352,222	$194,640	$94,835	$52,635	$25,860	$6,968
	Promotion & Admin Costs	$500	$500	$500	$500	$500	$500
	Total Project Cost	$352,722	$195,140	$95,335	$53,135	$26,360	$7,468
	Annual O&M	$19,568	$10,813	$5,269	$2,924	$1,437	$387
	Term Cost/lb/yr (30 yr)	$1,590	$931	$582	$451	$373	$303

3rd Tier Recommendation

An alternate best management practice that could be placed within catchment 5-4 includes retrofitting a storm pond within the beginning of the channel to control volume, allow settling of pollutants, and serve as a BMP example for the school to incorporate into the outdoor education classroom. With cooperation from the landowners, the City of Vadnais Heights and the White Bear Lake Schools, this storm water pond could be installed north of the discharge point. Given the approximate watershed size flowing to this point estimated at 22 acres the permanent pool of the pond could be sized at 1466 cubic yards with a live storage area of approximately half of the permanent pool size estimated at 733 cubic yards. An estimated cost for the excavation of the pond is $43,980. This estimate does not include topsoil, seeding, blanket, fertilizer, outlet structure or forebay- which is recommended to be sized at 10% of the pond area recommended. It is recommended that the watershed district's engineer first model for this pond addition (i.e., depth, outlet elevation, etc.) for treatment and cost analysis before committing to bioretention. 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.


Moderate Bioretention
Extended Detention
Pond Retrofits
COUNTY ROAD E
ARCADE ST
CENTERVILLE RD
KOHLER RD

10-3

Catchment Summary	
Acres	181
Dominant Land Cover	Commercial
Parcels	500
Volume (acre-feet/yr)	129.9
TP (lb/yr)	149.8
TSS (lb/yr)	46,857

Model Inputs	
Parameter	Input
Pervious Curve Number	69
Indirectly connected Impervious Fraction	0.07
Directly Connected Impervious Fraction	0.34
Hydraulic Conductivity (in/hr)	1.35

DESCRIPTION

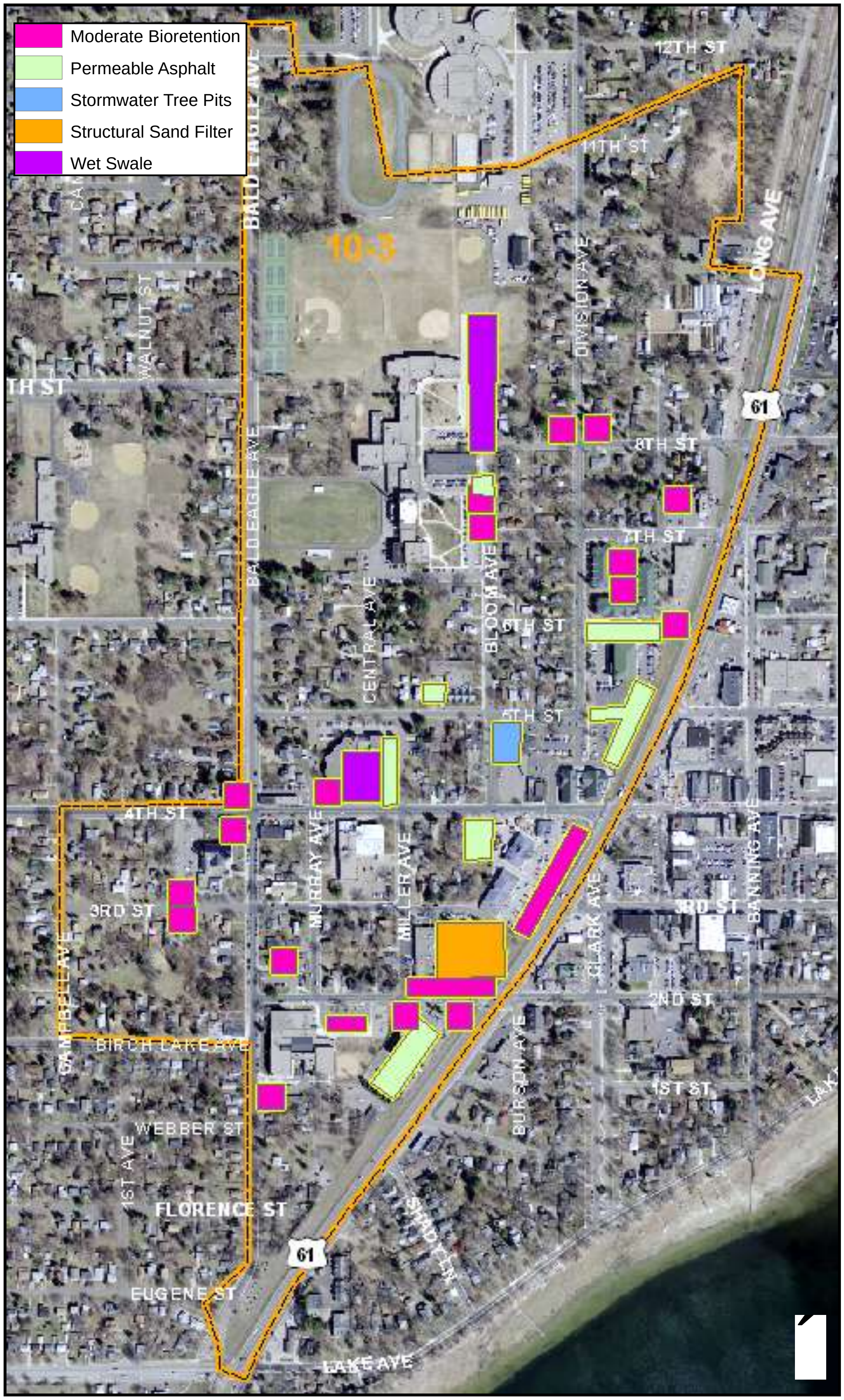
This catchment is comprised of medium density, single-family residential development, multi-family residential, commercial, and institutional. This catchment has little to no storm water treatment features and is drained via storm sewer system tying into a large main that discharges into Whitaker Pond, the head waters of Lambert Creek.

