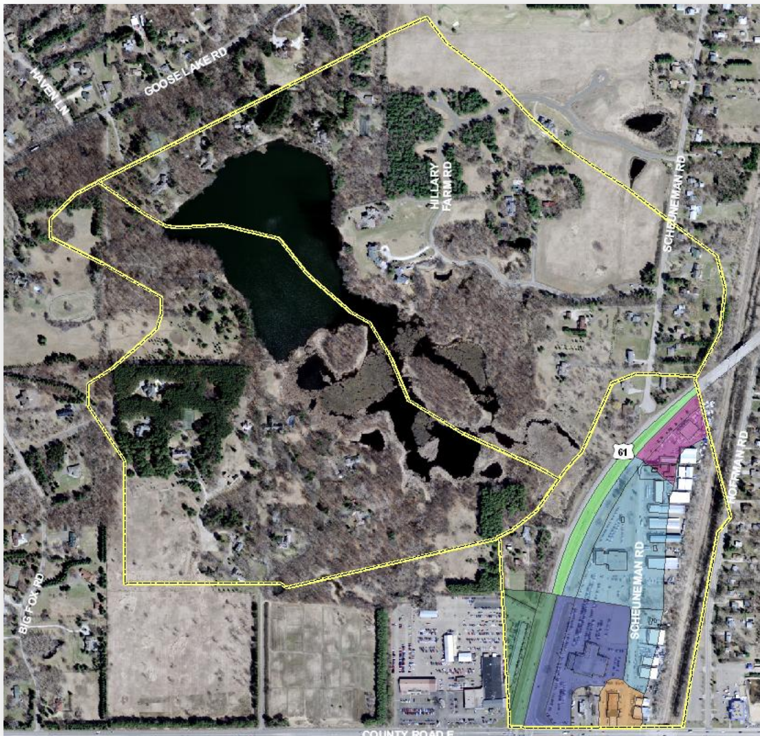
Gem Lake Stormwater Retrofit Assessment



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This report details a subwatershed stormwater retrofit assessment resulting in recommended catchments for placement of Best Management Practice (BMP) retrofits. 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 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.

