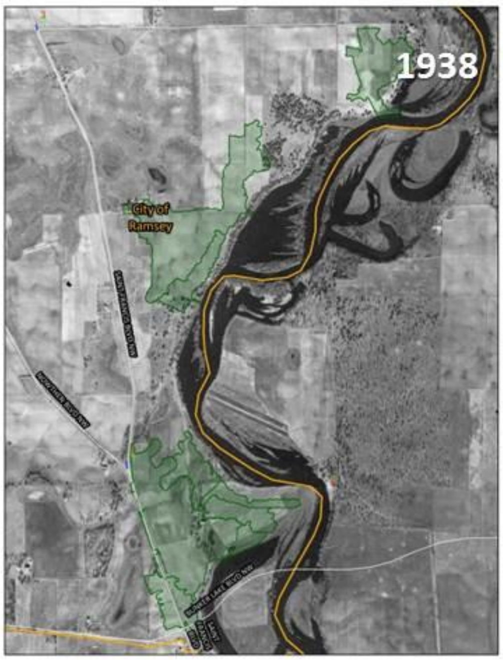

City of Ramsey
Stormwater Retrofit Analysis

Prepared by:

ANOKA CONSERVATION DISTRICT

for the

CITY OF RAMSEY AND

LOWER RUM RIVER WATERSHED MANAGEMENT ORGANZIZATION

June 2016

Cover photo: Historical and 2014 aerial photographs of subwatersheds analyzed in this report that drain to either the Mississippi (top pictures) or Rum River (bottom pictures).

Disclaimer: At the time of printing, this report identifies and ranks potential BMPs for selected subwatersheds in the City of Ramsey that drain to the Mississippi or Rum River. This list of practices is not all-inclusive and does not preclude adding additional priority BMPs in the future. An updated copy of the report shall be housed at either the Anoka Conservation District, the City of Ramsey, or the Lower Rum River Watershed Management Organization.

Table of Contents

List of Figures

List of Tables

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Executive Summary

The City of Ramsey and Lower Rum River Watershed Management Organization (LRRWMO) 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 selected subwatersheds that drain to either the Mississippi or Rum River. The subwatersheds are located along the southern City boundary (Mississippi River) and the eastern City boundary (Rum River) and consist of commercial, industrial, and residential land uses. Volume, total phosphorus (TP), and total suspended solids (TSS) were the target parameters analyzed.

This analysis is primarily intended to identify potential projects within the target area to improve water quality in the Mississippi and Rum Rivers 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. 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,
- Current BMP modification,
- Iron-enhanced sand filter check dams,
- Iron-enhanced sand filter pond benches, and

- Hydrodynamic devices.

If all of these practices were installed, significant volume and pollutant reductions could be accomplished. However, funding limitations and landowner interest make this 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. iron-enhanced sand filter pond benches and pond modifications) 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.

The 448 acre target study area was divided into 16 catchments and two drainage networks (groups of catchments draining to a common point) based on drainage patterns influenced by topography and stormwater infrastructure. The Mississippi River network consists of seven catchments (320 acres), and the Rum River network consists of nine catchments (128) acres. Based on WinSLAMM model results, the Mississippi River network contributes an estimated 101 acre-feet of runoff, 28,083 pounds of TSS, and 85 pounds of TP annually to the Mississippi River. The Rum River network contributes an estimated 61 acre-feet of runoff, 19,764 pounds of TSS, and 63 pounds of TP annually to the Rum River.

The tables in the Project Ranking and Selection section (pages 14 - 17) 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 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 drainage areas targeted for this analysis were consolidated into 16 catchments distributed between two drainage networks and assigned unique identification numbers. For each catchment, the following information is detailed:

Drainage Network

Catchments were grouped into drainage networks based on their drainage to a common waterbody (i.e. Mississippi River or Rum River). 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 City of Ramsey. 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 subwatersheds 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 drainage areas studied for this analysis are located in the City of Ramsey and discharge to either the Mississippi or Rum Rivers. Those discharging to the Mississippi River are located along the southern boundary of Ramsey primarily between Ramsey Blvd. NW on the west and Tungsten St. NW on the east. The railroad tracks just north of US-10 serve as much of the northern boundary. The total area of the seven catchments that comprise the Mississippi River network is 320 acres. The nine catchments discharging to the Rum River are located on the eastern boundary of the City primarily between Alpine Dr. NW on the north and Bunker Lake Blvd. NW on the south. All catchments are primarily east of St. Francis Blvd. NW. The total area of the nine catchments that comprise the Rum River network is 128 acres.

These catchments were selected for analysis because they drain to high priority waterbodies, and existing treatment in many of the catchments was lacking. Therefore, stormwater retrofits may provide cost-effective options for additional treatment of runoff, thereby improving water quality in the Mississippi and Rum Rivers.

The catchments analyzed are urbanized. Development throughout the City of Ramsey 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 catchments. The runoff generated within the areas targeted for this analysis is still conveyed to the Mississippi and Rum Rivers, as it was historically. However, the runoff is now captured by catch basins and directed underground before being discharged to the Mississippi and Rum Rivers via stormwater pipe.

Stormwater runoff from impervious surfaces can carry a variety of pollutants. While stormwater treatment to remove these pollutants is adequate in some areas, other areas were built prior to modern-day stormwater treatment technologies and requirements. The City of Ramsey and LRRWMO contracted the ACD to complete this SRA for the purpose of identifying and analyzing projects to improve the quality of stormwater runoff to the Mississippi and Rum Rivers. Overall subwatershed loading of TP, TSS, and stormwater volume were estimated for selected drainage areas. 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 areas were the contributing drainage areas to storm sewer outfalls directly into the Mississippi and Rum Rivers. More specifically, outfalls with limited existing treatment were selected. Included are areas of residential, commercial, industrial, and institutional land uses. Existing stormwater infrastructure maps and topography data were used to determine drainage boundaries for the 16 catchments included in this analysis.

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 these catchments because stormwater is piped directly to the Mississippi and Rum Rivers.

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. WinSLAMM (version 10.2.0), which allows routing of multiple catchments and stormwater treatment practices, was used for this analysis. This is important for estimating treatment train effects associated with multiple BMPs in series. Furthermore, it allows for estimation of volume and pollutant loading at the outfall point to the waterbody, which is the primary point of interest in this type of study.

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 predominantly sandy based on the information available in the Anoka County soil survey. 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 using the watershed delineation tool in ArcSWAT. The drainage areas were then consolidated into catchments using geographic information systems (specifically, ArcGIS). Land use data (based on 2010 Metropolitan Council land use file) were used to calculate acreages of each land use type within each catchment. Each land use polygon classification was compared with 2014 aerial photography and corrected if land use had changed since 2010. This process addressed recent development throughout the study area by reclassifying land use types accordingly. Soil types throughout the subwatershed were modeled as sand and silt in this analysis based on the information available in the Anoka County soil survey. 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 were available from the City of Ramsey (Figure 1 and Figure 2). 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.

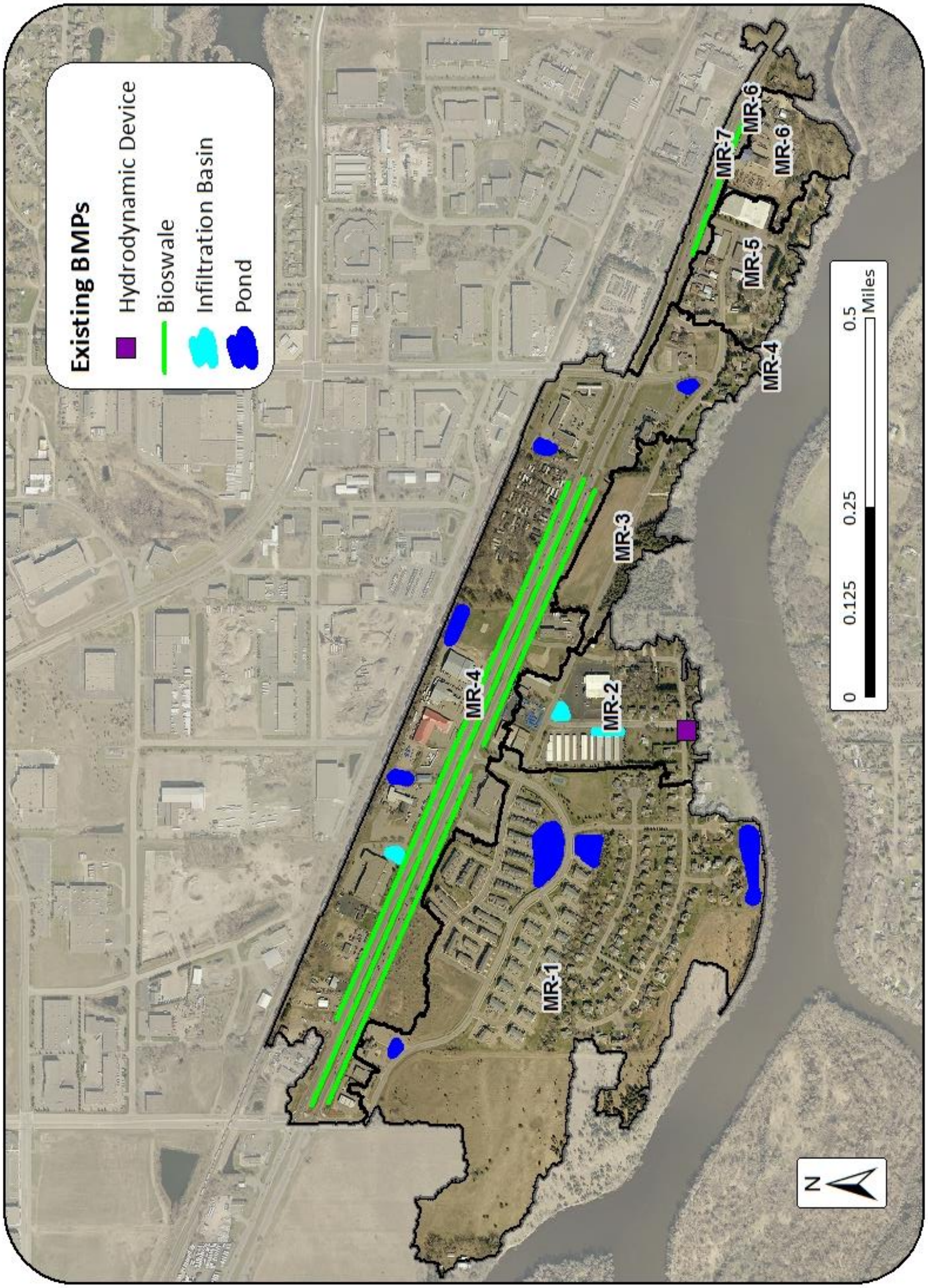


Figure 1: Mississippi River network-wide map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included where applicable in catchments within the network.

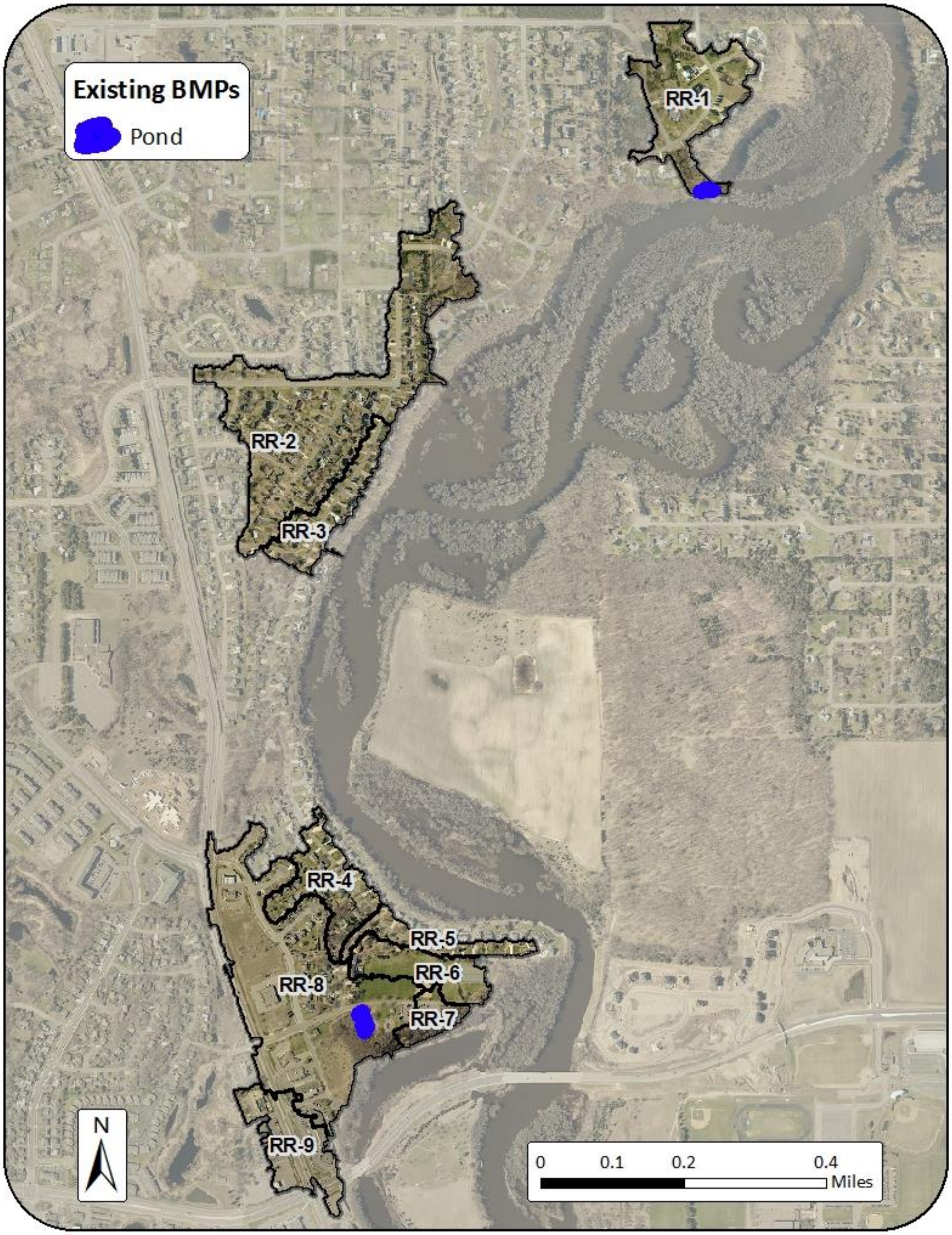


Figure 2: Rum River network-wide map showing existing BMPs included in the WinSLAMM model. Street sweeping is not shown on the map but was included where applicable in catchments within the network.

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.

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 2016 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. 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. 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 3 and Figure 4), 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. Tables were separated by drainage network (i.e. Mississippi River or Rum River), and projects were ranked in two ways:

1) Cost per pound of total phosphorus removed (Table 2 and Table 4) and
2) Cost per 1,000 pounds of total suspended solids removed (Table 3 and Table 5).

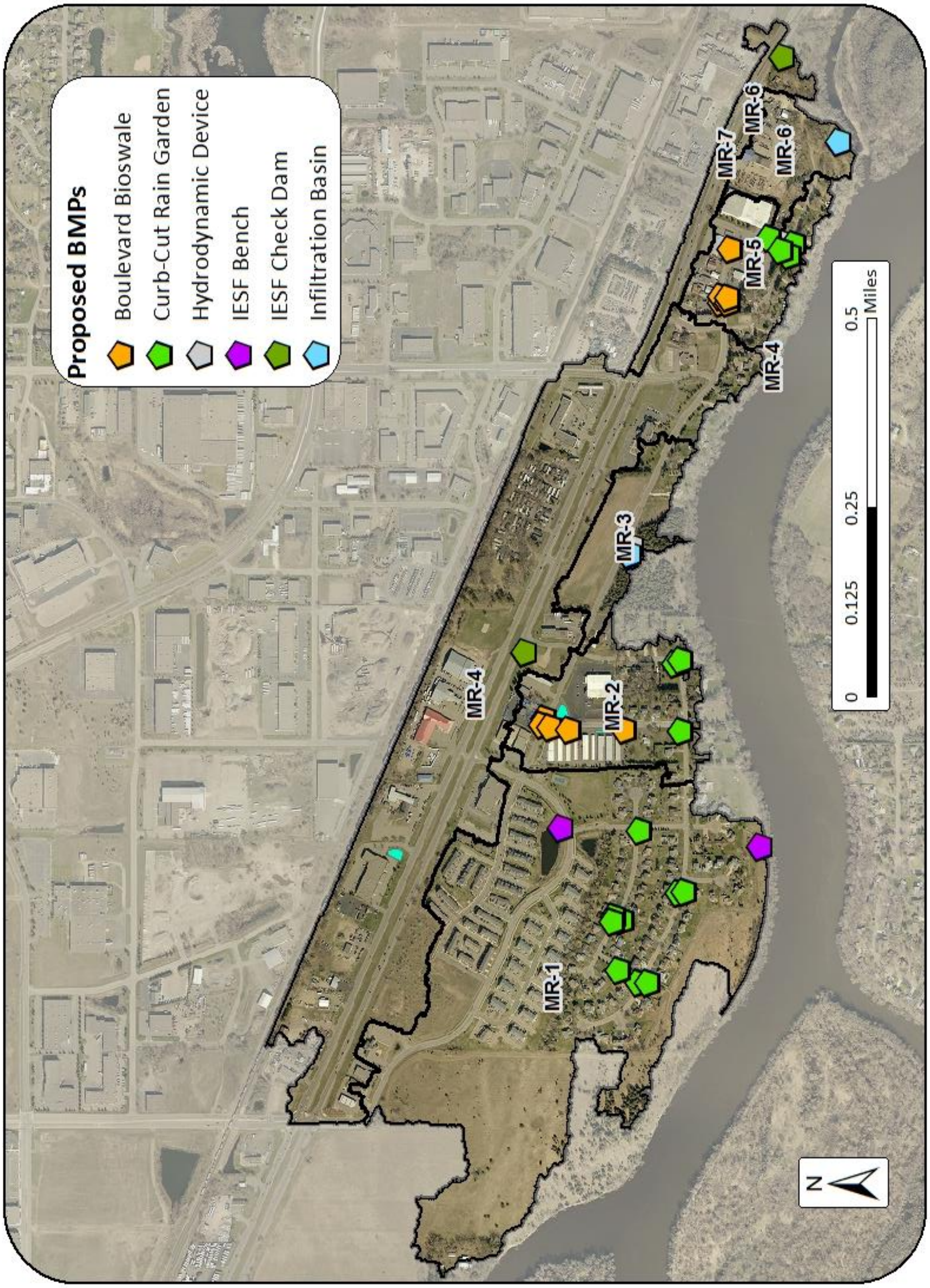


Figure 3: Mississippi River network-wide map showing all proposed retrofits.

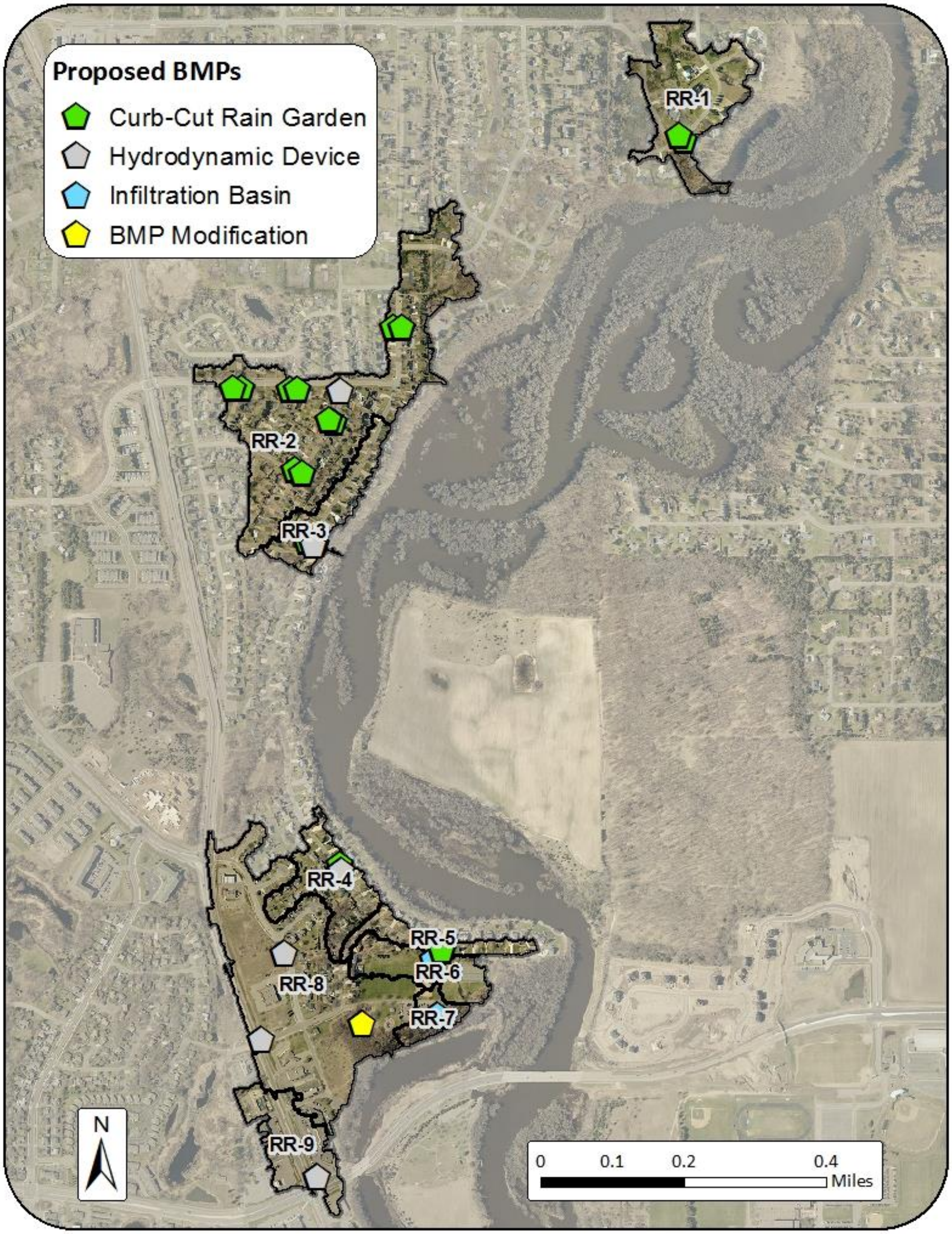


Figure 4: Rum River network-wide map showing all proposed retrofits.

Table 2: Mississippi River Network. Cost-effectiveness of retrofits with respect to TP reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ lb-TP/year (30-year)[1]
1	MR6-A	57	Infiltration Basin	Southeastern Portion of MR6	MR6	3.6 - 4.9	2,110 - 2,836	3.8 - 5.4	$43,796 - $83,796	$225	$468 - $616
2	MR3-A	44	Infiltration Basin	Riverdale Dr.	MR3	2.5 - 3.0	867-1,034	2.2-2.7	$33,796 - $53,796	$225	$541 - $673
3	MR5-A	52	Curb-Cut Rain Garden	Tungsten St. and Rivlyn Ave.	MR5	0.4-0.5	155-249	0.4-0.6	$8,982	$225	$1,049 - $1,311
4	MR1-C	36	IESF Bench	Hematite Cir. and Garnet St.	MR1	7.6	0	0.0	$235,035	$1,377	$1,212
5	MR2-A	40	Curb-Cut Rain Garden	Ebony St. and 137th Ave.	MR2	0.4-1.2	112-336	0.3-0.9	$8,982 - $26,946	$225 - $675	$1,311
6	MR1-A	34	Curb-Cut Rain Garden	Various locations in MR1	MR1	0.8-2.3	166-493	1.5-3.3	$32,348 - $81,860	$675 - $2,025	$2,033 - $2,192
7	MR1-B	35	IESF Bench	Feldspar St. and Garnet St.	MR1	2.4	0	0.0	$143,475	$459	$2,202
8	MR5-B	53	Boulevard Bioswales	Riverdale Dr.	MR5	0.1	61	0.1	$8,526	$225	$2,603
9	MR2-B	41	Boulevard Bioswales	Riverdale Dr. and Ebony St.	MR2	0.1	61	0.1	$8,526	$225	$3,395
10	MR7-A	60	IESF Check Dam	US-10	MR7	0.2	15	0.0	$15,448	$365	$4,526
11	MR4-A	49	IESF Check Dam	US-10	MR4	0.2	15	0.0	$15,448	$365	$4,549
12	MR5-C	54	Hydrodynamic Device	Tungsten St. and Rivlyn Ave.	MR5	0.9	682	0.0	$109,752	$630	$4,765
13	MR3-B	45	Hydrodynamic Device	Riverdale Dr.	MR3	0.4	211	0.0	$109,752	$630	$10,721

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

Table 3: Mississippi River Network. Cost-effectiveness of retrofits with respect to TSS reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
1	MR6-A	57	Infiltration Basin	Southeastern Portion of MR6	MR6	3.6 - 4.9	2,110 - 2,836	3.8 - 5.4	$43,796 - $83,796	$225	$799 - $1,064
2	MR3-A	44	Infiltration Basin	Riverdale Dr.	MR3	2.5 - 3.0	867-1,034	2.2-2.7	$33,796 - $53,796	$225	$1,559 - $1,952
3	MR5-A	52	Curb-Cut Rain Garden	Tungsten St. and Rivlyn Ave.	MR5	0.4-0.5	155-249	0.4-0.6	$8,982	$225	$2,106 - $3,383
4	MR2-A	40	Curb-Cut Rain Garden	Ebony St. and 137th Ave.	MR2	0.4-1.2	112-336	0.3-0.9	$8,982 - $26,946	$225 - $675	$4,682
5	MR5-B	53	Boulevard Bioswales	Riverdale Dr.	MR5	0.1	61	0.1	$8,526	$225	$4,839
6	MR5-C	54	Hydrodynamic Device	Tungsten St. and Rivlyn Ave.	MR5	0.9	682	0.0	$109,752	$630	$6,288
7	MR2-B	41	Boulevard Bioswales	Riverdale Dr. and Ebony St.	MR2	0.1	61	0.1	$8,526	$225	$8,526
8	MR1-A	34	Curb-Cut Rain Garden	Various locations in MR1	MR1	0.8-2.3	166-493	1.5-3.3	$32,348 - $81,860	$675 - $2,025	$9,642 - $10,562
9	MR3-B	45	Hydrodynamic Device	Riverdale Dr.	MR3	0.4	211	0.0	$109,752	$630	$20,324
10	MR7-A	60	IESF Check Dam	US-10	MR7	0.2	15	0.0	$15,448	$365	$58,662
11	MR4-A	49	IESF Check Dam	US-10	MR4	0.2	15	0.0	$15,448	$365	$59,056
13	MR1-B	35	IESF Bench	Feldspar St. and Garnet St.	MR1	2.4	0	0.0	$143,475	$459	N/A
13	MR1-C	36	IESF Bench	Hematite Cir. and Garnet St.	MR1	7.6	0	0.0	$235,035	$1,377	N/A