RETROFIT RECOMMENDATION

A number of BMP types are recommended for this catchment, including bioretention, filtration, and infiltration. Many of the proposed bioretention locations along the residential areas will rely 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. Larger impervious complexes within this catchment, including several apartment buildings and a public school, were found to be optimal locations for retrofits due to ease of installation and expanse of impervious surface contributing runoff to the proposed BMP locations. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	70	50	30	10
Treatment	**TP Reduction (lb/yr)**	104.9	74.8	44.9	15.0
	TSS Reduction (lb/yr)	39,409	32,620	24,674	13,473
	TSS Reduction (%)	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	84.7	61.2	37.6	12.2
	Volume Reduction (%)	65%	47%	29%	9%
	Live Storage Volume (cubic feet)	51,871	28,779	14,053	3,747
Costs	**Materials/Labor/Design**	$700,262	$388,519	$189,709	$50,582
	Promotion & Admin Costs	$500	$500	$500	$500
	Total Project Cost	$700,762	$389,019	$190,209	$51,082
	Annual O&M	$38,903	$21,584	$10,539	$2,810
	Term Cost/lb/yr (30 yr)	$594	$462	$376	$301

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. Due to the numerous retrofit opportunities within this catchment it is suggested that BMP's such as the proposed wet swales and bioretention locations be considered first, and more expensive structures such as permeable asphalt and sand filters be considered lastly. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart above. The minimum storage size requirements are also listed for the associated percent of treatment.



10-4

Catchment Summary	
Acres	161
Dominant Land Cover	Residential
Parcels	775
Volume (acre-feet/yr)	87.5
TP (lb/yr)	100.3
TSS (lb/yr)	31,298

Model Inputs	
Parameter	**Input**
Pervious Curve Number	68
Indirectly connected Impervious Fraction	0.09
Directly Connected Impervious Fraction	0.25
Hydraulic Conductivity (in/hr)	1.36

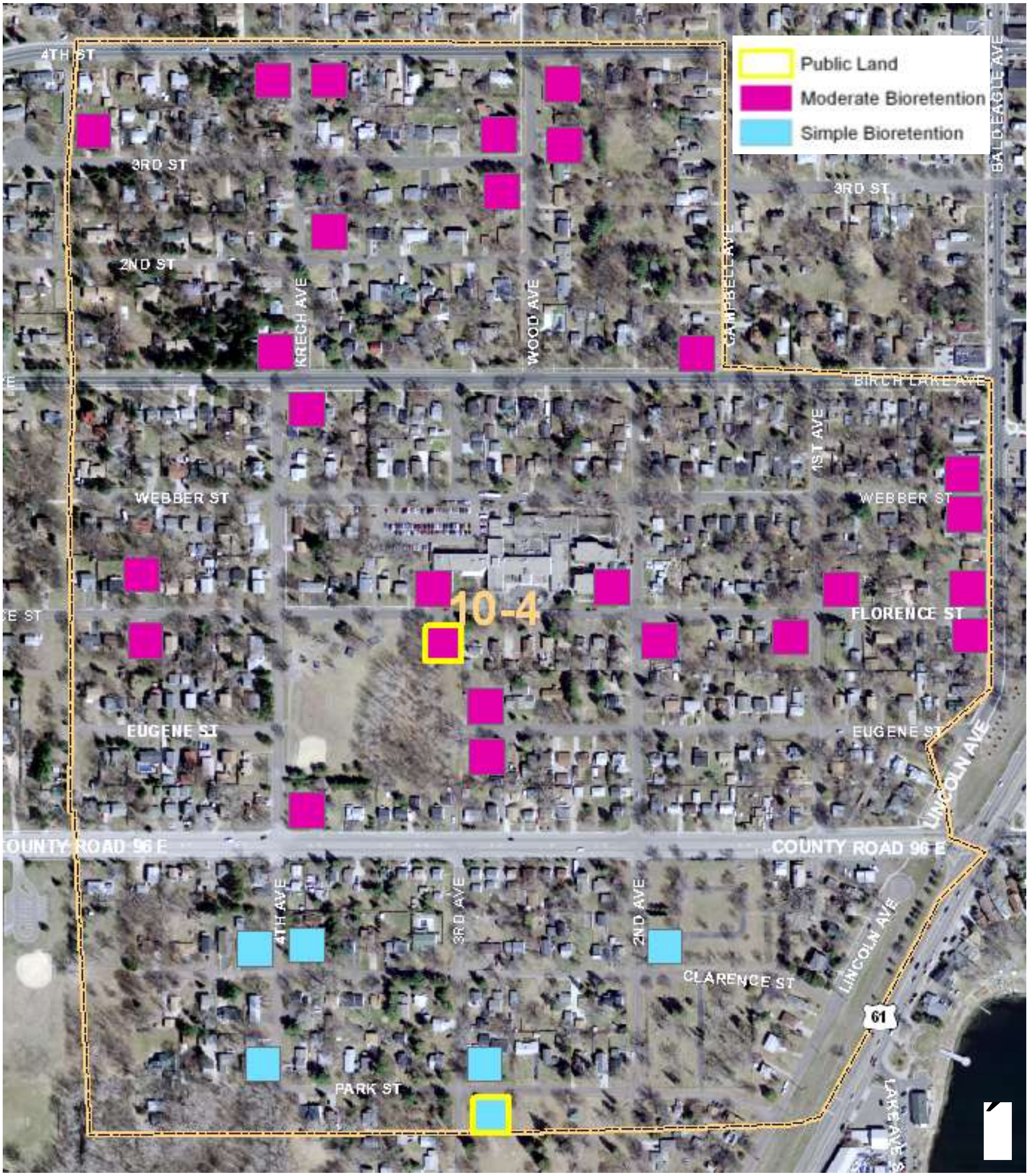
DESCRIPTION

This catchment is comprised of mainly medium density, single-family residential land use. This catchment has little to no storm water treatment features. The majority of this catchment drains east to west via a storm sewer system which ties into a large main that discharges into Whitaker Pond, the head waters of Lambert Creek, the remaining area south of Highway 96 drains through a ditch system of turf grass and culverts.

