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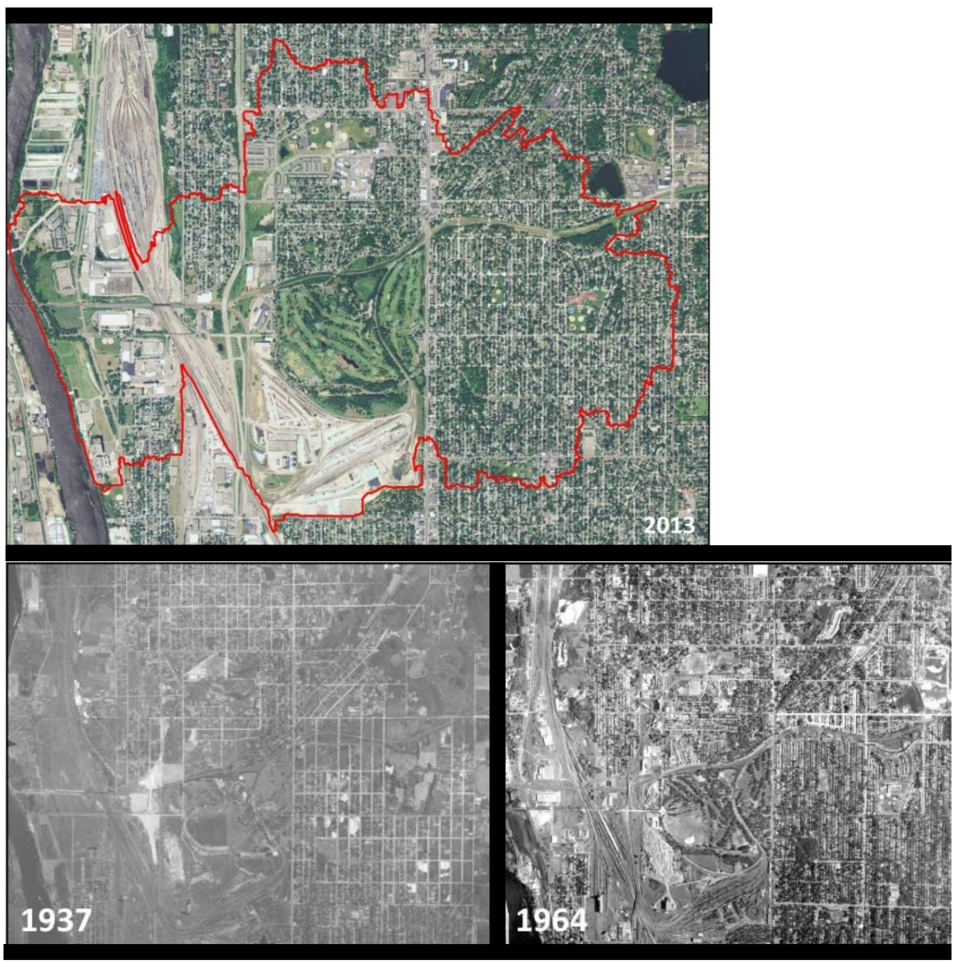
Southern Columbia Heights and Northeast Minneapolis Stormwater Retrofit Analysis



MWMO Watershed Bulletin: 2014-5

Prepared for the MWMO by:
the Anoka Conservation District

Southern Columbia Heights and Northeast Minneapolis Stormwater Retrofit Analysis: 2014

Prepared for the MWMO by:
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Front Cover: Aerial photographs of the 1NE subwatershed from 1937, 1964, and 2013.

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Southern Columbia Heights and Northeast Minneapolis Stormwater Retrofit Analysis

MWMO Watershed Bulletin: 2014-5

Prepared for the MWMO by:
the Anoka Conservation District

Abstract

The Mississippi Watershed Management Organization (MWMO) contracted the Anoka Conservation District to complete this stormwater retrofit analysis (SRA) for the purpose of identifying and ranking water quality improvement projects in the 1NE outfall drainage area. The 1NE outfall drainage area consists of portions of southern Columbia Heights and Northeast Minneapolis that drain to the Mississippi River. The MWMO specified total phosphorus (TP) and total suspended solids (TSS) as the target pollutants for the analysis. An overall annual subwatershed-wide reduction goal of 25% for both TP and TSS was identified. The intent of this goal is for use in judging the overall impact of implementing BMPs in the study area.

This analysis is primarily intended to identify potential projects within the target area to improve water quality in the Mississippi River through stormwater retrofits. In this SRA, both costs and pollutant reductions were estimated and used to calculate cost effectiveness for each potential retrofit identified. Water quality benefits associated with the installation of each identified project were individually modeled using the Source Loading and Management Model for Windows (WinSLAMM). The volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential retrofit projects. The costs associated with project design, administration, promotion, land acquisition, opportunity costs, construction oversight, installation, and maintenance were estimated. The total costs over the assumed effective life of each project were then divided by the modeled benefits over the same time period to enable ranking by cost-effectiveness.

Drainage areas within the 2,075 acre 1NE subwatershed were consolidated into 18 catchments and 5 drainage networks (groups of catchments draining to a common point). Based on WinSLAMM model results, the 2,075 acre drainage area contributes an estimated 1,194 acre-feet of runoff, 486,766 pounds of TSS, and 1,387 pounds of TP annually. A variety of stormwater retrofit approaches were identified, and potential projects are organized from most cost effective to least based on pollutants removed.

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Executive Summary

The Mississippi Watershed Management Organization (MWMO) contracted the Anoka Conservation District (ACD) to complete this stormwater retrofit analysis (SRA) for the purpose of identifying and ranking water quality improvement projects in the 1NE outfall drainage area. The 1NE outfall drainage area consists of portions of southern Columbia Heights and Northeast Minneapolis that drain to the Mississippi River. The MWMO specified total phosphorus (TP) and total suspended solids (TSS) as the target pollutants for the analysis. An overall annual subwatershed-wide reduction goal of 25% for both TP and TSS was identified. The intent of this goal is for use in judging the overall impact of implementing BMPs in the study area.

This analysis is primarily intended to identify potential projects within the target area to improve water quality in the Mississippi River through stormwater retrofits. Stormwater retrofits refer to best management practices (BMPs) that are added to an already developed landscape where little open space exists. The process is investigative and creative. Stormwater retrofits can be improperly judged by the total number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this SRA, both costs and pollutant reductions were estimated and used to calculate cost effectiveness for each potential retrofit identified.

Water quality benefits associated with the installation of each identified project were individually modeled using the Source Loading and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the upper-midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model “landscape”. WinSLAMM uses rainfall and temperature data from a typical year (1959 data from Minneapolis for this analysis), routing stormwater through the user’s model for each storm.

WinSLAMM estimates volume and pollutant loading based on acreage, land use, and soils information. Therefore, the volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential retrofit projects. Soils throughout the study area were assumed to be silty based on the limited soils information available. Specific model inputs (e.g. pollutant probability distribution, runoff coefficient, particulate solids concentration, particle residue delivery, and street delivery files) are detailed in Appendix A.

The costs associated with project design, administration, promotion, land acquisition, opportunity costs, construction oversight, installation, and maintenance were estimated. The total costs over the assumed effective life of each project were then divided by the modeled benefits over the same time period to enable ranking by cost-effectiveness.

A variety of stormwater retrofit approaches were identified. They included:

- Bioretention,
- Bioswales,
- New stormwater pond opportunities,
- Iron enhanced sand filters,

- Permeable pavement,
- Hydrodynamic separators,
- Underground storage, and
- Water reuse.

If all of these practices were installed, significant volume and pollutant reductions could be accomplished. However, funding limitations and landowner interest make this goal unlikely. Instead, it is recommended that projects be installed in order of cost effectiveness (pounds of pollution reduced per dollar spent). Other factors, including a project's educational value/visibility, construction timing, total cost, or non-target pollutant reduction also affect project installation decisions and will need to be weighed by resource managers when selecting projects to pursue.

For each type of recommended retrofit, conceptual siting is provided in the project profiles section. The intent of these figures is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits (e.g. new ponds) will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners, both public and private.

Drainage areas within the 2,075 acre 1NE subwatershed were consolidated into 18 catchments and 5 drainage networks (groups of catchments draining to a common point). Based on WinSLAMM model results, the 2,075 acre drainage area contributes an estimated 1,194 acre-feet of runoff, 486,766 pounds of TSS, and 1,387 pounds of TP annually.

The tables in the Project Ranking and Selection section (pages 20 - 29) summarize potential projects ranked by cost effectiveness with respect to either TP or TSS. Potential projects are organized from most cost effective to least based on pollutants removed. Installation of the two new large pond projects within catchment 14 (page 136) would achieve an estimated 33% reduction in TSS (160,505 pounds) and a 38% reduction in TP (523 pounds) annually.

Installation of projects in series will result in lower total treatment than the simple sum of treatment achieved by the individual projects due to treatment train effects. Reported treatment levels are dependent upon optimal site selection and sizing. More detail about each project can be found in the catchment profile pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or expense were not included in this report.

Document Organization

This document is organized into five sections, plus references and appendices. Each section is briefly discussed below.

Background

The background section provides a brief description of the landscape characteristics within the study area.

Analytical Process and Elements

The analytical process and elements section overviews the procedures that were followed when analyzing the subwatershed. It explains the processes of retrofit scoping, desktop analysis, field investigation, modeling, cost/treatment analysis, project ranking, and project selection. Refer to Appendix A for a detailed description of the modeling methods.

Project Ranking and Selection

The project ranking and selection section describes the methods and rationale for how projects were ranked. Local resource management professionals will be responsible to select and pursue projects, taking into consideration the many possible ways to prioritize projects. Several considerations in addition to project cost-effectiveness for prioritizing installation are included. Project funding opportunities may play a large role in project selection, design, and installation.

This section also ranks stormwater retrofit projects across all catchments to create a prioritized project list. The list is sorted by the amount of pollutant removed by each project over 30 years. The final cost per pound treatment value includes installation and maintenance costs over the estimated life of the project. If a practice's effective life was expected to be less than 30 years, rehabilitation or reinstallation costs were included in the cost estimate. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point.

BMP Descriptions

For each type of project included in this report, there is a description of the rationale for including that type of project, the modeling method employed, and the cost calculations used to estimate associated installation and maintenance expenses.

Catchment Profiles

The 1NE subwatershed was divided into 18 stormwater catchments which were assigned a unique identification number and grouped into five drainage networks for the purpose of this analysis. For each catchment, the following information is detailed:

Drainage Network

Catchments were grouped into drainage networks based on their drainage to a common point. The drainage networks were used to further subdivide the report to aid with organization and clarity.

Catchment Description

Within each catchment profile is a table that summarizes basic catchment information including acres, land cover, parcels, and estimated annual pollutant and volume loads under existing conditions. Existing conditions included notable stormwater treatment practices for which information was available from the Cities of Columbia Heights and Minneapolis. Small, site-specific practices (e.g. rain-leader disconnect rain gardens) were not included in the existing conditions model. A brief description of the land cover, stormwater infrastructure, and any other important general information is also described in this section. Notable existing stormwater practices are explained, and their estimated effectiveness presented.

Retrofit Recommendations

Retrofit recommendations are presented for each catchment and include a description of the proposed BMP, cost effectiveness table including modeled volume and pollutant reductions, and an overview map showing the contributing drainage area for each BMP.

References

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

Appendices

This section provides supplemental information and/or data used during the analysis.

Background

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 high priority waterbody.

The subwatershed studied for this analysis is located in the northeast portion of the MWMO's boundary and discharges to the Mississippi River. The subwatershed spans the boundary of Anoka and Hennepin Counties and includes portions of the cities of Columbia Heights and Minneapolis. It extends as far north as 42nd Ave NE and as far south as 27th Ave NE. It is bordered by the Mississippi River on the west and Stinson Parkway NE on the east. The total area of the subwatershed analyzed in this report is 2,075 acres. It was selected for analysis due to several reasons: 1) water quality and quantity monitoring data are available, 2) there is currently limited existing stormwater treatment throughout the subwatershed, and 3) a hydraulic and hydrologic analysis is being conducted simultaneously in the same subwatershed, thereby allowing both water quantity and quality issues to be investigated.

The MWMO watershed is highly urbanized. Development throughout the MWMO watershed has resulted in the installation of subsurface drainage systems (i.e. stormwater infrastructure) to convey stormwater runoff, which increased due to the coverage of impervious surfaces throughout the watershed. The runoff generated within the 1NE subwatershed targeted for this analysis is still conveyed to the Mississippi River, as it was historically. However, the runoff is now captured by catch basins and directed underground before being discharged to the Mississippi River via stormwater pipe.

Stormwater runoff enters the Mississippi River via the 1NE outfall, which drains the majority of the target subwatershed. The 96" diameter corrugated iron pipe outfall is located on the east bank of the Mississippi River on the Xcel Energy Riverside Power Plant property at river mile 857.2. Monitoring by the MWMO has identified continuous baseflow from the stormwater drainage system (MWMO, 2013).

Stormwater runoff from impervious surfaces can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, many other areas were built prior to modern-day stormwater treatment technologies and requirements. The MWMO identified urban stormwater management as a focus area within their 2011-2021 Watershed Management Plan and explicitly cited the challenges associated with implementing stormwater retrofits within a highly urbanized watershed (MWMO, 2011b). This SRA is intended to identify potential projects throughout the 1NE subwatershed.

The MWMO contracted the ACD to complete this SRA for the purpose of identifying and analyzing projects to improve the quality of stormwater runoff from the 1NE outfall drainage area. Overall subwatershed loading of TP, TSS, and stormwater volume were estimated for subdivided drainage areas within the subwatershed. Proposed retrofits were modeled to estimate each practice's capability for removing pollutants and reducing volume. Finally, each project was ranked based on the estimated cost effectiveness of the project to reduce pollutants.

Analytical Process and Elements

This stormwater retrofit analysis is a watershed management tool to identify and prioritize potential stormwater retrofit projects by performance and cost effectiveness. This process helps maximize the value of each dollar spent. 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 & Kitchell, 2005 and Schueler et al. 2007). Locally relevant design considerations were also incorporated into the process (Technical Documents, Minnesota Stormwater Manual, 2014).

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 areas that drain to the 1NE outfall and into the Mississippi River. Included are areas of residential, commercial, industrial, and institutional land uses. The subwatershed was divided into 18 catchments using a combination of existing subwatershed mapping data, stormwater infrastructure maps, and observed topography.

The targeted pollutants for this study were TP and TSS, though volume was also estimated and reported. Volume of stormwater was tracked throughout this study because it is necessary for pollutant loading calculations and potential retrofit project considerations. Table 1 describes the target pollutants and their role in water quality degradation. Projects that effectively reduce loading of multiple target pollutants can provide greater immediate and long-term benefits.

Table 1: Target Pollutants

Target Pollutant	Description
Total Phosphorus (TP)	Phosphorus is a nutrient essential to plant growth and is commonly the factor that limits the growth of plants in surface water bodies. TP is a combination of particulate phosphorus (PP), which is bound to sediment and organic debris, and dissolved phosphorus (DP), which is in solution and readily available for plant growth (active).
Total Suspended Solids (TSS)	Very small mineral and organic particles that can be dispersed into the water column due to turbulent mixing. TSS loading can create turbid and cloudy water conditions and carry with it PP. As such, reductions in TSS will also result in TP reductions.
Volume	Higher runoff volumes and velocities can carry greater amounts of TSS to receiving water bodies. It can also exacerbate in-stream erosion, thereby increasing TSS loading. As such, reductions in volume may reduce TSS loading and, by extension, TP loading. However, in-stream erosion is not an issue in the 1NE subwatershed because stormwater is piped directly to the Mississippi River.

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. Accurate GIS data are extremely valuable in conducting the desktop retrofit analysis. Some of the most important GIS layers include: 2-foot or finer topography (Light Detection and Ranging [LiDAR] was used for this analysis), surface hydrology, soils, watershed/subwatershed boundaries, parcel boundaries, high-resolution aerial photography and the stormwater drainage infrastructure (with invert elevations).

Field investigation is conducted after potential retrofits are identified in the desktop analysis to evaluate each site and identify additional opportunities. During the investigation, the drainage area and surface 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.

Modeling involves assessing multiple scenarios to estimate pollutant loading and potential reductions by proposed retrofits. The newest version of WinSLAMM (version 10.1.1), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis because of the unique connectivity amongst the catchments identified in the 1NE subwatershed. Areas throughout the subwatershed are routed through multiple catchments before being discharged to the Mississippi River. This creates a network of stormwater treatment. Therefore, estimated volume and pollutant loads to the Mississippi River from any given catchment must take into consideration other treatment practices within the same network.

WinSLAMM estimates volume and pollutant loading based on acreage, land use, and soils information. Therefore, the volume and pollutant estimates in this report are not waste load allocations, nor does this report serve as a TMDL for the study area. The WinSLAMM model was not calibrated and was only used as an estimation tool to provide relative ranking across potential retrofit projects. Soils throughout the study area were assumed to be silty based on the soils information available. Specific model inputs (e.g. pollutant probability distribution, runoff coefficient, particulate solids concentration, particle residue delivery, and street delivery files) are detailed in Appendix A.

The initial step was to create a "base" model which estimates 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, drainage area delineations were completed by Houston Engineering, Inc. as part of the hydrologic and hydraulic model for the same subwatershed (1NE). The delineation file used to inform this report is "All_Catchments", developed on July 1st, 2014 by Houston Engineering, Inc. The drainage areas were consolidated into catchments using geographic information systems (specifically, ArcMap). Land use data (based on 2010 Metropolitan Council land use file) were used to calculate acreages of each land use type within each catchment. Soil types throughout the subwatershed were modeled as silt in this analysis based on the information available from the Cities of Columbia Heights and Minneapolis. 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.

Once the "base" model was established, an "existing conditions" model was created by incorporating notable existing stormwater treatment practices in the catchment for which data was available from the Cities of Columbia Heights and Minneapolis (Figure 1). For example, street cleaning with mechanical or vacuum street sweepers, stormwater treatment ponds, and others were included in the "existing conditions" model if information was available.

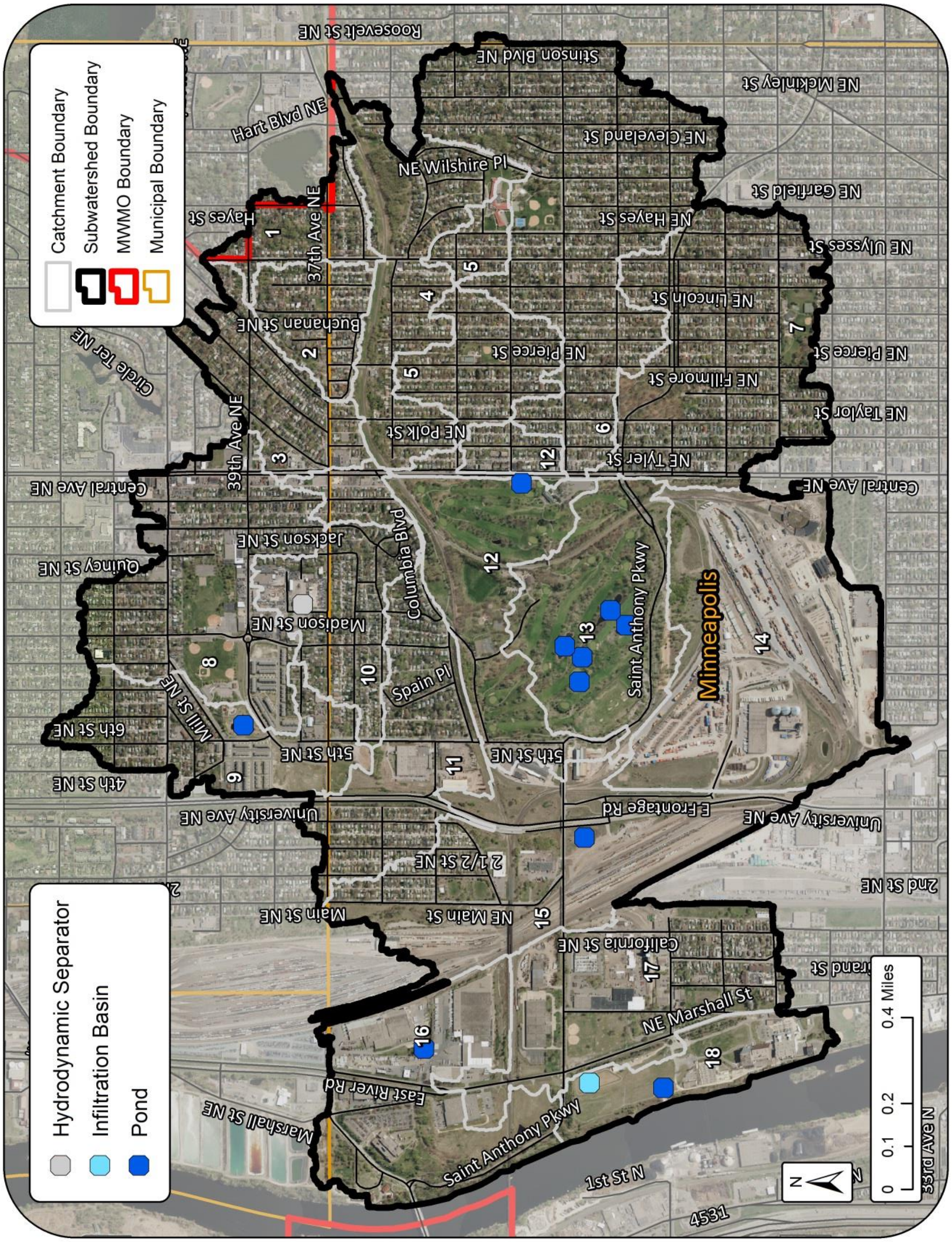


Figure 1: Subwatershed-wide map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included throughout the subwatershed.

Finally, each proposed stormwater retrofit practice was added individually to the "existing conditions" model and pollutant reductions were estimated. 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 each practice was modeled individually, and the benefits of projects may not be additive, especially if serving the same area (i.e. treatment train effects). Reported treatment levels are dependent upon optimal site selection and sizing. Additional information on the WinSLAMM models can be found in Appendix A.

Several types of bioretention retrofits were modeled as biofiltration as well as bioinfiltration practices. While the soils were assumed to be silty throughout the 1NE subwatershed based on information provided by the Cities of Columbia Heights and Minneapolis, the MWMO requested that some bioinfiltration scenarios also be modeled in the event that site-specific native soil characteristics were conducive to infiltration. Native soil infiltration rates of 0.2"/hour (biofiltration) and 1.0"/hour (bioinfiltration) were used to estimate volume and pollutant reductions of the proposed retrofits. The 0.2"/hour rate was the native soil infiltration rate assumed throughout the 1NE subwatershed because of the silty soils. The 1.0"/hour infiltration rate was used for the bioinfiltration retrofits based on guidance from the Minnesota Stormwater Manual (Technical Documents, Minnesota Stormwater Manual, 2014). Furthermore, 1.0"/hour infiltration rate is identified as the minimum infiltration rate required for bioretention cells without an underdrain (Virginia DCR Stormwater Design Specification No. 9, 2013 and Environmental Services Division Department of Environmental Resources The Prince George's County, Maryland, 2007).

Cost estimating is essential for the comparison and ranking of projects, development of work plans, and pursuit of grants and other funds. All estimates were developed using 2014 dollars. Costs throughout this report were estimated using a multitude of sources. Costs were derived from The Center for Watershed Protection's Urban Subwatershed Restoration Manuals (Schueler & Kitchell, 2005 and Schueler et al. 2007) and recent installation costs and cost estimates provided to the ACD by personal contacts. For comparison purposes, Appendix D presents BMP cost estimates from a 2011 analysis of the Bridal Veil Creek subwatershed completed by the Ramsey Conservation District for the MWMO (MWMO, 2011a). Cost estimates were annualized costs that incorporated the elements listed below over a 30-year period.

Project promotion and administration includes local staff efforts to reach out to landowners, administer related grants, and complete necessary administrative tasks.
Design includes site surveying, engineering, and construction oversight.
Land or easement acquisition cover the cost of purchasing property or the cost of obtaining necessary utility and access easements from landowners.
Construction calculations are project specific and may include all or some of the following; grading, erosion control, vegetation management, structures, mobilization, traffic control, equipment, soil disposal, and rock or other materials.
Maintenance includes annual inspections and minor site remediation such as vegetation management, structural outlet repair and cleaning, and washout repair.

In cases where promotion to landowners is important, such as rain gardens, those costs were included as well. For projects within the railroad right of way, an additional $15,000 was added for permitting. 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.

Project ranking is essential to identify which projects may be pursued to achieve water quality goals. Project ranking tables are presented based on cost per pound of TP removed and cost per 1,000 pounds of TSS removed.

Project selection involves considerations other than project ranking, including but not limited to total cost, treatment train effects, social acceptability, and political feasibility.

Project Ranking and Selection

The intent of this analysis is to provide the information necessary to enable local natural resource managers to successfully secure funding for the most cost-effective projects to achieve water quality goals. This analysis ranks potential projects by cost-effectiveness to facilitate project selection. There are many possible ways to prioritize projects, and the list provided in this report is merely a starting point. Local resource management professionals will be responsible to select projects to pursue. Several considerations in addition to project cost-effectiveness for prioritizing installation are included.

Project Ranking

If all identified practices were installed (Figure 2), significant pollution reduction could be accomplished. However, funding limitations and landowner interest will be a limiting factor in implementation. The tables on the following pages rank all modeled projects by cost-effectiveness. Projects in the tables were color coded based on the drainage networks shown in Figure 3. Projects were ranked in two ways:

1) Cost per pound of total phosphorus removed (Table 2 - Table 6) and
2) Cost per 1,000 pounds of total suspended solids removed (Table 7 - Table 11).

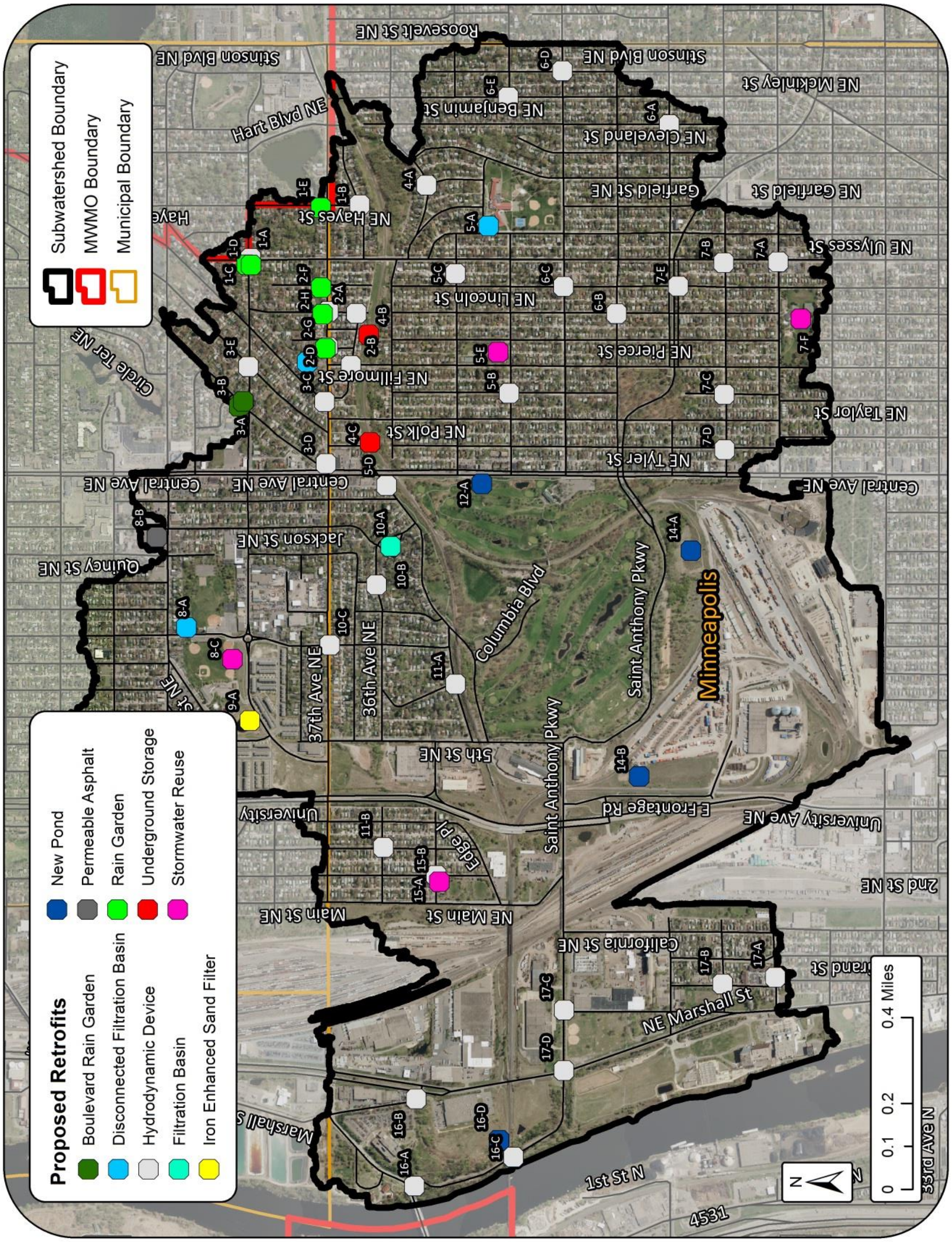


Figure 2: Subwatershed-wide map showing all proposed retrofits included in this report.

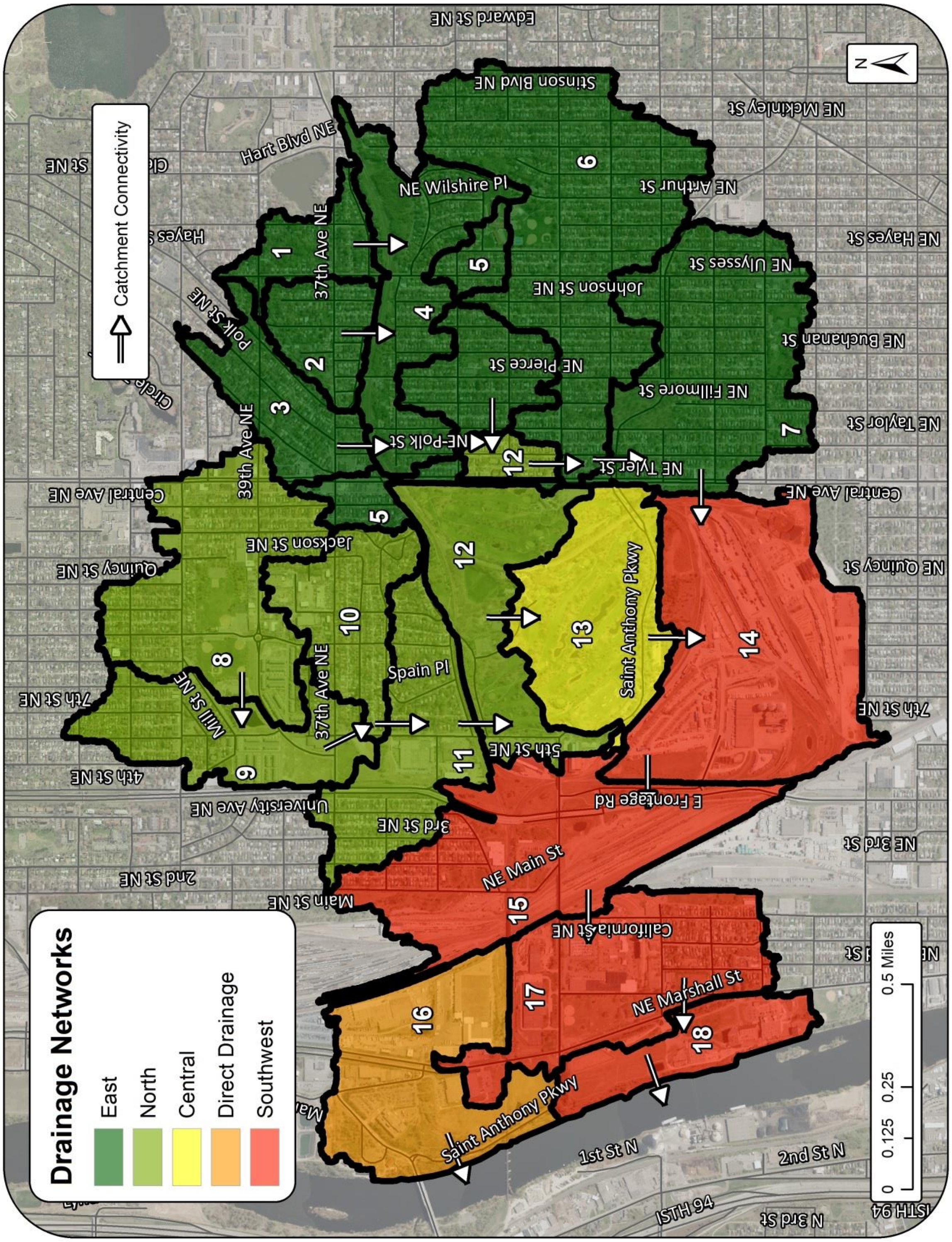


Figure 3: Subwatershed-wide map showing drainage networks referenced in project ranking tables.

Table 2: Cost-effectiveness of retrofits with respect to TP reduction. Projects 1 - 10. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)[1]
1	14-A2	138	Pond with IESF	Eastern Railroad Yard	14	404.5	108,697	3.2	$3,559,490	$17,792	$337
2	14-A1	138	Pond	Eastern Railroad Yard	14	291.2	108,697	3.2	$2,750,840	$6,313	$337
3	14-B	140	Pond	Western Railroad Yard	14	118.1	51,808	8.7	$1,875,840	$5,877	$579
4	9-A	117	IESF	IESF Retrofit to Huset Park Pond	9	10.0	0	0.0	$146,200	$1,015	$589
5	12-A	129	Pond	New Columbia Golf Course Pond	12	8.3	3,399	0.1	$158,340	$413	$686
6	16-D	159	Pond	New Bureau of Engraving Pond	16	12.5	8,989	0.5	$328,340	$918	$949
7	8-A1	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 4,000 sq-ft top area	8	1.9	1,316	0.8	$63,796	$225	$1,238
8	4-C	86	Underground Storage	Catchment 3 Underground Storage	4	18.6	6,326	8.9	$641,965	$2,000	$1,258
9	NSS-E2	40	Bioswale	Boulevard Bioswale; 1.0 in/hr infiltration rate	Any	0.4	115	0.2	$8,526	$225	$1,306
10	4-B	85	Underground Storage	Catchment 2 Underground Storage	4	13.8	4,167	6.9	$501,840	$2,000	$1,357

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Eastern Drainage Network

Northern Drainage Network

Southwestern Drainage Network

Direct Drainage

Non-Site Specific BMPs

Table 3: Cost-effectiveness of retrofits with respect to TP reduction. Projects 11 - 27. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)[1]
11	8-A2	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 6,800 sq-ft top area	8	2.4	2,042	1.3	$105,796	$225	$1,563
12	NSS-D2	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.5	142	0.3	$20,621	$225	$1,862
13	10-A	120	Curb-Cut Filtration Basin	Architect Triangle Curb-Cut Filtration Basin	10	0.5	756	0.3	$29,296	$225	$2,403
14	7-F	108	Water Reuse	Audobon Park Water Reuse	7	7.2	2,117	7.0	$449,590	$3,000	$2,498
15	NSS-C2	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.2	60	0.1	$8,526	$225	$2,546
16	3-A	77	Curb-Cut Rain Garden	Boulevard Rain Garden East	3	0.2	223	0.1	$9,796	$225	$2,758
17	NSS-E1	40	Bioswale	Boulevard Bioswale; 0.2 in/hr infiltration rate	Any	0.2	57	0.1	$8,526	$225	$2,829
18	NSS-A2	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 1.0 in/hr infiltration rate	Any	0.1	17	0.0	$4,909	$25	$3,042
19	NSS-B2	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 1.0. in/hr infiltration rate	Any	1.7	429	1.0	$116,205	$1,320	$3,110
20	11-A	125	Hydrodynamic Device	35th & Spain Place Hydrodynamic Device	11	1.4	509	0.0	$109,752	$840	$3,213
21	5-A2	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 4,000 sq-ft top area	5	0.7	1,079	0.6	$63,796	$225	$3,359
22	5-E	93	Water Reuse	Catchment 5 Water Reuse	5	3.9	1,079	2.9	$303,340	$3,000	$3,362
23	5-A1	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 2,000 sq-ft top area	5	0.4	790	0.4	$33,796	$225	$3,379
24	15-B	144	Water Reuse	Hi-view Park Water Reuse	15	5.2	1,469	3.4	$449,590	$3,000	$3,459
25	17-D	150	Hydrodynamic Device	St. Anthony & Marshall Hydrodynamic Device	17	1.3	1,105	0.0	$109,752	$840	$3,460
26	NSS-A1	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	16	0.0	$4,909	$25	$3,559
27	8-C	114	Water Reuse	Huset Park Water Reuse	8	5.0	836	12.6	$449,590	$3,000	$3,597

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Table 4: Cost-effectiveness of retrofits with respect to TP reduction. Projects 28 - 44. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)[1]
T28	4-A	84	Hydrodynamic Device	36th & Wilshire Hydrodynamic Device	4	1.2	436	0.0	$109,752	$840	$3,749
T28	5-B	90	Hydrodynamic Device	34th & Taylor Hydrodynamic Device	5	1.2	445	0.0	$109,752	$840	$3,749
T28	5-C	91	Hydrodynamic Device	35th & Lincoln Hydrodynamic Device	5	1.2	462	0.0	$109,752	$840	$3,749
T28	6-E	100	Hydrodynamic Device	34th & Benjamin Hydrodynamic Device	6	1.2	429	0.0	$109,752	$840	$3,749
T32	2-D	70	Hydrodynamic Device	37th & Pierce Hydrodynamic Device	2	0.7	233	0.0	$55,752	$840	$3,855
T32	16-C	158	Hydrodynamic Device	Railroad & St. Anthony Hydrodynamic Device	16	0.7	233	0.0	$109,752	$840	$3,855
T34	6-C	98	Hydrodynamic Device	33rd & Lincoln Hydrodynamic Device	6	1.1	406	0.0	$109,752	$840	$4,089
T34	7-E	107	Hydrodynamic Device	St. Anthony Parkway & Lincoln Hydrodynamic Device	7	1.1	413	0.0	$109,752	$840	$4,089
T34	10-B	121	Hydrodynamic Device	36th & Monroe Hydrodynamic Device	10	1.1	406	0.0	$109,752	$840	$4,089
T34	11-B	126	Hydrodynamic Device	36th & 2 1/2 Place Hydrodynamic Device	11	1.1	406	0.0	$109,752	$840	$4,089
T34	17-C	149	Hydrodynamic Device	St. Anthony & Columbia Hydrodynamic Device	17	1.1	941	0.0	$109,752	$840	$4,089
T39	2-C	69	Hydrodynamic Device	37th & Buchanan Hydrodynamic Device	2	1.0	356	0.0	$109,752	$840	$4,498
T39	3-E	81	Hydrodynamic Device	39th & Tyler Hydrodynamic Device	3	1.0	350	0.0	$109,752	$840	$4,498
T39	5-D	92	Hydrodynamic Device	Columbia & Van Buren Hydrodynamic Device	5	1.0	420	0.0	$109,752	$840	$4,498
T39	7-B	104	Hydrodynamic Device	30th & Johnson Hydrodynamic Device	7	1.0	382	0.0	$109,752	$840	$4,498
T39	15-A	143	Hydrodynamic Device	35th & 2nd Hydrodynamic Device	15	1.0	339	0.0	$109,752	$840	$4,498
T39	16-B	157	Hydrodynamic Device	Marshall & East River Road Hydrodynamic Device	16	1.0	339	0.0	$109,752	$840	$4,498

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Table 5: Cost-effectiveness of retrofits with respect to TP reduction. Projects 45 - 61. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)[1]
T45	1-B	61	Hydrodynamic Device	Hollywood & Hayes Hydrodynamic Device	1	0.9	330	0.0	$109,752	$840	$4,998
T45	6-A	96	Hydrodynamic Device	31st & Cleveland Hydrodynamic Device	6	0.9	336	0.0	$109,752	$840	$4,998
T45	6-B	97	Hydrodynamic Device	32nd & Buchanan Hydrodynamic Device	6	0.9	317	0.0	$109,752	$840	$4,998
T45	7-A	103	Hydrodynamic Device	29th & Johnson Hydrodynamic Device	7	0.9	377	0.0	$109,752	$840	$4,998
T45	7-C	105	Hydrodynamic Device	30th & Taylor Hydrodynamic Device	7	0.9	338	0.0	$109,752	$840	$4,998
50	3-B	78	Curb-Cut Rain Garden	Boulevard Rain Garden West	3	0.1	185	0.1	$9,796	$225	$5,515
T51	3-C	79	Hydrodynamic Device	37th & Polk Hydrodynamic Device	3	0.8	276	0.0	$109,752	$840	$5,623
T51	3-D	80	Hydrodynamic Device	37th & Reservoir Hydrodynamic Device	3	0.8	401	0.0	$109,752	$840	$5,623
T51	17-A	147	Hydrodynamic Device	29th & Randolph Hydrodynamic Device	17	0.8	375	0.0	$109,752	$840	$5,623
T51	17-B	148	Hydrodynamic Device	30th & Randolph Hydrodynamic Device	17	0.8	300	0.0	$109,752	$840	$5,623
T55	2-B	68	Hydrodynamic Device	36 1/2 & Fillmore Hydrodynamic Device	2	0.3	95	0.0	$28,752	$840	$5,995
T55	16-A	156	Hydrodynamic Device	37th & St. Anthony Hydrodynamic Device	16	0.3	159	0.0	$28,752	$840	$5,995
T57	1-A	60	Hydrodynamic Device	39th & Johnson Hydrodynamic Device	1	0.4	159	0.0	$55,752	$840	$6,133
T57	2-A	67	Hydrodynamic Device	36 1/2 & Buchanan Hydrodynamic Device	2	0.4	159	0.0	$55,752	$840	$6,133
T59	6-D	99	Hydrodynamic Device	33rd & McKinley Hydrodynamic Device	6	0.7	286	0.0	$109,752	$840	$6,426
T59	7-D	106	Hydrodynamic Device	30th and Tyler Hydrodynamic Device	7	0.7	337	0.0	$109,752	$840	$6,426
T59	10-C	122	Hydrodynamic Device	37th and Madison Place Hydrodynamic Device	10	0.7	383	0.0	$109,752	$840	$6,426

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Table 6: Cost-effectiveness of retrofits with respect to TP reduction. Projects 62 - 73. TSS and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ lb-TP/year (30-year)[1]
62	2-G	73	Curb-Cut Rain Garden	37th and Pierce Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$6,615
T63	1-E	64	Curb-Cut Rain Garden	37th and Hayes Curb-Cut Rain Garden	1	0.1	116	0.1	$11,110	$225	$7,442
T63	2-F	72	Curb-Cut Rain Garden	37th and Lincoln Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$7,442
65	NSS-F	52	Underground Storage	Green Alley Underground Storage	Any	1.9	604	1.0	$410,115	$2,000	$8,291
66	2-E	71	Disconnect Filtration Basin	Disconnect Filtration Basin	2	0.1	128	0.1	$21,076	$225	$9,275
T67	2-H	74	Curb-Cut Rain Garden	37th and Buchanan Curb-Cut Rain Garden	2	0.1	98	0.0	$11,110	$225	$9,922
T67	1-C	62	Curb-Cut Rain Garden	39th and Johnson North Curb-Cut Rain Garden	1	0.1	93	0.0	$11,110	$225	$9,922
69	NSS-B1	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 0.2 in/hr infiltration rate	Any	0.5	394	0.3	$128,205	$1,320	$10,554
70	1-D	63	Curb-Cut Rain Garden	39th and Johnson South Curb-Cut Rain Garden	1	0.1	78	0.0	$11,110	$225	$11,907
71	NSS-D1	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	101	0.0	$20,621	$225	$13,034
72	NSS-C1	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.0	33	0.0	$8,526	$225	$16,973
73	8-B	113	Permeable Asphalt	Imaculate Conception School Permeable Asphalt	8	0.7	346	1.3	$139,066	$10,200	$21,194

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual TP Reduction)]

Table 7: Cost-effectiveness of retrofits with respect to TSS reduction. Projects 1 - 10. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
1	14-A1	138	Pond	Eastern Railroad Yard	14	291.2	108,697	3.2	$2,750,840	$6,313	$902
2	14-A2	138	Pond with IESF	Eastern Railroad Yard	14	404.5	108,697	3.2	$3,559,490	$17,792	$1,255
T3	14-B	140	Pond	Western Railroad Yard	14	118.1	51,808	8.7	$1,875,840	$5,877	$1,320
T3	16-D	159	Pond	New Bureau of Engraving Pond	16	12.5	8,989	0.5	$328,340	$918	$1,320
5	10-A	120	Curb-Cut Filtration Basin	Architect Triangle Curb-Cut Filtration Basin	10	0.5	756	0.3	$29,296	$225	$1,589
6	12-A	129	Pond	New Columbia Golf Course Pond	12	8.3	3,399	0.1	$158,340	$413	$1,674
7	5-A1	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 2,000 sq-ft top area	5	0.4	790	0.4	$33,796	$225	$1,711
8	8-A1	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 4,000 sq-ft top area	8	1.9	1,316	0.8	$63,796	$225	$1,787
9	8-A2	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 6,800 sq-ft top area	8	2.4	2,042	1.3	$105,796	$225	$1,837
10	5-A2	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 4,000 sq-ft top area	5	0.7	1,079	0.6	$63,796	$225	$2,179

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [(30*(Annual TSS Reduction))/(1,000 lb TSS)]

- Eastern Drainage Network
- Northern Drainage Network
- Southwestern Drainage Network
- Direct Drainage
- Non-Site Specific BMPs

Table 8: Cost-effectiveness of retrofits with respect to TSS reduction. Projects 11 - 27. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
11	3-A	77	Curb-Cut Rain Garden	Boulevard Rain Garden East	3	0.2	223	0.1	$9,796	$225	$2,473
12	3-B	78	Curb-Cut Rain Garden	Boulevard Rain Garden West	3	0.1	185	0.1	$9,796	$225	$2,981
13	4-C	86	Underground Storage	Catchment 3 Underground Storage	4	18.6	6,326	8.9	$641,965	$2,000	$3,699
14	17-D	150	Hydrodynamic Device	St. Anthony & Marshall Hydrodynamic Device	17	1.3	1,105	0.0	$109,752	$840	$4,071
15	NSS-E2	40	Bioswale	Boulevard Bioswale; 1.0 in/hr infiltration rate	Any	0.4	115	0.2	$8,526	$225	$4,428
16	4-B	85	Underground Storage	Catchment 2 Underground Storage	4	13.8	4,167	6.9	$501,840	$2,000	$4,494
17	17-C	149	Hydrodynamic Device	St. Anthony & Columbia Hydrodynamic Device	17	1.1	941	0.0	$109,752	$840	$4,780
18	1-E	64	Curb-Cut Rain Garden	37th and Hayes Curb-Cut Rain Garden	1	0.1	116	0.1	$11,110	$225	$5,132
T19	2-F	72	Curb-Cut Rain Garden	37th and Lincoln Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$5,177
T19	2-G	73	Curb-Cut Rain Garden	37th and Pierce Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$5,177
21	2-H	74	Curb-Cut Rain Garden	37th and Buchanan Curb-Cut Rain Garden	2	0.1	98	0.0	$11,110	$225	$6,075
22	1-C	62	Curb-Cut Rain Garden	39th and Johnson North Curb-Cut Rain Garden	1	0.1	93	0.0	$11,110	$225	$6,401
23	NSS-D2	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.5	142	0.3	$20,621	$225	$6,425
24	2-E	71	Disconnect Filtration Basin	Disconnect Filtration Basin	2	0.1	128	0.1	$21,076	$225	$7,246
25	1-D	63	Curb-Cut Rain Garden	39th and Johnson South Curb-Cut Rain Garden	1	0.1	78	0.0	$11,110	$225	$7,632
26	NSS-C2	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.2	60	0.1	$8,526	$225	$8,487
27	7-F	108	Water Reuse	Audobon Park Water Reuse	7	7.2	2,117	7.0	$449,590	$3,000	$8,496

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [(30*(Annual TSS Reduction))/(1,000 lb TSS)]

Table 9: Cost-effectiveness of retrofits with respect to TSS reduction. Projects 28 - 44. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
28	11-A	125	Hydrodynamic Device	35th & Spain Place Hydrodynamic Device	11	1.4	509	0.0	$109,752	$840	$8,838
29	NSS-E1	40	Bioswale	Boulevard Bioswale; 0.2 in/hr infiltration rate	Any	0.2	57	0.1	$8,526	$225	$8,933
30	NSS-D1	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	101	0.0	$20,621	$225	$9,033
31	5-C	91	Hydrodynamic Device	35th & Lincoln Hydrodynamic Device	5	1.2	462	0.0	$109,752	$840	$9,737
32	5-B	90	Hydrodynamic Device	34th & Taylor Hydrodynamic Device	5	1.2	445	0.0	$109,752	$840	$10,109
33	4-A	84	Hydrodynamic Device	36th & Wilshire Hydrodynamic Device	4	1.2	436	0.0	$109,752	$840	$10,317
34	6-E	100	Hydrodynamic Device	34th & Benjamin Hydrodynamic Device	6	1.2	429	0.0	$109,752	$840	$10,486
35	5-D	92	Hydrodynamic Device	Columbia & Van Buren Hydrodynamic Device	5	1.0	420	0.0	$109,752	$840	$10,710
36	NSS-A2	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 1.0 in/hr infiltration rate	Any	0.1	17	0.0	$4,909	$25	$10,841
37	7-E	107	Hydrodynamic Device	St. Anthony Parkway & Lincoln Hydrodynamic Device	7	1.1	413	0.0	$109,752	$840	$10,892
T38	6-C	98	Hydrodynamic Device	33rd & Lincoln Hydrodynamic Device	6	1.1	406	0.0	$109,752	$840	$11,080
T38	10-B	121	Hydrodynamic Device	36th & Monroe Hydrodynamic Device	10	1.1	406	0.0	$109,752	$840	$11,080
T38	11-B	126	Hydrodynamic Device	36th & 2 1/2 Place Hydrodynamic Device	11	1.1	406	0.0	$109,752	$840	$11,080
41	3-D	80	Hydrodynamic Device	37th & Reservoir Hydrodynamic Device	3	0.8	401	0.0	$109,752	$840	$11,218
42	16-A	156	Hydrodynamic Device	37th & St. Anthony Hydrodynamic Device	16	0.3	159	0.0	$28,752	$840	$11,311
T43	2-D	70	Hydrodynamic Device	37th & Pierce Hydrodynamic Device	2	0.7	233	0.0	$55,752	$840	$11,581
T43	16-C	158	Hydrodynamic Device	Railroad & St. Anthony Hydrodynamic Device	16	0.7	233	0.0	$109,752	$840	$11,581

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [(30*(Annual TSS Reduction))/(1,000 lb TSS)]

Table 10: Cost-effectiveness of retrofits with respect to TSS reduction. Projects 45 - 61. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
45	10-C	122	Hydrodynamic Device	37th and Madison Place Hydrodynamic Device	10	0.7	383	0.0	$109,752	$840	$11,745
46	7-B	104	Hydrodynamic Device	30th & Johnson Hydrodynamic Device	7	1.0	382	0.0	$109,752	$840	$11,776
47	7-A	103	Hydrodynamic Device	29th & Johnson Hydrodynamic Device	7	0.9	377	0.0	$109,752	$840	$11,932
48	17-A	147	Hydrodynamic Device	29th & Randolph Hydrodynamic Device	17	0.8	375	0.0	$109,752	$840	$11,996
49	NSS-A1	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	16	0.0	$4,909	$25	$12,015
50	NSS-B2	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 1.0. in/hr infiltration rate	Any	1.7	429	1.0	$116,205	$1,320	$12,106
51	5-E	93	Water Reuse	Catchment 5 Water Reuse	5	3.9	1,079	2.9	$303,340	$3,000	$12,151
52	15-B	144	Water Reuse	Hi-view Park Water Reuse	15	5.2	1,469	3.4	$449,590	$3,000	$12,244
53	2-C	69	Hydrodynamic Device	37th & Buchanan Hydrodynamic Device	2	1.0	356	0.0	$109,752	$840	$12,636
54	3-E	81	Hydrodynamic Device	39th & Tyler Hydrodynamic Device	3	1.0	350	0.0	$109,752	$840	$12,853
T55	15-A	143	Hydrodynamic Device	35th & 2nd Hydrodynamic Device	15	1.0	339	0.0	$109,752	$840	$13,270
T55	16-B	157	Hydrodynamic Device	Marshall & East River Road Hydrodynamic Device	16	1.0	339	0.0	$109,752	$840	$13,270
57	7-C	105	Hydrodynamic Device	30th & Taylor Hydrodynamic Device	7	0.9	338	0.0	$109,752	$840	$13,309
58	7-D	106	Hydrodynamic Device	30th and Tyler Hydrodynamic Device	7	0.7	337	0.0	$109,752	$840	$13,348
59	6-A	96	Hydrodynamic Device	31st & Cleveland Hydrodynamic Device	6	0.9	336	0.0	$109,752	$840	$13,388
60	1-B	61	Hydrodynamic Device	Hollywood & Hayes Hydrodynamic Device	1	0.9	330	0.0	$109,752	$840	$13,632
61	6-B	97	Hydrodynamic Device	32nd & Buchanan Hydrodynamic Device	6	0.9	317	0.0	$109,752	$840	$14,191

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [(30*(Annual TSS Reduction))/(1,000 lb TSS)]

Table 11: Cost-effectiveness of retrofits with respect to TSS reduction. Projects 62 - 73. TP and volume reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
62	NSS-B1	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 0.2 in/hr infiltration rate	Any	0.5	394	0.3	$128,205	$1,320	$14,197
63	17-B	148	Hydrodynamic Device	30th & Randolph Hydrodynamic Device	17	0.8	300	0.0	$109,752	$840	$14,995
64	NSS-C1	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.0	33	0.0	$8,526	$225	$15,430
65	6-D	99	Hydrodynamic Device	33rd & McKinley Hydrodynamic Device	6	0.7	286	0.0	$109,752	$840	$15,729
66	3-C	79	Hydrodynamic Device	37th & Polk Hydrodynamic Device	3	0.8	276	0.0	$109,752	$840	$16,299
T67	1-A	60	Hydrodynamic Device	39th & Johnson Hydrodynamic Device	1	0.4	159	0.0	$55,752	$840	$16,971
T67	2-A	67	Hydrodynamic Device	36 1/2 & Buchanan Hydrodynamic Device	2	0.4	159	0.0	$55,752	$840	$16,971
69	2-B	68	Hydrodynamic Device	36 1/2 & Fillmore Hydrodynamic Device	2	0.3	95	0.0	$28,752	$840	$18,931
70	8-C	114	Water Reuse	Huset Park Water Reuse	8	5.0	836	12.6	$449,590	$3,000	$21,515
71	NSS-F	52	Underground Storage	Green Alley Underground Storage	Any	1.9	604	1.0	$410,115	$2,000	$25,945
72	8-B	113	Permeable Asphalt	Imaculate Conception School Permeable Asphalt	8	0.7	346	1.3	$139,066	$10,200	$42,877
73	9-A	117	IESF	IESF Retrofit to Huset Park Pond	9	10.0	0	0.0	$146,200	$1,015	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [(30*(Annual TSS Reduction))/(1,000 lb TSS)]

Project Selection

The combination of projects selected for pursuit could strive to achieve TSS and TP reductions in the most cost-effective manner possible. Several other factors affecting project installation decisions should be weighed by resource managers when selecting projects to pursue. These factors include but are not limited to the following:

- Total project costs
- Cumulative treatment
- Availability of funding
- Economies of scale
- Landowner willingness
- Project combinations with treatment train effects
- Non-target pollutant reductions
- Timing coordination with other projects to achieve cost savings
- Stakeholder input
- Number of parcels (landowners) involved
- Project visibility
- Educational value
- Long-term impacts on property values and public infrastructure

BMP Descriptions

BMP types proposed throughout the subwatershed are detailed in this section. This was done to reduce duplicative reporting. For each BMP type, the method of modeling, assumptions made, and cost estimate considerations are described.

Most BMPs were proposed for a specific site within the research area. Each of these projects, including site location, size, and estimated cost and pollutant reduction potential are noted in detail in the Catchment Profiles section. Some practices are such that they could be installed in many locations throughout the subwatershed. These projects, termed "**NON-SITE SPECIFIC**" BMPs, are described completely within this section. Each project's general design guidelines, estimated cost, and estimated pollutant reduction capacity are noted here. Whether a practice is "**SITE SPECIFIC**" or "**NON-SITE SPECIFIC**" is identified following the title of each practice. Also the list below explains whether each project is site specific or non-site specific. For non-site specific projects, the Project IDs, which are used to reference the projects in the ranking tables and throughout the BMP Descriptions section of the report, are provided in parentheses. Project types included in the following sections are:

- Bioretention
    - Curb-cut Rain Garden Without Sidewalk (Site Specific)
    - Rain Leader Disconnect Rain Garden (NSS-A1 and NSS-A2)
    - Condemned Property Rain Garden (NSS-B1 and NSS-B2)
    - Standard and Expanded Boulevard Rain Gardens (NSS-C1, NSS-C2, NSS-D1, and NSS-D2)
    - Boulevard Bioswale (NSS-E1 and NSS-E2)
    - Disconnect Filtration Basin (Site Specific)
- New Wet Retention Ponds (Site Specific)
- Modification to an Existing Pond (Site Specific)
- Iron Enhanced Sand Filters (Site Specific)
- Hydrodynamic Devices (Site Specific)
- Permeable Asphalt (Site Specific)
- Stormwater Reuse (Site Specific)
- Underground Storage
    - Catchments 2 and 3 Underground Storage (Site Specific)
    - Green Alley Underground Storage (NSS-F)

Bioretention (SITE AND NON-SITE SPECIFIC)

Bioretention is a BMP that uses soil and vegetation to treat stormwater runoff from roads, driveways, roof tops, and other impervious surfaces. Differing levels of volume and/or pollutant reductions can be achieved depending on the type of bioretention selected.