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

Table 4: Rum River Network. Cost-effectiveness of retrofits with respect to TP reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ lb-TP/year (30-year)[1]
1	RR6-A	83	Infiltration Basin	142nd LN.	RR6	4.2 - 4.8	1,139 - 1,267	2.6 - 2.9	$63,796 - $83,796	$225	$560 - $629
2	RR3-A	71	Curb-Cut Rain Garden	Waco St.	RR3	0.6 - 0.7	188 - 204	0.5	$8,982	$225	$749 - $874
3	RR8-A	89	Pond Modification	Rivers Bend Park	RR8	7.7	3,672	0.2	$140,840 - $215,840	$900	$779 - $1,203
4	RR1-A	64	Curb-Cut Rain Garden	Oneida St.	RR1	0.4 - 0.5	111 - 118	0.6 - 0.7	$8,982	$225	$1,049 - $1,311
4	RR4-A	75	Curb-Cut Rain Garden	Waco St.	RR4	0.4 - 0.5	122 - 155	0.3 - 0.4	$8,982	$225	$1,049 - $1,311
6	RR2-A	67	Curb-Cut Rain Garden	Various locations in RR2	RR2	0.5 - 5.0	155 - 1,551	0.4 - 3.8	$15,844 - $90,112	$225 - $2,250	$1,051 - $1,506
7	RR5-A	79	Curb-Cut Rain Garden	142nd LN.	RR5	0.37 - 0.43	110 - 129	0.26 - 0.30	$8,982	$225	$1,220 - $1,417
8	RR7-A	86	Infiltration Basin	Rivers Bend Park Parking Lot	RR7	0.20 - 0.32	59 - 72	0.12 - 0.15	$7,796 - $9,796	$225	$1,724 - $2,424
9	RR9-A	94	Hydrodynamic Device	St. Francis Blvd. and Bunker Lake Blvd.	RR9	0.7	364	0.0	$55,752	$630	$3,555
10	RR4-B	76	Hydrodynamic Device	Waco St.	RR4	0.5	200	0.0	$55,752	$630	$4,977
11	RR5-B	80	Hydrodynamic Device	142nd LN.	RR5	0.3	111	0.0	$28,752	$630	$5,295
12	RR2-B	68	Hydrodynamic Device	Xkimo St.	RR2	0.8	322	0.0	$109,752	$630	$5,361
13	RR3-B	72	Hydrodynamic Device	Waco St.	RR3	0.4	167	0.0	$55,752	$630	$6,221
14	RR8-B	90	Hydrodynamic Device	142nd Ave.	RR8	0.2	108	0.0	$28,752	$630	$7,942
15	RR8-C	91	Hydrodynamic Device	Xkimo St.	RR8	0.5	220	0.0	$109,752	$630	$8,577

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

Table 5: Rum River Network. Cost-effectiveness of retrofits with respect to TSS reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ 1,000lb-TSS/year (30-year)[1]
1	RR8-A	89	Pond Modification	Rivers Bend Park	RR8	7.7	3,672	0.2	$140,840 - $215,840	$900	$1,633 - $2,522
2	RR6-A	83	Infiltration Basin	142nd LN.	RR6	4.2 - 4.8	1,139 - 1,267	2.6 - 2.9	$63,796 - $83,796	$225	$2,065 - $2,382
3	RR4-A	75	Curb-Cut Rain Garden	Waco St.	RR4	0.4 - 0.5	122 - 155	0.3 - 0.4	$8,982	$225	$3,383 - $4,298
4	RR2-A	67	Curb-Cut Rain Garden	Various locations in RR2	RR2	0.5 - 5.0	155 - 1,551	0.4 - 3.8	$15,844 - $90,112	$225 - $2,250	$3,387 - $4,859
5	RR3-A	71	Curb-Cut Rain Garden	Waco St.	RR3	0.6 - 0.7	188 - 204	0.5	$15,844	$225	$3,692 - $4,006
6	RR5-A	79	Curb-Cut Rain Garden	142nd LN.	RR5	0.37 - 0.43	110 - 129	0.26 - 0.30	$8,982	$225	$4,065 - $4,767
7	RR1-A	64	Curb-Cut Rain Garden	Oneida St.	RR1	0.4 - 0.5	111 - 118	0.6 - 0.7	$8,982	$225	$4,444 - $4,724
8	RR9-A	94	Hydrodynamic Device	St. Francis Blvd. and Bunker Lake Blvd.	RR9	0.7	364	0.0	$55,752	$630	$6,836
9	RR7-A	86	Infiltration Basin	Rivers Bend Park Parking Lot	RR7	0.20 - 0.32	59 - 72	0.12 - 0.15	$7,796 - $9,796	$225	$7,660 - $8,218
10	RR4-B	76	Hydrodynamic Device	Waco St.	RR4	0.5	200	0.0	$55,752	$630	$12,442
11	RR2-B	68	Hydrodynamic Device	Xkimo St.	RR2	0.8	322	0.0	$109,752	$630	$13,318
12	RR5-B	80	Hydrodynamic Device	142nd LN.	RR5	0.3	111	0.0	$28,752	$630	$14,310
13	RR8-B	90	Hydrodynamic Device	142nd Ave.	RR8	0.2	108	0.0	$28,752	$630	$14,707
14	RR3-B	72	Hydrodynamic Device	Waco St.	RR3	0.4	167	0.0	$55,752	$630	$14,901
15	RR8-C	91	Hydrodynamic Device	Xkimo St.	RR8	0.5	220	0.0	$109,752	$630	$19,493

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

Project Selection

The combination of projects selected for pursuit could strive to achieve TP and/or TSS 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 target areas 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.

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. Project types included in the following sections are:

- Bioretention
  - Curb-cut Rain Garden
  - Boulevard Bioswale
  - Infiltration Basin
- Hydrodynamic Device
- Iron-Enhanced Sand Filter Pond Bench
- Iron-Enhanced Sand Filter Check Dam
- Modification to an Existing Pond

Bioretention

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 (Table 6).

Table 6: 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	

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 are appropriate for infiltration.

Curb-cut Rain Gardens

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. Bioinfiltration was solely proposed (as opposed to biofiltration) as the available soil information suggested infiltration rates could be sufficient to allow complete draw-down within 24-48 hours following a storm event (Figure 5).

Figure 5: Rain garden before/after and during a rainfall event

All curb-cut rain gardens were presumed to have a 12” ponding depth, 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 at years 10 and 20. Annual maintenance was assumed to be completed by the landowner of the property at which the rain garden could be installed.

Boulevard Bioswale (NSS-E1)

One option for retrofitting a stormwater BMP within an existing boulevard is 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 6). Unlike rain gardens, these practices are typically much shallower (1-3” in depth) and have a curb-cut inlet and outlet (Figure 6). Although many rain gardens have outlets in the form of underdrains or risers, the bioswale outlet allows for a

Figure 6: Right-of-way bioswale installed in New York City (NYC Environmental Protection, 2013)

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 7). A 20' long (parallel to roadway), 4' wide (perpendicular to roadway), and 3" deep bioswale was modeled with an infiltration rate of 2.5"/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 7: WinSLAMM model results for the boulevard bioswale with a 2.5"/hour infiltration rate.

Drainage Area (acres)	*Standard Boulevard Bioswale*					
	TP Removal		TSS Removal		Volume Removal	
	lbs-TP	%	lbs-TSS	%	ac-ft	%
0.25	0.07	33.3%	43	38.0%	0.058	21.9%
0.5	0.09	23.7%	61	28.3%	0.067	12.6%
1	0.08	13.0%	53	15.6%	0.074	7.0%
2	0.07	8.0%	45	9.8%	0.082	3.8%
3	0.08	6.8%	47	8.6%	0.087	2.7%
4	0.08	6.2%	48	8.0%	0.09	2.1%

Infiltration Basin

Infiltration basins function identically to the curb-cut rain gardens previously described in this bioretention section. However, these basins are proposed in locations where a large amount of space is available. This presents an opportunity to construct a large-scale (i.e. > 500 sq-ft.) infiltration basin. This would allow stormwater runoff to fill the basin and be filtered by the soil and vegetation.

Probable project cost includes installation of the project as well as promotion, administrative, and design costs, all in 2016 dollars. A reduced construction cost (i.e. \$15 to \$20 per ft.^{2}) relative to other bioretention practices was proposed for the infiltration 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 by city public works crews. Maintenance costs were also included for rehabilitation of the basin every 10 years for the life of the project.

Hydrodynamic Devices

In heavily urbanized settings 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 7). 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.

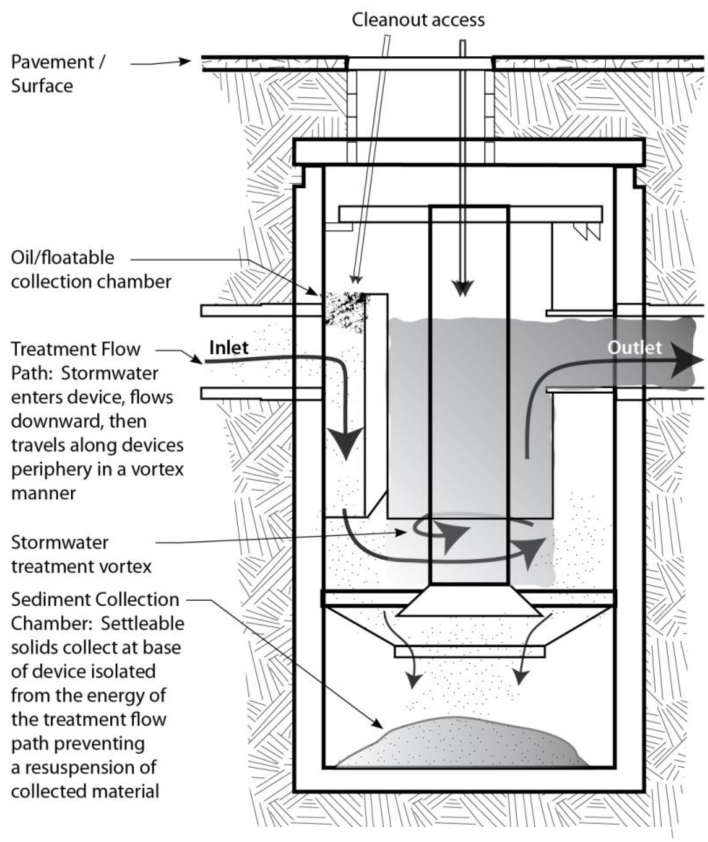


Figure 7: Schematic of a typical hydrodynamic device

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.

Iron-Enhanced Sand Filter Pond Bench

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 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 8)". 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 8 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.

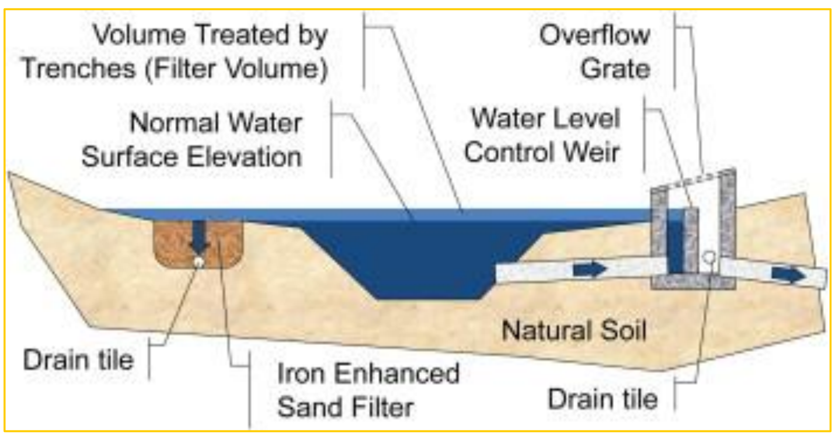


Figure 8: Iron Enhanced Sand Filter Concept (Erickson & Gulliver, 2010)

Benefits for stormwater ponds were modeled utilizing WinSLAMM. 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 at the pond outlet were entered into WinSLAMM as inputs into the IESF. Various iterations of IESFs were modeled to identify an optimal treatment level compared to construction costs and space available. 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.

Iron Enhanced Sand Filter Check Dam

Figure 9: Rock check dams in a small ditch (www.casfm.org/stormwater_committee/LID-Summary.htm)

Permeable check dams provide additional treatment for pollutants within ditches and grassed waterways through two processes. First, the dams act as a barrier to flow through the channel, allowing sediment and particulate pollutants to drop out of solution upstream of the dam. This promotes infiltration and evaporation of stormwater as well. Second, any water retained behind the dam can seep through a sand filter located within the rock dam. The sand, mixed with iron filings (similar to an IESF pond bench), creates an opportunity for dissolved pollutant species to be filtered out of the stormwater runoff.

These practices are often installed in a series, from two to a dozen practices depending on the length and slope of the ditch or waterway (Figure 9). For short ditch lengths a single check dam is often sufficient. The dams include an inner sand filter mixed with iron filings. The ratio of iron filings to sand should be between 5-8% by weight and these should be mixed thoroughly prior to installation. The sand-iron mix should be encased within a permeable membrane allowing for flow in and out of the filter. This filter is surrounded by rocks to promote settling and inhibit clogging of the filter.

It is recommended that these dams are installed such that the buried rock toe of the upstream dam is at the same elevation as the top of any downstream dams (Figure 10). This reduces the likelihood of scouring downstream of dams as water flowing over the dam intercepts ponded water rather than erodible soil. Also, the top of the most upstream dam should be installed below the outlet elevation of any pipe draining to the practice to ensure water does not back up into the upstream storm sewer infrastructure.

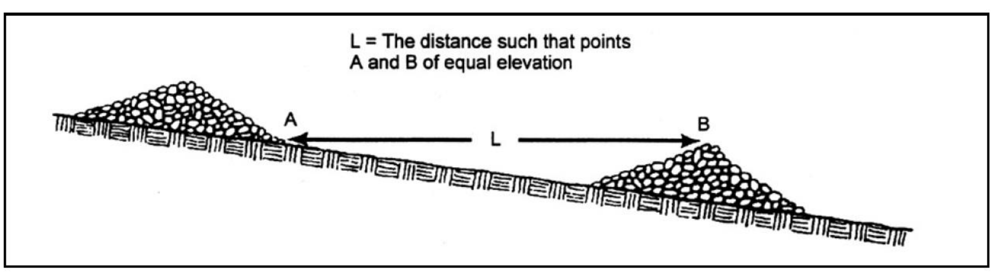


Figure 10: Check dam schematic (MPCA 2000)

The pollutant removal potential of permeable check dams was estimated using WinSLAMM. The ponding volume behind the dams was determined using LIDAR. Based on results of other IESFs, it was assumed that 80% of DP flowing through the dam was retained (Erickson & Gulliver, 2010). 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.

Modification to an Existing Pond

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 best available information for pond characteristics and land use and soils. One proposed modification, excavating the pond bottom to increase storage, often has a very wide range in expected cost due to the nature of the excavated soil. If the soil has been contaminated and requires landfilling, the cost for disposal can quickly lead to a doubling in project cost. For this reason, projects which include the excavation of ponds have been priced based on the following criteria:

- Management Level 1: Dredged pond soil is suitable for use or reuse on properties with a residential or recreational use
- Management Level 2: Dredged pond soil is suitable for use or reuse on properties with an industrial use
- Management Level 3: Dredged pond soil is considered significantly contaminated and must be managed specifically for the contaminants present

Costs within each of these levels can even range widely, but were estimated to be $20/cu-yd., $35/cu-yd., and $50/cu-yd. for levels 1, 2, and 3, respectively. Additional costs associated with specific projects are listed in Appendix B.

Catchment Profiles

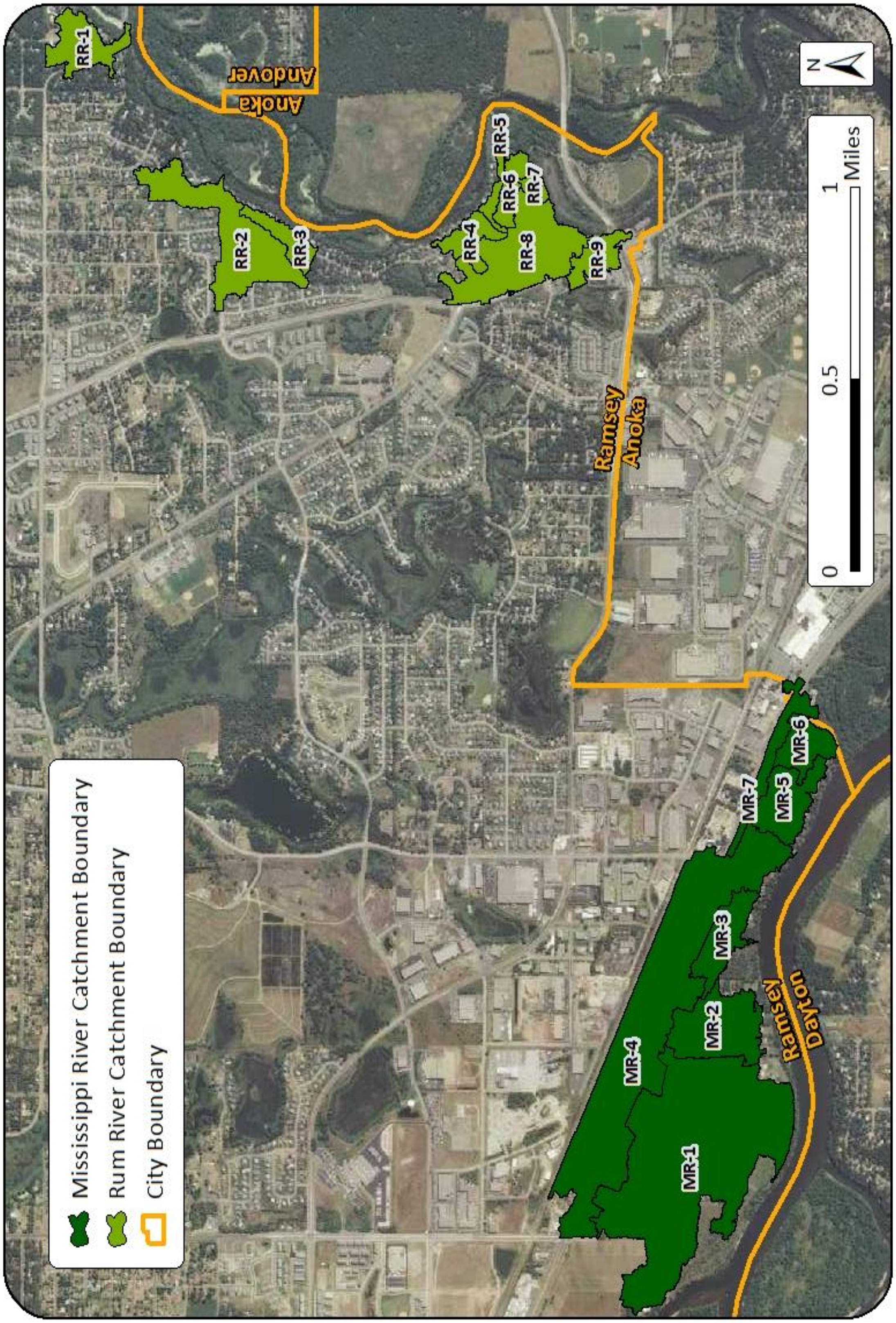
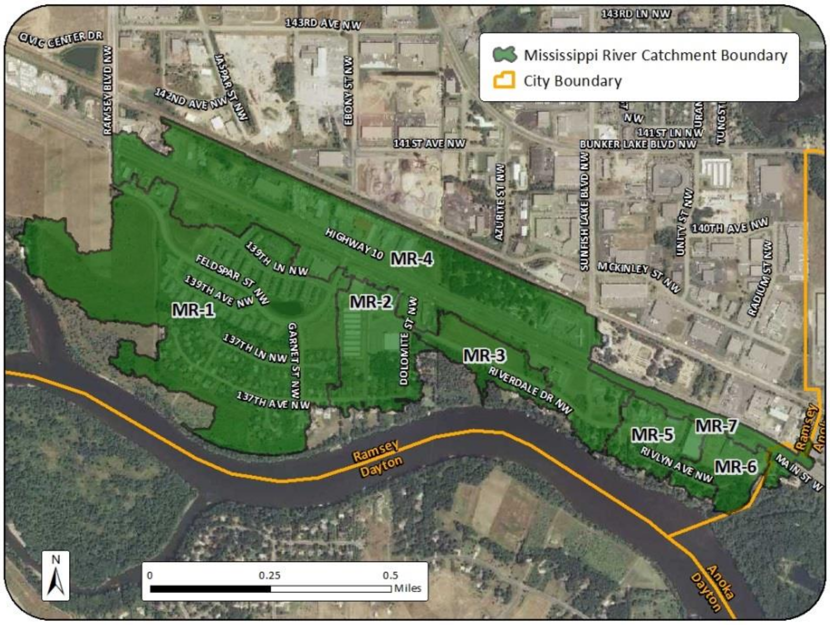


Figure 11: The 448 acre drainage area was divided into 2 drainage networks, which were subdivided into a total of 16 catchments for this analysis. Catchment profiles on the following pages provide additional information.

Mississippi River Drainage Network

Catchment ID	Page
MR-1	31
MR-2	37
MR-3	42
MR-4	46
MR-5	50
MR-6	55
MR-7	58

Existing Network Summary	
Acres	320.0
Dominant Land Cover	Residential
Volume (ac-ft/yr)	101.4
TP (lb/yr)	84.9
TSS (lb/yr)	28,083



DRAINAGE NETWORK SUMMARY

This network includes all of the catchments that discharge to the Mississippi River explored through this analysis. Catchments were chosen based on each major outfall to the Mississippi River, and were named in order from west to east using the 'MR' designator for 'Mississippi River'. The outfalls are located (from west to east) at Garnet St. (MR-1), Ebony St. (MR-2), Riverdale Dr. (MR-3), Sunfish Lake Blvd. (MR-4), Tungsten St. (MR-5), and Kings Island (MR-6 and MR-7).

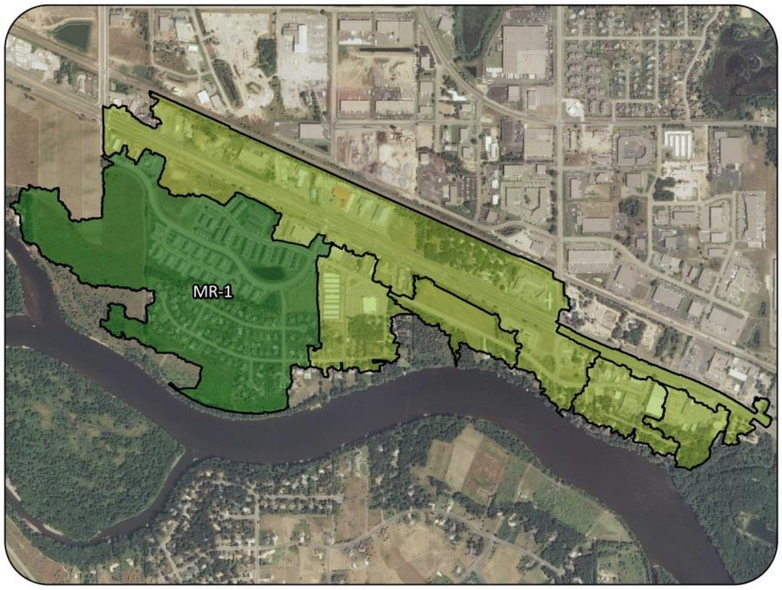
The seven catchments comprising the drainage network are all south of the Burlington Northern railroad tracks. Other than catchment MR-4, all catchments are south of US-10. Land use across these catchments varies from commercial, industrial, and freeway along the US-10 corridor to primarily residential and commercial along the riverfront and roadways south of US-10. Soils throughout the network are predominantly coarse sand (Hubbard series) and sandy loam (Dickman and Duelm), with some silty sand loam (Becker) soils in the southern portions of Catchments MR-1 and MR-2.

EXISTING STORMWATER TREATMENT

Sixteen BMPs are scattered throughout the drainage network. Of these, eight are stormwater retention ponds located in Catchments MR-1 and MR-4. Catchments MR-2, MR-4, and MR-7 have the remaining eight BMPs, including four grass swales (which represent portions of the US-10 ditches and median), three infiltration basins, and one hydrodynamic device. Municipal street cleaning occurs in all the catchments with exception to MR-6 and MR-7 where no streets exist. Additional detail for each of these BMPs is provided in their respective Catchment ID Page.

Catchment MR-1

Existing Catchment Summary	
Acres	131.1
Dominant Land Cover	Residential
Parcels	404



CATCHMENT DESCRIPTION
Catchment MR-1 includes all of the geographic area draining to an outfall directly south of Garnet St. The catchment is predominantly single family and multifamily residential parcels with some commercial properties along Feldspar St. and Riverdale Dr. The catchment also includes approximately 40 acres of Mississippi West Regional Park. Soils across the catchment are evenly split between sandy soils to the north and silty loam soils to the south.

EXISTING STORMWATER TREATMENT
Four stormwater retention ponds installed on residential and commercial property provide treatment to runoff in this catchment. The pond on commercial property, installed during construction of Village Bank, provides treatment to only the bank property. The three other ponds treat multiple parcels in the residential areas of the catchment. Ponds P34434 and P34418 treat the Rivenwick Village apartment development along Feldspar St. as well as commercial and parkland property from the west. These ponds discharge into the Garnet St. storm sewer pipe, which subsequently discharges into retention pond P34404 and finally the Mississippi River. In addition to treating stormwater runoff from ponds P34434 and P34418, pond P34304 also treats 53 acres of single family residential and parkland land uses.