RETROFIT RECOMMENDATION

Due to sandy soil types on site, a combination of bio-infiltration types is recommended for this catchment. Where soils are found to be less than favorable additional soil amendments or bio-retention cells should be utilized. Within the area drained by the storm sewer system the majority of these bio-infiltration cells will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. It is recommended that the suggested locations for bioinfiltration cells located on public lands be considered first for installation, all the areas drained by storm sewer secondly, and the remaining ditched areas be considered lastly. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	70	50	30	10
Treatment	TP Reduction (lb/yr)	70.2	50.1	30.1	10.0
	TSS Reduction (lb/yr)	26,317	21,804	16,496	8,999
	TSS Reduction (%)	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	57.2	41.1	25.2	8.2
	Volume Reduction (%)	65%	47%	29%	9%
	Live Storage Volume (cubic feet)	34,619	19,269	9,409	2,505
Costs	Materials/Labor/Design	$467,360	$260,134	$127,021	$33,819
	Promotion & Admin Costs	$500	$500	$500	$500
	Total Project Cost	$467,860	$260,634	$127,521	$34,319
	Annual O&M	$25,964	$14,452	$7,057	$1,879
	Term Cost/lb/yr (30 yr)	$592	$462	$376	$302


Public Land
Moderate Bioretention
Simple Bioretention
10-4
4TH ST
3RD ST
2ND ST
KRECH AVE
WOOD AVE
CAMPBELL AVE
BALD EAGLE AVE
BIRCH LAKE AVE
1ST AVE
WEBBER ST
FLORENCE ST
EUGENE ST
COUNTY ROAD 96 E
LINCOLN AVE
4TH AVE
3RD AVE
2ND AVE
CLARENCE ST
PARK ST
LAKE AVE S
61

7-3

Catchment Summary	
Acres	150
Dominant Land Cover	medium residential
Parcels	473
Volume (acre-feet/yr)	72.3
TP (lb/yr)	82.9
TSS (lb/yr)	25889.8

Model Inputs	
Parameter	**Input**
Pervious Curve Number	67
Indirectly connected Impervious Fraction	0.08
Directly Connected Impervious Fraction	0.23
Hydraulic Conductivity (in/hr)	0.88

DESCRIPTION

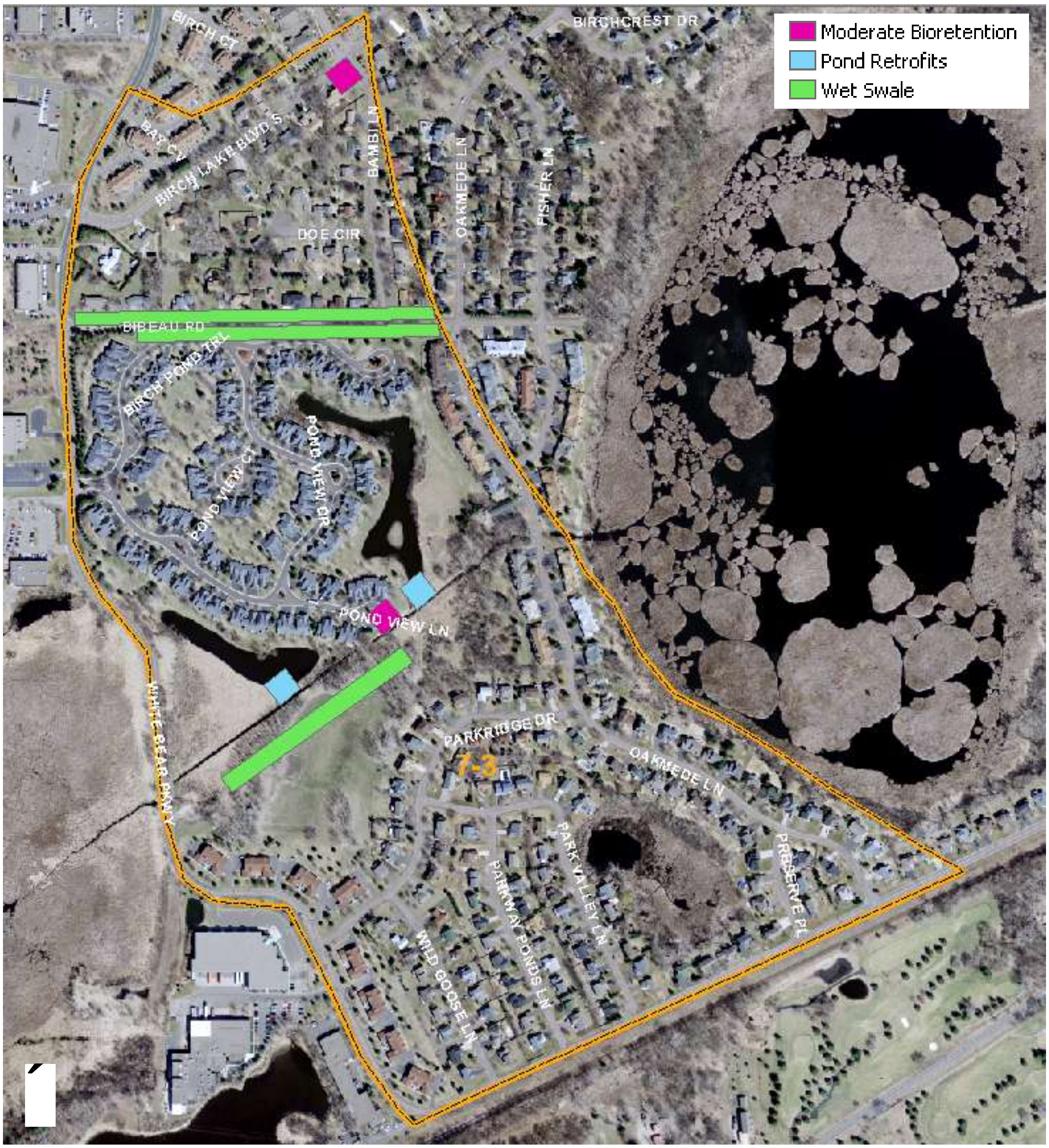
The southern portion of this catchment is comprised of mainly medium density, single-family residential land use that drains through a ditched system before entering Lambert Creek. The northern portion of this catchment mainly consists of multiple family dwelling condominiums, which drain through a storm sewer system that empties into two stormwater ponds. These ponds were constructed around 25-30 years ago to capture runoff from the condominiums.