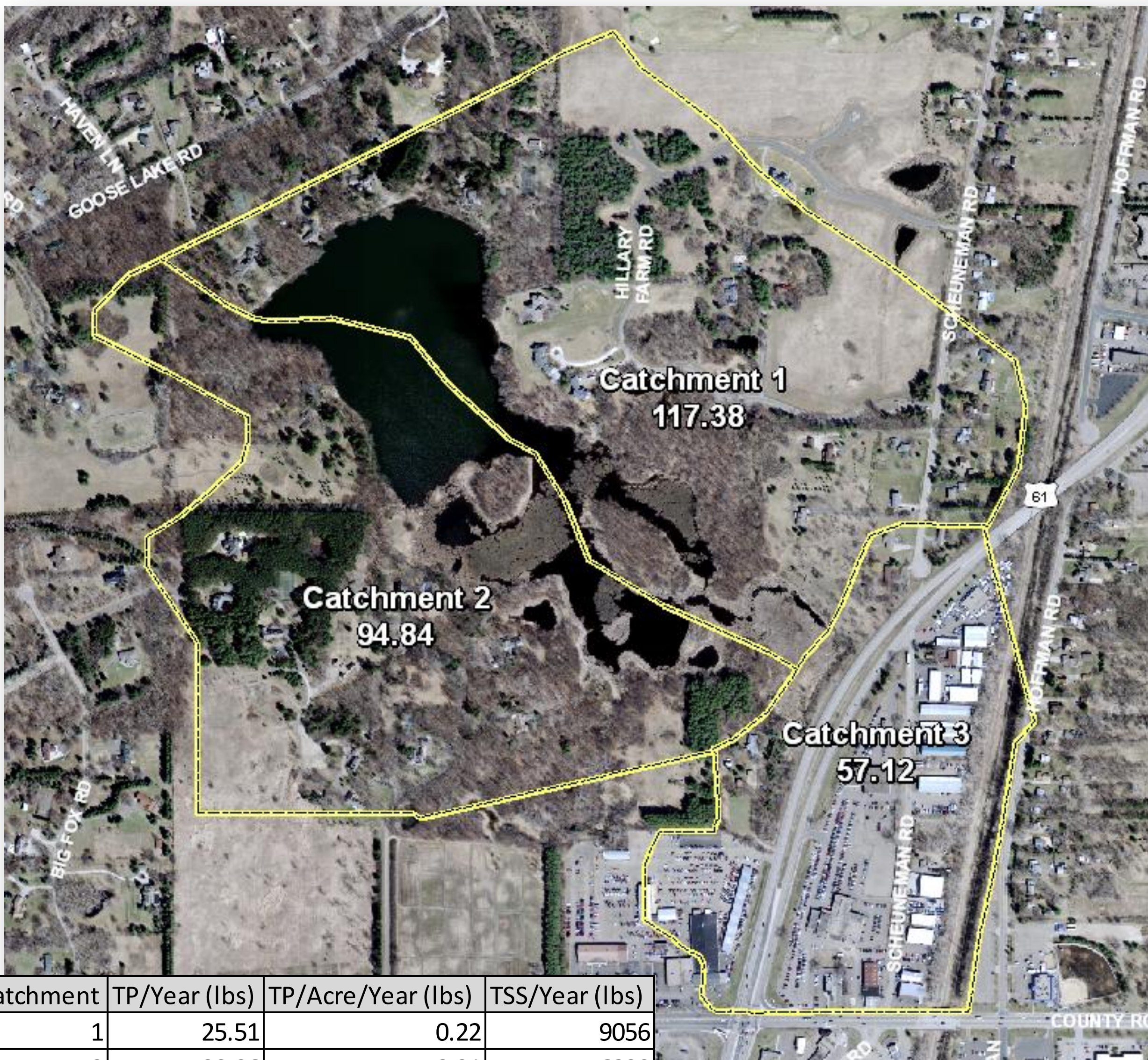
Results of this assessment are based on the development of catchment-specific *conceptual* stormwater treatment best management practices that either supplement existing stormwater infrastructure or provide quality and volume treatment where none currently exists. Relative comparisons are then made between 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

The Gem Lake subwatershed was broken into three catchments which were analyzed for annual pollutant loading of total phosphorous (TP) and total suspended solids (TSS). These catchment boundaries were defined by their drainage systems into Gem Lake. The boundaries and their associated annual loads can be seen in Figure 1.

Figure 1. Gem Lake Subwatershed and associated pollutant loads



Catchment	TP/Year (lbs)	TP/Acre/Year (lbs)	TSS/Year (lbs)
1	25.51	0.22	9056
2	20.06	0.21	6920
3	37.75	0.66	28563

Figure 2. comparison of all subcatchments within catchment 3.

Catchment	Loading	TP	TSS	TP Removal	% TP Removal
3-1	Entire system	1.749	1782		
	Current BMP	0.2204	262.4	1.5286	87%
3-2	Entire system	1.5798	1317		
	Current BMP	0.5884	508.7	1.0144	64%
3-3	Entire system	9.173	7121		
	Current BMP	5.152	4120	4.021	44%
3-5	Entire system	5.601	4785		
	Current BMP	3.217	2866	2.384	43%
3-6	Entire system	7.526	5303		
	Current BMP	4.395	3155	3.131	42%

