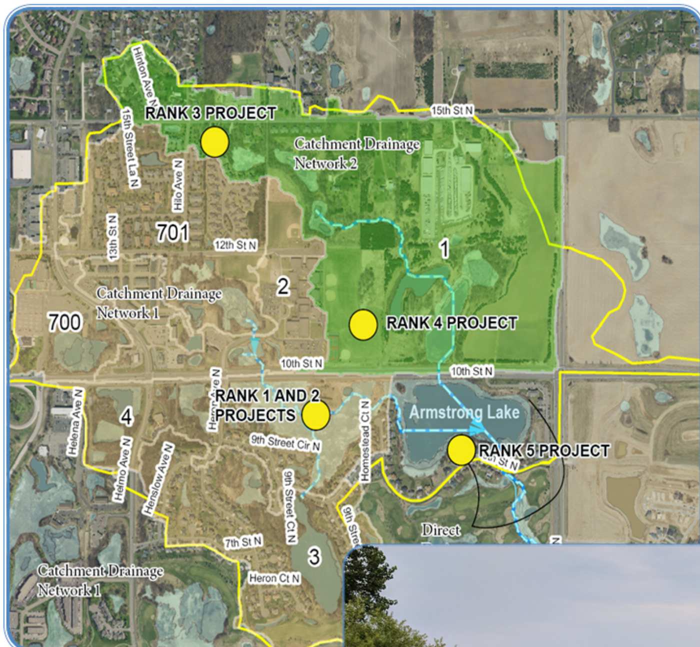
ARMSTRONG LAKE SUBWATERSHED RETROFIT ANALYSIS



SEPTEMBER, 2018

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Summary

This analysis provides a prioritized list (ranked by cost effectiveness) of stormwater retrofit recommendations to primarily reduce Total Phosphorus (TP) loading to Armstrong Lake a 39 acre lake surface area with a 487 acre subwatershed area entirely within the South Washington Watershed District (SWWD) boundary. This very shallow and flat lake is located in the headwaters of the Northern Watershed (NWS). The lake is divided by County Road 10 with a culvert connecting to two basins. A majority of the drainage area to the lake is from Oakdale and is comprised mostly of low density residential land use with some farm areas; few undeveloped parcels remain. The lake is primarily used for wildlife viewing and aesthetics; although, non-motorized boating is possible. Though not listed as impaired, TP is the target pollutant as it has been found in concentrations exceeding the State's water quality standard concentration of 0.060 mg/L. However, SWWD has set an interim goal concentration range of TP from 0.059-0.073mg/L. Current monitoring results show concentrations fall within SWWD's interim range, however, exceeding the State's water quality standard by approximately 20%. Therefore the goal for this analysis is to find Stormwater BMP retrofit opportunities to reduce total phosphorus inputs to Armstrong Lake by up to 20%.

For this analysis, we used existing lidar, landuse, and stormsewer infrastructure data to develop a WinSLAMM model for the subwatershed. Areas that did not fit WinSLAMM modeling (e.g. agricultural row crop), were removed from the model. The agricultural areas will be looked at separately. Catchment networks, consisting of multiple catchments sharing the same outfall to Armstrong Lake were identified.

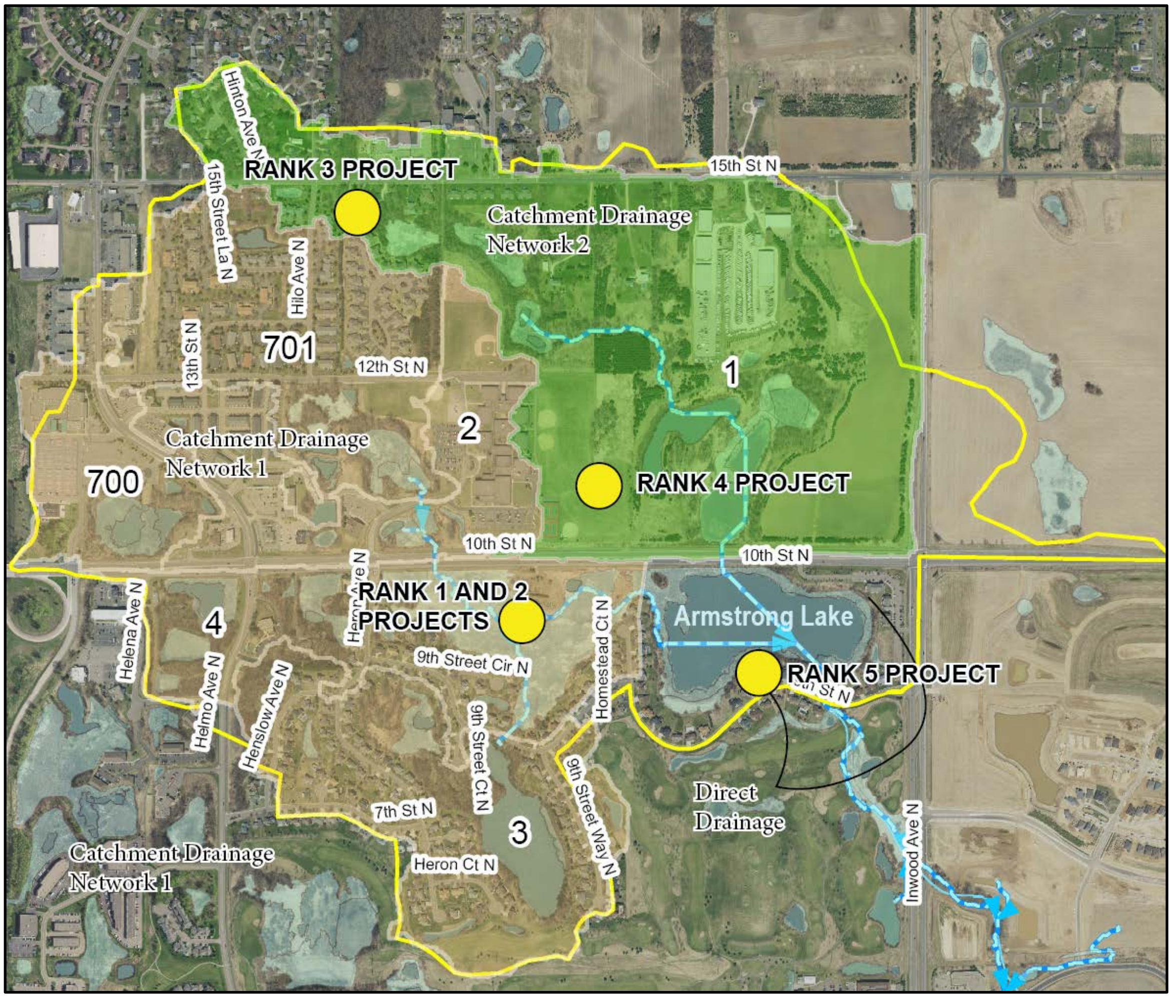
The proposed stormwater management practices within each catchment network were analyzed for annual pollutant loading - Total Phosphorus (TP), Total Suspended Solids (TSS) and Water Quality Volume (WQV) specifically. All known existing BMPs and their load reductions were accounted for in the modeling process. Though not listed as impaired, TP is the target pollutant as it has been found in concentrations exceeding the State's water quality standard concentration of 0.060 mg/L. However, SWWD has set an interim goal concentration range of TP from 0.059-0.073mg/L. Current monitoring results show concentrations fall within SWWD's interim range, however, exceeding the State's water quality standard by approximately 20%. Therefore the goal for this analysis is to find Stormwater BMP retrofit opportunities to reduce total phosphorus inputs to Armstrong Lake by up to 20%.