RETROFIT RECOMMENDATION

A few locations were found to be ideal for retrofitting stormwater features within this catchment, including 3 areas for wet swales and 2 spots for bioretention. The ditched area along both sides of Bibeau Road was confirmed in the field as an excellent location to create swales to capture runoff. Soils along this road also indicate fair infiltration rates. The two locations suggested for bio infiltration will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. Where elevations of the road and/or land behind the curb line are more than gradual, retaining walls will be necessary. The soils in these locations are shown to be excellent for infiltration. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	*Percent TP Reduction Level*					
		95	**90**	**70**	**50**	**30**	**10**
Treatment	**TP Reduction (lb/yr)**	78.8	74.68	58.1	41.5	24.9	8.3
	TSS Reduction (lb/yr)	25705.5	25113.78	21,899	18,244	13,888	7,726
	TSS Reduction (%)	99%	97%	85%	70%	54%	30%
	Volume Reduction (acre-feet/yr)	68.3	61.95	45.8	32.4	19.6	6.0
	Volume Reduction (%)	94%	86%	63%	45%	27%	8%
	Live Storage Volume (cubic feet)	123535.6155	65535.46	31,614	17,782	8,724	2,306
Costs	**Materials/Labor/Design**	$1,667,731	$884,729	$426,795	$240,053	$117,768	$31,133
	Promotion & Admin Costs	$500	$500	$500	$500	$500	$500
	Total Project Cost	$1,668,231	$885,229	$427,295	$240,553	$118,268	$31,633
	Annual O&M	$92,652	$49,152	$23,711	$13,336	$6,543	$1,730
	Term Cost/lb/yr (30 yr)	$1,881	$1,053	$653	$515	$421	$335

It is also highly recommended that the watershed district's engineer review the current state of the two stormwater treatment ponds receiving runoff from the condominium complex. It was noted during the field survey that both ponds outlet structures were in serious need of review and maintenance. The water level elevation in the west pond was equal to the elevation of the water in Lambert Creek and was intermixing at that time. The east ponds elevation was higher than the stream; however the outlet structure was dilapidated allowing less regulated flow. It is suggested, in addition to the outlet structures, that the ponds be surveyed to determine if they are providing adequate treatment.



8-3

Catchment Summary	
Acres	103
Dominant Land Cover	residential
Parcels	231
Volume (acre-feet/yr)	47.0
TP (lb/yr)	55.0
TSS (lb/yr)	17294.8

Model Inputs	
Parameter	**Input**
Pervious Curve Number	54.71
Indirectly connected Impervious Fraction	0.06
Directly Connected Impervious Fraction	0.22
Hydraulic Conductivity (in/hr)	1.25