Catchments 1 and 2 share similar land use types consisting of low density residential residence and large open spaces. These two catchments contribute comparatively low TP and TSS levels into Gem Lake and have little opportunity for retrofit BMP's, and therefore were not considered for further analysis within this report. Catchment 3 consists of a mix of commercial land use which is drained via turf grass swales into Gem Lake. In comparison to the other two Catchments, Catchment 3 contributes a large amount of TP and TSS to Gem Lake. Due to the high pollutant load runoff from Catchment 3 it was determined that this area be evaluated further. Therefore, Catchment 3 was broken down in to 9 smaller catchments that were assessed further to determine their individual pollutant loads. Six of the 9 smaller catchments were found to have direct source runoff into Gem Lake (see Appendix A). These catchments were modeled further to determine base loads and loads from current stormwater treatment features, which are turf grass swales within all six catchments. Catchment 3-4 was disregarded because of its little runoff contribution and limited retrofit opportunity. The remaining catchments base loads and current feature pollutant loads can be seen in Figure 2. The threshold to assess for further implementation of retrofit BMP's was set at 50%, so any catchments with current stormwater features that reduced TP 50% or more were not modeled for additional BMP's. As seen in Figure 2, the current grass swales in 3-1 and 3-2 are currently treating 50% or more of the TP load from the impervious areas within the catchment, so these catchments were not modeled for additional BMP's. Below documents the study background, methods, and ranking of the BMP options within catchments 3-3, 3-5 and 3-6.

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.

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.

Retrofit Profiles

When applicable, each retrofit profile is labeled with a unique ID to coincide with the subwatershed name (e.g., 3-3 for Gem Lake Catchment 3-3). 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 estimated annual pollutant load (and other pollutants and volumes as specified by the LGU). 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.

Methods

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. This step helped to define preferred retrofit treatment options and retrofit performance criteria.

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).

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.

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.

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.

Step 5: Evaluation and Ranking

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

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. Each Catchment Profile includes a table showing the data relevant to various levels of treatment associated with different BMP options.