Most identified and modeled catchment networks received field reconnaissance visits including all identified BMP opportunities. Proposed BMP options were then compared for each sub-catchment, given their specific site constraints and characteristics. Each final stormwater practice was selected and ranked by weighing cost, pollution reduction benefits, ease of installation and maintenance, and ability to serve multiple functions. A Ranking Table can be found on the following page and in the Appendix.

Most of the soils in the Armstrong Lake subwatershed have limited infiltration potential. Therefore, the practices identified are do not rely on infiltration. The cost-benefit value for annual TP reduction over 20 years ranges from $85 to $3,533 per lb. The estimated TP load reduction for the identified projects exceed the goal reduction of up to 20% over the entire subwatershed.

IDENTIFIED RETROFIT PROJECT LOCATIONS AND RELATIVE RANKING

The graphic below shows identified project locations within this analysis and their relative ranking. Ranking details provided in the table below.



Stormwater Retrofit Ranking by BMP Cost Effectiveness

The following table summarizes the assessment results, ascending in rank by $Cost per lb of TP removed over 20 years. 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. See Methods Section for how rankings were determined.

Rank	Drainage Network/ Outfall	BMP Type	Projects Identified	BMP Location	TP Red (lb/yr)	TSS Red (lb/yr)	Volume Red (acft/yr)	Total Project	Annual O&M	Cost/lb-TP/year (20 years)	Cost/ton TSS/year (20 years)
1	**Network 1 - large wetland**	Cattail Harvesting	1	adjacent west of Armstrong Lake	40 - 350	N/A	N/A	$65,000 - $80,000	$15,000 - $25,000	$80 - $437	**N/A**
2	**Network 1 - large wetland**	Spent Lime Filter	1	adjacent west of Armstrong Lake	31	N/A	20	$280,000	$2,000	$516	**N/A**
3	**Network 2 - 15th St and Hilo**	IESF	1	SE corner of 15th St. and Hilo Ave	3.7	500	N/A	$38,000	$1,000	$725	**$11,600**
4	**Network 2 - 15th St and Skyview Elementary**	Reuse irrigation system on athletic fields	1	Athletic fields on east side of Skyview Elementary School	14	7,650	25	$300,000	$1,000	$1,142	**$4,183**
5	**Network 3 - Direct Drainage**	Shoreline Buffer	29	Private residences and office park along south and east shoreline of Armstrong lake	4.5	2,068	N/A	$248,000	$3,500	$3,533	**$15,200**

About this Document

This Subwatershed Stormwater Retrofit Analysis 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.

Document Organization

This document is organized into three major sections, plus references and appendices. Each section is briefly described below.

Methods

The methods section outlines general procedures used when analyzing the subwatershed. It provides an overview of processes involved in retrofit scoping, desktop analysis, retrofit reconnaissance investigation, cost/treatment analysis and project ranking. See Appendix A for a detailed description of the methods for both the overall analysis as well as for how other practices were factored into the modelling and reporting.

Catchment Profiles

The Armstong Lake Subwatershed was determined from existing SWWD catchment delineation data. Catchment drainage networks were delineated based existing catchment data, stormsewer data, and ground truthing. The numbering system for identifying the drainage networks is only for use in this report, whereas individual catchment identification numbers correlate with catchment datasets. For each catchment and drainage network, the following information is detailed:

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, dominant land use, and estimated existing annual pollutant and volume loading. A brief description of the land use, stormwater infrastructure, exceedance of acceptable TP loading in comparison to the Mississippi River TMDL, and any other important general information is also described. Existing stormwater practices are noted, and their estimated effectiveness presented. Appendix B outlines how to read a typical Catchment Profile.

BMP Retrofit Recommendations

The recommendation section describes the conceptual retrofit(s) that were identified. It includes tables outlining the estimated pollutant removals by all practices proposed, as well as costs and overall cost-benefit ranking. Following this Retrofit Recommendations summary page, each practice has its own page which includes a map, individual cost-benefit analysis, and site specific comments on the individual proposed retrofit.

Retrofit Rankings

This section ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by cost-per-pound of total phosphorus removed for each project over 20 years. The final cost-per-pound treatment value includes design, installation, and maintenance costs (in 2018 dollars). Cost estimates vary in precision due to exposure to real-world bids for specific practices, and will also vary when unknown site parameters are addressed during the design phase.

There are many possible ways to prioritize projects, and the list provided is merely a starting point. Other considerations for prioritizing installation may include:

- Non-target pollutant reductions
- Timing projects to occur with other CIPs
- Project visibility
- Availability of funding
- Total project costs
- Educational value
- Additional ecological and habitat connectivity value

References

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

Appendix

This section provides supplemental information and/or data used in various portions of the analysis protocol.

Stormwater BMP types identified in this report

Filtration Systems

Spent Lime Filter, Iron Enhanced Sand Filter, Shoreline Buffer Restoration

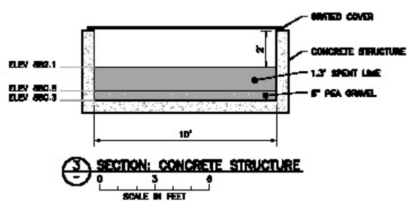
Summary

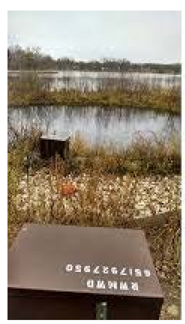
Filtration BMPs are a preferred practice in areas where infiltration is not feasible due to poor or contaminated soils, high water tables, or risks to adjacent structures.

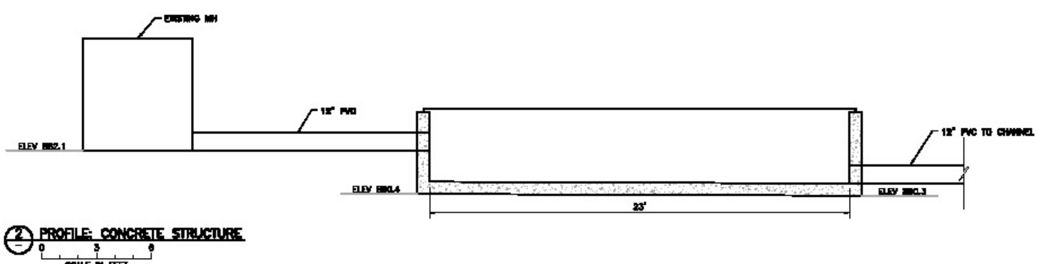
Spent Lime Filter

Spent lime filters are a new technology where a byproduct of the drinking water filtration process, spent lime, is placed in low cfs treatment scenarios to filter stormwater runoff. Initial research has shown a 60-70% reduction in dissolved phosphorus. Both above-ground and below-ground construction scenarios have been implemented successfully in areas adjacent to wetlands like the scenario identified in this report. One of the biggest benefits of a spent lime BMP is that filter continues to bind with pollutants in periods of extended inundation.