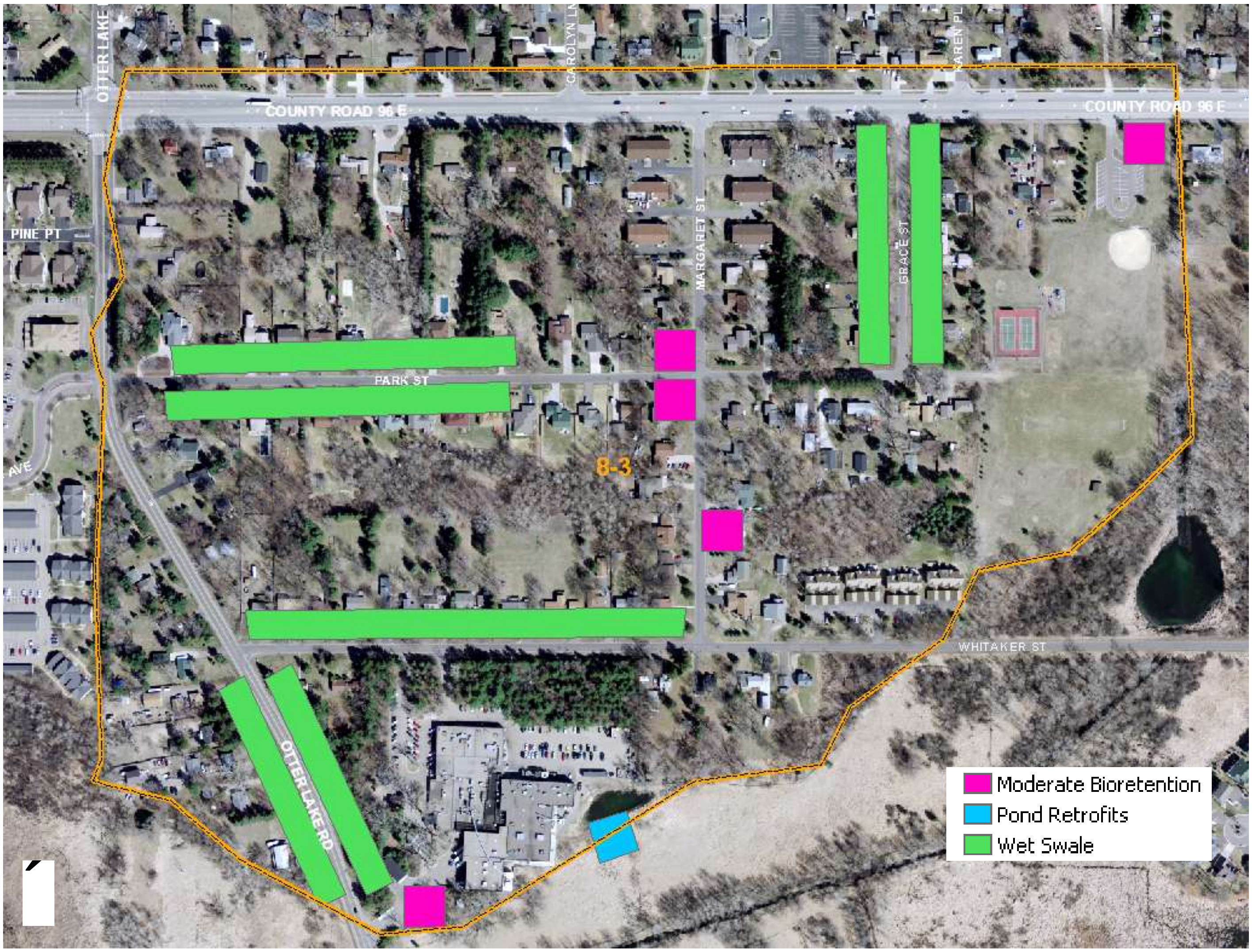
DESCRIPTION

This catchment is comprised of low density, single-family residential, multi-family and industrial land use. This catchment has little to no storm water treatment features. The majority of this catchment drains through turf grass ditches that discharge overland into Lambert Creek. The north edge of the catchment along Highway 96 drains through a storm sewer system which travels east, tying into a large main that discharges into Whitaker Pond, the head waters of Lambert Creek. The majority of the soils within this catchment are good to excellent for the implementation of infiltration practices.

RETROFIT RECOMMENDATION

A combination of swales, bioinfiltration cells, and maintenance of a pond outlet structure are recommended for this catchment. The suggested locations for the swales and bioinfiltration cells are within the ditch system, which will make for lower cost installation without the added cost of curb cuts. It is suggested that the proposed retrofit BMP's surrounding the highly light industrial site located in the southern tip of the catchment be considered first. These include a bioinfiltration cell in the south west corner and the improvement of an outlet structure for the stormwater pond located on the site. Currently a dilapidated box weir controls the water level within the treatment pond and it was observed that a functioning structure would provide more adequate water treatment.

	Cost/Benefit Analysis	*Percent TP Reduction Level*					
		95	**90**	**70**	**50**	**30**	**10**
Treatment	**TP Reduction (lb/yr)**	52.2	49.5	38.5	27.5	16.5	5.5
	TSS Reduction (lb/yr)	17162.364	16757.81	14,553	12039.7	9,118	4989.55
	TSS Reduction (%)	99%	97%	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	44.31	40.3	30.5	22.2	13.6	4.4
	Volume Reduction (%)	94%	86%	65%	47%	29%	9%
	Live Storage Volume (cubic feet)	71093.44836	39705.06	19,358	10,717	5,240	1,394
Costs	**Materials/Labor/Design**	$959,762	$536,018	$261,335	$144,679	$70,745	$18,820
	Promotion & Admin Costs	$500	$500	$500	$500	$500	$500
	Total Project Cost	$960,262	$536,518	$261,835	$145,179	$71,245	$19,320
	Annual O&M	$53,320	$29,779	$14,519	$8,038	$3,930	$1,046
	Term Cost/lb/yr (30 yr)	$1,635	$963	$604	$469	$382	$307


OTTER LAKE
CAROLYN LN
KAREN PL
COUNTY ROAD 96 E
COUNTY ROAD 96 E
PINE PT
MARGARET ST
GRACE ST
PARK ST
AVE
8-3
WHITAKER ST
OTTER LAKE RD
Moderate Bioretention
Pond Retrofits
Wet Swale

10-2

Catchment Summary	
Acres	206
Dominant Land Cover	Residential
Parcels	683
Volume (acre-feet/yr)	88.6
TP (lb/yr)	100.6
TSS (lb/yr)	31,254

Model Inputs	
Parameter	**Input**
Pervious Curve Number	55.17
Indirectly connected Impervious Fraction	0.10
Directly Connected Impervious Fraction	0.20
Hydraulic Conductivity (in/hr)	1.44