Lastly, street cleaning is provided by the City of Ramsey twice per year using mechanical sweepers. 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	5			
	BMP Types	4 Ponds, Street Cleaning			
	TP (lb/yr)	68.2	32.9	48%	**35.3**
	TSS (lb/yr)	20,545	13,924	68%	**6,621**
	Volume (acre-feet/yr)	55.2	0.0	0%	**55.2**

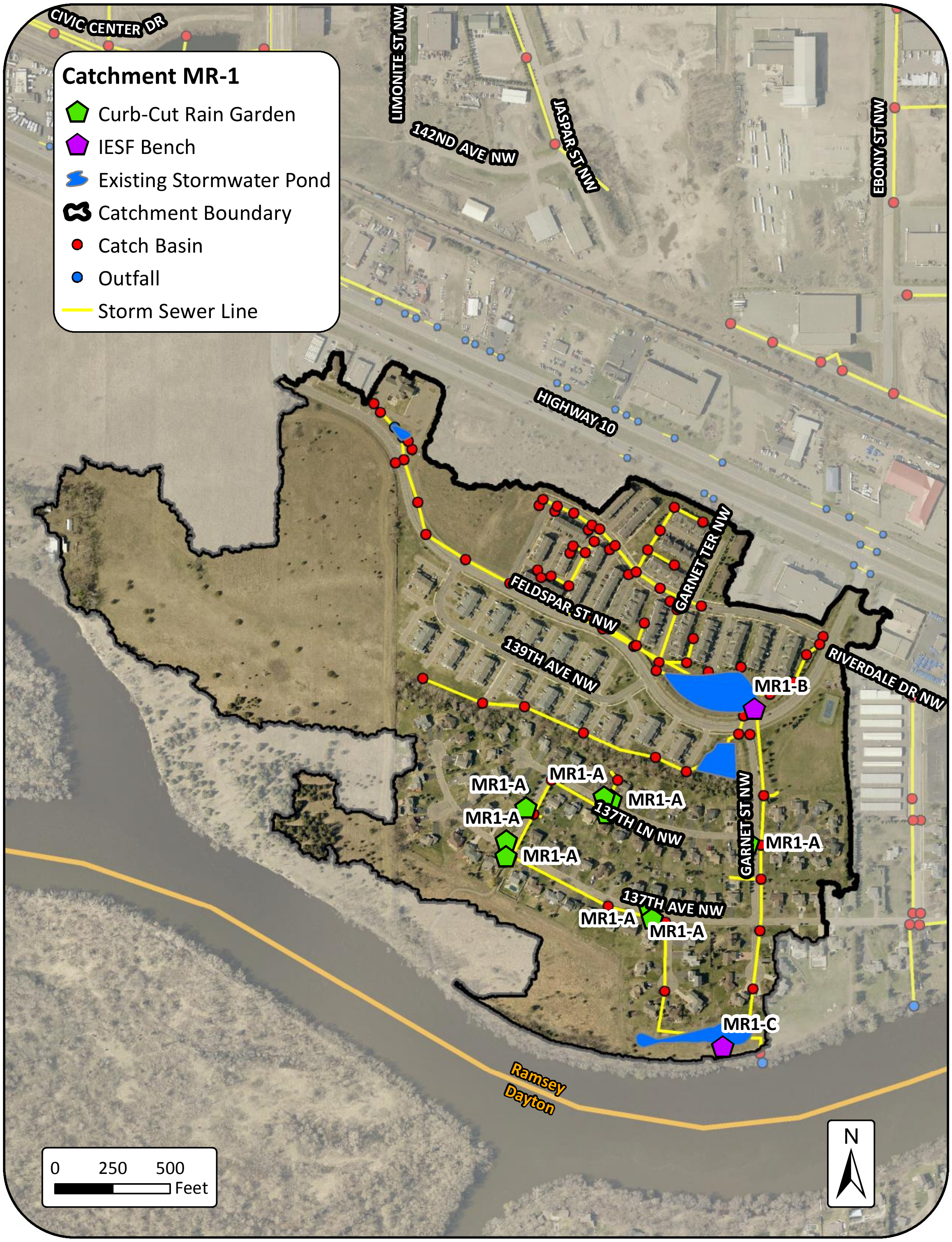
PROPOSED RETROFITS OVERVIEW

Proposed retrofits look to enhance pollutant retention within the catchment and provide additional treatment not already provided by the retention ponds. Two IESF benches are proposed for the largest ponds, P34304 and P34418. These benches would be installed along the bank for each respective pond and provide additional dissolved phosphorus treatment. In addition, curb-cut rain gardens were proposed within the single family residential neighborhood to increase infiltration and retention prior to discharge into the most downstream pond, P34304.

RETROFITS CONSIDERED BUT REJECTED

A hydrodynamic device was proposed along 137th Ave. to treat 17 acres of single family residential properties along Ironstone St., 137th Ln., and 137th Ave. However, this practice was rejected because it would only provide an additional annual TP reduction of 0.1 lb.

RETROFIT RECOMMENDATIONS



Project ID: MR1-A

Curb-Cut Rain Gardens

Drainage Area – 4.5 to 13.5 acres
Location – Scattered throughout catchment
Property Ownership – Private
Site Specific Information – Single-family lots in the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private property. Considering typical landowner participation rates, scenarios with 3, 6, and 9 rain gardens were analyzed to treat the drainage area, each with a 1.5 acre contributing drainage area.

	Curb-Cut Rain Garden						
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	3		6		9	
	Total Size of BMPs	750	sq-ft	1,500	sq-ft	2,250	sq-ft
	TP (lb/yr)	0.8	2.3%	1.6	4.5%	2.3	6.5%
	TSS (lb/yr)	166	2.5%	330	5.0%	493	7.4%
	Volume (acre-feet/yr)	1.5	2.8%	2.4	4.4%	3.3	5.9%
Cost	Administration & Promotion Costs*	$10,220		$12,848		$15,476	
	Design & Construction Costs**	$22,128		$44,256		$66,384	
	Total Estimated Project Cost (2016)	**$32,348**		**$57,104**		**$81,860**	
	Annual O&M***	$675		$1,350		$2,025	
Efficiency	30-yr Average Cost/lb-TP	**$2,192**		**$2,033**		**$2,067**	
	30-yr Average Cost/1,000lb-TSS	**$10,562**		**$9,859**		**$9,642**	
	30-yr Average Cost/ac-ft Vol.	**$1,140**		**$1,350**		**$1,448**	

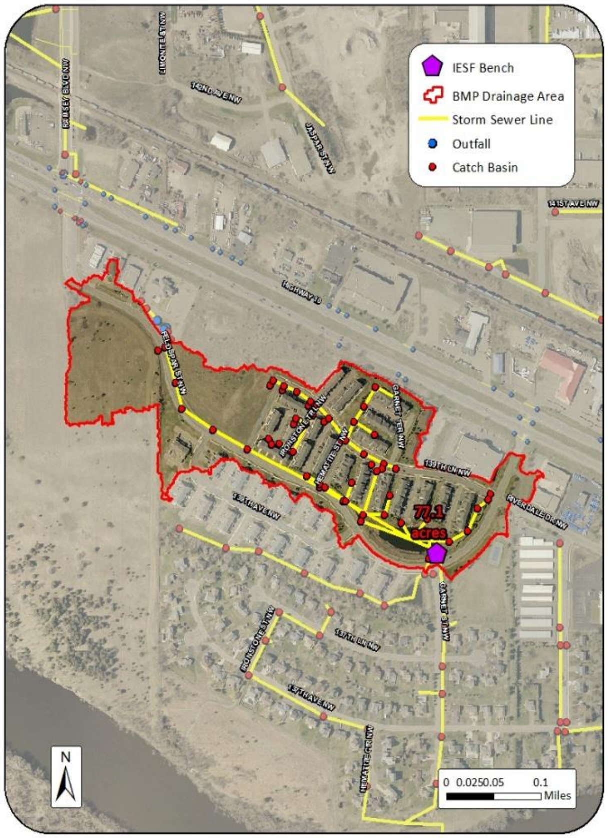
*Indirect Cost: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: MR1-B

Feldspar St. and Garnet St.
IESF Bench



Drainage Area – 77.1 acres
Location – Intersection of Feldspar St. NW and Garnet St. NW
Property Ownership – Private
Site Specific Information – An IESF bench is proposed as an improvement to the existing pond (P34418). The pond currently provides treatment through retention and settling. However, the addition of an IESF will increase removal of dissolved phosphorus. The project is proposed on the southeastern shore of the pond. The IESF was sized to 2,000 sq-ft based on available space between existing storm sewer pipes and the roadway.

	IESF Bench		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	2,000	sq-ft
	TP (lb/yr)	2.4	6.7%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,475	
	Design & Construction Costs**	$138,000	
	Total Estimated Project Cost (2016)	**$143,475**	
	Annual O&M***	$459	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,202**	
	30-yr Average Cost/1,000lb-TSS	**N/A**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

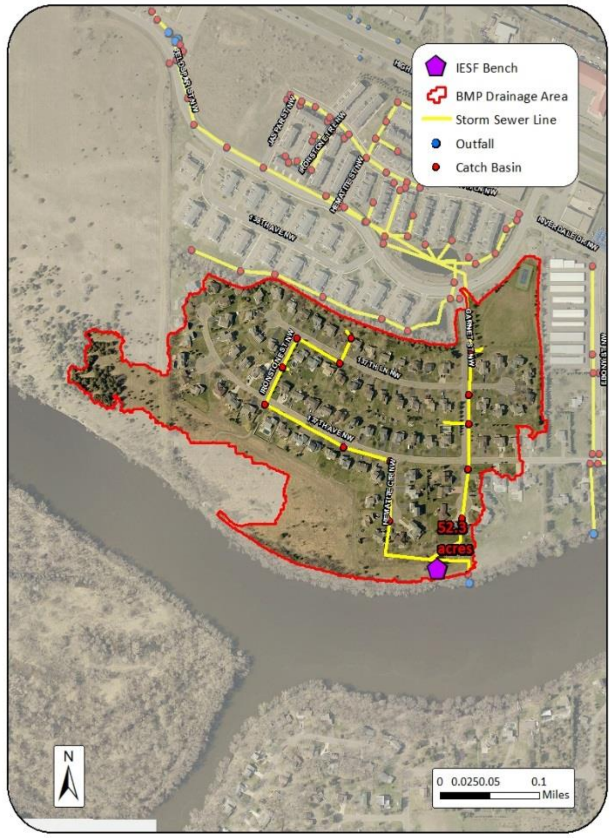
*Indirect Cost: 75 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$10,000/acre for IESF

Project ID: MR1-C

Hematite Cir. and Garnet St.
IESF Bench



Drainage Area – 52.3 acres
Location – Between Hematite Cir. NW and Garnet St. NW
Property Ownership – Public
Site Specific Information – An IESF bench was proposed as an improvement to the existing pond (P34304). The pond currently provides treatment through retention and settling. However, the addition of an IESF will increase removal of dissolved phosphorus. The project is proposed on the southern shore of the pond. The IESF was sized at 6,000 sq-ft based on available space.

IESF Bench

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	6,000	sq-ft
	TP (lb/yr)	7.6	21.5%
	TSS (lb/yr)	0	0.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$5,475	
	Design & Construction Costs**	$229,560	
	Total Estimated Project Cost (2016)	**$235,035**	
	Annual O&M***	$1,377	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,212**	
	30-yr Average Cost/1,000lb-TSS	**N/A**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

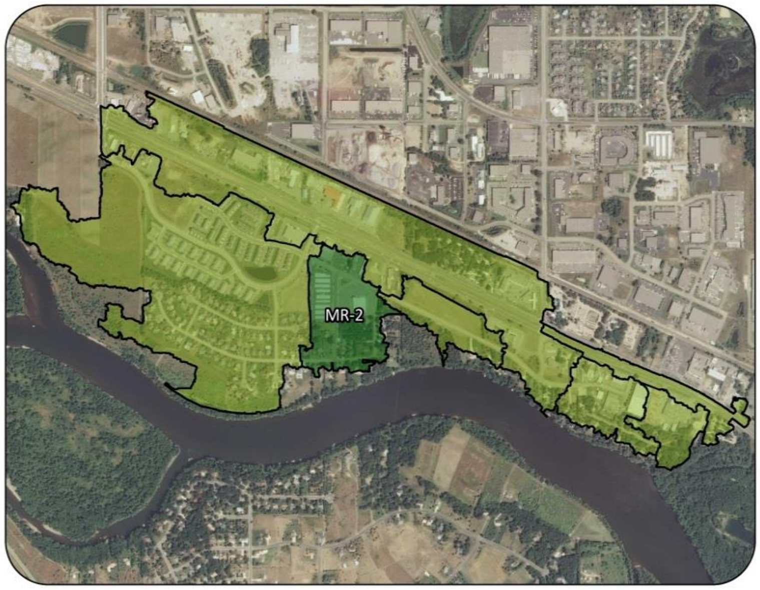
*Indirect Cost: 75 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***$10,000/acre for IESF

Catchment MR-2

Existing Catchment Summary	
Acres	25.8
Dominant Land Cover	Commercial
Parcels	42



CATCHMENT DESCRIPTION

Catchment MR-2 includes portions of Riverdale Dr., 137th Ave., Dolomite St., and Ebony St. south of US-10. Land use in the catchment is almost evenly split between commercial and industrial properties to the north and single family residential properties to the south. Soils follow a similar divide, with coarse, sandy soils to the north and more sandy loam soils to the south.

EXISTING STORMWATER TREATMENT

All of the stormwater generated within this catchment flows to storm sewer lines along Ebony St. and 137th Ave. These pipes drain to a single hydrodynamic device installed at the intersection of Ebony St. and 137th Ave. This structure, along with street cleaning performed twice annually with mechanical sweepers by the City of Ramsey, are the two forms of catchment-wide stormwater treatment.

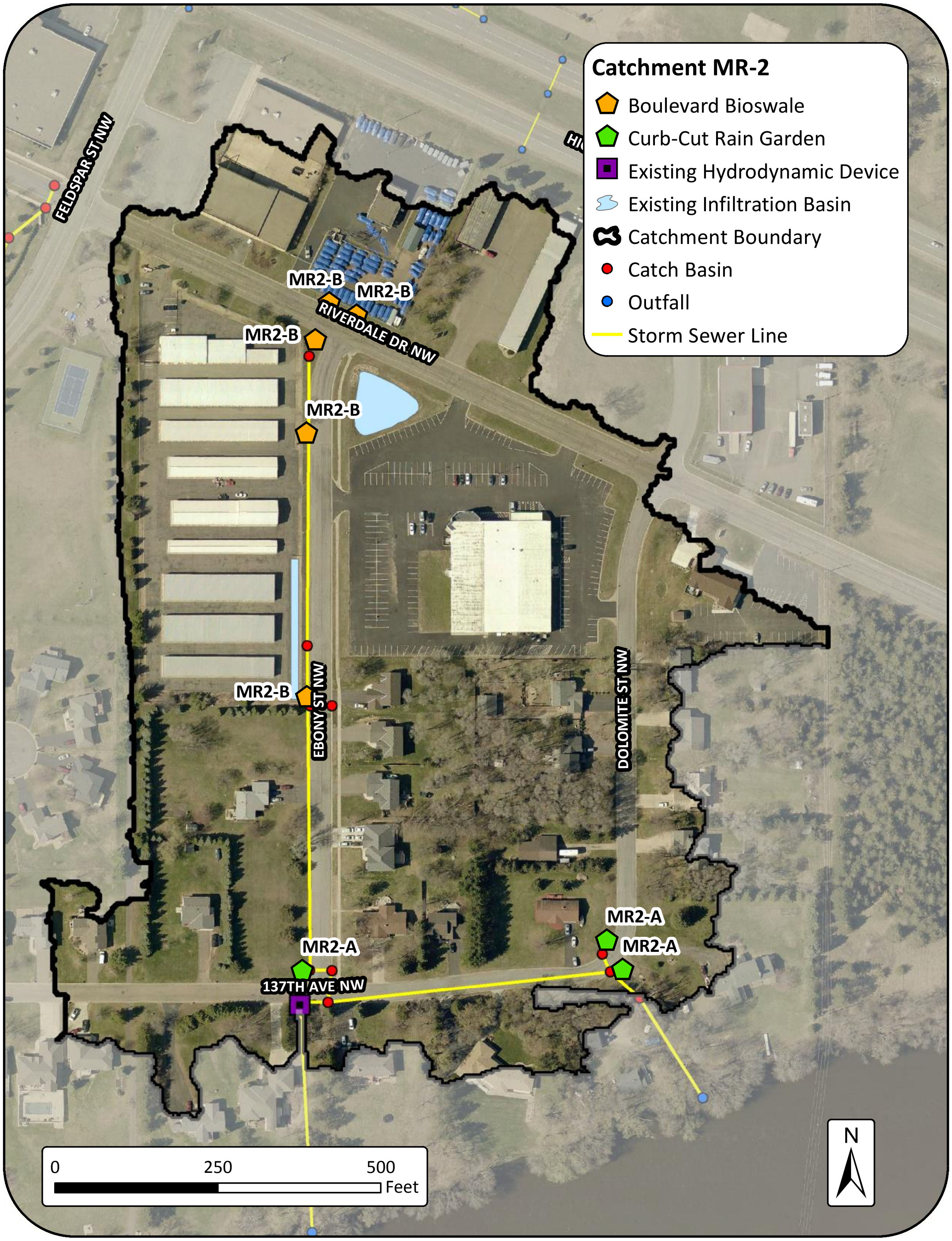
Additional treatment is provided by two privately-owned stormwater BMPs. The first is an infiltration basin located on the Super Bowl property at the southeast corner of the Ebony St. – Riverdale Dr. intersection, which treats about 3 acres of the commercial property. The second BMP is an infiltration basin on the storage facility property along Ebony St. This BMP provides some internal ponding storage, and was therefore modeled as an infiltration basin treating 3.6 acres of the property. Both of these BMPs were modeled with the Ebony St. hydrodynamic device and street cleaning to determine the present-day stormwater pollutant loading and treatment, which is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	4			
	BMP Types	2 Infil. Basins, 1 Hydrodyn. Device, Street Cleaning			
	TP (lb/yr)	20.3	6.4	32%	**13.9**
	TSS (lb/yr)	8,153	3,130	38%	**5023**
	Volume (acre-feet/yr)	22.0	6.7	30%	**15.4**

PROPOSED RETROFITS OVERVIEW

Like Catchment MR-1, proposed retrofits in Catchment MR-2 look to either supplement existing treatment practices or provide additional treatment where they may be lacking. Up to five boulevard bioswales were proposed along Riverdale Dr. and Ebony St. to treat commercial and industrial property not already treated by the Super Bowl or Ebony St. storage facility infiltration basins. In addition, three curb-cut rain gardens were proposed along Dolomite St. and 137th Ave. to treat overland runoff prior to it reaching storm sewer catch basins.

RETROFIT RECOMMENDATIONS



Project ID: MR2-A

Ebony St. and 137th Ave.

Curb-Cut Rain Gardens

Drainage Area – 1.5 to 4.5 acres
Location – Along Ebony St. NW and 137th Ave NW
Property Ownership – Private
Site Specific Information- Single-family lots in the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private property. Considering typical landowner participation rates, scenarios with one, two, and three rain gardens were analyzed to treat the drainage area. Each proposed rain garden was modeled with a 1.5 acre contributing drainage area.

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		2		3	
	Total Size of BMPs	250	sq-ft	500	sq-ft	750	sq-ft
	TP (lb/yr)	0.4	2.9%	0.8	5.8%	1.2	8.6%
	TSS (lb/yr)	112	2.2%	224	4.5%	336	6.7%
	Volume (acre-feet/yr)	0.3	1.8%	0.6	3.7%	0.9	5.5%
Cost	Administration & Promotion Costs*	$1,606		$3,212		$4,818	
	Design & Construction Costs**	$7,376		$14,752		$22,128	
	Total Estimated Project Cost (2016)	**$8,982**		**$17,964**		**$26,946**	
	Annual O&M***	$225		$450		$675	
Efficiency	30-yr Average Cost/lb-TP	**$1,311**		**$1,311**		**$1,311**	
	30-yr Average Cost/1,000lb-TSS	**$4,682**		**$4,682**		**$4,682**	
	30-yr Average Cost/ac-ft Vol.	**$1,853**		**$1,853**		**$1,851**	

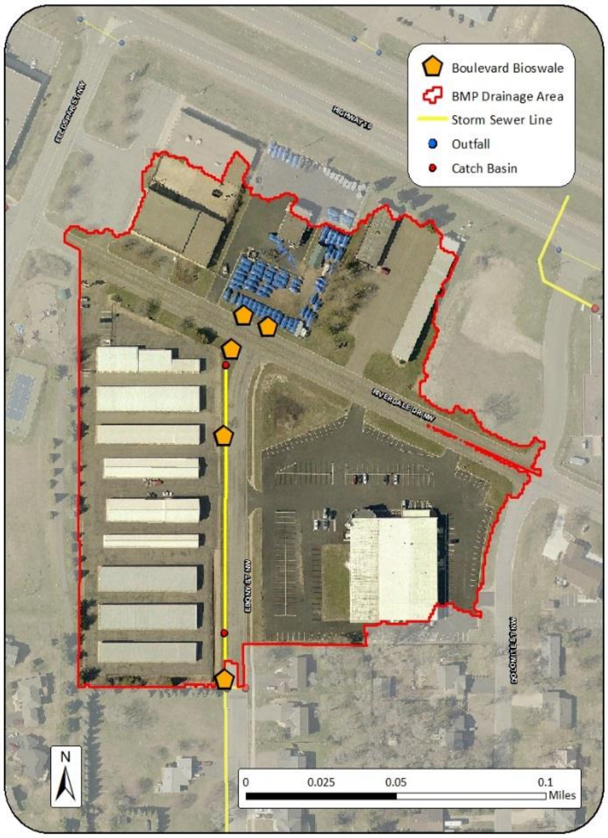
*Indirect Cost: (22 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: MR2-B

Riverdale Dr. and Ebony St. Boulevard Bioswales



Drainage Area –Approximately 0.5 acres each
Location - Along Riverdale Dr. NW and Ebony St. NW
Property Ownership – Public
Site Specific Information – Bioswales are proposed for installation along Riverdale Dr. and Ebony St. to reduce sediment and phosphorus loads. Locations for up to five bioswales are sited, where they will serve to treat runoff from the streets and the surrounding commercial properties.

Boulevard Bioswale			
	Cost/Removal Analysis	**2.5"/hr Infilt. Rate**	
		New Treatment	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	80	sq-ft
	TP (lb/yr)	0.2	1.1%
	TSS (lb/yr)	59	1.2%
	Volume (acre-feet/yr)	0.1	0.9%
Cost	**Administration & Promotion Costs***	$3,650	
	Design & Construction Costs**	$4,876	
	Total Estimated Project Cost	**$8,526**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,395**	
	30-yr Average Cost/1,000lb-TSS	**$8,693**	
	30-yr Average Cost/ac-ft Vol.	**$3,512**	

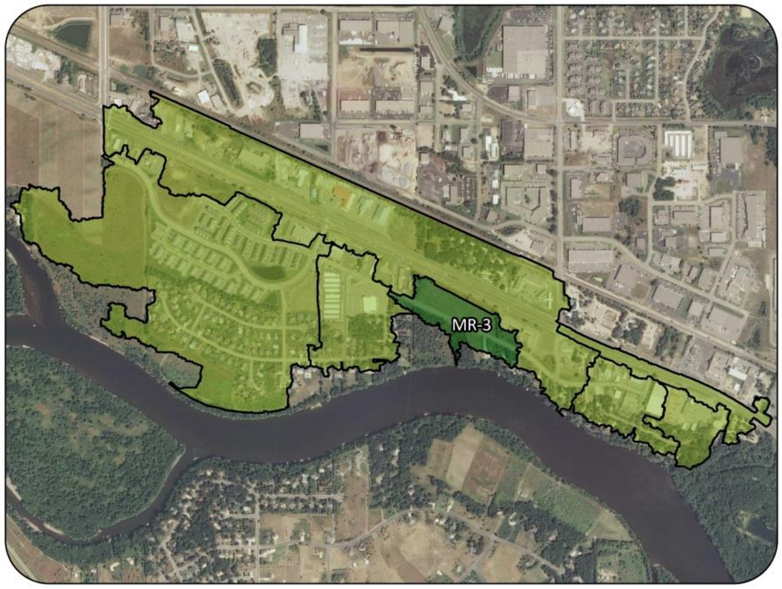
*Indirect Cost: (50 hours at $73/hour)

**Direct Cost: ($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)

Catchment MR-3

Existing Catchment Summary	
Acres	14.2
Dominant Land Cover	Undeveloped
Parcels	8



CATCHMENT DESCRIPTION

Catchment MR-3 is characterized by over 9 acres of undeveloped property adjacent to Riverdale Dr. owned by a trust. There are only seven other parcels in the catchment, including four single family homes, a portion of GB Properties, and a portion of the Anoka-Ramsey Congregation of Jehovah's Witnesses church. Runoff generated north of Riverdale Dr. flows overland to a network of four catch basins on Riverdale Dr. Drainage from these catch basins is conveyed directly to the Mississippi River via a 21" storm sewer pipe.

EXISTING STORMWATER TREATMENT

Street cleaning is provided by the City of Ramsey along Riverdale Dr. twice per year using mechanical sweepers. 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)	3.8	0.3	8%	**3.5**
	TSS (lb/yr)	1,322	157	12%	**1,165**
	Volume (acre-feet/yr)	3.2	0.0	0%	**3.2**

PROPOSED RETROFITS OVERVIEW

A hydrodynamic device is proposed to treat runoff from all four catch basins at this intersection. Additionally, an infiltration basin is proposed along the southern side of Riverdale Dr., just downstream of the hydrodynamic device to treat runoff from developed land uses and Riverdale Drive.

RETROFIT RECOMMENDATIONS

Project ID: MR3-A

Riverdale Dr.
Infiltration Basin

Drainage Area – 13.5 acres
Location – South side of Riverdale Dr. NW
Property Ownership – Public
Site Specific Information –An infiltration basin is proposed to intercept runoff from Riverdale Dr. NW before the runoff enters the existing catch basins. This practice will serve to reduce stormwater pollutants and decrease runoff peak flows reaching the Mississippi River. It will also serve to increase groundwater recharge within the catchment. Three sizes were modeled for present-day conditions (i.e. primarily undeveloped land use) and estimated volume and pollutant reductions are shown in the table below.

Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Ponding Depth of BMP	1 foot		1 foot		1 foot	
	Total Size of BMP	1,500	sq-ft	2,000	sq-ft	2,500	sq-ft
	TP (lb/yr)	2.5	71%	2.8	80%	3.0	86%
	TSS (lb/yr)	867	74%	971	83%	1,034	89%
	Volume (acre-feet/yr)	2.2	69%	2.5	78%	2.7	85%
Cost	Administration & Promotion Costs*	$2,920		$2,920		$2,920	
	Design & Construction Costs**	$30,876		$40,876		$50,876	
	Total Estimated Project Cost (2016)	**$33,796**		**$43,796**		**$53,796**	
	Annual O&M***	$225		$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$541**		**$602**		**$673**	
	30-yr Average Cost/1,000lb-TSS	**$1,559**		**$1,735**		**$1,952**	
	30-yr Average Cost/ac-ft Vol.	**$602**		**$661**		**$735**	

*Indirect Cost: 40 hours at $73/hour

**Direct Cost: ($20/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: MR3-B

Riverdale Dr.
Hydrodynamic Device

Drainage Area – 13.5 acres
Location – South side of Riverdale Dr. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed on the south side of Riverdale Drive and would accept runoff from Riverdale Dr. and the surrounding undeveloped land use. The estimated pollutant reductions shown below are for present-day conditions (i.e. primarily undeveloped land use).