Example spent lime filter details below from Barr Engineering's design report for Lake Susan in Chanhassen to Riley Purgatory Bluff Creek Watershed District:

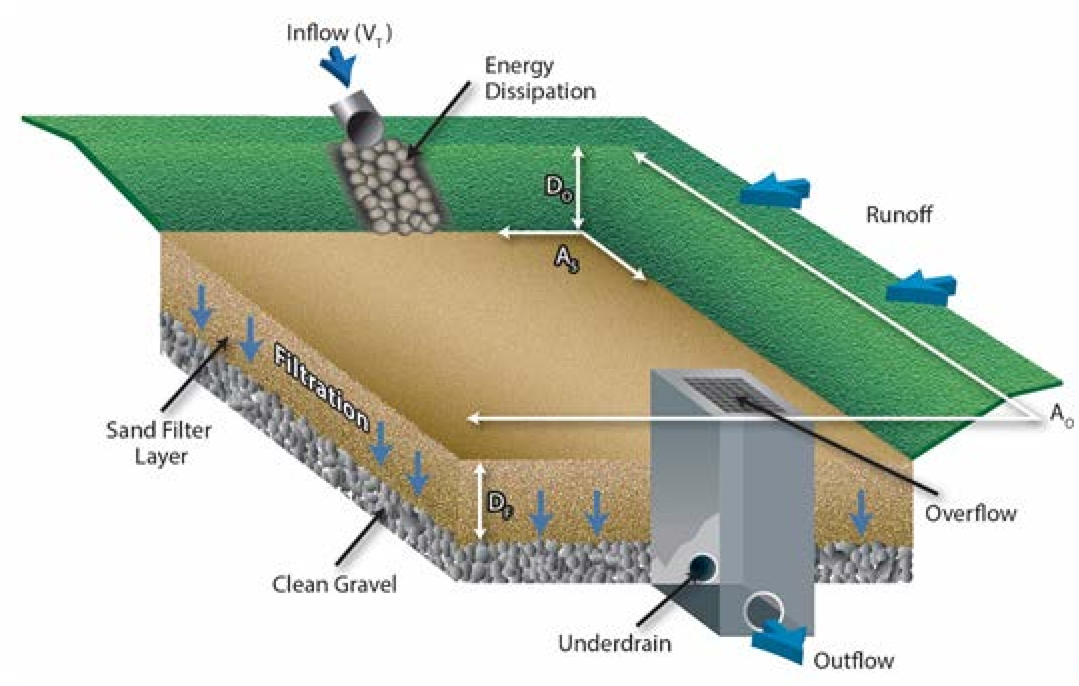






Iron Enhanced Sand Filter

Iron enhanced Sand filters are exceptional at removing dissolved phosphorus, at rates up to 85% removal. They're biggest limitation is that the sand/iron profile must not become anoxic as the iron will release the bound phosphorus. The scenario presented in this report is designed to dry out after each rain event, preventing an anoxic condition. Example iron enhanced sand filter detail below provided by the Minnesota PCA.



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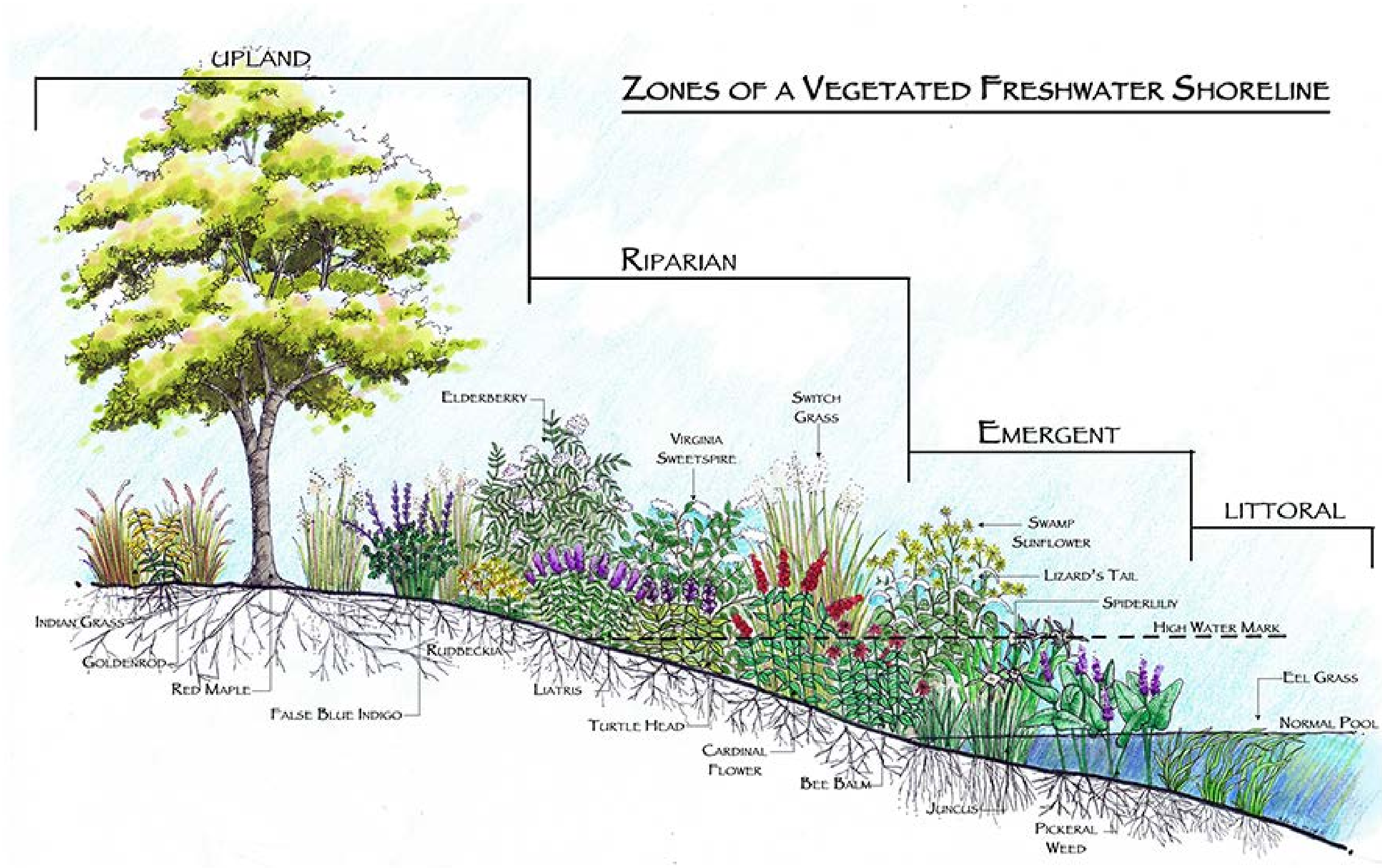
Shoreline Buffer

Restoring shoreline vegetation has been a proven BMP to filter upland runoff and stabilize the upland, transitional and littoral zones reducing erosion potential.