CATCHMENT 3-3

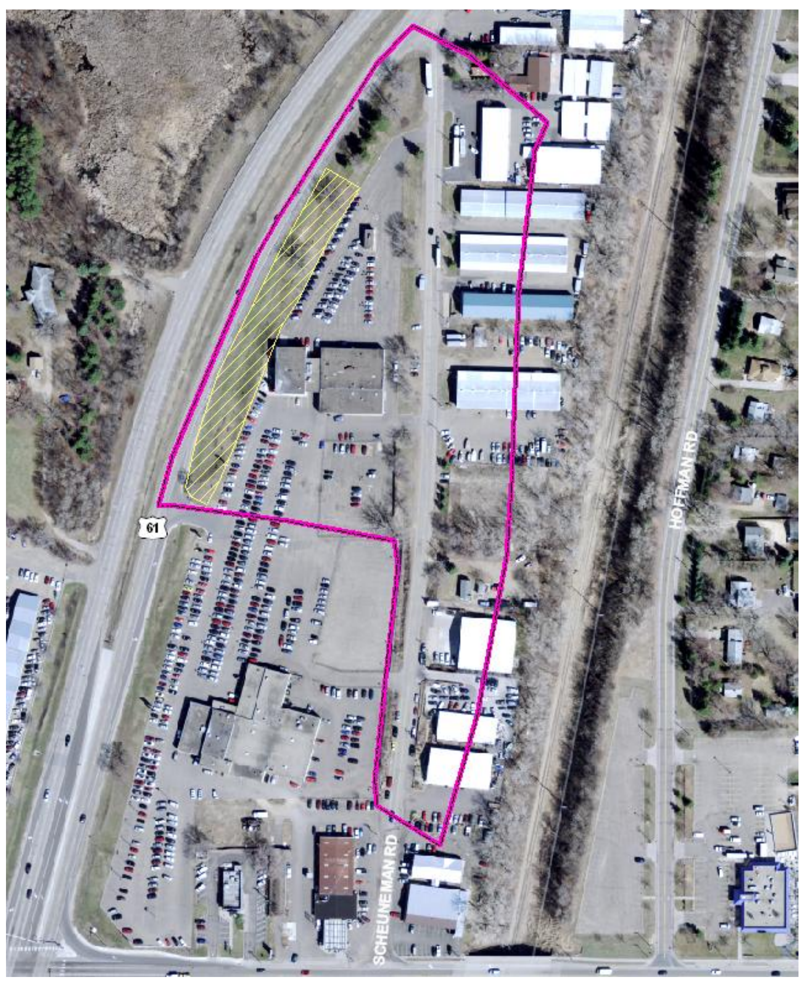
DESCRIPTION

Catchment 3-3 is 11.44 acres of predominantly impervious land cover consisting of commercial land use of buildings, parking lots and a portion of Highway 61. The majority of the catchment sheds water west to southwest and into a grass swale between the structures and Highway 61, which flows south and eventually into Gem Lake. Catchment 3-3 contributes a large volume of water at 16 acre/ft/year. As shown in Figure 3, the current TP load analysis shows that the base load of TP is 9.2 lb/yr and that the current grass swale removes 4 lb/yr leaving 5.2 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

Figure 3. Catchment 3-3 Existing Conditions

EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	9.2	5.2	43.84%
TSS (lb/yr)	7121	4120	42.14%
Volume (acre-feet/yr)	16.06	10.43	35.06%

Figure 4. Outline of Catchment 3-3 and area of future BMP locations



RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-3 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 4. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration

Figure 5. BMP options, pollutant removal and costs for Catchment 3-3

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP								
BMP Type	Grass Swale		Moderately Complex Bioretention		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	4.93	46%	4.57	50%	4.70	49%	4.38	52%
TSS (lb/yr)	3944.00	45%	3744.00	47%	3826.00	46%	3587.00	50%
Volume (acre-feet/yr)	10.05	37%	9.13	43%	9.43	41%	8.77	45%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	7000		2000		1485		9000	
Materials/Labor/Design	$14,210		$28,010		$20,852		$42,220	
Unit Promotion & Admin Costs*	$82		$206		$255		$288	
Total Project Cost**	$19,984		$32,122		$24,645		$52,106	
Annual O&M	$1,750		$1,500		$1,114		$3,250	
Term Cost/lb/yr (30 yr)	$570		$558		$432		$1,041	
% Change in TP	2.40%		6.37%		4.98%		8.41%	

cells within the swale, and a combination of the two.

Tier 1- Bioinfiltration cells
Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas. Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 5, two bio infiltration cells were modeled, one sized at 1485 sq ft and another at 2000 sq ft, to reduce the TP levels to 49% and 50% respectively. These bioinfiltration cells were modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 0.5 inches per hour. The 1485 sq ft cell, which would remove another 5% TP compared to the current turf grass swale, is estimated to cost $24,645 with an annual cost of $1,114, which equates to a cost of $432 per year, per lb of TP removed over 30 years. The 2000 sq ft cell, which would remove another 6.4% TP compared to the current turf grass swale, is estimated to cost $32,122 with an annual cost of $1500, which equates to a cost of $558 per year, per lb of TP removed.

Tier 2 - Grass Swale
Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic and educational value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $19,984, with an annual maintenance cost of $1,750, which would lower over the years as the grass swale established. This equates to a cost of $570 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration
As seen in Figure 5, a combination grass swale and 2000 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 8.41% at a total cost of $52,106.00. This BMP option had the highest cost per lb of TP removed with a $1,041 price per year over 30 years.

Alternative Options
Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would

not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

CATCHMENT 3-5

DESCRIPTION

Catchment 3-5 is 7.69 acres of predominantly impervious land cover consisting of commercial land use of one large building, parking lots and a portion of Highway 61. The majority of the catchment sheds water west to northwest and into a grass swale between the structures and Highway 61, which flows north and eventually into Gem Lake.