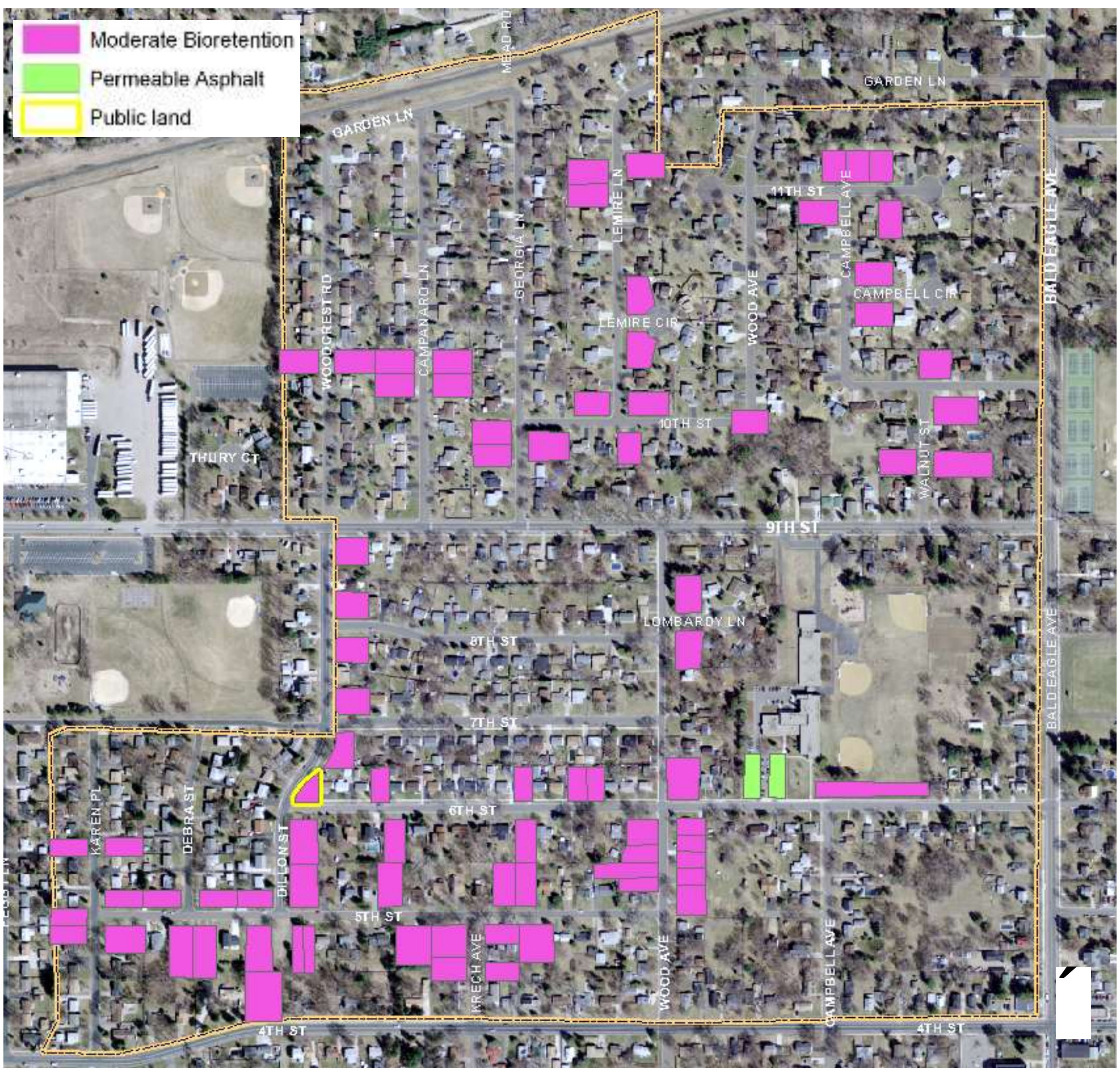
DESCRIPTION

This catchment is comprised of medium density single-family residential and institutional development. This catchment has little to no storm water treatment features and is drained via storm sewer system tying into a large main that discharges into Whitaker Pond, the head waters of Lambert Creek. The majority of the residential area is curb and gutter.

RETROFIT RECOMMENDATION

A combination of bio-infiltration types is recommended for this catchment. Where soils are found to be less than favorable additional soil amendments or bio-retention cells should be utilized. The majority of these bio-infiltration cells will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. 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 sidewalk and curb lines define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. Since there are so many options for the location of bio-infiltration it is suggested that bio-infiltration cells located on public land and those within hdyric soil groups A and B should be considered first for installation. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below. The minimum storage size requirements are also listed for the associated percent of treatment.

	Cost/Benefit Analysis	Percent TP Reduction Level			
		70	50	30	10
Treatment	TP Reduction (lb/yr)	70.4	50.3	30.2	10.1
	TSS Reduction (lb/yr)	26,281	21,810	16,476	8,986
	TSS Reduction (%)	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	58.0	41.5	25.5	8.3
	Volume Reduction (%)	65%	47%	29%	9%
	Live Storage Volume (cubic feet)	34,501	19,257	9,369	2,500
Costs	Materials/Labor/Design	$465,762	$259,974	$126,480	$33,750
	Promotion & Admin Costs	$500	$500	$500	$500
	Total Project Cost	$466,262	$260,474	$126,980	$34,250
	Annual O&M	$25,876	$14,443	$7,027	$1,875
	Term Cost/lb/yr (30 yr)	$588	$460	$373	$299



10-5

Catchment Summary	
Acres	74
Dominant Land Cover	Residential
Parcels	201
Volume (acre-feet/yr)	28.6
TP (lb/yr)	33.4
TSS (lb/yr)	10,485

Model Inputs	
Parameter	**Input**
Pervious Curve Number	55.56
Indirectly connected Impervious Fraction	0.09
Directly Connected Impervious Fraction	0.19
Hydraulic Conductivity (in/hr)	1.44