Stormwater BMP types identified in this report

Vegetation Harvesting - Cattails

Research out of the U of MN Crookston has shown that harvesting cattails can significantly reduce phosphorus in wetland settings. Harvesting cattails in the winter yields an average of 4 lbs of TP/ac, whereas growing season harvesting yields an average of 70 lbs of TP/ac. A secondary benefit of harvesting cattails (especially during the growing season) is the overall wetland responds with increased species diversity and more open water areas – both critical to restoring a wetland and its habitat function. Availability of wetland sensitive equipment is the biggest limitation of this BMP. The equipment must be low compaction and potential able to harvest in standing water. There is a specific piece of equipment available in the upper Midwest or is available for purchase (UK company) for $180K. Example below shows harvesting equipment outlined in U of MN Crookston Cattail Harvesting Study:

The challenge when using equipment pairing like this is that trail groomers typically have hydraulic systems to power implements on the front and rear whereas balers are driven by power-take-off (PTO). Furthermore, most trail groomers have 12 inches or less of ground clearance, hardly enough to pass over a cattail swath when production levels approach 8-10 tons per acre. Figure 21 shows a traditional Bombardier trail groomer with hydraulic power, front and rear.

It would seem to be most efficient to have a swather and baler combination to allow harvesting with a single pass like the Sumo Quaxi machine made in Austria (Figure 22). It is unknown if a machine such as this is operating in North America. Figure 23 shows a computer-generated model of the concept but a working system of this sort that has been adapted to operate in wet conditions has not been located in the Northern Great Plains.

Bi-directional tractors are available which have PTOs front and back that could be fitted with tracks to operate in wet areas (Figure 24). Figure 25 shows a conventional tractor fitted with tracks for trail grooming that probably has hydraulics on the front and assuredly PTO at the back that could power a baler. In northwestern Minnesota, there are tractors of this sort equipped to groom snowmobile trails. These could conceivably be available for rent during the fall cattail-harvesting window after fall frost and before the snow season. This scenario has not been confirmed at this time.

There are front-mounted mowers that run by hydraulics on tracked skid-steers (Figure 26). While they are fine for mowing cattails, they have low clearance and would probably chop the material up too much to bale. A rear-mounted mower is shown in Figure 27 on a "Marshmaster." This machine could operate in wet conditions but it is doubtful if it could be adapted to bale cattails due to limited power. It does have somewhat greater ground clearance than Bombardier trail groomers.

If a one-pass operation is desired, what is needed is a front-

FIGURE 20. Modified Piston Bully harvesting reed (*Phragmites sp.*) in Germany. Apparently, the unit converts hydraulics to run the PTO driven baler. Note the track-equipped baler and the supplemental radiator for additional cooling capacity of the hydraulic system.

FIGURE 21. Bombardier trail groomer with front and rear hydraulics for powering implements.

Stormwater BMP types identified in this report

Stormwater Reuse

Reusing stormwater for irrigation has been an increasingly common practice in Minnesota. Similar to the scenario in this analysis, using stormwater to irrigate removes dissolved phosphorus from the stormwater drainage network while also reducing groundwater consumption. Barriers to implementation include access to power supply and whether existing irrigation system exists.

Catchment Drainage Network Profiles and BMP Rankings

Catchment Drainage Network 1

CATCHMENT DRAINAGE NETWORK DESCRIPTION

Catchment drainage network 1 (catchments 700,701,2,3,4) is approximately 299 acres (53% of total subwatershed). The outfall to Armstrong lake is the large wetland (20 acre) immediately to the west of Armstrong lake south of Cty Rd 10. The dominant land use is residential. The existing bmps and maintenance attributes are 15 stormwater ponds, 5 wetland complexes, 3 biofiltration practices, and biannual street sweeping.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading	Avg Loading per acre
Treatment	TP (lb/yr)	227	123.6	54.40%	**103.6**	**0.4**
	TSS (lb/yr)	108,141	54,125	50.00%	**54,016**	**196**
	Volume (acre-feet/yr)	189.4	20	11.00%	**169.4**	**0.62**
	Number of BMP's	25				
	BMP Size/Description	18 constructed, 5 wetland complexes, 2 maintenance (street sweeping)				

Network 1: Wetland Restoration, Cattail Harvesting, Spent Lime Filtraton

Drainage Area – 299 acres
Location – Large 20 acre wetland west of Armstrong Lake – South side of County Road 10
Property Ownership – Public

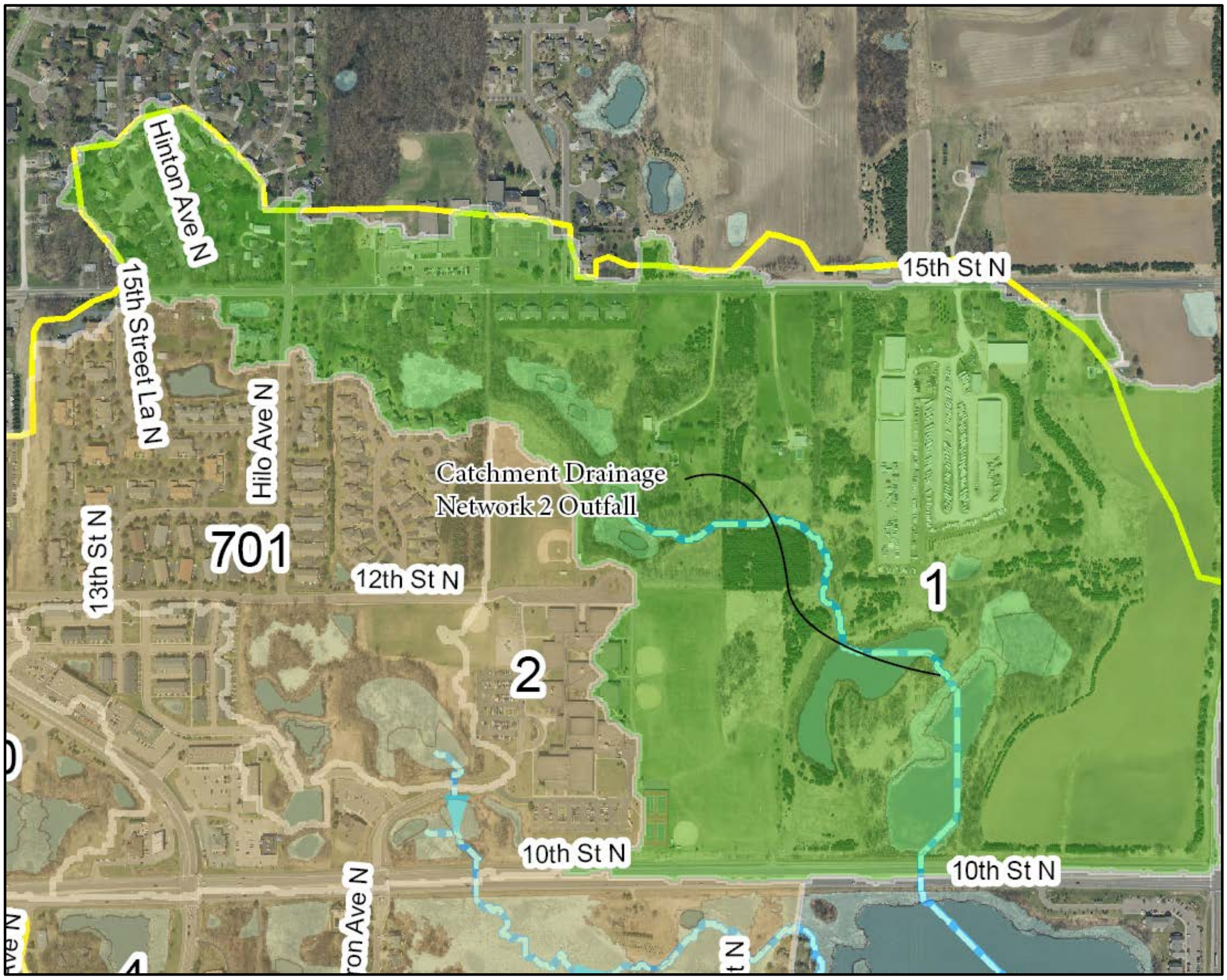
Description – There are 3 BMPs identified for at this location including (1) restoring hydrology as the wetland has been channelized since before 1945, (2) harvesting the cattail dominant vegetation, and (3) modifying the existing wetland outlet to filter flows through a spent lime filter. Restoring the wetland hydrology is assumed prior to reporting the load reduction benefits of the BMP performance table below. No load reduction benefit is reported for restoring wetland hydrology – however, TP reduction benefits are likely. These BMPs may be installed together as they may target different conditions of phosphorus present in the wetland and catchment network. For example - cattail harvesting may help remove internal loading TP while the spent lime filter may removal filterable phosphorus in the water column.