Figure 6. Existing conditions within Catchment 3-5

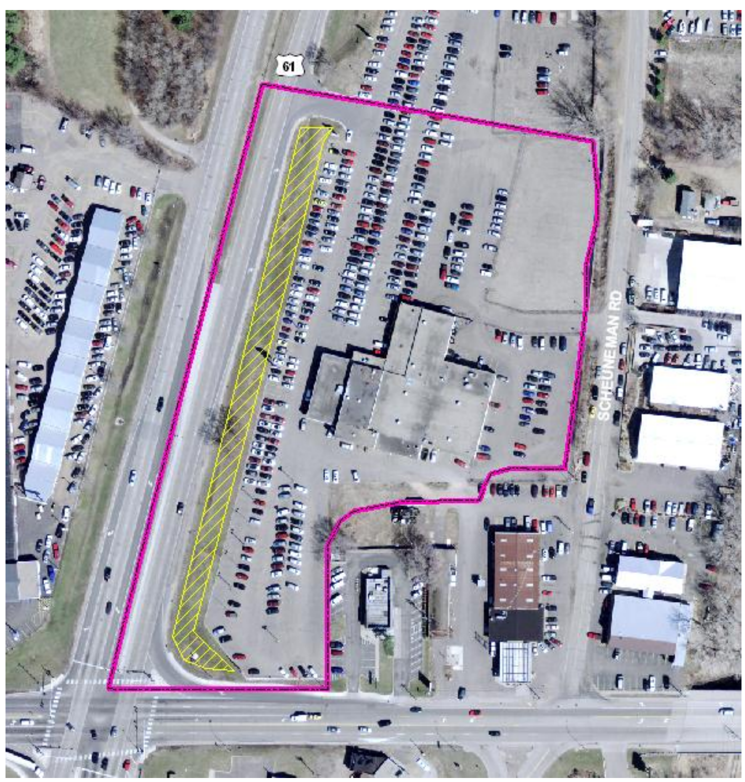
EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	5.6	3.2	42.56%
TSS (lb/yr)	4785	2866	40.10%
Volume (acre-feet/yr)	11.55	7.74	32.97%

As shown in Figure 6, the current TP load analysis shows that the base load of TP is 5.6 lb/yr and that the current grass swale removes 2.4 lb/yr leaving 3.2 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-5 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 7. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration cells within the swale, and a combination of the two.

Figure 7. Outline of Catchment 3-5 and area of future BMP locations



Tier 1- Bioinfiltration cells

Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas.

Figure 8. BMP options, pollutant removal and costs for Catchment 3-5

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP								
BMP Type	Grass Swale		Moderately Complex Bioretention		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	2.80	50%	2.90	48%	2.40	57%	2.55	54%
TSS (lb/yr)	2497.00	48%	2661.00	44%	2224.00	54%	2335.00	51%
Volume (acre-feet/yr)	6.77	41%	6.89	40%	5.69	51%	6.09	47%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	6345		500		1000		6845	
Materials/Labor/Design	$12,900		$7,160		$14,110		$20,060	
Unit Promotion & Admin Costs*	$89		$565		$341		$653	
Total Project Cost**	$18,522		$9,984		$17,518		$28,506	
Annual O&M	$1,586		$375		$750		$1,961	
Term Cost/lb/yr (30 yr)	$786		$262		$416		$954	
% Change in TP	7.48%		5.62%		14.64%		11.93%	

Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 8, two bio infiltration cells were modeled, one sized at 500 sq ft and another at 1000 sq ft, to reduce the TP levels to 48% and 57% respectively. These bioinfiltration cells were modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 0.5 inches per hour. The 500 sq ft cell, which would remove another 6% TP compared to the current turf grass swale, is estimated to cost $9,984 with an annual cost of $375, which equates to a cost of $262 per year, per lb of TP removed. The 1000 sq ft cell, which would remove another 15% TP compared to the current turf grass swale, is estimated to cost $17,518 with an annual cost of $750, which equates to a cost of $416 per year, per lb of TP removed.

Tier 2 - Grass Swale

Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $18,522, with an annual maintenance cost of $1,586, which would lower over the years as the grass swale established. This equates to a cost of $786 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration

As seen in Figure 8, a combination grass swale and 500 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 12% at a total cost of $28,506. This BMP option had the highest cost per lb of TP removed with a $954 price per year over 30 years.