Bioretention can function as either filtration (biofiltration) or infiltration (bioinfiltration). Biofiltration BMPs are designed with a buried perforated drain tile that allows water in the basin to discharge to the stormwater drainage system after having been filtered through the soil. Bioinfiltration BMPs have no underdrain, ensuring that all water that enters the basins will either infiltrate into the soil or be evapotranspired into the air. Bioinfiltration provides 100% retention and treatment of captured stormwater, whereas biofiltration basins provide excellent removal of particulate contaminants but limited removal of dissolved contaminants, such as DP.

The treatment efficacy of a particular bioretention project depends on many factors, including but not limited to the pollutant of concern, the quality of water entering the project, the intensity and duration of storm events, project size, position of the project in the landscape, existing downstream treatment, soil and vegetation characteristics, and project type (i.e. bioinfiltration or biofiltration). Optimally, new bioretention will capture water that would otherwise discharge into a priority waterbody untreated.

The volume and pollutant removal potential of each bioretention practice was estimated using WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach and promotion, project design, project administration, and project maintenance over the anticipated life of the practice were considered in addition to actual construction costs. If multiple projects were installed, cost savings could be achieved on the administration and promotion costs (and possibly the construction costs for a large and competitive bid).

Please note infiltration examples included in this section would require site specific investigations to verify soils would be appropriate for infiltration. The infiltration examples are included only to highlight their potential for pollutant and volume reductions.

Curb-cut Rain Gardens without Sidewalk (Site Specific)

Curb-cut rain gardens capture stormwater that is in roadside gutters and redirect it into shallow roadside basins. These curb-cut rain gardens can provide treatment for impervious surface runoff from one to many properties and can be located anywhere sufficient space is available. Because curb-cut rain gardens capture water that is already part of the stormwater drainage system, they are more likely to provide higher benefits. Generally, curb-cut rain gardens were proposed in areas without sufficient existing stormwater treatment and located immediately up-gradient of a catch basin serving a large drainage area.

This type of curb-cut rain garden was only proposed in Catchments 1 and 2 (Columbia Heights) where no sidewalk existed. Biofiltration was solely proposed (as opposed to bioinfiltration) as the City of Columbia Heights indicated all bioretention throughout the City must have an underdrain installed due to the low infiltration rate of the native soils. Rain gardens are recommended to draw-down completely within 24-48 hours following a storm event (Figure 4: Rain gardens before and during rainfall events). Curb-cut rain gardens in Catchments 1 and 2 would require underdrains, which could be connected to a subsurface storm sewer pipe at each of the proposed locations.

Figure 4: Rain gardens before and during rainfall events

All curb-cut rain gardens were presumed to have a 12" ponding depth, underdrains, amended soils, pretreatment, mulch, and perennial ornamental and native plants. The useful life of the project was assumed to be 30 years and so all costs are amortized over that time period. Additional costs were included for rehabilitation of the garden every 10 years. Annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

Table 12 conveys the general efficacy of the two types of curb-cut rain gardens (biofiltration and bioinfiltration) in terms of the three most common pollutants, TSS, PP, DP, and stormwater volume.

Table 12: Matrix describing curb-cut rain garden efficacy for pollutant removal based on type.

Curb-cut Rain Garden Type	TSS Removal	PP Removal	DP Removal	Volume Reduction	Size of Area Treated	Site Selection and Design Notes
Bioinfiltration	High	High	High	High	High	Optimal sites are low enough in the landscape to capture most of the watershed but high enough to ensure adequate separation from the water table for treatment purposes. Higher soil infiltration rates allow for deeper basins and may eliminate the need for underdrains.
Biofiltration	High	Moderate	Low	Low	High	

Rain Leader Disconnect Rain Gardens (NSS-A1 and NSS-A2)

Rain leader disconnect rain gardens capture stormwater that is redirected to the garden as it discharges from gutter downspouts. Generally, they are positioned near buildings in lower areas of the property and provide treatment only for stormwater runoff generated on roof tops and upland portions of the property. Therefore, many rain leader disconnect rain gardens intercept water that would have been filtered through turf grass or other vegetation, or even infiltrated, thereby providing reduced water quality benefit relative to practices that treat runoff already in the stormwater conveyance system (e.g. curb-cut rain gardens). Table 13 conveys the general efficacy of the two types of rain leader disconnect rain gardens (biofiltration and bioinfiltration) in terms of the three most common pollutants, TSS, PP, DP, and stormwater volume.

Table 13: Matrix describing rain leader disconnect rain garden efficacy for pollutant removal based on type.

Rain Leader Disconnect Rain Garden Type	TSS Removal	PP Removal	DP Removal	Volume Reduction	Size of Area Treated	Site Selection and Design Notes
Bioinfiltration	High	High	High	High	Low	Optimal sites are those where downspout discharge makes it into the stormwater drainage system, a simple downspout redirection into vegetated areas is not sufficient to treat runoff, concentrated flow occurs, and adequate treatment is absent.
Biofiltration	High	Moderate	Low	Low	Low	

As this practice can be installed in virtually any residential lot with gutter downspouts, benefits were estimated for a typical property in the research area. A 6" deep, 250 sq-ft garden was modeled in WinSLAMM with a contributing drainage area of half an average lot size in Minneapolis (6,300 sq-ft). The contributing drainage area consisted primarily of runoff from rooftops and landscaped areas (i.e. yards).

Lower costs (relative to curb-cut rain gardens) for annual operations and maintenance are proposed for rain leader disconnect rain gardens (i.e. $25 per year) because these practices only receive runoff from rooftops and landscaped areas. Therefore, the amount of sediment they collect has not generally required a 10-year rehabilitation plan as in curb-cut rain gardens. However, similar to the curb-cut rain gardens, annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

The table below lists pollutant reduction totals for volume, TP, and TSS for two distinct soil infiltration rates. The first, 0.2"/hour, is for a more poorly-drained, silty loam soil. The second, 1.0"/hour, is for a sandy loam soil. Underdrains are not typically installed with rain leader disconnect rain gardens due to their relatively small contributing drainage area, shallower ponding depth, and greater distance from stormwater infrastructure. Therefore, the two scenarios presented in the table below were modeled without underdrains. Probable project cost includes installation of the project ($10.00 per ft^2) as well as promotion, administrative, and design costs, all in 2014 dollars.

NSS-A1 and NSS-A2

Rain Leader Disconnect Rain Garden					
	Cost/Removal Analysis	0.2"/hr Infiltration Rate Without Underdrain		1.0"/hr Infiltration Rate Without Underdrain	
		New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.053	81.5%	0.062	95.4%
	TSS (lb/yr)	15.7	88.2%	17.4	97.8%
	Volume (acre-feet/yr)	0.028	82.4%	0.033	97.1%
Cost	Administration & Promotion Costs*	$2,190		$2,190	
	Design & Construction Costs**	$2,719		$2,719	
	Total Estimated Project Cost (2014)	**$4,909**		**$4,909**	
	Annual O&M***	$25		$25	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,559**		**$3,042**	
	30-yr Average Cost/1,000lb-TSS	**$12,015**		**$10,841**	
	30-yr Average Cost/ac-ft Vol.	**$6,737**		**$5,716**	

*30 hours at $73/hour

**($10/sq-ft for materials and labor) + (3 hours/BMP at $73/hour for design)

***Per BMP: $25 per year for routine maintenance

Condemned Property Rain Garden (NSS-B1 and NSS-B2)

Another non-site specific bioretention option could involve the purchase of a condemned or foreclosed property. Existing structures on the property could be razed and replaced with a large rain garden. Input to the garden could come from the street via a curb-cut, as well as the alley through a pipe or French drain. This practice would likely require an underdrain unless it is installed on well-drained, sandy soils. Scenarios were modeled using WinSLAMM for varying rain garden sizes, drainage areas, and infiltration rates. Table 14, Table 15, and Table 16 list WinSLAMM model results for a 12" deep rain garden installed on soils with a 0.2"/hour native soil infiltration rate. Each scenario in these tables includes an underdrain as well. Table 17, Table 18, and Table 19 list results for a 12" deep rain garden installed on soils with a 1.0"/hour native soil infiltration rate. No underdrain was modeled for these gardens.

Table 14: Estimated annual TP reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in lbs-TP and the percentage is the percent of the pollutant removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 0.2"/hour native soil infiltration rate.

Drainage Area (acres)	*Rain Garden Size (sq-ft)*					
	500	1,000	2,000	3,000	4,000	5,000
0.5	0.08 (19%)	0.14 (33%)	NM	NM	NM	NM
1	0.10 (11%)	0.18 (20%)	0.30 (33%)	NM	NM	NM
2	0.13 (8%)	0.22 (13%)	0.40 (24%)	0.53 (32%)	NM	NM
3	0.14 (6%)	0.26 (10%)	0.45 (18%)	0.61 (24%)	0.75 (30%)	NM
4	0.15 (5%)	0.28 (9%)	0.48 (15%)	0.67 (21%)	0.84 (26%)	0.97 (30%)
5	0.16 (4%)	0.29 (7%)	0.52 (12%)	0.71 (17%)	0.90 (22%)	1.06 (25%)

Table 15: Estimated annual TSS reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in lbs-TSS and the percentage is the percent of the pollutant removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 0.2"/hour native soil infiltration rate.

Drainage Area (acres)	***Rain Garden Size (sq-ft)***					
	500	1,000	2,000	3,000	4,000	5,000
0.5	88 (82%)	107 (100%)	NM	NM	NM	NM
1	174 (70%)	211 (85%)	246 (99%)	NM	NM	NM
2	192 (45%)	295 (69%)	358 (83%)	394 (92%)	NM	NM
3	219 (34%)	367 (57%)	501 (78%)	538 (84%)	570 (89%)	NM
4	231 (27%)	409 (48%)	618 (72%)	691 (81%)	718 (84%)	749 (88%)
5	242 (23%)	439 (41%)	686 (64%)	817 (76%)	877 (82%)	899 (84%)

Table 16: Estimated annual stormwater runoff volume reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in ac-ft and the percentage is the percent of the water removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 0.2"/hour native soil infiltration rate.

Drainage Area (acres)	***Rain Garden Size (sq-ft)***					
	500	1,000	2,000	3,000	4,000	5,000
0.5	0.05 (21%)	0.08 (33%)	NM	NM	NM	NM
1	0.06 (13%)	0.11 (23%)	0.18 (38%)	NM	NM	NM
2	0.08 (8%)	0.13 (14%)	0.23 (24%)	0.31 (33%)	NM	NM
3	0.09 (6%)	0.15 (11%)	0.26 (18%)	0.36 (25%)	0.44 (31%)	NM
4	0.09 (5%)	0.17 (9%)	0.29 (15%)	0.40 (21%)	0.49 (26%)	0.58 (31%)
5	0.10 (4%)	0.18 (8%)	0.31 (13%)	0.42 (18%)	0.53 (22%)	0.62 (26%)

Table 17: Estimated annual TP reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in lbs-TP and the percentage is the percent of the pollutant removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 1.0"/hour native soil infiltration rate.

Drainage Area (acres)	***Rain Garden Size (sq-ft)***					
	500	1,000	2,000	3,000	4,000	5,000
0.5	0.36 (86%)	0.42 (100%)	NM	NM	NM	NM
1	0.70 (78%)	0.81 (90%)	0.90 (100%)	NM	NM	NM
2	0.95 (57%)	1.30 (78%)	1.52 (91%)	1.67 (100%)	NM	NM
3	1.15 (46%)	1.72 (69%)	2.06 (82%)	2.30 (92%)	2.49 (99%)	NM
4	1.27 (40%)	1.84 (58%)	2.46 (77%)	2.67 (84%)	2.93 (92%)	3.14 (98%)
5	1.36 (33%)	2.32 (56%)	3.14 (75%)	3.38 (81%)	3.61 (86%)	3.87 (93%)

Table 18: Estimated annual TSS reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in lbs-TSS and the percentage is the percent of the pollutant removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 1.0"/hour native soil infiltration rate.

Drainage Area (acres)	*Rain Garden Size (sq-ft)*					
	500	1,000	2,000	3,000	4,000	5,000
0.5	97 (91%)	107 (100%)	NM	NM	NM	NM
1	212 (86%)	231 (94%)	247 (100%)	NM	NM	NM
2	275 (64%)	362 (84%)	401 (94%)	429 (100%)	NM	NM
3	339 (53%)	490 (76%)	563 (88%)	606 (94%)	640 (99%)	NM
4	378 (44%)	575 (67%)	728 (85%)	766 (90%)	811 (95%)	849 (99%)
5	405 (38%)	677 (63%)	886 (83%)	929 (87%)	970 (91%)	1,017 (95%)

Table 19: Estimated annual stormwater runoff volume reduction for various rain garden sizes based on the contributing medium-density residential drainage area. Units are in ac-ft and the percentage is the percent of the water removed from the overall load within the respective drainage area. 'NM' means "not modeled." All scenarios run with a 1.0"/hour native soil infiltration rate.

Drainage Area (acres)	*Rain Garden Size (sq-ft)*					
	500	1,000	2,000	3,000	4,000	5,000
0.5	0.21 (88%)	0.42 (100%)	NM	NM	NM	NM
1	0.38 (81%)	0.43 (92%)	0.47 (100%)	NM	NM	NM
2	0.57 (60%)	0.77 (81%)	0.87 (92%)	0.95 (100%)	NM	NM
3	0.69 (48%)	1.02 (71%)	1.20 (84%)	1.32 (92%)	1.42 (99%)	NM
4	0.77 (41%)	1.18 (63%)	1.54 (81%)	1.65 (87%)	1.77 (93%)	1.88 (99%)
5	0.83 (35%)	1.37 (58%)	1.86 (78%)	1.98 (83%)	2.09 (88%)	2.23 (94%)

As this practice could treat runoff draining from both the roadway and alleyway, the drainage area for this practice could potentially be much larger than other curb-cut rain gardens. In the 1NE subwatershed, catch basins are located at most street corners. As a result, flow to these practices would likely be no more than just the city block the project is installed upon. Thus, up to one half of a city block could be treated. This was estimated to be about 2 acres of drainage area.

A cost/benefit analysis for this project installed on a lot treating 2 acres of medium-density residential runoff is listed in the table below. Project cost would need to include purchase of the residential lot, which was estimated to be $50,000 based on local parcel information. All other costs are similar to those for other biofiltration and bioinfiltration projects proposed in this report, with the exception of annual maintenance, which was assumed to be completed by City staff and therefore reflects an increased cost.

A 3,000 sq-ft garden is proposed as this practice size is estimated to remove 90% of TSS from the contributing drainage area if an underdrain has to be installed. If this project can be installed on native soils infiltrating at 1.0"/hour or better (and therefore not requiring an underdrain), then 100% of TSS and TP could be treated.

NSS-B1 and NSS-B2

	Condemned Property Rain Garden				
	Cost/Removal Analysis	0.2"/hr Infiltration Rate With Underdrain		1.0"/hr Infiltration Rate Without Underdrain	
		New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	3,000	sq-ft	3,000	sq-ft
	TP (lb/yr)	0.53	31.7%	1.67	100.0%
	TSS (lb/yr)	394	91.8%	429	100.0%
	Volume (acre-feet/yr)	0.31	32.6%	0.95	100.0%
Cost	Administration & Promotion Costs*	$5,110		$5,110	
	Design & Construction Costs**	$123,095		$111,095	
	Total Estimated Project Cost (2014)	**$128,205**		**$116,205**	
	Annual O&M***	$1,320		$1,320	
Efficiency	30-yr Average Cost/lb-TP	**$10,554**		**$3,110**	
	30-yr Average Cost/1,000lb-TSS	**$14,197**		**$12,106**	
	30-yr Average Cost/ac-ft Vol.	**$18,044**		**$5,467**	

*70 hours at $73/hour

**($24/sq-ft for materials and labor [or $20/sq-ft without underdrain]) + (15 hours at $73/hour for design) + $50,000 to purchase property

***Per BMP: ($200/year for 10-year rehabilitation) + (8 visits/year * 2 hours/visit * $70/hour)

Standard and Expanded Boulevard Rain Gardens (NSS-C1, NSS-C2, NSS-D1, and NSS-D2)

Boulevard space between the roadway curb and sidewalk within the public right-of-way could provide a unique opportunity for stormwater practices throughout developed residential areas. The location of the boulevard along the gutter line could allow for a curb-cut inlet to a rain garden that could treat stormwater runoff from rooftops, driveways, sidewalks, and the roadway. Gardens could either utilize the existing boulevard space, termed a “standard” boulevard rain garden, or be enlarged to increase the storage capacity of the practice, an “expanded” boulevard rain garden. This expansion could be achieved in one of two ways. One option includes rerouting the sidewalk around the garden, with a fence installed along the sidewalk to provide a barrier between the walkway and garden depression. A second option could be keeping the sidewalk intact while allowing the garden to occupy a portion of the low-traffic area of the roadway. In either case, a one foot wide, level bench would be recommended along the curb line to ensure space is available for people exiting vehicles parked along the street. Also, an underdrain is recommended for gardens where the infiltration rate in the native soils is too slow to provide complete infiltration of stormwater within 48 hours of the garden filling. Please note these BMPs are presented to simply provide an estimate of their potential benefit, and it should be clarified that these types of BMPs may not be favorable in the 1NE subwatershed.

This practice can be placed in a variety of locations throughout the 1NE subwatershed where boulevards are present using either option noted above. Therefore, multiple scenarios were modeled, both in garden size and drainage area. The standard boulevard rain garden was modeled with top dimensions of 20’ in length (parallel to roadway) by 4’ in width (perpendicular to roadway), which fits into the existing boulevard space between the sidewalk and roadway curb in the 1NE subwatershed. The expanded boulevard rain garden was modeled with a top area of 250 sq-ft, which is the approximate size of an elliptically shaped garden 20' long (parallel to roadway) and 15' wide (perpendicular to roadway). Any expanded boulevard rain garden configuration would work for this scenario as long as the top area is 250 sq-ft.

Both the standard and expanded boulevard rain gardens were modeled for medium density residential drainage areas ranging from 0.25 to 4 acres. Two distinct infiltration rates were modeled to estimate reduction capacity for poorly-drained and more well-drained soils. Poorly-drained soils were modeled with a 0.2"/hour infiltration rate and included an underdrain. More well-drained soils were modeled with a 1.0"/hour infiltration rate and did not include an underdrain. Pollutant reduction estimates for TP, TSS, and stormwater volume are summarized in the tables below for both the standard and expanded boulevard rain gardens in each soil type.

Table 20: WinSLAMM model results for the standard boulevard rain garden with a 0.2"/hour infiltration rate.

Drainage Area (acres)	***Standard Boulevard Rain Garden With an Underdrain***					
	TP Removal		**TSS Removal**		**Volume Removal**	
	lbs-TP	**%**	**lbs-TSS**	**%**	**ac-ft**	**%**
0.25	0.02	9.5%	25	46.3%	0.01	8.3%
0.5	0.02	4.8%	31	29.0%	0.01	4.2%
1	0.03	3.6%	33	15.4%	0.02	4.2%
2	0.03	1.8%	34	7.9%	0.02	2.1%
3	0.03	1.2%	35	5.4%	0.02	1.4%
4	0.03	1.0%	37	4.3%	0.02	1.1%

Table 21: WinSLAMM model results for the standard boulevard rain garden with a 1.0"/hour infiltration rate.

Drainage Area (acres)	***Standard Boulevard Rain Garden Without an Underdrain***					
	TP Removal		**TSS Removal**		**Volume Removal**	
	lbs-TP	**%**	**lbs-TSS**	**%**	**ac-ft**	**%**
0.25	0.12	57.1%	35	64.8%	0.07	58.3%
0.5	0.16	38.1%	49	45.8%	0.1	41.7%
1	0.2	23.8%	60	28.0%	0.12	25.0%
2	0.23	13.8%	68	15.9%	0.14	14.7%
3	0.24	9.6%	71	11.0%	0.14	9.9%
4	0.24	7.2%	74	8.6%	0.15	7.9%

Table 22: WinSLAMM model results for the expanded boulevard rain garden with a 0.2"/hour infiltration rate.

Drainage Area (acres)	***Expanded Boulevard Rain Garden With an Underdrain***					
	TP Removal		**TSS Removal**		**Volume Removal**	
	lbs-TP	**%**	**lbs-TSS**	**%**	**ac-ft**	**%**
0.25	0.04	19.0%	45	83.3%	0.02	16.7%
0.5	0.05	11.9%	73	68.2%	0.03	12.5%
1	0.07	8.3%	101	47.2%	0.04	8.3%
2	0.08	4.8%	123	28.7%	0.05	5.3%
3	0.09	3.6%	132	20.5%	0.05	3.5%
4	0.09	2.7%	133	15.5%	0.06	3.2%

Table 23: WinSLAMM model results for the expanded boulevard rain garden with a 1.0"/hour infiltration rate.

Drainage Area (acres)	Expanded Boulevard Rain Garden Without an Underdrain					
	TP Removal		TSS Removal		Volume Removal	
	lbs-TP	%	lbs-TSS	%	ac-ft	%
0.25	0.18	85.7%	49	90.7%	0.11	91.7%
0.5	0.32	76.2%	90	84.1%	0.19	79.2%
1	0.49	58.3%	142	66.4%	0.29	60.4%
2	0.66	39.5%	197	45.9%	0.4	42.1%
3	0.75	29.9%	224	34.8%	0.45	31.7%
4	0.8	24.0%	240	28.0%	0.49	25.8%

In this research area, where catch basins are located at most corners within residential neighborhoods, drainage areas for boulevard rain gardens are likely to be equal to or less than 1 acre. For a 1 acre drainage area, a cost benefit analysis for a standard boulevard rain garden yields the following results:

NSS-C1 and NSS-C2

	Standard Boulevard Rain Garden				
	Cost/Removal Analysis	0.2"/hr Infiltration Rate With Underdrain		1.0"/hr Infiltration Rate Without Underdrain	
		New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	80	sq-ft	80	sq-ft
	TP (lb/yr)	0.03	3.6%	0.20	23.8%
	TSS (lb/yr)	33	15.4%	60	28.0%
	Volume (acre-feet/yr)	0.02	4.2%	0.12	25.0%
Cost	Administration & Promotion Costs*	$3,650		$3,650	
	Design & Construction Costs**	$4,876		$4,876	
	Total Estimated Project Cost (2014)	**$8,526**		**$8,526**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$16,973**		**$2,546**	
	30-yr Average Cost/1,000lb-TSS	**$15,430**		**$8,487**	
	30-yr Average Cost/ac-ft Vol.	**$25,460**		**$4,243**	

*50 hours at $73/hour

**($50/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Similarly, an expanded boulevard rain garden treating a 1 acre drainage area has the following cost effectiveness:

NSS-D1 and NSS-D2

	Expanded Boulevard Rain Garden				
	Cost/Removal Analysis	0.2"/hr Infiltration Rate With Underdrain		1.0"/hr Infiltration Rate Without Underdrain	
		New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.07	8.3%	0.49	58.3%
	TSS (lb/yr)	101	47.2%	142	66.4%
	Volume (acre-feet/yr)	0.04	8.3%	0.29	60.4%
Cost	Administration & Promotion Costs*	$4,745		$4,745	
	Design & Construction Costs**	$15,876		$15,876	
	Total Estimated Project Cost (2014)	**$20,621**		**$20,621**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$13,034**		**$1,862**	
	30-yr Average Cost/1,000lb-TSS	**$9,033**		**$6,425**	
	30-yr Average Cost/ac-ft Vol.	**$22,809**		**$3,146**	

*65 hours at $73/hour

**($60/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Boulevard Bioswale (NSS-E1 and NSS-E2)

Figure 5: Right-of-way bioswale installed in New York City (NYC Environmental Protection, 2013)

Another option for retrofitting a stormwater BMP within a small boulevard may be a bioswale. This practice is similar to the boulevard rain garden in its orientation and size. Bioswales typically range from 5-30' in length, house a rich native plant community, and are installed between the existing sidewalk and roadway curb (Figure 5). Unlike rain gardens, these practices are typically much shallower (1-3" in depth) and have a curb-cut inlet and outlet (Figure 5). Although many rain gardens have outlets in the form of underdrains or risers, the bioswale outlet allows for a nearly continuous flow of stormwater through the practice. Although some infiltration does occur, the primary form of treatment is the settling of pollutants as stormwater flows through the dense plant community.

This practice was modeled to estimate the pollutant reduction capacity for TSS, TP, and stormwater volume in medium density residential drainage areas ranging from 0.25 to 4 acres (Table 24 and Table 25). A 20' long (parallel to roadway), 4' wide (perpendicular to roadway), and 3" deep bioswale was modeled with infiltration rates of 0.2"/hour and 1.0"/hour. No underdrain was modeled with this practice as they are designed to be flow-through systems with limited ponding (≤ 3"). Additional model inputs are noted in Appendix A.

Table 24: WinSLAMM model results for the boulevard bioswale with a 0.2"/hour infiltration rate.

Drainage	*Standard Boulevard Bioswale*					
Area	TP Removal		TSS Removal		Volume Removal	
(acres)	lbs-TP	%	lbs-TSS	%	ac-ft	%
0.25	0.04	19.0%	14	25.9%	0.01	8.3%
0.5	0.09	21.4%	29	27.1%	0.03	12.5%
1	0.18	21.4%	57	26.6%	0.06	12.5%
2	0.35	21.0%	112	26.1%	0.13	13.7%
3	0.52	20.7%	163	25.3%	0.2	14.0%
4	0.65	19.5%	204	23.8%	0.28	14.7%

Table 25: WinSLAMM model results for the boulevard bioswale with a 1.0"/hour infiltration rate.

Drainage	*Standard Boulevard Bioswale*					
Area	TP Removal		TSS Removal		Volume Removal	
(acres)	lbs-TP	%	lbs-TSS	%	ac-ft	%
0.25	0.09	42.9%	27	50.0%	0.05	41.7%
0.5	0.19	45.2%	56	52.3%	0.1	41.7%
1	0.39	46.4%	115	53.6%	0.2	41.7%
2	0.82	49.1%	237	55.2%	0.43	45.3%
3	1.26	50.2%	363	56.5%	0.69	48.3%
4	1.71	51.2%	487	56.8%	0.95	50.0%

In this research area, where catch basins are located at most corners within residential neighborhoods, drainage areas for boulevard bioswales are likely to be equal to or less than 1 acre. For a 1 acre drainage area, a cost benefit analysis yields the following results:

NSS-E1 and NSS-E2

	Boulevard Bioswale				
	Cost/Removal Analysis	0.2"/hr Infiltration Rate		1.0"/hr Infiltration Rate	
		New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	80	sq-ft	80	sq-ft
	TP (lb/yr)	0.18	21.4%	0.39	46.4%
	TSS (lb/yr)	57	26.6%	115	53.7%
	Volume (acre-feet/yr)	0.06	12.5%	0.20	41.7%
Cost	Administration & Promotion Costs*	$3,650		$3,650	
	Design & Construction Costs**	$4,876		$4,876	
	Total Estimated Project Cost (2014)	**$8,526**		**$8,526**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$2,829**		**$1,306**	
	30-yr Average Cost/1,000lb-TSS	**$8,933**		**$4,428**	
	30-yr Average Cost/ac-ft Vol.	**$8,487**		**$2,546**	

*50 hours at $73/hour

**($50/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Disconnect Filtration Basin (Site Specific)

Disconnect filtration basins function identically to the other types of biofiltration described throughout this bioretention section. However, these basins are proposed in locations where a large amount of space is available and stormwater infrastructure passes nearby. The combination of these two site characteristics presents an opportunity to construct a large-scale (i.e. >1,000 sq-ft) biofiltration basin into which the existing stormwater infrastructure could be daylighted. The storm sewer line could be redirected and daylighted into a 12” deep biofiltration basin. This would allow stormwater runoff to fill the disconnect filtration basin and be filtered by the soil and vegetation. The basin could also have an emergency overflow (e.g. riser with a beehive grate) to accommodate higher flows from larger contributing drainage areas.

In most cases, two different sizes of biofiltration basins were modeled and presented based on the space available. Because these are site specific practices and native infiltration rates throughout the 1NE subwatershed were assumed to be 0.2”/hour, the disconnect filtration basins were modeled with a 0.2”/hour infiltration rate and an underdrain.

Probable project cost includes installation of the project as well as promotion, administrative, and design costs, all in 2014 dollars. A reduced construction cost (i.e. $15.00 per ft^2) relative to other biofiltration practices was proposed for the disconnect filtration basin because of assumed cost savings with a larger project. Furthermore, the large open spaces available at each of the proposed project locations could allow the basins to be constructed without retaining walls, which would result in a significant cost savings. Maintenance was assumed to be completed largely by volunteers as these practices are proposed in public parks and a school campus. Nevertheless, maintenance costs were included for annual plant replacement and pretreatment cleaning as well as rehabilitation of the basin every 10 years for the life of the project.

New Wet Retention Ponds (SITE SPECIFIC)

If properly designed, wet retention ponds have controlled outflows to manage discharge rates and are sized to achieve predefined water quality goals. Wet retention ponds treat stormwater through a variety of processes, but primarily through sedimentation. Ponds are most often designed to contain a permanent pool storage depth; it is this permanent pool of water that separates the practice from most other stormwater BMPs, including detention ponds (Figure 6).

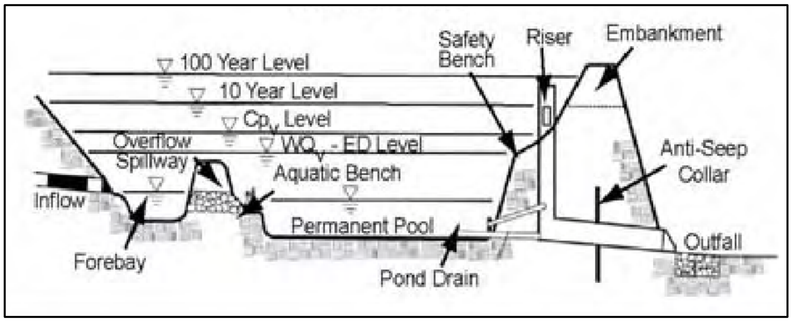


Figure 6: Schematic of a stormwater retention pond. Figure from the Urban Subwatershed Restoration Manual Series, Chapter 3: Urban Stormwater Retrofit Practices.

Wet retention pond depth generally ranges from 3-8' deep. If ponds are less than 3' deep, winds can increase mixing through the full water depth and resuspend sediments, thereby increasing turbidity. Scour may also occur during rain events following dry periods. If more than 8' deep, thermal stratification can occur creating a layer of low dissolved oxygen near the sediment that can release bound phosphorus. Above the permanent pool depth is the flood depth, which provides water quality treatment directly following storm events. Separating the permanent pool depth and the flood depth is the primary outlet control, which is often designed to control outflow rate. Configurations for the outlet control may include a V-notch or circular weir, multiple orifices, or a multiple-stage weir. Each of these can be configured within a skimmer structure or trash rack to provide additional treatment for larger, floatable items. Above the flood depth is the emergency control structure, which is available to bypass water from the largest rainfall events, such as the 100-year precipitation event. Ponds also often include a pretreatment practice, either a forebay or sedimentation basin adjacent to the pond or storm sewer sumps, hydrodynamic devices, or other basins upstream of the practice.

Outside of sedimentation, other important processes occurring in ponds are nutrient assimilation and evapotranspiration by plants. The addition of shoreline plants to pond designs has increased greatly since the 1980's because of the positive effects these plants were found to have for both water quality purposes and increasing terrestrial and aquatic wildlife habitat. The ability of the pond to regulate discharge rates should also be noted. This can reduce downstream in-channel erosion, thereby decreasing TSS and TP loading from within the channel.

With the multitude of considerations for these practices, ponds must be designed by professional engineers. This report provides a rudimentary description of ponding opportunities and cost estimates for project planning purposes. Ponds proposed in this analysis are designed and simulated within the water quality model WinSLAMM, which takes into account upland pollutant loading, pond bathymetry, and outlet control device(s) to estimate stormwater volume, TSS, and TP retention capacity. The model was run with and without the identified project and the difference in pollutant loading was calculated.

In order to calculate cost-benefit, the cost of each project had to be estimated. All new stormwater ponds were assumed to involve excavation and disposal of soil, installation of inlet and outlet control structures and emergency overflow, land acquisition, erosion control, and vegetation management. Additionally, project engineering, promotion, administration, construction oversight, and long-term maintenance (including annual inspections and removal of accumulated sediment/debris from the pretreatment area) had to be considered in order to capture the true cost of the effort. Complete pond dredging is not included in the long-term maintenance cost because project life is estimated to be 30 years. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Modification to an Existing Pond (SITE SPECIFIC)

Developments prior to enactment of contemporary stormwater rules often included wet detention ponds which were frequently designed purely for flood control based on the land use, impervious cover, soils, and topography of the time. Changes to stormwater rules since the early 1970's have greatly altered the way ponds are designed.

Enactment of the National Pollution Discharge Elimination System (NPDES) in 1972 followed by research conducted by the Environmental Protection Agency in the early 1980's as part of the Nationwide Urban Runoff Program (NURP) set standards by which stormwater best management practices should be designed. Municipal Separate Storm Sewer System (MS4) guidelines issued in 1990 (affecting cities with more than 100,000 residents) and 1999 (for cities with less than 100,000 residents) required municipalities to obtain an NPDES permit and develop a plan for managing their stormwater.

Listed below are five strategies which exist for retrofitting a stormwater pond to increase pollutant retention (modified from *Urban Stormwater Retrofit Practices*):

- Excavate pond bottom to increase permanent pool storage
- Raise the embankment to increase flood pool storage
- Widen pond area to increase both permanent and flood pool storage
- Modify the riser
- Update pool geometry or add pretreatment (e.g. forebay)

These strategies can be employed separately or together to improve BMP effectiveness. Each strategy is limited by cost-effectiveness and constraints of space on the current site. Pond retrofits are preferable to most new BMPs as additional land usually does not need to be purchased, stormwater easements already exist, maintenance issues change little following project completion, and construction costs are greatly cheaper. There can also be a positive effect on reducing the rate of overflow from the pond, thereby reducing the risk for erosion (and thus further pollutant generation) downstream.

For this analysis, all existing ponds were modeled in the water quality model WinSLAMM to estimate their effectiveness based on present-day pond characteristics and land use and soil information. WinSLAMM model results found that all ponds performed adequately in treating their upstream drainage areas. Opportunities do exist for improving some ponds, but these were not considered cost-effective and were not pursued. Thus, no pond modifications are proposed in this analysis.

Iron Enhanced Sand Filters (SITE SPECIFIC)

Wet retention ponds, although very effective in treating stormwater for suspended sediment and nutrients bound to sediment, have shown a limited ability at retaining dissolved species of nutrients. This is most notable for phosphorus, which easily adsorbs to sediment when in particulate form. Median values for pollutant removal percentage by wet retention ponds are 84% for TSS and 50% for TP (MN Stormwater Manual). For the case of phosphorus, dissolved species typically constitute 40-50% of TP in urban stream systems, but only 34% (median efficiency; Weiss et al., 2005) of dissolved phosphorus is treated by the pond. Thus, a majority of the phosphorus escaping wet retention ponds is in dissolved form. This has important effects downstream as dissolved phosphorus is a readily available nutrient for algal uptake in waterbodies and can be a main cause for nutrient eutrophication.

To address this deficiency, researchers in at the University of Minnesota developed a method to augment phosphorus retention within a sand filter. They've named this technology the "Iron Enhanced Sand Filter (IESF; Figure 7)". Locally, this practice has also gone by the name "Minnesota Filter." IESFs rely on the properties of iron to bind dissolved phosphorus as it passes through an iron rich medium. Depending on topographic characteristics of the installation sites, IESFs can rely on gravitational flow and natural water level fluctuation, or water pumping to hydrate the IESF. IESFs must be designed to prevent anoxic conditions in the filter medium because such conditions will release the bound phosphorus. Because IESFs are intended to remove dissolved phosphorus and not organic phosphorus, they are typically constructed just downstream of stormwater ponds, minimizing the amount of suspended solids that could compromise their efficacy and drastically increase maintenance. As an alternative to an IESF, a ferric-chloride injection system could be installed to bind dissolved phosphorus into a flocculent, which would settle in the bottom of the new pond.

Figure 7 shows an IESF that is installed at an elevation slightly above the normal water level of the pond so that following a storm event the increase in depth of the pond would be first diverted to the IESF. The filter would have drain tile installed along the base of the trench and would outlet downstream of the current pond outlet. Large storm events that overwhelm the IESF's capacity would exit the pond via the existing outlet.

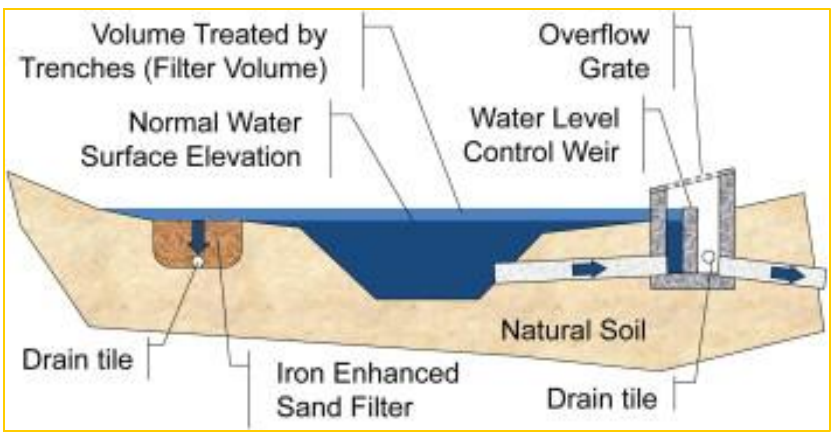


Figure 7: Iron Enhanced Sand Filter Concept (Erickson & Gulliver, 2010)

Benefits for stormwater ponds were modeled utilizing WinSLAMM as described in the previous section "New Wet Retention Pond." After selecting an optimal pond configuration in terms of cost-benefit, or by using the existing pond configuration if no updates are needed, modeling for an IESF was also completed in WinSLAMM. WinSLAMM is able to calculate flow through constructed features such as rain gardens with underdrains, soil amendments, and controlled overflow elevations. An IESF works much the same way. Storm event based discharge volumes and phosphorus concentrations estimated by WinSLAMM after construction of the pond were entered into WinSLAMM as inputs into the IESF (baseflow, if pond is installed in-line, was discounted as it would bypass the IESF). Various iterations of IESFs were modeled to identify an optimal treatment level compared to construction costs. A detailed account of the methodologies used is included in Appendix A. To account for the DP treated by the IESF, an additional 80% DP removal was assumed for each IESF in addition to any removal by the pond. This value is based on laboratory and field tests performed by the University of Minnesota (Erickson & Gulliver, 2010) and assumes only removal of DP species within the device. Load reduction estimates for these projects are noted in the Catchment Profiles sections.

In order to calculate cost-benefit, the cost of each project had to be estimated. IESF projects were assumed to involve some excavation and disposal of soil, land acquisition (if necessary), erosion control, and vegetation management. Additionally, project engineering, promotion, administration, construction oversight, and long-term maintenance had to be considered in order to capture the true cost of the effort. Annual maintenance costs were estimated to be $10,000 per acre of IESF based on information received from local private consulting firms.

Hydrodynamic Devices (SITE SPECIFIC)

In heavily urbanized settings such as northeastern Minneapolis and southern Columbia Heights, stormwater is immediately intercepted along roadway catch basins and conveyed rapidly via storm sewer pipes to its destination. Once stormwater is intercepted by catch basins, it can be very difficult to supply treatment without large end-of-pipe projects such as regional ponds. One of the possible solutions is the hydrodynamic device (Figure 8). These are installed in-line with the existing storm sewer network and can provide treatment for up to 10-15 acres of upland drainage. This practice applies some form of filtration, settling, or hydrodynamic separation to remove coarse sediment, litter, oil, and grease. These devices are particularly useful in small but highly urbanized drainage areas and can be used as pretreatment for other downstream stormwater BMPs.

Each device's pollutant removal potential was estimated using WinSLAMM. Devices were sized based on upstream drainage area to ensure peak flow does not exceed each device's design guidelines. For this analysis, Downstream Defender devices were modeled based on available information and to maintain continuity across other SRAs. Devices were proposed along particular storm sewer lines and often just upstream of intersections with another, larger line. Model results assume the device is receiving input from all nearby catch basins noted.

In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

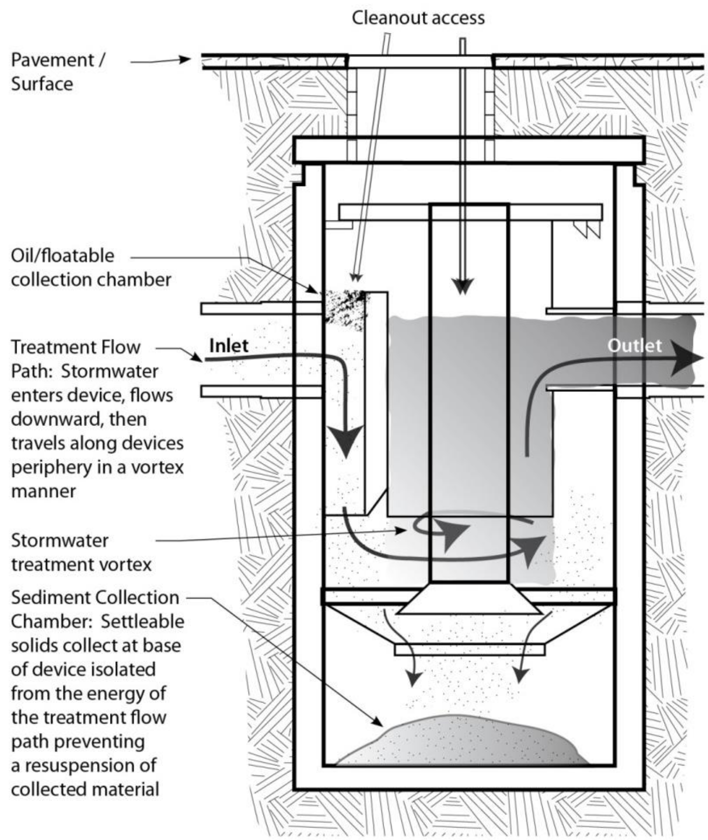


Figure 8: Schematic of a typical hydrodynamic device

Permeable Asphalt (SITE SPECIFIC)

Relatively flat, low traffic areas provide the perfect location for diverting stormwater runoff from impervious surfaces to porous pavement. Void space between concrete pavers or within permeable asphalt and concrete allow water to percolate through the surface to an underlying layer(s) of coarse aggregate rock (Figure 9). This aggregate can act as a reservoir providing water quality and quantity benefits by filtering the stormwater and creating storage. From here water can either be stored temporarily or can infiltrate into the ground to recharge local groundwater aquifers. Many designs include permeable geotextile fabric to separate the uncompacted soil subgrade from the coarse aggregate and to facilitate infiltration. If soils don't allow for infiltration, a liner can be installed with an underdrain attached to nearby storm sewers or additional stormwater BMPs. This still allows for filtration through the pavement and aggregate and reduces the peak discharge from the site.

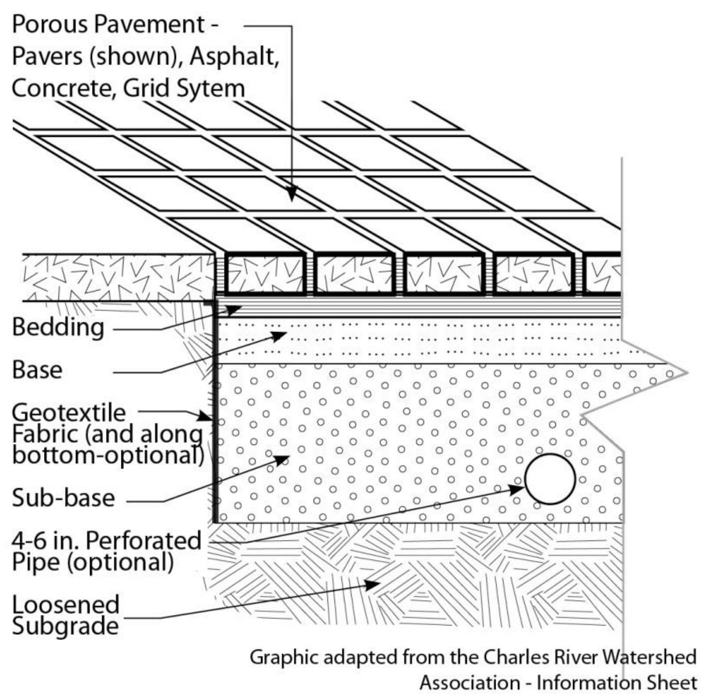


Figure 9: Schematic of typical permeable pavement surface and subgrade.

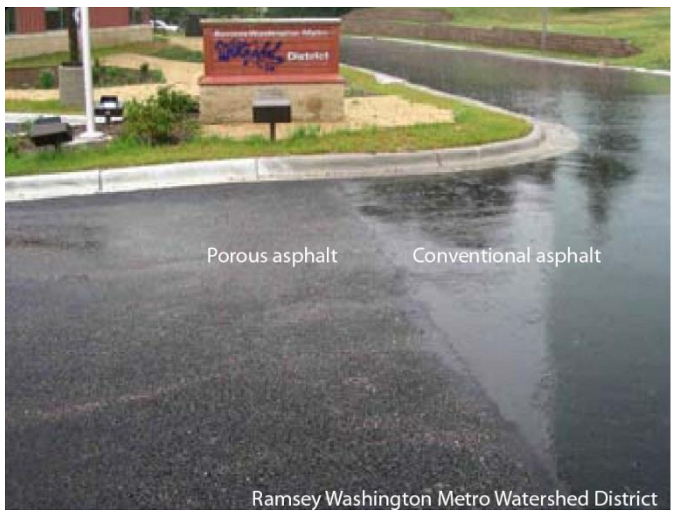


Figure 10: Photo comparing conventional and permeable asphalt

This practice is ideally suited for small drainage areas flowing to low traffic pavement surfaces (Figure 10). For a residential property, roof runoff can be diverted via rain leaders to a permeable driveway. On a commercial property, parking spaces within a large parking lot could be converted to permeable pavement to capture runoff from the parking lot, sidewalks, and any buildings on the property. On a residential roadway, parking spaces on either side of the street could be converted to permeable asphalt. In this case the practice could treat not just the roadway but multiple properties along the street. Permeable asphalt can be used for many other scenarios in areas where soil type, seasonal water table, and frost line allow for groundwater recharge.

The capacity for this practice is completely dependent on the reservoir size within the aggregate and whether or not infiltration can occur on the site. In most cases the permeable asphalt treats stormwater received from just the surface itself and adjacent impervious surfaces. A general design guideline used in this analysis is a ratio between the permeable asphalt surface area and the area of the impervious surface draining to the practice of 1:3. Besides reservoir capacity, this ratio also depends on the infiltration rate (in the case that the BMP allows for infiltration) or drainage time (if an underdrain is installed) and how well the practice is maintained as clogging can greatly decrease the ability of the practice to capture runoff.

The pollutant removal potential of permeable asphalt was estimated using WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Stormwater Reuse (SITE SPECIFIC)

Some of the major water resource issues today include improving stormwater treatment (quantity and quality), increasing groundwater recharge, and decreasing public water usage. Stormwater reuse is a powerful BMP strategy that can be applied to address each of these on a scale ranging from a single property to an entire neighborhood. Stormwater reuse allows for the utilization of stormwater, supplementing potable sources, in applications that do not require water to be at a standard set for consumption. An example of this might be using captured stormwater to irrigate a golf course or recreational fields.

Benefits from this practice are twofold. First, stormwater runoff is given multiple opportunities for treatment. Treatment through settling, filtering, or hydrodynamic separation at the BMP site provides initial treatment of particulates, litter, and other debris. Application of the stormwater as irrigation allows for infiltration through the soil layer and treatment of the dissolved load of pollutants that may have remained. The second benefit is the reduced usage of potable water. As there is no need for highly treated water when irrigating a lawn, the stress placed on water treatment facilities and the water distribution network can be slightly reduced.

The concept for this practice at its smallest scale is that of a rain barrel on a residential property. Runoff from the impervious roof is captured by gutters and diverted to the rain barrel until it is needed for watering the lawn or garden. At a larger scale, runoff from roofs, driveways, sidewalks, and roadways is diverted to roadway catch basins and to the storm sewer network. A cistern or similar containment unit holds water from storm sewers until it is needed for irrigation. These structures can vary in size from tens of gallons to hundreds of thousands of gallons. Stormwater detention and retention ponds are also popular choices as construction and maintenance costs are often much cheaper than underground cisterns.

These practices often require significant capital investment as updates to the local stormwater infrastructure may be needed. Large cisterns, whether made of concrete or plastic, can require hefty transportation and installation costs. Additional infrastructure may also be necessary, including a foundation to sustain the weight of the cistern (whether above or below ground), pump, and conveyance system. A detailed maintenance plan is also necessary even if other forms of pretreatment (e.g. hydrodynamic device, baffle, etc.) are installed. Lastly, during dry periods potable water may still be needed to supplement stormwater when the containment unit is empty.

While there are currently few actively irrigated parks or fields within the 1NE subwatershed, water reuse was identified as a potential BMP that could be implemented in the future at the locations identified in this analysis. The Cities of Columbia Heights and Minneapolis were interested to see the estimated benefits of water reuse for irrigation.

The pollutant removal potential of stormwater reuse devices was estimated using the stormwater model WinSLAMM. In order to calculate cost-benefit, the cost of each project had to be estimated. To fully estimate the cost of project installation, labor costs for project outreach, promotion, design, administration, and maintenance over the anticipated life of the practice were considered in addition to actual construction costs. Costs for projects are listed in detail in Appendix B. Load reduction estimates for these projects are noted in the Catchment Profiles section.

Underground Storage (SITE AND NON-SITE SPECIFIC)

Similar to stormwater reuse, underground storage involves the capture and detention of stormwater from the existing storm sewer network to a large, below-grade (usually) device. Underground storage differs in that stored water is never returned to the surface for use. The device in which stormwater is detained is designed to allow for seepage of the stormwater into the ground. Therefore, these practices can often be cheaper than stormwater reuse practices as a pumping and filtering system is not needed.

For this analysis, a combination of aggregate rock and perforated corrugated metal pipes (CMP) were used to provide storage of the stormwater below ground elevation. The CMP is proposed in addition to the aggregate rock to increase the storage capacity of the practice (as water storage within the aggregate is only found in pore space). Stormwater will be delivered to the aggregate rock and CMP via stormwater catch basins along the existing storm sewer network. A grate at the top of the catch basin and sump at the bottom will provide pretreatment to the practice for large debris and sediment. Infiltration of the stored stormwater into the ground from the aggregate rock and perforated CMPs will capture particulate and dissolved stormwater pollutants, reduce high-flow runoff, and replenish local groundwater aquifers.

Two distinct types of underground storage are proposed in this analysis. The first is located along the railroad in catchments 2 and 3. These would divert flow from the existing storm sewer network into large CMPs located between the railroad tracks and residential properties. The CMPs would be encased in aggregate to provide additional storage and structure to the project. Additional details for these practices, including assumed location, size, cost, and estimated reduction potential, are noted in the Catchment Profiles section.

The second practice is non-site specific, and could be proposed for most alleyways throughout the 1NE subwatershed. This practice could include the installation of aggregate rock and CMP below an alleyway to provide for pollutant treatment and water detention from a large portion of a single block. The practice would be installed at the downstream end of the block, and would collect runoff from portions of the block draining to the alleyway.

The aggregate and pipe dimensions proposed for the alleyway project are based on designs in the *Technical Memorandum: Analysis and Evaluation for Shared, Stacked-Function, Green Infrastructure* prepared for the City of St. Paul by SRF Consulting and amended to meet site considerations for residential neighborhoods in the research area. Aggregate and pipe storage was estimated based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. At the time of publication this rainfall amount is 1.17". To treat the average alleyway in this research area (1.71 total acres, 1.09 acres of which is impervious), 4,629 cu-ft. of water storage would be needed. To achieve this, a 100' long, 12' wide, and 8' deep aggregate basin is proposed with two in-parallel 48" CMPs running the length of the basin. Other dimensions, such as a longer but skinnier basin, would also work assuming there is enough storage available to treat the 1.17" 24-hr rainfall event. A native soil infiltration rate of 0.2"/hour was assumed for this practice.

WinSLAMM modeling results for the Green Alley Underground Storage practice are listed in the table below. Costs for this project are similar to those noted in Appendix B for the underground storage devices in catchments 2 and 3. The only exceptions are the additional cost for this project to tear up and repave the alleyway and the removal of the railroad permit, which may be needed to install a project within the railroad corridor. This project could be completed during the regular schedule of alleyway resurfacing performed by each city. Thus, the cost of repaving was not included in the overall project cost. A detailed cost estimate for each portion of the project can be found in Appendix B. Listed below are results from a cost-benefit of a typical green alley underground storage project. Reduction totals are for the 1.71 acre drainage area only.

NSS-F

	Green Alley Underground Storage		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	1.89	90.9%
	TSS (lb/yr)	604	91.5%
	Volume (acre-feet/yr)	1.04	95.4%
Cost	Administration & Promotion Costs*	$5,840	
	Design & Construction Costs**	$404,275	
	Total Estimated Project Cost (2014)	**$410,115**	
	Annual O&M***	$2,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$8,291**	
	30-yr Average Cost/1,000lb-TSS	**$25,945**	
	30-yr Average Cost/ac-ft Vol.	**$15,068**	

*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Catchment Profiles

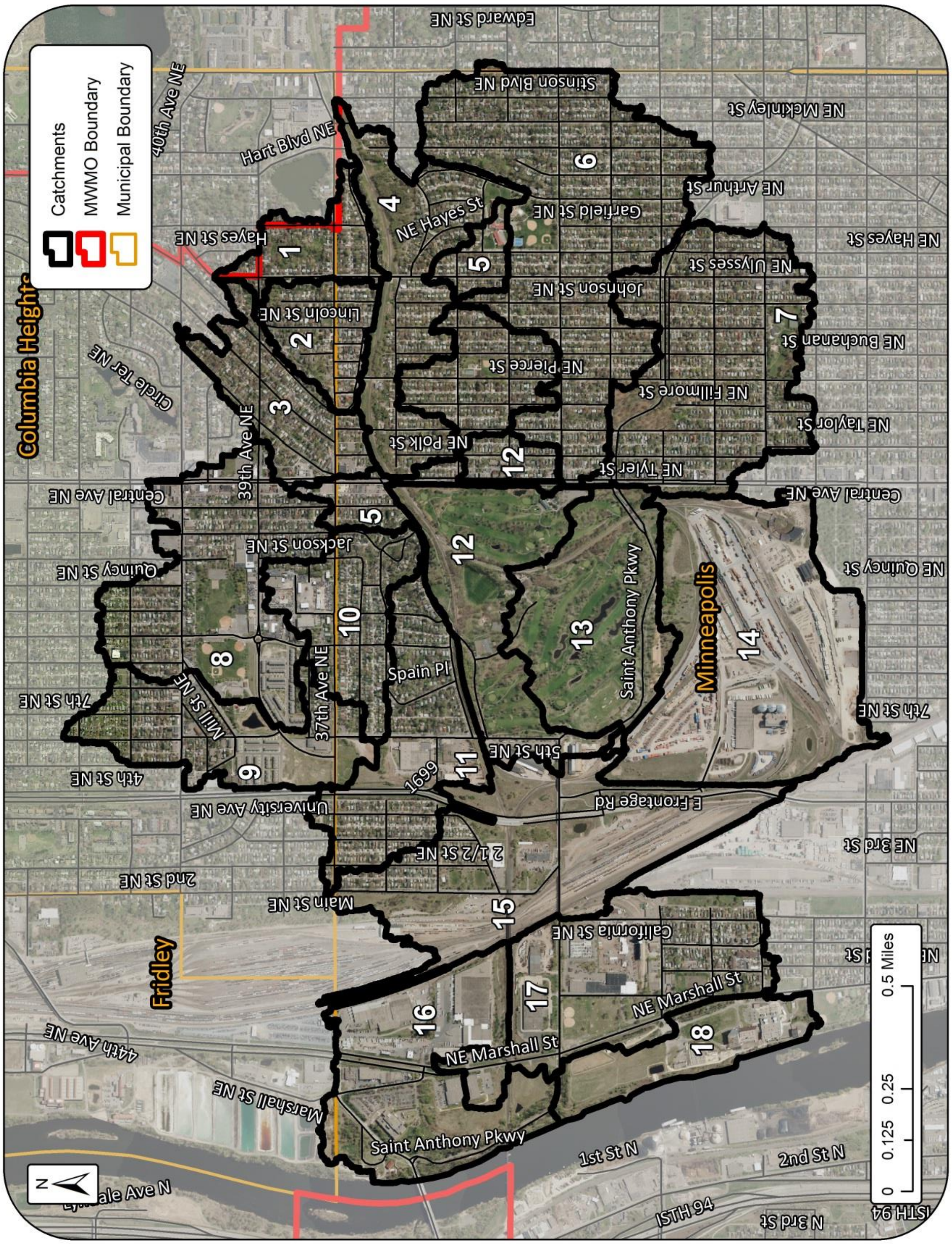


Figure 11: The 2,075 acre 1NE outfall drainage area was divided into 18 catchments for this analysis. Catchment profiles on the following pages provide additional information.