	Cost/Removal Analysis	Project ID Cattail Harvesting		Project ID Spent Lime Filter		Project ID Wetland Hydrology Restoration	
		New treatment	Net %	New treatment	Net %	New treatment	Net %
Treatment	TP (lb/yr)	40 - 350	39% - 338%	31	41.4%	n/a	n/a
	TSS (lb/yr)	n/a	n/a	n/a	n/a	n/a	n/a
	Volume (acre-feet/yr)	n/a	n/a	n/a	n/a	20	12%
	Number of BMP's	1		1		1	
	BMP Size/Description	10 acres (harvest half the wetland at a time) Range in treatment reflects winter (4 lbs/ac TP removal) and growing season harvesting (70 lbs TP removal) + wetland seed and chemical control of invasive species		1,920 cuft trench (120'x8'x2') with level spreader and high flow bypass.		Hydraulic and vegetative restoration achieved by other BMP recommendations	
	BMP Type	Vegetation Removal + Native Vegetation Restoration		Spent Lime Filter		Wetland Restoration	
Cost	Materials/Labor/Design	$55,000 - $70,000		$270,000		Included in other BMPs	
	Promotion & Admin Costs	$10,000		$10,000		"	
	Probable Project Cost	**$65,000 - $80,000**		**$280,000**		"	
	Annual O&M	$15,000 - $25,000		$2,000		"	
	20-yr Cost/lb-TP/yr	**$80 - $437**		**$516**		"	
	20-yr Cost/2,000lb-TSS/yr	**n/a**		**n/a**		"	

Catchment Drainage Network 2

CATCHMENT DRAINAGE NETWORK DESCRIPTION

Catchment drainage network 2 is approximately 200 acres. 28 acres of agricultural land use was removed as WinSLAMM is an urban model. The dominant land uses are residential and institutional (school). The existing bmps and maintenance attributes are 9 stormwater wetlands, 2 extended practices, and biannual street sweeping.



	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading	Avg Loading per acre
Treatment	TP (lb/yr)	98.6	41.4	42.0	**57.2**	**0.33**
	TSS (lb/yr)	49,440	21,123	42.7	**28,317**	**165**
	Volume (acre-feet/yr)	75.60	5.49	1.3%	**70.11**	**0.4**
	Number of BMP's	13				
	BMP Size/Description	9 stormwater wetlands, 2 constructed, 2 maintenance (street sweeping)				

Network 2: Iron Enhanced Sand Filter

Drainage Area –20 acres
Location – SE corner of Hilo Ave and 15th Street
Property Ownership – Public Parcel
Description – The proposed BMP at this location is an offline iron enhanced sand filter filtering low stormwater flow between an existing detention basin and a wetland. The BMP is located on an existing city parcel. Access to the parcel is across private property. The iron enhanced sand filter is approximately 2 feet deep with underdrains connecting to an existing dry creek bed.

	Cost/Removal Analysis	***Project ID***	
		IESF	
		New treatment	**Net %**
Treatment	**TP (lb/yr)**	3.7	6.5%
	TSS (lb/yr)	500	2%
	Volume (acre-feet/yr)	n/a	n/a
	Number of BMP's	1	
	BMP Size each/Description	700	sqft
	BMP Type	Iron Enhanced Sand Filter	
Cost	**Materials/Labor/Design**	$35,000	
	Promotion & Admin Costs	$3,000	
	Probable Project Cost	**$38,000**	
	Annual O&M	$1,000	
	20-yr Cost/lb-TP/yr	**$725**	
	20-yr Cost/2,000lb-TSS/yr	**$11,600**	

Network 2: Stormwater Reuse at School

Drainage Area –1240 acres
Location – 3 acre pond east of school
Property Ownership – Public Parcel
Description – This pond is in between the wetland and Armstrong Lake. According to NWI, the pond was excavated. Water from this pond could be pumped to irrigate the existing athletic fields at Skyview Elementary School. Project barriers include relatively high pumping required due to existing topography and access to electricity.