Alternative Options

Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

CATCHMENT 3-6

DESCRIPTION

Catchment 3-6 is 8.6 acres of predominantly impervious land cover consisting of a large parking lot, numerous buildings, and a portion of Highway 61. The majority of the catchment sheds water east to a grass swale between the structures and Highway 61, which flows north and eventually into Gem Lake.

Figure 9. Existing conditions within Catchment 3-6

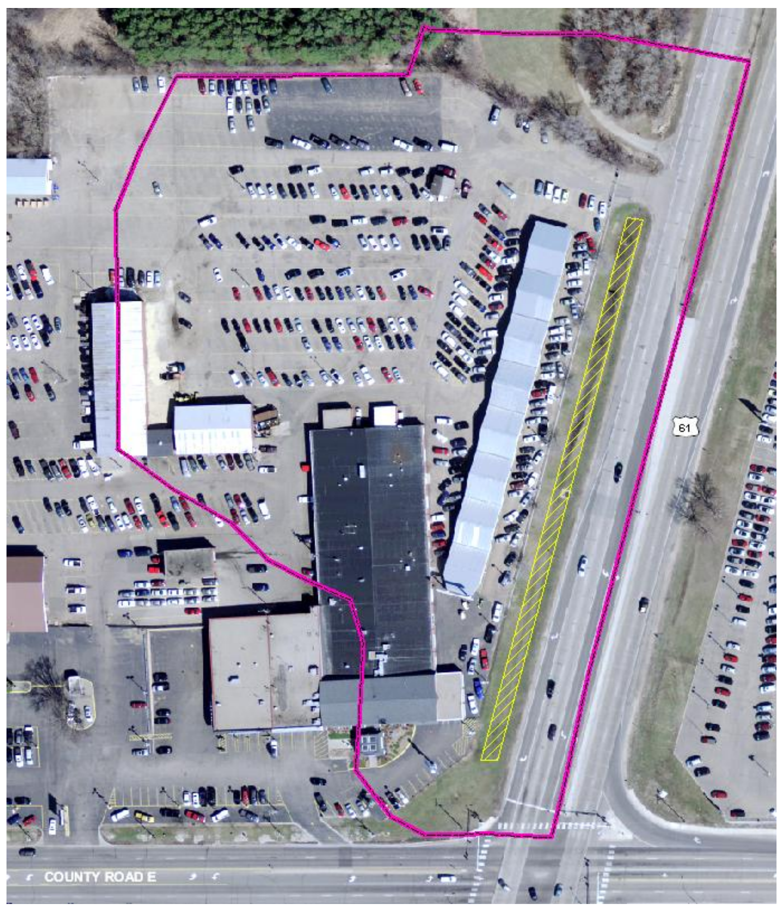
EXISTING CONDITIONS			
BMP Type	Base Loading	Grass Swale Treatment	
TP (lb/yr)	7.5	4.5	40.78%
TSS (lb/yr)	5303	3202	39.62%
Volume (acre-feet/yr)	10.80	7.50	30.56%

As shown in Figure 9, the current TP load analysis shows that the base load of TP is 7.5 lb/yr and that the current grass swale removes 3 lb/yr leaving 4.5 lb/yr of TP that leaves this catchment. To further reduce the TP loading several BMP scenarios were modeled to determine their cost and efficiency.

RETROFIT RECOMMENDATION

Different sizes and combinations of two BMP types were modeled for Catchment 3-6 and recommended to be installed within the same area as the turf grass swale currently draining the catchment, see Figure 10. These BMP's included replacing the turf grass with native grasses within the swale, bioinfiltration cells within the swale, and a combination of the two.