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.4	11%
	TSS (lb/yr)	211	18%
	Volume (acre-feet/yr)	0.0	0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2016)	**$109,752**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$10,721**	
	30-yr Average Cost/1,000lb-TSS	**$20,324**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

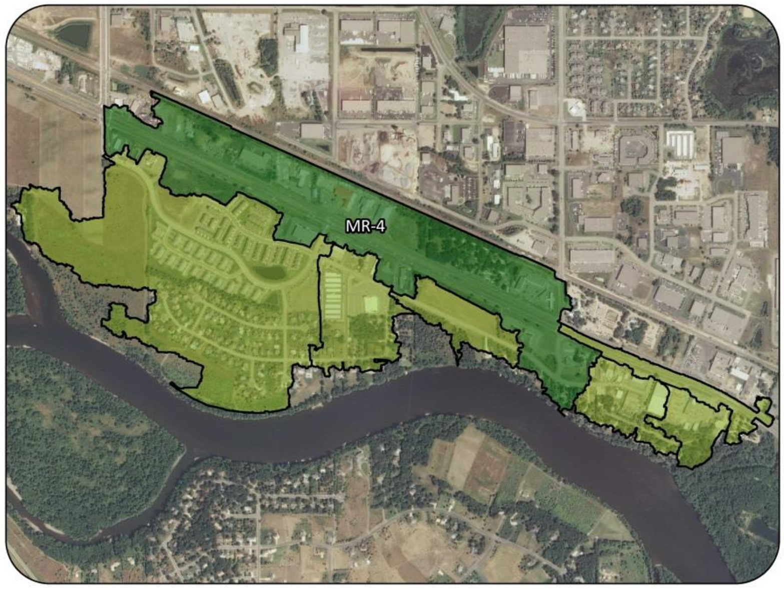
*Indirect Cost: (24 hours at $73/hour)

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

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

Catchment MR-4

Existing Catchment Summary	
Acres	110.1
Dominant Land Cover	Commercial
Parcels	73



CATCHMENT DESCRIPTION

Catchment MR-4 extends from Ramsey Blvd. in the west to Sunfish Lake Blvd. in the east. MR-4 includes nearly all commercial and industrial properties between Ramsey Blvd. and Sunfish Lake Blvd. within the Burlington Northern railroad tracks and US-10 corridor. The catchment also includes a handful of commercial properties on the southern end of the US-10 corridor as well as properties along the Sunfish Lake Blvd. – Riverdale Dr. intersection. The catchment has predominantly commercial, industrial, and freeway land uses. Soils are exclusively hydrologic group A coarse sands (Hubbard and Duelm series).

EXISTING STORMWATER TREATMENT

All stormwater runoff generated within the catchment flows to a single outfall located directly south of the Sunfish Lake Blvd. – Riverdale Dr. intersection. Upstream of this outfall, stormwater is collected from municipal and state-owned storm sewer systems along Sunfish Lake Blvd. and US-10. Much of the runoff from US-10 is carried overland through a ditch and culvert network and is intercepted by the storm sewer pipe network at Sunfish Lake Blvd.

Eight stormwater BMPs provide treatment to select areas of the catchment, including four retention ponds, one infiltration basin, and three grass swales. The retention ponds and infiltration basin were all built to provide stormwater treatment to the properties they were installed upon. The three grass swales represent the ditches running parallel to US-10, and are the northern ditch, the median, and the southern ditch. These were modeled as stormwater BMPs because in many areas they provide for sedimentation and filtration. Lastly, street cleaning is provided twice annually by the City of Ramsey on municipal streets.

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	9			
	BMP Types	4 ponds, 1 Infilt. Basin, 3 Swales, Street Cleaning			
	TP (lb/yr)	68.9	55.0	80%	**13.9**
	TSS (lb/yr)	29,220	23,461	80%	**5,759**
	Volume (acre-feet/yr)	84.8	64.9	77%	**19.9**

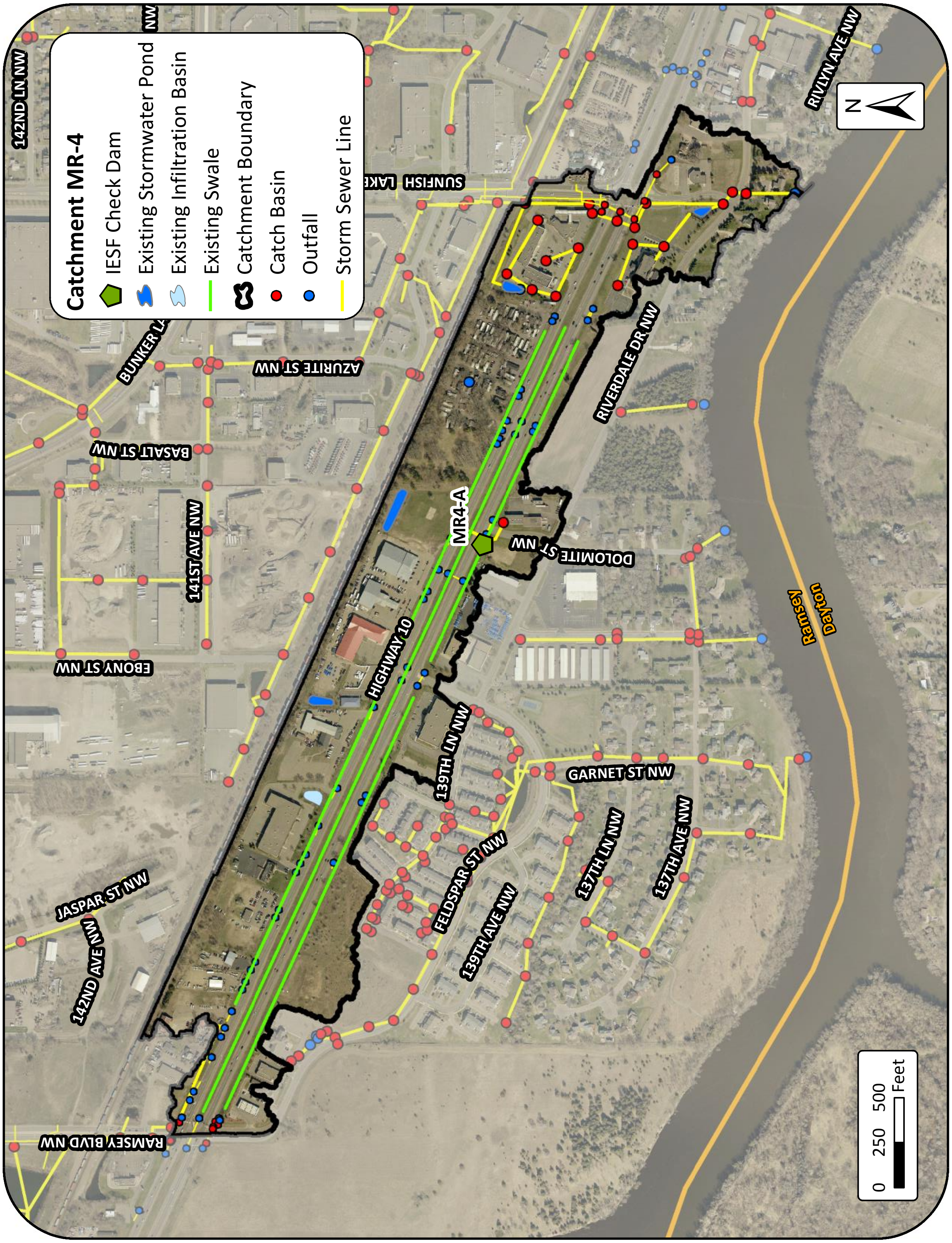
PROPOSED RETROFITS OVERVIEW

One permeable IESF check dam is proposed in this catchment. This BMP is sited to be placed in the US-10 southern ditch. This is an area where the additional treatment would be beneficial to the existing treatment from the grass swale in the ditch.

RETROFITS CONSIDERED BUT REJECTED

A permeable IESF check dam was also proposed in the US-10 median. However, this practice was rejected because the 3,500' grass swale in the median provides sufficient treatment. The WinSLAMM model suggests that because of the infiltration rate within the ditch, runoff from only a few of the largest events annually exits the ditch. Therefore, the US-10 median ditch is estimated to provide nearly 100% volume and pollutant reductions from its contributing drainage areas.

RETROFIT RECOMMENDATIONS



Project ID: MR4-A

US-10

IESF Check Dam

Drainage Area – 19.9 acres
Location – US-10 southern ditch
Property Ownership – Public
Site Specific Information –One IESF check dam is proposed as an improvement to the US-10 southern ditch to increase dissolved phosphorous removal. The grass bioswale upstream of the IESF check dam reduces TSS and particulate phosphorous. This BMP could increase the retention time of stormwater within the ditch, which promotes some additional suspended solid and particulate phosphorous removal. Furthermore iron-enhanced sand within the check dam would reduce dissolved phosphorus.

Permeable Check Dam

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMP	150	cu-ft
	TP (lb/yr)	0.2	0.1%
	TSS (lb/yr)	15	0.0%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$12,528	
	Total Estimated Project Cost (2015)	**$15,448**	
	Annual O&M***	$365	
Efficiency	30-yr Average Cost/lb-TP	**$4,549**	
	30-yr Average Cost/1,000lb-TSS	**$59,056**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

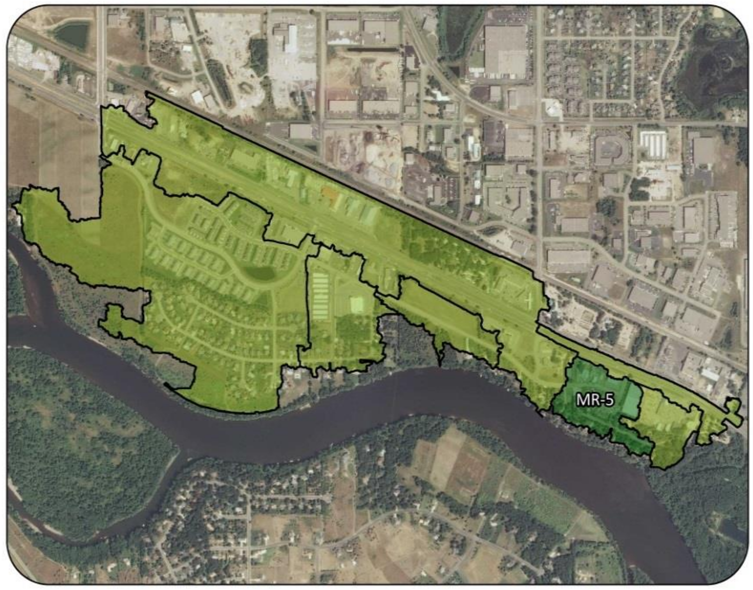
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: See Appendix B for detailed cost information

***(5 hours for each dam at $73/hour for cleaning sediment/debris and maintenance)

Catchment MR-5

Existing Catchment Summary	
Acres	16.6
Dominant Land Cover	Commercial
Parcels	44



CATCHMENT DESCRIPTION

Catchment MR-5 includes commercial and single-family residential properties along Riverdale Dr., Tungsten St., and Rivlyn Ave. south of US-10. The catchment is characterized as the geographical area draining to the storm sewer system below Riverdale Dr. and Tungsten St. This network discharges into the Mississippi River directly southwest from the Tungsten St. – Rivlyn Ave. intersection via a 27” pipe. Similar to other nearby catchments, MR-5 soils are predominantly coarse sand (Hubbard and Dickman series).

EXISTING STORMWATER TREATMENT

Street cleaning is provided by the City of Ramsey using mechanical street sweepers twice annually. No other structural BMPs exist within the catchment. 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)	12.1	0.7	6%	**11.4**
	TSS (lb/yr)	6,236	433	7%	**5,803**
	Volume (acre-feet/yr)	12.8	0.0	0%	**12.8**

PROPOSED RETROFITS OVERVIEW

Because of the course, sandy soils, infiltration practices were promoted above others. Infiltration practices tend to be the most cost-effective for reducing TP and TSS loads and can be highly effective at reducing peak volume through increased volume retention. Up to four curb-cut rain gardens are proposed along Tungsten St. and Rivlyn Ave. and up to five boulevard bioswales are proposed along Riverdale Dr. Lastly, a hydrodynamic device is proposed on the north side of the Tungsten St. – Rivlyn Ave. intersection to treat stormwater runoff collected from the commercial and residential properties along Riverdale Dr. and Tungsten St.

RETROFIT RECOMMENDATIONS

Project ID: MR5-A

Tungsten St. and Rivlyn Ave.
Curb-Cut Rain Garden

Drainage Area – 1.5 – 6.0 acres
Location – Along Tungsten St NW and Rivlyn Ave NW
Property Ownership – Private
Site Specific Information –Locations for four proposed rain gardens were marked along Tungsten St. NW and Rivlyn Ave. NW. Two of the sites could treat runoff originating from residential areas and two sites could treat runoff from light industrial land use. The chart below outlines the expected pollutant and volume reductions from a rain garden placed to treat runoff from a residential land use (MDRNA) and an industrial land use (LI). Each scenario has a 1.5 acre contributing drainage area. The rain garden sites are located in soils that are predominantly coarse sand, and therefore should be favorable for infiltration practices.

Curb-Cut Rain Garden					
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1 - MDRNA		1 - LI	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.5	4.4%	0.4	3.5%
	TSS (lb/yr)	155	2.7%	249	4.3%
	Volume (acre-feet/yr)	0.4	3.0%	0.6	4.3%
Cost	**Administration & Promotion Costs***	$1,606		$1,606	
	Design & Construction Costs**	$7,376		$7,376	
	Total Estimated Project Cost (2016)	**$8,982**		**$8,982**	
	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,049**		**$1,311**	
	30-yr Average Cost/1,000lb-TSS	**$3,383**		**$2,106**	
	30-yr Average Cost/ac-ft Vol.	**$1,380**		**$950**	

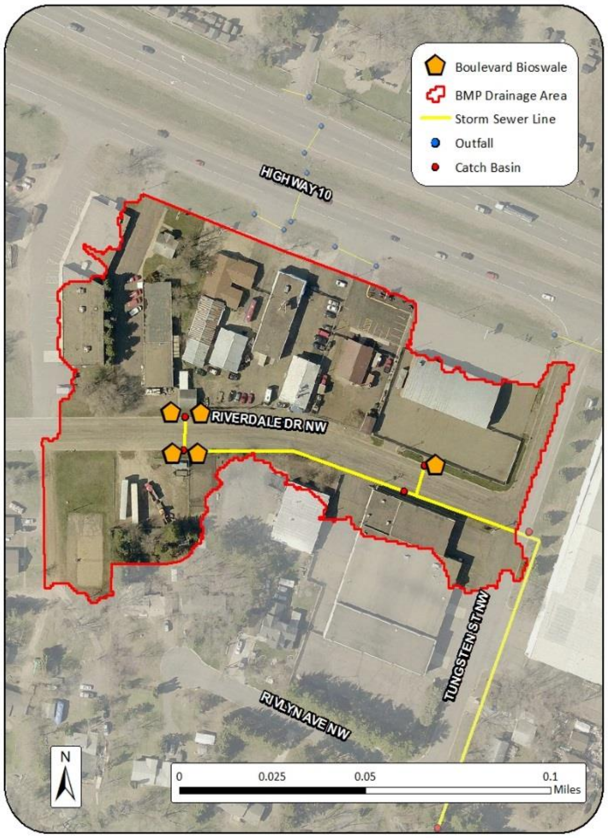
*Indirect Cost: (22 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: MR5-B

Riverdale Dr.
Boulevard Bioswales



Drainage Area – 0.5 acre
Location – Riverdale Dr. NW
Property Ownership – Public
Site Specific Information – Bioswales were proposed along Riverdale Dr. NW to reduce sediment and phosphorus loads. Locations for up to five bioswales were found that could treat runoff from Riverdale Dr. and the surrounding commercial properties. The table below shows potential volume and pollutant reductions for a standard sized bioswale with a 0.5 acre contributing drainage area.

Boulevard Bioswale			
	Cost/Removal Analysis	**2.5"/hr Infilt. Rate**	
		New Treatment	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	80	sq-ft
	TP (lb/yr)	0.2	1.7%
	TSS (lb/yr)	105	1.8%
	Volume (acre-feet/yr)	0.2	1.5%
Cost	**Administration & Promotion Costs***	$3,650	
	Design & Construction Costs**	$4,876	
	Total Estimated Project Cost	**$8,526**	
	Annual O&M***	$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$2,603**	
	30-yr Average Cost/1,000lb-TSS	**$4,839**	
	30-yr Average Cost/ac-ft Vol.	**$2,714**	

*Indirect Cost: (50 hours at $73/hour)

**Direct Cost: ($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)

Project ID: MR5-C

Tungsten St. and Rivlyn Ave.
Hydrodynamic Device

Drainage Area – 12 acres
Location – Intersection of Tungsten St. and Rivlyn Ave.
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed for installation on the northeast corner of the Tungsten St. – Rivlyn Ave. intersection. It could provide treatment to an approximately 12-acre drainage area primarily consisting of industrial land use.

	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	8%
	TSS (lb/yr)	682	12%
	Volume (acre-feet/yr)	0.0	0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2016)	**$109,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$4,765**	
	30-yr Average Cost/1,000lb-TSS	**$6,288**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

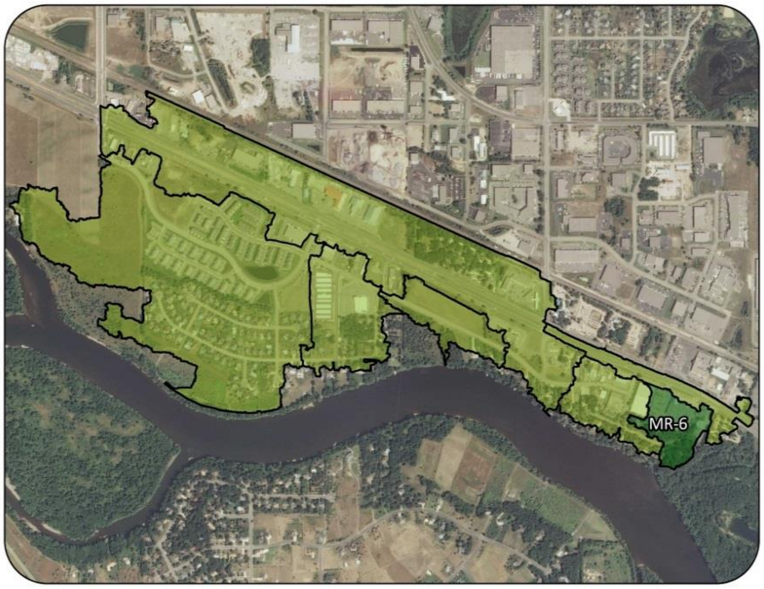
*Indirect Cost: (24 hours at $73/hour)

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

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

Catchment MR-6

Existing Catchment Summary	
Acres	10.9
Dominant Land Cover	Industrial
Parcels	14



CATCHMENT DESCRIPTION

Stormwater runoff generated in catchment MR-6 is predominantly from commercial land uses and flows overland toward the southeast prior to discharging into the Mississippi River on the upstream side of King's Island.

EXISTING STORMWATER TREATMENT

This catchment does not have any existing stormwater treatment. Street cleaning was not applied to this catchment as no municipal streets lie within the catchment boundary. 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	0			
	BMP Types	N/A			
	TP (lb/yr)	5.9	0.0	0%	**5.9**
	TSS (lb/yr)	3,390	0	0%	**3390**
	Volume (acre-feet/yr)	6.7	0.0	0%	**6.7**

PROPOSED RETROFITS OVERVIEW

Soils in the catchment are exclusively coarse sands, making this catchment a great prospect for infiltration practices. Stormwater runoff flows south to a small depression near the King's Island Walking Bridge. A proposed infiltration basin at this site could effectively disconnect the southern ends of many of the businesses adjacent to US-10 from discharging stormwater directly into the Mississippi River (during most storm events).

RETROFIT RECOMMENDATION

Project ID: MR6-A

Southeastern Portion Infiltration Basin

Drainage Area – 10.9 acres
Location – Southeastern portion of the catchment
Property Ownership – Private
Site Specific Information – An infiltration basin is proposed on the southeastern portion of the catchment. Stormwater in the catchment currently flows south to a depression near the King's Island Walking Bridge. An infiltration basin is proposed in this depression to more effectively retain stormwater during peak flow events and reduce the pollutant loads discharging from this catchment into the Mississippi River. Three basin sizes were modeled and their respective estimated volume and pollutant reductions are summarized in the table below.

Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Ponding Depth of BMP	1 foot		1 foot		1 foot	
	Total Size of BMP	2,000	sq-ft	3,000	sq-ft	4,000	sq-ft
	TP (lb/yr)	3.6	61%	4.4	75%	4.9	83%
	TSS (lb/yr)	2,110	62%	2,543	75%	2,836	84%
	Volume (acre-feet/yr)	3.8	57%	4.7	71%	5.4	80%
Cost	Administration & Promotion Costs*	$2,920		$2,920		$2,920	
	Design & Construction Costs**	$40,876		$60,876		$80,876	
	Total Estimated Project Cost (2016)	**$43,796**		**$63,796**		**$83,796**	
	Annual O&M***	$225		$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$468**		**$534**		**$616**	
	30-yr Average Cost/1,000lb-TSS	**$799**		**$925**		**$1,064**	
	30-yr Average Cost/ac-ft Vol.	**$440**		**$495**		**$562**	

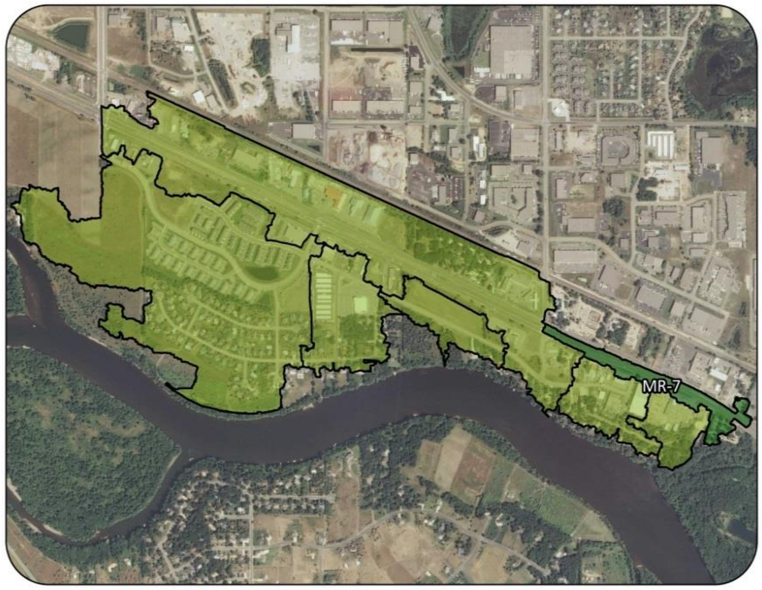
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: ($20/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment MR-7

Existing Catchment Summary	
Acres	11.3
Dominant Land Cover	Commercial
Parcels	12



CATCHMENT DESCRIPTION

Catchment MR-7 includes portions of both the City of Ramsey and the City of Anoka. Stormwater generated on the predominantly freeway and commercial land uses of the catchment flows east through the US-10 median to the southern ditch. This ditch discharges into a small channel adjacent to King's Island within the City of Anoka. As most of the catchment lies within the City of Ramsey, it was included within this analysis.

EXISTING STORMWATER TREATMENT

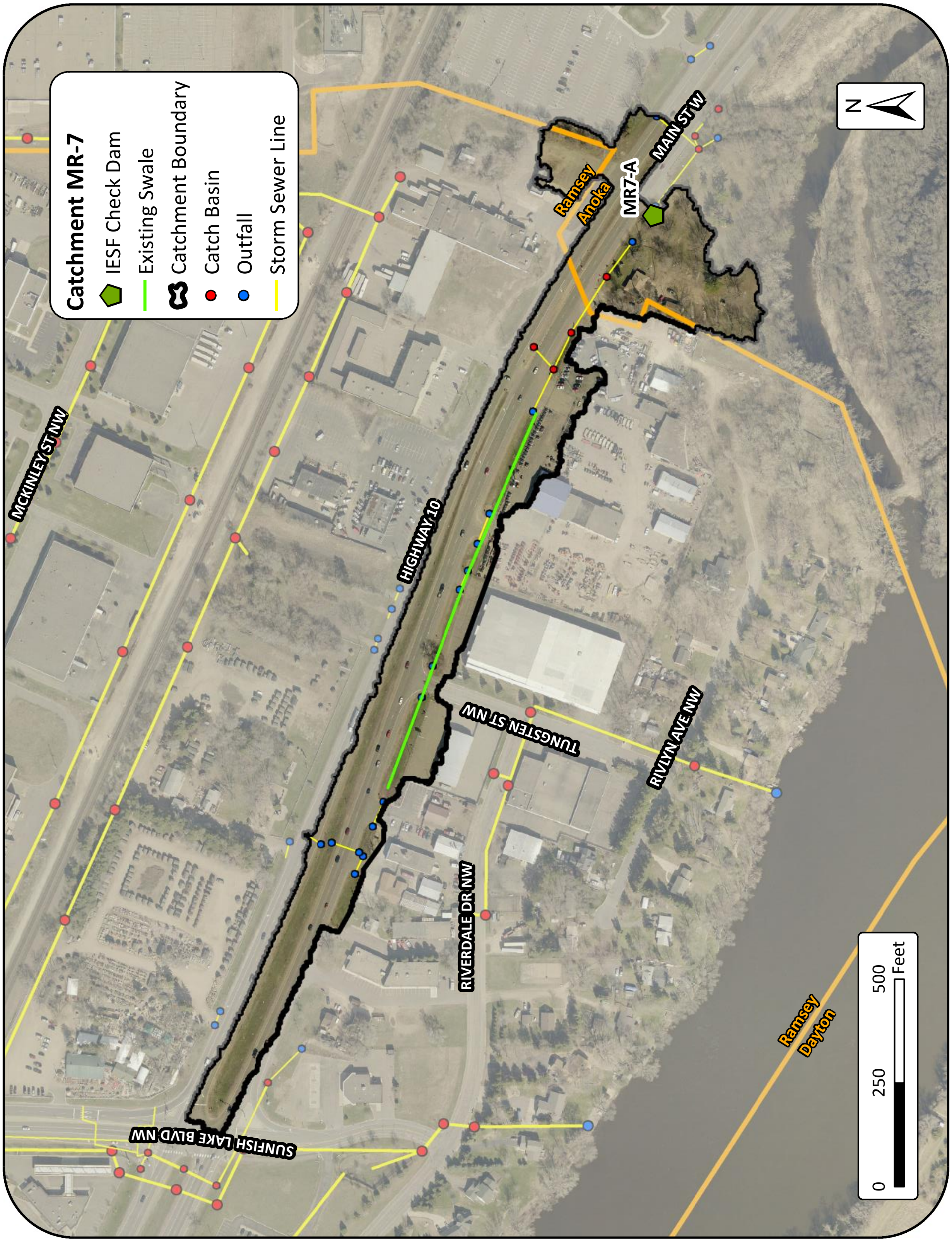
Runoff from US-10 and adjacent commercial properties is directed into either the median or the southern ditch. These features provide stormwater treatment in most areas through sedimentation and filtration. Street cleaning was not applied to this catchment as no municipal streets lie within the catchment boundary. 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	Grass Swale			
	TP (lb/yr)	6.8	5.9	87%	**0.9**
	TSS (lb/yr)	2,552	2,230	87%	**322**
	Volume (acre-feet/yr)	6.7	5..8	75%	**0.9**

PROPOSED RETROFITS OVERVIEW

A permeable IESF check dam is proposed along the southern ditch of US-10. Stormwater runoff from the median and from portions of the US-10 commercial properties could be directed to a check dam along the southern ditch. This BMP is effective at reducing the dissolved phosphorus load through filtration.