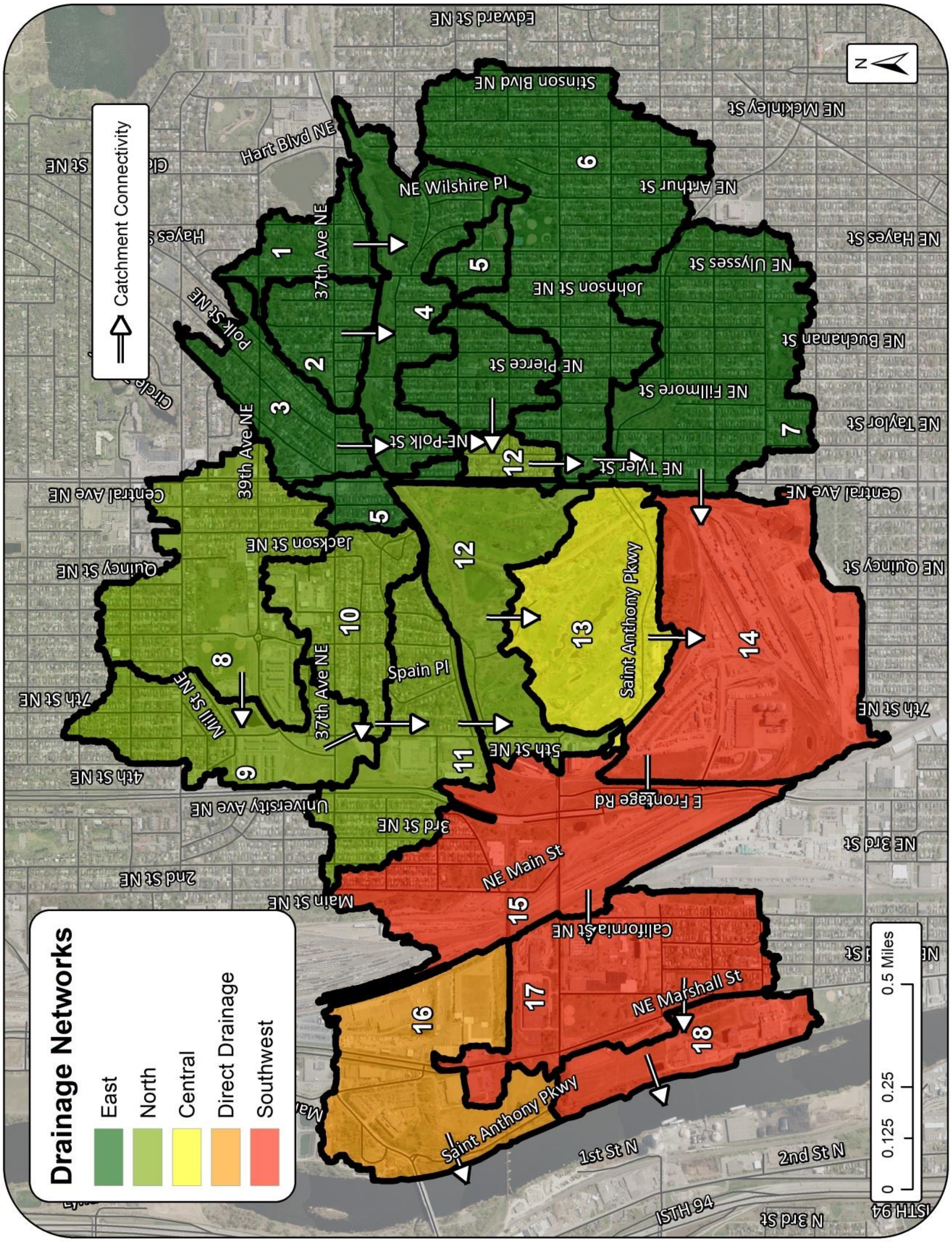
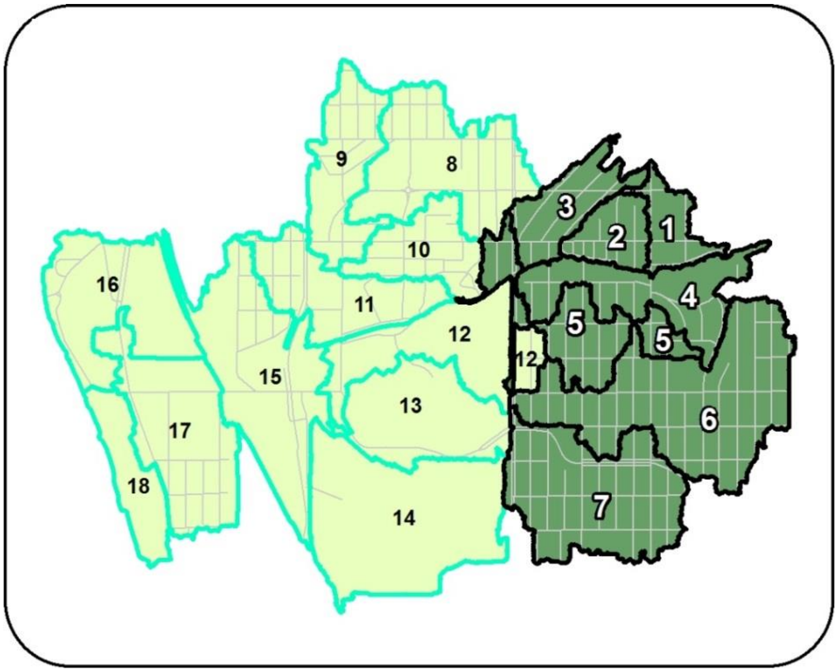


Figure 12: The 18 catchments were further grouped into five drainage areas to better organize the report. The catchment profiles on the following pages are organized by drainage network.

Eastern Drainage Network

Catchment ID	Page
1	58
2	65
3	75
4	82
5	87
6	94
7	101



Existing Network Summary	
Acres	726.2
Dominant Land Cover	Residential
Volume (ac-ft/yr)	355.6
TP (lb/yr)	578.6
TSS (lb/yr)	153,574

DRAINAGE NETWORK SUMMARY

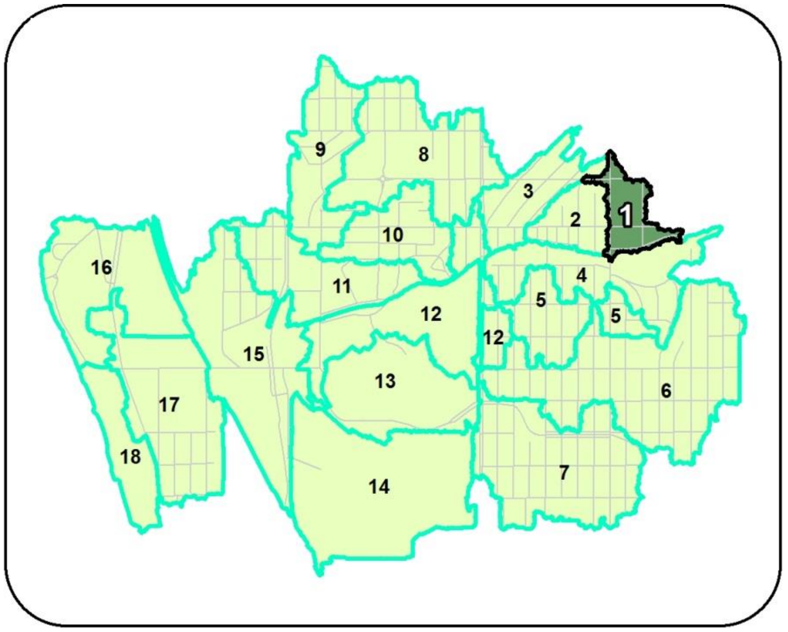
This network is comprised of the seven catchments east of Central Ave. NE. Stormwater runoff from these catchments largely flows west toward Central Ave. NE before being directed south by stormwater infrastructure along Central Ave. NE. Land use throughout these seven catchments is dominated by residential land use. The northern residential areas (i.e. catchments 1, 2, and 3) in Columbia Heights are primarily medium density residential without alleys while the catchments in Minneapolis are medium density residential with alleys.

EXISTING STORMWATER TREATMENT

Street cleaning by the cities of Columbia Heights (four times annually) and Minneapolis (three times annually) is the primary existing stormwater treatment in these seven catchments.

Catchment 1

Existing Catchment Summary	
Acres	37.5
Dominant Land Cover	Residential
Parcels	168
Volume (ac-ft/yr)	18.1
TP (lb/yr)	30.4
TSS (lb/yr)	7,736



CATCHMENT DESCRIPTION

This catchment is located on the west side of Hart Lake and is bounded by Johnson Street to the west and the rail road tracks to the south.

All stormwater runoff generated within this catchment is immediately intercepted by roadway catch basins to be transported directly into the storm sewer network. Once in the storm sewer, water flows south to just beyond the railroad tracks, where it enters a west flowing system to ultimately join the primary storm sewer infrastructure at Central Ave.

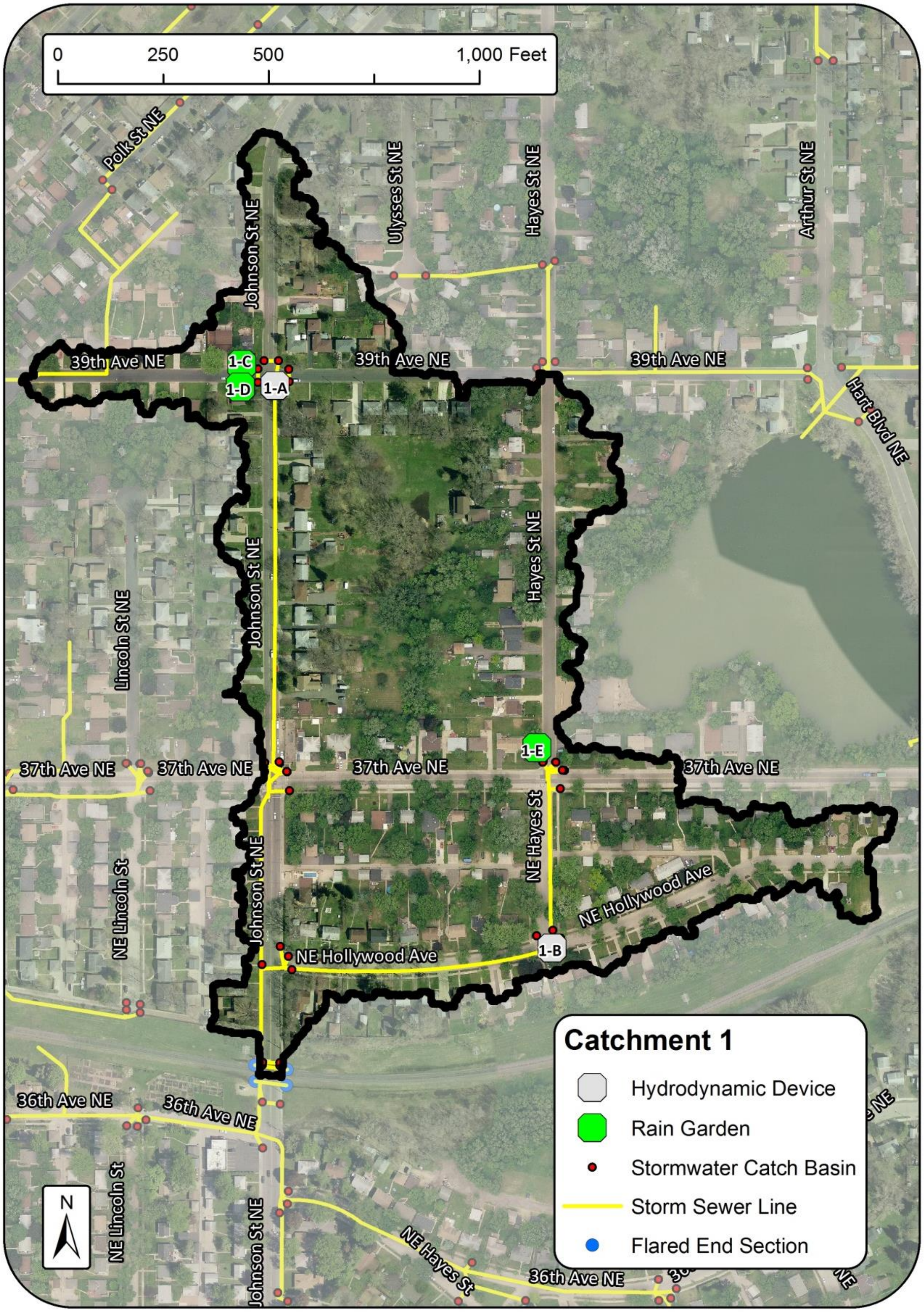
The catchment is comprised primarily of single family residential homes with a few multi-family properties and one small business.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed four times per year by the City of Columbia Heights. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	32.4	2.0	6%	**30.4**
	TSS (lb/yr)	8,613	877.0	10%	**7,736**
	Volume (acre-feet/yr)	18.1	0.0	0%	**18.1**

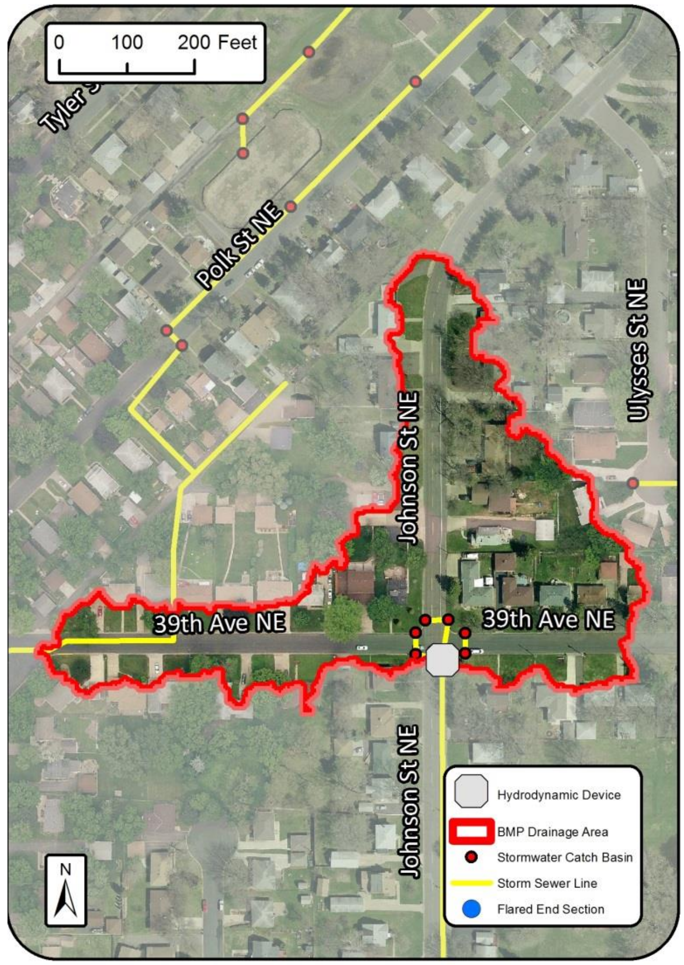
RETROFIT RECOMMENDATIONS



Project ID: 1-A

39th Ave. NE and Johnson St. NE Hydrodynamic Device

Drainage Area – 5.1 acres
Location – Intersection of 39th Ave. and Johnson St. NE
Property Ownership – Public (City of Columbia Heights)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 39th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.



Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	8	ft diameter
	TP (lb/yr)	0.4	1.4%
	TSS (lb/yr)	159	2.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2014)	**$55,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$6,133**	
	30-yr Average Cost/1,000lb-TSS	**$16,971**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

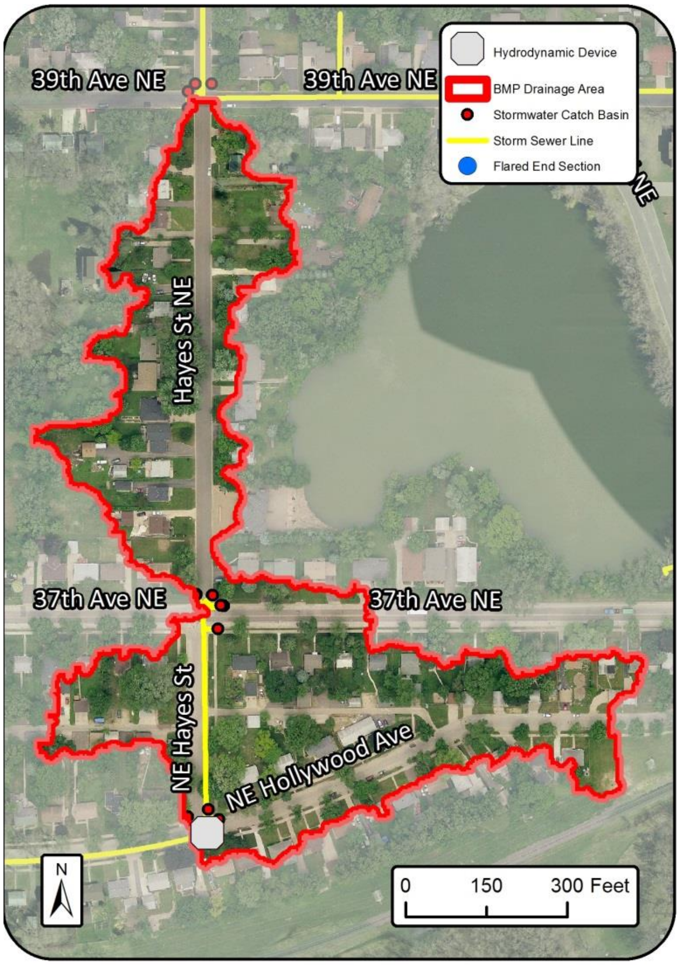
**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 1-B

Hollywood Ave. NE and Hayes St. NE Hydrodynamic Device

Drainage Area – 12.1 acres
Location – Intersection of Hollywood Ave. NE and Hayes St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north and east of Hollywood Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.



Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.9	3.0%
	TSS (lb/yr)	330	4.3%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,998**	
	30-yr Average Cost/1,000lb-TSS	**$13,632**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

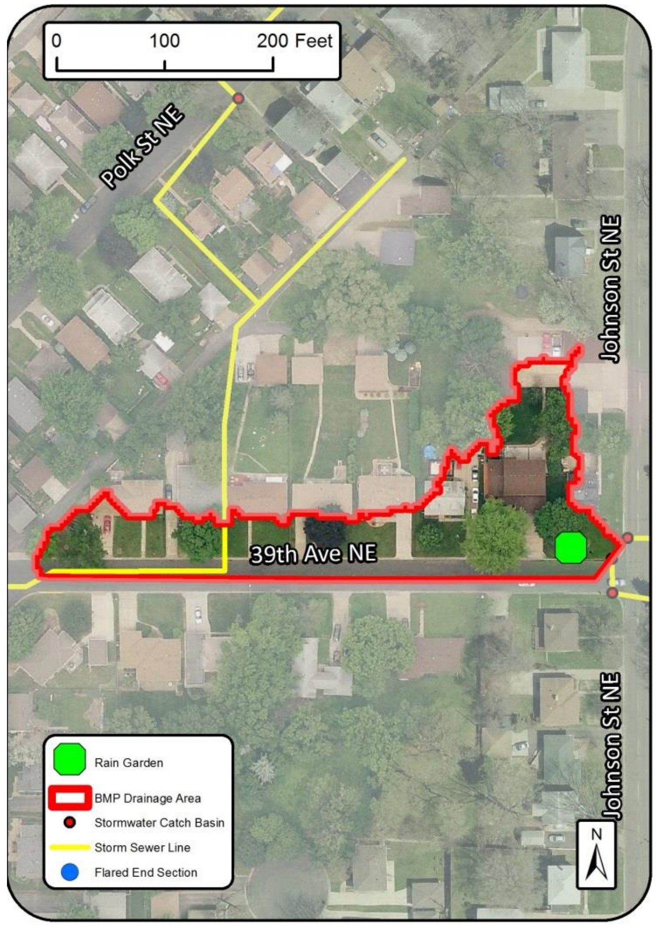
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 1-C

39th Ave. and Johnson St. NE
North Curb-Cut Rain Garden



Drainage Area – 1.0 acres
Location – Northwest corner of intersection between 39th Ave. NE and Johnson St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

	Curb-Cut Rain Garden		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.06	0.2%
	TSS (lb/yr)	93	1.2%
	Volume (acre-feet/yr)	0.04	0.2%
Cost	**Administration & Promotion Costs***	$4,234	
	Design & Construction Costs**	$6,876	
	Total Estimated Project Cost (2014)	**$11,110**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$9,922**	
	30-yr Average Cost/1,000lb-TSS	**$6,401**	
	30-yr Average Cost/ac-ft Vol.	**$16,537**	

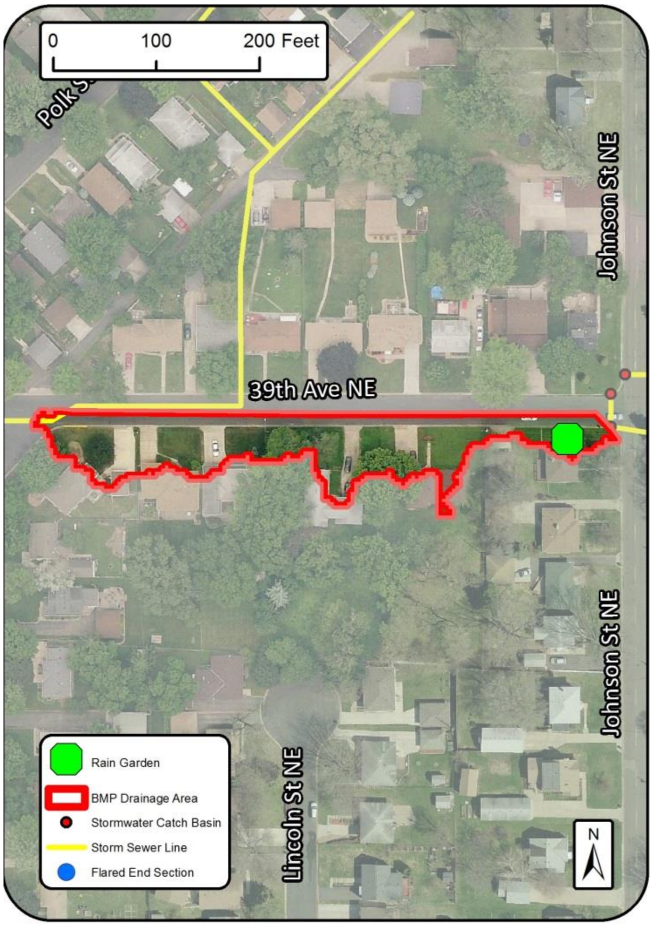
*58 hours/BMP at $73/hour

**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 1-D

39th Ave. and Johnson St. NE
South Curb-Cut Rain Garden



Drainage Area – 0.7 acres
Location – Southwest corner of intersection between 39th Ave. NE and Johnson St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	250	sq-ft
Treatment	TP (lb/yr)	0.05	0.2%
Treatment	TSS (lb/yr)	78	1.0%
Treatment	Volume (acre-feet/yr)	0.03	0.2%
Cost	Administration & Promotion Costs*	$4,234	
Cost	Design & Construction Costs**	$6,876	
Cost	Total Estimated Project Cost (2014)	**$11,110**	
Cost	Annual O&M***	$225	
Efficiency	30-yr Average Cost/lb-TP	**$11,907**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$7,632**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$19,844**	

*58 hours/BMP at $73/hour
**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)
***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 1-E

37th Ave. and Hayes St. NE
Curb-Cut Rain Garden

Drainage Area – 3.1 acres
Location – Intersection of 37th Ave. NE and Hayes St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

	Curb-Cut Rain Garden		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
Treatment	**Total Size of BMPs**	250	sq-ft
Treatment	**TP (lb/yr)**	0.08	0.3%
Treatment	**TSS (lb/yr)**	116	1.5%
Treatment	**Volume (acre-feet/yr)**	0.05	0.3%
Cost	**Administration & Promotion Costs***	$4,234	
Cost	**Design & Construction Costs****	$6,876	
Cost	**Total Estimated Project Cost (2014)**	**$11,110**	
Cost	**Annual O&M*****	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$7,442**	
Efficiency	**30-yr Average Cost/1,000lb-TSS**	**$5,132**	
Efficiency	**30-yr Average Cost/ac-ft Vol.**	**$11,907**	

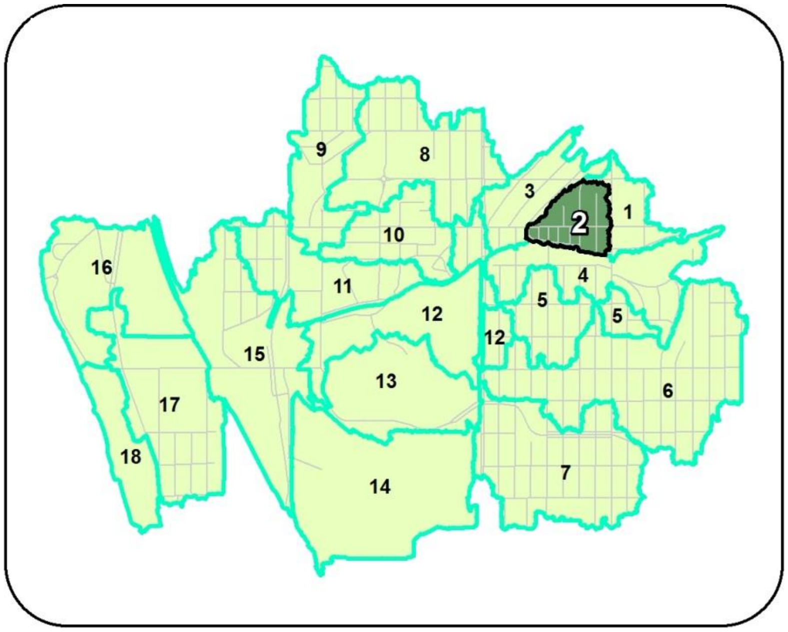
*58 hours/BMP at $73/hour

**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Catchment 2

Existing Catchment Summary	
Acres	40.5
Dominant Land Cover	Residential
Parcels	202
Volume (acre-feet/yr)	19.6
TP (lb/yr)	32.4
TSS (lb/yr)	8,111



CATCHMENT DESCRIPTION

Catchment 2 is bounded by residences on Polk St. NE, 39th Ave. NE, Johnson St. NE, and the railroad tracks. 37th Ave. NE bisects the catchment from east to west. The catchment is comprised primarily of single family residential properties. There are a few multi-family homes as well as one commercial property.

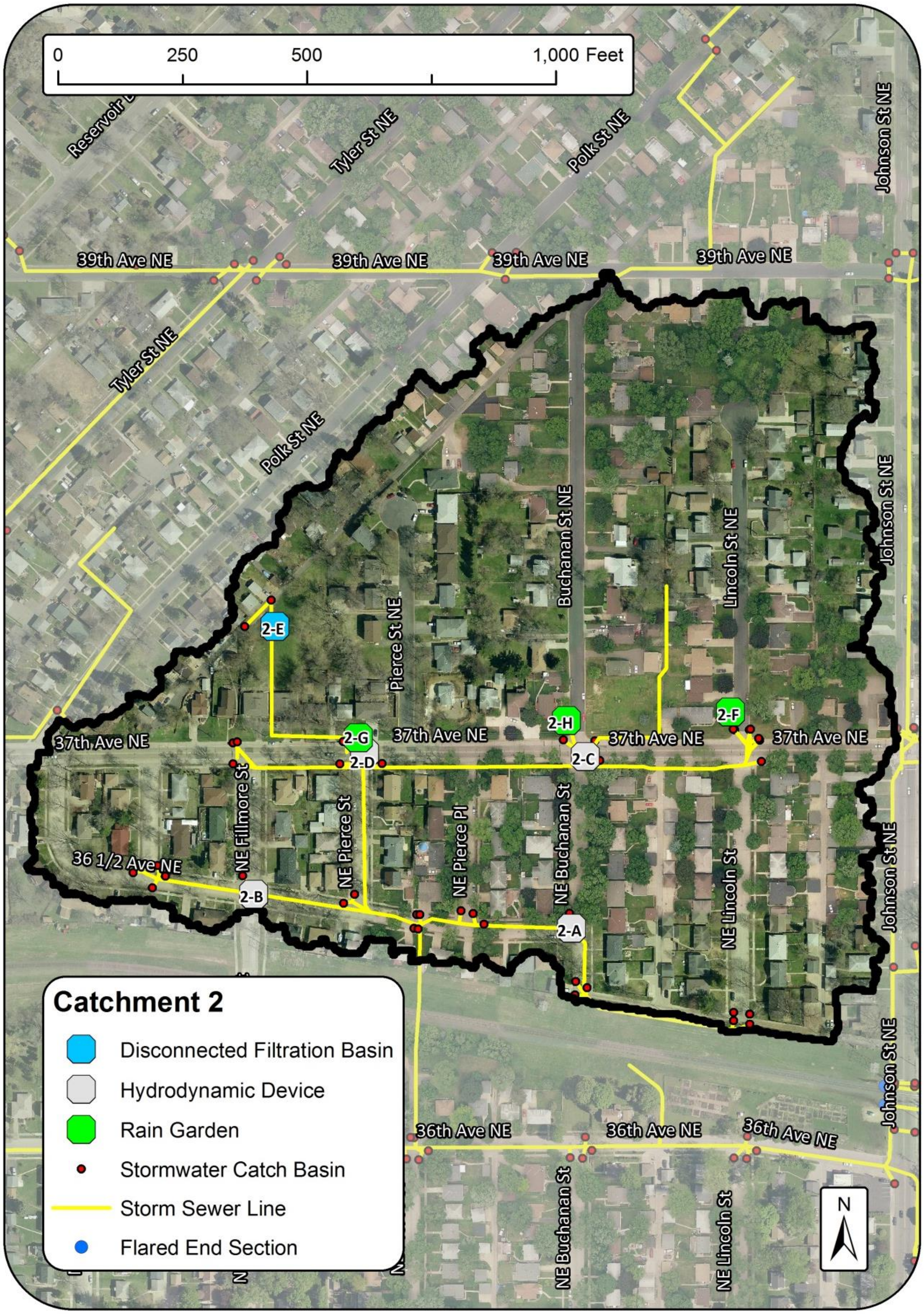
All stormwater runoff generated in this catchment flows overland to the south and is collected by catch basins. The water is then conveyed south via storm sewers to just beyond the railroad tracks, where it joins a west flowing system and ultimately discharges into the primary storm sewer infrastructure at Central Ave.

EXISTING STORMWATER TREATMENT

The primary existing stormwater treatment in the catchment is street cleaning, performed four times per year by the City of Columbia Heights. Present-day stormwater pollutant loading and treatment is summarized in the table below.

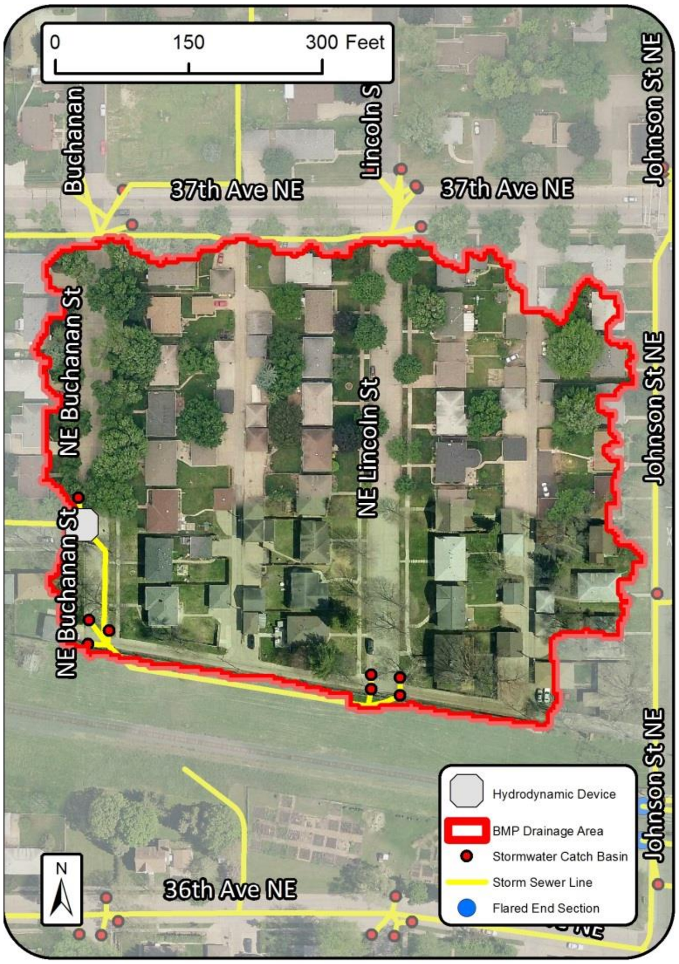
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	34.5	2.1	6%	**32.4**
	TSS (lb/yr)	9,012	901.0	10%	**8,111**
	Volume (acre-feet/yr)	19.6	0.0	0%	**19.6**

RETROFIT RECOMMENDATIONS



Project ID: 2-A

36 ½ Ave. NE and Buchanan St. NE Hydrodynamic Device



Drainage Area – 7.0 acres
Location – Intersection of 36 ½ Ave. NE and Buchanan St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area east of Buchanan St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	8	ft diameter
	TP (lb/yr)	0.4	1.4%
	TSS (lb/yr)	159	2.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2014)	**$55,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,133**	
	30-yr Average Cost/1,000lb-TSS	**$16,971**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

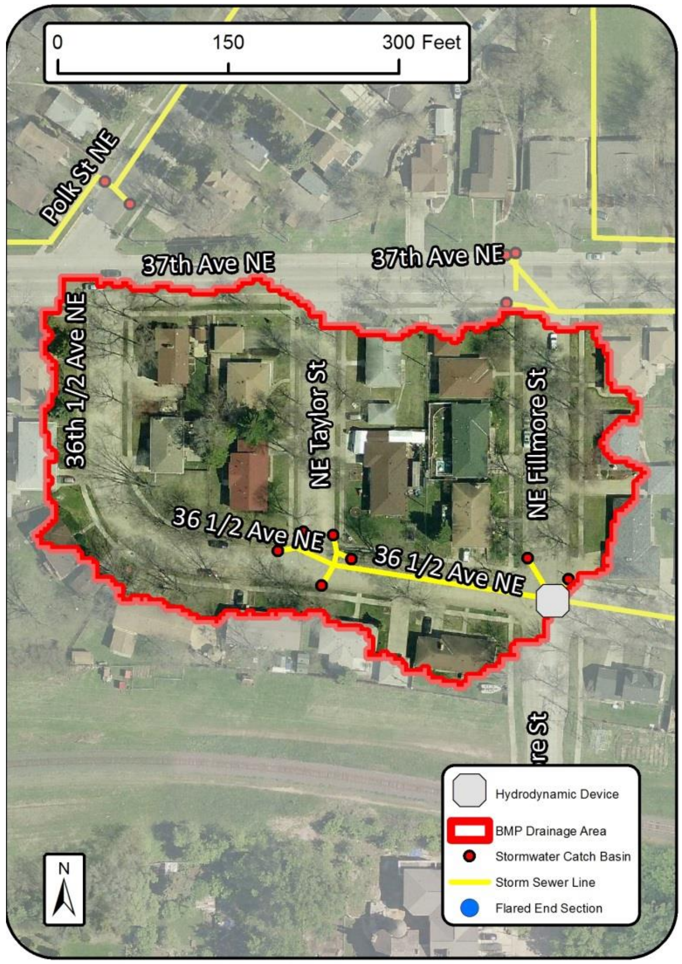
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 2-B

36 ½ Ave. NE and Fillmore St. NE Hydrodynamic Device



Drainage Area – 3.2 acres
Location – Intersection of 36 ½ Ave. NE and Fillmore St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north and west of Fillmore St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	6	ft diameter
	TP (lb/yr)	0.3	0.9%
	TSS (lb/yr)	95	1.2%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2014)	**$28,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,995**	
	30-yr Average Cost/1,000lb-TSS	**$18,931**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

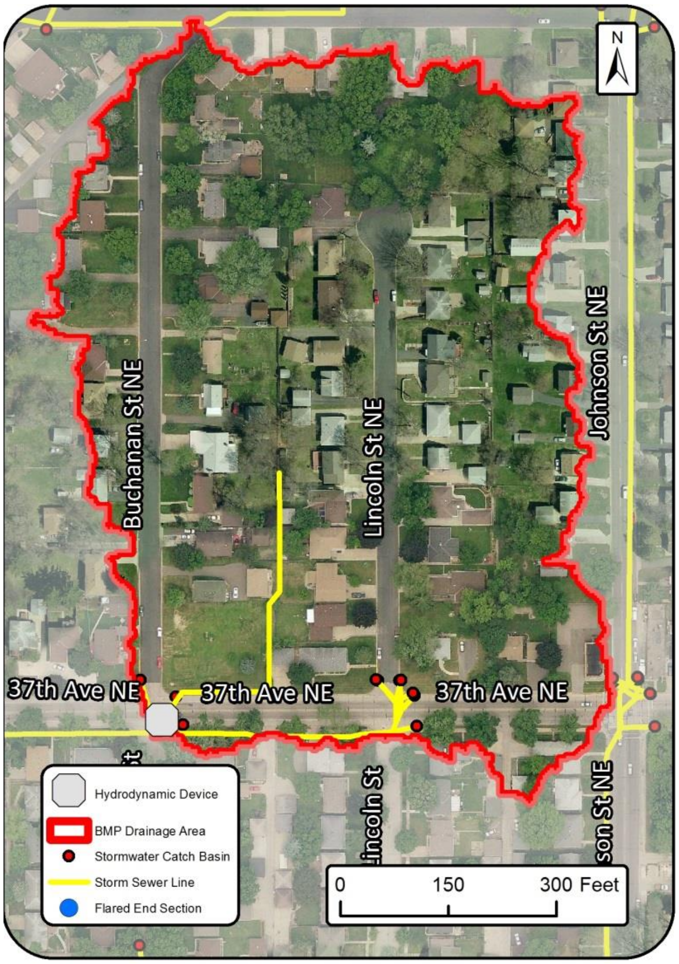
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 2-C

37th Ave. NE and Buchanan St. NE Hydrodynamic Device



Drainage Area – 14.5 acres
Location – Intersection of 37th Ave. NE and Buchanan St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north and east of 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	3.1%
	TSS (lb/yr)	356	4.4%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$12,636**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

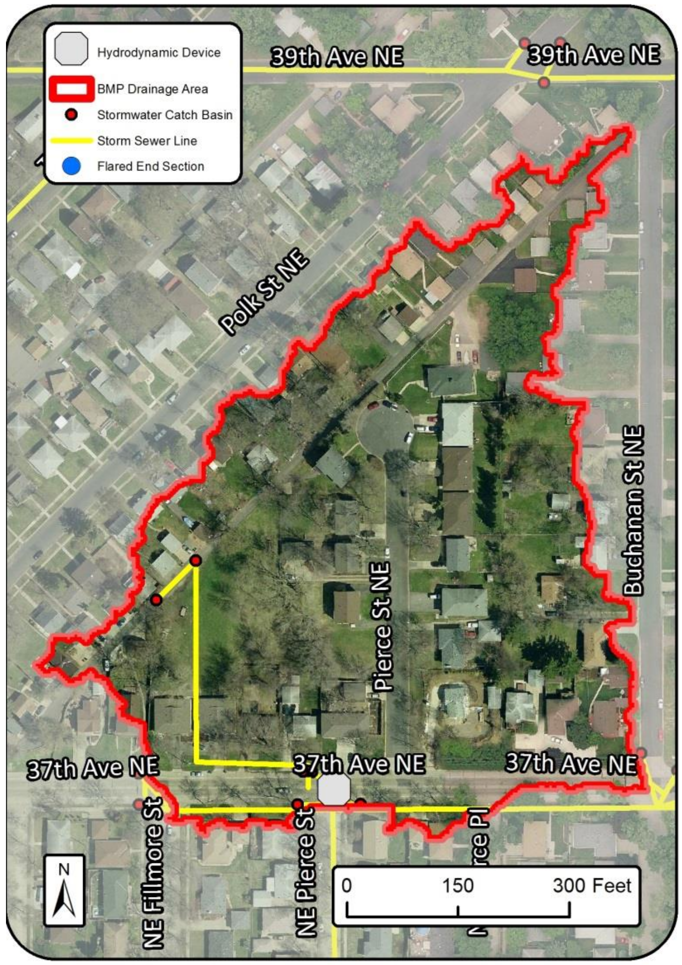
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 2-D

37th Ave. NE and Pierce St. NE
Hydrodynamic Device



Drainage Area – 9.9 acres
Location – Intersection of 37th Ave. NE and Pierce St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	8	ft diameter
	TP (lb/yr)	0.7	2.2%
	TSS (lb/yr)	233	2.9%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2014)	**$55,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,855**	
	30-yr Average Cost/1,000lb-TSS	**$11,581**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

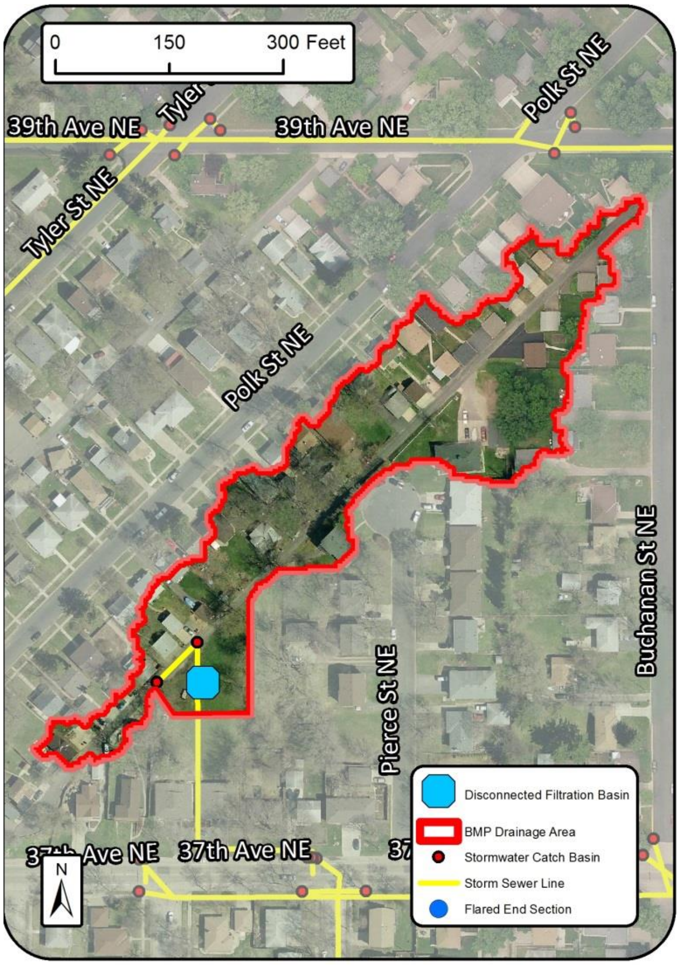
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 2-E

Disconnect Filtration Basin – N of 37th Ave. NE



Drainage Area – 2.9 acres
Location – North of 37th Ave. NE and west of Pierce St. NE. Basin is south of the alley.
Property Ownership – Private
Site Specific Information – A 720 sq-ft filtration basin was modeled for this site. Stormwater from the alley drains to a low spot with two catch basins. The runoff is then directed south to the storm sewer line on 37th Ave. NE. The proposed filtration basin is located on private property behind the apartment complex adjacent to 37th Ave. NE. There is a large open space that could be converted to a filtration basin into which the existing storm sewer line could be daylighted (i.e. remove a section of storm sewer line). Overflow from the filtration basin could then be directed back into the storm sewer line on the downstream side of the filtration basin. This project assumes a partnership could be developed with the apartment complex, so no land acquisition costs were included.

	Disconnect Filtration Basin		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	720	sq-ft
	TP (lb/yr)	0.1	0.3%
	TSS (lb/yr)	128	1.6%
	Volume (acre-feet/yr)	0.1	0.5%
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$18,156	
	Total Estimated Project Cost (2014)	**$21,076**	
	Annual O&M***	$225	
Efficiency	30-yr Average Cost/lb-TP	**$9,275**	
	30-yr Average Cost/1,000lb-TSS	**$7,246**	
	30-yr Average Cost/ac-ft Vol.	**$9,275**	

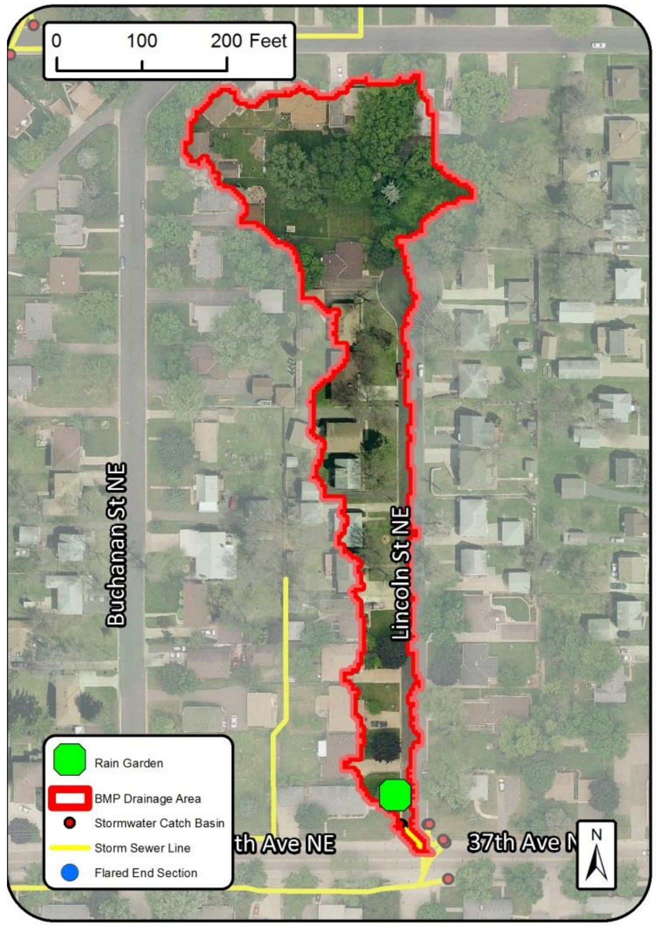
*40 hours at $73/hour

**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 2-F

37th Ave. NE and Lincoln St. NE - Curb-Cut Rain Garden



Drainage Area – 3.1 acres
Location – Intersection of 37th Ave. NE and Lincoln St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

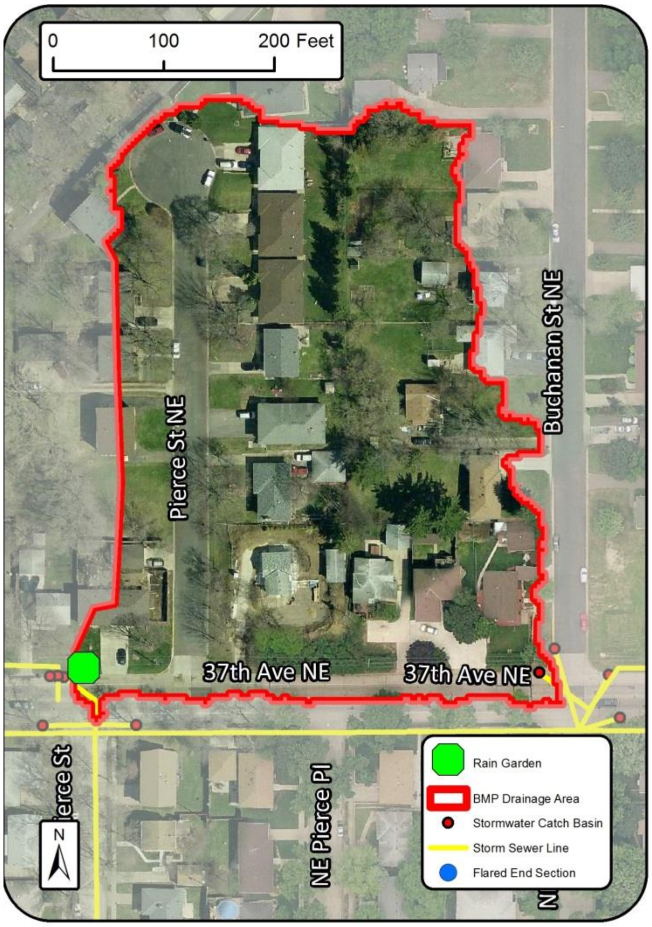
Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	250	sq-ft
Treatment	TP (lb/yr)	0.08	0.2%
Treatment	TSS (lb/yr)	115	1.4%
Treatment	Volume (acre-feet/yr)	0.05	0.2%
Cost	Administration & Promotion Costs*	$4,234	
Cost	Design & Construction Costs**	$6,876	
Cost	Total Estimated Project Cost (2014)	**$11,110**	
Cost	Annual O&M***	$225	
Efficiency	30-yr Average Cost/lb-TP	**$7,442**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$5,177**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$12,667**	

*58 hours/BMP at $73/hour
**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)
***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 2-G

37th Ave. NE and Pierce St. NE
Curb-Cut Rain Garden



Drainage Area – 4.3 acres
Location – Intersection of 37th Ave. NE and Pierce St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

	Curb-Cut Rain Garden		
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.09	0.3%
	TSS (lb/yr)	115	1.4%
	Volume (acre-feet/yr)	0.05	0.3%
Cost	Administration & Promotion Costs*	$4,234	
	Design & Construction Costs**	$6,876	
	Total Estimated Project Cost (2014)	**$11,110**	
	Annual O&M***	$225	
Efficiency	30-yr Average Cost/lb-TP	**$6,615**	
	30-yr Average Cost/1,000lb-TSS	**$5,177**	
	30-yr Average Cost/ac-ft Vol.	**$11,025**	

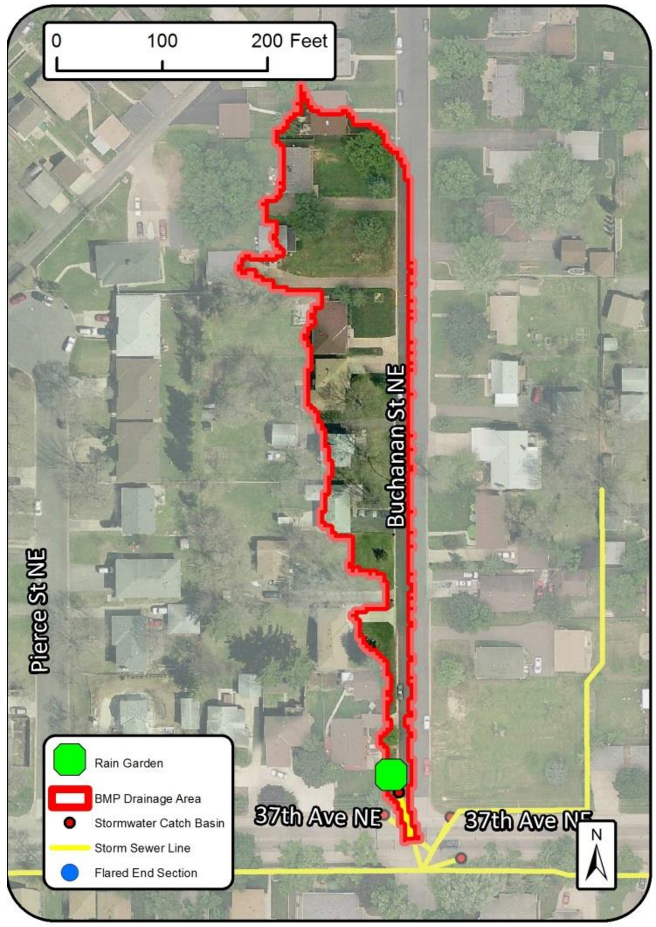
*58 hours/BMP at $73/hour

**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 2-H

37th Ave. NE and Buchanan St. NE - Curb-Cut Rain Garden



Drainage Area – 1.2 acres
Location – Intersection of 37th Ave. NE and Buchanan St. NE
Property Ownership – Private
Site Specific Information – A curb-cut rain garden was proposed at this location to maximize contributing drainage area and ensure close proximity to an existing catch basin if an underdrain would be required.

	Curb-Cut Rain Garden		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.06	0.2%
	TSS (lb/yr)	98	1.2%
	Volume (acre-feet/yr)	0.04	0.2%
Cost	**Administration & Promotion Costs***	$4,234	
	Design & Construction Costs**	$6,876	
	Total Estimated Project Cost (2014)	**$11,110**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$9,922**	
	30-yr Average Cost/1,000lb-TSS	**$6,075**	
	30-yr Average Cost/ac-ft Vol.	**$16,090**	

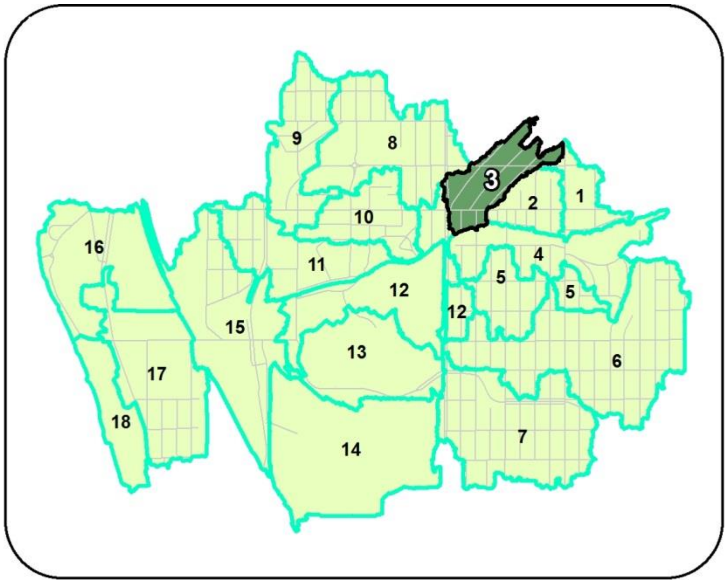
*58 hours/BMP at $73/hour

**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Catchment 3

Existing Catchment Summary	
Acres	60.0
Dominant Land Cover	Residential
Parcels	202
Volume (acre-feet/yr)	33.8
TP (lb/yr)	48.0
TSS (lb/yr)	13,092



CATCHMENT DESCRIPTION

This catchment runs diagonally between Reservoir Boulevard NE and Polk Street NE starting from 40th Ave. NE on the north border to Central Ave. NE and the railroad to the south. The catchment is primarily comprised of single family homes. There are a variety of multi-family homes spread throughout the catchment and the southwest corner of the catchment near Central Ave. NE consists entirely of businesses.

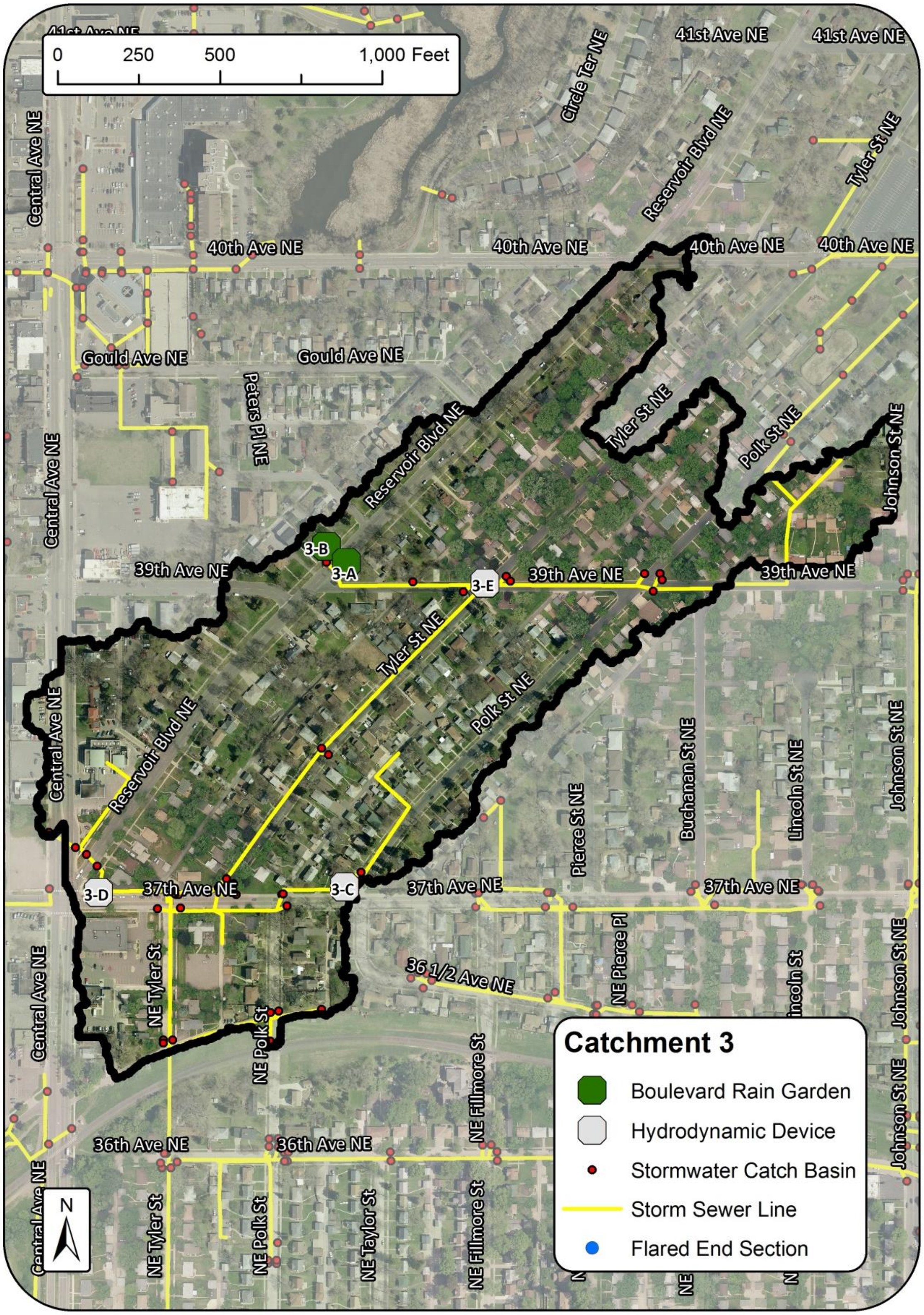
All stormwater generated in this catchment flows south overland and is collected in nearby catch basins. Once collected, the water is conveyed through stormwater pipes south where it connects to the primary stormwater infrastructure at Central Ave. NE.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed four times per year by the City of Columbia Heights.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	**Number of BMPs**	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	50.7	2.7	5%	**48.0**
	TSS (lb/yr)	14,323	1,231.0	9%	**13,092**
	Volume (acre-feet/yr)	33.8	0.0	0%	**33.8**

RETROFIT RECOMMENDATIONS



Project ID: 3-A

Boulevard Rain Garden –
E Side Reservoir Blvd. NE

Drainage Area – 4.0 acres
Location – Basin is positioned within the existing boulevard on the east side of Reservoir Blvd. NE north of 39th Ave. NE.
Property Ownership – Private
Site Specific Information – A 250 sq-ft boulevard cub-cut rain garden with an underdrain was modeled for this site. The existing boulevard is wide enough (i.e. 10') to accommodate a rain garden.