Figure 10. Outline of Catchment 3-5 and area of future BMP locations



Tier 1- Bioinfiltration cells

Bioinfiltration cells can be an effective, inexpensive way to infiltrate runoff. However, the cost can significantly increase if site soils do not drain well and need to be replaced with a soil type that infiltrates at a rate of 0.5 inches per hour or better. The soil survey shows no infiltration information about the soils within these areas. Therefore, before bioinfiltration cells are installed, the soils will have to be assessed for infiltration rates. As seen in Figure 11, a bio

Figure 11. BMP options, pollutant removal and costs for Catchment 3-6

RETROFIT OPTIONS RetroMarginal Network Treatment By BMP						
BMP Type	Grass Swale		Moderately Complex Bioretention		Grass Swale and Moderatley Complex Biorentention	
TP (lb/yr)	4.38	42%	3.75	50%	3.67	51%
TSS (lb/yr)	3146.00	41%	2768.00	48%	2713.00	49%
Volume (acre-feet/yr)	7.37	32%	6.17	43%	6.14	43%
Square feet of practice (or, CU FT of storage for WP, ED, SW)	9450		1500		9950	
Materials/Labor/Design	$19,110		$21,060		$40,170	
Unit Promotion & Admin Costs*	$66		$254		$320	
Total Project Cost**	$25,373		$24,863		$50,237	
Annual O&M	$2,363		$1,125		$3,488	
Term Cost/lb/yr (30 yr)	$1,019		$517		$1,340	
% Change in TP	1.04%		9.46%		10.42%	

infiltration cell was modeled at 1500 sq ft, to reduce the TP levels to 50% respectively. This bioinfiltration cell was modeled and priced with the assumption that the soils will need to be altered to reach a minimum infiltration rate of 1.0 inches per hour. This cell would remove another 9.46% TP compared to the current turf grass swale, is estimated to cost $24,863 with an annual cost of $1,125, which equates to a cost of $517 per year, per lb of TP removed.

Tier 2 - Grass Swale

Another BMP option would be a grass swale. This would require the replacement of the turf grass within the swale with native plants. Grass swales improve the filtering and infiltration of pollutant runoff as well as offer aesthetic value. Installing a native grass swale in lieu of the current turf grass swale would cost a total of $25,373, with an annual maintenance cost of $2,363 which would lower over the years as the grass swale established. This equates to a cost of $1,019 per year, per lb of TP removed.

Tier 3 – Grass Swale /Bioinfiltration

As seen in Figure 11, a combination grass swale and 1500 sq ft bioinfiltration was modeled together. The combination of these two BMP's would reduce the TP level by 10.42% at a total cost of $50,237. This BMP option had the highest cost per lb of TP removed with a $1,340 price per year over 30 years.

Alternative Options

Additional options that were unable to be modeled, but are highly reccomended to be explored further include the installation of berms within the grass swale and/or the rising of the outlet structure. It is recommended that the watershed district's engineer first model for these BMP's to ensure there would not be an issue with limiting capacity of the system and to determine the treatment and cost analysis before committing to any other options.

Retrofit Ranking

As shown in Figure 12, the different BMP options that are listed above for catchments 3-3 3-5 and 3-6 are categorized from lowest term cost of lb/TP/year to the highest term cost. Since this term cost is calculated to determine the lowest cost of TP removal per pound per year over 30 years, this list can be used to give priority to projects with the lowest term cost. As seen below, the most efficient and cost effective measures proposed are the bioinfiltration cells. The percent of TP reduction was not uniform for each proposed BMP modeled, so a TP reduction goal should be considered when deciding on a BMP option for each site.

Figure 12. BMP options, pollutant removal and costs for Catchment 3-3, 3-5 and 3-6

Catchment or Pond ID	Retro Type	Total Est. Term Cost/lb-TP/yr	Square ft of BMPs	TP Reduction (%)	Overall Cost
3-5	B	$262	500	5.62	$9,984
3-5	B	$416	1000	14.64	$17,518
3-3	B	$432	1485	4.98	$24,645
3-6	B	$517	1500	9.46	$24,863
3-3	B	$558	2000	6.37	$32,122
3-3	VS	$570	7000	2.4	$19,984
3-5	VS	$786	6345	7.48	$18,522
3-5	B/VS	$954	6845	11.93	$28,506
3-3	B/VS	$1,041	9000	8.41	$52,106
3-6	B/VS	$1,340	9950	10.42	$50,237