	Cost/Removal Analysis	***Project ID***	
		Stormwater Reuse	
		New treatment	**Net %**
Treatment	**TP (lb/yr)**	14	24%
	TSS (lb/yr)	7650	27%
	Volume (acre-feet/yr)	25	36%
	Number of BMP's	1	
	BMP Size each/Description	9	acres
	BMP Type	Reuse Irrigation Pump and Distribution	
Cost	**Materials/Labor/Design**	$285,000	
	Promotion & Admin Costs	$15,000	
	Probable Project Cost	**$300,000**	
	Annual O&M	$1,000	
	20-yr Cost/lb-TP/yr	**$1,142**	
	20-yr Cost/2,000lb-TSS/yr	**$4,183**	

Catchment Drainage Network – Direct Drainage

CATCHMENT DRAINAGE NETWORK DESCRIPTION

Catchment drainage network Direct Drainage is approximately 13 acres. 10 acres of agricultural land use was removed as WinSLAMM is an urban model. The dominant land uses are residential and agricultural. The existing bmps and maintenance attributes are 1 stormwater pond and biannual street sweeping.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading	Avg Loading per acre
Treatment	TP (lb/yr)	11.5	1.8	15.1	**9.7**	**.75**
	TSS (lb/yr)	5055	920	18.2	**4136**	**318**
	Volume (acre-feet/yr)	8.5	.5	1 %	**8**	**0.6**
	Number of BMP's	1				
	BMP Size/Description	Stormwater pond and biannual street sweeping				

Network Direct Drainage: Shoreline Buffer

Drainage Area –20 acres
Location – South and east shores of Armstrong Lake
Property Ownership – Private Parcels (29 total)
Description – The proposed BMP is a shoreline buffer at each property adjacent to the southern and eastern shore of Armstrong lake (south of cty road 10). There is some existing tall vegetation (cattails) within the littoral zone but upland buffering would increase TP removal efficiencies. Extensive outreach would be required to get all 29 properties to adopt shoreline buffer practices.

	Cost/Removal Analysis	*Project ID*	
		Shoreline Buffer	
		New treatment	Net %
Treatment	TP (lb/yr)	4.5	6.5%
	TSS (lb/yr)	2,068	2%
	Volume (acre-feet/yr)	n/a	n/a
	Number of BMP's	29	
	BMP Size each/Description	1000	sqft
	BMP Type	Vegetated Shoreline Buffer	
Cost	Materials/Labor/Design	$240,000	
	Promotion & Admin Costs	$8,000	
	Probable Project Cost	**$248,000**	
	Annual O&M	$3500	
	20-yr Cost/lb-TP/yr	**$3,500**	
	20-yr Cost/2,000lb-TSS/yr	**$15,200**	

Appendix A: Methods

Methods

Selection of Subwatershed

Many factors are considered when choosing which subwatershed to analyze 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. Stormwater retrofit analyses supported by a Local Government Unit with sufficient capacity (staff, funding, available GIS data, etc.) to greater facilitate the process also rank highly. For some communities a stormwater retrofit analysis complements their MS4 stormwater permit. The focus is always on a priority waterbody.

For this analysis, the Armstrong Lake Subwatershed was chosen for the study as the total phosphorus concentration in Armstrong Lake nearly exceeds or is exceeding the state standard and SWWD transition standard. Identifying areas that receive little treatment or have degraded or underutilized green infrastructure become a priority as these areas typically have a large impact on water quality.

Stormwater runoff from impervious surfaces like pavement and roofs can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, other areas were built before modern-day stormwater treatment

technologies and requirements or have undersized treatment devices.

Stormwater Retrofit Analysis Methods

The process used for this analysis is outlined in the following pages 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 incorporated 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 management organization members 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 analyze in large subwatersheds, a focus area may be determined.

In this analysis, the focus area was all catchments either partially or wholly within the City of Newport. This selection was primarily due to a recent completion of a hydraulic and hydrologic model. Included are areas of residential, commercial, industrial, institutional, and agricultural land uses, as well as undeveloped areas of mature woodlands. The subwatershed was divided into subcatchments using a combination of existing subwatershed catchment data, stormwater infrastructure maps, and observed topography.

The targeted pollutant for this study was Total Suspended Solids (TSS), though Total Phosphorus (TP) and Water Quality Volume (WQV) were also modeled and reported allow for multiple approaches to prioritize projects for implementation.

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 analyzed because of existing stormwater infrastructure or disconnection from the target water body. Several catchments and associated drainage networks that were identified as isolated basins on a 10-year event (existing dataset) or had multiple stormwater BMPs in place (northern part of the City – hwy 61 and 494 interchange) were removed.

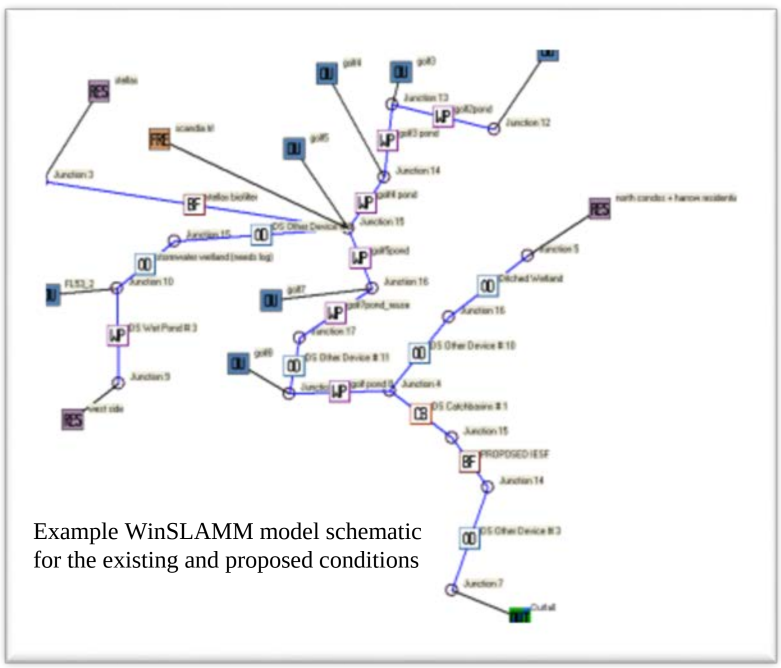
Desktop retrofit analysis features to look for and potential stormwater retrofit projects.

Feature	*Potential Retrofit Project*

Existing Ponds	Add storage and/or improve water 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, curb-cut rain gardens, or filter systems before water enters storm drain network.

Step 3: Reconnaissance Investigation

After identifying potential retrofit sites through this desktop search, a field investigation was conducted to evaluate each site and identify additional opportunities. 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.



Example WinSLAMM model schematic for the existing and proposed conditions

Step 4: Treatment Analysis/Cost Estimates

Sites most likely to be conducive to addressing the cities' and watershed district's goals and appear to have simple-to-moderate design, installation, and maintenance were chosen for a cost/benefit analysis. Estimated costs included design, installation, and maintenance annualized across a 30-year period. Estimated benefits included are pounds of phosphorus and total suspended solids removed, though projects were ranked only by cost per pound of phosphorus removed annually.