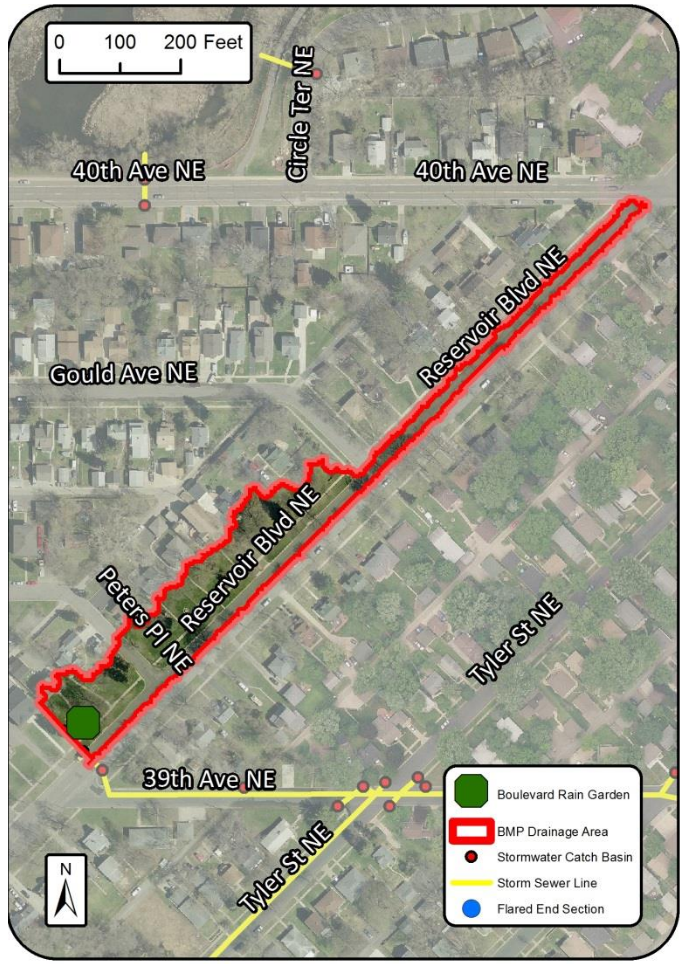
Boulevard Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.2	0.4%
	TSS (lb/yr)	223	1.7%
	Volume (acre-feet/yr)	0.1	0.3%
Cost	Administration & Promotion Costs*		$2,920
	Design & Construction Costs**		$6,876
	Total Estimated Project Cost (2014)		**$9,796**
	Annual O&M***		$225
Efficiency	30-yr Average Cost/lb-TP	**$2,758**	
	30-yr Average Cost/1,000lb-TSS	**$2,473**	
	30-yr Average Cost/ac-ft Vol.	**$5,515**	

*40 hours at $73/hour
**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)
***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 3-B

Boulevard Rain Garden –
W Side of Reservoir Blvd. NE



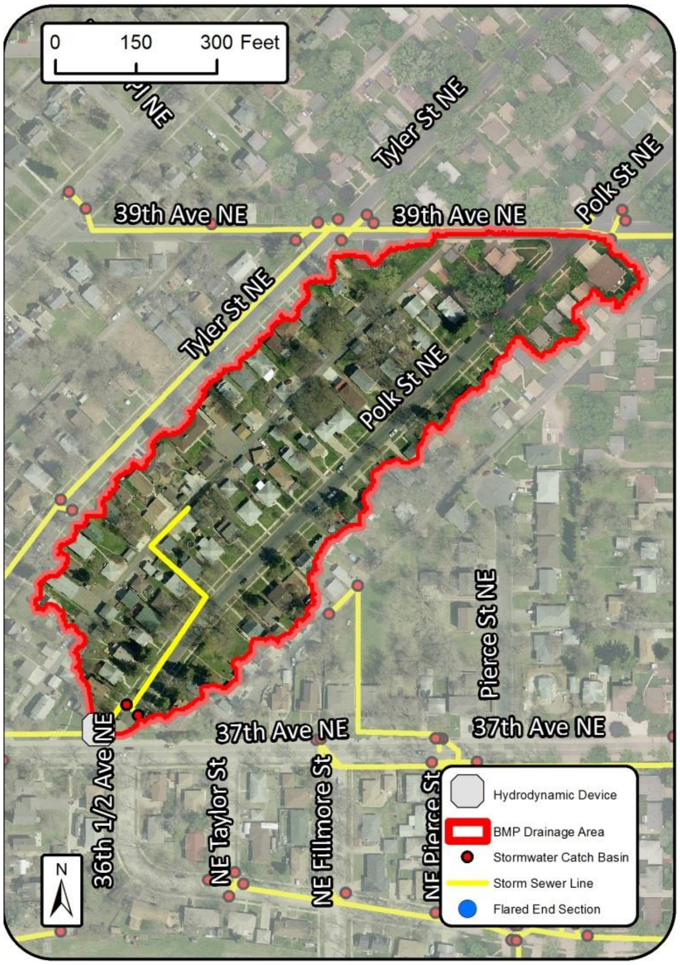
Drainage Area – 2.1 acres
Location – Basin is positioned within the existing boulevard on the west side of Reservoir Blvd. NE north of 39th Ave. NE.
Property Ownership – Private
Site Specific Information – A 250 sq-ft boulevard cub-cut rain garden with an underdrain was modeled for this site. The existing boulevard is wide enough (i.e. 10') to accommodate a rain garden.

Boulevard Rain Garden			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	250	sq-ft
	TP (lb/yr)	0.1	0.2%
	TSS (lb/yr)	185	1.4%
	Volume (acre-feet/yr)	0.1	0.3%
Cost	**Administration & Promotion Costs***	$2,920	
	Design & Construction Costs**	$6,876	
	Total Estimated Project Cost (2014)	**$9,796**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,515**	
	30-yr Average Cost/1,000lb-TSS	**$2,981**	
	30-yr Average Cost/ac-ft Vol.	**$5,515**	

*40 hours at $73/hour
**($24/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)
***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 3-C

37th Ave. NE and Polk St. NE
Hydrodynamic Device



Drainage Area – 9.6 acres
Location – Intersection of 37th Ave. NE and Polk St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north and east of 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.8	1.7%
	TSS (lb/yr)	276	2.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,623**	
	30-yr Average Cost/1,000lb-TSS	**$16,299**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 3-D

37th Ave. NE and Reservoir Blvd. NE Hydrodynamic Dev.

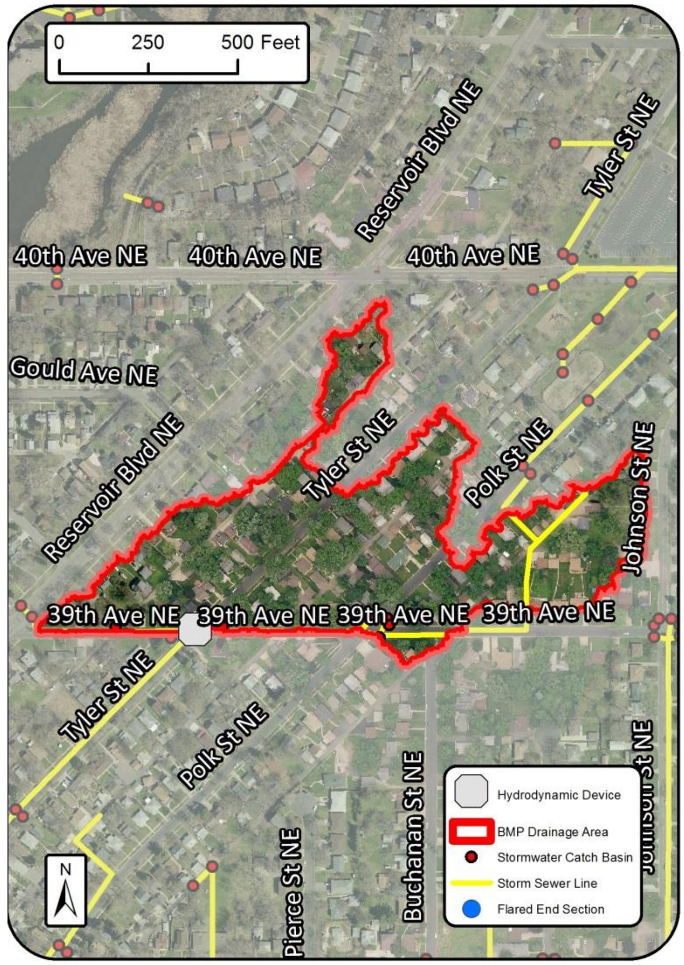
Drainage Area – 9.3 acres
Location – Intersection of 37th Ave. NE and Reservoir Blvd. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north and east of 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.8	1.7%
	TSS (lb/yr)	401	3.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$5,623**	
	30-yr Average Cost/1,000lb-TSS	**$11,218**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 3-E

39th Ave. NE and Tyler St. NE
Hydrodynamic Device



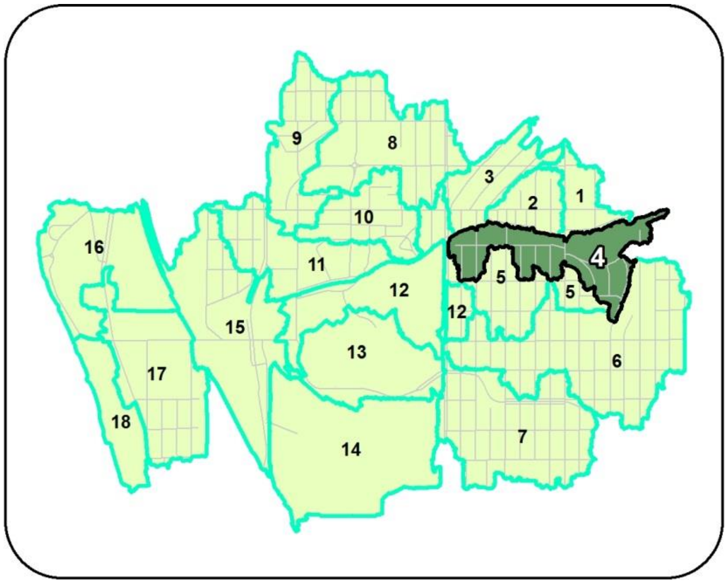
Drainage Area – 14.6 acres
Location – Intersection of 39th Ave. NE and Tyler St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 39th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	2.1%
	TSS (lb/yr)	350	2.7%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$12,853**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment 4

Existing Catchment Summary	
Acres	102.5
Dominant Land Cover	Residential
Parcels	93
Volume (acre-feet/yr)	41.7
TP (lb/yr)	70.1
TSS (lb/yr)	17,593



CATCHMENT DESCRIPTION

This catchment is bisected east to west by 36th Ave. NE and stretches from Central Ave. NE on the west to NE Cleveland Street on the east. While the railroad makes up the orthern border, elevation in the southern portion of the catchment causes the southern border to vary from as far south as Waite Park Elementary to 36th Ave. NE. Other than the open space of the railroad to the north this catchment is comprised entirely of single family homes.

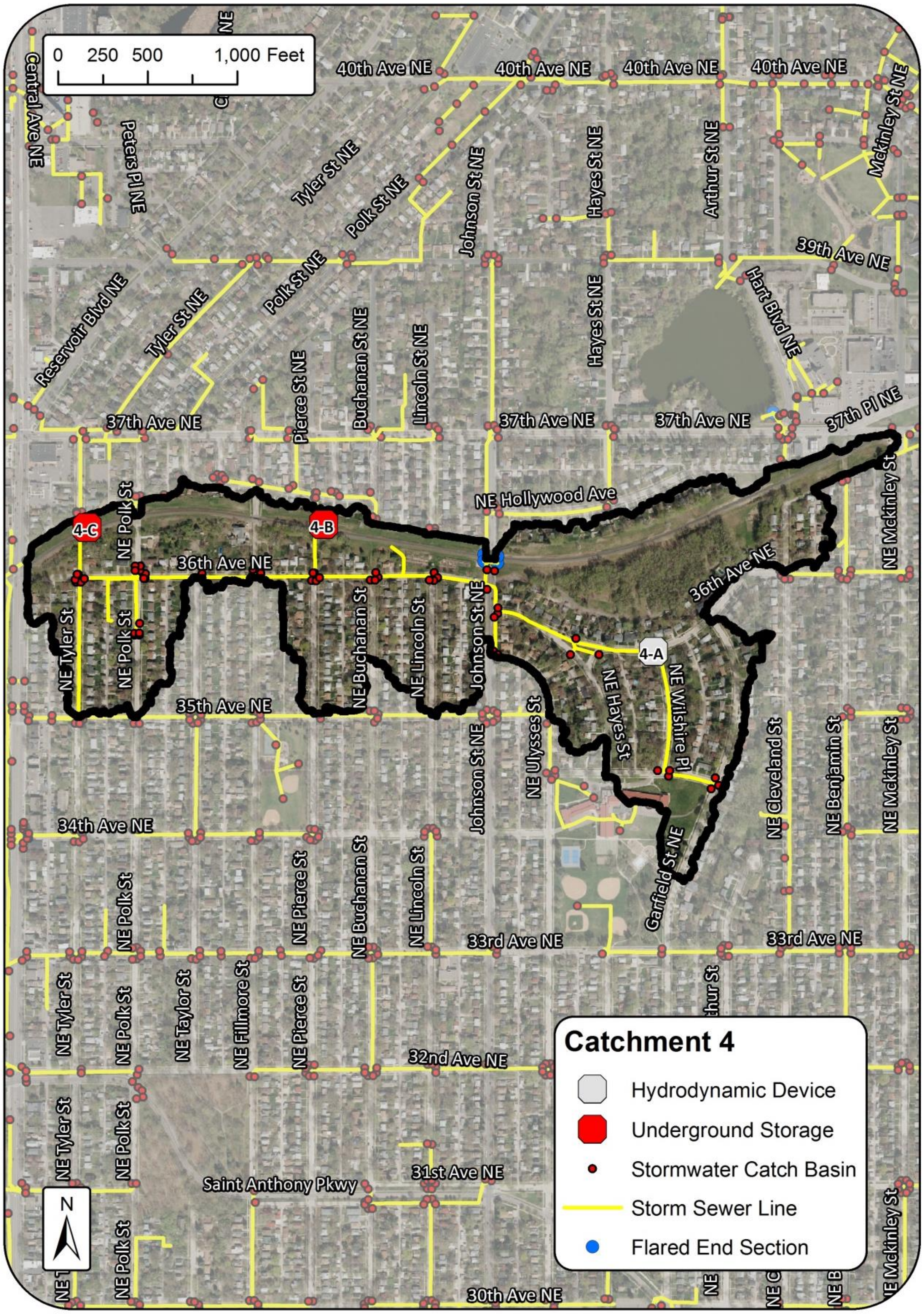
All stormwater generated in this catchment flows overland towards 36th Ave. NE where it is directed to catch basins and conveyed via storm sewers west to the primary stormwater infrastructure at Central Ave. NE.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

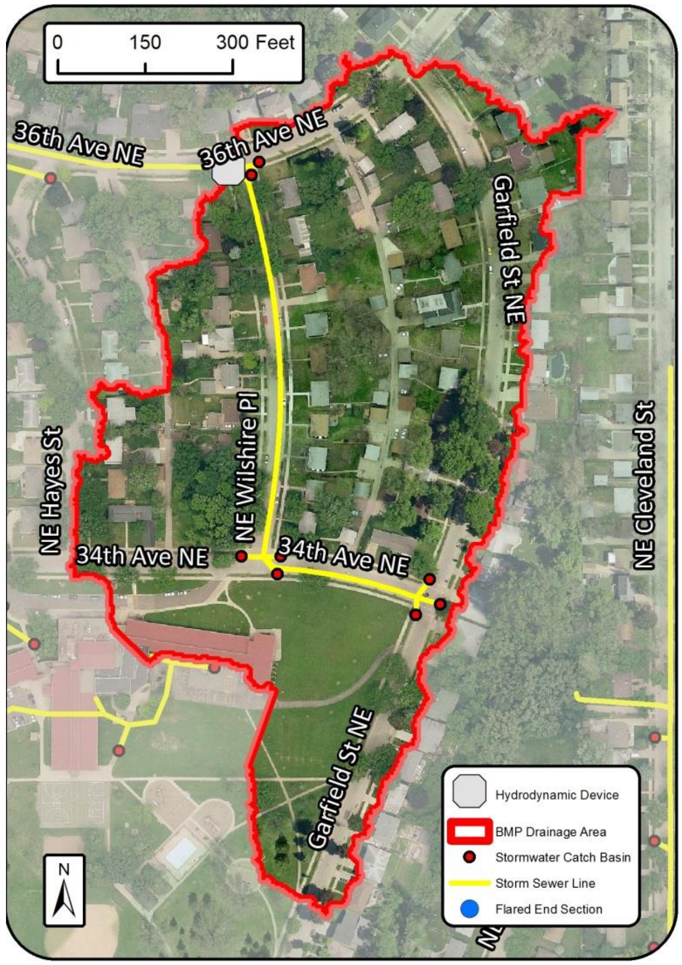
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	74.9	4.8	6%	**70.1**
	TSS (lb/yr)	19,712	2,119.0	11%	**17,593**
	Volume (acre-feet/yr)	41.7	0.0	0%	**41.7**

RETROFIT RECOMMENDATIONS



Project ID: 4-A

36th Ave. NE and Wilshire Pl. NE Hydrodynamic Device



Drainage Area – 16.6 acres
Location – Intersection of 36th Ave. NE and Wilshire Pl. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area south of 36th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.2	1.7%
	TSS (lb/yr)	436	2.5%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$3,749**	
	30-yr Average Cost/1,000lb-TSS	**$10,317**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

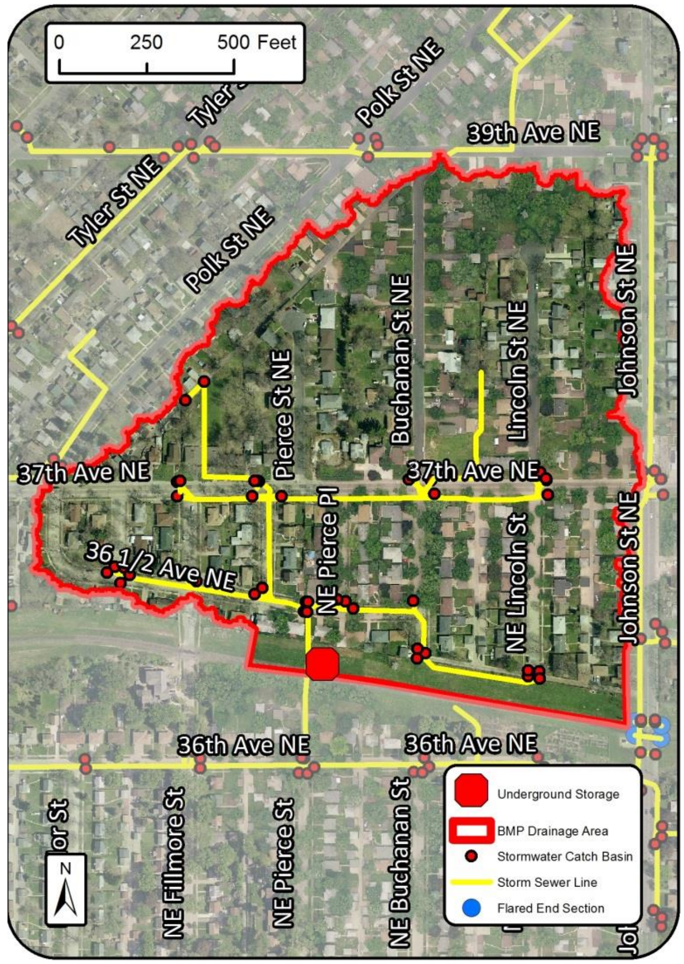
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 4-B

Underground Storage to treat Catchment 2



Drainage Area – 40.5 acres
Location – South of the residential properties along 36 ½ Ave. NE and east of Fillmore St. NE., positioned north of the railroad tracks
Property Ownership – Private (Soo Line RR)
Site Specific Information – A combination of aggregate rock and perforated CMP (corrugated metal pipe) could be installed to provide storage and treatment for stormwater runoff. Stormwater could be diverted to the aggregate rock and CMP from the 36" storm sewer line through a sump at the inlet to provide pretreatment. Aggregate and pipe storage was estimated based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. To treat the 1.17" 24-hour event for Catchment 2 (40.5 total acres), 44,411 cu-ft. of water volume storage will be needed. To achieve this, a 200' long, 28' wide, and 16' deep aggregate basin is proposed with two in-parallel 96" CMPs running the length of the basin. This configuration provides 44,420 cu-ft. of storage.

	Underground Storage		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
Treatment	**Total Size of BMPs**	44,420	cu-ft
Treatment	**TP (lb/yr)**	13.8	42.6%
Treatment	**TSS (lb/yr)**	4,167	51.4%
Treatment	**Volume (acre-feet/yr)**	6.9	35.2%
Cost	**Administration & Promotion Costs***	$5,840	
Cost	**Design & Construction Costs****	$496,000	
Cost	**Total Estimated Project Cost (2014)**	**$501,840**	
Cost	**Annual O&M*****	$2,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,357**	
Efficiency	**30-yr Average Cost/1,000lb-TSS**	**$4,494**	
Efficiency	**30-yr Average Cost/ac-ft Vol.**	**$2,714**	

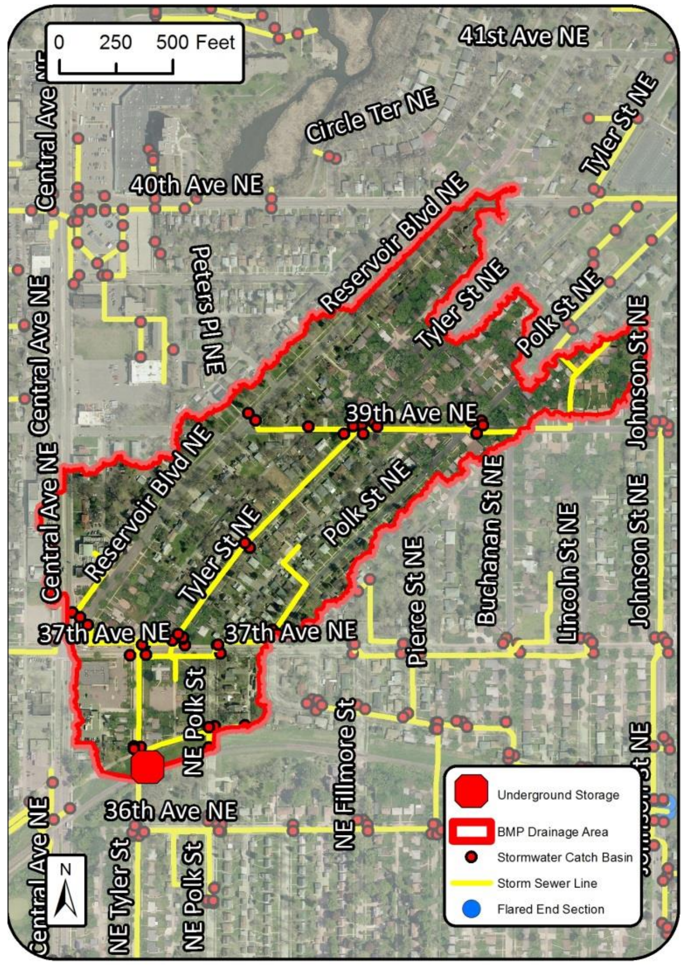
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Project ID: 4-C

Underground Storage to treat Catchment 3



Drainage Area – 60.0 acres
Location – South of the residential properties and west of Polk St. NE., north of RR
Property Ownership – Private (Soo Line RR)
Site Specific Information – A combination of aggregate rock and perforated CMP (corrugated metal pipe) could be installed to provide storage and treatment for stormwater runoff. Stormwater would be diverted to the aggregate rock and CMP from the 27" storm sewer line through a sump at the inlet to provide pretreatment. Aggregate and pipe storage was estimated based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. To treat the 1.17" 24-hour event for Catchment 3 (60.0 total acres), 77,523 cu-ft. of water volume storage will be needed. To achieve this, a 256' long, 32' wide, and 18' deep aggregate basin with two in-parallel 120" CMPs running the length of the basin is needed. This configuration provides 77,752 cu-ft. of storage.

Underground Storage

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	77,752	cu-ft
	TP (lb/yr)	18.6	38.8%
	TSS (lb/yr)	6,326	48.3%
	Volume (acre-feet/yr)	8.9	26.3%
Cost	Administration & Promotion Costs*	$5,840	
	Design & Construction Costs**	$636,125	
	Total Estimated Project Cost (2014)	**$641,965**	
	Annual O&M***	$2,000	
Efficiency	30-yr Average Cost/lb-TP	**$1,258**	
	30-yr Average Cost/1,000lb-TSS	**$3,699**	
	30-yr Average Cost/ac-ft Vol.	**$2,629**	

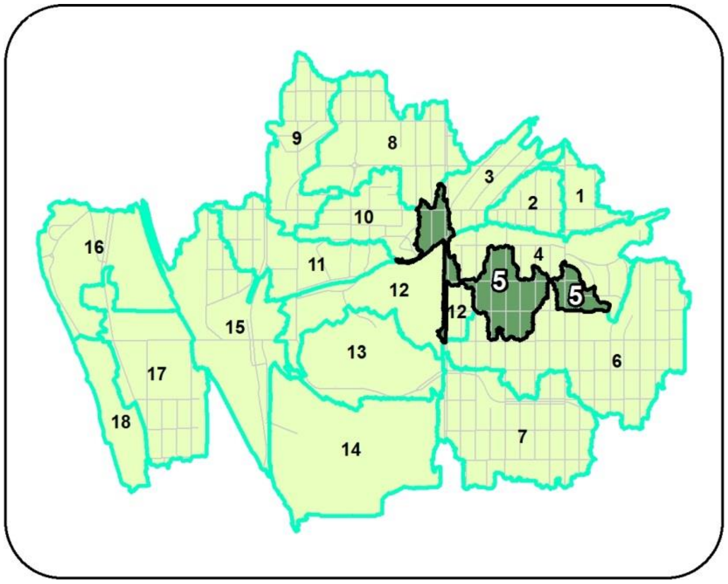
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Catchment 5

Existing Catchment Summary	
Acres	93.0
Dominant Land Cover	Residential
Parcels	508
Volume (acre-feet/yr)	47.5
TP (lb/yr)	74.6
TSS (lb/yr)	20,341



CATCHMENT DESCRIPTION

This catchment extends from Waite Park Elementary on the eastern border to Central Ave. NE as the western border. It is bisected by 35th Ave. NE and the northern and southern edges of the catchment range from as far north as 36th Ave. NE and south to 33rd Ave. NE. There are a few apartment complexes located along Central Ave. NE, though the catchment is primarily made up of single family homes. Also located within this catchment are Waite Park Elementary School and Cavell Playground.

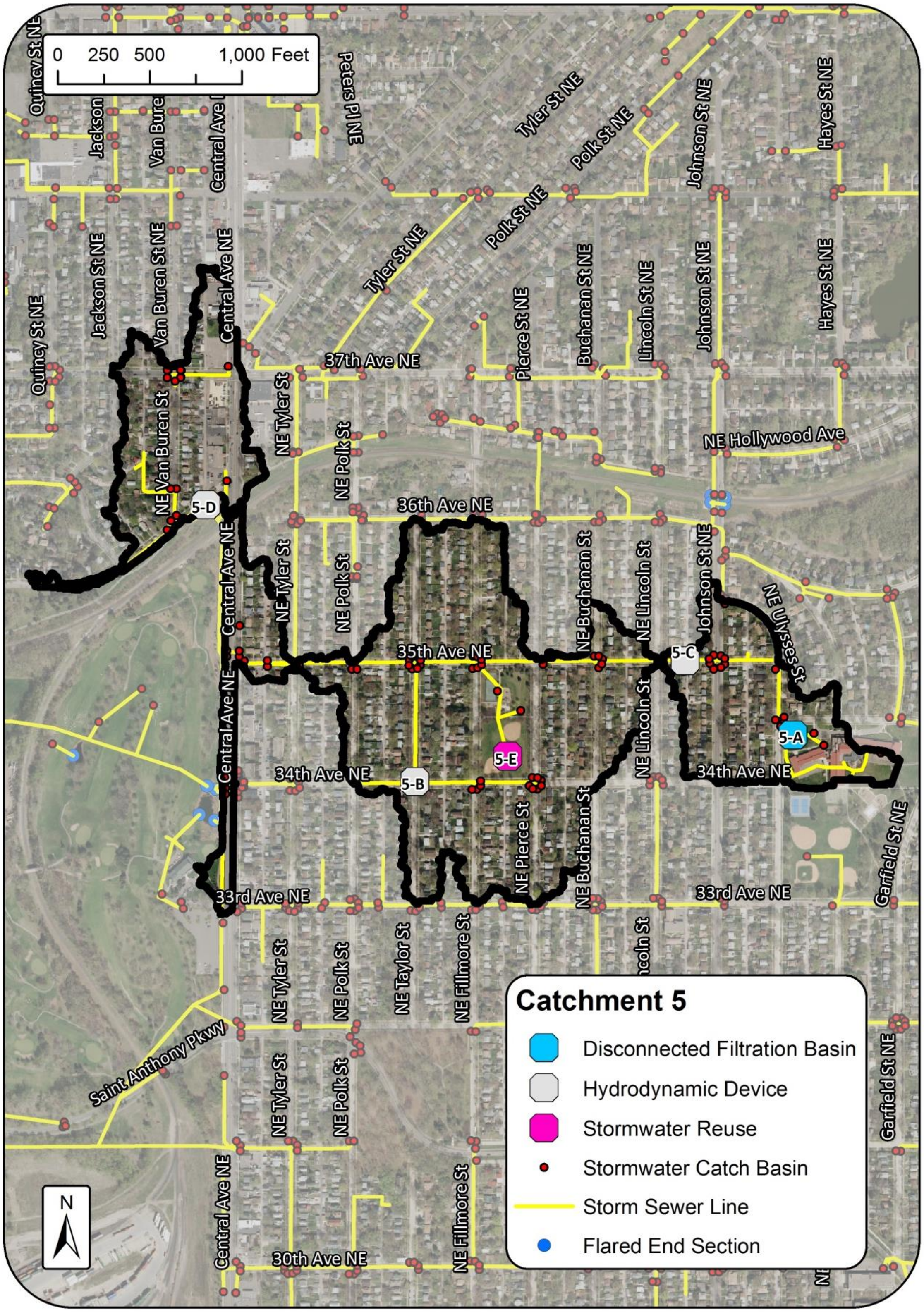
Most of the stormwater generated in this catchment flows overland toward 35th Ave. NE. The water is collected by catch basins while enroute to 35th Ave. NE and transferred through storm sewers to the primary stormwater infrastructure at Central Ave.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

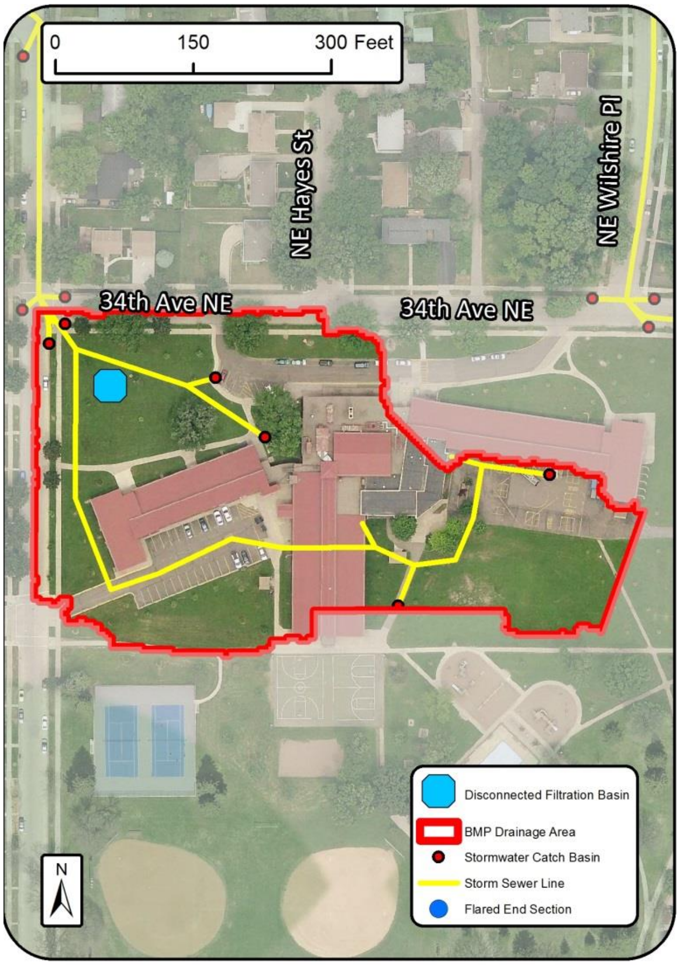
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	**Number of BMPs**	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	79.5	4.9	6%	**74.6**
	TSS (lb/yr)	22,522	2,181.0	10%	**20,341**
	Volume (acre-feet/yr)	47.5	0.0	0%	**47.5**

RETROFIT RECOMMENDATIONS



Project ID: 5-A1 and 5-A2

Disconnect Filtration Basin – Waite Park Elementary



Drainage Area – 4.1 acres
Location – Southeast corner of intersection between 34th Ave. NE and Ulysses St. NE. Basin is positioned on the Waite Park Elementary campus.
Property Ownership – Public (Waite Park Elementary)
Site Specific Information – A filtration basin on the Waite Park Elementary campus was proposed to treat runoff. The northeast corner of the campus has a large open space that could accommodate a large rain garden. Two sizes (2,000 sq-ft [5-A1] and 4,000 sq-ft [5-A2]) were modeled to provide treatment for the 4.1 acre drainage area. The storm sewer lines draining the campus could be daylighted into the basin. Overflow from the filtration basin could be directed back into the storm sewer system on the downstream end of the basin.

	Disconnect Filtration Basin				
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1		1	
	Total Size of BMPs	2,000	sq-ft	4,000	sq-ft
	TP (lb/yr)	0.4	0.5%	0.7	0.9%
	TSS (lb/yr)	790	3.9%	1,079	5.3%
	Volume (acre-feet/yr)	0.4	0.8%	0.6	1.3%
Cost	**Administration & Promotion Costs***	$2,920		$2,920	
	Design & Construction Costs**	$30,876		$60,876	
	Total Estimated Project Cost (2014)	**$33,796**		**$63,796**	
	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,379**		**$3,359**	
	30-yr Average Cost/1,000lb-TSS	**$1,711**		**$2,179**	
	30-yr Average Cost/ac-ft Vol.	**$3,379**		**$3,919**	

*40 hours at $73/hour

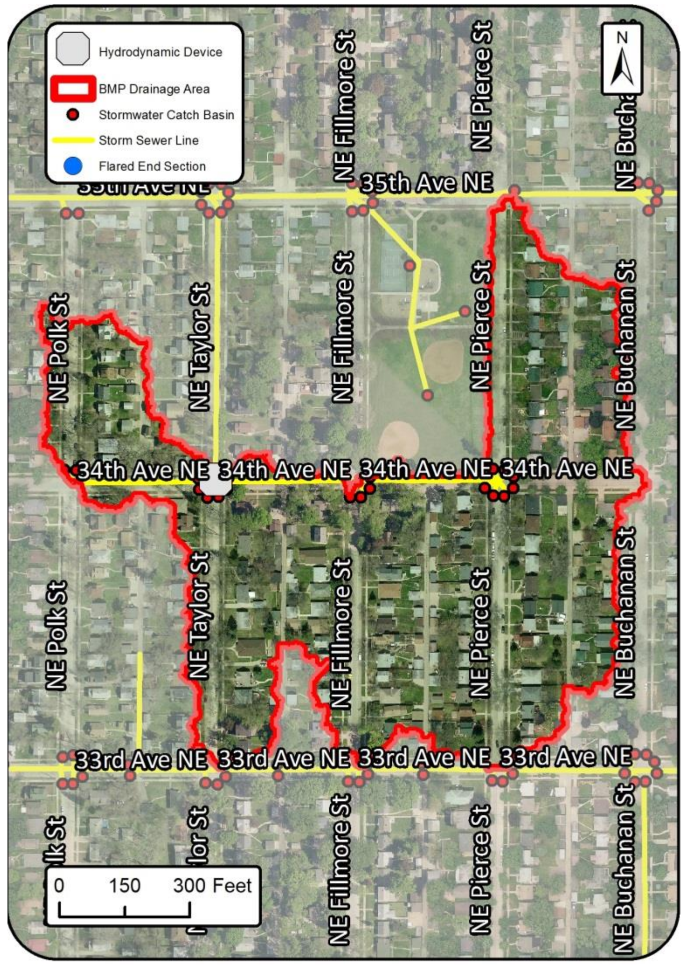
**($15/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 5-B

34th Ave. NE and Taylor St. NE
Hydrodynamic Device

Drainage Area – 20.0 acres
Location – Intersection of 34th Ave. NE and Taylor St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area south of 34th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.



Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.2	1.6%
	TSS (lb/yr)	445	2.2%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$3,749**	
	30-yr Average Cost/1,000lb-TSS	**$10,109**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 5-C

35th Ave. NE and Lincoln St. NE Hydrodynamic Device

Drainage Area – 16.4 acres
Location – Intersection of 35th Ave. NE and Lincoln St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area southeast of 35th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location. This location would provide treatment to a section of Waite Park Elementary as well as sections of Ulysses St. NE and 35th Ave. NE.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.2	1.6%
	TSS (lb/yr)	462	2.3%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,749**	
	30-yr Average Cost/1,000lb-TSS	**$9,737**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 5-D

Columbia Blvd. NE and Van Buren St. NE Hydrodynamic Device

Drainage Area – 14.5 acres
Location – East of intersection of Columbia Ave. NE and Van Buren St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of Columbia Blvd. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	1.3%
	TSS (lb/yr)	420	2.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$10,710**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

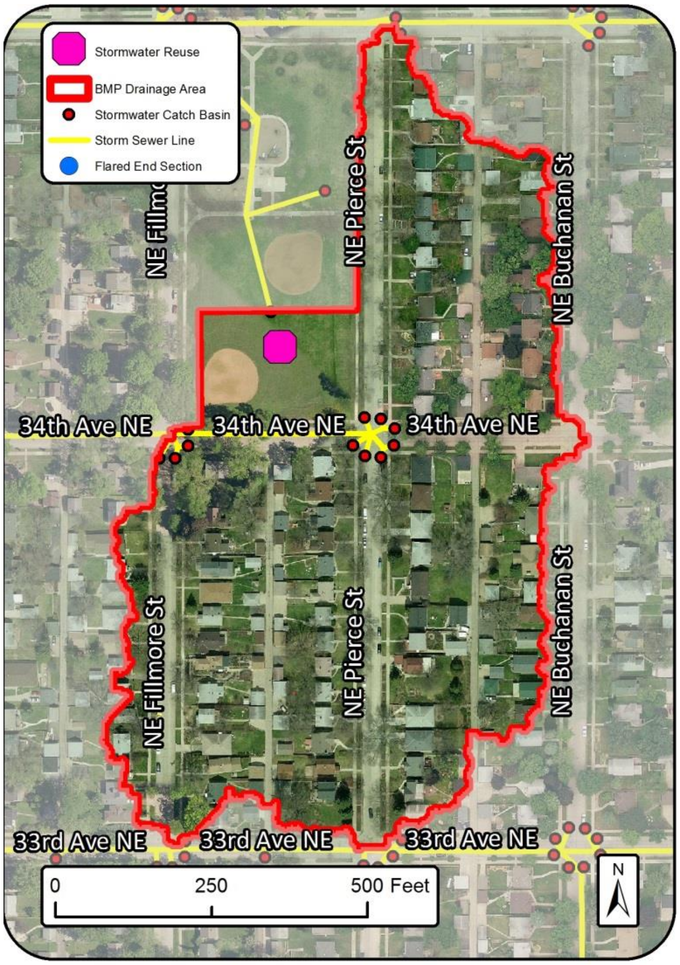
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 5-E

Water Reuse in Cavell Playground Park



Drainage Area – 13.2 acres
Location – Within Cavell Park
Property Ownership – Public (City of Minneapolis Park and Recreation Board)
Site Specific Information – A water reuse system has been proposed in Cavell Park. An irrigation system (does not currently exist) could reuse the rainfall captured in this system which would provide water quality treatment as well as water conservation benefits. An underground cistern was sized based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. To treat the 1.17" 24-hour event for the 13.2 acre contributing drainage area, 47,090 gallons of storage is required. Therefore, a 50,000 gallon cistern was proposed.

Stormwater Reuse

	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	50,000	gallons
	TP (lb/yr)	3.9	5.2%
	TSS (lb/yr)	1,079	5.3%
	Volume (acre-feet/yr)	2.9	6.1%
Cost	**Administration & Promotion Costs***	$5,840	
	Design & Construction Costs**	$297,500	
	Total Estimated Project Cost (2014)	**$303,340**	
	Annual O&M***	$3,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,362**	
	30-yr Average Cost/1,000lb-TSS	**$12,151**	
	30-yr Average Cost/ac-ft Vol.	**$4,521**	

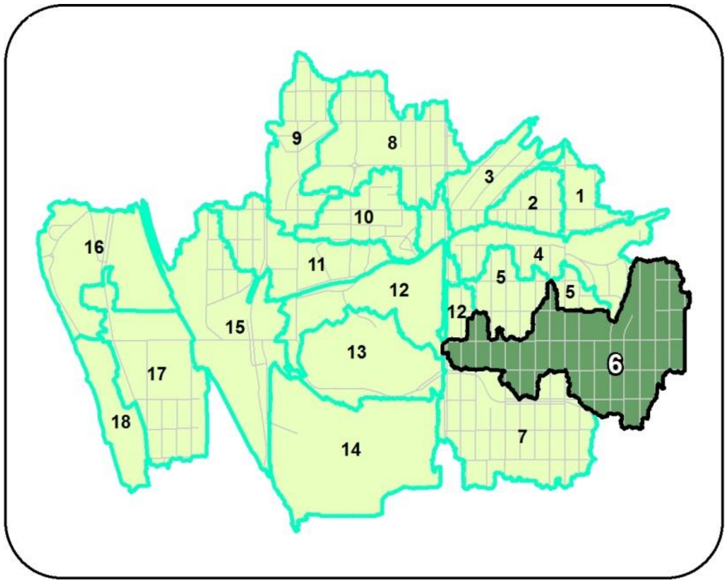
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Catchment 6

Existing Catchment Summary	
Acres	226.8
Dominant Land Cover	Residential
Parcels	1,208
Volume (acre-feet/yr)	108.6
TP (lb/yr)	187.5
TSS (lb/yr)	49,704



CATCHMENT DESCRIPTION

This catchment is bordered by Central Ave. NE on the west and Stinson Blvd. NE on the east. The northern and southern borders vary between 30th Ave. NE and 35th Ave. NE. Other than the few small businesses located along sections of Stinson Blvd. NE, Johnson St. NE, and Central Ave. NE, the catchment is primarily comprised of single family homes.

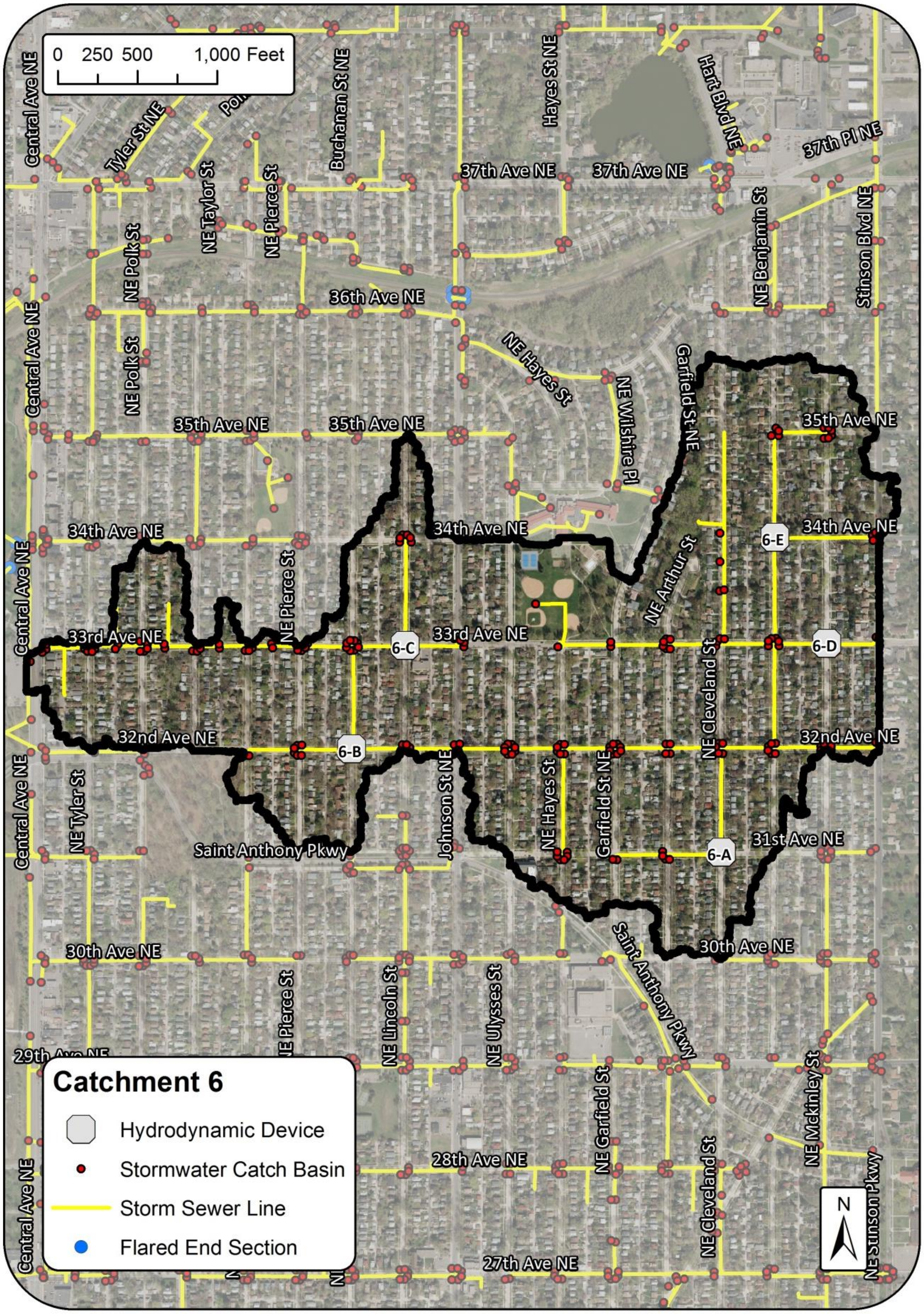
All stormwater runoff generated in this catchment flows overland and is intercepted by nearby catch basins. It is then conveyed via storm sewers to the main stormwater system located at Central Ave. NE.

EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

	Existing Conditions	**Base Loading**	**Treatment**	**Net Treatment %**	**Existing Loading**
Treatment	**Number of BMPs**	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	200.7	13.2	7%	**187.5**
	TSS (lb/yr)	55,468	5,764.0	10%	**49,704**
	Volume (acre-feet/yr)	108.6	0.0	0%	**108.6**

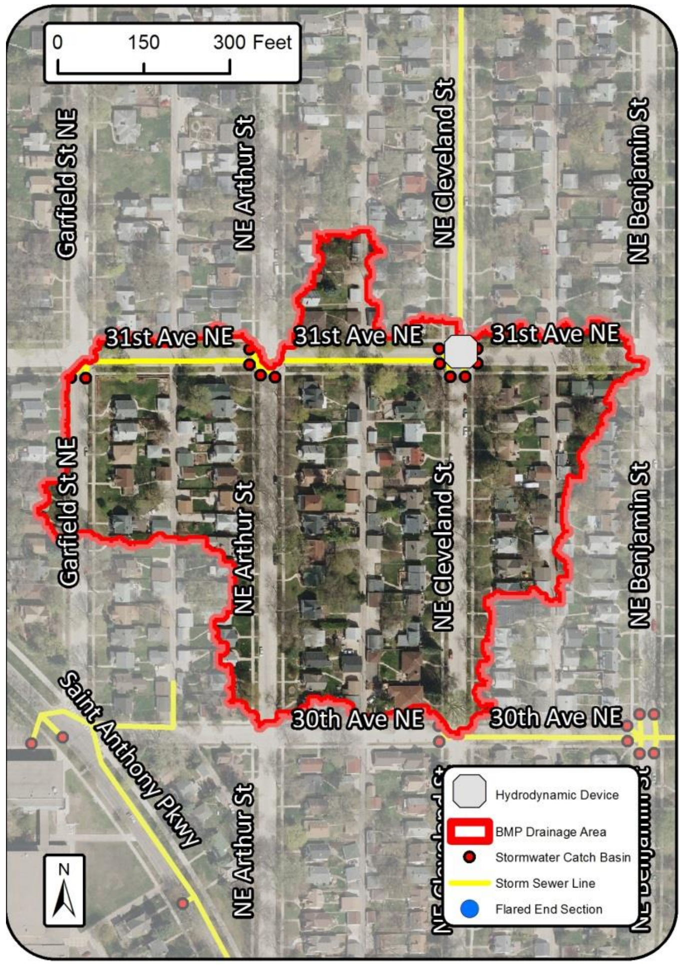
RETROFIT RECOMMENDATIONS



Project ID: 6-A

31st Ave. NE and Cleveland St. NE Hydrodynamic Device

Drainage Area – 11.7 acres
Location – Intersection of 31st Ave. NE and Cleveland St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area south of 31st Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.



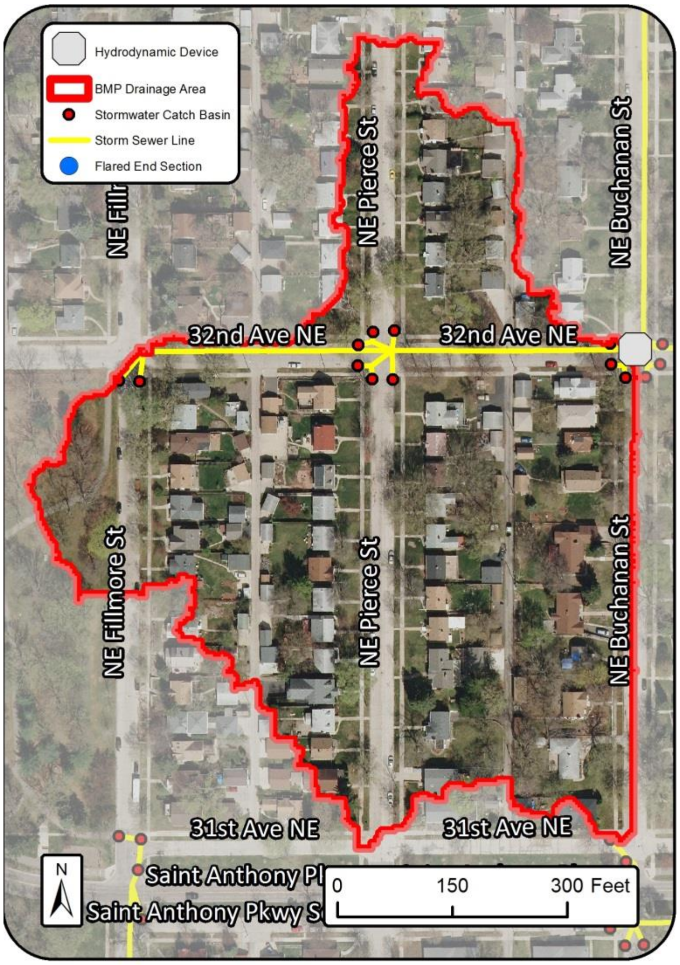
Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.9	0.5%
	TSS (lb/yr)	336	0.7%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$4,998**	
	30-yr Average Cost/1,000lb-TSS	**$13,388**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 6-B

32nd Ave. NE and Buchanan St. NE Hydrodynamic Device



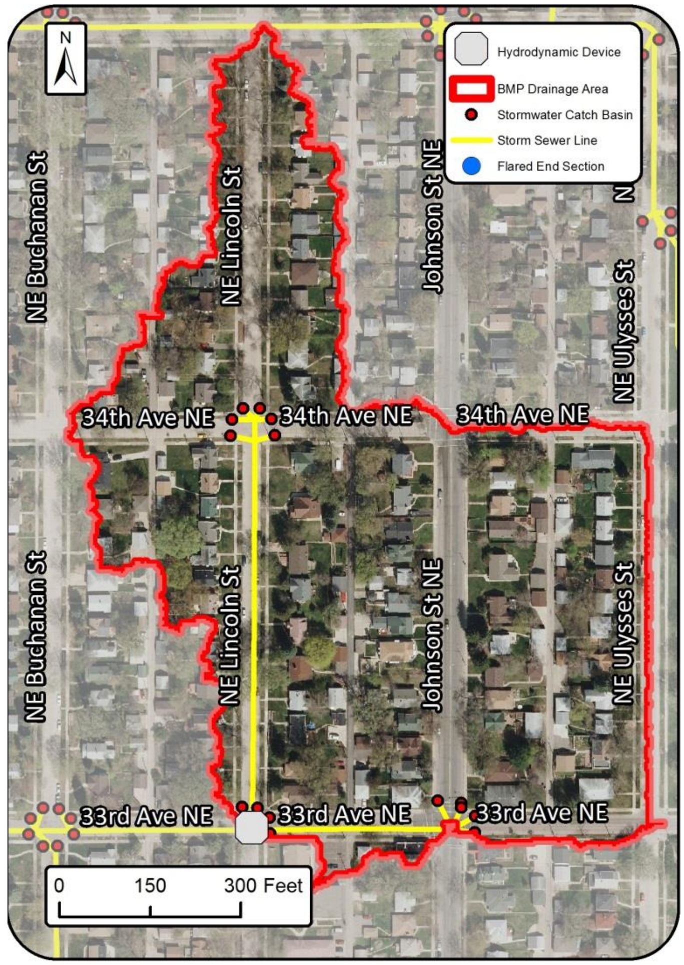
Drainage Area – 10.8 acres
Location – Intersection of 32nd Ave. NE and Buchanan St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area south of 32nd Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.9	0.5%
	TSS (lb/yr)	317	0.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,998**	
	30-yr Average Cost/1,000lb-TSS	**$14,191**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 6-C

33rd Ave. NE and Lincoln St. NE Hydrodynamic Device



Drainage Area – 16.6 acres
Location – Intersection of 33rd Ave. NE and Lincoln St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 33rd Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.1	0.6%
	TSS (lb/yr)	406	0.8%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,089**	
	30-yr Average Cost/1,000lb-TSS	**$11,080**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

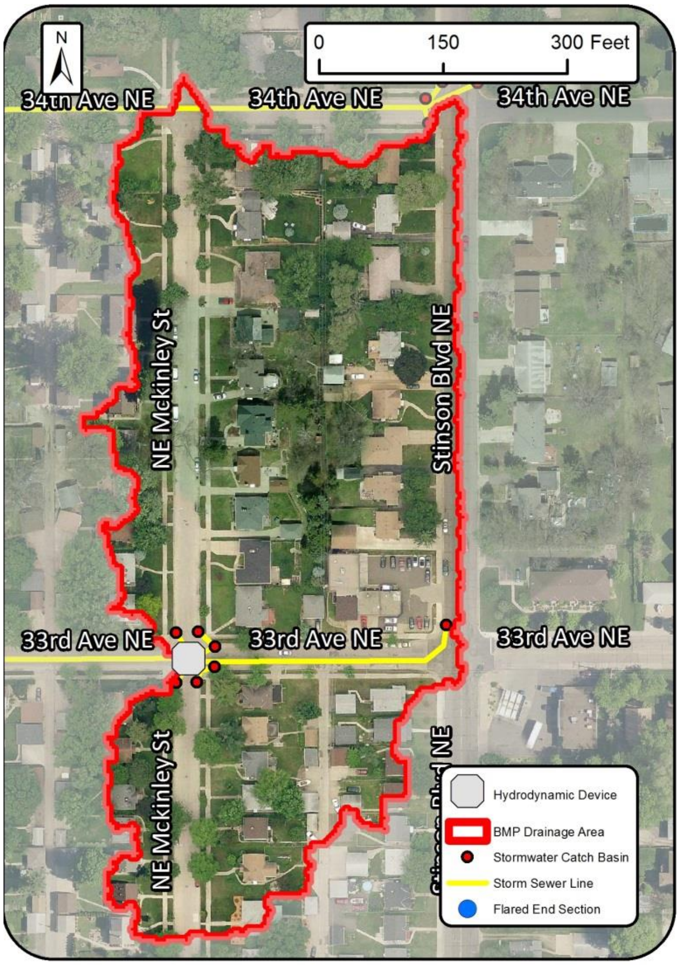
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 6-D

33rd Ave. NE and McKinley St. NE Hydrodynamic Device



Drainage Area – 8.1 acres
Location – Intersection of 33rd Ave. NE and McKinley St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area east of McKinley St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.7	0.4%
	TSS (lb/yr)	286	0.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,426**	
	30-yr Average Cost/1,000lb-TSS	**$15,729**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

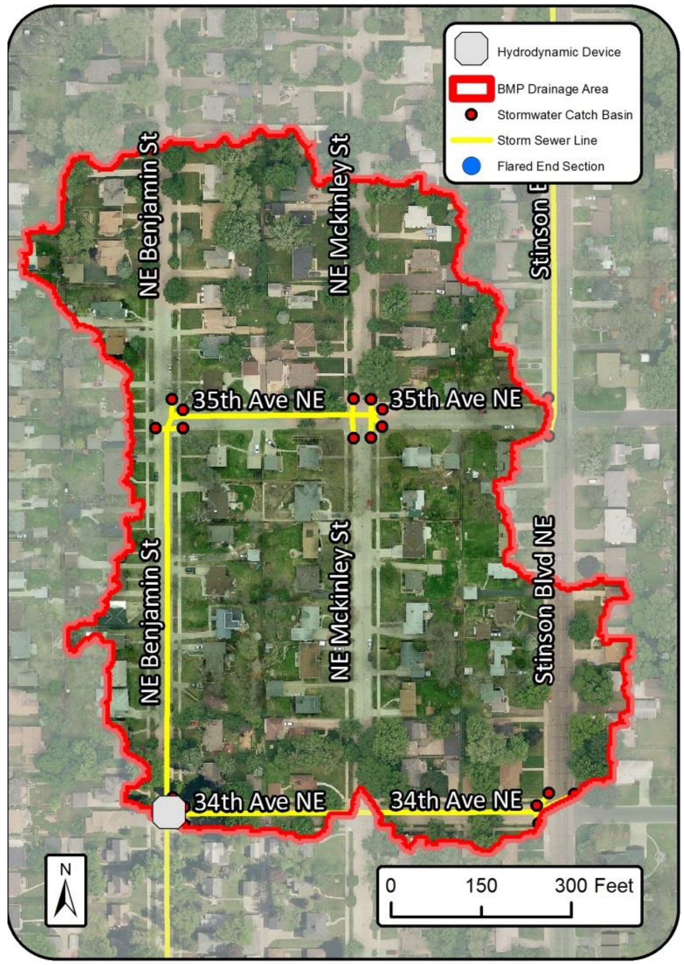
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 6-E

34th Ave. NE and Benjamin St. NE Hydrodynamic Device



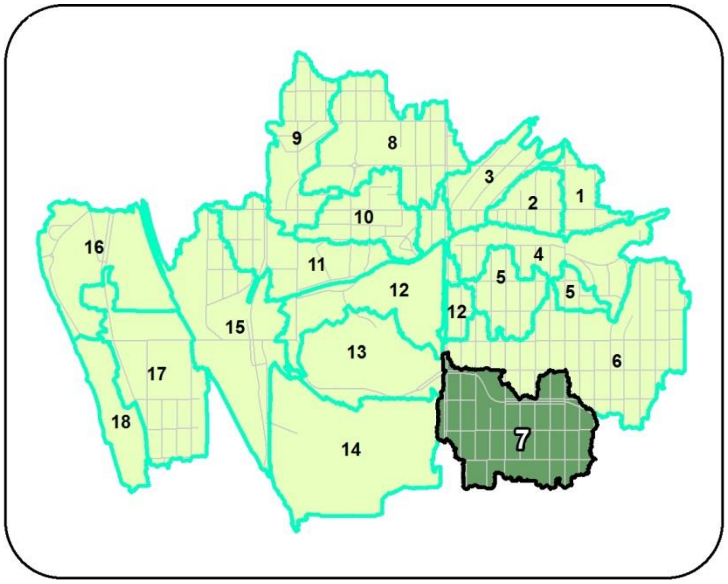
Drainage Area – 18.7 acres
Location – Intersection of 34th Ave. NE and Benjamin St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 34th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device			
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.2	0.6%
	TSS (lb/yr)	429	0.9%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,749**	
	30-yr Average Cost/1,000lb-TSS	**$10,486**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment 7

Existing Catchment Summary	
Acres	165.9
Dominant Land Cover	Residential
Parcels	800
Volume (acre-feet/yr)	86.4
TP (lb/yr)	135.7
TSS (lb/yr)	36,997



CATCHMENT DESCRIPTION

This catchment is bordered by Central Ave. NE to the west and Hayes St. NE on the east. The southern and northern borders are 28th Ave. NE and St. Anthony Pkwy., respectively. Land use within this catchment is primarily single-family residential lots. Also within the catchment are Deming Heights Park and Audubon Park as well as a number of businesses along Johnson St. NE.