B = Bioretention (infiltration and/or filtration)
VS = Vegetated Swale (wet or dry)
[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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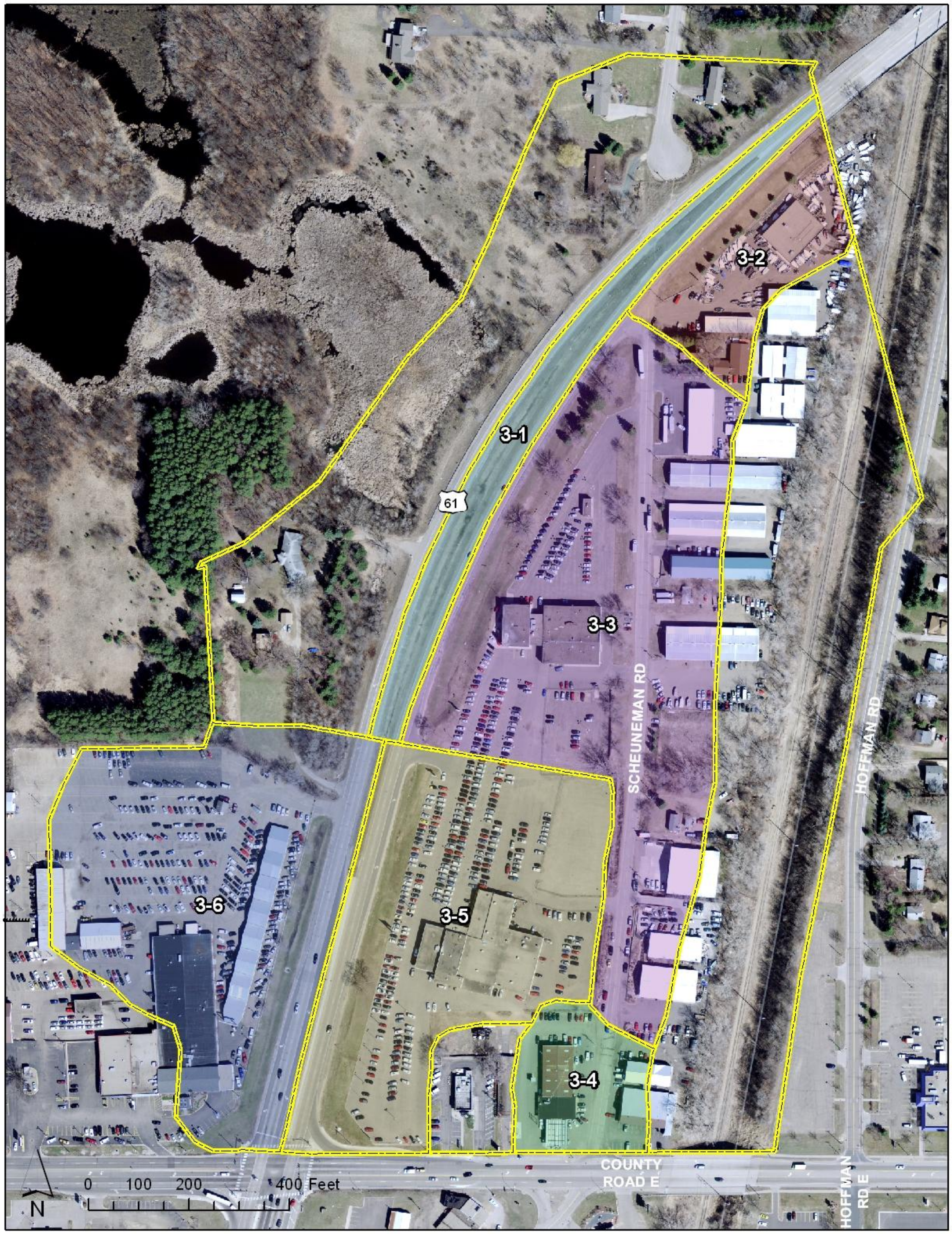
Appendix A: Overview of all catchments within study area 3



Appendix B: All catchments considered in the study area