Treatment analysis

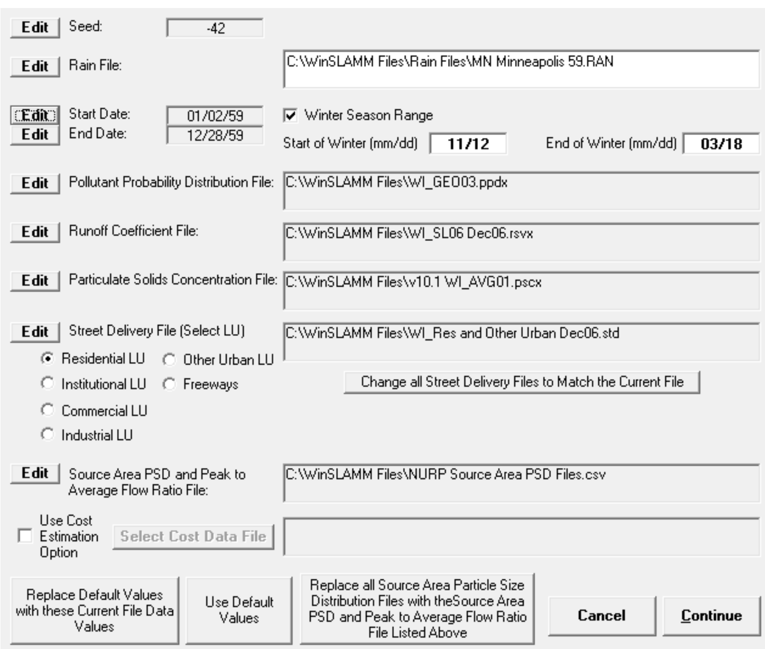
For the entire analysis WinSLAMM was used to analyze existing conditions and proposed BMP scenarios and iterations. WinSLAMM uses an abundance of stormwater data from the upper Midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It is useful for determining the effectiveness of proposed stormwater control practices. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape" that reflects the actual landscape being considered. The user is allowed to place a variety of stormwater treatment practices that treat water from various parts of this landscape. It uses rainfall and temperature data from a typical year, routing stormwater through the user's model for each storm.

The initial step was to create a "base" model which estimated pollutant loading from each catchment in its present-day state without taking into consideration any existing stormwater treatment. To accurately model the land uses in each catchment, we delineated each land use in each catchment using geographic information systems (specifically, ArcMap), and assigned each a WinSLAMM standard land use file. A site specific land use file was created by adjusting total acreage and accounting for local soil types (all soils were modeled as silt in this analysis). This process resulted in a model that included estimates of the acreage of each type of source area (roof, road, lawn, etc.) in each catchment. For certain source areas critical to our models we verified that model estimates were accurate by calculating actual acreages in ArcMap, and adjusting the model acreages if needed.

Once the "base" model was established, an "existing conditions" model was created by incorporating any existing stormwater treatment practices in the catchment. For example, street cleaning with mechanical or vacuum street sweepers, rain gardens, stormwater treatment ponds, and others were included in the "existing conditions" model if they were present in the catchment.

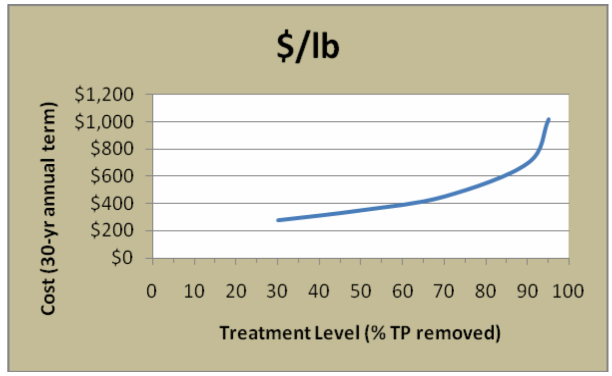
Finally, each proposed stormwater treatment practice was added to the "existing conditions" model and pollutant reductions were generated. Because neither a detailed design of each practice nor in-depth site investigation was completed, a generalized design for each practice was used. Whenever possible, site-specific parameters were included. Design parameters were modified to obtain various levels of treatment. It is worth noting that we modeled each practice individually, and the benefits of projects may not be additive, especially if serving the same area. Reported treatment levels are dependent upon optimal site selection and sizing.

WinSLAMM stormwater model inputs



Cost Estimates

All estimates were developed using 2018 dollars. Cost estimates were annualized costs that incorporated design, installation, installation oversight, and maintenance over a 20-year period. In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. In cases where multiple, similar projects are proposed in the same locality, promotion and administration costs were estimated using a non-linear relationship that accounted for savings with scale. Design assistance from an engineer is assumed for practices in-line with the stormwater conveyance system, involving complex stormwater treatment interactions, or posing a risk for upstream flooding. It should be understood that no site-specific construction investigations were done as part of this stormwater retrofit analysis, and therefore cost estimates account for only general site considerations.



The costs associated with several different pollution reduction levels were calculated. Generally, more or larger practices result in greater pollution removal. However the costs of obtaining the highest levels of treatment are often prohibitively expensive (see figure). By comparing costs of different treatment levels, the cities and watershed district can best choose the project sizing that meets their goals.

Step 5: Evaluation and Ranking

The cost per ton of TSS treated was calculated for each potential retrofit project. Only projects that seemed realistic and feasible were considered. The recommended level was the level of treatment that would yield the greatest benefit per dollar spent while being considered feasible and not falling below a minimal amount needed to justify crew mobilization and outreach efforts. Local officials may wish to revise the recommended level based on water quality goals, finances, or public opinion.

Appendix B:
How to Read Catchment Profiles

Catchment Profiles and How to Read Them

The analysis contains pages referred to as "Catchment Profiles." These profiles provide the most important details of this report, including:

- Summary of existing conditions, including existing stormwater infrastructure, and estimated pollutant export to target water body.
- Map of the catchment
- Recommended stormwater retrofits, pollutant reductions, and costs.

Following all of the catchment profiles (also in the executive summary) is a summary table that ranks all projects in all catchments by cost effectiveness.

To save space and avoid being repetitive, explanations of the catchment profiles are provided below. We strongly recommend reviewing this section before moving forward in the report.

The analyses of each catchment are broken into "base, existing, and proposed" conditions. They are defined as follows:

Existing conditions - Volume and pollutant loadings after already-existing stormwater practices are taken into account.

Proposed conditions - Volume and pollutant loadings after proposed stormwater retrofits.

Analyses were performed at one of two geographic scales, "catchment or network." They are defined as follows:

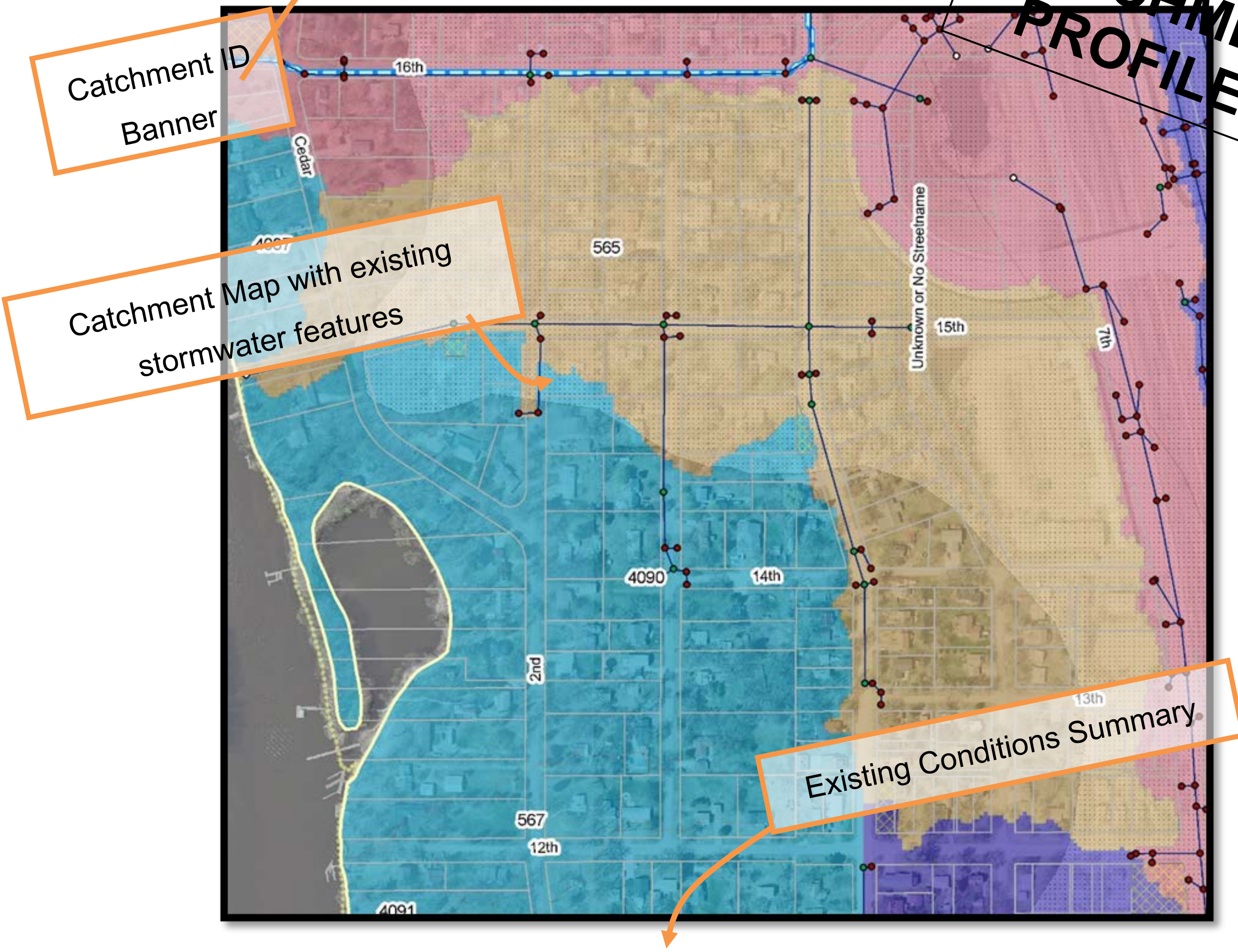
BMP Sub-catchment level analyses - V o l u m e and pollutant loads exiting the sub-catchment of the proposed BMP or the proposed Priority Shoreline Catchment. BMP Sub-catchments are then ranked on a cost/Lb Tp/10years and compared to all other proposed practices. This method highlights best BMPs overall, irrespective of sub-catchment location.

The example catchment profile on the following pages explains important features of each profile.

HOW TO READ CATCHMENT PROFILES

1

EXAMPLE Catchment Network 6



CATCHMENT DRAINAGE NETWORK DESCRIPTION

Catchment drainage network 6 is 46 acres. The dominant land cover is residential. There is 1 stormwater pond located within network. Like all areas, one street sweeping per year is assumed in the model existing conditions.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading	Avg Loading per acre	Network Treatment needed to reach resource goal
Treatment	TP (lb/yr)	37.3	1.7	4.5%	**35.6**	**0.8**	**n/a**
	TSS (lb/yr)	17,402	1,362.0	7.8%	**16,040**	**350**	**8,988**
	Volume (acre-feet/yr)	26.3	0.0	0.0%	**26.3**	**0.6**	**n/a**
	Number of BMP's	1 constructed, 1 maintenance					
	BMP Size/Description	1 stormwater ponds, and street sweeping					

Network 6: Underground Upflo Filtration

BMP Name and Site Description

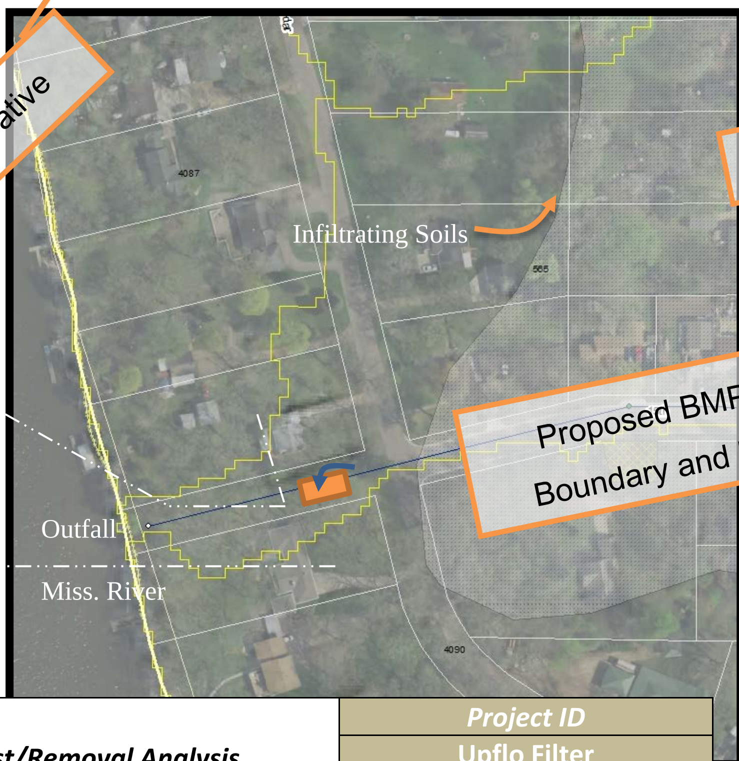
Rank 6 of 12

Drainage Area – 45 acres
Location – Cedar Lane and 15th Street
Property Ownership – Public

Description – The proposed BMP is located at the end of the drainage network, therefore an opportunity to filter runoff from nearly all of the 45 acres. The proposed offline underground hydrodynamic device and stormfilter provides a lot of TSS (and TP) treatment at a very small footprint. Keeping a small footprint is important as the bedrock is shallow (high cost for excavation) and is able to fit within public property.

Practice Design Narrative

Practice Ranking



Proposed BMP Catchment Boundary and BMP Location

	Cost/Removal Analysis	Project ID	
		Upflo Filter	
		New treatment	Net %
Treatment	TP (lb/yr)	13.5	38%
	TSS (lb/yr)	7,300	46%
	Volume (acre-feet/yr)	0.1	0%
	Number of BMP's	1	
	BMP Size/Description	100	sqft
	BMP Type	Upflo Filter with 8 foot deep sump	
Cost	Materials/Labor/Design	$160,000	
	Promotion & Admin Costs	$3,000	
	Probable Project Cost	**$163,000**	
	Annual O&M	$15,000	
	20-yr Cost/lb-TP/yr	**$1,715**	
	20-yr Cost/2,000lb-TSS/yr	**$6,342**	

Practice Sizing and Treatment Summary

Design, Install, Maintenance, and Promotion Costs

Proposed Cost per Lb of TP and TSS