RETROFIT RECOMMENDATIONS



Project ID: MR7-A

US-10

IESF Check Dam

Drainage Area – 11.3 acres
Location – Along southern ditch of US-10
Property Ownership – Public
Site Specific Information – One permeable IESF check dam was proposed along the southern ditch of US-10. Stormwater from the median and from portions of the US-10 commercial properties could be directed to a check dam along the southern ditch that could reduce dissolved phosphorous loads. This BMP could also increase the retention time of stormwater within the ditch, which could provide additional TSS and particulate phosphorous treatment that is not captured by the grass bioswale upstream of this proposed practice.

Permeable Check Dam

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMP	150	cu-ft
	TP (lb/yr)	0.2	22.2%
	TSS (lb/yr)	15	4.7%
	Volume (acre-feet/yr)	n/a	n/a
Cost	Administration & Promotion Costs*	$2,920	
	Design & Construction Costs**	$12,528	
	Total Estimated Project Cost (2015)	**$15,448**	
	Annual O&M***	$365	
Efficiency	30-yr Average Cost/lb-TP	**$4,526**	
	30-yr Average Cost/1,000lb-TSS	**$58,662**	
	30-yr Average Cost/ac-ft Vol.	**n/a**	

*Indirect Cost: 40 hours at $73/hour

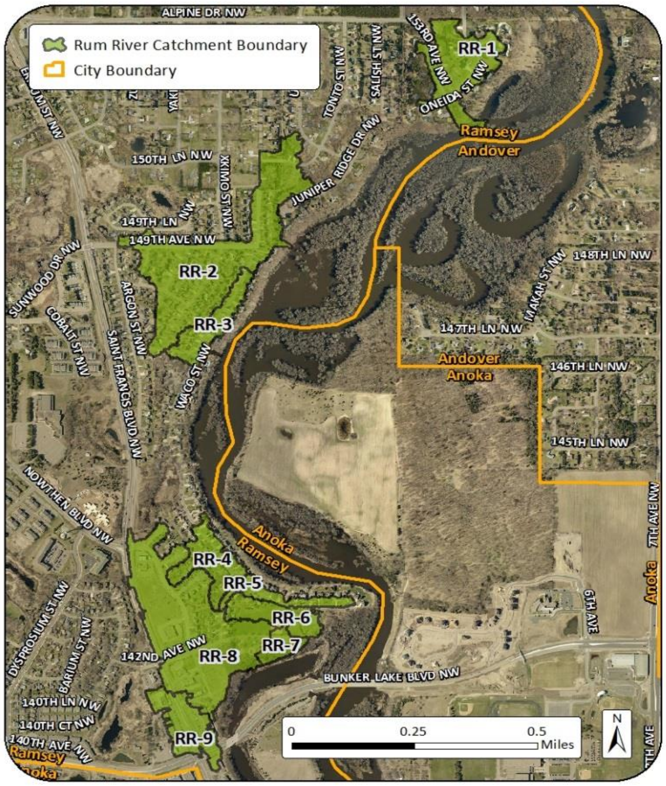
**Direct Cost: See Appendix B for detailed cost information

***(5 hours for each dam at $73/hour for cleaning sediment/debris and maintenance)

Rum River Drainage Network

Catchment ID	Page
RR-1	62
RR-2	65
RR-3	69
RR-4	73
RR-5	77
RR-6	81
RR-7	84
RR-8	87
RR-9	92

Existing Network Summary	
Acres	127.7
Dominant Land Cover	Residential
Volume (ac-ft/yr)	61.3
TP (lb/yr)	62.5
TSS (lb/yr)	19,764



DRAINAGE NETWORK SUMMARY

This network includes all of the catchments that discharge to the Rum River explored in this analysis. Catchments were chosen based on each major outfall to the Rum River and were named in order from north to south using the 'RR' designator for 'Rum River'. The outfalls are located (from north to south) at 153rd Ave. and Oneida St. (Catchment RR-1), 149th Ave. and Waco St. (RR-2), 147th Ln. and Waco St. (RR-3), Waco St. east of 143rd Ave. (RR-4), 142nd Ln south of Waco St. (RR-5), Rivers Bend Park north of the parking lot (RR-6) and south of the parking lot (RR-7), 142nd Ave. (RR-8), and Bunker Lake Blvd. (RR-9).

These nine catchments have a wide variety of land uses, including single-family and multi-family residential, commercial, parkland, and industrial. Soils are generally sandy, and range from fine sand loams (Becker series) to coarse sands (Duelm series).

EXISTING STORMWATER TREATMENT

Catchment boundaries and research areas within the Rum River drainage network were specifically chosen to locate and assess areas which were not already receiving stormwater treatment from constructed ponds and basins or wetlands. Only three existing BMPs were present within the nine catchments modeled. Two of these existing BMPs, stormwater retention ponds P19E304 in Catchment RR-1 and P25216 in Catchment RR-8, treat their entire respective catchments. The third BMP, street cleaning, is provided network-wide across all municipal streets by the City of Ramsey twice per year using mechanical sweepers. Additional detail for each of these BMPs is provided in the respective Catchment ID Pages.

Catchment RR-1

Existing Catchment Summary	
Acres	14.5
Dominant Land Cover	Residential
Parcels	26

CATCHMENT DESCRIPTION

This catchment includes portions of 26 single- family residential properties along 153rd Ave. and Oneida St. Stormwater runoff generated on rooftops, driveways, sidewalks, and roadways is directed to a storm sewer network below Oneida St. This network drains into a pond southeast of the catchment and subsequently discharges into the Rum River.

EXISTING STORMWATER TREATMENT

A retention pond (city retention pond P19E304) located southeast of the catchment and adjacent to the Rum River treats all 14.5 acres of single-family residential lots. In addition to the pond, street cleaning is supplied twice annually by the City of Ramsey using mechanical sweepers. 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	2			
	BMP Types	Stormwater Pond and Street Cleaning			
	TP (lb/yr)	7.7	3.4	44%	**4.3**
	TSS (lb/yr)	2,405	1,395	58%	**1,010**
	Volume (acre-feet/yr)	5.5	0.0	0%	**5.5**

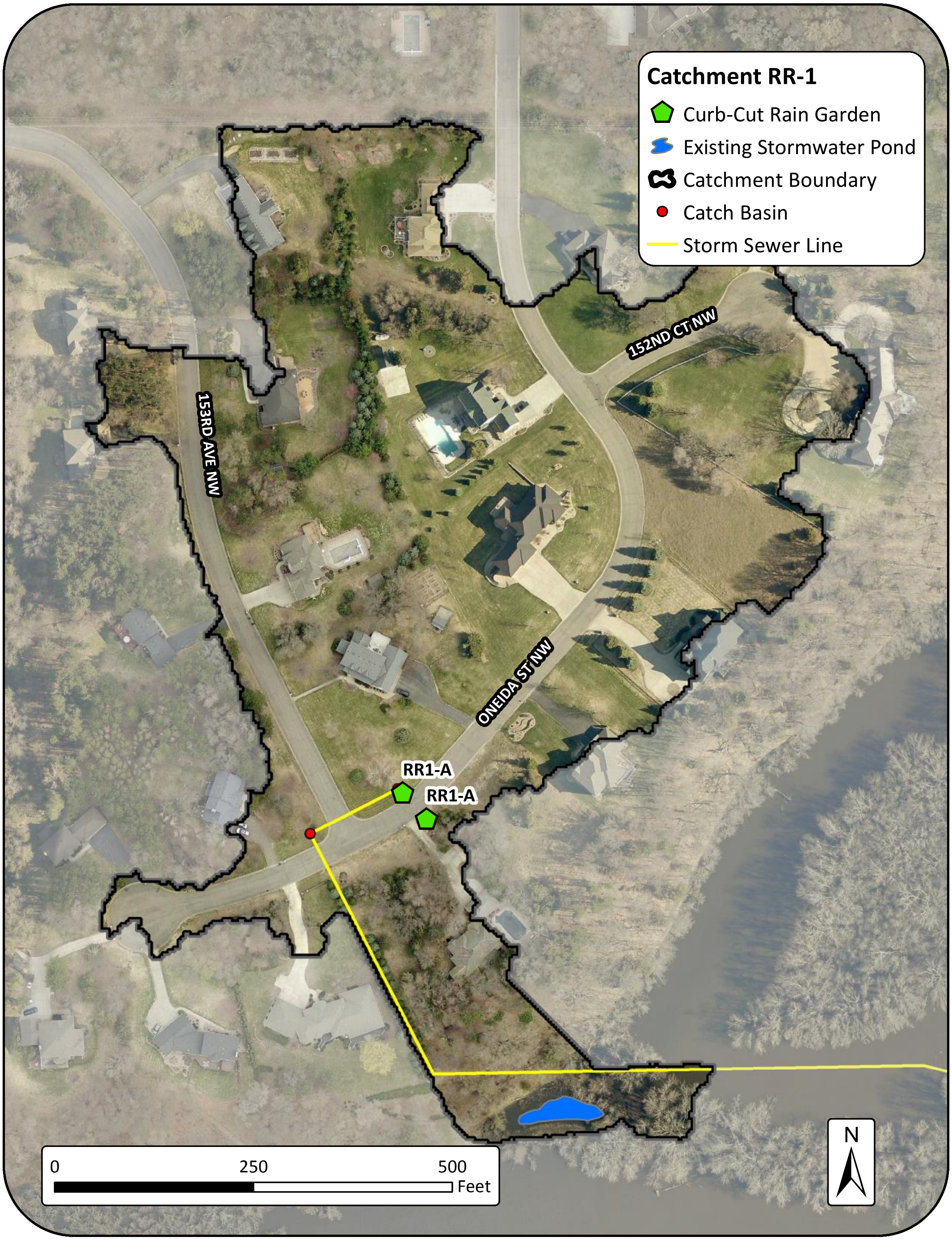
PROPOSED RETROFITS OVERVIEW

Two curb-cut rain gardens are proposed upstream of the retention pond to help reduce pollutant loading to the pond and increase overall catchment-wide reductions. These BMPs could be installed on properties with sandy soils and therefore high infiltration rates, upstream of the catch basins.

RETROFITS CONSIDERED BUT REJECTED

A hydrodynamic device was proposed at the intersection of Oneida St. NW and 153rd Ave NW. This BMP was rejected because WinSLAMM estimated it did not provide significant additional treatment due to the existing stormwater pond.

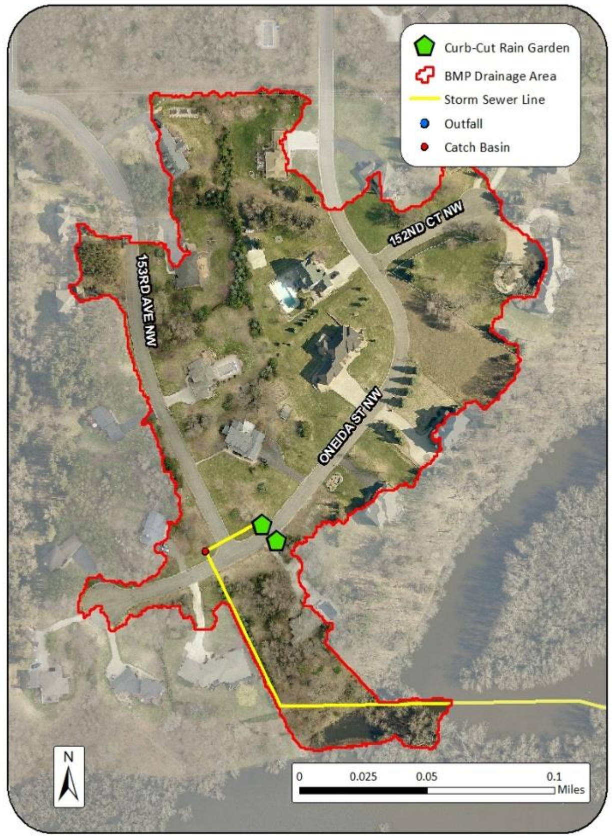
RETROFIT RECOMMENDATIONS



Project ID: RR1-A

Oneida St.

Curb-Cut Rain Gardens



Drainage Area – 1.5 - 3.0 acres
Location – North and South side of Oneida St. NW
Property Ownership – Private
Site Specific Information – Two locations were found where curb-cut rain gardens could be installed on single-family lots to treat stormwater pollutants originating from private properties. The table below shows the estimated pollutant and volume reductions expected from a rain garden installed on the north side of Oneida St. NW and one installed on the south side. Sites were selected that are near existing catch basins and in locations where the soils should be favorable for infiltration (i.e. sandy).

Curb-Cut Rain Garden

	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1 - North		1 - South	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.5	11.6%	0.4	9.3%
	TSS (lb/yr)	118	11.7%	111	11.0%
	Volume (acre-feet/yr)	0.7	12.4%	0.6	10.6%
Cost	**Administration & Promotion Costs***	$1,606		$1,606	
	Design & Construction Costs**	$7,376		$7,376	
	Total Estimated Project Cost (2016)	**$8,982**		**$8,982**	
	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,049**		**$1,311**	
	30-yr Average Cost/1,000lb-TSS	**$4,444**		**$4,724**	
	30-yr Average Cost/ac-ft Vol.	**$763**		**$899**	

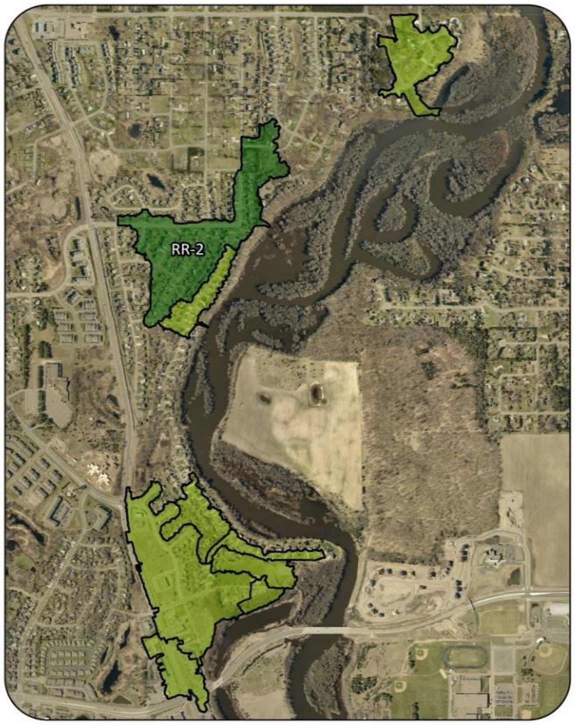
*Indirect Cost: (22 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment RR-2

Existing Catchment Summary	
Acres	36.9
Dominant Land Cover	Residential
Parcels	117



CATCHMENT DESCRIPTION

Catchment RR-2 is characterized as the geographical area draining to the 149th Ave. storm sewer line. This area was chosen because no stormwater treatment (outside of street cleaning) is provided to runoff from this area prior to discharge to the Rum River. The neighborhood is nearly completely built out within the catchment and is almost exclusively single-family residential lots. Soils in the catchment are exclusively loamy sands (Nymore series) with high infiltration rates.

EXISTING STORMWATER TREATMENT

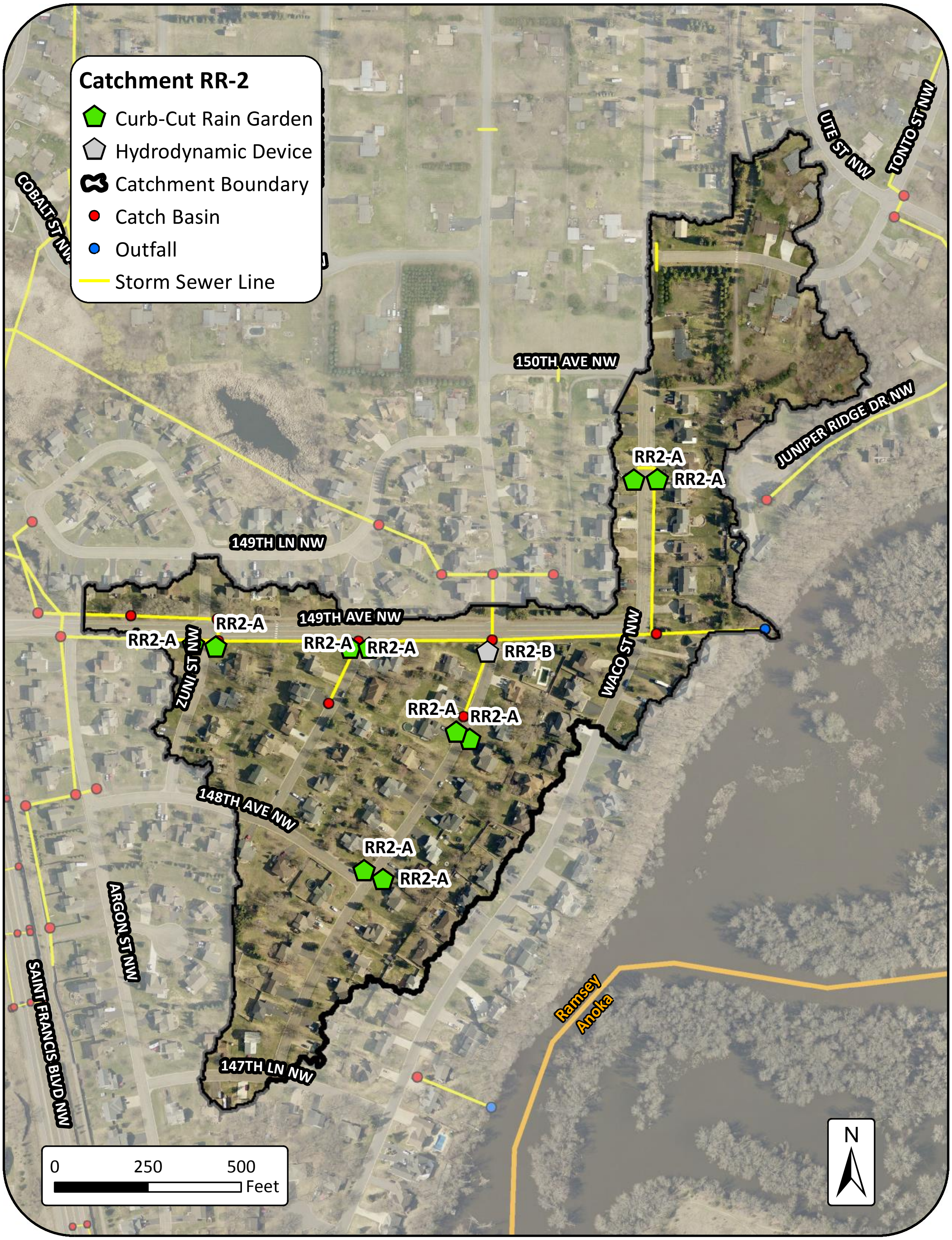
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	20.5	1.8	9%	**18.7**
	TSS (lb/yr)	6,420	791	12%	**5629**
	Volume (acre-feet/yr)	14.8	0.0	0%	**14.8**

PROPOSED RETROFITS OVERVIEW

Up to ten curb-cut rain gardens were proposed to take advantage of the high infiltration rates and the large drainage areas to many potential garden sites throughout the catchment. In addition, a hydrodynamic device was proposed along the Xkimo St. storm sewer line to treat runoff from the residential properties along the roadway.

RETROFIT RECOMMENDATIONS



Project ID: RR2-A

Curb-Cut Rain Gardens

Drainage Area – 1.5 to 15 acres
Location – Scattered throughout catchment
Property Ownership – Private
Site Specific Information – Single-family lots in the catchment provide various locations for curb-cut rain gardens to treat stormwater pollutants originating from private properties. Considering typical landowner participation rates, scenarios with one, five, and ten rain gardens were analyzed to treat the drainage area. Sites with sandy soils that should be suitable for infiltration practices were selected throughout the catchment. Each proposed rain garden was modeled with a 1.5 acre contributing drainage area.

	Curb-Cut Rain Garden						
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1		5		10	
	Total Size of BMPs	250	sq-ft	1,250	sq-ft	2,500	sq-ft
	TP (lb/yr)	0.5	2.7%	2.5	13.4%	5.0	26.7%
	TSS (lb/yr)	155	2.8%	776	13.8%	1,551	27.6%
	Volume (acre-feet/yr)	0.4	2.6%	1.9	12.9%	3.8	25.7%
Cost	Administration & Promotion Costs*	$8,468		$11,972		$16,352	
	Design & Construction Costs**	$7,376		$36,880		$73,760	
	Total Estimated Project Cost (2016)	**$15,844**		**$48,852**		**$90,112**	
	Annual O&M***	$225		$1,125		$2,250	
Efficiency	30-yr Average Cost/lb-TP	**$1,506**		**$1,101**		**$1,051**	
	30-yr Average Cost/1,000lb-TSS	**$4,859**		**$3,548**		**$3,387**	
	30-yr Average Cost/ac-ft Vol.	**$1,982**		**$1,451**		**$1,384**	

*Indirect Cost: (104 hours at $73/hour base cost) + (12 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: RR2-B

Xkimo St.
Hydrodynamic Device

Drainage Area – 15.7 acres
Location – Intersection of Xkimo St. NW and 149th Ave. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed in-line with the sewer system on Xkimo St. This proposed BMP could treat runoff from residential properties, resulting in increased stormwater pollutant retention.

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	4%
	TSS (lb/yr)	322	6%
	Volume (acre-feet/yr)	0.0	0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2016)	**$109,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$5,361**	
	30-yr Average Cost/1,000lb-TSS	**$13,318**	
	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: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment RR-3

Existing Catchment Summary	
Acres	7.2
Dominant Land Cover	Residential
Parcels	35

CATCHMENT DESCRIPTION

Catchment RR-3 includes portions of 35 single family residential properties along 147th Ln. and Waco St. Stormwater runoff generated on each of these properties flows to one of two catch basins 100' north of the 147th Ln – Waco St. intersection. Stormwater collected in these catch basins is discharged directly into the Rum River via an 18" storm sewer pipe.

EXISTING STORMWATER TREATMENT

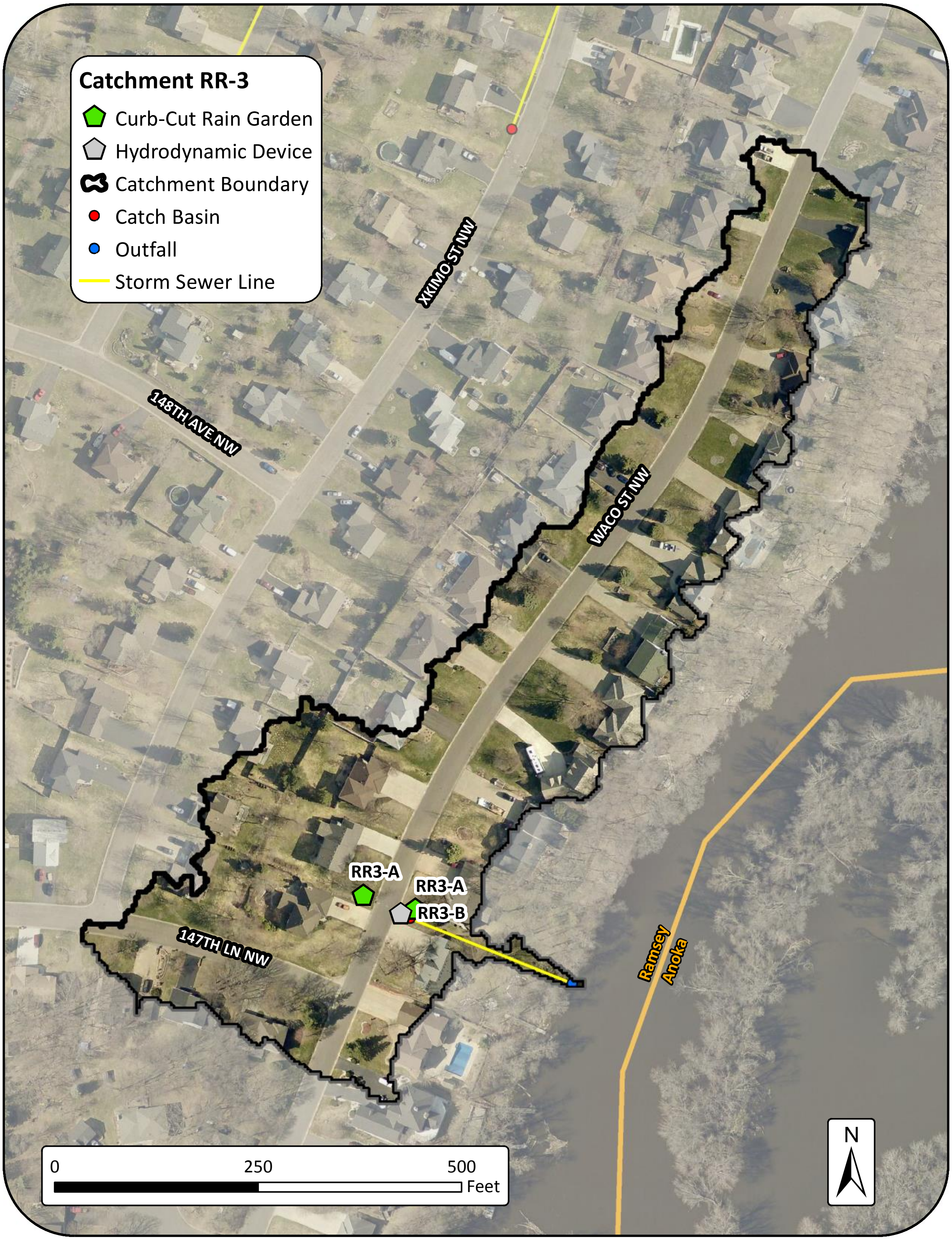
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	4.0	0.4	10%	**3.6**
	TSS (lb/yr)	1,254	154	12%	**1,100**
	Volume (acre-feet/yr)	2.9	0.0	0%	**2.9**

PROPOSED RETROFITS OVERVIEW

The Nymore series soils underlying this catchment are great soils for infiltration practices due to their often high infiltration rates. Two curb-cut rain gardens were proposed just upstream of the roadway catch basins to provide treatment through infiltration to many of the residential properties within the catchment. In addition, a hydrodynamic device was proposed along the 18" storm sewer line to treat the two catch basins draining the entire catchment.

RETROFIT RECOMMENDATIONS



Project ID: RR3-A

Waco St.

Curb-Cut Rain Gardens

Drainage Area – 1.5 to 3.0 acres
Location – East and West side of Waco St. NW
Property Ownership – Private
Site Specific Information – Two locations were found where curb-cut rain garden could be installed on single-family lots to treat stormwater originating from private properties. The below table gives the pollutant and volume reductions anticipated from a rain garden installed on the east side of Waco St. NW and one installed on the west side. Sites were selected that are upstream of the catchment and in locations where the soils should be favorable for infiltration practices. Each of the rain gardens was modeled with a 1.5 acre contributing drainage area.

Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1 - West		1 - East	
Treatment	Total Size of BMPs	250	sq-ft	250	sq-ft
Treatment	TP (lb/yr)	0.6	16.7%	0.7	19.4%
Treatment	TSS (lb/yr)	188	17.1%	204	18.5%
Treatment	Volume (acre-feet/yr)	0.5	15.8%	0.5	17.1%
Cost	Administration & Promotion Costs*	$1,606		$1,606	
Cost	Design & Construction Costs**	$7,376		$7,376	
Cost	**Total Estimated Project Cost (2016)**	**$8,982**		**$8,982**	
Cost	Annual O&M***	$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$874**		**$749**	
Efficiency	30-yr Average Cost/1,000lb-TSS	**$2,789**		**$2,571**	
Efficiency	30-yr Average Cost/ac-ft Vol.	**$1,150**		**$1,062**	

*Indirect Cost: (22 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: RR3-B

Waco St.