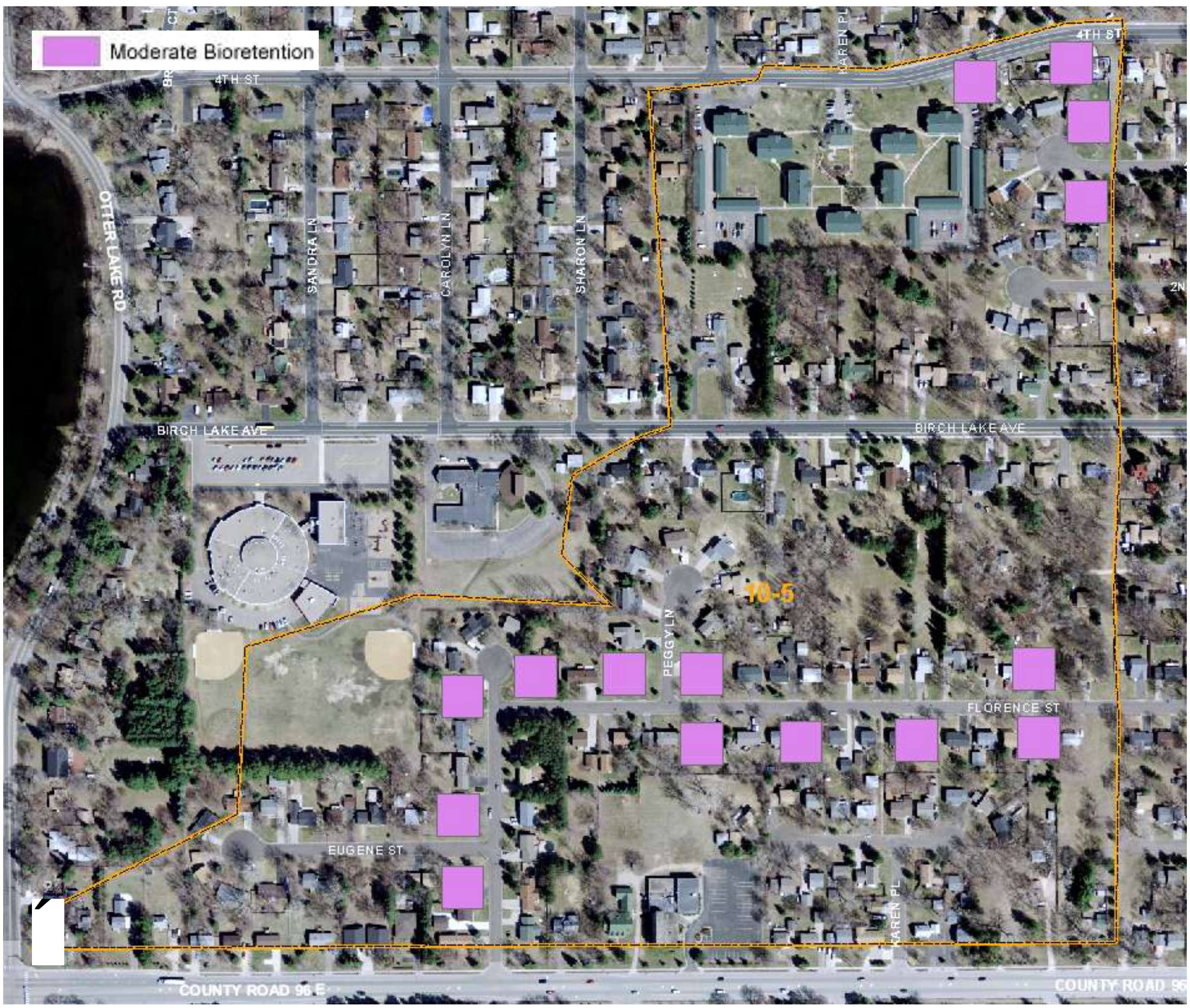
DESCRIPTION

This catchment is comprised of medium density single-family and multi-family residential development. This catchment has little to no storm water treatment features and drains east by a storm sewer system which ties into a large main that discharges south into Whitaker Pond, the head waters of Lambert Creek. The majority of the residential area is curb and gutter.

RETROFIT RECOMMENDATION

A combination of bio-infiltration types is recommended for this catchment. Where soils are found to be less than favorable additional soil amendments or bio-retention cells should be utilized. The majority of these bio-infiltration cells will rely on newly poured curb cut inlets and sediment forebays for conveyance of street runoff to the treatment cell. 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 sidewalk and curb lines define the useable space, we recommend poured concrete wall retainment to form “box planters” along the streetscape. The live storage volume calculated can easily be met within this catchment so that the 30% reduction in total phosphorous can be obtained. The Bioinfiltration cells at the suggested locations should be sized to total the 3,062 cubic feet of live storage goal. If there are restrictions that limit the size of these bio infiltration cells at these locations, then additional locations should be found within the cathment. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below.

	Cost/Benefit Analysis	Percent TP Reduction Level			
		70	50	30	10
Treatment	TP Reduction (lb/yr)	23.4	16.7	10.0	3.3
	TSS Reduction (lb/yr)	8,806	7,274	5,495	2,989
	TSS Reduction (%)	84%	69%	52%	29%
	Volume Reduction (acre-feet/yr)	18.7	13.7	8.4	2.7
	Volume Reduction (%)	65%	48%	29%	9%
	Live Storage Volume (cubic feet)	11,327	6,270	3,062	816
Costs	Materials/Labor/Design	$152,908	$84,649	$41,341	$11,018
	Promotion & Admin Costs	$500	$500	$500	$500
	Total Project Cost	$153,408	$85,149	$41,841	$11,518
	Annual O&M	$8,495	$4,703	$2,297	$612
	Term Cost/lb/yr (30 yr)	$582	$452	$369	$302



10-1

Catchment Summary	
Acres	68
Dominant Land Cover	Open Space
Parcels	23
Volume (acre-feet/yr)	25.2
TP (lb/yr)	28.6
TSS (lb/yr)	8,887

Model Inputs	
Parameter	**Input**
Pervious Curve Number	59
Indirectly connected Impervious Fraction	0.04
Directly Connected Impervious Fraction	0.17
Hydraulic Conductivity (in/hr)	1.41