Stormwater runoff generated within this catchment flows overland and is intercepted by catch basins. Once collected, water is conveyed via storm sewers to the primary infrastructure at Central Ave. NE.

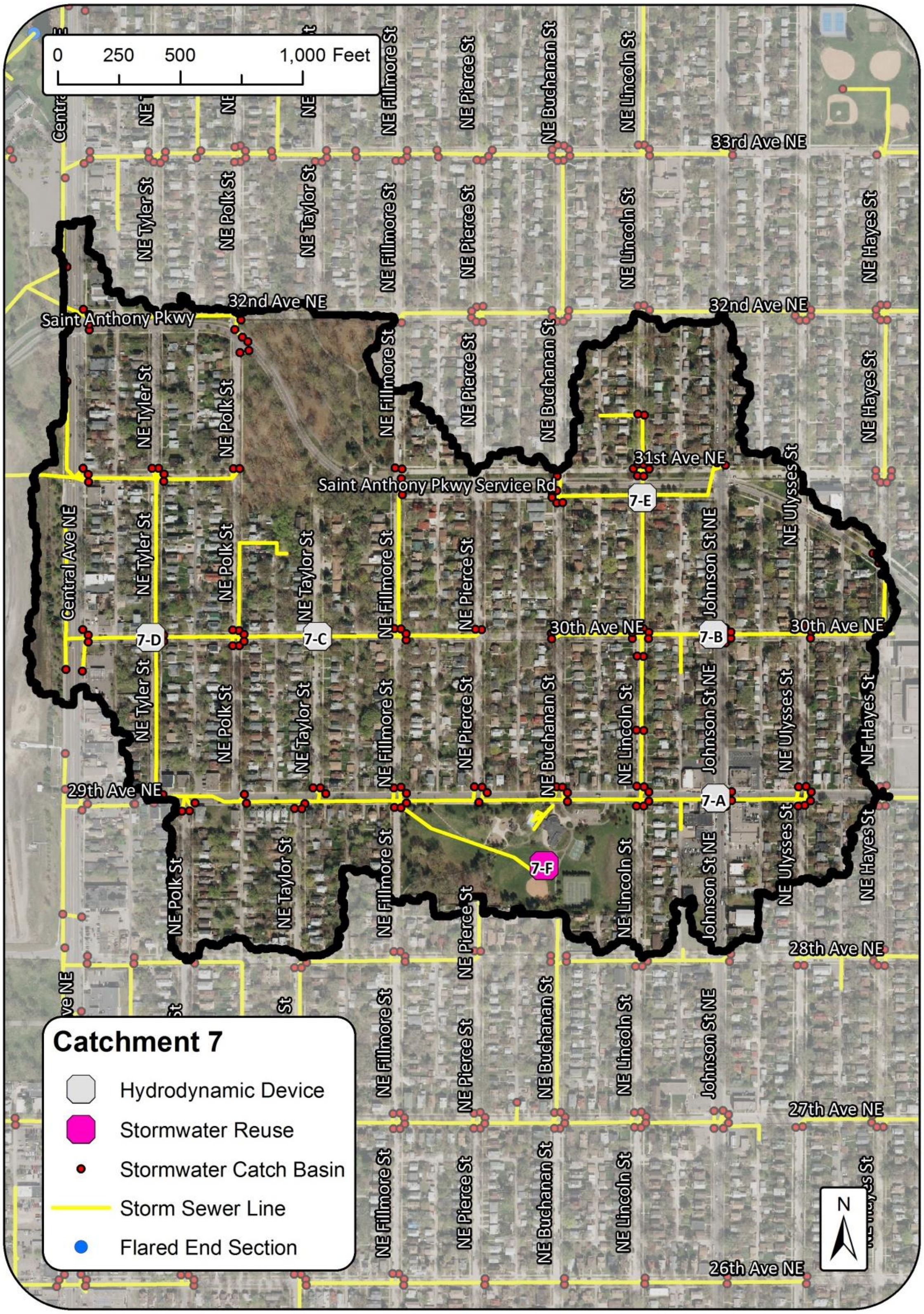
EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

Existing Conditions

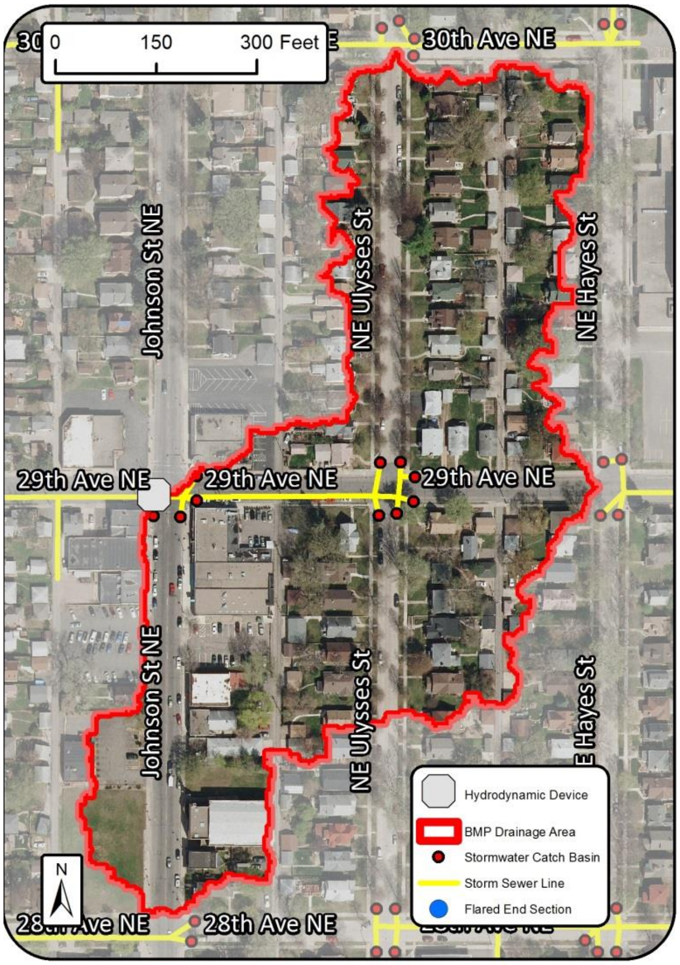
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	144.9	9.2	6%	**135.7**
	TSS (lb/yr)	41,117	4,120	10%	**36,997**
	Volume (acre-feet/yr)	86.4	0.0	0%	**86.4**

RETROFIT RECOMMENDATIONS



Project ID: 7-A

29th Ave. NE and Johnson St. NE Hydrodynamic Device



Drainage Area – 11.5 acres
Location – Intersection of 29th Ave. NE and Johnson St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area east of Johnson St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.9	0.7%
	TSS (lb/yr)	377	1.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,998**	
	30-yr Average Cost/1,000lb-TSS	**$11,932**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 7-B

30th Ave. NE and Johnson St. NE Hydrodynamic Device

Drainage Area – 13.7 acres
Location – Intersection of 30th Ave. NE and Johnson St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area east of Johnson St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	0.7%
	TSS (lb/yr)	382	1.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$11,776**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 7-C

30th Ave. NE and Taylor St. NE
Hydrodynamic Device

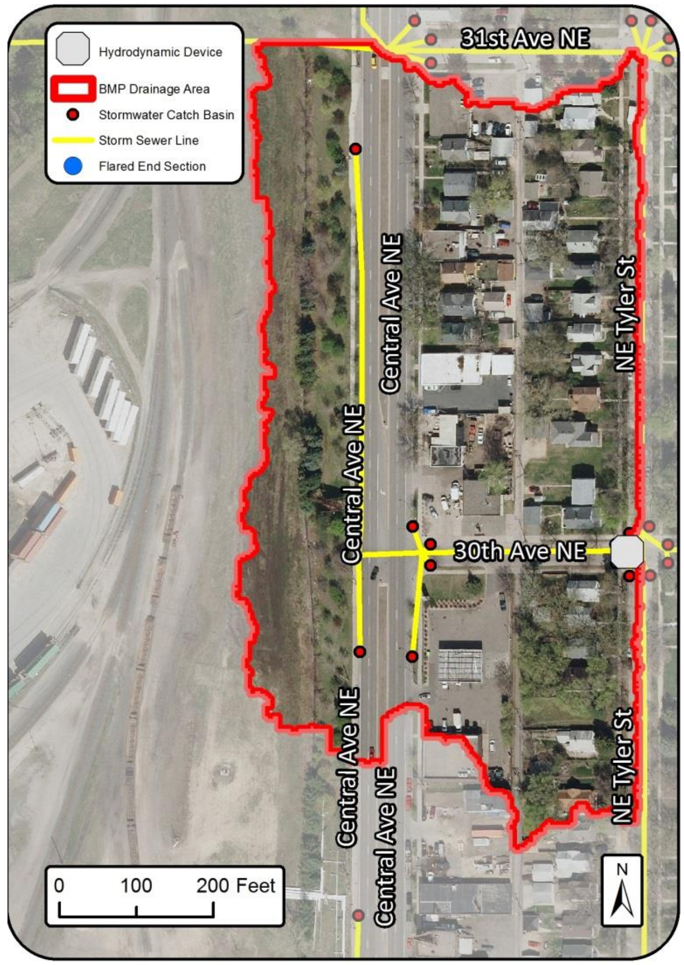
Drainage Area – 12.5 acres
Location – Intersection of 30th Ave. NE and Taylor St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 30th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.9	0.7%
	TSS (lb/yr)	338	0.9%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,998**	
	30-yr Average Cost/1,000lb-TSS	**$13,309**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 7-D

30th Ave. NE and Tyler St. NE
Hydrodynamic Device



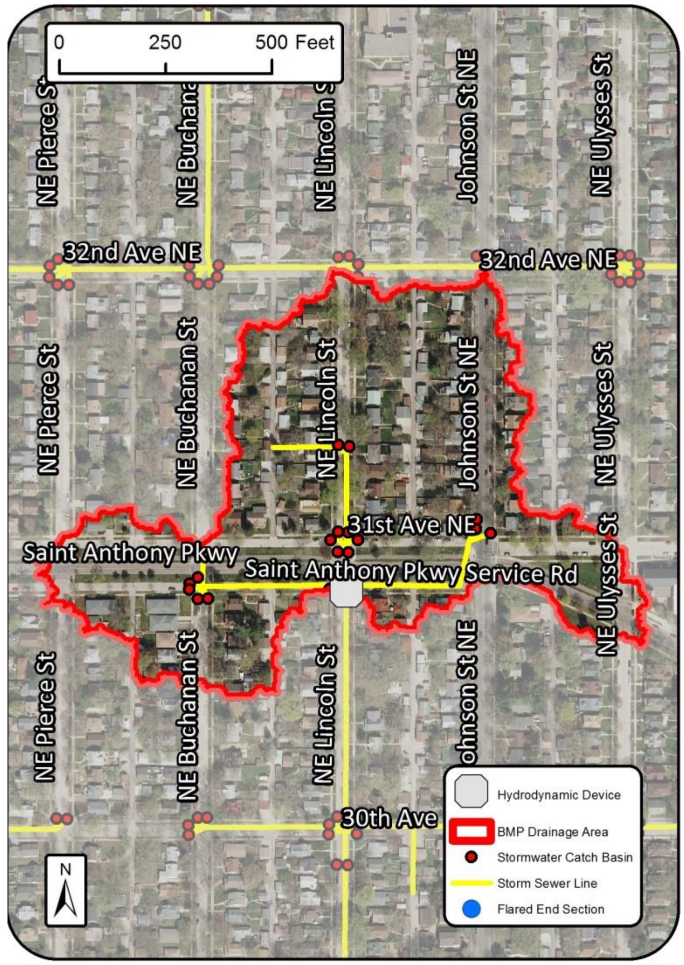
Drainage Area – 10.4 acres
Location – Intersection of 30th Ave. NE and Tyler St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area west of Tyler St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.7	0.5%
	TSS (lb/yr)	337	0.9%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,426**	
	30-yr Average Cost/1,000lb-TSS	**$13,348**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 7-E

St. Anthony Pkwy. Service Rd. and Lincoln St. NE Hydrodynamic Device



Drainage Area – 16.2 acres
Location – Intersection of St. Anthony Pkwy. Service Rd. and Lincoln St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of the St. Anthony Pkwy. Service Rd. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.1	0.8%
	TSS (lb/yr)	413	1.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$4,089**	
	30-yr Average Cost/1,000lb-TSS	**$10,892**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

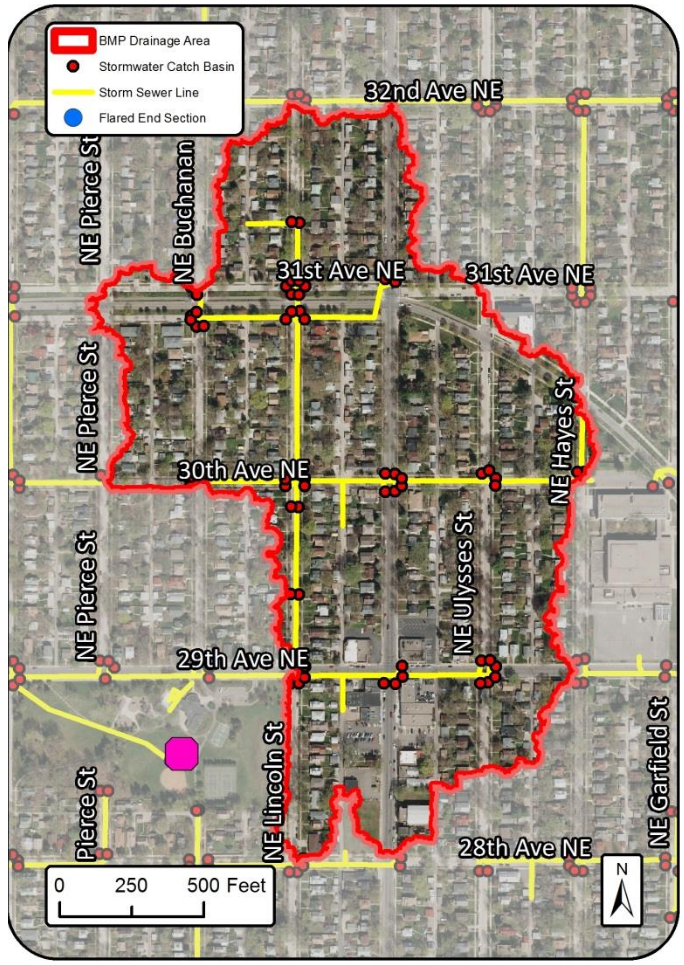
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 7-F

Water Reuse in Audubon Park



Drainage Area – 17.5 acres
Location – Within Audubon Park
Property Ownership – Public (City of Minneapolis Park and Recreation Board)
Site Specific Information – A water reuse system has been proposed in Audubon Park. An irrigation system (does not currently exist) within the park could reuse the rainfall captured in this system which would provide water quality treatment as well as water conservation benefits. An underground cistern was sized based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. To treat the 1.17" 24-hour event for the 17.5 acre contributing drainage area, 302,841 gallons of storage would be required. Based on feasibility, a 100,000 gallon cistern was proposed.

	Stormwater Reuse		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	100,000	gallons
	TP (lb/yr)	7.2	5.3%
	TSS (lb/yr)	2,117	5.7%
	Volume (acre-feet/yr)	7.0	8.1%
Cost	**Administration & Promotion Costs***	$5,840	
	Design & Construction Costs**	$443,750	
	Total Estimated Project Cost (2014)	**$449,590**	
	Annual O&M***	$3,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,498**	
	30-yr Average Cost/1,000lb-TSS	**$8,496**	
	30-yr Average Cost/ac-ft Vol.	**$2,569**	

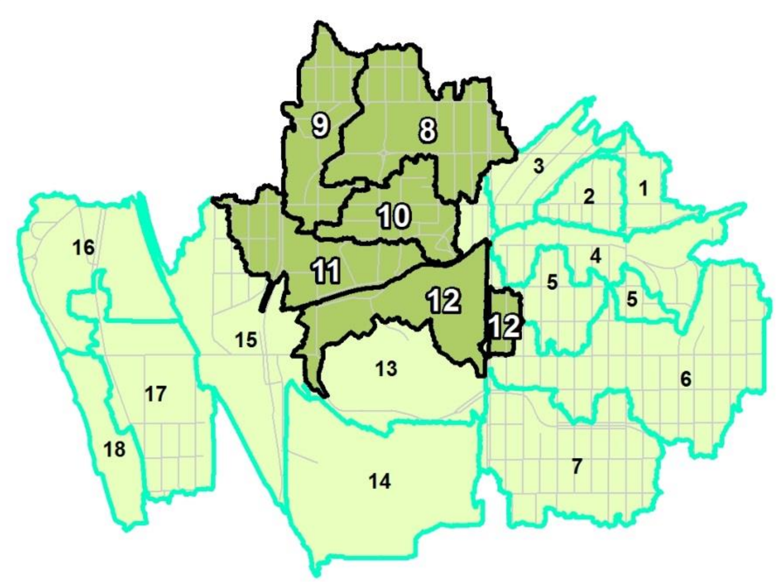
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

North Drainage Network

Catchment ID	Page
8	110
9	115
10	118
11	123
12	127



Existing Network Summary	
Acres	519.9
Dominant Land Cover	Residential
Volume (ac-ft/yr)	285.5
TP (lb/yr)	327.0
TSS (lb/yr)	93,763

DRAINAGE NETWORK SUMMARY

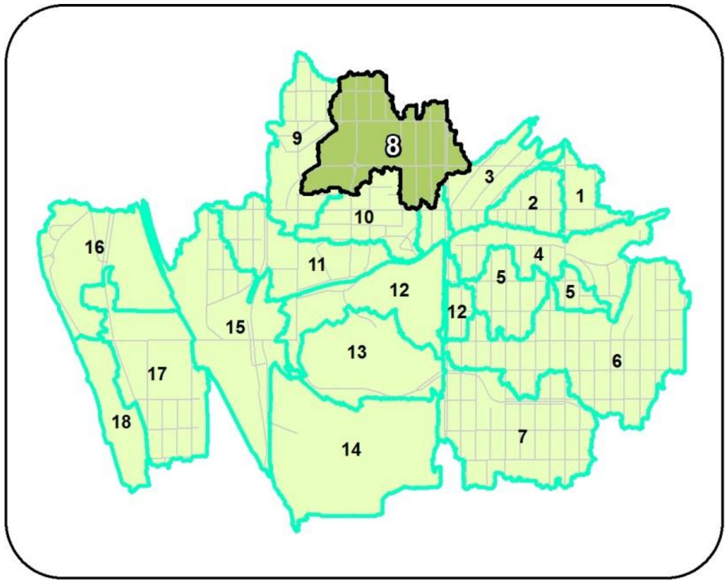
This network consists of catchments 8, 9, 10, 11, and 12 in the north central area of the target subwatershed. Stormwater largely drains from north to south along 5th St. NE. Land use is dominated by medium density residential with alleys in both the cities of Columbia Heights and Minneapolis. The drainage network also includes Huset Park (catchment 8) and the north half of Columbia Golf Course (catchment 12).

EXISTING STORMWATER TREATMENT

This drainage network has the largest amount of existing stormwater treatment of all the drainage networks in the target subwatershed. In addition to street cleaning (four times annually by the City of Columbia Heights and three times annually by the City of Minneapolis), stormwater ponds exist in catchments 9 and 12. The City of Columbia Heights also has a hydrodynamic device that provides treatment for their public works facility (catchment 10).

Catchment 8

Existing Catchment Summary[1]	
Acres	144.2
Dominant Land Cover	Residential
Parcels	622
Volume (acre-feet/yr)	139.3
TP (lb/yr)	122.1
TSS (lb/yr)	31,809



CATCHMENT DESCRIPTION

This catchment is comprised of Huset Park and its neighboring community. The border of this catchment includes Central Ave. NE to the east, 5th St. NE to the west, 38th Ave. NE to the south, and 41st Ave. NE to the north. This catchment has a wide variety of land uses including open park space, residential single-family homes, Columbia Park Clinic, small businesses, the Immaculate Conception School, commercial manufacturing, Columbia Heights Public Library, and Park View multi-family development in the southwest portion.

All stormwater generated in this catchment flows overland and is intercepted by catch basins. Storm sewers then convey the captured water westward accumulating along the way as branches converge.

EXISTING STORMWATER TREATMENT

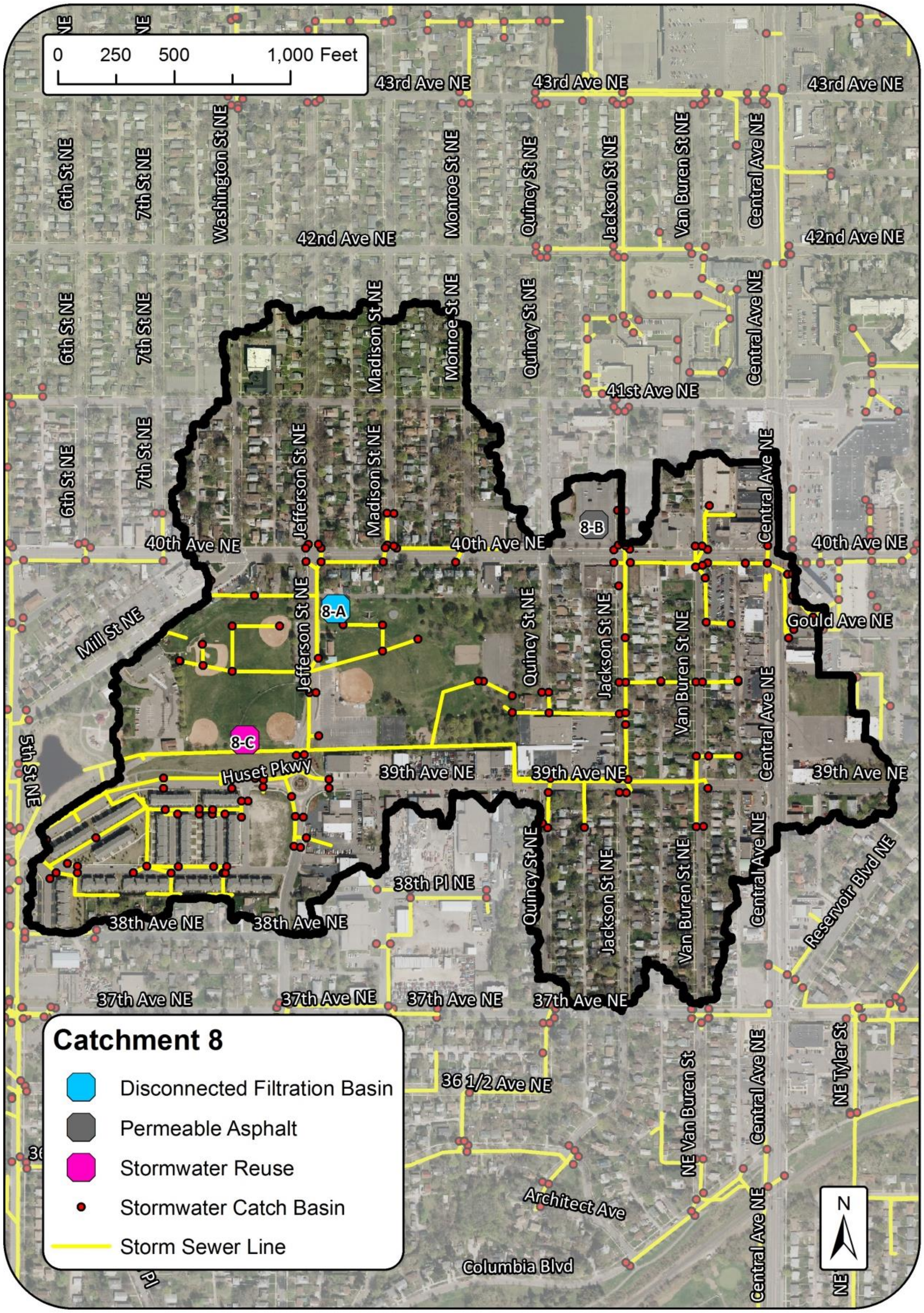
All stormwater generated in this catchment flows through a stormwater pond southwest of Huset Park located in catchment 9 prior to joining the primary storm sewer system. Details on this pond can be found in the catchment 9 summary. In addition, street cleaning is conducted four times annually by the City of Columbia Heights.

***Existing Conditions*[2]**

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Huset Park Pond			
	TP (lb/yr)	193.4	71.3	37%	**122.1**
	TSS (lb/yr)	62,813	31,004	49%	**31,809**
	Volume (acre-feet/yr)	143.4	4.1	3%	**139.3**

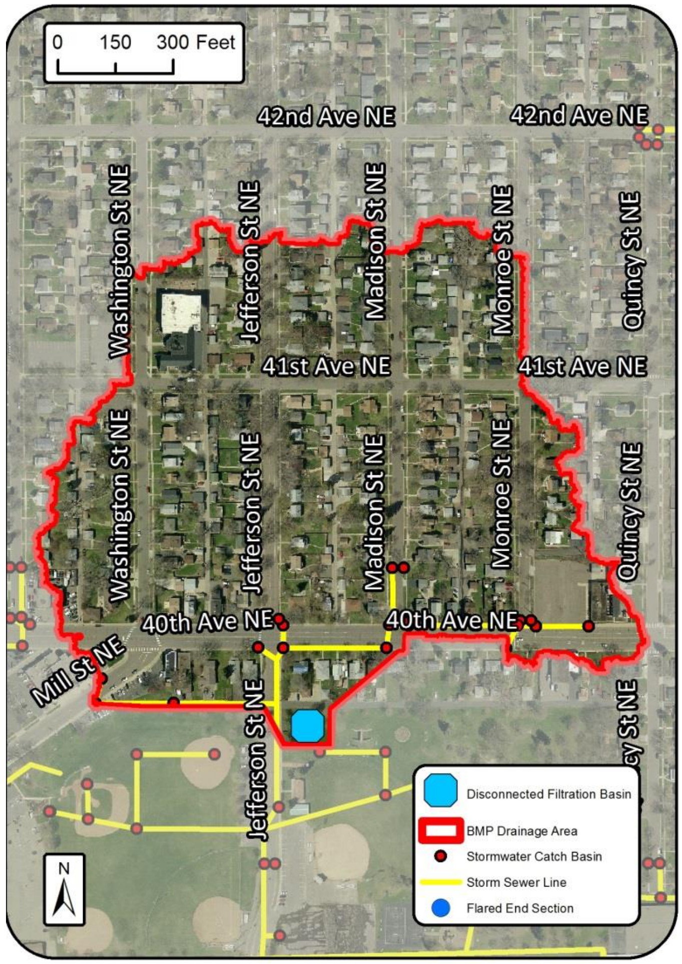
[1] Volume, TP, and TSS loading represents the network of catchments 8 and 9. Acres, dominant land cover, and parcels are specific to catchment 8.
[2] Similar to the Existing Catchment Summary table, the Existing Conditions table includes volume and pollutant loading for the network of catchments 8 and 9.

RETROFIT RECOMMENDATIONS



Project ID: 8-A1 and 8-A2

Disconnect Filtration Basin – Huset Park



Drainage Area – 31.7 acres
Location – Southeast corner of intersection between 40th Ave. NE and Jefferson St. NE. Basin is positioned within Huset Park.
Property Ownership – Public (City of Columbia Heights)
Site Specific Information – A filtration basin within Huset Park was proposed to provide treatment for the drainage area north of the site. The north end of the park has a large open space east of Jefferson St. NE that could accommodate a large rain garden. Two sizes (4,000 [8-A1] and 6,800 sq-ft [8-A2]) were modeled for the area based on available space. The storm sewer line draining south along Jefferson St. NE would be directed into the basin.

Disconnect Filtration Basin

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		1	
	Total Size of BMPs	4,000	sq-ft	6,800	sq-ft
	TP (lb/yr)	1.9	1.6%	2.4	2.0%
	TSS (lb/yr)	1,316	4.1%	2,042	6.4%
	Volume (acre-feet/yr)	0.8	0.6%	1.3	0.9%
Cost	Administration & Promotion Costs*	$2,920		$2,920	
	Design & Construction Costs**	$60,876		$102,876	
	Total Estimated Project Cost (2014)	**$63,796**		**$105,796**	
	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$1,238**		**$1,563**	
	30-yr Average Cost/1,000lb-TSS	**$1,787**		**$1,837**	
	30-yr Average Cost/ac-ft Vol.	**$2,939**		**$2,886**	

*40 hours at $73/hour

**($15/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 8-B

Permeable Asphalt at Immaculate Conception School

Drainage Area – 1.7 acres
Location – Southeast corner Immaculate Conception School campus parking lot
Property Ownership – Private (Immaculate Conception School)
Site Specific Information – Permeable asphalt has been proposed for the parking lot of Immaculate Conception School. This would be a favorable option as permeable asphalt allows the treatment of a large surface area with minimal impact on the usable space. To treat the 1.7 acre parking lot, 13,600 sq-ft of permeable asphalt was proposed.

Permeable Asphalt

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	13,600	sq-ft
	TP (lb/yr)	0.7	0.6%
	TSS (lb/yr)	346	1.1%
	Volume (acre-feet/yr)	1.3	0.9%
Cost	Administration & Promotion Costs*	$2,190	
	Design & Construction Costs**	$136,876	
	Total Estimated Project Cost (2014)	**$139,066**	
	Annual O&M***	$10,200	
Efficiency	30-yr Average Cost/lb-TP	**$21,194**	
	30-yr Average Cost/1,000lb-TSS	**$42,877**	
	30-yr Average Cost/ac-ft Vol.	**$11,412**	

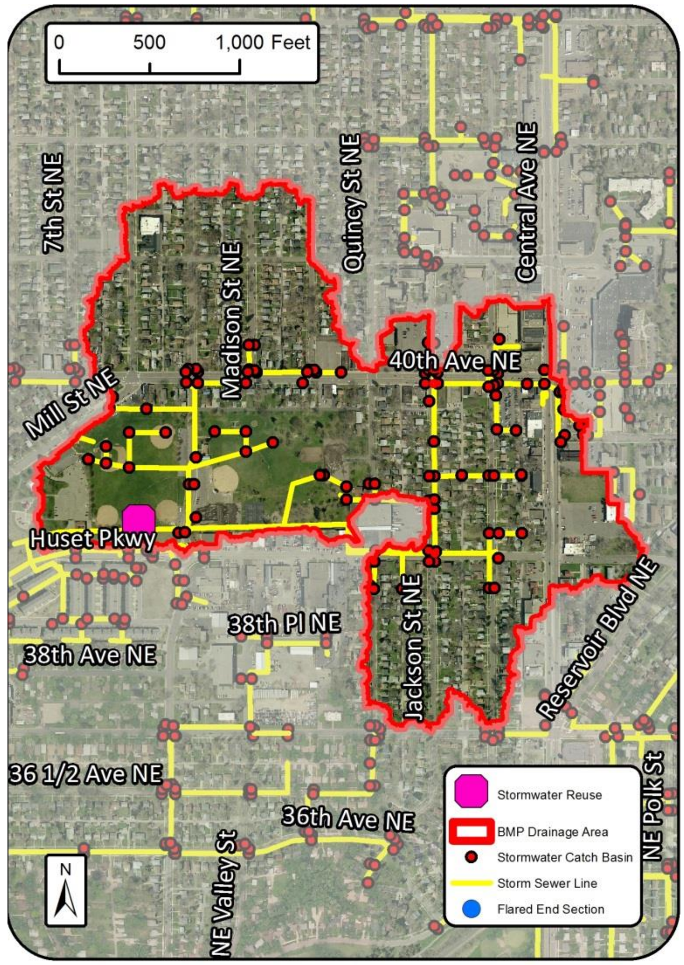
*30 hours at $73/hour

**($10/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***$0.75/sq-ft

Project ID: 8-C

Water Reuse in Huset Park



Drainage Area – 119.2 acres
Location – Within Huset Park
Property Ownership – Public (City of Columbia Heights)
Site Specific Information –
A water reuse system has been proposed in the southwestern portion of Huset Park. An irrigation system (does not currently exist) within the park could reuse the rainfall captured in this system which would provide water quality treatment as well as water conservation benefits. An underground cistern was sized based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. It is infeasible to treat the 1.17" 24-hour event for the 119.2 acre contributing drainage area. Based on feasibility, a 100,000 gallon cistern was proposed.

	Stormwater Reuse		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	100,000	gallons
	TP (lb/yr)	5.0	4.1%
	TSS (lb/yr)	836	2.6%
	Volume (acre-feet/yr)	12.6	9.0%
Cost	**Administration & Promotion Costs***		$5,840
	Design & Construction Costs**		$443,750
	Total Estimated Project Cost (2014)		**$449,590**
	Annual O&M***		$3,000
Efficiency	**30-yr Average Cost/lb-TP**	**$3,597**	
	30-yr Average Cost/1,000lb-TSS	**$21,515**	
	30-yr Average Cost/ac-ft Vol.	**$1,427**	

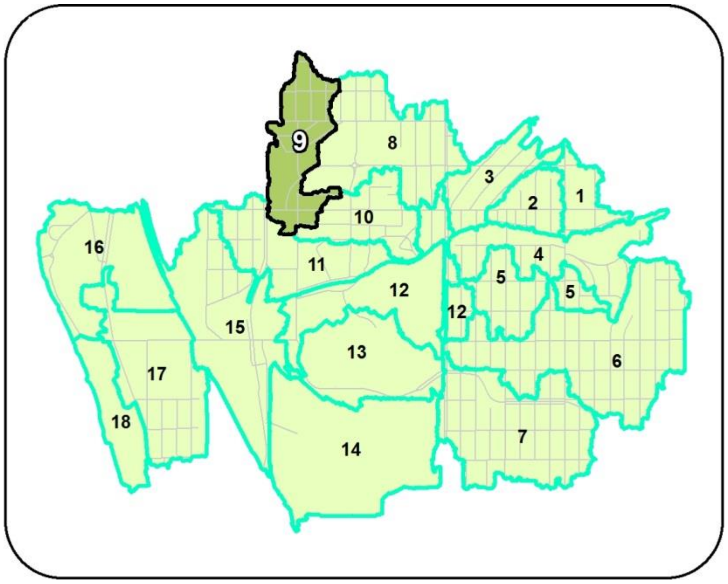
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Catchment 9

Existing Catchment Summary[3]	
Acres	89.1
Dominant Land Cover	Residential
Parcels	428
Volume (acre-feet/yr)	139.3
TP (lb/yr)	122.1
TSS (lb/yr)	31,809



CATCHMENT DESCRIPTION

This catchment is bordered by University Ave. NE to the west and Huset Park to the east. Catchment 9 is bisected by 5th St. NE starting at 42nd Ave. NE on the northern border to 37th Ave. NE on the south. This catchment has a wide variety of land uses including open park space, residential single-family homes, and a multi-family complex located along 5th St. NE across from Huset Park. Some reference landmarks also located in this catchment are Columbia Heights City Hall, The Pit Stop Grill, Angell Dentistry, and Huset Park Pond.

All stormwater generated in this catchment flows toward 5th St. NE but is intercepted by catch basins and conveyed via storm sewers beneath 5th St. NE to the primary storm sewer infrastructure to the south.

EXISTING STORMWATER TREATMENT

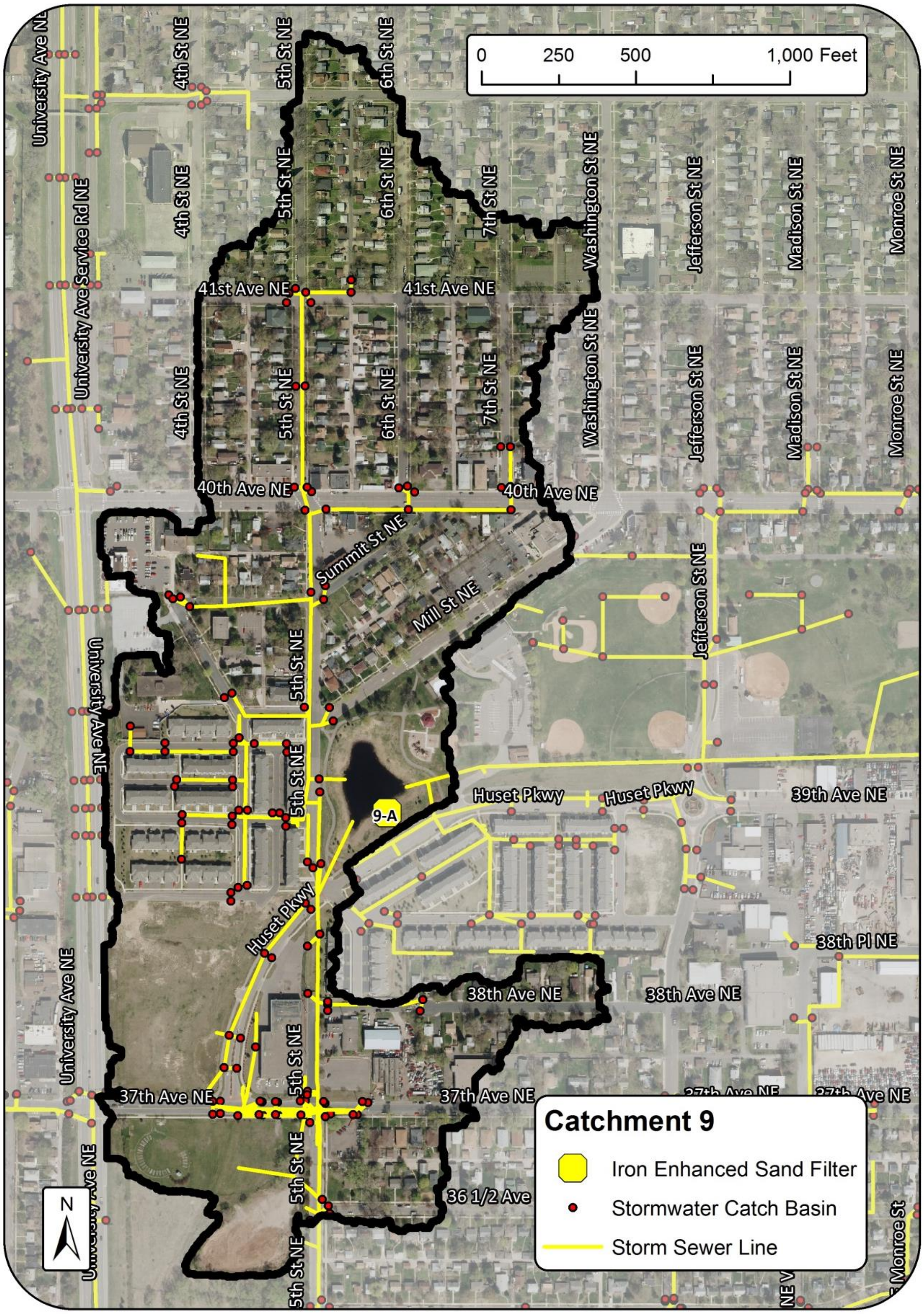
Huset Park pond receives stormwater from catchment 8 prior to discharging into the storm sewer system at 5th St. NE. Street cleaning is also conducted by the City of Columbia Heights four times annually.

Existing Conditions[4]

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Huset Park Pond			
	TP (lb/yr)	193.4	71.3	37%	**122.1**
	TSS (lb/yr)	62,813	31,004	49%	**31,809**
	Volume (acre-feet/yr)	143.4	4.1	3%	**139.3**

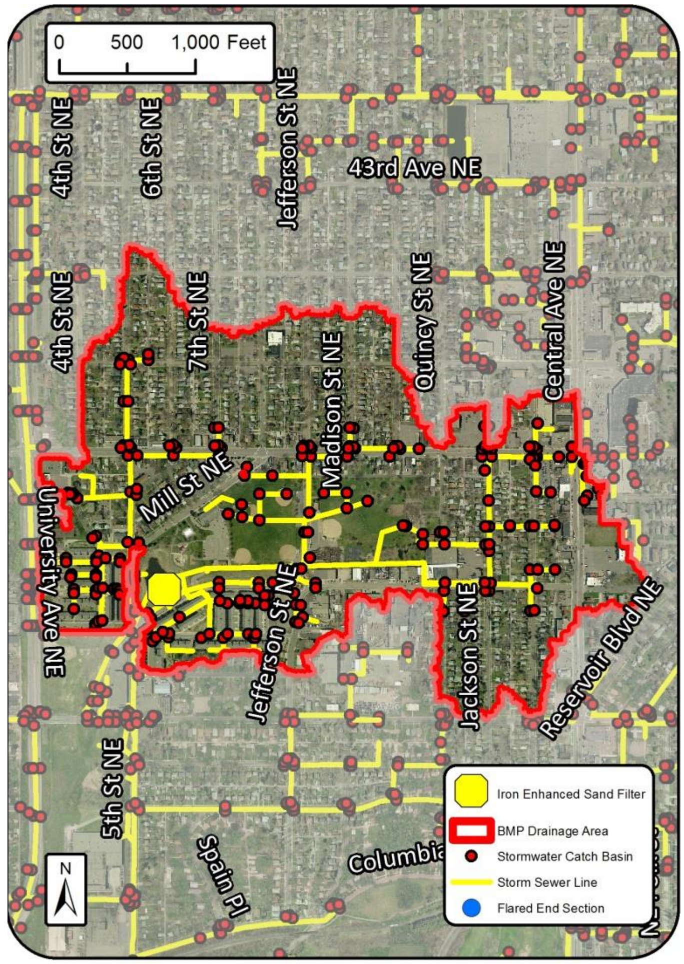
[3] Volume, TP, and TSS loading represents network of catchments 8 and 9. Acres, dominant land cover, and parcels are specific to catchment 9.
[4] Similar to the Existing Catchment Summary table, the Existing Conditions table includes volume and pollutant loading for the network of catchments 8 and 9.

RETROFIT RECOMMENDATIONS



Project ID: 9-A

Iron Enhanced Sand Filter – Huset Park Pond



Drainage Area – 205.6 acres
Location – Along perimeter of existing Huset Park Pond
Property Ownership – Public (City of Columbia Heights)
Site Specific Information – An Iron enhanced sand filter was proposed as an improvement to the Huset Park pond treatment. The pond currently provides treatment through retention and settling. However, the addition of an IESF will increase removal of dissolved phosphorus as well. The IESF was sized to 0.1 acres (approximately 17' wide and 260' long) and positioned on the south side of the existing pond to accommodate underdrain connection to the existing outlet.

	Huset Park Pond IESF		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	4,420	sq-ft
	TP (lb/yr)	10.0	8.2%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$3,650	
	Design & Construction Costs**	$142,550	
	Total Estimated Project Cost (2014)	**$146,200**	
	Annual O&M***	$1,015	
Efficiency	**30-yr Average Cost/lb-TP**	**$589**	
	30-yr Average Cost/1,000lb-TSS	**N/A**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

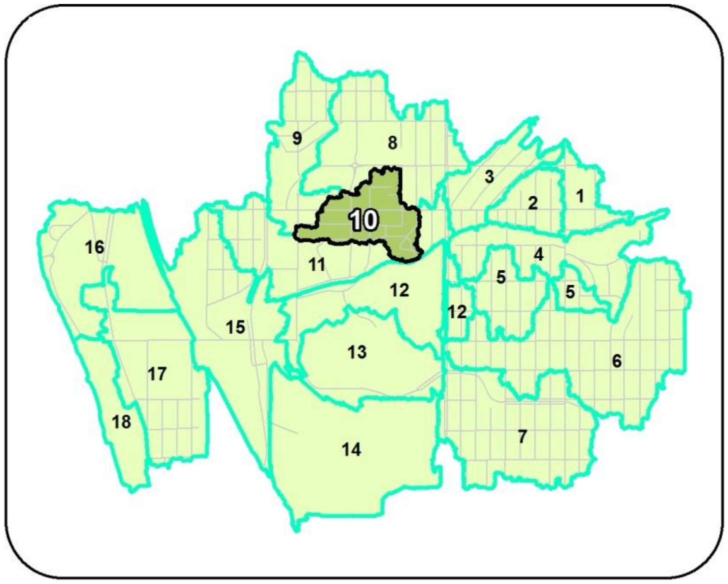
*50 hours at $73/hour

**See Appendix B for detailed cost information

***$10,000/acre for IESF

Catchment 10

Existing Catchment Summary	
Acres	69.4
Dominant Land Cover	Residential
Parcels	287
Volume (acre-feet/yr)	40.0
TP (lb/yr)	56.3
TSS (lb/yr)	17,906



CATCHMENT DESCRIPTION

This catchment stretches from 39th Ave. NE on the north to Columbia Blvd. on the south and from 5th St. NE on the west to Architect Ave. on the east. Land use south of 37th Ave. NE is exclusively single-family residential. The area north of 37th Ave. NE is dominated by industrial businesses and City facilities such as Columbia Heights Public Works and Recycling Center.

Stormwater generated within this catchment flows overland and is intercepted by catch basins. The water is then conveyed via storm sewers to the main system located along 5th Ave. NE.

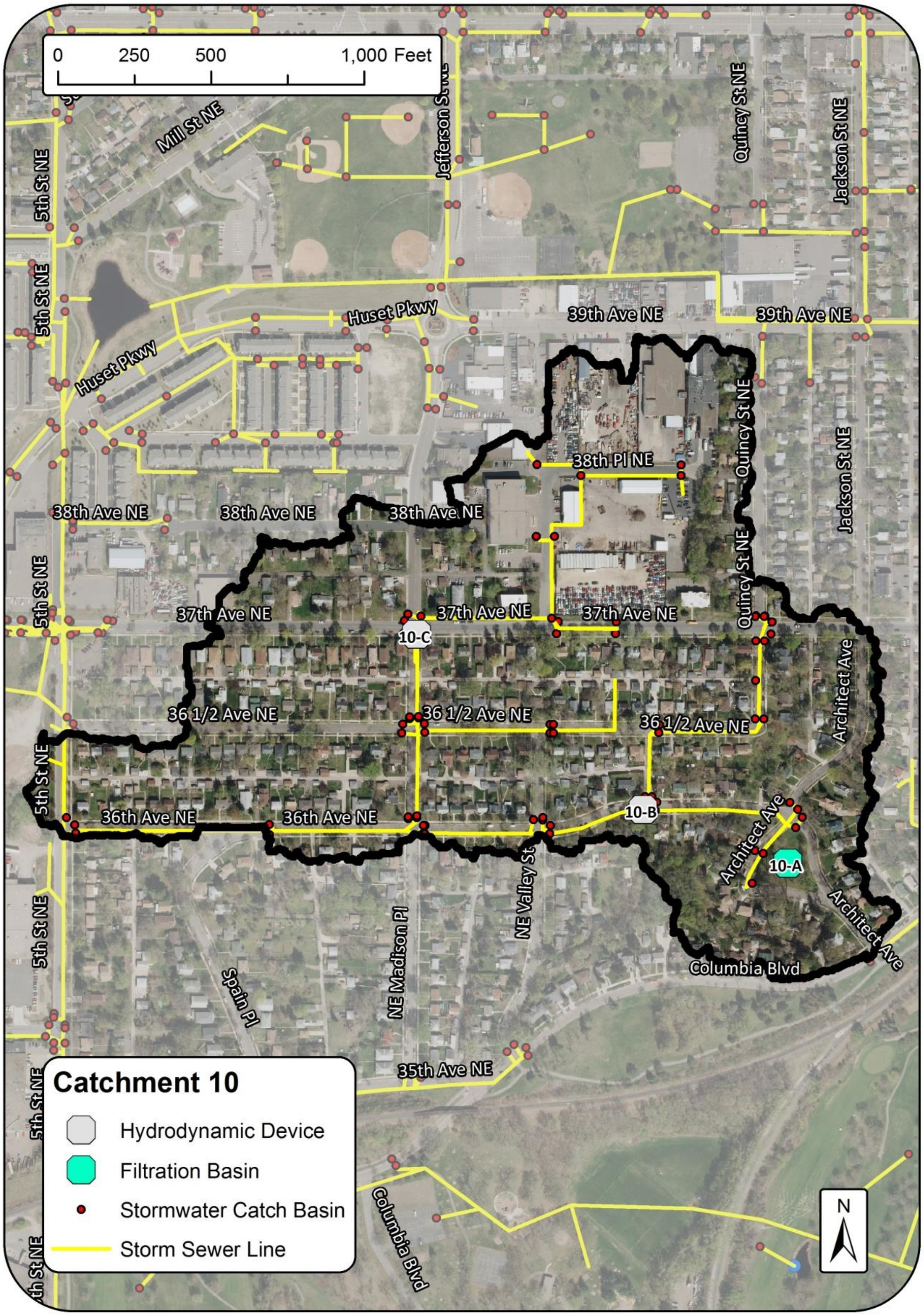
EXISTING STORMWATER TREATMENT

The City of Columbia Heights' public works yard has a hydrodynamic device that treats runoff from the site. In addition, street cleaning is performed three times per year by the City of Minneapolis.

Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	60.8	4.4	7%	**56.3**
	TSS (lb/yr)	20,220	2,314	11%	**17,906**
	Volume (acre-feet/yr)	40.0	0.0	0%	**40.0**

RETROFIT RECOMMENDATIONS



Project ID: 10-A

Filtration Basin in Architect Triangle

Drainage Area – 6.4 acres
Location – Located within Architect Triangle south of 36th Ave. NE
Property Ownership – Public (City of Minneapolis Park and Recreation Board)
Site Specific Information – A filtration basin within Architect Triangle was proposed to provide treatment for the drainage area surrounding the site. The triangle has sufficient open space to accommodate a filtration basin. Stormwater runoff could be directed to the basin by multiple curb-cuts. The north end of the park has a large open space east of Jefferson St. NE that could accommodate a large rain garden. One 1,700 sq-ft basin was modeled for the site.