Hydrodynamic Device

Drainage Area – 13.0 acres
Location – Southeast side of Waco St. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed on Waco St., in-line with the storm sewer line. At this location the proposed BMP could treat the entire catchment drainage area and could serve to increase pollutant retention within the watershed.

	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	11.1%
	TSS (lb/yr)	167	15.2%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2016)	**$55,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$6,221**	
	30-yr Average Cost/1,000lb-TSS	**$14,901**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

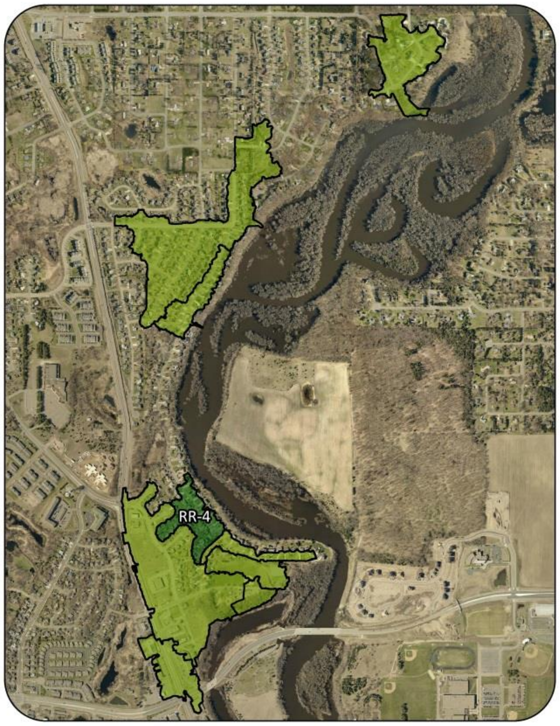
*Indirect Cost: (24 hours at $73/hour)

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

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

Catchment RR-4

Existing Catchment Summary	
Acres	8.5
Dominant Land Cover	Residential
Parcels	39



CATCHMENT DESCRIPTION

Catchment RR-4 includes all of the area draining stormwater to two catch basins along Waco Street. Land use in the catchment is entirely single-family residential lots. Soils in the catchment are generally sandy but vary from fine loam (Becker series)) to coarse soils (Nymore series).

EXISTING STORMWATER TREATMENT

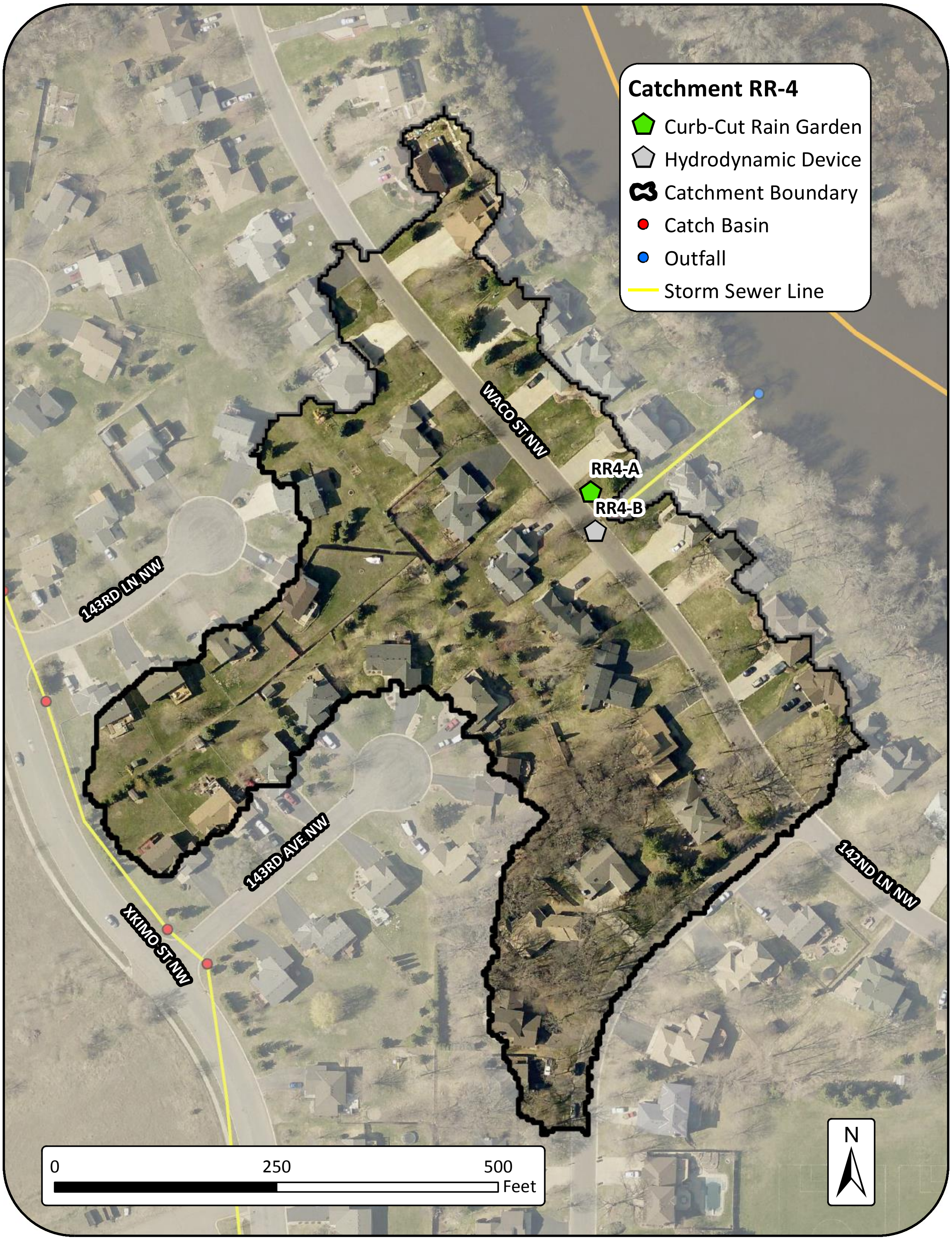
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	5.5	0.4	7%	**5.1**
	TSS (lb/yr)	1,595	184	12%	**1411**
	Volume (acre-feet/yr)	3.6	0.0	0%	**3.6**

PROPOSED RETROFITS OVERVIEW

A curb-cut rain garden is proposed upstream of the two catch basins on Waco St. to treat stormwater from the residential properties. In addition, a hydrodynamic device is proposed downstream of the two catch basins draining Waco Street.

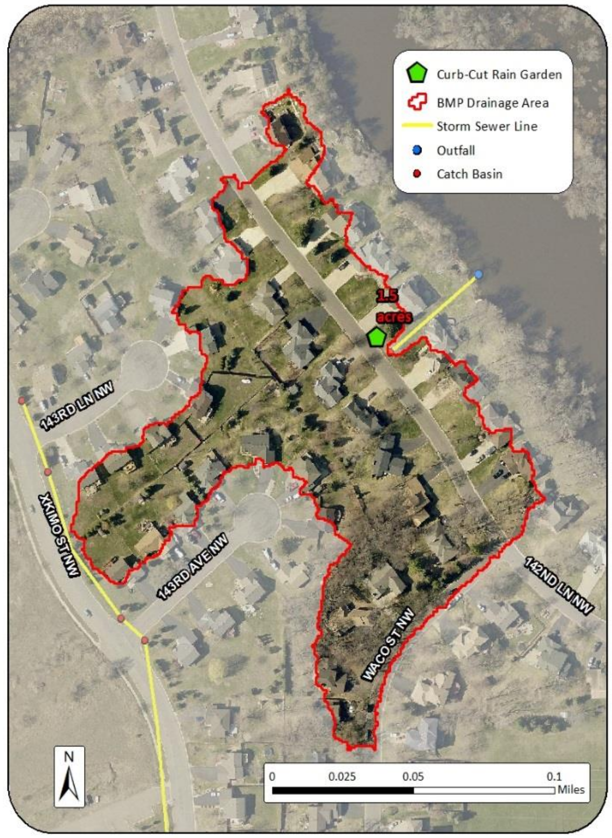
RETROFIT RECOMMENDATIONS



Project ID: RR4-A

Waco St.
Curb-Cut Rain Gardens

Drainage Area – 1.5 acres
Location –Waco St. NW
Property Ownership – Private
Site Specific Information – A curb-cut rain garden is proposed for this catchment, to be installed on a single-family lot upstream of the catch basins. This BMP could treat stormwater pollutants originating from private properties. This catchment contains regions of sandy soils and other regions with silty soils. The table below gives the estimated pollutant and volume reductions from a rain garden installed on either sandy or silty soil. Each scenario was modeled with a 1.5 acre contributing drainage area.



Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	**Number of BMPs**	1 - Sand		1 - Silt	
	Total Size of BMPs	250	sq-ft	250	sq-ft
	TP (lb/yr)	0.5	9.8%	0.4	7.8%
	TSS (lb/yr)	155	11.0%	122	8.6%
	Volume (acre-feet/yr)	0.4	10.5%	0.3	7.8%
Cost	**Administration & Promotion Costs***	$1,606		$1,606	
	Design & Construction Costs**	$7,376		$7,376	
	Total Estimated Project Cost (2016)	**$8,982**		**$8,982**	
	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,049**		**$1,311**	
	30-yr Average Cost/1,000lb-TSS	**$3,383**		**$4,298**	
	30-yr Average Cost/ac-ft Vol.	**$1,380**		**$1,846**	

*Indirect Cost: (22 hours/BMP at $73/hour)

**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: RR4-B

Waco St.

Hydrodynamic Device

Drainage Area – 8.5 acres
Location – Waco St. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed in-line with the storm sewer system on Waco Street. It is proposed at a location where it could treat runoff from the entire catchment.

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	8	ft diameter
	TP (lb/yr)	0.5	9.8%
	TSS (lb/yr)	200	14.2%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2016)	**$55,752**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$4,977**	
	30-yr Average Cost/1,000lb-TSS	**$12,442**	
	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: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment RR-5

Existing Catchment Summary	
Acres	4.4
Dominant Land Cover	Residential
Parcels	21

CATCHMENT DESCRIPTION

This catchment, like Catchments RR-3 and RR-4, is solely single family residential properties draining to a set of catch basins that ultimately discharge to the Rum River. Soils in the catchment are mostly sandy loam (Becker series) and have high infiltration rates.

EXISTING STORMWATER TREATMENT

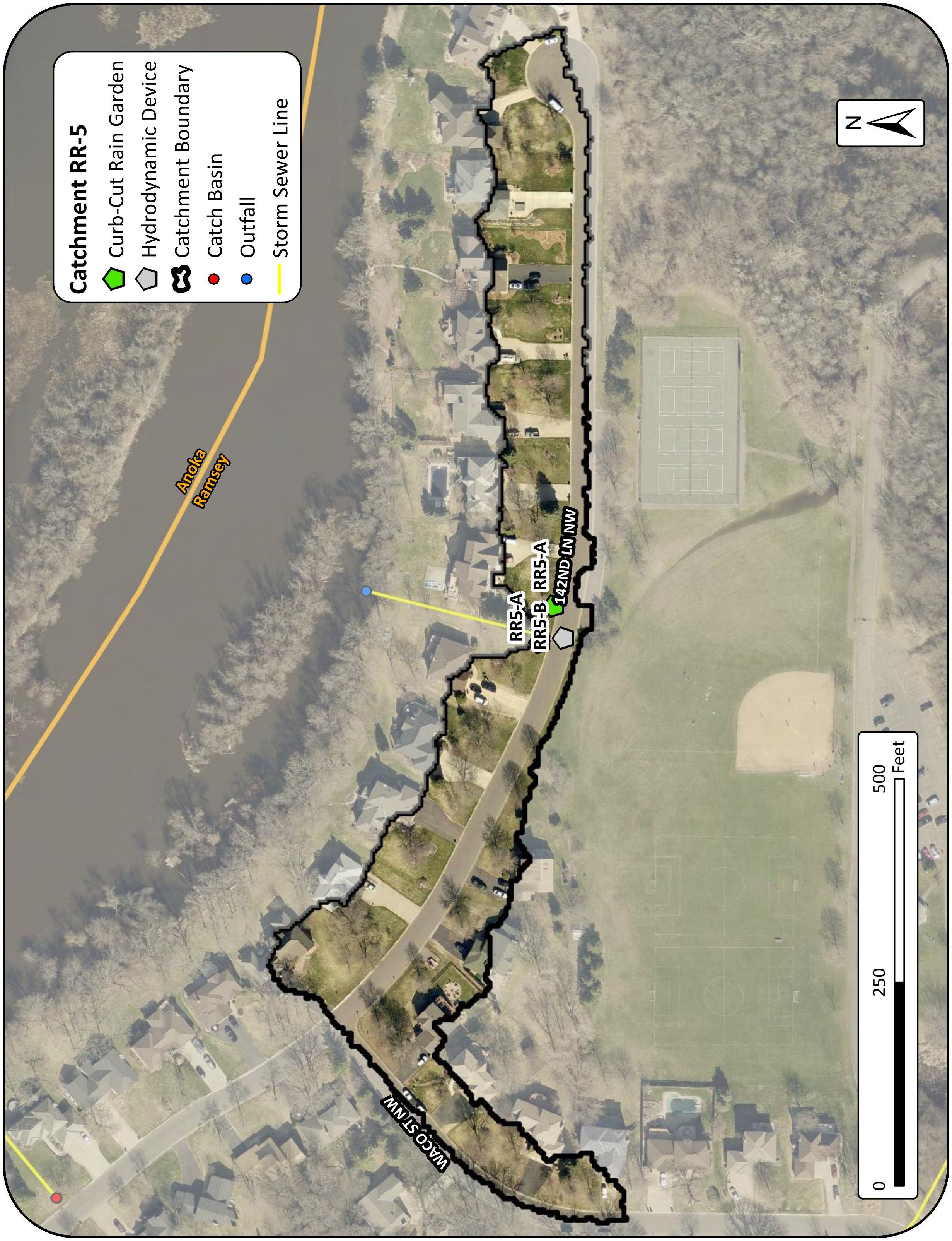
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	3.1	0.2	6%	**2.9**
	TSS (lb/yr)	842	91	11%	**751**
	Volume (acre-feet/yr)	1.9	0.0	0%	**1.9**

PROPOSED RETROFITS OVERVIEW

A curb-cut rain garden is proposed just upstream of the two catch basins on 142nd Ln. to treat stormwater from the residential properties north of the road. In addition, a hydrodynamic device is proposed to treat the catchment prior to discharge into the Rum River.

RETROFIT RECOMMENDATIONS

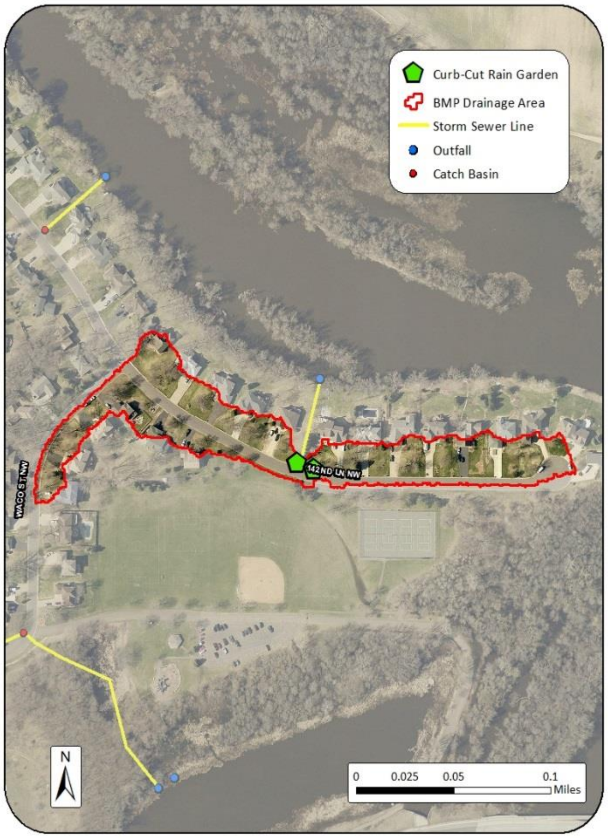


Project ID: RR5-A

142nd LN.

Curb-Cut Rain Garden

Drainage Area – 1.5 to 3.0 acres
Location – North side of 142nd LN. NW
Property Ownership – Private
Site Specific Information – Two locations were found where curb-cut rain gardens could be installed on single-family lots to treat stormwater pollutants originating from private properties. The below table gives the pollutant and volume reductions anticipated from a rain garden installed on the east side of the storm sewer pipe and one installed on the west side. Both site locations are placed in sandy soils that should be favorable for infiltration practices. Each scenario was modeled with a 1.5 acre contributing drainage area.



Curb-Cut Rain Garden

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Number of BMPs	1 - West		1 - East	
Treatment	Total Size of BMPs	250	sq-ft	250	sq-ft
Treatment	TP (lb/yr)	0.37	12.8%	0.43	14.8%
Treatment	TSS (lb/yr)	110	14.6%	129	17.2%
Treatment	Volume (acre-feet/yr)	0.26	13.8%	0.30	16.1%
Cost	Administration & Promotion Costs*	$1,606		$1,606	
Cost	Design & Construction Costs**	$7,376		$7,376	
Cost	**Total Estimated Project Cost (2016)**	**$8,982**		**$8,982**	
Cost	Annual O&M***	$225		$225	
Efficiency	**30-yr Average Cost/lb-TP**	**$1,417**		**$1,220**	
Efficiency	**30-yr Average Cost/1,000lb-TSS**	**$4,767**		**$4,065**	
Efficiency	**30-yr Average Cost/ac-ft Vol.**	**$2,017**		**$1,725**	

*Indirect Cost: (22 hours/BMP at $73/hour)

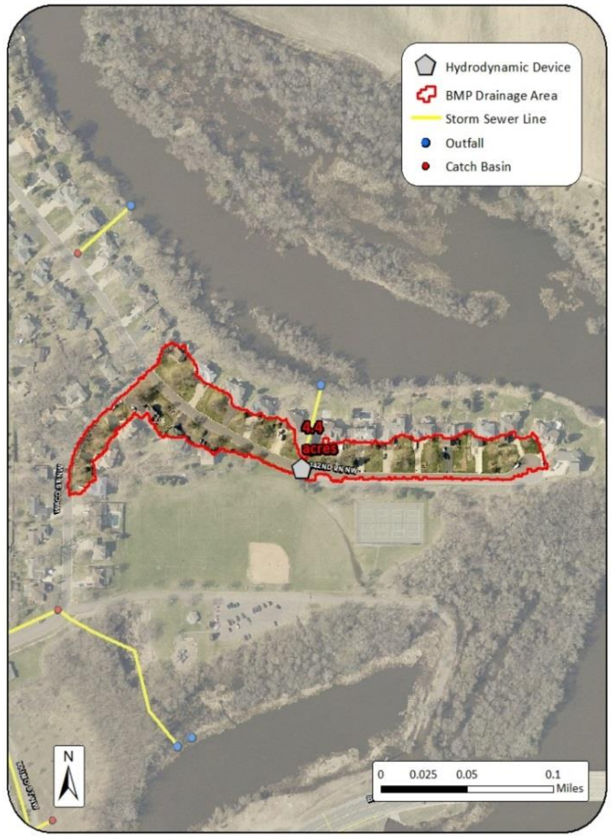
**Direct Cost: ($26/sq-ft for materials and labor) + (12 hours/BMP at $73/hour for design)

***Per BMP: ($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Project ID: RR5-B

142nd LN.

Hydrodynamic Device



Drainage Area – 4.4 acres
Location – 142nd Ln. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device is proposed to be installed in-line with the storm sewer system to treat the runoff from the entire catchment prior to discharging into the Rum River.

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	10.3%
	TSS (lb/yr)	111	14.8%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2016)	**$28,752**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$5,295**	
	30-yr Average Cost/1,000lb-TSS	**$14,310**	
	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: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment RR-6

Existing Catchment Summary	
Acres	6.7
Dominant Land Cover	Park
Parcels	10

CATCHMENT DESCRIPTION

Catchment RR-6 includes the northern portions of Rivers Bend Park along with the backyards of nine single-family residential homes along 142nd Ln. and Waco Street. Runoff is conveyed to a small culvert below the access road to the portion of Rivers Bend Park north of Bunker Lake Blvd.

EXISTING STORMWATER TREATMENT

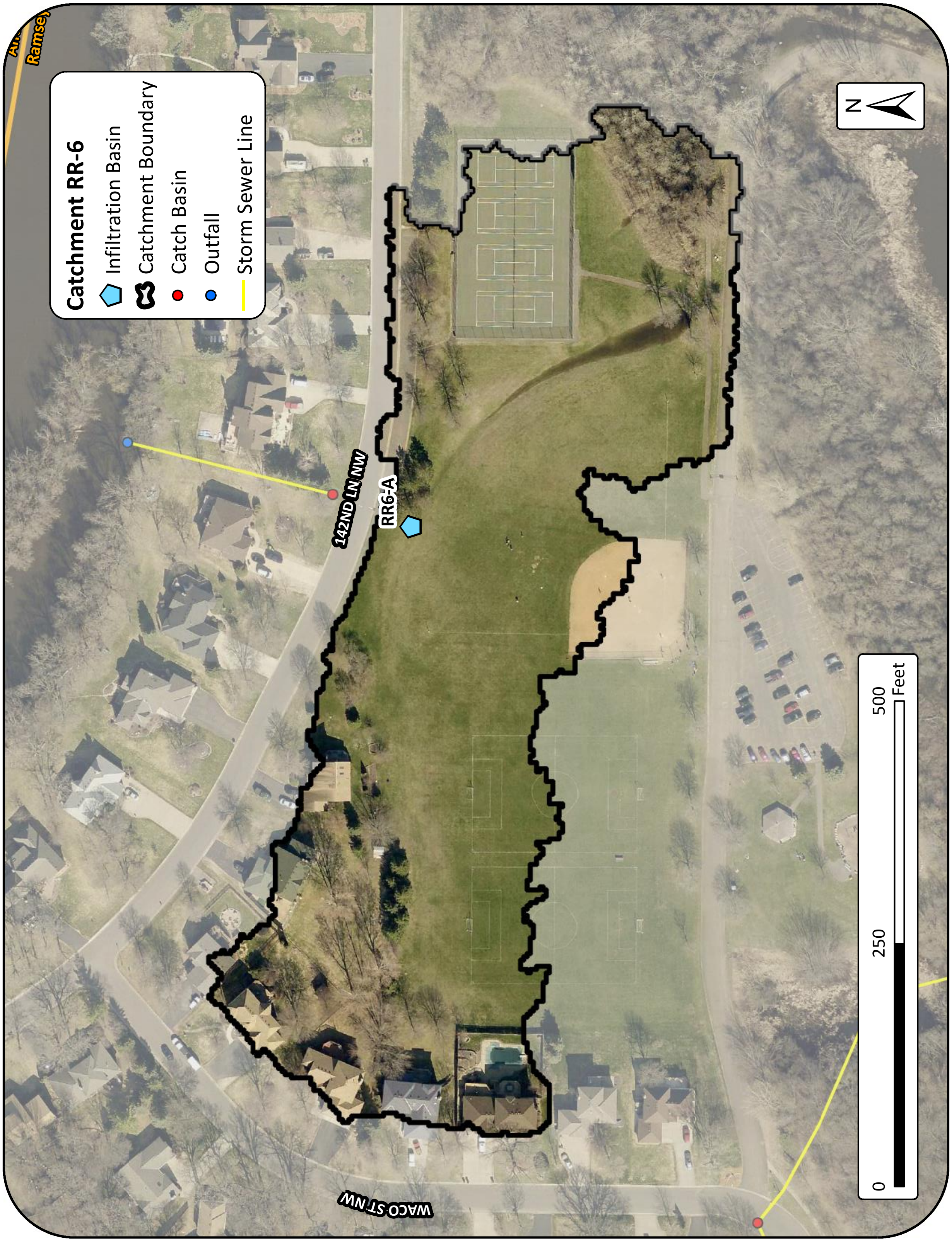
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	7.1	0.4	6%	**6.7**
	TSS (lb/yr)	1,763	156	9%	**1607**
	Volume (acre-feet/yr)	3.8	0.0	0%	**3.8**

PROPOSED RETROFITS OVERVIEW

An infiltration basin is proposed south of 142nd Ln which could accept stormwater diverted from the 142nd Ln catch basins in Catchment RR-5. This basin could then treat the 4.4 acres of residential properties in Catchment RR-5 in addition to portions of Rivers Bend Park and other residential properties in Catchment RR-6.

RETROFIT RECOMMENDATIONS



Project ID: RR6-A

142nd LN.
Infiltration Basin

Drainage Area – 11.1 acres
Location – South side of 142nd LN. NW
Property Ownership – Public
Site Specific Information –An infiltration basin is proposed on the south side of 142nd LN, in an open area where it could capture runoff from the western portion of Catchment RR-6 and diverted runoff from Catchment RR-5 (additional 4.4 acres). The table below shows percent reductions relative to the entire 11.1 acre contributing drainage area (i.e. assumes catchment RR-5 is rerouted to the new BMP). This practice could serve to reduce stormwater pollutants and decrease runoff peak flows reaching the Rum River. It could also serve to increase groundwater recharge within the catchment.

Infiltration Basin

	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Ponding Depth of BMP	1 foot		1 foot		1 foot	
	Total Size of BMP	3,000	sq-ft	3,500	sq-ft	4,000	sq-ft
	TP (lb/yr)	4.2	44%	4.5	47%	4.8	50%
	TSS (lb/yr)	1,139	48%	1,219	52%	1,267	54%
	Volume (acre-feet/yr)	2.6	46%	2.8	49%	2.9	51%
Cost	Administration & Promotion Costs*	$2,920		$2,920		$2,920	
	Design & Construction Costs**	$75,876		$85,876		$95,876	
	Total Estimated Project Cost (2016)	**$78,796**		**$88,796**		**$98,796**	
	Annual O&M***	$225		$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$679**		**$708**		**$733**	
	30-yr Average Cost/1,000lb-TSS	**$2,504**		**$2,613**		**$2,777**	
	30-yr Average Cost/ac-ft Vol.	**$1,093**		**$1,139**		**$1,207**	

*Indirect Cost: 40 hours at $73/hour
**Direct Cost: ($20/sq-ft for materials and labor) + $15,000 for RR-5 pipe diversion + (12 hours at $73/hour for design)
***($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment RR-7

Existing Catchment Summary	
Acres	2.9
Dominant Land Cover	Park
Parcels	1

CATCHMENT DESCRIPTION

Catchment RR-7 is completely contained within City of Ramsey Rivers Bend Park property. Stormwater runoff from the roadway and southern parking lot is diverted through a shallow channel south of the parking lot.