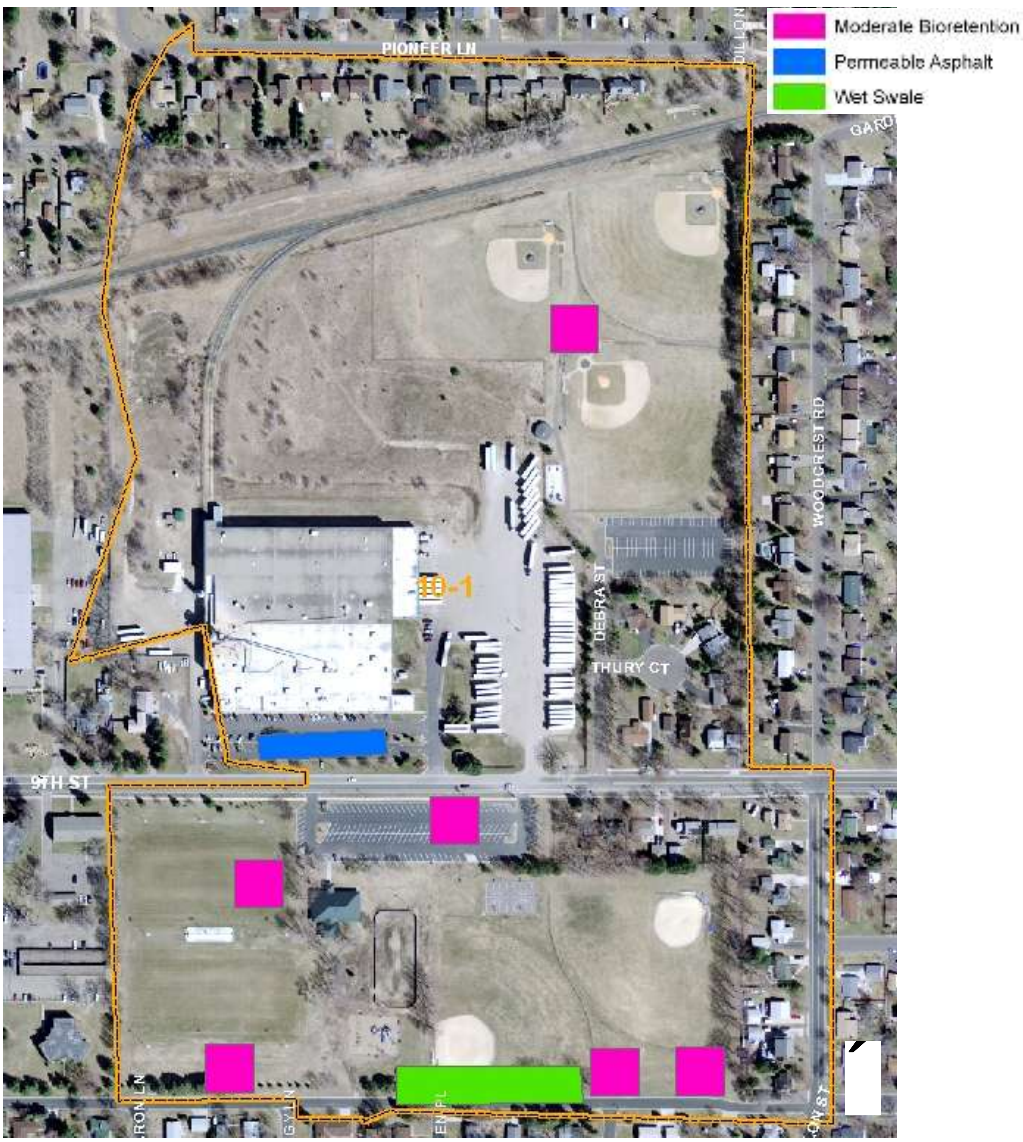
DESCRIPTION

This catchment is comprised of open park space, an industrial site and some medium density single home residential development. This catchment has little to no storm water treatment features and drains east by a storm sewer system which ties into a large main that discharges south into Whitaker Pond, the head waters of Lambert Creek.

RETROFIT RECOMMENDATION

A combination of bio-infiltration, a wet swale, and permeable asphalt strips is recommended for this catchment. The proposed bioinfiltration cells are suggested to be installed around storm sewer inlets that receive runoff from large expanses of turf grass from multiple sports fields. Where soils are found to be less than favorable in these areas additional soil amendments or bio-retention cells should be utilized. The live storage volume calculated can easily be met within this catchment so that the 30% reduction in total phosphorous can be obtained. The combined suggested BMP's should be sized to total the 2,664 cubic feet of live storage goal. If there are restrictions that limit the installation size of these BMP's, then additional BMP's should be installed within the catchment. The estimated costs and percent treatment levels for bio-infiltration can be seen in the chart below.

	Cost/Benefit Analysis	Percent TP Reduction Level			
		70	50	30	10
Treatment	TP Reduction (lb/yr)	20.0	14.3	8.6	2.9
	TSS Reduction (lb/yr)	7,475	6,203	4,686	2,556
	TSS Reduction (%)	84%	70%	53%	29%
	Volume Reduction (acre-feet/yr)	16.5	11.8	7.2	2.4
	Volume Reduction (%)	66%	47%	29%	10%
	Live Storage Volume (cubic feet)	9,815	5,477	2,664	712
Costs	Materials/Labor/Design	$132,508	$73,945	$35,971	$9,606
	Promotion & Admin Costs	$500	$500	$500	$500
	Total Project Cost	$133,008	$74,445	$36,471	$10,106
	Annual O&M	$7,362	$4,108	$1,998	$534
	Term Cost/lb/yr (30 yr)	$590	$461	$374	$304



Retrofit Ranking

Catchment or Pond ID	Retro Type	Qty of 100 ft^3 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
LC10-3	B, F, PS, VS	37	10	15	12.2	$51,,082	30	$301
LC10-4	B	25	10	10	8.2	$34,319	30	$302
LC8-3	B. PM, VS	14	10	5.5	4.4	$19,320	30	$307
LC7-1	B, PS, WD	23	10	9	7	$31,654	30	$310
LC7-3	B. PM, VS	23	10	8.3	6	$31,633	30	$335
LC10-5	B	30	30	10	8.4	$41,841	30	$369
LC5-4	B, PM, WD	19	30	6.2	5.2	$26,360	30	$373
LC10-2	B, PS	93	30	30.2	25.5	$126,980	30	$373
LC10-1	B, PS, VS	26	30	8.6	7.2	$36,471	30	$374

B = Bioretention (infiltration and/or filtration)
F = Filtration (sand curtain, surface sand filter, sump, etc)
IR = Impervious [cover] Reduction
PM = Pond Modification (increased area/depth, additional cells, forebay, and/or outlet modification)
PS = Permeable Surface (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
WD = New [wet] Detention or Wetland creation
[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.

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Appendix A. Overview of entire subwatershed and associated catchments