	Filtration Basin		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	1,700	sq-ft
	TP (lb/yr)	0.5	0.4%
	TSS (lb/yr)	756	2.4%
	Volume (acre-feet/yr)	0.3	0.2%
Cost	**Administration & Promotion Costs***	$2,920	
	Design & Construction Costs**	$26,376	
	Total Estimated Project Cost (2014)	**$29,296**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,403**	
	30-yr Average Cost/1,000lb-TSS	**$1,589**	
	30-yr Average Cost/ac-ft Vol.	**$4,005**	

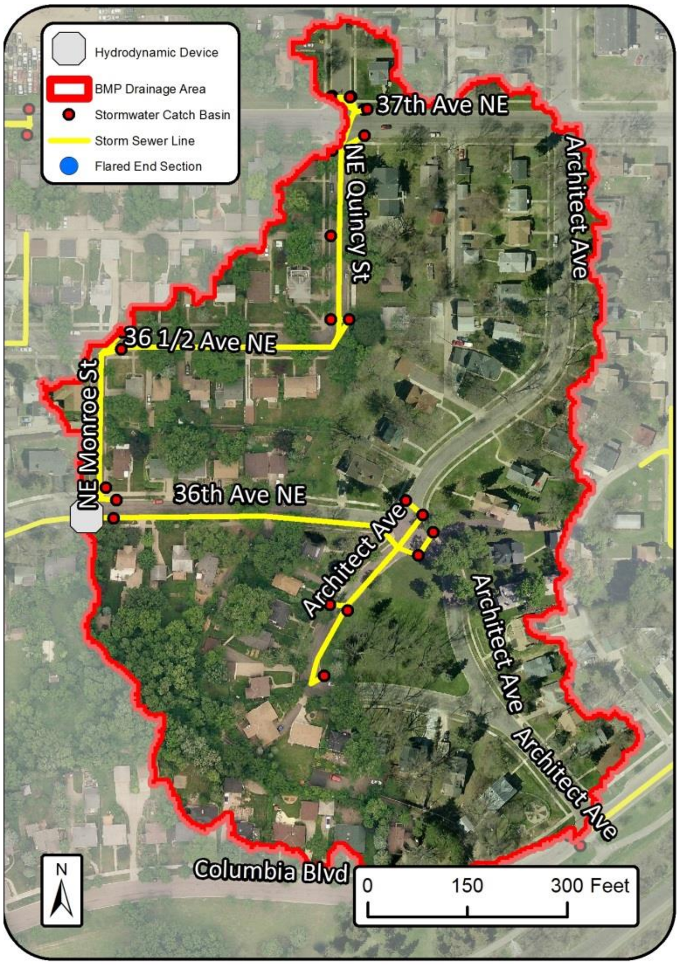
*40 hours at $73/hour

**($15/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for 10-year rehabilitation) + ($75/year for routine maintenance)

Project ID: 10-B

36th Ave. NE and Monroe St. NE Hydrodynamic Device



Drainage Area – 17.2 acres
Location – Intersection of 36th Ave. NE and Monroe St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area east of Monroe St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.1	2.0%
	TSS (lb/yr)	406	2.3%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,089**	
	30-yr Average Cost/1,000lb-TSS	**$11,080**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

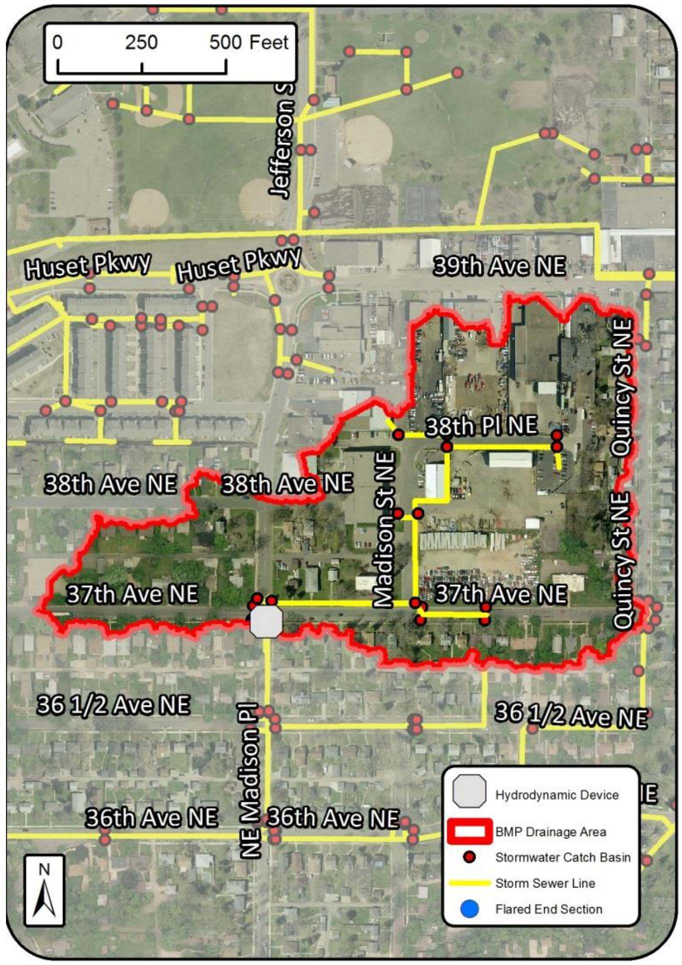
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 10-C

37th Ave. NE and Madison Pl. NE Hydrodynamic Device



Drainage Area – 26.5 acres
Location – Intersection of 37th Ave. NE and Madison Pl. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.7	1.2%
	TSS (lb/yr)	383	2.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,426**	
	30-yr Average Cost/1,000lb-TSS	**$11,745**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

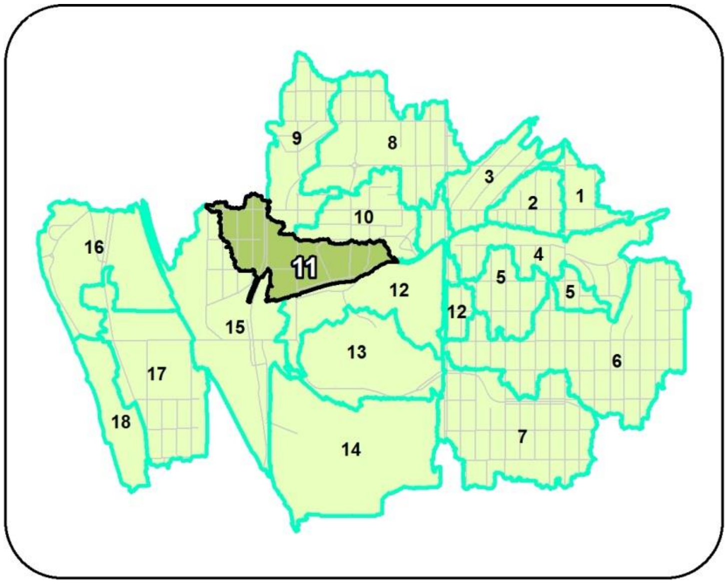
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment 11

Existing Catchment Summary	
Acres	98.3
Dominant Land Cover	Residential
Parcels	306
Volume (acre-feet/yr)	60.8
TP (lb/yr)	78.8
TSS (lb/yr)	25,912



CATCHMENT DESCRIPTION
This catchment makes up the area from Columbia Blvd. on the south to 37th Ave. NE on the north and from 2nd St. NE on the west to Valley St. NE on the east. The residential areas on the east and west of this catchment are entirely comprised of single-family homes. Splitting the two residential areas is a corridor of businesses including Moorhead Machinery and United Business Mail.

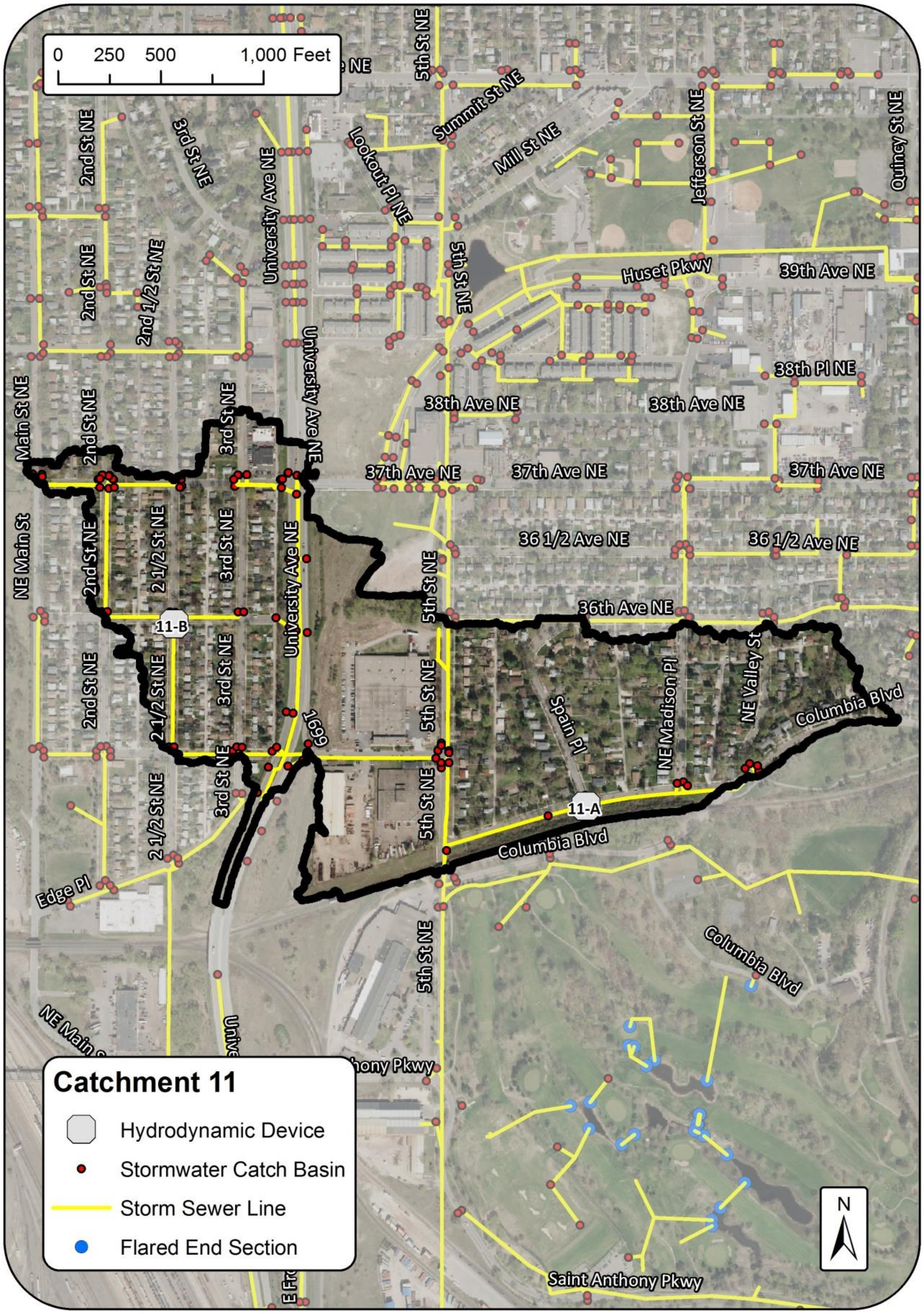
All stormwater runoff generated in this catchment flows overland south but is intercepted by catch basins and conveyed via storm sewers to the primary system to the south of Columbia Golf Club.

EXISTING STORMWATER TREATMENT
The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

Existing Conditions

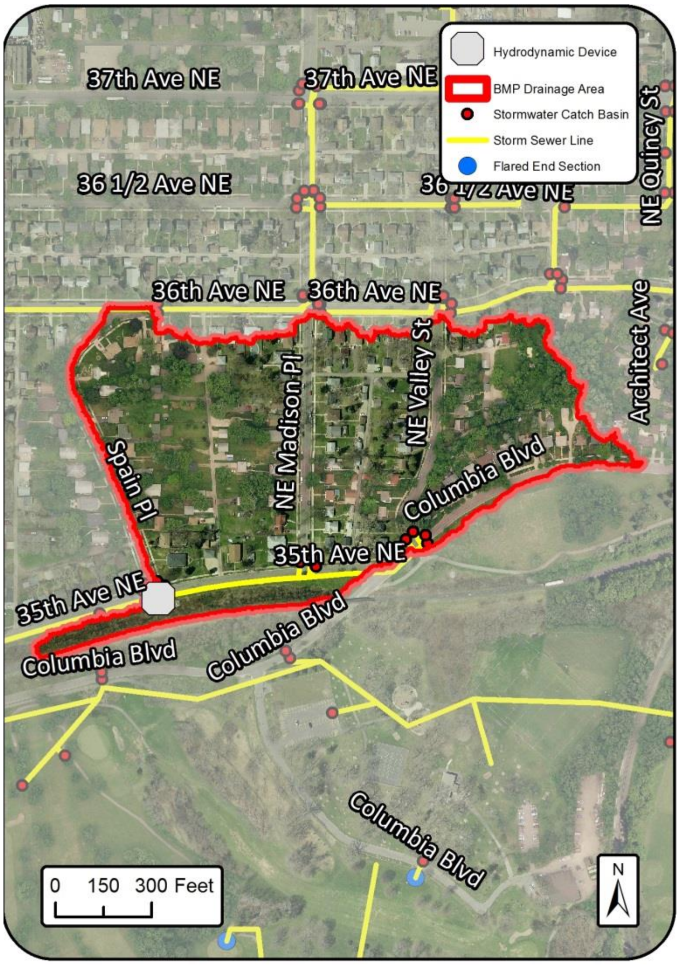
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	83.0	4.2	5%	**78.8**
	TSS (lb/yr)	27,928	2,016	7%	**25,912**
	Volume (acre-feet/yr)	60.8	0.0	0%	**60.8**

RETROFIT RECOMMENDATIONS



Project ID: 11-A

35th Ave. NE and Spain Pl. NE
Hydrodynamic Device



Drainage Area – 26.4 acres
Location – Intersection of 35th Ave. NE and Spain Pl. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 35th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.4	1.8%
	TSS (lb/yr)	509	2.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,213**	
	30-yr Average Cost/1,000lb-TSS	**$8,838**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 11-B

36th Ave. NE and 2 ½ St. NE
Hydrodynamic Device

Drainage Area – 16.0 acres
Location – Intersection of 36th Ave. NE and 2 ½ St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 36th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.1	1.4%
	TSS (lb/yr)	406	1.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,089**	
	30-yr Average Cost/1,000lb-TSS	**$11,080**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

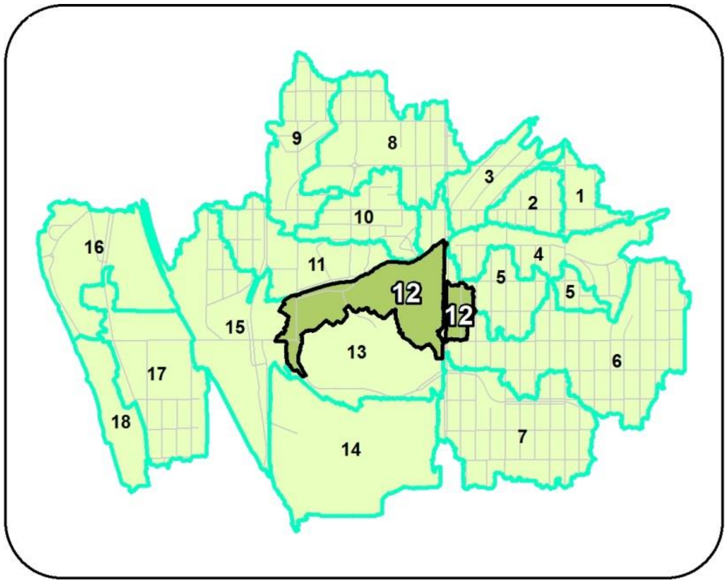
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment 12

Existing Catchment Summary	
Acres	118.9
Dominant Land Cover	Golf Course
Parcels	86
Volume (acre-feet/yr)	45.4
TP (lb/yr)	69.7
TSS (lb/yr)	18,136



CATCHMENT DESCRIPTION

This catchment is primarily made up of Columbia Park and the northern section of Columbia Golf Club. Because of this, most of the land in this catchment is heavily managed open space. A small portion near 5th St. NE, the western border, includes the Learning for Leadership charter school as well as the business Pallet One.

Only the eastern most area of the catchment currently receives any treatment prior to discharging into the storm sewer systems. All other stormwater generated in the catchment flows overland to the nearest catch basin and is conveyed via storm sewer system.

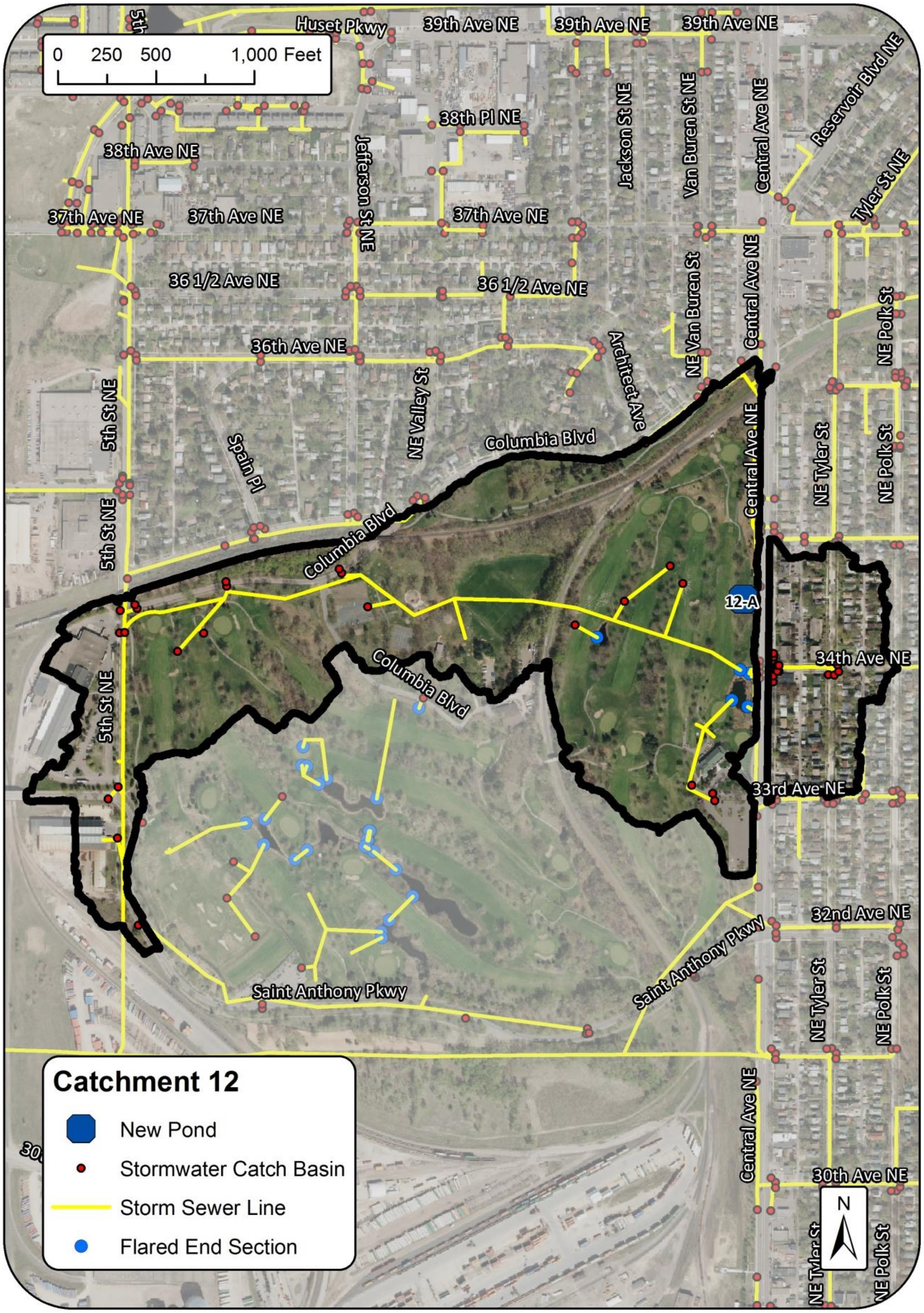
EXISTING STORMWATER TREATMENT

There is a stormwater retention pond located along Central Ave. NE just north of the Columbia Golf Club Clubhouse. This pond collects stormwater generated from both the clubhouse parking lot and a small portion of the residential neighborhood immediately east of the pond. The pond provides the area with a means of flood control as well as water quality treatment through retention. When filled, the pond discharges to the northwest into the main storm sewer system of this catchment. During times of extreme flow the pond has an emergency outlet to the storm sewer system at Central Ave. NE. Additionally, the City of Minneapolis conducts street cleaning three times annually.

Existing Conditions

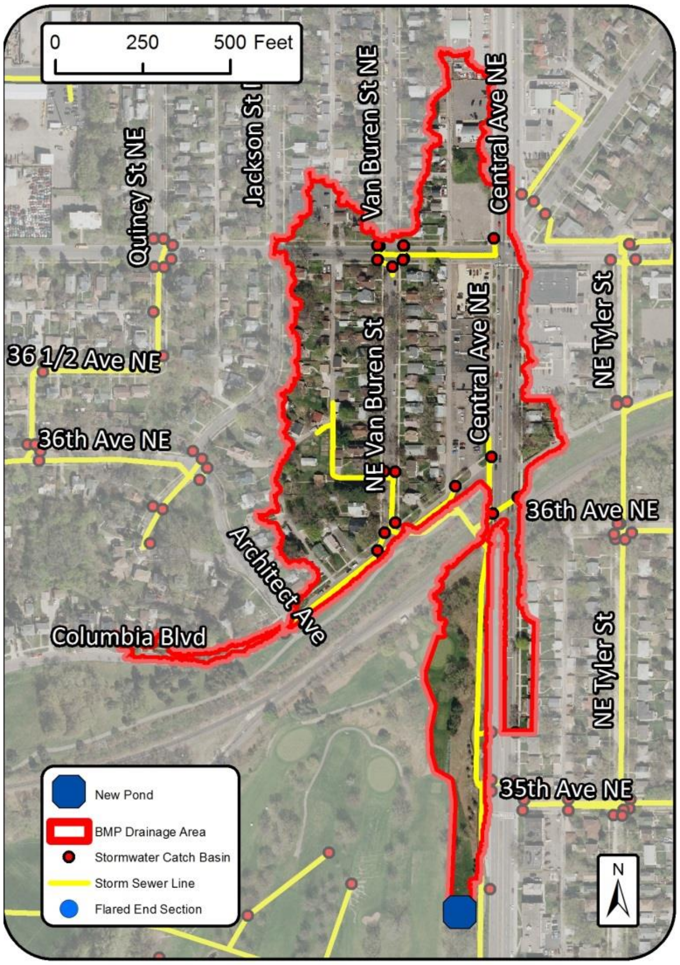
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	82.3	12.6	15%	**69.7**
	TSS (lb/yr)	22,853	4,717	21%	**18,136**
	Volume (acre-feet/yr)	46.9	1.5	3%	**45.4**

RETROFIT RECOMMENDATIONS



Project ID: 12-A

New Pond – Columbia Golf Course



Drainage Area – 21.7 acres[5]
Location – West of Central Ave. NE in the Columbia Golf Course, north of the existing pond also located in the Columbia Golf Course
Property Ownership – Public (City of Minneapolis Park and Recreation Board)
Site Specific Information – Up to 0.5 acres of land is available between the fairway on the 9th Hole and the sidewalk along Central Ave. NE in the Columbia Golf Club Course. A large storm sewer line (84" diameter) runs along this open space but treats too large of a drainage area (~300 acres) to be treated by a pond on this site. Rather, the 30" line north of the site draining residential and commercial properties between Architect Ave. NE and Central Ave. NE along and north of Columbia Blvd. NE can be diverted to the pond. Overflow from the pond could be directed back to the 84" line.

	New Pond		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	18,000	sq-ft
	TP (lb/yr)	8.3	10.1%
	TSS (lb/yr)	3,399	15.5%
	Volume (acre-feet/yr)	0.1	0.2%
Cost	**Administration & Promotion Costs***	$5,840	
	Design & Construction Costs**	$152,500	
	Total Estimated Project Cost (2014)	**$158,340**	
	Annual O&M***	$413	
Efficiency	**30-yr Average Cost/lb-TP**	**$686**	
	30-yr Average Cost/1,000lb-TSS	**$1,674**	
	30-yr Average Cost/ac-ft Vol.	**$56,910**	

*80 hours at $73/hour

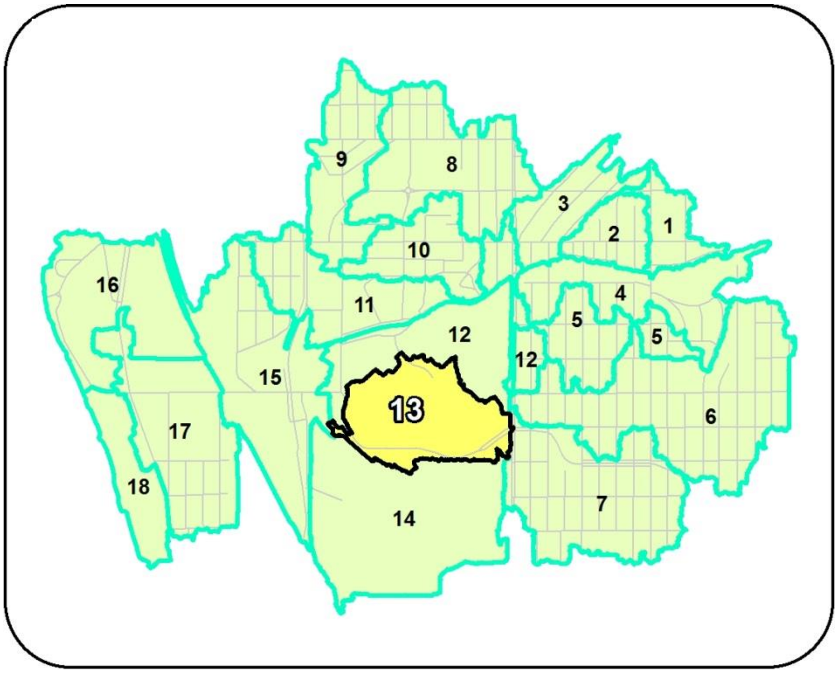
**See Appendix B for detailed cost information

***$1,000/acre - Annual inspection and sediment/debris removal from pretreatment area

[5] This drainage area includes 14.5 acres of additional drainage from catchment 5.

Central Drainage Network

Catchment ID	Page
13	132



Existing Network Summary	
Acres	115.2
Dominant Land Cover	Golf Course
Volume (ac-ft/yr)	9.4
TP (lb/yr)	18.3
TSS (lb/yr)	4,532

DRAINAGE NETWORK SUMMARY

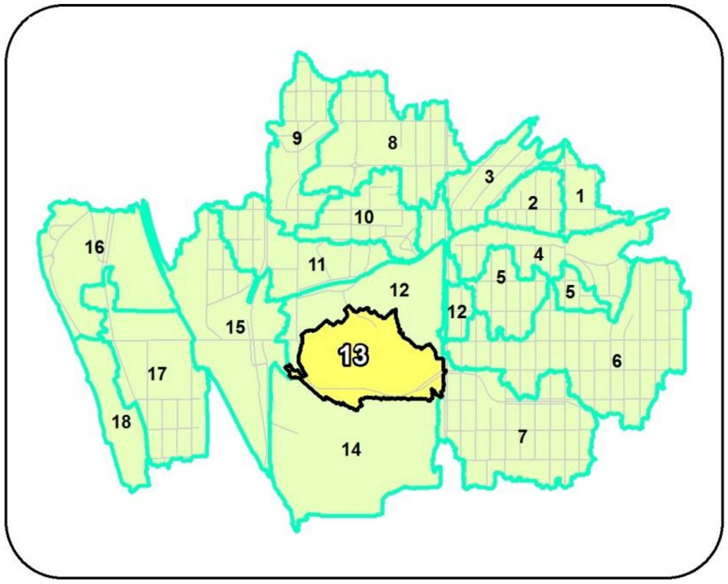
This network consists of only catchment 13, which is the southern half of Columbia Golf Course.

EXISTING STORMWATER TREATMENT

A network of stormwater ponds exist within the golf course. A lift station located at the southern boundary of the golf course directs water across St. Anthony Pkwy. where it connects to the main storm sewer line that discharges to the Mississippi River at the 1NE outfall. The City of Minneapolis also conducts street cleaning three times per year.

Catchment 13

Existing Catchment Summary	
Acres	115.2
Dominant Land Cover	Golf Course
Parcels	7
Volume (acre-feet/yr)	9.4
TP (lb/yr)	18.3
TSS (lb/yr)	4,532



CATCHMENT DESCRIPTION

This catchment is made up of all aspects of Columbia Golf Club south of Columbia Park as well as the land immediately surrounding St. Anthony Pkwy. between 5th St. NE and Central Ave. NE. A small section of St. Anthony Parkway near Central Ave. NE is captured by catch basins at the railroad crossing and conveyed via storm sewer to the main system immediately south of St. Anthony Pkwy. All other stormwater generated in this catchment is transported overland or via storm sewer to ponds located within Columbia Golf Club. During periods of high water there is a lift station capable of diverting water from the ponds into the storm sewer system to the south.

EXISTING STORMWATER TREATMENT

There are currently five stormwater ponds located in the southern portion of Columbia Golf Club. This is typically a closed system and receives treatment through retention. The other form of stormwater treatment in the catchment is street cleaning, performed three times per by the City of Minneapolis.

Existing Conditions

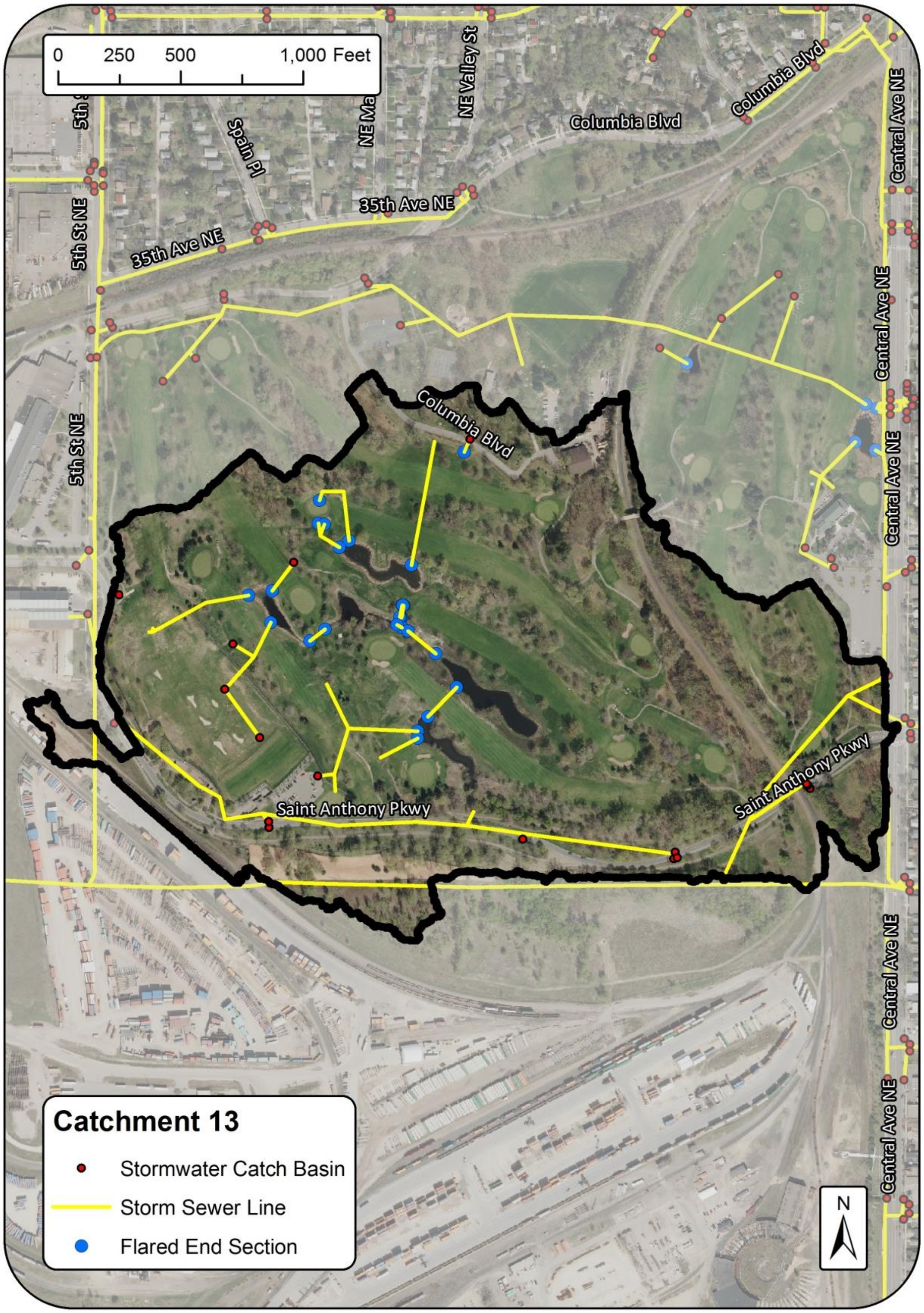
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	**Number of BMPs**	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	68.7	50.4	73%	**18.3**
	TSS (lb/yr)	15,619	11,087	71%	**4,532**
	Volume (acre-feet/yr)	30.4	20.9	69%	**9.4**

PROPOSED RETROFITS OVERVIEW

There are no proposed retrofits for this catchment. The vast majority of stormwater generated within this catchment is retained and properly treated or repurposed.

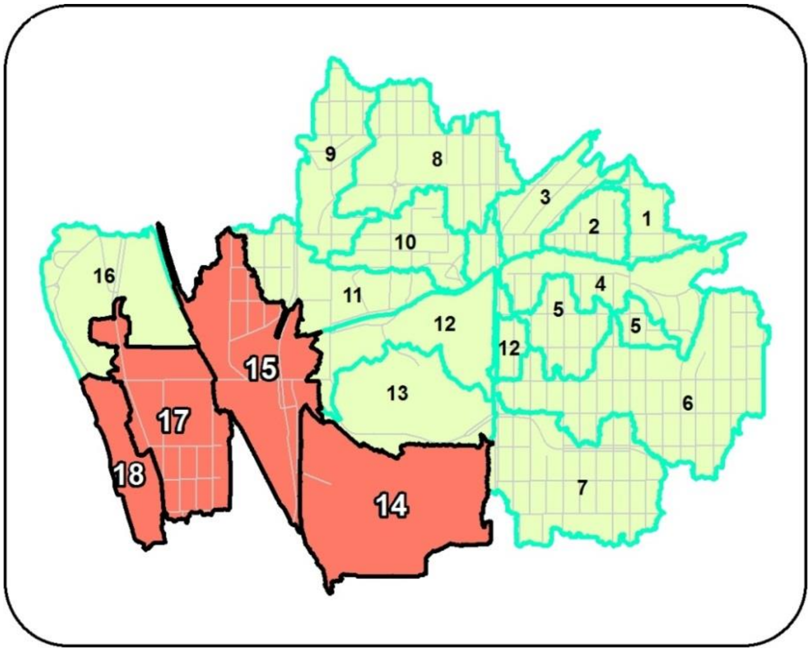
RETROFIT RECOMMENDATIONS

There are no proposed retrofits for this catchment. The vast majority of stormwater generated within this catchment is retained and properly treated or repurposed.



Southwest Drainage Network

Catchment ID	Page
14	136
15	141
17	145
18	151



Existing Network Summary	
Acres	581.6
Dominant Land Cover	Rail Yard
Volume (ac-ft/yr)	441.4
TP (lb/yr)	392.1
TSS (lb/yr)	204,182

DRAINAGE NETWORK SUMMARY

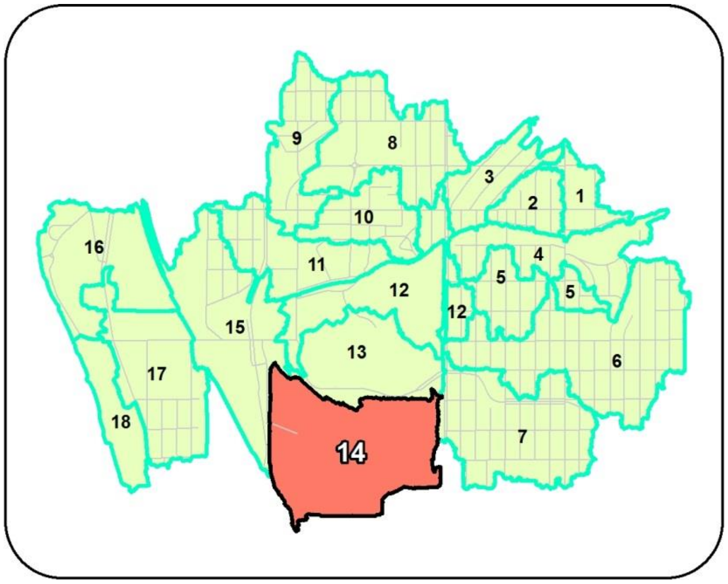
The southwest drainage network consists of catchments 14, 15, 17, and 18. Catchments 14 and 15 are largely comprised of the Canadian Pacific Railroad Twin Cities Intermodal Terminal and Distribution Centers of MN, Inc. property. Stormwater is conveyed from east to west via a 102" diameter pipe to the Mississippi River.

EXISTING STORMWATER TREATMENT

Street cleaning is conducted throughout the southwest drainage area three times annually by the City of Minneapolis. Additionally, there is a stormwater treatment pond in catchment 15 and a stormwater treatment pond with a large infiltration basin in catchment 18 on the Xcel Energy property adjacent to the Mississippi River.

Catchment 14

Existing Catchment Summary	
Acres	209.6
Dominant Land Cover	Rail Yard
Parcels	262
Volume (acre-feet/yr)	190.5
TP (lb/yr)	160.7
TSS (lb/yr)	92,624



CATCHMENT DESCRIPTION

This catchment is the area between 27th Ave. NE and St. Anthony Pkwy. from Central Ave. NE westward to University Ave. NE. Land use in this catchment is strictly industrial and contains the Canadian Pacific Railroad Twin Cities Intermodal Terminal and Distribution Centers of MN, Inc.

Please note this catchment may be largely non-contributing to the 1NE subwatershed outfall into the Mississippi River. This is based on preliminary data available at the time of publication of this report from the hydraulic and hydrologic study being completed on the 1NE subwatershed by Houston Engineering, Inc. As there is no network-wide treatment (existing or proposed) downstream of this catchment, inclusion or exclusion of volume and pollutant loads solely from Catchment 14 in this analysis has no broader impacts on the relative ranking of proposed retrofits.

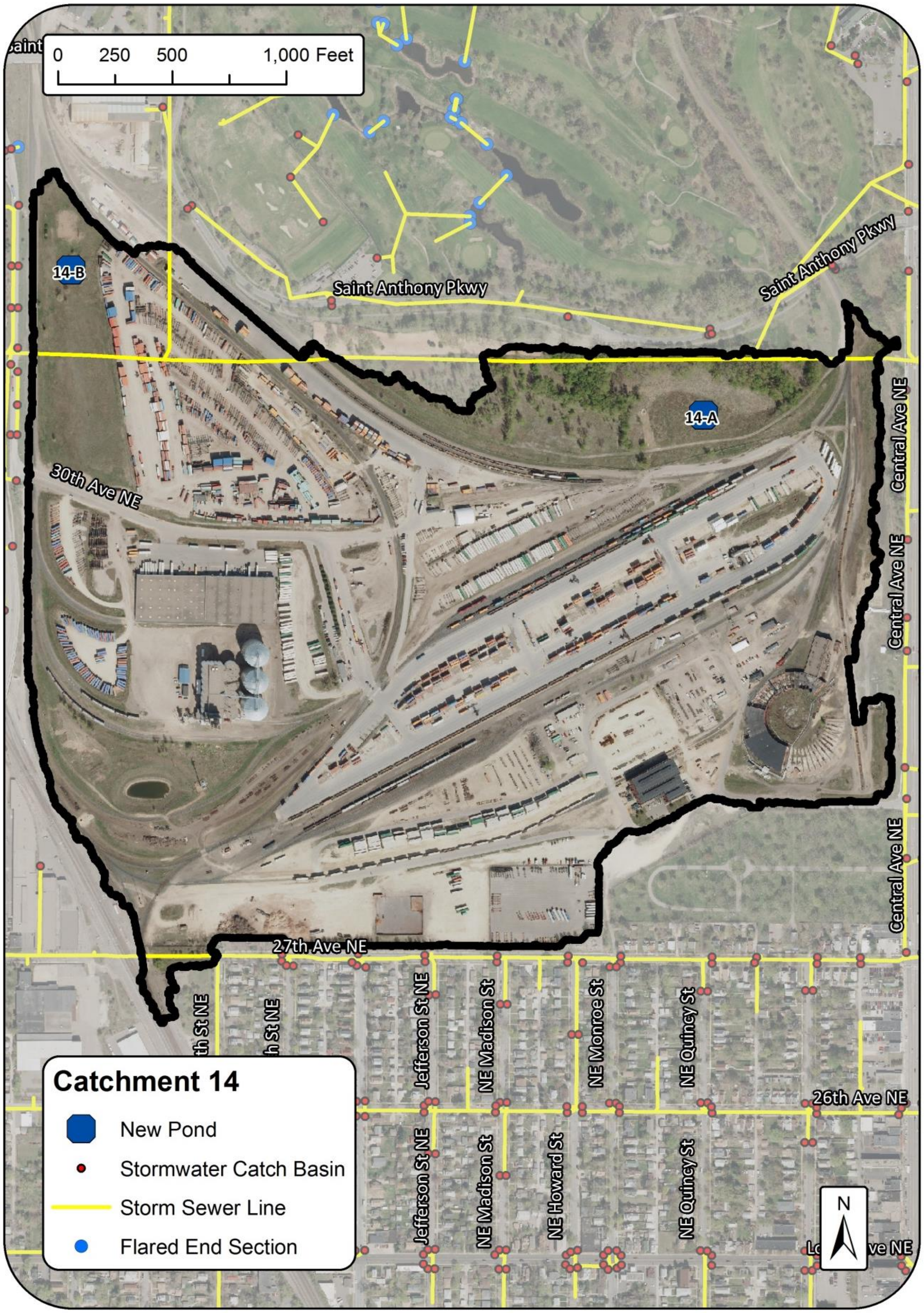
EXISTING STORMWATER TREATMENT

There is currently no known stormwater treatment within this catchment.

Existing Conditions

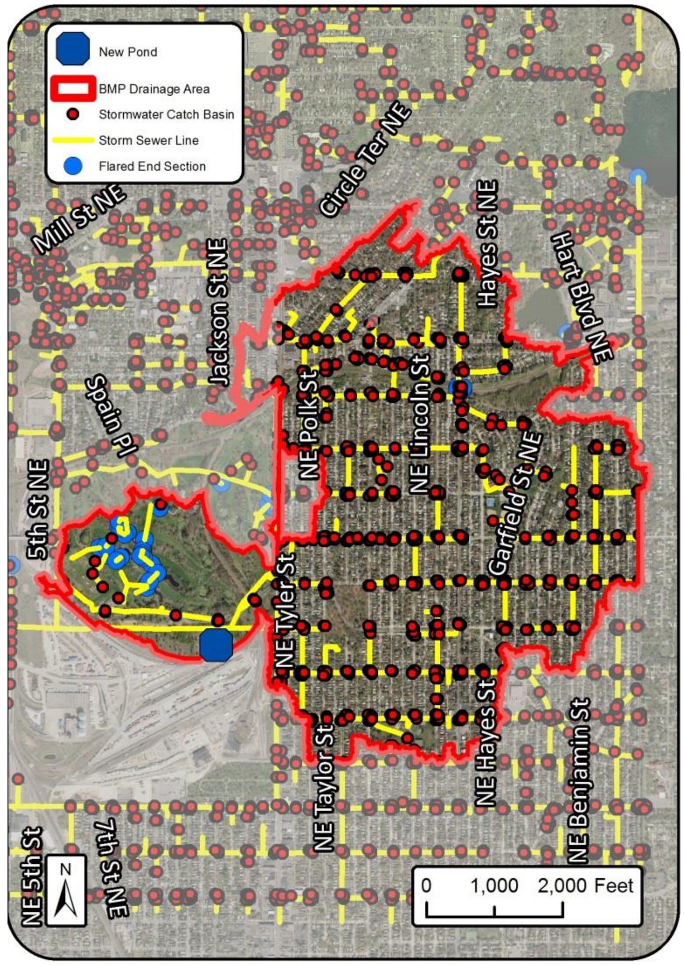
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	165.3	4.6	3%	**160.7**
	TSS (lb/yr)	96,446	3,822	4%	**92,624**
	Volume (acre-feet/yr)	190.5	0.0	0%	**190.5**

RETROFIT RECOMMENDATIONS



Project ID: 14-A1 and 14-A2

New Pond + IESF – Catchment 14 East



Drainage Area – 841.4 acres
Location – Northeast corner of Shoreham Yards
Property Ownership – Private
Site Specific Information – Catchments 1-7 and catchment 13 all drain to a 102" storm sewer running from west to east just north of the railroad yards. Approximately 20 acres of undeveloped open space is available between St. Anthony Parkway and the railroad yards for a stormwater BMP (note that this property is owned by the railroad authority). A treatment train of stormwater BMPs is proposed for this space, including a new 6.35 acre stormwater retention pond and an IESF. These BMPs will treat all 748 acres of upstream runoff from catchments 1-7 and catchment 13. Stormwater entering this treatment train will be first diverted into the stormwater pond, which is designed to remove large debris and particulate pollutants. The second BMP, the IESF, will be positioned on a bench along the southern and western shores of the pond. The practice will treat the dissolved pollutant species (particularly phosphorus) which can often escape stormwater ponds untreated. Overflow from the pond will spill into the IESF, where it will seep through the sand layer to an underdrain. The underdrain will connect back to the 102" line downstream of the pond. A secondary outlet could also be installed for storms which may overwhelm the IESF.

Please note there is currently a shallow depression at this proposed location that receives overflow from the storm sewer system during heavy rainfall events. However, this project proposes a substantial expansion and formalization of the stormwater BMP.

WinSLAMM model results for scenarios with only the pond (14-A1) and the pond with the IESF (14-A2) are presented on the following page.

New Pond

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	275,000	sq-ft
	TP (lb/yr)	291.2	47.2%
	TSS (lb/yr)	108,697	68.1%
	Volume (acre-feet/yr)	3.2	0.8%
Cost	Administration & Promotion Costs*	$5,840	
	Design & Construction Costs**	$2,745,000	
	Total Estimated Project Cost (2014)	**$2,750,840**	
	Annual O&M***	$6,313	
Efficiency	30-yr Average Cost/lb-TP	**$337**	
	30-yr Average Cost/1,000lb-TSS	**$902**	
	30-yr Average Cost/ac-ft Vol.	**$30,627**	

*80 hours at $73/hour

**See Appendix B for detailed cost information

***$1,000/acre - Annual inspection and sediment/debris removal from pretreatment area

New Pond with IESF

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	325,000****	sq-ft
	TP (lb/yr)	404.5	65.6%
	TSS (lb/yr)	108,697	68.1%
	Volume (acre-feet/yr)	3.2	0.8%
Cost	Administration & Promotion Costs*	$9,490	
	Design & Construction Costs**	$3,550,000	
	Total Estimated Project Cost (2014)	**$3,559,490**	
	Annual O&M***	$17,792	
Efficiency	30-yr Average Cost/lb-TP	**$337**	
	30-yr Average Cost/1,000lb-TSS	**$1,255**	
	30-yr Average Cost/ac-ft Vol.	**$42,638**	

*50 hours at $73/hour for IESF (in addition to 80 hours spent on pond)

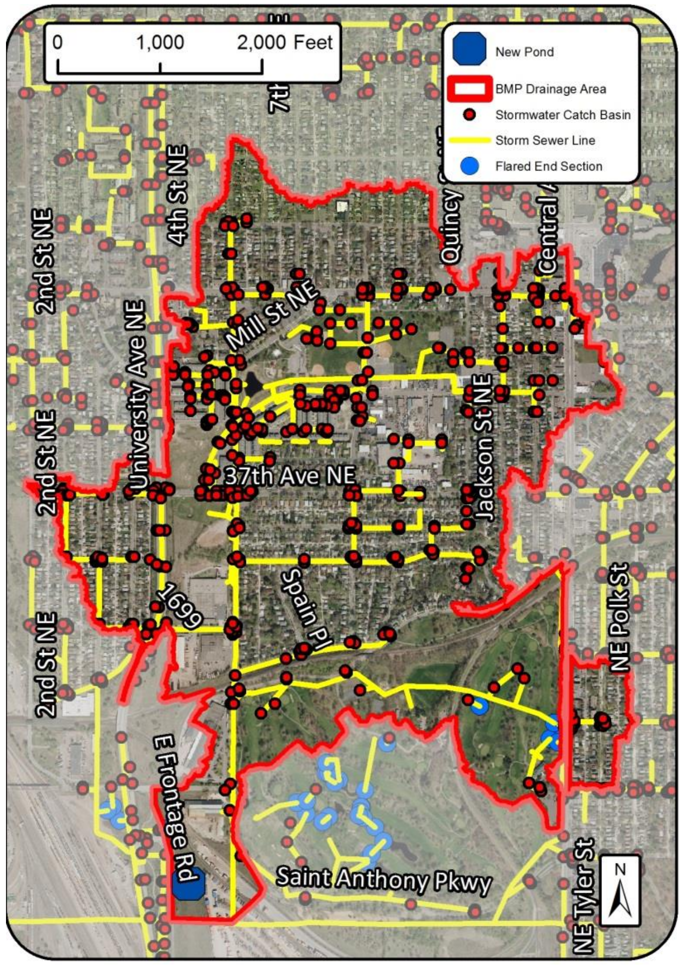
**See Appendix B for detailed cost information, costs are aggregated for pond and IESF

***$1,000/acre - Annual inspection and sediment/debris removal from pretreatment area + $10,000/acre for IESF maintenance

***Includes size of pond (275,000 sq-ft) and IESF (50,000 sq-ft)

Project ID: 14-B

New Pond – Catchment 14 West



Drainage Area – 519.9 acres
Location – Between East Frontage Road and the railroad tracks in the northwest corner of the rail yard.
Property Ownership – Private
Site Specific Information – Catchments 8-12 would be treated by this new stormwater pond. This pond could be positioned north of the 102" line running along the north side of the rail yard to ensure adequate separation between the pipe and the pond bottom. Approximately 6 acres is available in the northwest corner of the rail yard (note this property is owned by the railroad authority). An IESF in addition to the pond was not proposed at this location because of space limitations within the rail yard.

	New Pond			
	Cost/Removal Analysis	**New Treatment**		**% Reduction**
Treatment	**Number of BMPs**	1		
	Total Size of BMPs	256,000	sq-ft	
	TP (lb/yr)	118.1		36.1%
	TSS (lb/yr)	51,808		55.3%
	Volume (acre-feet/yr)	8.7		3.0%
Cost	**Administration & Promotion Costs***	$5,840		
	Design & Construction Costs**	$1,870,000		
	Total Estimated Project Cost (2014)	**$1,875,840**		
	Annual O&M***	$5,877		
Efficiency	**30-yr Average Cost/lb-TP**	**$579**		
	30-yr Average Cost/1,000lb-TSS	**$1,320**		
	30-yr Average Cost/ac-ft Vol.	**$7,863**		

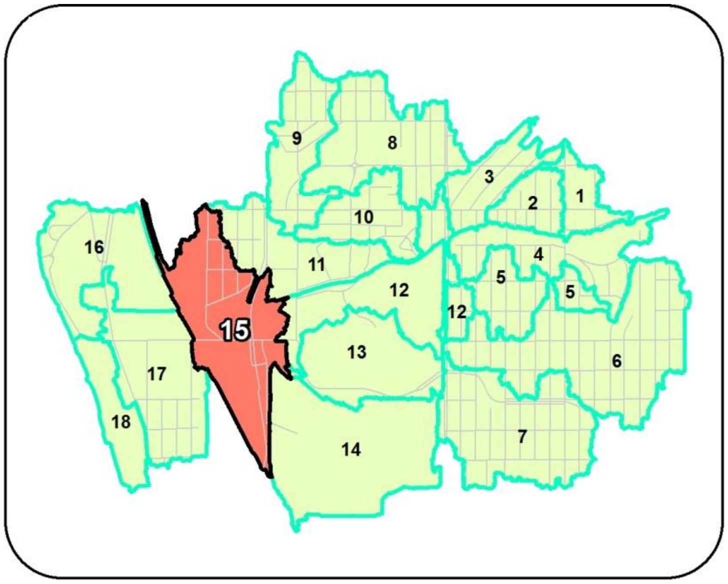
*80 hours at $73/hour

**See Appendix B for detailed cost information

***$1,000/acre - Annual inspection and sediment/debris removal from pretreatment area

Catchment 15

Existing Catchment Summary	
Acres	177.5
Dominant Land Cover	Rail Yard
Parcels	167
Volume (acre-feet/yr)	136.1
TP (lb/yr)	118.8
TSS (lb/yr)	58,104



CATCHMENT DESCRIPTION

This catchment has a very diverse set of land uses. The catchment contains all aspects of the rail yard that runs parallel to University Ave. NE as well as Highpoint Park and a small section of a residential neighborhood in the northeast corner of the catchment from 37th Ave. NE down to Edge Pl. There are also a few businesses within the catchment along University Ave. NE, including Custom Business Forms and Wentworth Screen Printing.

The stormwater runoff generated within this catchment flows overland to the nearest catch basin and is conveyed via storm sewer to join the primary storm sewer infrastructure in the southern portion of the catchment.

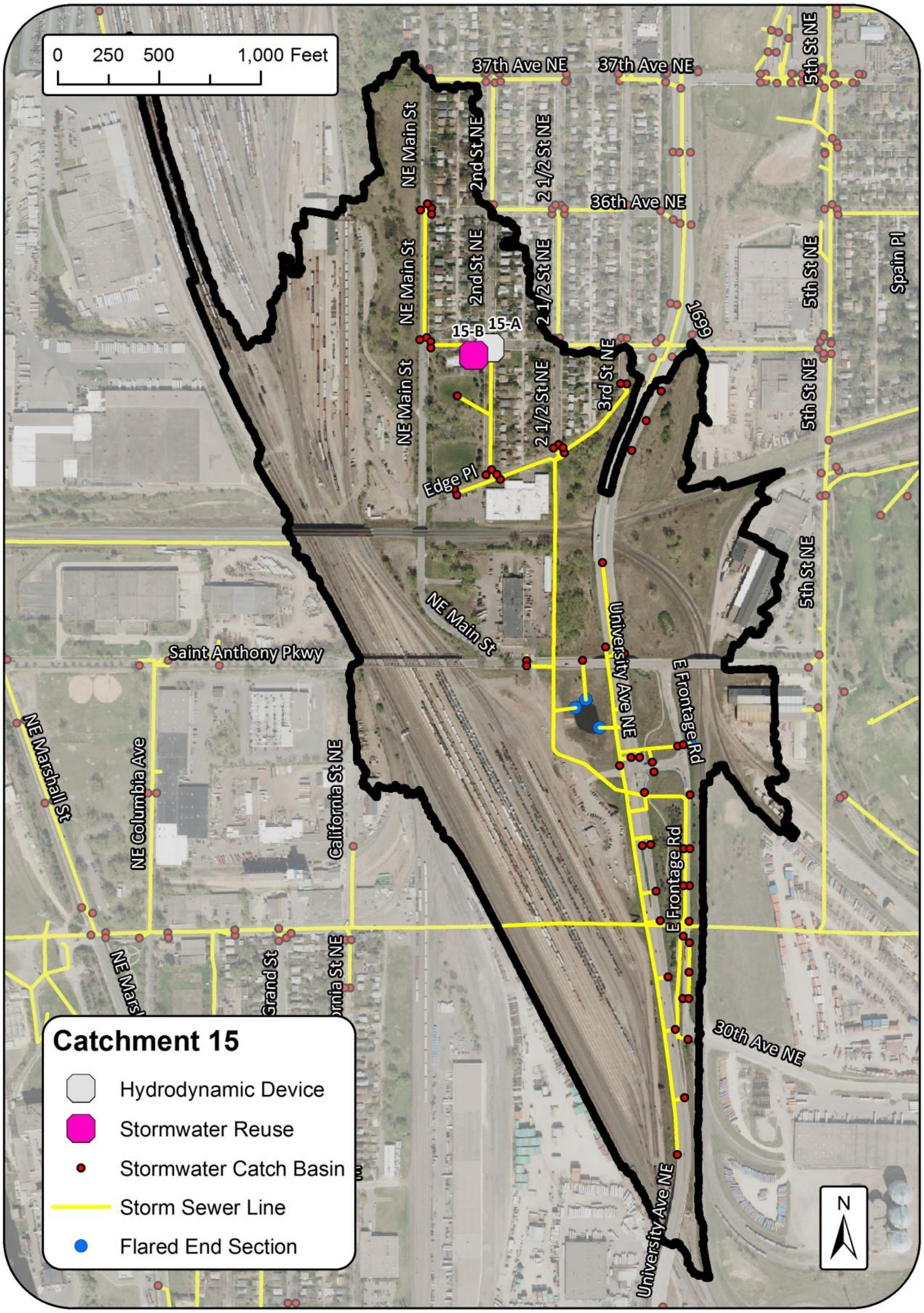
EXISTING STORMWATER TREATMENT

There is currently one pond located on the eastern portion of the rail yard near St. Anthony Pkwy. and University Ave. NE. The pond accepts stormwater from both St. Anthony Pkwy. and a small portion of University Ave. NE. Once full, the west side of the pond has an emergency overflow which discharges into the storm sewer system. Additionally, the City of Minneapolis conducts street cleaning three times annually throughout the catchment.

Existing Conditions

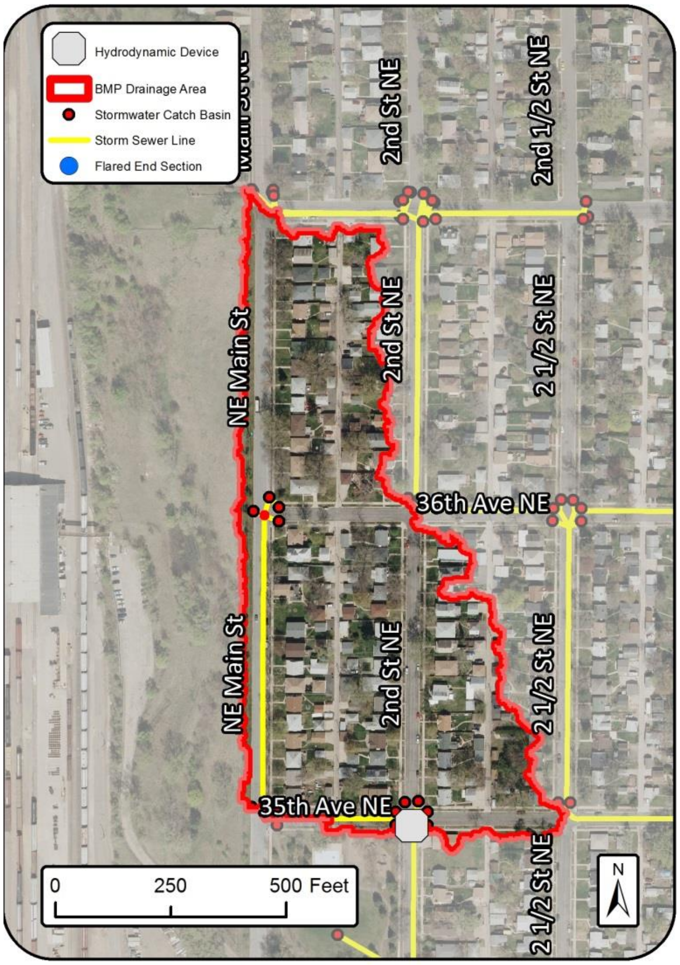
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Kutty Park Pond			
	TP (lb/yr)	126.6	7.8	6%	**118.8**
	TSS (lb/yr)	63,131	5,027	8%	**58,104**
	Volume (acre-feet/yr)	137.1	0.9	1%	**136.1**

RETROFIT RECOMMENDATIONS



Project ID: 15-A

35th Ave. NE and 2nd St. NE
Hydrodynamic Device



Drainage Area – 13.3 acres
Location – Intersection of 35th Ave. NE and 2nd St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 35th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	0.8%
	TSS (lb/yr)	339	0.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$13,270**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 15-B

Water Reuse in Hi-View Park

Drainage Area – 13.2 acres
Location – Within Hi-View Park
Property Ownership – Public (City of Minneapolis Park and Recreation Board)
Site Specific Information – A water reuse system has been proposed in Hi-View Park. An irrigation system (does not currently exist) within the park could reuse the rainfall captured in this system which would provide water quality treatment as well as water conservation benefits. An underground cistern was sized based on the MWMO's standard to treat 90% of TSS from the 95th percentile daily rainfall event. To treat the 1.17" 24-hour event for the 13.2 acre contributing drainage area, 99,812 gallons of storage would be required. Therefore, a 100,000 gallon cistern was proposed.