EXISTING STORMWATER TREATMENT

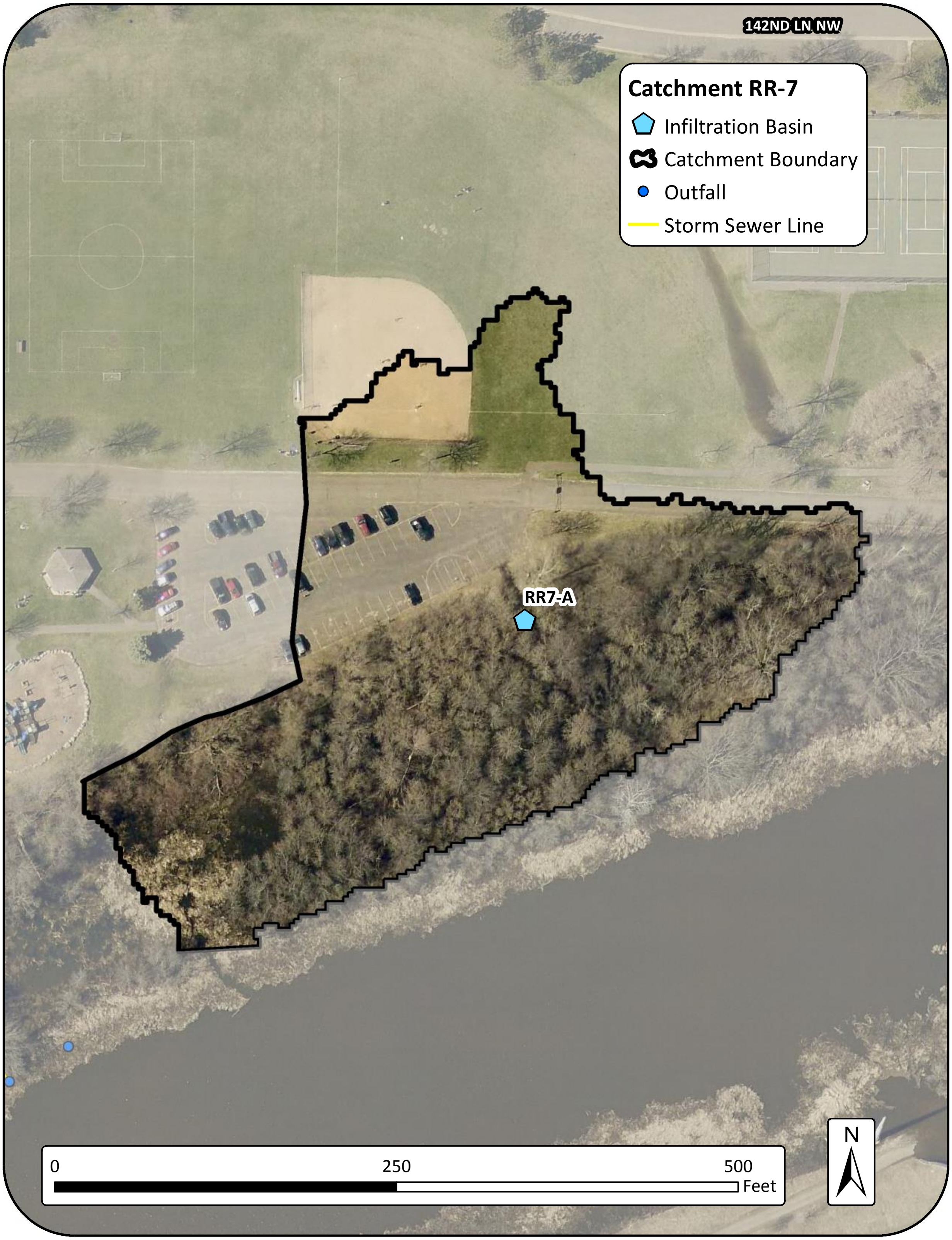
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	1.1	0.0	0%	**1.1**
	TSS (lb/yr)	209	21	10%	**188**
	Volume (acre-feet/yr)	0.6	0.0	0%	**0.6**

PROPOSED RETROFITS OVERVIEW

An infiltration basin is proposed south of the Rivers Bend Park parking lot. The infiltration basin could ensure stormwater does not reach the Rum River without receiving treatment.

RETROFIT RECOMMENDATIONS



Project ID: RR7-A

Rivers Bend Park Parking Lot Infiltration Basin

Drainage Area – 0.9 acres
Location – Rivers Bend Park parking lot
Property Ownership – Public
Site Specific Information –An infiltration basin is proposed on the southeast side of the Rivers Bend Park parking lot and could treat all the runoff from the catchment's drainage area before it reaches the Rum River. Three basin sizes were modeled and estimated volume and pollutant reductions are shown in the table below. This practice will serve to reduce stormwater pollutants and decrease runoff peak flows reaching the Rum River. It will also serve to increase groundwater recharge within the catchment.

	Infiltration Basin						
	Cost/Removal Analysis	New Treatment	% Reduction	New Treatment	% Reduction	New Treatment	% Reduction
Treatment	Ponding Depth of BMP	1 foot		1 foot		1 foot	
	Total Size of BMP	200	sq-ft	250	sq-ft	300	sq-ft
	TP (lb/yr)	0.20	18%	0.27	25%	0.32	29%
	TSS (lb/yr)	59	31%	67	36%	72	38%
	Volume (acre-feet/yr)	0.12	20%	0.14	23%	0.15	25%
Cost	Administration & Promotion Costs*	$2,920		$2,920		$2,920	
	Design & Construction Costs**	$4,876		$5,876		$6,876	
	Total Estimated Project Cost (2016)	**$7,796**		**$8,796**		**$9,796**	
	Annual O&M***	$225		$225		$225	
Efficiency	30-yr Average Cost/lb-TP	**$2,424**		**$1,919**		**$1,724**	
	30-yr Average Cost/1,000lb-TSS	**$8,218**		**$7,734**		**$7,660**	
	30-yr Average Cost/ac-ft Vol.	**$4,007**		**$3,810**		**$3,727**	

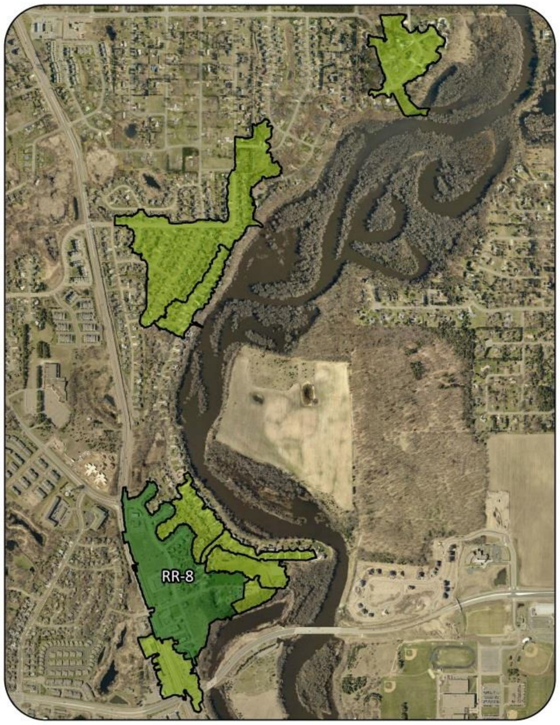
*Indirect Cost: 40 hours at $73/hour

**Direct Cost: ($20/sq-ft for materials and labor) + (12 hours at $73/hour for design)

***($150/year for rehabilitations at years 10 and 20) + ($75/year for routine maintenance)

Catchment RR-8

Existing Catchment Summary	
Acres	38.1
Dominant Land Cover	Residential
Parcels	68



CATCHMENT DESCRIPTION

This catchment contains a nearly even mix of single-family residential, commercial, and undeveloped land uses. Stormwater generated within this catchment is directed to a storm sewer network below 142nd Ave. which discharges into retention pond P25216 just east of Xkimo Street. The pond subsequently discharges into an oxbow lake adjacent to the Rum River.

EXISTING STORMWATER TREATMENT

Stormwater retention pond P25216 provides pollutant treatment for the entire 38-acre catchment. In addition to the pond, street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. Present-day stormwater pollutant loading and treatment is summarized in the table below.

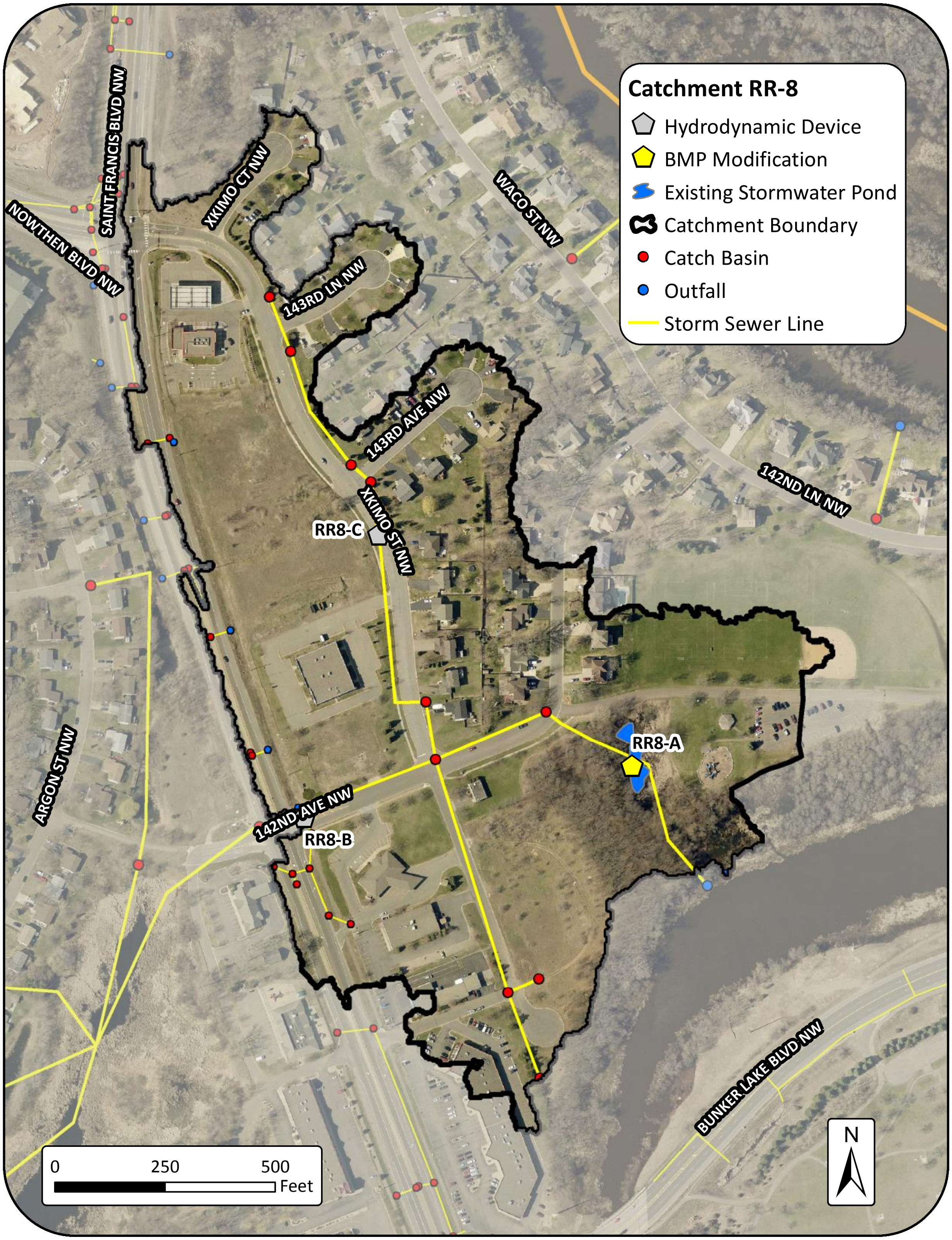
	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	2			
	BMP Types	Stormwater Pond and Street Cleaning			
	TP (lb/yr)	19.0	2.9	15%	**16.1**
	TSS (lb/yr)	6,895	1,367	20%	**5,528**
	Volume (acre-feet/yr)	19.3	0.0	0%	**19.3**

PROPOSED RETROFITS OVERVIEW

Retention pond P25216 appears to be a natural depression which was retrofitted with an outlet control device to manage flow discharge. This pond could be modified to increase storage capacity to more sufficiently treat its developed drainage area.

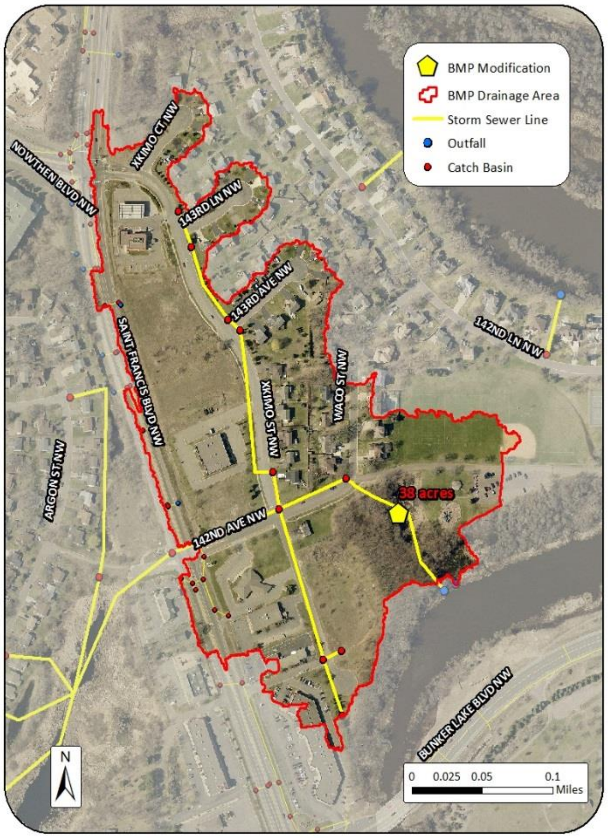
Hydrodynamic devices were also proposed along the tertiary storm sewer lines on 142nd Ave and Xkimo St. These devices were purposefully sited to achieve contributing drainage areas of approximately 10 acres in size. This limits high peak discharges through the device that could cause sediment resuspension and decreased effectiveness.

RETROFIT RECOMMENDATIONS



Project ID: RR8-A

Rivers Bend Park
Pond Modification



Drainage Area – 38.0 acres
Location – Rivers Bend Park south of 142nd Ave NW – Waco St. NW intersection
Property Ownership – Public
Site Specific Information – The existing pond, P25216 receives drainage from the entire catchment and is currently undersized to treat the contributing drainage area. An expansion and dredging of the pond is recommended to increase the permanent pool storage, thereby promoting sediment settling and phosphorus retention. Proposed increases in pond storage will increase permanent pool surface area from .11 acres to .82 acres and average ponding depth from 1 ft. to 6 ft. Cumulative pond storage volume could increase from an estimated 0.05 acre-feet to approximately 2.0 acre-feet.

	BMP Modification						
	Cost/Removal Analysis	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**	**New Treatment**	**% Reduction**
Treatment	**Pond Management Level**	1		2		3	
	Amount of Soil Excavated	3,100	cu-yards	3,100	cu-yards	3,100	cu-yards
	TP (lb/yr)	7.7	47.8%	7.7	47.8%	7.7	47.8%
	TSS (lb/yr)	3,672	66.4%	3,672	66.4%	3,672	66.4%
	Volume (acre-feet/yr)	0.2	1.0%	0.2	1.0%	0.2	1.0%
Cost	**Administration & Promotion Costs***	$5,840		$5,840		$5,840	
	Design & Construction Costs**	$147,000		$193,500		$245,000	
	Total Estimated Project Cost (2016)	**$152,840**		**$199,340**		**$250,840**	
	Annual O&M***	$900		$900		$900	
Efficiency	**30-yr Average Cost/lb-TP**	**$779**		**$980**		**$1,203**	
	30-yr Average Cost/1,000lb-TSS	**$1,633**		**$2,055**		**$2,522**	
	30-yr Average Cost/ac-ft Vol.	**N/A**		**N/A**		**N/A**	

*Indirect Cost: 80 hours at $73/hour

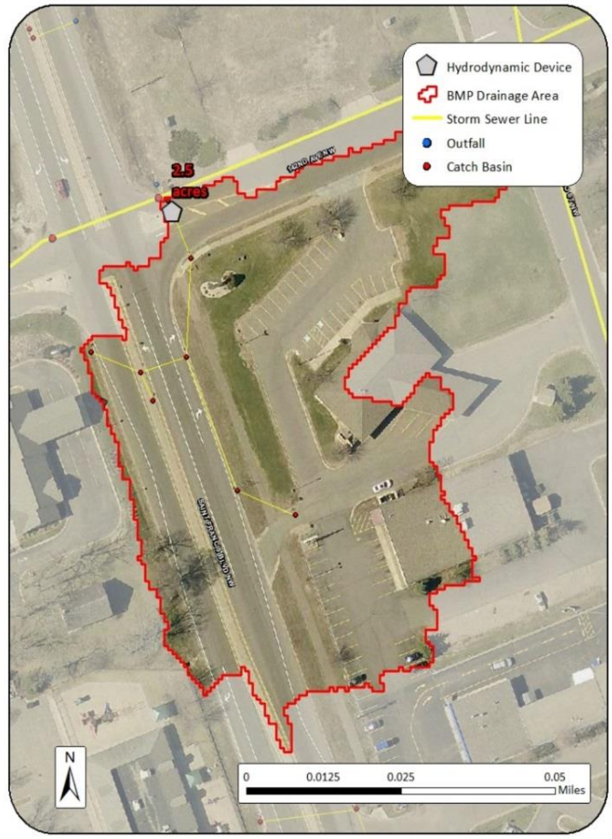
**Direct Cost: See Appendix B for detailed cost information

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

Project ID: RR8-B

142nd Ave.

Hydrodynamic Device



Drainage Area – 2.5 acres
Location – 142nd Ln. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed in-line with the storm sewer system to accept runoff from stormwater catch basins draining 142nd Ave NW and surrounding public and commercial properties.

Hydrodynamic Device

	Cost/Removal Analysis	New Treatment	% Reduction
Treatment	Number of BMPs	1	
	Total Size of BMPs	6	ft diameter
	TP (lb/yr)	0.2	1.2%
	TSS (lb/yr)	108	2.0%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	Administration & Promotion Costs*	$1,752	
	Design & Construction Costs**	$27,000	
	Total Estimated Project Cost (2016)	**$28,752**	
	Annual O&M***	$630	
Efficiency	30-yr Average Cost/lb-TP	**$7,942**	
	30-yr Average Cost/1,000lb-TSS	**$14,707**	
	30-yr Average Cost/ac-ft Vol.	**N/A**	

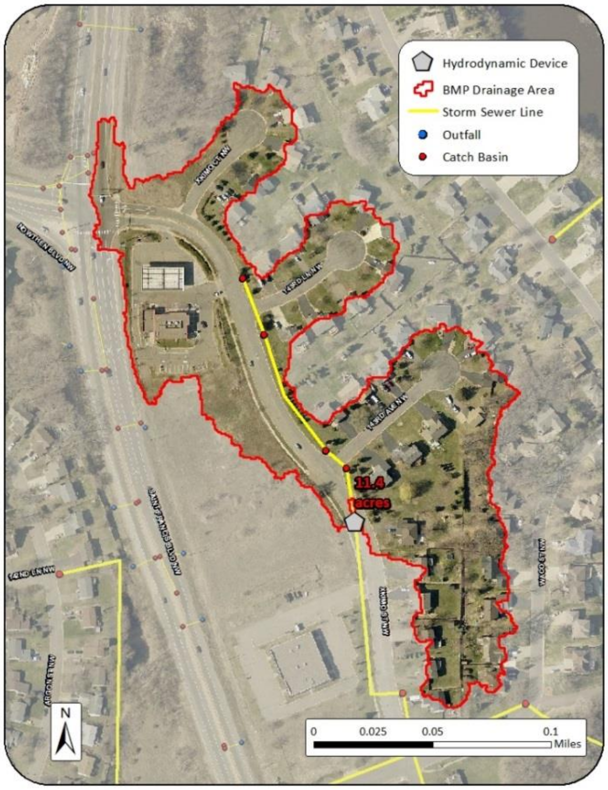
*Indirect Cost: (24 hours at $73/hour)

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

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

Project ID: RR8-C

Xkimo St.
Hydrodynamic Device



Drainage Area – 11.4 acres
Location – Xkimo St. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed in-line with the storm sewer system to accept runoff from stormwater catch basins draining Xkimo St. NW and the surrounding single-family residential and commercial properties.

	Hydrodynamic Device		
	Cost/Removal Analysis	**New Treatment**	**% Reduction**
Treatment	**Number of BMPs**	1	
	Total Size of BMPs	10	ft diameter
	TP (lb/yr)	0.5	3%
	TSS (lb/yr)	220	4%
	Volume (acre-feet/yr)	0.0	0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$108,000	
	Total Estimated Project Cost (2016)	**$109,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$8,577**	
	30-yr Average Cost/1,000lb-TSS	**$19,493**	
	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: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

Catchment RR-9

Existing Catchment Summary	
Acres	8.5
Dominant Land Cover	Commercial
Parcels	11

CATCHMENT DESCRIPTION

Catchment RR-9 is the southernmost catchment draining to the Rum River and includes many of the commercial properties along St. Francis Blvd. between 142nd Ave. and Bunker Lake Boulevard. Stormwater generated on the impervious pavement, buildings, and roadways is directed to storm sewer lines below St. Francis Blvd., eventually discharging into the Rum River through an outfall just north of Bunker Lake Blvd.

EXISTING STORMWATER TREATMENT

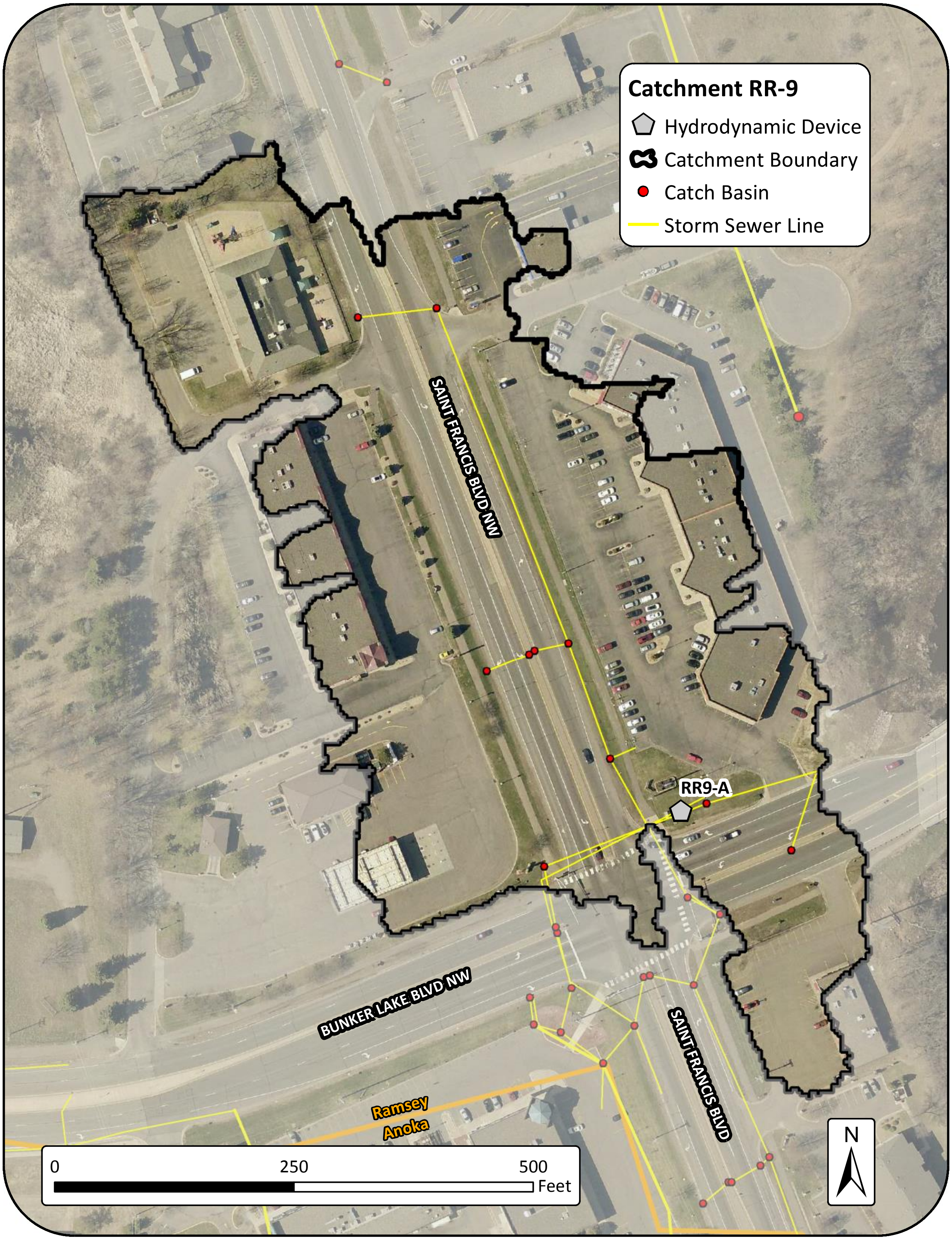
Street cleaning is provided by the City of Ramsey twice per year with mechanical sweepers. No structural stormwater devices exist within this catchment. Present-day stormwater pollutant loading and treatment is summarized in the table below.

	Existing Conditions	Base Loading	Treatment	Net Treatment %	Existing Loading
Treatment	Number of BMPs	1			
	BMP Types	Street Cleaning			
	TP (lb/yr)	7.2	0.2	3%	**7.0**
	TSS (lb/yr)	3,429	137	4%	**3,292**
	Volume (acre-feet/yr)	10.8	0.0	0%	**10.8**

PROPOSED RETROFITS OVERVIEW

A hydrodynamic device is proposed to treat the St. Francis Blvd. storm line before the water discharges into the Rum River.

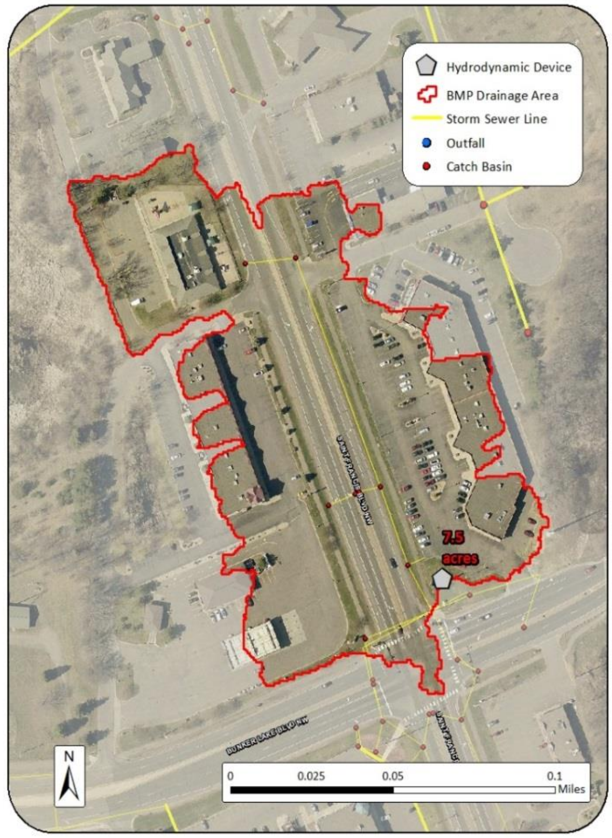
RETROFIT RECOMMENDATIONS



Project ID: RR9-A

St. Francis Blvd. and Bunker Lake Blvd.