	Stormwater Reuse		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	100,000	gallons
	TP (lb/yr)	5.2	4.4%
	TSS (lb/yr)	1,469	2.5%
	Volume (acre-feet/yr)	3.4	2.5%
Cost	**Administration & Promotion Costs***	$5,840	
	Design & Construction Costs**	$443,750	
	Total Estimated Project Cost (2014)	**$449,590**	
	Annual O&M***	$3,000	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,459**	
	30-yr Average Cost/1,000lb-TSS	**$12,244**	
	30-yr Average Cost/ac-ft Vol.	**$5,290**	

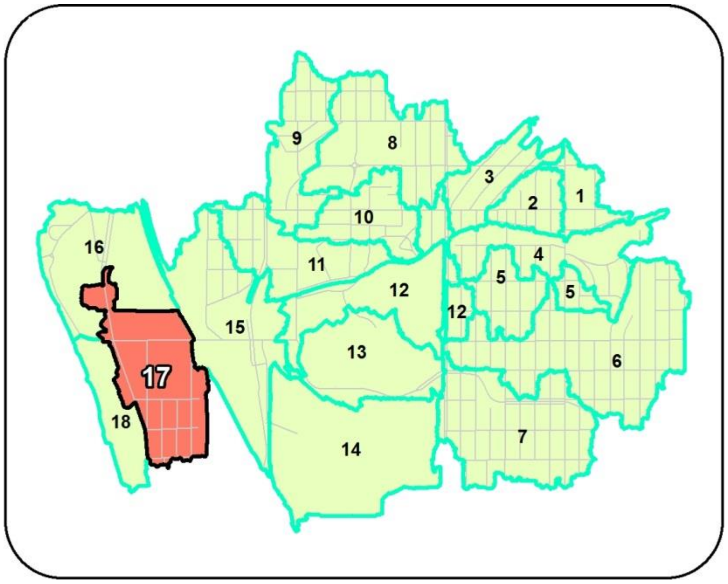
*80 hours at $73/hour

**See Appendix B for detailed cost information

***Includes cleaning of unit and disposal of sediment/debris

Catchment 17

Existing Catchment Summary	
Acres	139.2
Dominant Land Cover	Residential
Parcels	167
Volume (acre-feet/yr)	110.1
TP (lb/yr)	106.1
TSS (lb/yr)	52,202



CATCHMENT DESCRIPTION

This catchment spans the area between Marshall St. NE and California St. NE from 29th Ave. NE on the south to the railroad on the north. The main line of storm sewer conveyance to the river runs east to west beneath 31st Ave. NE.

All stormwater generated within this catchment flows overland to nearby catch basins and is conveyed via storm sewers to the main line. The water is then discharged directly into the Mississippi River. The border between industrial land uses and Kempf Paper Corporation to the north and the single family residential neighborhood to the south is 31st Ave. NE.

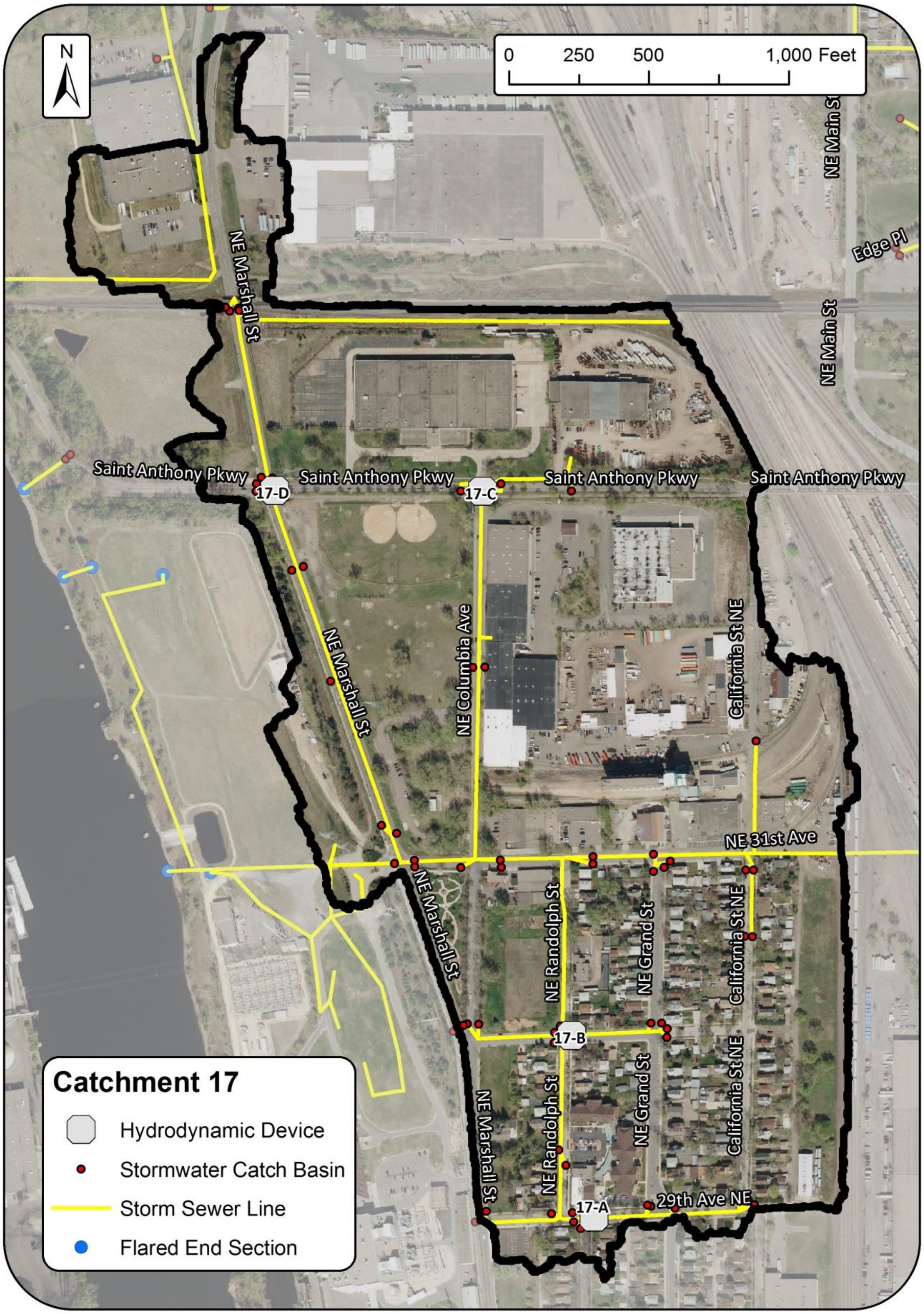
EXISTING STORMWATER TREATMENT

The primary stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

Existing Conditions

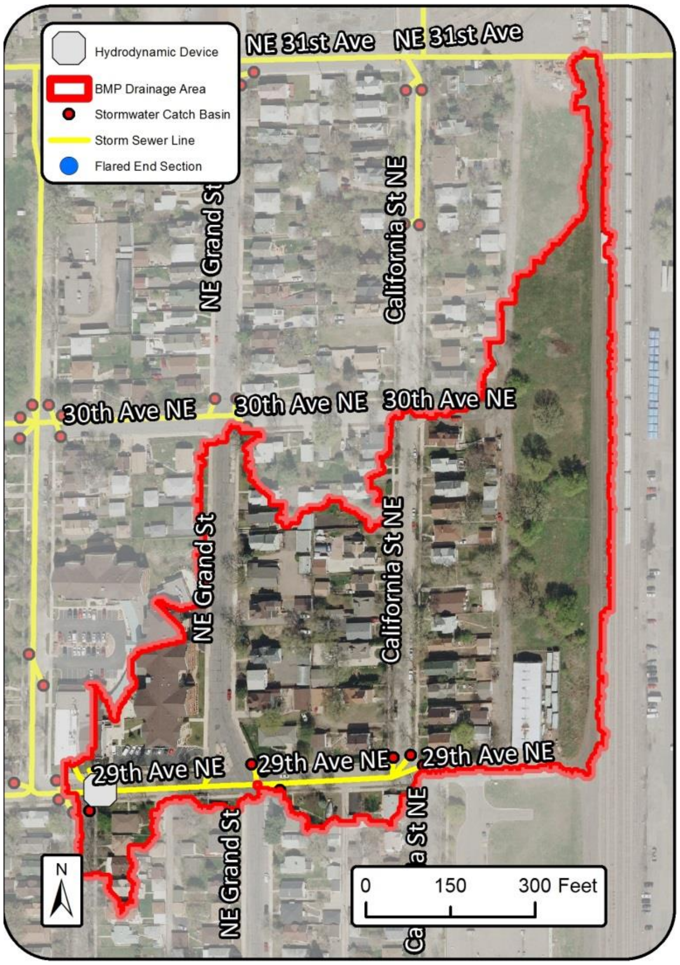
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	110.1	4.0	4%	**106.1**
	TSS (lb/yr)	54,857	2,655.0	5%	**52,202**
	Volume (acre-feet/yr)	110.1	0.0	0%	**110.1**

RETROFIT RECOMMENDATIONS



Project ID: 17-A

29th Ave. NE and Randolph St. NE Hydrodynamic Device



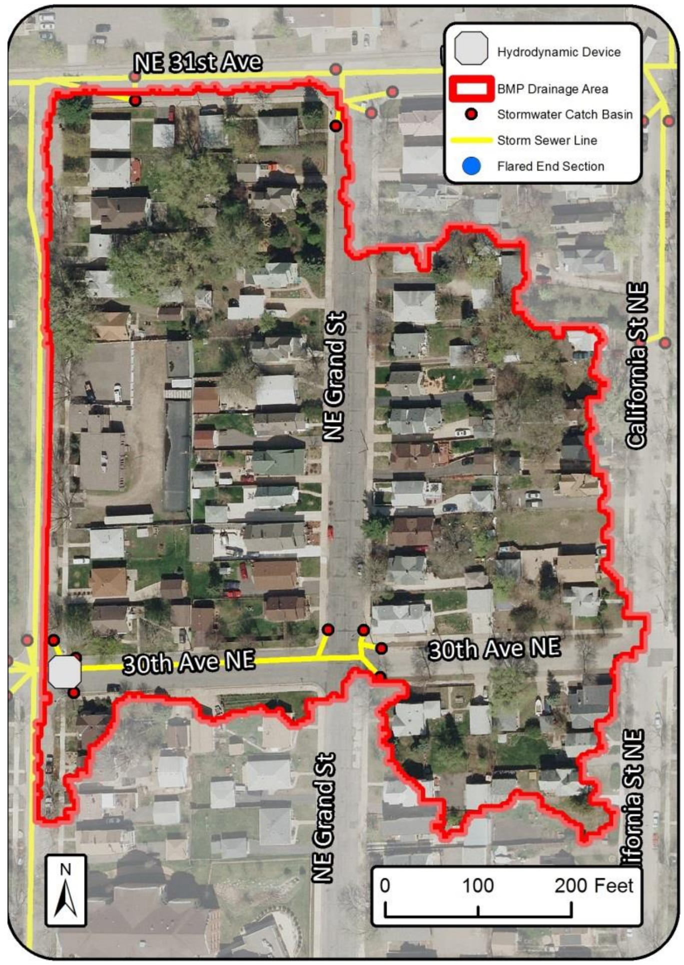
Drainage Area – 13.5 acres
Location – Intersection of 29th Ave. NE and Randolph St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 29th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.8	0.8%
	TSS (lb/yr)	375	0.7%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,623**	
	30-yr Average Cost/1,000lb-TSS	**$11,996**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 17-B

30th Ave. NE and Randolph St. NE Hydrodynamic Device



Drainage Area – 8.7 acres
Location – Intersection of 30th Ave. NE and Randolph St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of 30th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.8	0.8%
	TSS (lb/yr)	300	0.6%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$5,623**	
	30-yr Average Cost/1,000lb-TSS	**$14,995**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 17-C

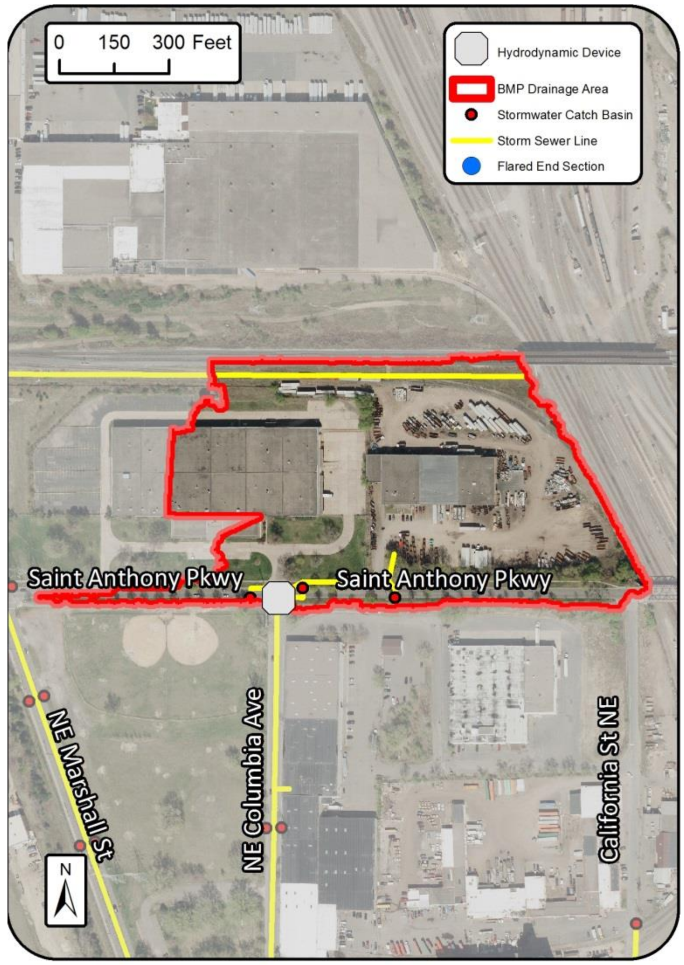
St. Anthony Pkwy. and Columbia Ave. NE Hydrodynamic Device

Drainage Area – 16.9 acres

Location – Intersection of St. Anthony Pkwy. and Columbia Ave. NE

Property Ownership – Public (City of Minneapolis)

Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of St. Anthony Pkwy. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.



Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	10	ft diameter
Treatment	TP (lb/yr)	1.1	1.0%
Treatment	TSS (lb/yr)	941	1.8%
Treatment	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
Cost	Design & Construction Costs**	$108,000	
Cost	Total Estimated Project Cost (2014)	**$109,752**	
Cost	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$4,089**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$4,780**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**N/A**	

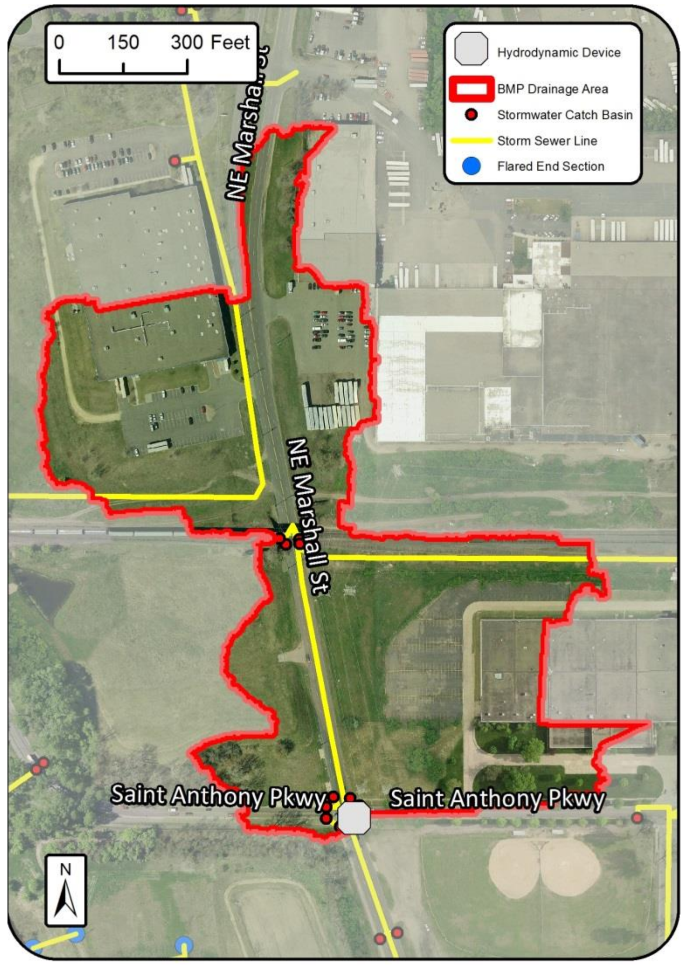
*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 17-D

St. Anthony Pkwy. and Marshall St. NE Hydrodynamic Device



Drainage Area – 22.2 acres
Location – Intersection of St. Anthony Pkwy. and Marshall St. NE
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area north of St. Anthony Pkwy. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

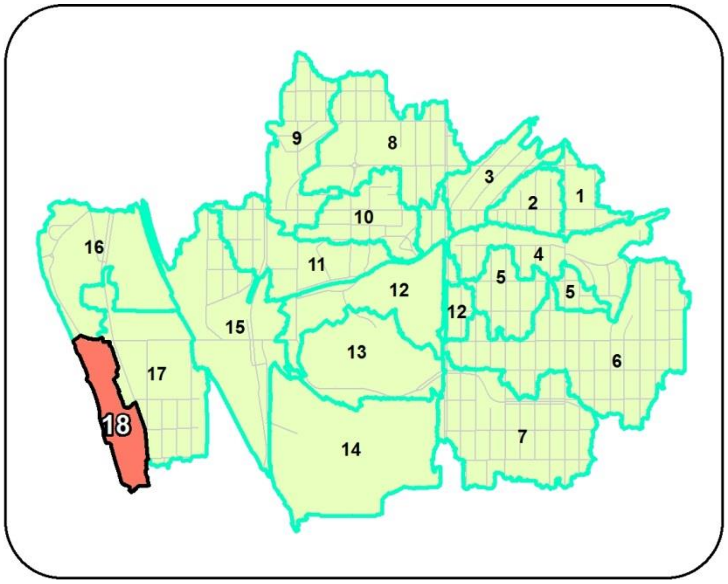
Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.3	1.2%
	TSS (lb/yr)	1,105	2.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$3,460**	
	30-yr Average Cost/1,000lb-TSS	**$4,071**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment 18

Existing Catchment Summary	
Acres	53.7
Dominant Land Cover	Industrial
Parcels	3
Volume (acre-feet/yr)	4.6
TP (lb/yr)	6.5
TSS (lb/yr)	1,252



CATCHMENT DESCRIPTION

This catchment runs between the Mississippi River and Marshall St. NE from 27th Ave. NE on the south to St. Anthony Pkwy. on the north. This catchment does include a small portion of Marshall Terrace Park in the south, but the majority is comprised of property owned and operated by the Xcel Energy Riverfront Generating Plant.

Most of the stormwater generated in this catchment is collected by infrastructure within the Xcel Energy property. The storm sewer infrastructure at Marshall Terrace Park is its own separate system and directly discharges into the Mississippi River.

EXISTING STORMWATER TREATMENT

Stormwater collected within the Xcel Energy property is conveyed via storm sewer to a holding pond. The pond has a pump that moves water to a large infiltration basin located in the northeast corner of the property. In addition to this treatment, the City of Minneapolis conducts street cleaning three times annually.

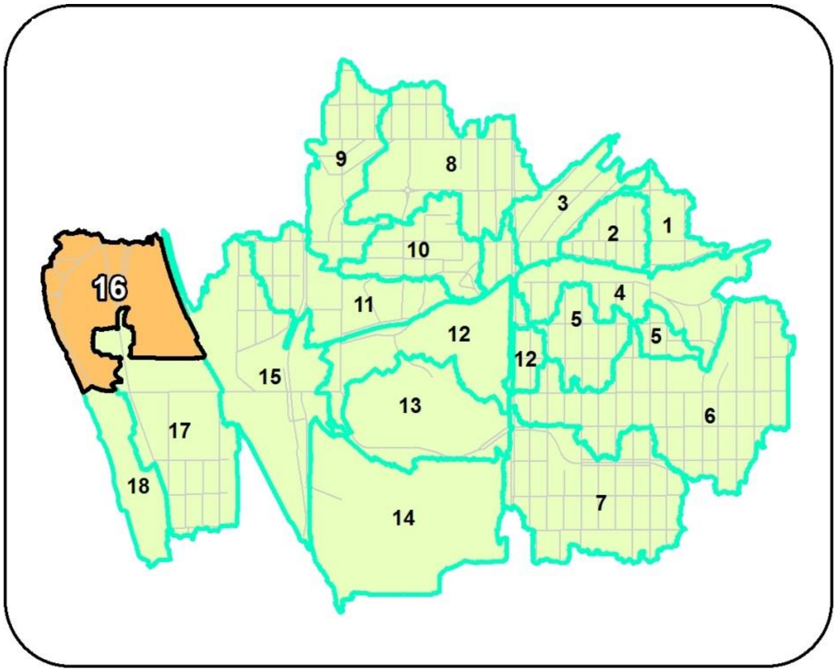
Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning, Ponds, Infiltration Basin			
	TP (lb/yr)	34.5	28.0	81%	**6.5**
	TSS (lb/yr)	17,903	16,651.0	93%	**1,252**
	Volume (acre-feet/yr)	36.9	32.3	88%	**4.6**

RETROFIT RECOMMENDATIONS
No retrofits were proposed in this catchment.

Direct Drainage Network

Catchment ID	Page
16	154



Existing Network Summary	
Acres	131.9
Dominant Land Cover	Industrial
Volume (ac-ft/yr)	102.7
TP (lb/yr)	70.8
TSS (lb/yr)	30,715

DRAINAGE NETWORK SUMMARY

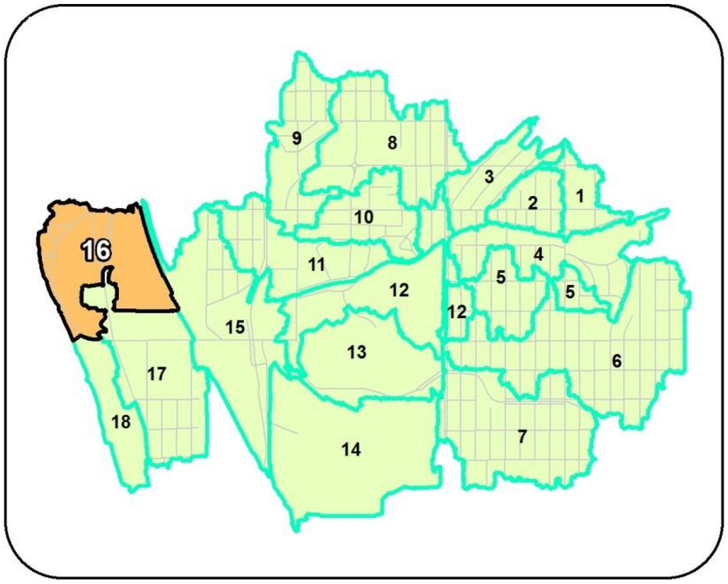
This network consists of only catchment 16. Stormwater runoff is directed to the Mississippi River from east to west within this catchment. Five separate outfalls exist into the Mississippi River. Four of the outfalls each drain relatively small stretches of St. Anthony Pkwy. One outfall drains the majority of the industrial land use that exists in catchment 16.

EXISTING STORMWATER TREATMENT

In addition to street cleaning conducted by the City of Minneapolis three times annually, a private stormwater pond exists on the industrial property located in the northeast corner of the catchment.

Catchment 16

Existing Catchment Summary	
Acres	131.9
Dominant Land Cover	Industrial
Parcels	25
Volume (acre-feet/yr)	102.7
TP (lb/yr)	70.8
TSS (lb/yr)	30,715



CATCHMENT DESCRIPTION

This catchment is bisected by Marshall St. NE and stretches from 37th Ave. NE on the north down to St. Anthony Pkwy. to the south. The Mississippi river acts as the western boundary while the rail yard makes up the eastern border. Other than Mississippi River Park, land use within the catchment is industrial.

Stormwater generated within this catchment flows overland and is captured by nearby catch basins. The water is then conveyed via storm sewer directly to the Mississippi River. The storm sewer system in this catchment stands alone and does not interact with the larger system to the south.

EXISTING STORMWATER TREATMENT

There is a privately owned pond which collects the stormwater runoff captured from the roof of Smurfit Stone Inc. located in the northeast portion of the catchment. Another form of stormwater treatment in the catchment is street cleaning, performed three times per year by the City of Minneapolis.

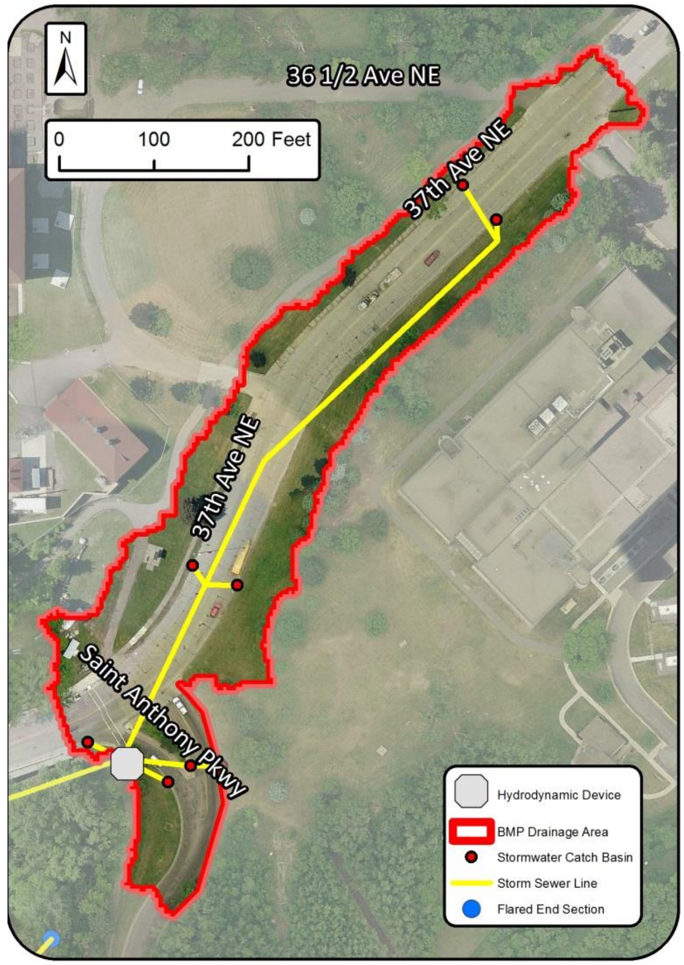
Existing Conditions

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Street Cleaning, Kutty Park Pond			
	TP (lb/yr)	93.6	22.8	24%	**70.8**
	TSS (lb/yr)	49,138	18,423.0	37%	**30,715**
	Volume (acre-feet/yr)	103.1	0.4	0%	**102.7**

RETROFIT RECOMMENDATIONS

Project ID: 16-A

37th Ave. NE and St. Anthony Pkwy. Hydrodynamic Device



Drainage Area – 3.1 acres
Location – Intersection of 37th Ave. NE and St. Anthony Pkwy.
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area along 37th Ave. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	Number of BMPs	1	
	Total Size of BMPs	6	ft diameter
	TP (lb/yr)	0.3	0.4%
	TSS (lb/yr)	159	0.5%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2014)	**$28,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,995**	
	30-yr Average Cost/1,000lb-TSS	**$11,311**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)

**Direct Cost: ($18,000 for materials) + ($9,000 for labor and installation costs)

***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 16-B

Marshall St. NE and East River Rd. Hydrodynamic Device

Drainage Area – 14.6 acres
Location – Intersection of Marshall St. NE and East River Rd.
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage area west of Marshall St. NE. A device at this intersection provides benefit due to the convergence of multiple storm sewer lines at a single location.

Hydrodynamic Device

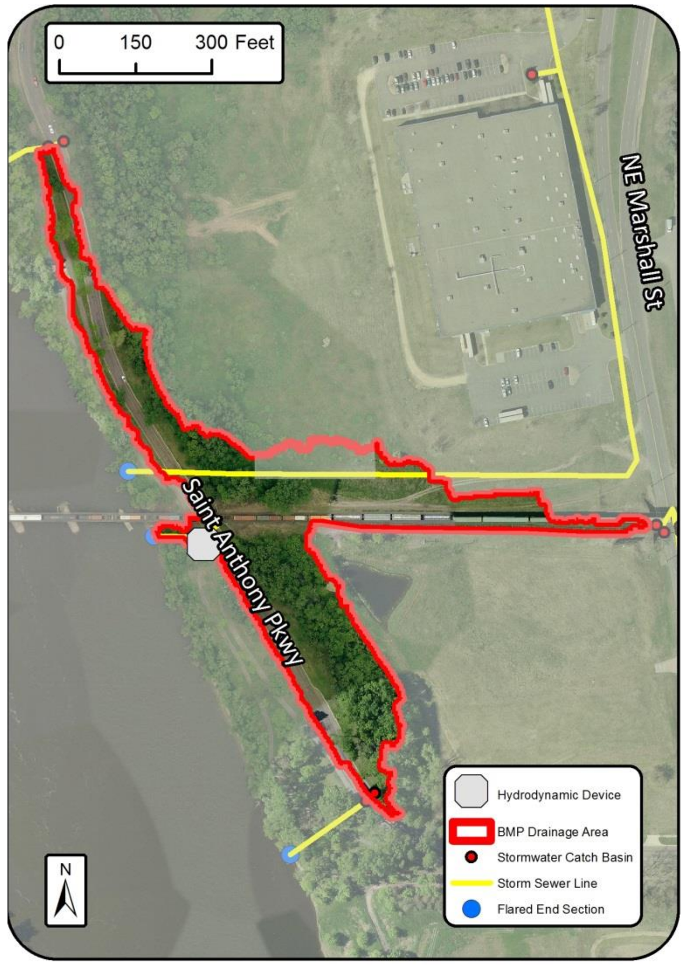
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	1.0	1.4%
	TSS (lb/yr)	339	1.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2014)	**$109,752**	
	Annual O&M***	$840	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,498**	
	30-yr Average Cost/1,000lb-TSS	**$13,270**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($72,000 for materials) + ($36,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 16-C

Railroad and St. Anthony Pkwy. Hydrodynamic Device

Drainage Area – 5.6 acres
Location – Intersection of railroad and St. Anthony Pkwy. directly east of the Mississippi River
Property Ownership – Public (City of Minneapolis)
Site Specific Information – Hydrodynamic device could be installed to accept runoff from the drainage along St. Anthony Pkwy.



Hydrodynamic Device

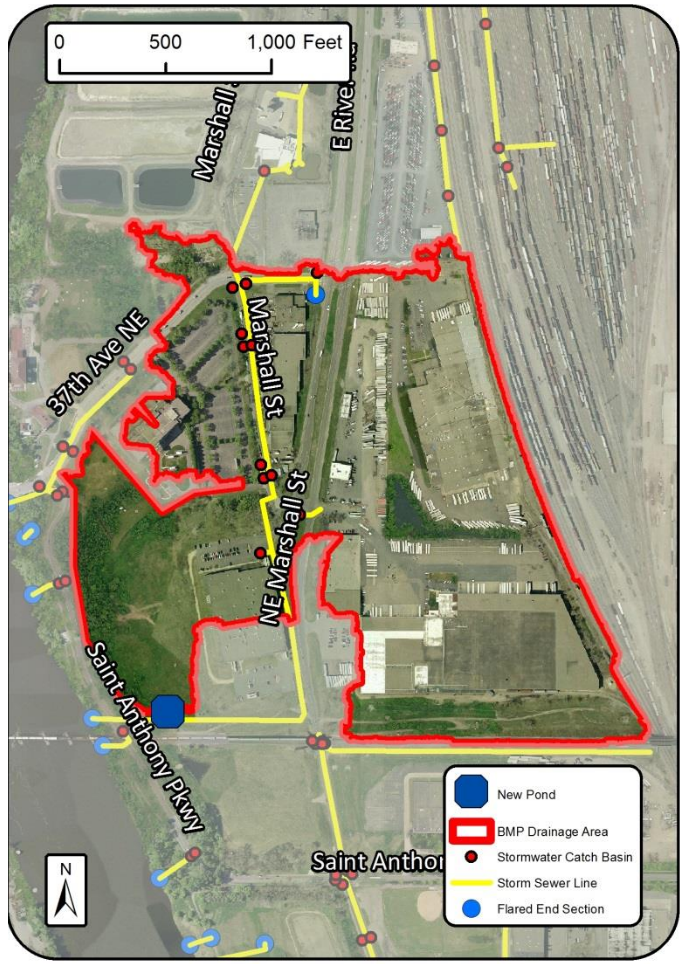
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	8	ft diameter
	TP (lb/yr)	0.7	1.0%
	TSS (lb/yr)	233	0.8%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2014)	**$55,752**	
	Annual O&M***	$840	
Efficiency	30-yr Average Cost/lb-TP	**$3,855**	
	30-yr Average Cost/1,000lb-TSS	**$11,581**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

*Indirect Cost: (24 hours at $73/hour)
**Direct Cost: ($36,000 for materials) + ($18,000 for labor and installation costs)
***Per BMP: (4 cleanings/year)*(3 hours/cleaning)*($70/hour)

Project ID: 16-D

New Pond – Catchment 16, Bureau of Engraving

Drainage Area – 94.3 acres
Location – East of St. Anthony Pkwy. on private property owned by Bureau of Engraving
Property Ownership – Private
Site Specific Information – A stormwater treatment pond is proposed in the open space on the Bureau of Engraving's property located north of the railroad tracks immediately east of St. Anthony Pkwy. The construction of this pond would include daylighting the storm sewer line which runs through the proposed pond location. This would provide treatment to all of the stormwater conveyed through these storm sewers prior to discharge into the Mississippi River.



New Pond			
	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
Treatment	Total Size of BMPs	40,000	sq-ft
Treatment	TP (lb/yr)	12.5	17.7%
Treatment	TSS (lb/yr)	8,989	29.3%
Treatment	Volume (acre-feet/yr)	0.5	0.5%
Cost	Administration & Promotion Costs*	$5,840	
Cost	Design & Construction Costs**	$322,500	
Cost	**Total Estimated Project Cost (2014)**	**$328,340**	
Cost	Annual O&M***	$918	
Efficiency	30-yr Average Cost/lb-TP	**$949**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$1,320**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$23,725**	

*80 hours at $73/hour

**See Appendix B for detailed cost information

***$1,000/acre - Annual inspection and sediment/debris removal from pretreatment area

References

Environmental Services Division Department of Environmental Resources The Prince George's County, Maryland. 2007. *Bioretention Manual*. 206 pp.

Erickson, A.J., and J.S. Gulliver. 2010. *Performance Assessment of an Iron-Enhanced Sand Filtration Trench for Capturing Dissolved Phosphorus*. University of Minnesota St. Anthony Falls Laboratory Engineering, Environmental and Geophysical Fluid Dynamics Project Report No. 549. Prepared for the City of Prior Lake, Prior Lake, MN.

Minnesota Pollution Control Agency (MPCA). 2014. *Design Criteria for Stormwater Ponds*. Web.

Technical documents. (2014, September 3). *Minnesota Stormwater Manual,* . Retrieved 16:35, September 18, 2014 from http://stormwater.pca.state.mn.us/index.php?title=Technical_documents&oldid=15214.

Mississippi Watershed Management Organization (MWMO). 2011a. *Bridal Veil Creek: Urban Subwatershed Stormwater Retrofit Assessment*. MWMO Watershed Bulletin 2011-6. 29 pp.

Mississippi Watershed Management Organization (MWMO). 2011b. *Watershed Management Plan 2011-2021*. MWMO Watershed Bulletin 2011-3. 190 pp.

Mississippi Watershed Management Organization (MWMO). 2013. *Annual Monitoring Report 2012.* MWMO Watershed Bulletin 2013-1. 68 pp.

New York City Environmental Protection. 2013. *NYC Green Infrastructure 2013 Annual Report*. 36 pp.

Schueler, T. and A. Kitchell. 2005. *Methods to Develop Restoration Plans for Small Urban Watersheds. Manual 2, Urban Subwatershed Restoration Manual Series*. Center for Watershed Protection. Ellicott City, MD.

Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. *Urban Stormwater Retrofit Practices. Manual 3, Urban Subwatershed Restoration Manual Series. Center for Watershed Protection*. Ellicott City, MD.

Virginia DCR Stormwater Design Specification No. 9. 2013. *Bioretention Version 2.0*. 59 pp.

Weiss, P.T., J.S. Gulliver, A.J. Erickson. 2005. The Cost and Effectiveness of Stormwater Management Practices. Minnesota Department of Transportation.

Appendix A – Modeling Methods

The following sections include WinSLAMM model details for each type of best management practice modeled for this analysis.

WinSLAMM

Pollutant and volume reductions were estimated using the stormwater model Source Load and Management Model for Windows (WinSLAMM). WinSLAMM uses an abundance of stormwater data from the upper-midwest and elsewhere to quantify runoff volumes and pollutant loads from urban areas. It has detailed accounting of pollutant loading from various land uses, and allows the user to build a model "landscape". WinSLAMM uses rainfall and temperature data from a typical year (1959 data from Minneapolis for this analysis), routing stormwater through the user's model for each storm. WinSLAMM version 10.1.222 was used for this analysis to estimate volume and pollutant loading and reductions. Additional inputs for WinSLAMM are provided in
Table 26.

Table 26: General WinSLAMM Model Inputs (i.e. Current File Data)

Parameter	File/Method
Land use acreage	ArcMap, Metropolitan Council 2010 Land Use[6]
Precipitation/Temperature Data	Minneapolis 1959 – best approximation of a typical year
Winter season	Included in model. Winter dates are 11-4 to 3-13.
Pollutant probability distribution	WI_GEO01.ppd
Runoff coefficient file	WI_SL06 Dec06.rsv
Particulate solids concentration file	WI_AVG01.psc
Particle residue delivery file	WI_DLV01.prr
Street delivery files	WI files for each land use

Retrofits Modeled, But Not Reported

Catchment 8 – Hydrodynamic devices were modeled within catchment 8. However, the existing Huset Park pond is effectively treating the contributing drainage area for both TSS and TP. Therefore, additional pollutant removal by inclusion of hydrodynamic devices was not achieved.

Catchment 9 - Hydrodynamic devices were also modeled within catchment 9. However, the existing Huset Park pond is effectively treating the contributing drainage area for both TSS and TP within the drainage areas where hydrodynamic devices were feasible. Therefore, additional pollutant removal by inclusion of hydrodynamic devices was not achieved.

Catchment 12 - Modifications to the existing treatment pond along Central Ave. NE were considered and modeled. However, modeling indicated the pond was sized appropriately to maximize removal of TP

[6] The MWMO Minnesota Land Cover Classification System (MLCCS) dataset is typically used for this type of analysis within the MWMO. However, the Metropolitan Council land use dataset was used for this report because of the increased resolution throughout the urbanized landscape (e.g. residential areas further classified as duplex or multi-family). A comparison of the two datasets shows no functional difference with respect to WinSLAMM modeling results.

and TSS from the contributing drainage area. Similarly, a hydrodynamic device was modeled at the intersection of 34th Ave. NE and Central Ave. NE. No net increase in TSS or TP treatment was observed because the existing pond located on the Columbia Golf Course property is providing sufficient treatment.

Alleyway Underground Storage

Representative blocks were chosen across the research subwatershed to estimate the average contribution of stormwater runoff to alleyways. Areas for rooftops, driveways, sidewalks, alleyways, and other impervious areas (e.g. tile patios) which drain to alleyways were delineated and entered manually into the stormwater quality model WinSLAMM. A summary of all delineated source areas is shown in the table below,

Block #	Block Area (acres)	Land Use Source Area (acres)				Source Area as a Fraction of Total Block Area (%)			
		Alleyways	Rooftops	Other Impervious Surfaces*	Landscaped Areas	Alleyways	Rooftops	Other Impervious Surfaces*	Landscaped Areas
1	1.83	0.17	0.46	0.46	0.73	9.20%	25.30%	46.10%	40.20%
2	1.68	0.11	0.48	0.42	0.67	6.80%	28.50%	41.60%	39.90%
3	1.62	0.17	0.5	0.49	0.47	10.40%	30.60%	48.80%	28.90%
Average	1.71	0.15	0.48	0.46	0.62	8.80%	28.10%	45.50%	36.30%

** 'Other Impervious Surfaces' includes driveway, sidewalks, tile patios, and isolated impervious areas.*

WinSLAMM allows the user to define what percentage of a contributing drainage area from an impervious surface discharges onto 1) a directly connected area or 2) a pervious area/partially connected impervious area. This distinction is made as runoff onto a pervious space (e.g. turf grass, garden) allows for settling of pollutants and infiltration whereas discharge to a directly-connected impervious area provides little opportunity for pollutant treatment. Breakdowns for each of the land use source areas are shown in the table below,

Land Use Source Area	Directly-Connected (%)	Disconnected or Partially Connected (%)
Rooftops	20%	80%
Driveways	100%	0%
Sidewalks	20%	80%
Alleyways	100%	0%

The 20%/80% breakdown for rooftops is a default value for medium-density residential lots with alleyways in WinSLAMM. The 20%/80% breakdown for sidewalks was assumed based on user experience. Each land use source area was modeled with exclusively silty soils.

The practice was sized to treat 90% of total suspended solids (TSS) from a 95th percentile, 24-hour storm event. This requires storage capacity of at least 4,629 cu-ft, assuming runoff from only impervious surfaces (1.09 acres for a typical residential block). To treat this block, a 100’ long, 12’ wide, and 8’ deep aggregate rock basin was modeled with two in-parallel 48” perforated CMPs (corrugated metal pipes) running the length of the basin. A porosity of 0.35 was assumed for the aggregate rock. Between the rock and perforated pipes 4,993 cu-ft of water storage is available. A conservative 0.2 in/hour infiltration rate across the 1,200 sq-ft practice base was applied considering the tight silty loam soils in the region. No underdrain was modeled for the practice.

Boulevard Rain Gardens

Expanded boulevard rain gardens were considered where opportunities may exist to narrow the roadway or to push the sidewalk further from the roadway curb to accommodate a larger garden size. The standard boulevard rain garden had the same inputs with exception to garden size, in which top area was modeled at 80 sq-ft and bottom area at 25 sq-ft. Native soil infiltration rate (in/hr) was also adjusted in model scenarios between 0.2 and 0.1 in/hr.

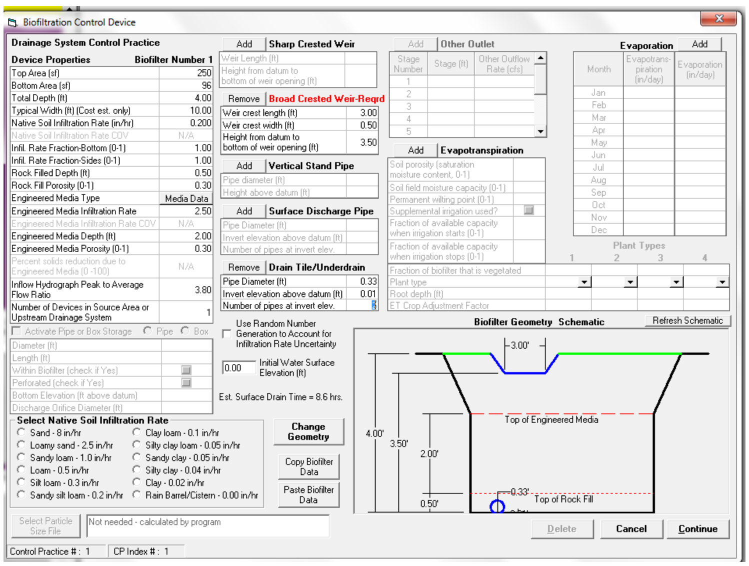


Figure 13: Expanded boulevard Rain Garden WinSLAMM model inputs

Curb-Cut Rain Garden

Curb-cut rain gardens were modeled as drainage area control practices within WinSLAMM. Each was modeled with an underdrain, as the silty soils in this region often lead to lower infiltration rates which can create ponding lasting longer than 48 hours. The underdrain will ensure the garden dries between rain events. If, based on soil tests, it is determined that an underdrain is not necessary, then expected reductions for TP, TSS, and volume will be larger. Table 27 describes specific input parameters for rain gardens in the WinSLAMM model. Figure 14 shows the WinSLAMM biofiltration parameter input screen.

Table 27: WinSLAMM Input Parameters for Curb-Cut Rain Gardens

Parameter	Unit	Value
Top Area	sq-ft	varies
Bottom Area	sq-ft	Varies
Total Depth	ft	4.0
Native Soil Infiltration Rate	in/hr	0.3
Infiltration Rate Fraction-Bottom (0-1)	-	1
Infiltration Rate Fraction-Sides (0-1)	-	1
Rock Filled Depth	ft	0.5
Rock Fill Porosity (0-1)	-	0.3
Engineered Media Infiltration Rate	in/hr	2.5
Engineered Media Depth	ft	2.0
Engineerd Media Porosity (0-1)	-	0.3
Inflow Hydrograph Peak to Average Flow Ratio	-	3.8
Broad Crested Weir Length	ft	3.0
Broad Crested Weir Width	ft	0.5
Height From Datum to Bottom of Weir Opening	ft	3.5
Underdrain Pipe Diameter	ft	0.33
Underdrain Invert Elevation Above Datum	ft	0.01
Number of pipes at invert elevation	-	varies[7]

[7] Additional underdrain pipe added every 250 sq-ft of top area.

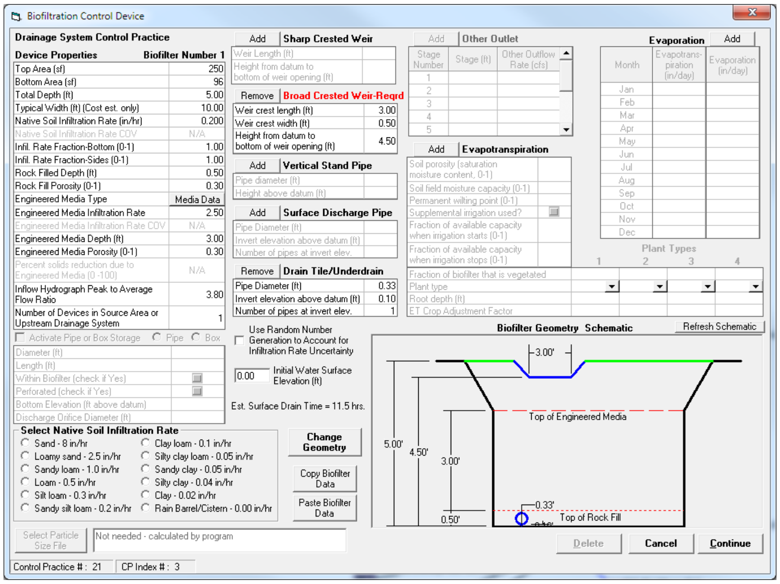


Figure 14: Biofiltration Control Practice Input Screen: Curb-cut Rain Garden (WinSLAMM)

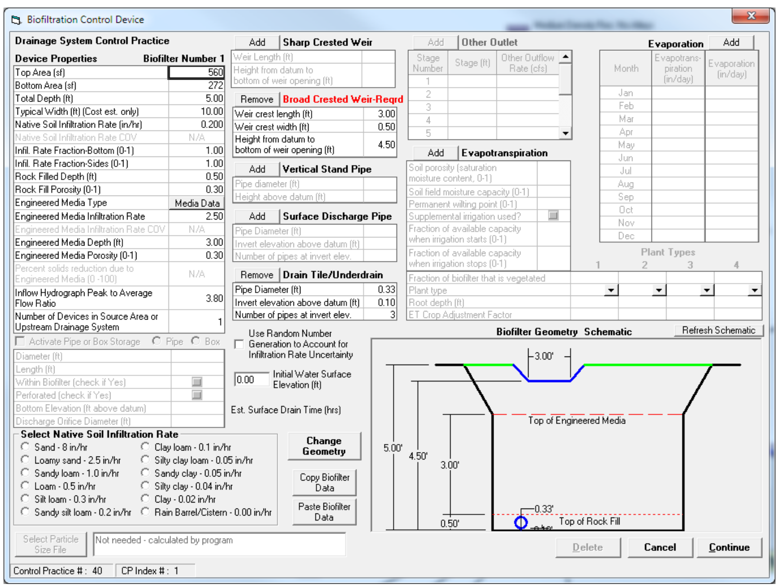


Figure 15: Boulevard Rain Garden East (Catchment 3) WinSLAMM model inputs

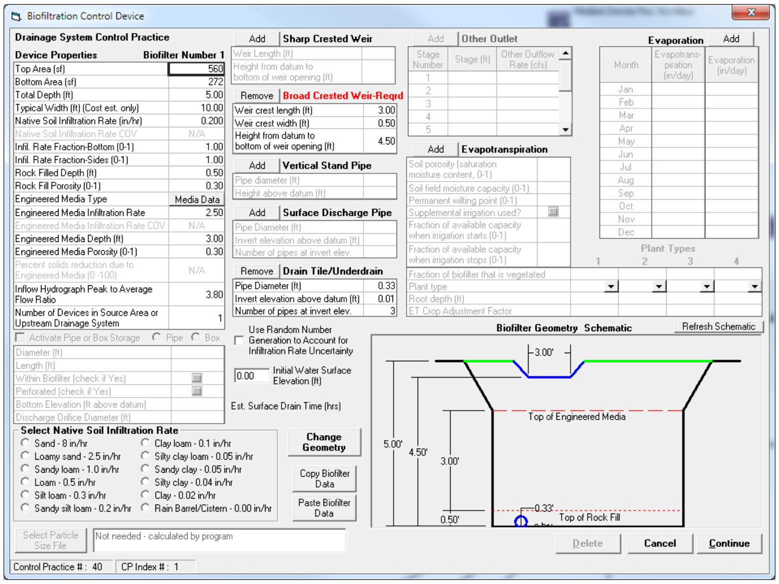


Figure 16: Boulevard Rain Garden West (Catchment 3) WinSLAMM model inputs

Disconnect Filtration Basin

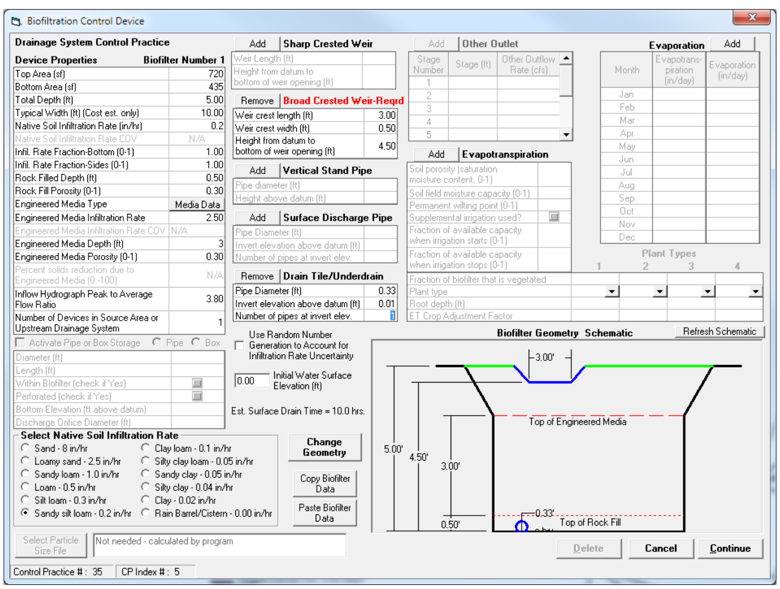


Figure 17: Disconnect Filtration Basin (Catchment 2) WinSLAMM model inputs

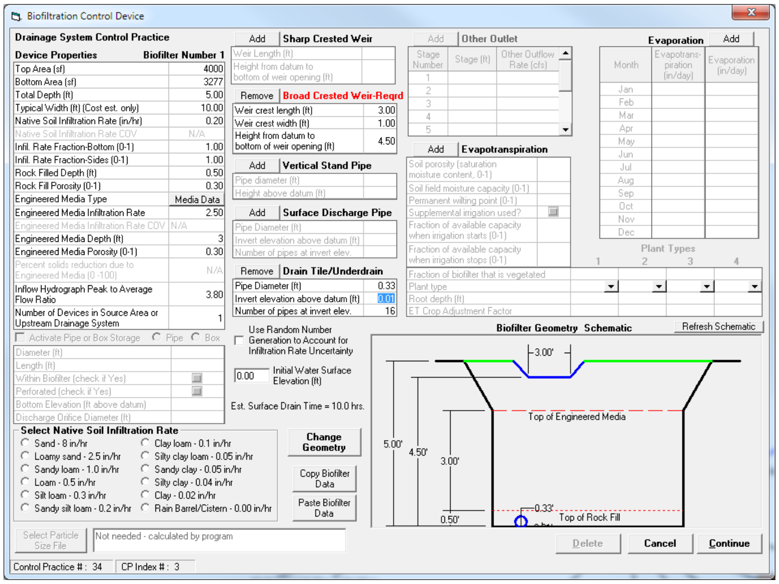


Figure 18: Disconnect Filtration Basin (Catchment 5 – 4000 sq-ft) WinSLAMM model inputs

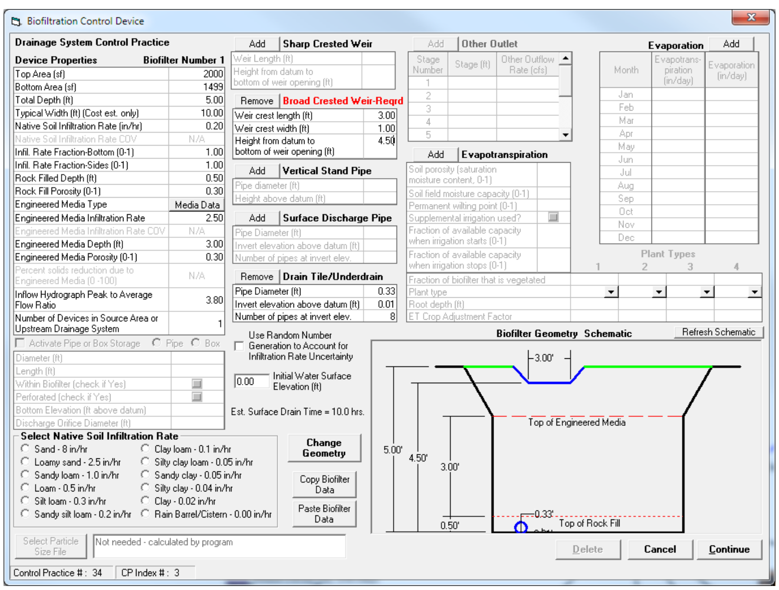


Figure 19: Disconnect Filtration Basin (Catchment 5 - 2000 sq-ft) WinSLAMM model inputs

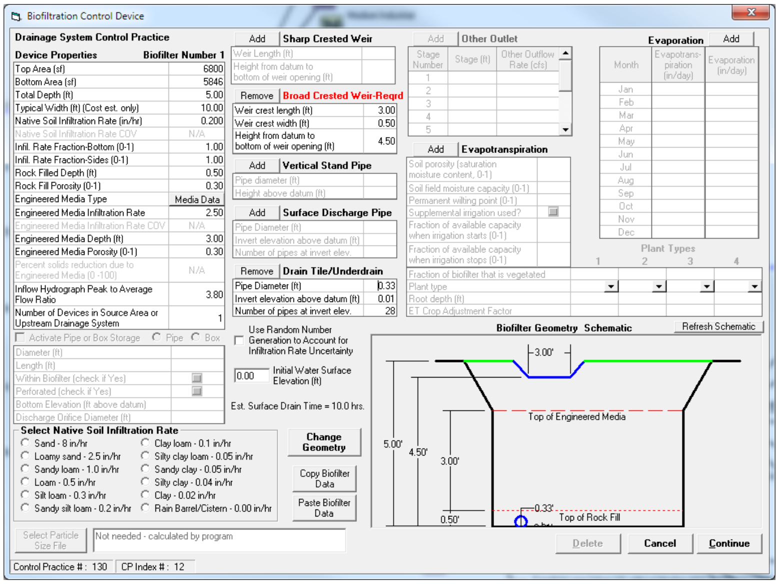


Figure 20: Disconnect Filtration Basin (Catchment 8, 6,800 sf top area) WinSLAMM model inputs

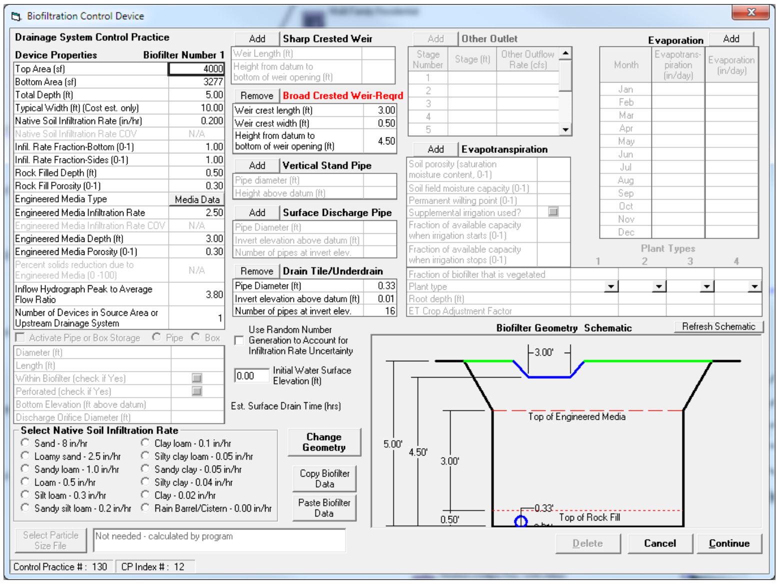


Figure 21: Disconnect Filtration Basin (Catchment 8, 4,000 sf top area) WinSLAMM model inputs

Filtration Basin

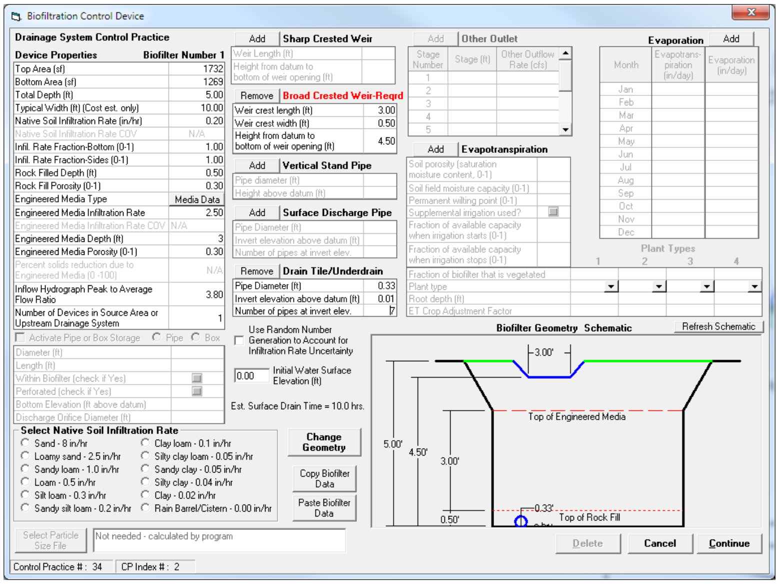


Figure 22: Filtration Basin (Catchment 10) WinSLAMM model inputs

Hydrodynamic Device

Table 28: Hydrodynamic Device Sizing Criteria

Drainage Area (acres)	Peak Q (cfs)	Hydrodynamic Device Diameter (ft)
1	1.97	4
2	3.90	6
3	5.83	6
4	7.77	6
5	9.72	8
6	11.68	8
7	13.65	8
≥8	15.63	10

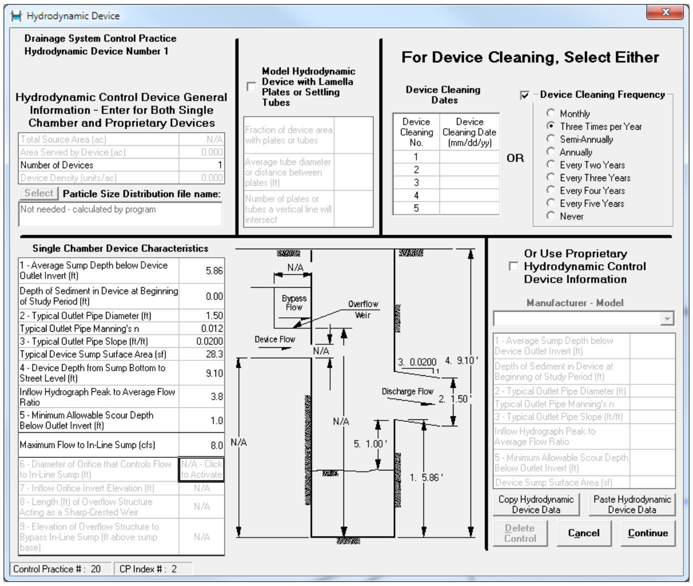


Figure 23: Hydrodynamic Device (6' diam.) WinSLAMM model inputs

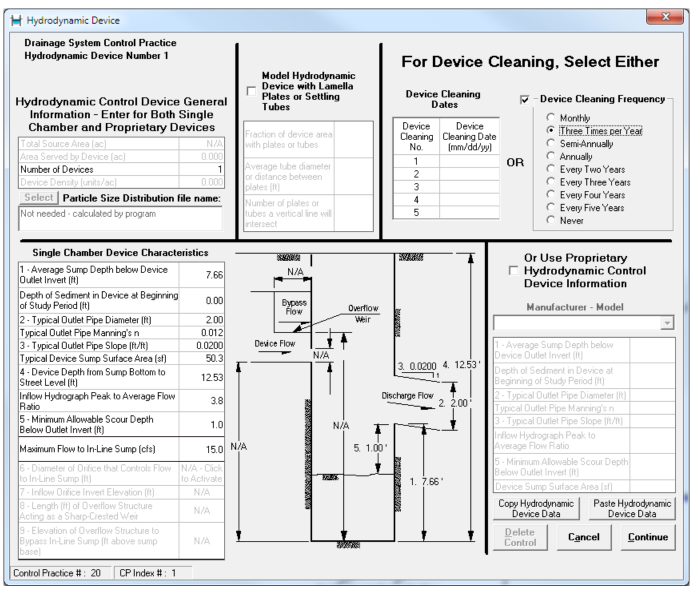


Figure 24: Hydrodynamic Device (8' diam.) WinSLAMM model inputs

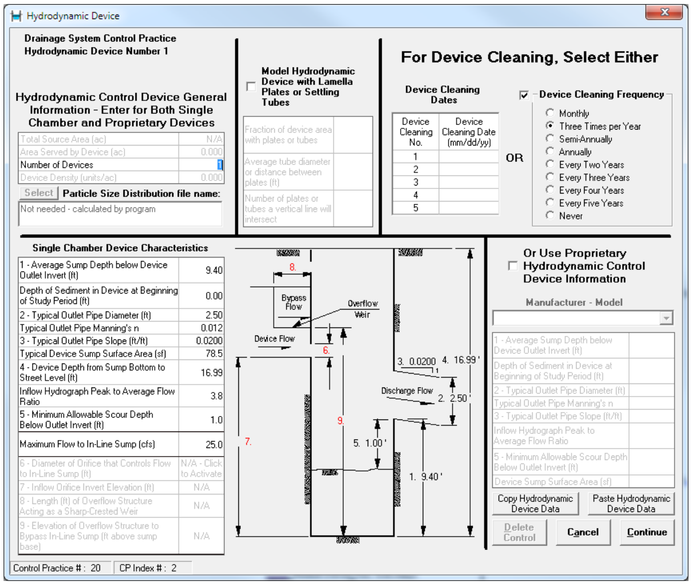


Figure 25: Hydrodynamic Device (10' diam.) WinSLAMM model inputs

Iron Enhanced Sand Filter

Wet ponds, by design, allow for sediments and other bound pollutants to drop out of suspension. This practice, though, often allows dissolved pollutants to advect through the system untreated. Iron-enhanced sand filters (IESF) can be retrofitted to or installed with wet ponds to treat this dissolved load.

During a storm event, the pond increases from its permanent-pond stage to its flood stage. The IESF is designed to accept input from the wet pond during storm events, allowing for infiltration of water through its iron rich media, where dissolved pollutants (particularly dissolved phosphorus (DP)) adsorb to the iron filings. DP is then retained within the media while the stormwater can seep into an underdrain. Lastly, the underdrain discharges downstream of the wet pond. IESFs can be installed without ponds, although it is recommended that some form of pretreatment is available to remove sediment, which can deposit within the pore space of the filter and clog the practice over time.

There is currently no drainage practice input for these features in WinSLAMM. As they behave similarly to a bioretention cell, they can be modeled as such. But, as they often operate in tandem with stormwater ponds, estimating when and how much water and pollutants they will receive can be problematic. WinSLAMM was utilized to estimate what percentage of the stormflow could be treated by the filter. Stormflow input into the practice is most dependent upon the volume which can be passed through the system’s underdrains. Stormflow treated by the device is a function of total area, depth, infiltration rate, and engineered media characteristics. WinSLAMM inputs used for this analysis are listed in Table 29.

Field tests of installed sand trenches conducted by the University of Minnesota concluded that a sand media mixed with 5% iron filings is capable of retaining 80% (or more) of the DP load of stormwater flowing through the media (Erickson and Gulliver, 2010). Thus, DP retention by the IESF can be estimated by the equation,

$$P_{RET} = 0.8 * [P_{IN}] * q_S$$

where P_{RET} is the DP load removed by the IESF, $[P_{IN}]$ is the concentration of the DP input, and q_S is the volume of stormflow passing through the IESF. q_S is a function of the storm event duration and intensity, stormwater pond storage (if in-line with a pond), and IESF storage volume (bottom area, top area, and depth). The 0.8 multiplier assumes the IESF removes only 80% of the DP load.

Table 29: WinSLAMM Input Parameters for Iron Enhanced Sand Filter

Parameter	Unit	Value
Top Area	sq-ft	varies
Bottom Area	sq-ft	varies
Total Depth	ft	5.0
Native Soil Infiltration Rate	in/hr	0.0
Infiltration Rate Fraction-Bottom (0-1)	-	1
Infiltration Rate Fraction-Sides (0-1)	-	1
Rock Filled Depth	ft	0.5
Rock Fill Porosity (0-1)	-	0.3
Engineered Media Infiltration Rate	in/hr	8.0
Engineered Media Depth	ft	1.5
Engineerd Media Porosity (0-1)	-	0.3
Inflow Hydrograph Peak to Average Flow Ratio	-	3.8
Broad Crested Weir Length	ft	10
Broad Crested Weir Width	ft	1.0
Height From Datum to Bottom of Weir Opening	ft	4.0
Underdrain Pipe Diameter	ft	0.5
Underdrain Invert Elevation Above Datum	ft	0.01
Number of Pipes at invert elevation	-	varies

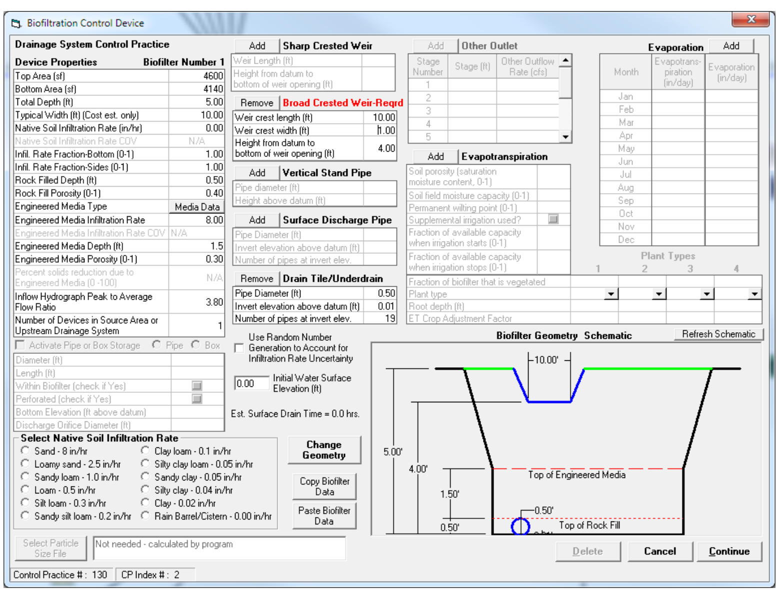


Figure 26: Iron Enhanced Sand Filter (Catchment 9) WinSLAMM model inputs

Permeable Asphalt

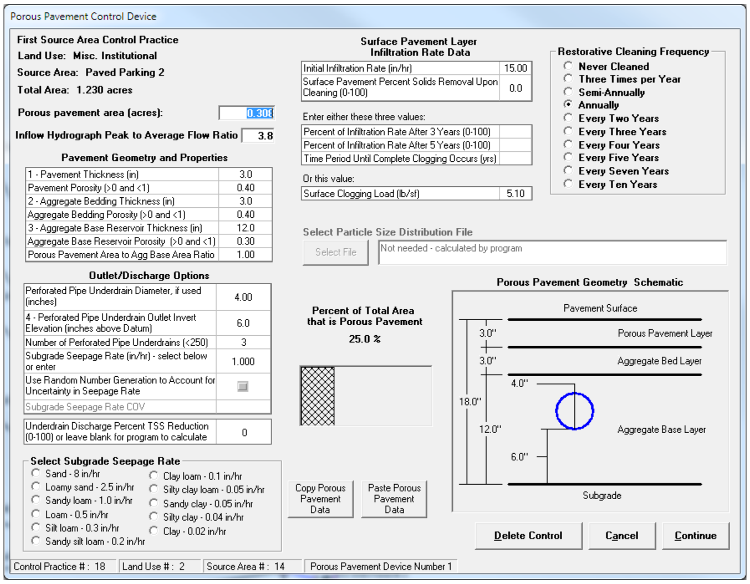


Figure 27: Permeable Asphalt (Catchment 8) WinSLAMM model inputs

Ponds

Ponds were proposed in the landscape where sufficient drainage area could sustain a permanent pool of water (MPCA, 2014). Ponds were proposed following guidance from the Minnesota Pollution Control Agency, in which depths are equal to or less than 8-10’ to prohibit stratification and at least 1,800 cu-ft. of pond storage is available for each acre of drainage area.

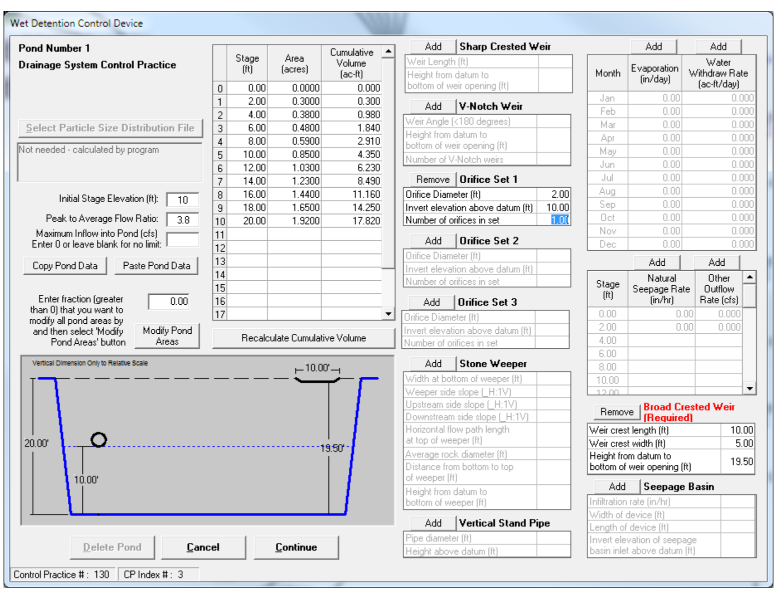


Figure 28: Huset Park Pond (Catchment 9) WinSLAMM model inputs

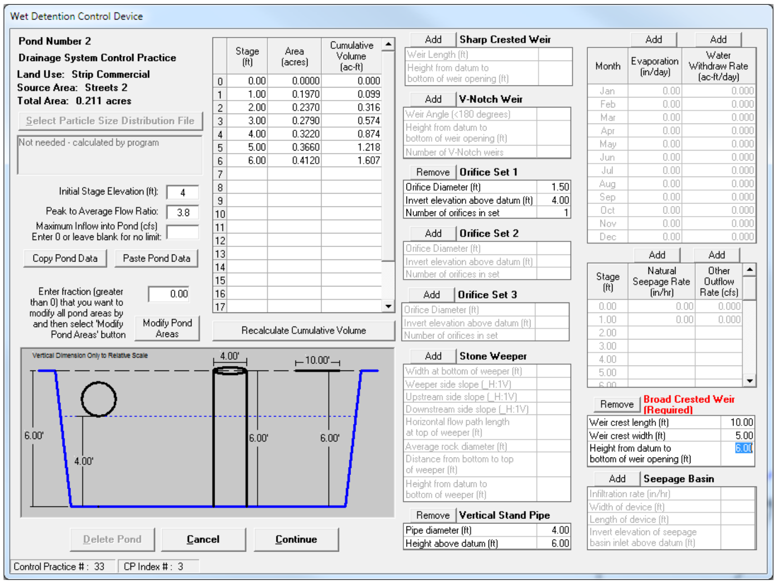


Figure 29: New Golf Course Pond (Catchment 12) WinSLAMM model inputs

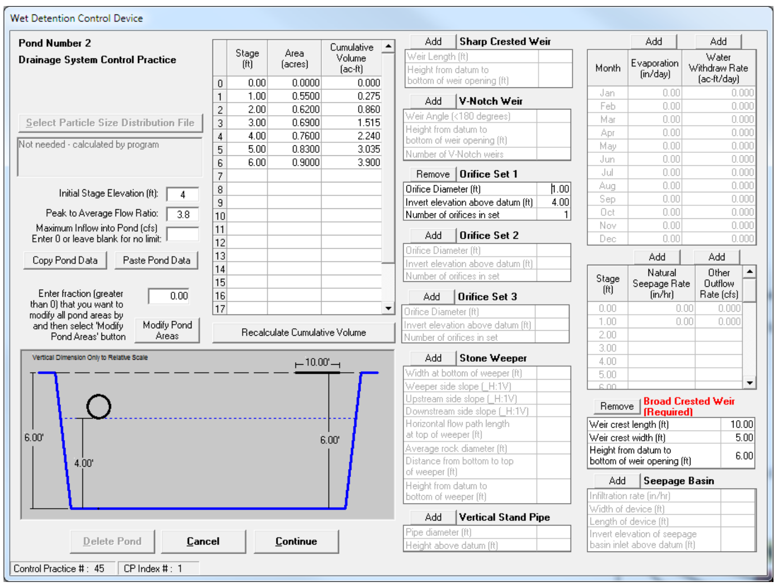


Figure 30: New Pond (Bureau of Engraving, Catchment 16) WinSLAMM model inputs

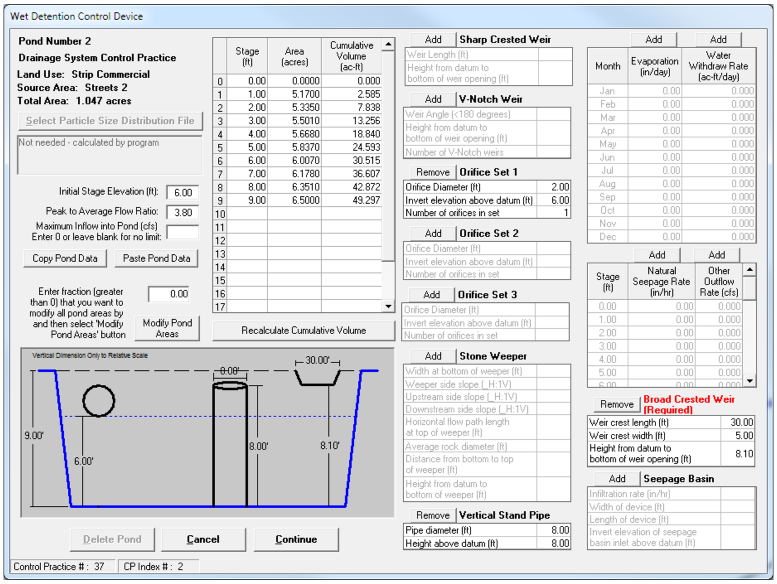


Figure 31: New Pond in Shoreham Yards (Catchment 14) WinSLAMM model inputs

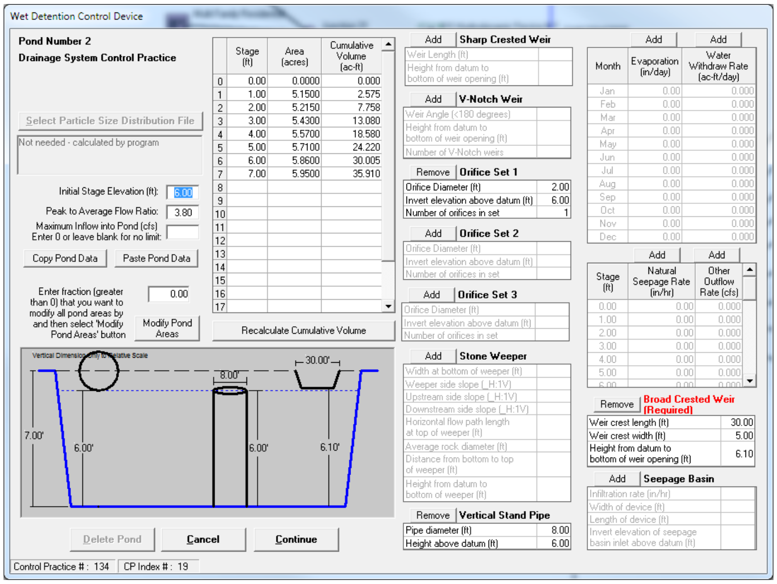


Figure 32: New pond in NW corner of railroad property (Catchment 14) WinSLAMM model inputs

Street Cleaning

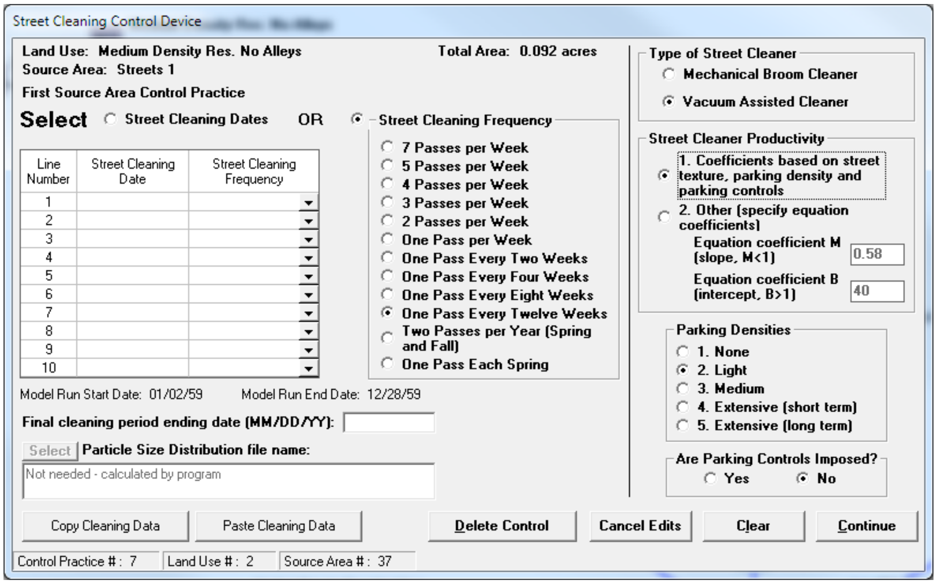


Figure 33: Street Cleaning WinSLAMM model inputs

Underground Storage

The CMP is proposed in addition to the aggregate rock to increase the storage capacity of the practice (as water storage within the aggregate is only found in pore space). The aggregate and pipe concept proposed for the project are based on designs in the *Technical Memorandum: Analysis and Evaluation for Shared, Stacked-Function, Green Infrastructure* prepared for the City of St. Paul by SRF Consulting and amended to meet site considerations for residential neighborhoods in the research area.

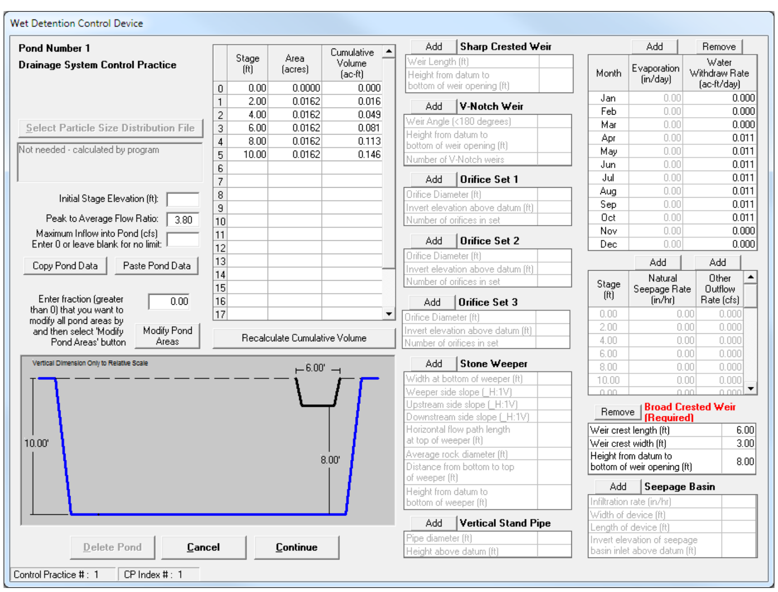


Figure 34: Alley Underground Storage WinSLAMM model inputs

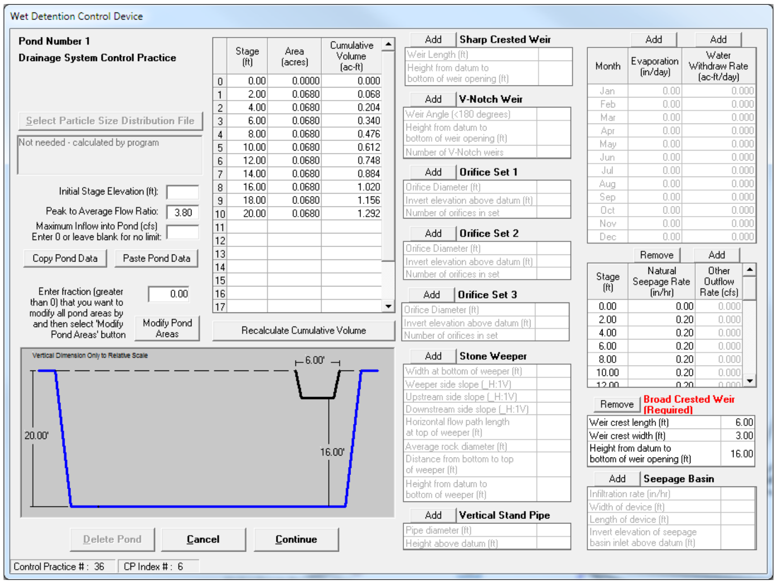


Figure 35: Underground Storage (Catchment 2) WinSLAMM model inputs

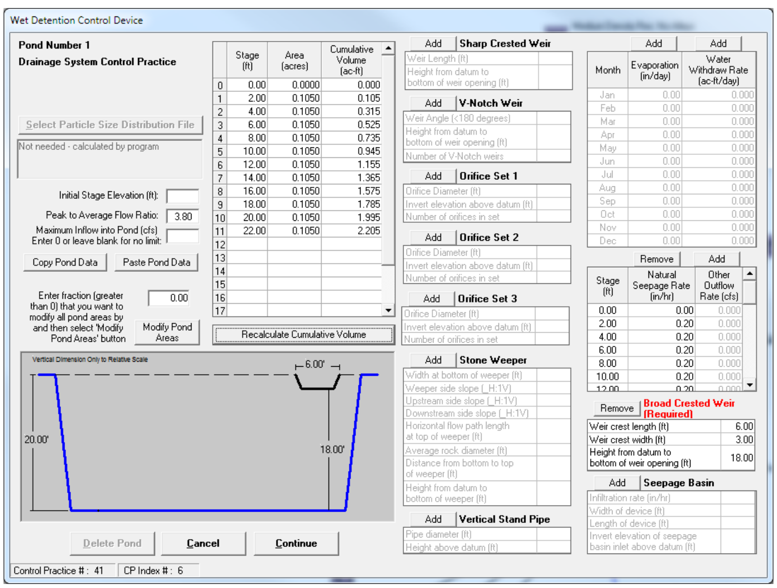


Figure 36: Underground Storage (Catchment 3) WinSLAMM model inputs

Water Reuse

Water reuse practices were modeled in WinSLAMM using a wet detention control device with a water withdraw rate tailored to each site. The volume of the pond reflects the recommended cistern size. The pond was modeled as 100' deep to eliminate the potential effects of sediment resuspension within the model.

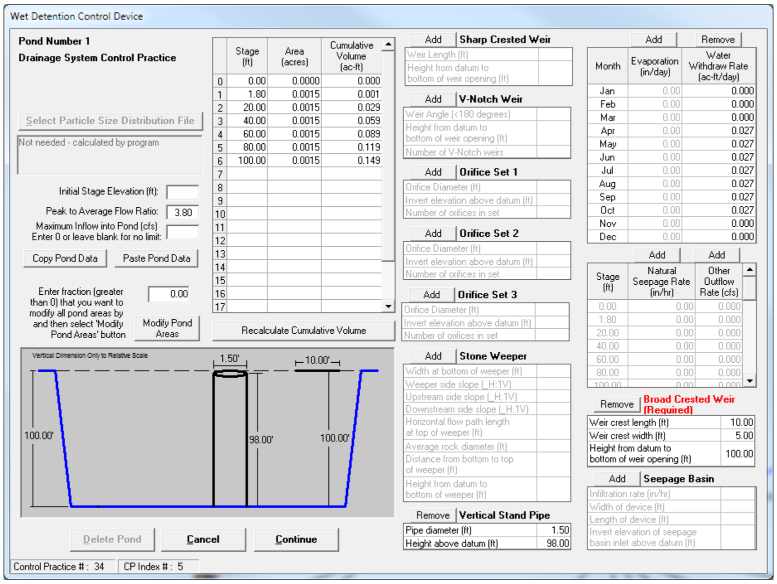


Figure 37: Water Reuse (Catchment 5 - 50,000 gal.) WinSLAMM model inputs

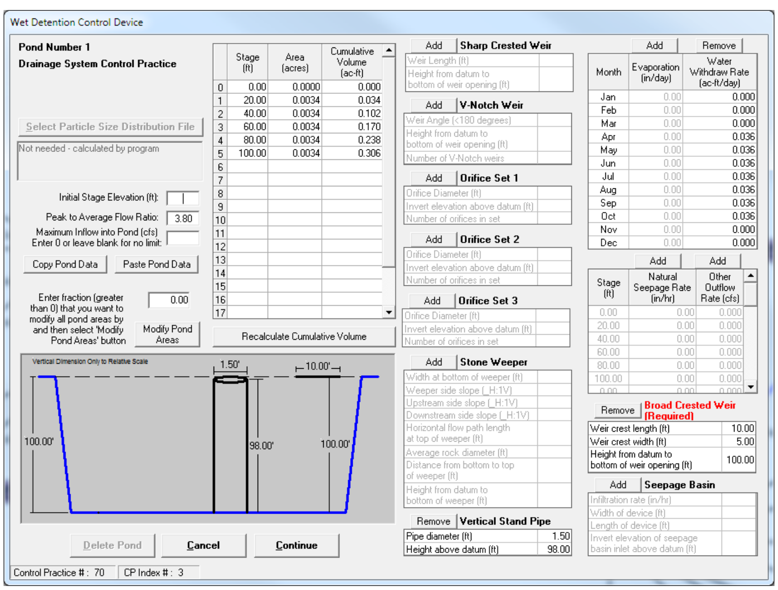


Figure 38: Water Reuse (Catchment 7, Audubon Park, 100,000 gal.) WinSLAMM model inputs

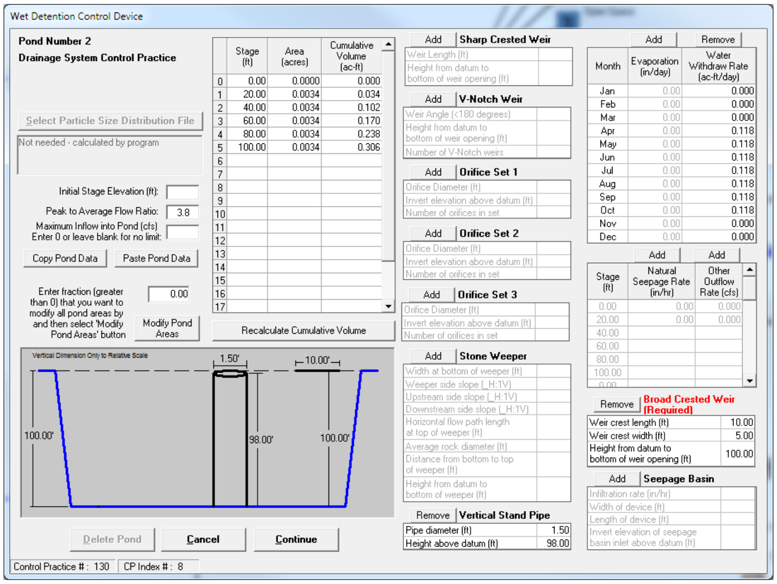


Figure 39: Water Reuse (Catchment 8, Huset Park, 100,000 gal.) WinSLAMM model inputs

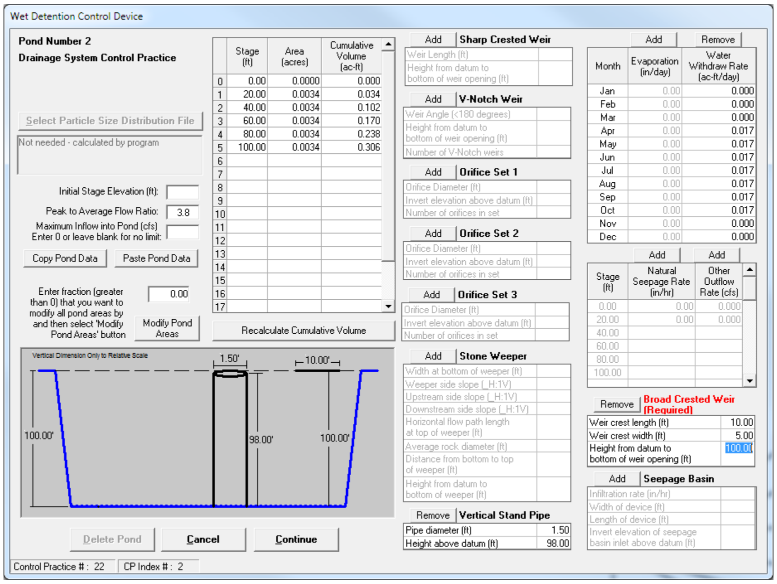


Figure 40: Water Reuse in Hi-View Park (Catchment 15) WinSLAMM model inputs

Appendix B – Project Cost Estimates

Introduction

The ‘Cost Estimates’ section on page 15 explains the elements of cost that were considered and the amounts and assumptions that were used. In addition, each project type concludes with budget assumptions listed in the footnotes. This appendix is a compilation of tables that shows in greater detail the calculations made and quantities used to arrive at the cost estimates for practices where the information provided elsewhere in the document is insufficient to reconstruct the budget. This section includes ponds, iron enhanced sand filters, stormwater reuse, and underground storage.

Ponds

Table 30: Catchment 12 – New Columbia Golf Course Pond

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 25,000.00	1	$ 25,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Excavation	cu-yards	$ 12.50	3,400	$ 42,500.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration/Revegetation	Each	$ 5,000.00	1	$ 5,000.00
		Total for project =		$ 152,500.00

Table 31: Catchment 14 – New Rail Yard Pond East

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 100,000.00	1	$ 100,000.00
Mobilization	Each	$ 20,000.00	1	$ 20,000.00
Land Acquisition	acres	$ 50,000.00	23	$ 1,150,000.00
Site Prep	Each	$ 30,000.00	1	$ 30,000.00
Excavation	cu-yards	$ 12.50	90,000	$ 1,125,000.00
Outlet Control Structure	Each	$ 20,000.00	1	$ 20,000.00
Existing Infrastructure Retrofit	Each	$ 100,000.00	1	$ 100,000.00
Site Restoration/Revegetation	Each	$ 200,000.00	1	$ 200,000.00
		Total for project =		$ 2,745,000.00

Table 32: Catchment 14 – New Rail Yard Pond East with IESF

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 20,000.00	1	$ 20,000.00
Mobilization	Each	$ 5,000.00	1	$ 5,000.00
Land Acquisition (already purchased as part of pond project)	acres	$ -	0	$ -
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Excavation (already included in pond cost)	cu-yards	$ 12.50	0	$ -
IESF Materials and Installation	sq-ft	$ 15.00	50,000	$ 750,000.00
Outlet Control Structure	Each	$ 20,000.00	1	$ 20,000.00
Pond Cost	Each	$ 2,745,000.00	1	$ 2,745,000.00
		Total for project =		$ 3,550,000.00

Table 33: Catchment 14 – New Rail Yard Pond West

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 100,000.00	1	$ 100,000.00
Mobilization	Each	$ 20,000.00	1	$ 20,000.00
Land Acquisition	acres	$ 50,000.00	12	$ 600,000.00
Site Prep	Each	$ 30,000.00	1	$ 30,000.00
Excavation	cu-yards	$ 12.50	64,000	$ 800,000.00
Outlet Control Structure	Each	$ 20,000.00	1	$ 20,000.00
Existing Infrastructure Retrofit	Each	$ 100,000.00	1	$ 100,000.00
Site Restoration/Revegetation	Each	$ 200,000.00	1	$ 200,000.00
		Total for project =		$ 1,870,000.00

Table 34: Catchment 16 – New Bureau of Engraving Pond

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 25,000.00	1	$ 25,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Excavation	cu-yards	$ 12.50	9,000	$ 112,500.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration/Revegetation	Each	$ 5,000.00	1	$ 5,000.00
Property Purchase		$ 100,000.00	1	$ 100,000.00
		Total for project =		$ 322,500.00

Iron Enhanced Sand Filters

Table 35: Catchment 9 – Huset Park Pond IESF

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 20,000.00	1	$ 20,000.00
Mobilization	Each	$ 5,000.00	1	$ 5,000.00
Land Acquisition (already owned by City of Columbia Heights)	acres	$ -	0	$ -
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Excavation	cu-yards	$ 12.50	1,700	$ 21,250.00
IESF Materials and Installation	sq-ft	$ 15.00	4,420	$ 66,300.00
Outlet Control Structure	Each	$ 20,000.00	1	$ 20,000.00
		Total for project =		$ 142,550.00

Stormwater Reuse

Table 36: Catchment 5 –Stormwater Reuse

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 30,000.00	1	$ 30,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	800	$ 10,000.00
Concrete Cistern	cu-yards	$ 550.00	250	$ 137,500.00
Pumping System (including filter system)	Each	$ 30,000.00	1	$ 30,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
		Total for project =		$ 297,500.00

Table 37: Catchment 7 – Audubon Park Stormwater Reuse

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 30,000.00	1	$ 30,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	1,500	$ 18,750.00
Concrete Cistern	cu-yards	$ 550.00	500	$ 275,000.00
Pumping System (including filter system)	Each	$ 30,000.00	1	$ 30,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
		Total for project =		$ 443,750.00

Table 38: Catchment 8 – Huset Park Stormwater Reuse

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 30,000.00	1	$ 30,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	1,500	$ 18,750.00
Concrete Cistern	cu-yards	$ 550.00	500	$ 275,000.00
Pumping System (including filter system)	Each	$ 30,000.00	1	$ 30,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
		Total for project =		$ 443,750.00

Table 39: Catchment 15 – Hi-view Park Stormwater Reuse

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 30,000.00	1	$ 30,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	1,500	$ 18,750.00
Concrete Cistern	cu-yards	$ 550.00	500	$ 275,000.00
Pumping System (including filter system)	Each	$ 30,000.00	1	$ 30,000.00
Existing Infrastructure Retrofit	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
		Total for project =		$ 443,750.00

Underground Storage

Table 40: Catchment 2 –Underground Seepage

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 50,000.00	1	$ 50,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	4,000	$ 50,000.00
CMP	linear-ft	$ 500.00	400	$ 200,000.00
Rock Aggregate	cu-yards	$ 35.00	2,600	$ 91,000.00
Existing Infrastructure Retrofit and Pretreatment	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
RR Permit	Each	$ 15,000.00	1	$ 15,000.00
		Total for project =		$ 496,000.00

Table 41: Catchment 3 –Underground Seepage

Activity	Units	Unit Price	Quantity	Unit Price
Design	Each	$ 50,000.00	1	$ 50,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Site Prep	Each	$ 25,000.00	1	$ 25,000.00
Excavation	cu-yards	$ 12.50	6,600	$ 82,500.00
CMP	linear-ft	$ 500.00	512	$ 256,000.00
Rock Aggregate	cu-yards	$ 35.00	4,075	$ 142,625.00
Existing Infrastructure Retrofit and Pretreatment	Each	$ 50,000.00	1	$ 50,000.00
Site Restoration	Each	$ 5,000.00	1	$ 5,000.00
RR Permit	Each	$ 15,000.00	1	$ 15,000.00
		Total for project =		$ 636,125.00

Appendix C – Volume Reduction Ranking Tables

Introduction

Volume reduction was not identified as a primary reduction target by the MWMO during the scoping phase of this project. This section is intended to serve as a quick reference if questions related to volume reduction arise. Projects are ranked based on cost per acre-foot of volume reduced.

Table 42: Cost-effectiveness of retrofits with respect to volume reduction. Projects 1 - 10. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ ac-ft Vol./year (30-year)
1	8-C	114	Water Reuse	Huset Park Water Reuse	8	5.0	836	12.6	$449,590	$3,000	$1,427
2	NSS-E2	40	Bioswale	Boulevard Bioswale; 1.0 in/hr infiltration rate	Any	0.4	115	0.2	$8,526	$225	$2,546
3	7-F	108	Water Reuse	Audobon Park Water Reuse	7	7.2	2,117	7.0	$449,590	$3,000	$2,569
4	4-C	86	Underground Storage	Catchment 3 Underground Storage	4	18.6	6,326	8.9	$641,965	$2,000	$2,629
5	4-B	85	Underground Storage	Catchment 2 Underground Storage	4	13.8	4,167	6.9	$501,840	$2,000	$2,714
6	8-A2	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 6,800 sq-ft top area	8	2.4	2,042	1.3	$105,796	$225	$2,886
7	8-A1	112	Disconnect Filtration Basin	Huset Park Disconnect Filtration Basin; 4,000 sq-ft top area	8	1.9	1,316	0.8	$63,796	$225	$2,939
8	NSS-D2	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.5	142	0.3	$20,621	$225	$3,146
9	5-A1	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 2,000 sq-ft top area	5	0.4	790	0.4	$33,796	$225	$3,379
10	5-A2	89	Disconnect Filtration Basin	Waite Park Elementary Disconnect Filtration Basin; 4,000 sq-ft top area	5	0.7	1,079	0.6	$63,796	$225	$3,919

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

- Eastern Drainage Network
- Northern Drainage Network
- Southwestern Drainage Network
- Direct Drainage
- Non-Site Specific BMPs

Table 43: Cost-effectiveness of retrofits with respect to volume reduction. Projects 11 - 27. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ ac-ft Vol./year (30-year)
11	10-A	120	Curb-Cut Filtration Basin	Architect Triangle Curb-Cut Filtration Basin	10	0.5	756	0.3	$29,296	$225	$4,005
12	NSS-C2	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 1.0 in/hr infiltration rate	Any	0.2	60	0.1	$8,526	$225	$4,243
13	5-E	93	Water Reuse	Catchment 5 Water Reuse	5	3.9	1,079	2.9	$303,340	$3,000	$4,521
14	15-B	144	Water Reuse	Hi-view Park Water Reuse	15	5.2	1,469	3.4	$449,590	$3,000	$5,290
15	NSS-B2	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 1.0. in/hr infiltration rate	Any	1.7	429	1.0	$116,205	$1,320	$5,467
T16	3-A	77	Curb-Cut Rain Garden	Boulevard Rain Garden East	3	0.2	223	0.1	$9,796	$225	$5,515
T16	3-B	78	Curb-Cut Rain Garden	Boulevard Rain Garden West	3	0.1	185	0.1	$9,796	$225	$5,515
18	NSS-A2	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 1.0 in/hr infiltration rate	Any	0.1	17	0.0	$4,909	$25	$5,716
19	NSS-A1	32	Rain Leader Disconnect Rain Garden	Rain Leader Disconnect Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	16	0.0	$4,909	$25	$6,737
20	14-B	140	Pond	Western Railroad Yard	14	118.1	51,808	8.7	$1,875,840	$5,877	$7,863
21	NSS-E1	40	Bioswale	Boulevard Bioswale; 0.2 in/hr infiltration rate	Any	0.2	57	0.1	$8,526	$225	$8,487
22	2-E	71	Disconnect Filtration Basin	Disconnect Filtration Basin	2	0.1	128	0.1	$21,076	$225	$9,275
23	2-G	73	Curb-Cut Rain Garden	37th and Pierce Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$11,025
24	8-B	113	Permeable Asphalt	Imaculate Conception School Permeable Asphalt	8	0.7	346	1.3	$139,066	$10,200	$11,412
25	1-E	64	Curb-Cut Rain Garden	37th and Hayes Curb-Cut Rain Garden	1	0.1	116	0.1	$11,110	$225	$11,907
26	2-F	72	Curb-Cut Rain Garden	37th and Lincoln Curb-Cut Rain Garden	2	0.1	115	0.1	$11,110	$225	$12,667
27	NSS-F	52	Underground Storage	Green Alley Underground Storage	Any	1.9	604	1.0	$410,115	$2,000	$15,068

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

Table 44: Cost-effectiveness of retrofits with respect to volume reduction. Projects 28 - 44. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ ac-ft Vol./year (30-year)
28	2-H	74	Curb-Cut Rain Garden	37th and Buchanan Curb-Cut Rain Garden	2	0.1	98	0.0	$11,110	$225	$16,090
29	1-C	62	Curb-Cut Rain Garden	39th and Johnson North Curb-Cut Rain Garden	1	0.1	93	0.0	$11,110	$225	$16,537
30	NSS-B1	34	Curb-Cut Rain Garden	Condemned Properties Rain Garden; 0.2 in/hr infiltration rate	Any	0.5	394	0.3	$128,205	$1,320	$18,044
31	1-D	63	Curb-Cut Rain Garden	39th and Johnson South Curb-Cut Rain Garden	1	0.1	78	0.0	$11,110	$225	$19,844
32	NSS-D1	37	Curb-Cut Rain Garden	Expanded Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.1	101	0.0	$20,621	$225	$22,809
33	16-D	159	Pond	New Bureau of Engraving Pond	16	12.5	8,989	0.5	$328,340	$918	$23,725
34	NSS-C1	37	Curb-Cut Rain Garden	Standard Boulevard Rain Garden; 0.2 in/hr infiltration rate	Any	0.0	33	0.0	$8,526	$225	$25,460
35	14-A1	138	Pond	Eastern Railroad Yard	14	291.2	108,697	3.2	$2,750,840	$6,313	$30,627
36	14-A2	138	Pond with IESF	Eastern Railroad Yard	14	404.5	108,697	3.2	$3,559,490	$17,792	$42,638
37	12-A	129	Pond	New Columbia Golf Course Pond	12	8.3	3,399	0.1	$158,340	$413	$56,910
T38	1-A	60	Hydrodynamic Device	39th & Johnson Hydrodynamic Device	1	0.4	159	0.0	$55,752	$840	N/A
T38	1-B	61	Hydrodynamic Device	Hollywood & Hayes Hydrodynamic Device	1	0.9	330	0.0	$109,752	$840	N/A
T38	2-A	67	Hydrodynamic Device	36 1/2 & Buchanan Hydrodynamic Device	2	0.4	159	0.0	$55,752	$840	N/A
T38	2-B	68	Hydrodynamic Device	36 1/2 & Fillmore Hydrodynamic Device	2	0.3	95	0.0	$28,752	$840	N/A
T38	2-C	69	Hydrodynamic Device	37th & Buchanan Hydrodynamic Device	2	1.0	356	0.0	$109,752	$840	N/A
T38	2-D	70	Hydrodynamic Device	37th & Pierce Hydrodynamic Device	2	0.7	233	0.0	$55,752	$840	N/A
T38	3-C	79	Hydrodynamic Device	37th & Polk Hydrodynamic Device	3	0.8	276	0.0	$109,752	$840	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

Table 45: Cost-effectiveness of retrofits with respect to volume reduction. Projects 45 - 61. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ ac-ft Vol./year (30-year)
T38	3-D	80	Hydrodynamic Device	37th & Reservoir Hydrodynamic Device	3	0.8	401	0.0	$109,752	$840	N/A
T38	3-E	81	Hydrodynamic Device	39th & Tyler Hydrodynamic Device	3	1.0	350	0.0	$109,752	$840	N/A
T38	4-A	84	Hydrodynamic Device	36th & Wilshire Hydrodynamic Device	4	1.2	436	0.0	$109,752	$840	N/A
T38	5-B	90	Hydrodynamic Device	34th & Taylor Hydrodynamic Device	5	1.2	445	0.0	$109,752	$840	N/A
T38	5-C	91	Hydrodynamic Device	35th & Lincoln Hydrodynamic Device	5	1.2	462	0.0	$109,752	$840	N/A
T38	5-D	92	Hydrodynamic Device	Columbia & Van Buren Hydrodynamic Device	5	1.0	420	0.0	$109,752	$840	N/A
T38	6-A	96	Hydrodynamic Device	31st & Cleveland Hydrodynamic Device	6	0.9	336	0.0	$109,752	$840	N/A
T38	6-B	97	Hydrodynamic Device	32nd & Buchanan Hydrodynamic Device	6	0.9	317	0.0	$109,752	$840	N/A
T38	6-C	98	Hydrodynamic Device	33rd & Lincoln Hydrodynamic Device	6	1.1	406	0.0	$109,752	$840	N/A
T38	6-D	99	Hydrodynamic Device	33rd & McKinley Hydrodynamic Device	6	0.7	286	0.0	$109,752	$840	N/A
T38	6-E	100	Hydrodynamic Device	34th & Benjamin Hydrodynamic Device	6	1.2	429	0.0	$109,752	$840	N/A
T38	7-A	103	Hydrodynamic Device	29th & Johnson Hydrodynamic Device	7	0.9	377	0.0	$109,752	$840	N/A
T38	7-B	104	Hydrodynamic Device	30th & Johnson Hydrodynamic Device	7	1.0	382	0.0	$109,752	$840	N/A
T38	7-C	105	Hydrodynamic Device	30th & Taylor Hydrodynamic Device	7	0.9	338	0.0	$109,752	$840	N/A
T38	7-D	106	Hydrodynamic Device	30th and Tyler Hydrodynamic Device	7	0.7	337	0.0	$109,752	$840	N/A
T38	7-E	107	Hydrodynamic Device	St. Anthony Parkway & Lincoln Hydrodynamic Device	7	1.1	413	0.0	$109,752	$840	N/A
T38	9-A	117	IESF	IESF Retrofit to Huset Park Pond	9	10.0	0	0.0	$146,200	$1,015	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

Table 46: Cost-effectiveness of retrofits with respect to volume reduction. Projects 62 - 73. TP and TSS reductions are also shown. For more information on each project refer to either the Catchment Profile or BMP Descriptions pages in this report. Volume and pollutant reduction benefits cannot be summed with other projects that provide treatment for the same source area.

Project Rank	Project ID	Page Number	Retrofit Type	Retrofit Location	Catchment	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Estimated Annual Operations & Maintenance (2014 Dollars)	Estimated cost/ ac-ft Vol./year (30-year)
T38	10-B	121	Hydrodynamic Device	36th & Monroe Hydrodynamic Device	10	1.1	406	0.0	$109,752	$840	N/A
T38	10-C	122	Hydrodynamic Device	37th and Madison Place Hydrodynamic Device	10	0.7	383	0.0	$109,752	$840	N/A
T38	11-A	125	Hydrodynamic Device	35th & Spain Place Hydrodynamic Device	11	1.4	509	0.0	$109,752	$840	N/A
T38	11-B	126	Hydrodynamic Device	36th & 2 1/2 Place Hydrodynamic Device	11	1.1	406	0.0	$109,752	$840	N/A
T38	15-A	143	Hydrodynamic Device	35th & 2nd Hydrodynamic Device	15	1.0	339	0.0	$109,752	$840	N/A
T38	16-A	156	Hydrodynamic Device	37th & St. Anthony Hydrodynamic Device	16	0.3	159	0.0	$28,752	$840	N/A
T38	16-B	157	Hydrodynamic Device	Marshall & East River Road Hydrodynamic Device	16	1.0	339	0.0	$109,752	$840	N/A
T38	16-C	158	Hydrodynamic Device	Railroad & St. Anthony Hydrodynamic Device	16	0.7	233	0.0	$109,752	$840	N/A
T38	17-A	147	Hydrodynamic Device	29th & Randolph Hydrodynamic Device	17	0.8	375	0.0	$109,752	$840	N/A
T38	17-B	148	Hydrodynamic Device	30th & Randolph Hydrodynamic Device	17	0.8	300	0.0	$109,752	$840	N/A
T38	17-C	149	Hydrodynamic Device	St. Anthony & Columbia Hydrodynamic Device	17	1.1	941	0.0	$109,752	$840	N/A
T38	17-D	150	Hydrodynamic Device	St. Anthony & Marshall Hydrodynamic Device	17	1.3	1,105	0.0	$109,752	$840	N/A

[1] [(Probable Project Cost) + 30*(Annual O&M)] / [30*(Annual Volume Reduction)]

Appendix D – Bridal Veil Creek SRA BMP Cost Estimates

Introduction

A stormwater retrofit analysis was completed in 2011 for the MWMO by the Ramsey Conservation District focused on the Bridal Veil Creek (BVC) subwatershed (MWMO, 2011a). The tables below summarize the cost estimate assumptions used in the BVC SRA and cost estimates used in this SRA for comparable practices. Please note many cost estimates in this SRA were project-specific and are detailed in Appendix B.

Table 47: Cost estimates used for the BVC SRA (MWMO, 2011a).

BMP	Installation Cost ($/ft^2)	Annual Maintenance Cost (contracted)	Operations & Maintenance Term	Design Cost ($70/hour)	Installation Oversight Cost ($70/hour)	Total Installation Cost (Includes design & 1-year maintenance)
Extended Detention	$5.00	$1,000/acre	30	$2,800/acre	$210 (3 visits)	(12.02)*(CU-FT^0.75)
Dry Swale	$3.00	$0.75/ft^2	30	$280/100 ft^2	$210 (3 visits)	$6.60/ft^2
Inlet Sump		$200	30	N/A	$210 (3 visits)	$3,000
Moderately Complex Bioretention	$12.00	$0.75/ft^2	30	$1,120/1,000 ft^2	$210 (3 visits)	$13.90/ft^2
Complex Bioretention	$14.00	$0.75/ft^2	30	$1,400/1,000 ft^2	$210 (3 visits)	$16.20/ft^2
Highly Complex Bioretention	$18.00	$0.75/ft^2	30	$1,400/1,000 ft^2	$210 (3 visits)	$19.90/ft^2
Underground Sand Filter	$65.00	$0.75/ft^2	30	140% above construction	$210 (3 visits)	$91.75/ft^2
Stormwater Tree Pits	$70.00	$0.75/ft^2	30	140% above construction	$210 (3 visits)	$98.75/ft^2
Permeable Asphalt	$10.00	$0.75/ft^2	30	140% above construction	$210 (3 visits)	$14.00/ft^2
Intensive Green Roof	$360.00	$750/1,000 ft^2	30	140% above construction	$210 (3 visits)	$504.75/ft^2

Table 48: Cost estimates used in this stormwater retrofit analysis that can be compared to the cost estimates in the BVC SRA (MWMO, 2011a).

BMP	Installation Cost ($/ft^2)	Annual Maintenance Cost (contracted)	Operations & Maintenance Term
Extended Detention	$7.30 - $9.98	$1,000/acre	30
Highly Complex Bioretention (i.e. Curb-Cut Rain Garden)	$24.00	$0.90/ft^2	30
Permeable Asphalt	$10.00	$0.75/ft^2	30

Appendix E – Alternative Street Cleaning Frequency Example

Introduction

Catchment 6 was modeled to estimate the benefits associated with an altered street cleaning schedule. Land use throughout Catchment 6 is predominantly medium density residential with alleys, and the total size of the catchment is 226.8 acres. Please see the Catchment 6 profile (page 94) for additional information. Below is a table that presents the estimated reductions in TP and TSS associated with varying street cleaning frequency.

Table 49: Estimated TP and TSS reductions within Catchment 6 as a result of altered street cleaning frequency. Reductions are relative to the base conditions and percent reductions are shown in parentheses.

Model ID	Street Cleaning Frequency (March 13 - November 4)	TSS Reduction from Base (lb/yr)	TP Reduction from Base (lb/yr)
Base	N/A	N/A	N/A
Existing	Every 12 weeks	5,764 (10%)	13.2 (7%)
Proposed A	Every 8 weeks	6,304 (11%)	14.4 (7%)
Proposed B	Every 4 weeks	10,628 (19%)	24.3 (12%)
Proposed C	Every 2 weeks	14,350 (26%)	32.8 (16%)
Proposed D	Every week	17,803 (32%)	40.7 (20%)