Hydrodynamic Device



Drainage Area – 7.5 acres
Location – Northeast corner at intersection of St. Francis Blvd. NW and Bunker Lake Blvd. NW
Property Ownership – Public
Site Specific Information – A hydrodynamic device could be installed to accept runoff from stormwater catch basins draining St. Francis Blvd. NW, Bunker Lake Blvd. NW, and the surrounding commercial properties.

	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	10.0%
	TSS (lb/yr)	364	11.1%
	Volume (acre-feet/yr)	0.0	0.0%
Cost	**Administration & Promotion Costs***	$1,752	
	Design & Construction Costs**	$54,000	
	Total Estimated Project Cost (2016)	**$55,752**	
	Annual O&M***	$630	
Efficiency	**30-yr Average Cost/lb-TP**	**$3,555**	
	30-yr Average Cost/1,000lb-TSS	**$6,836**	
	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: (3 cleanings/year)*(3 hours/cleaning)*($70/hour)

References

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Appendix A – Modeling Methods

The following sections include WinSLAMM model details for each type of best management practice modeled in 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 10.2.0 was used for this analysis to estimate volume and pollutant loading and reductions. Additional inputs for WinSLAMM are provided in Table 8.

Table 8: General WinSLAMM Model Inputs (i.e. Current File Data)

Parameter	File/Method
Land use acreage	ArcMap, Metropolitan Council 2010 Land Use
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

Existing Conditions

Existing stormwater BMPs were included in the WinSLAMM model for which information was available from the state (MNDOT), county (Anoka County), and the City of Ramsey. The practices listed below were included in the existing conditions model.

Bioswales

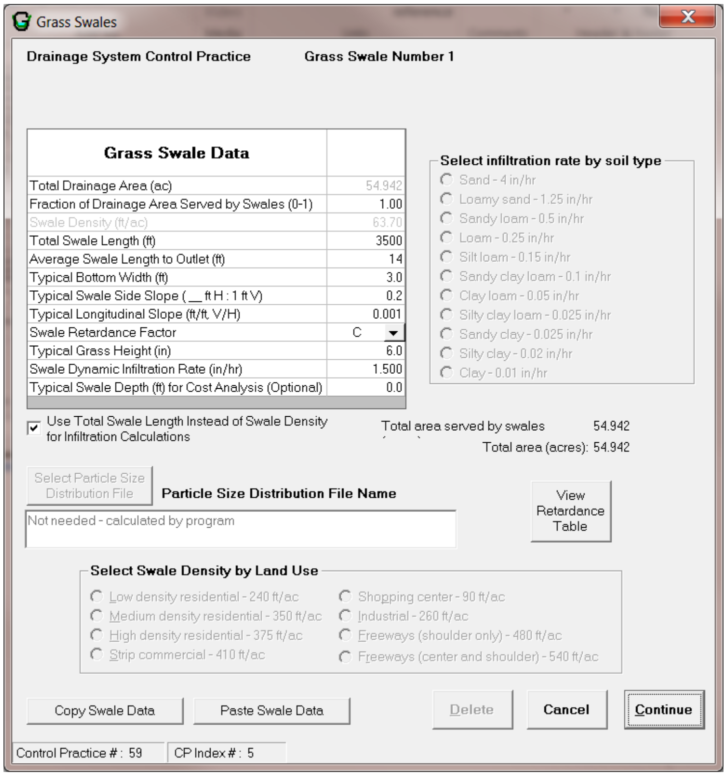

Figure 12: Bioswale (North Ditch) in MR-4 (WinSLAMM).

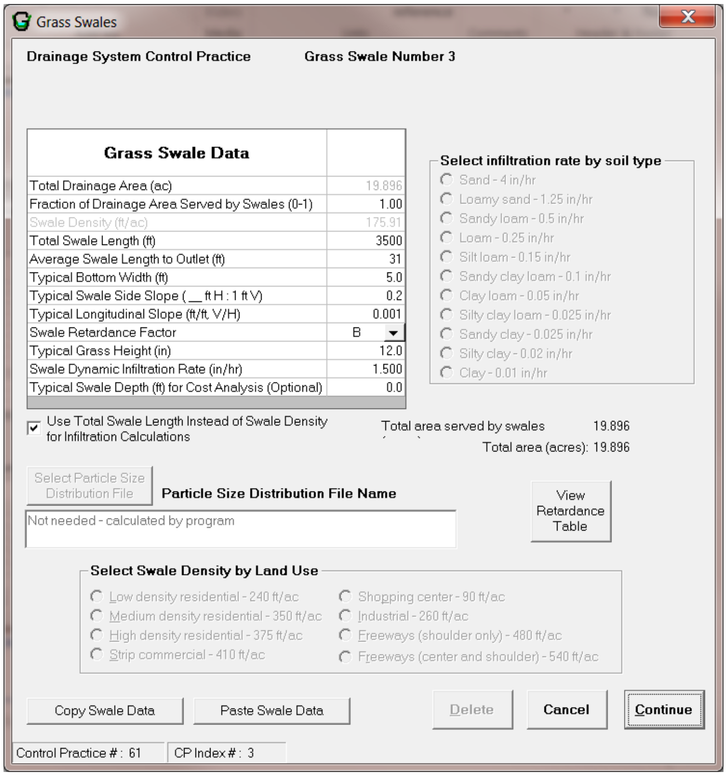

Figure 13: Bioswale (South Ditch West) in MR-4 (WinSLAMM).

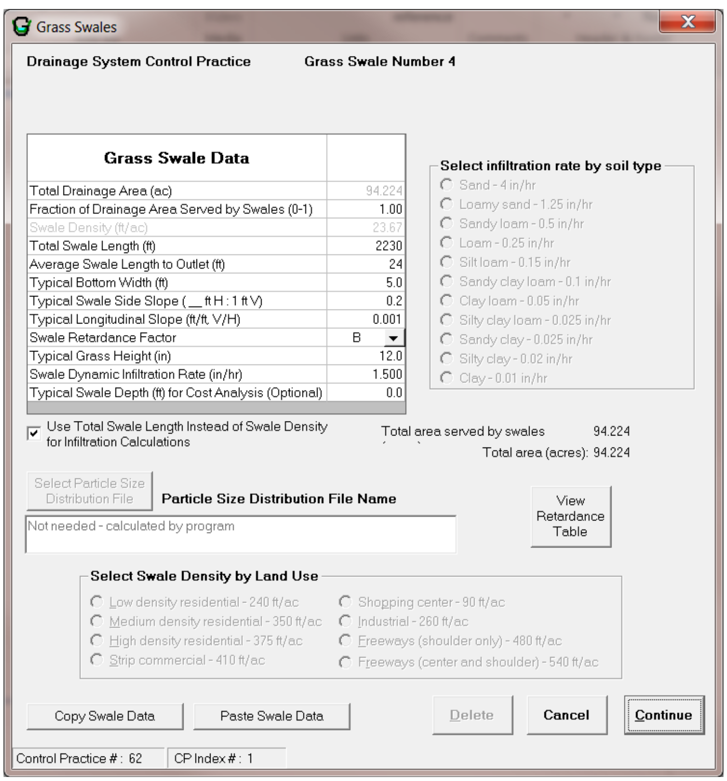

Figure 14: Bioswale (South Ditch East) in MR-4 (WinSLAMM).

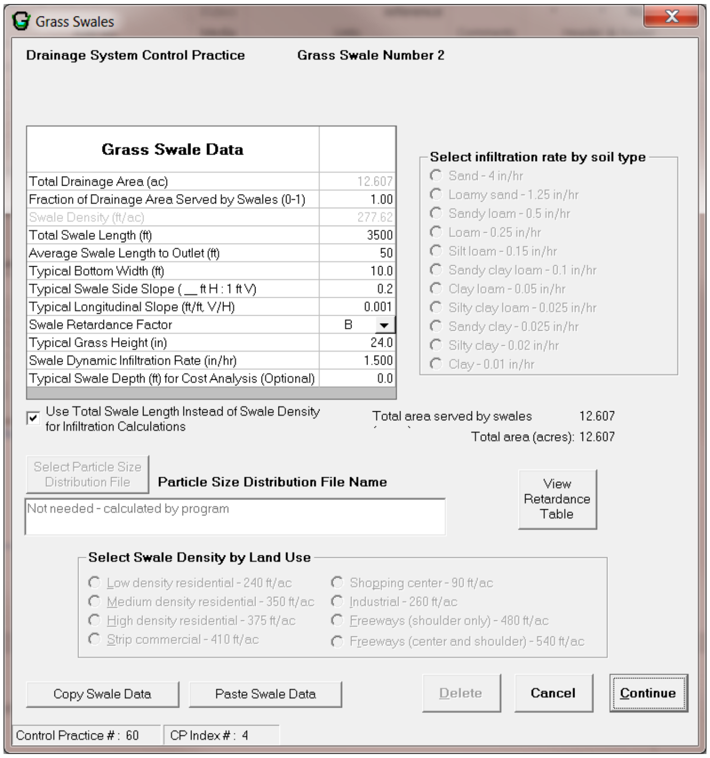

Figure 15: Bioswale (Median) in MR-4 (WinSLAMM).

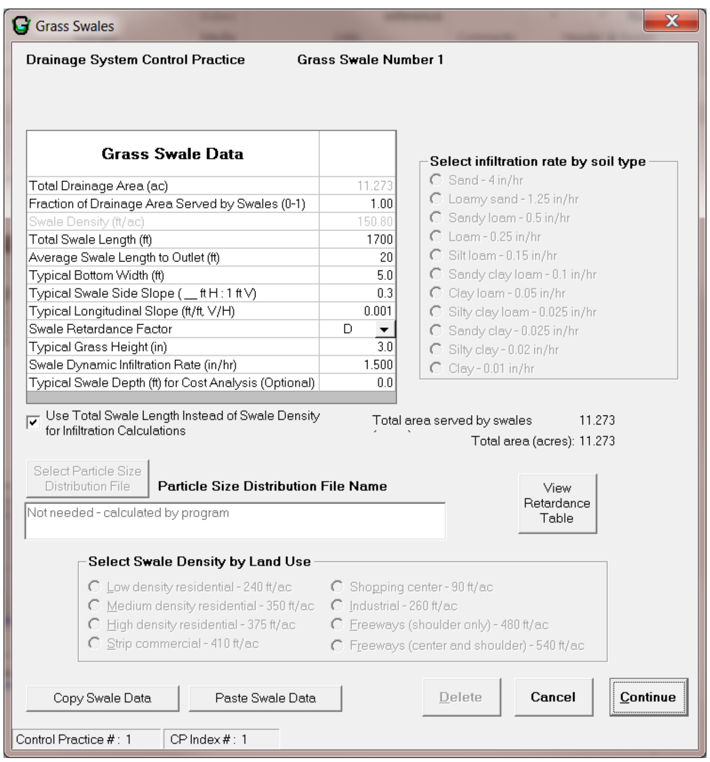

Figure 16: Bioswale (South Ditch) in MR-7 (WinSLAMM).

Hydrodynamic Devices

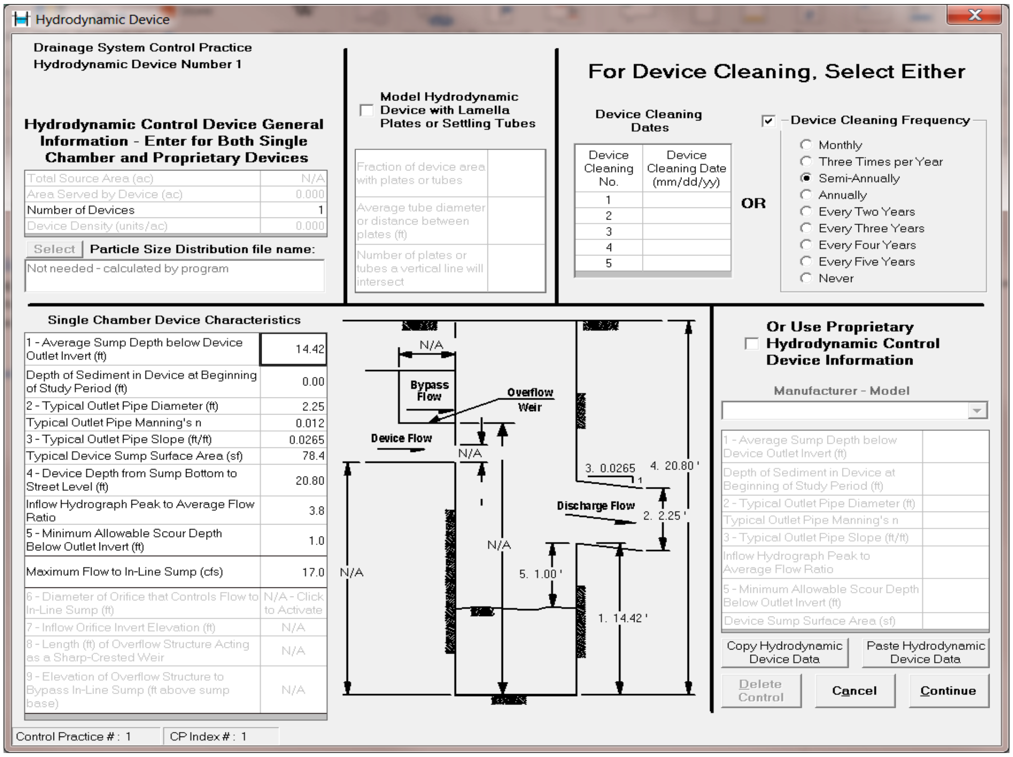

Figure 17: Hydrodynamic device at Ebony St. in MR-2 (WinSLAMM).

Infiltration Basins

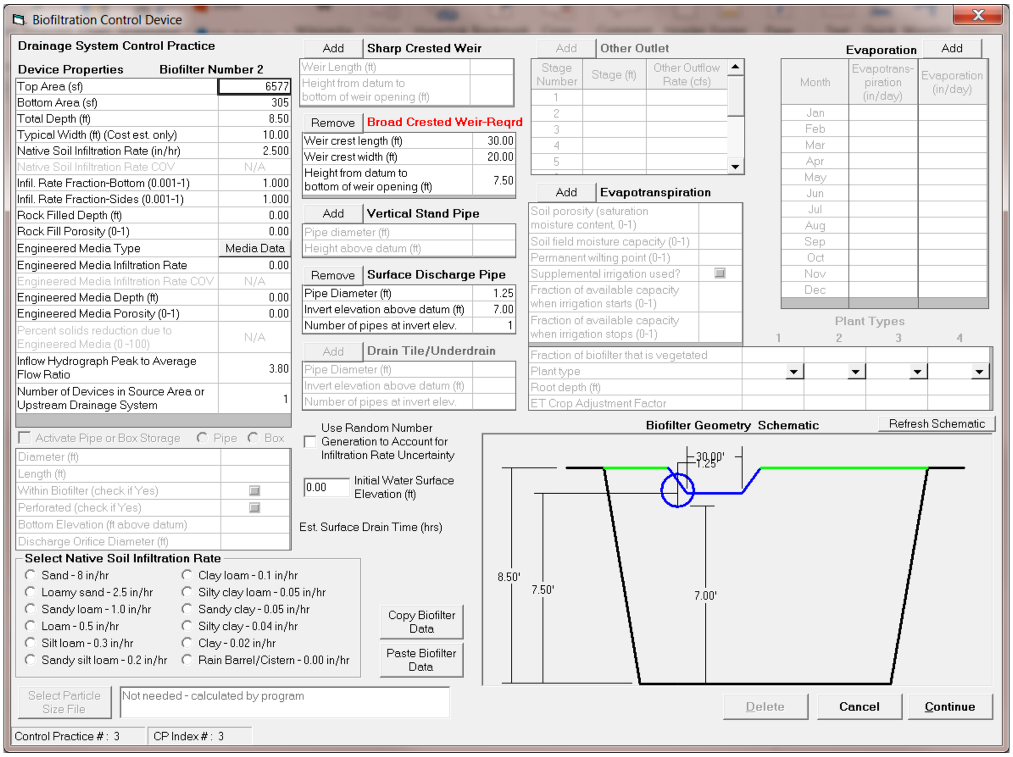

Figure 18: Infiltration Basin (Riverdale Basin) in MR-2 (WinSLAMM).

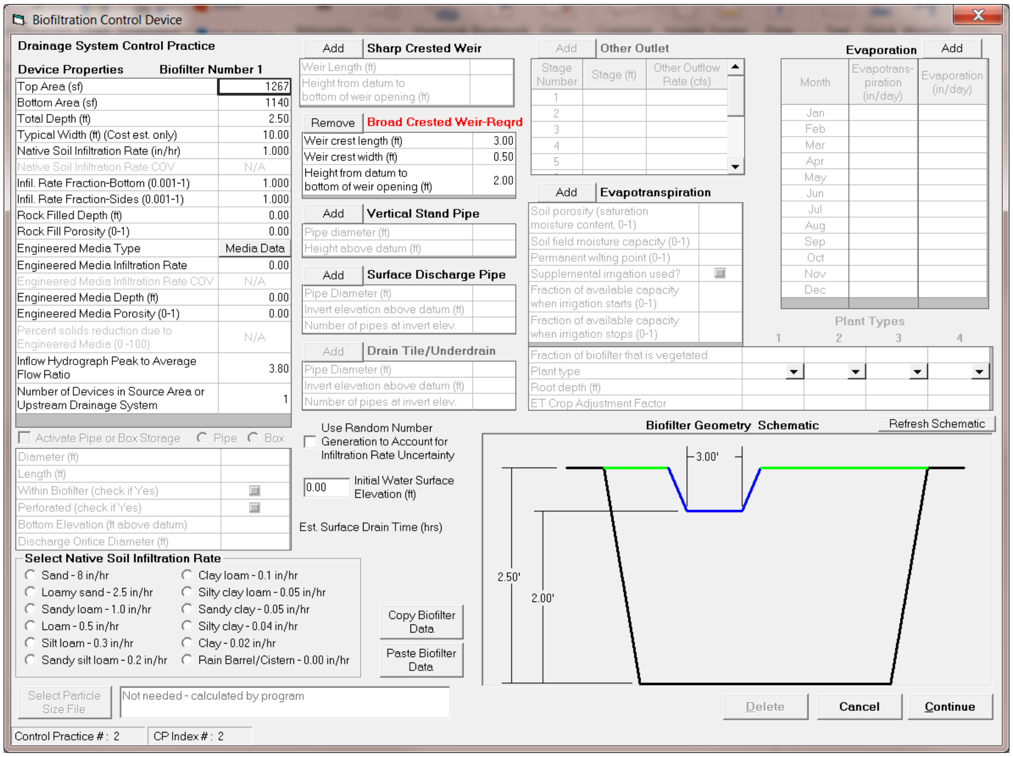

Figure 19: Infiltration Basin (Storage Facility) in MR-2 (WinSLAMM).

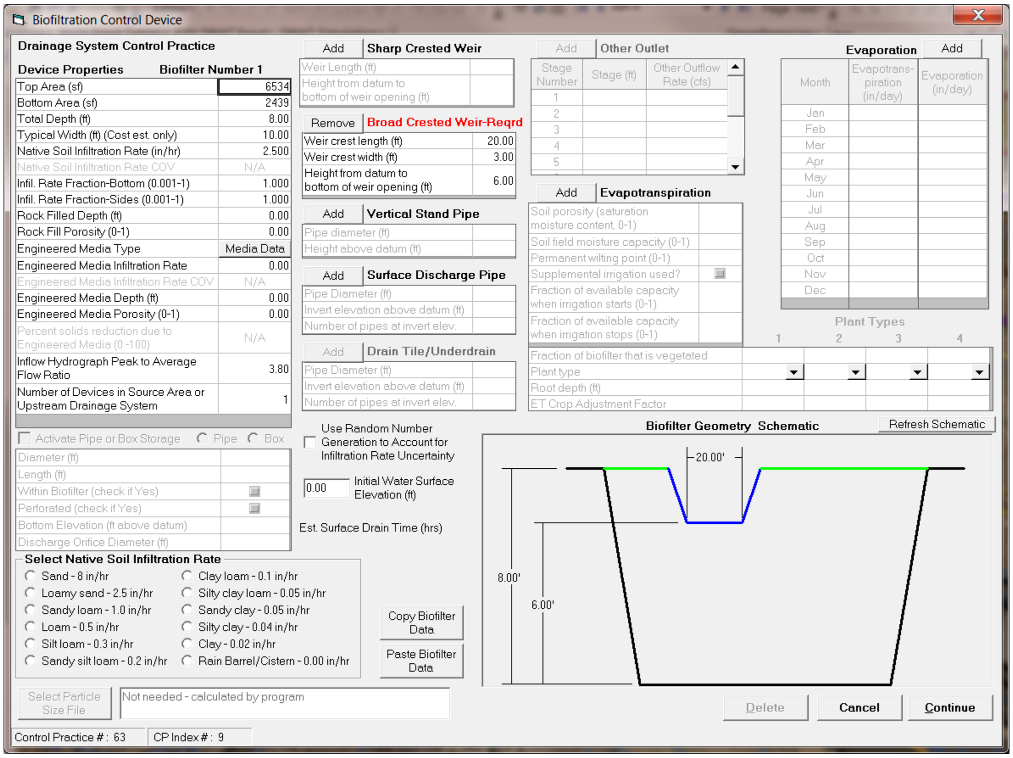

Figure 20: Infiltration Basin (P34406) in MR-4 (WinSLAMM).

Stormwater Ponds

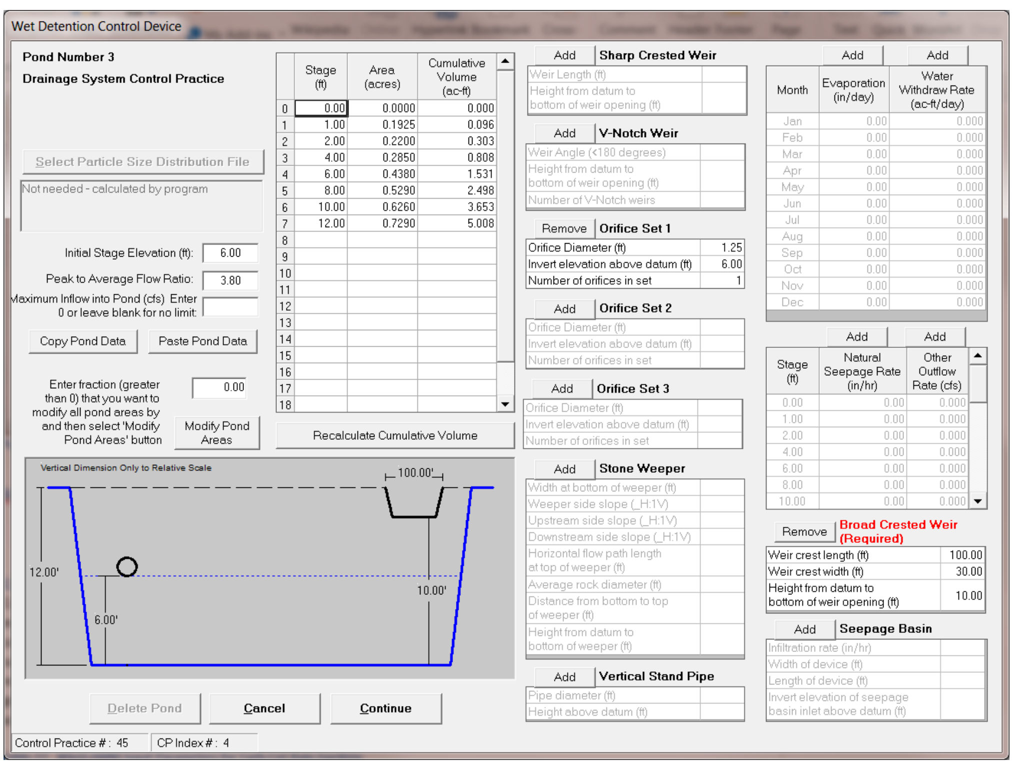

Figure 21: Stormwater pond (P34434) in MR-1 (WinSLAMM).

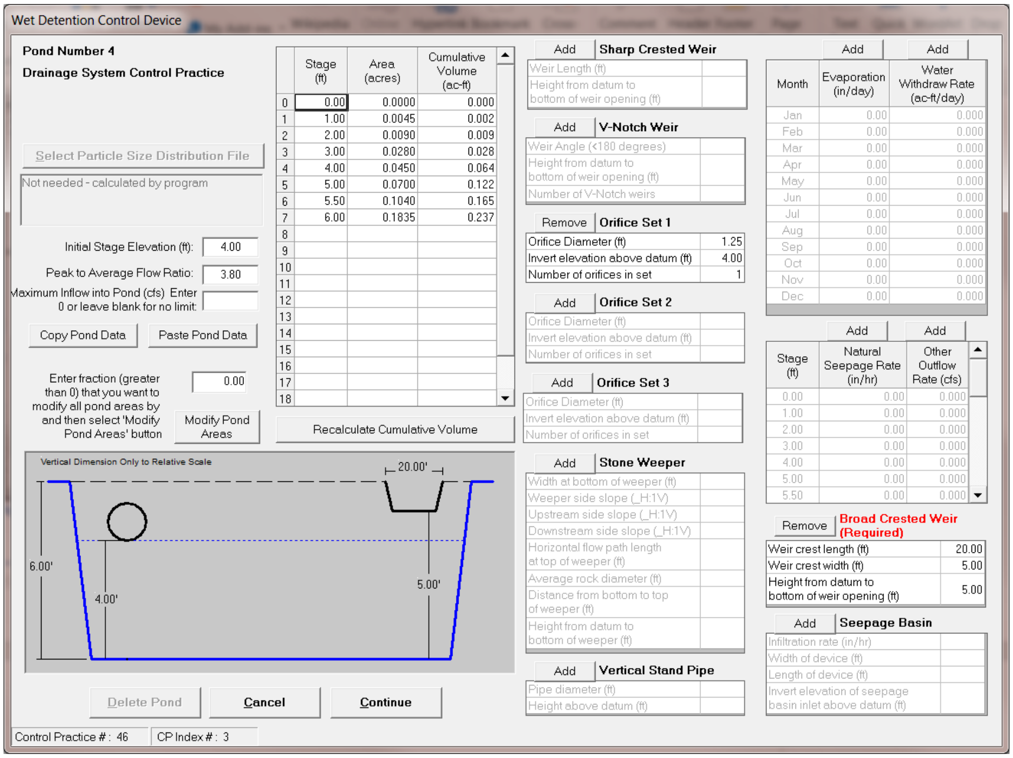

Figure 22: Stormwater pond (Village Bank) in MR-1 (WinSLAMM).

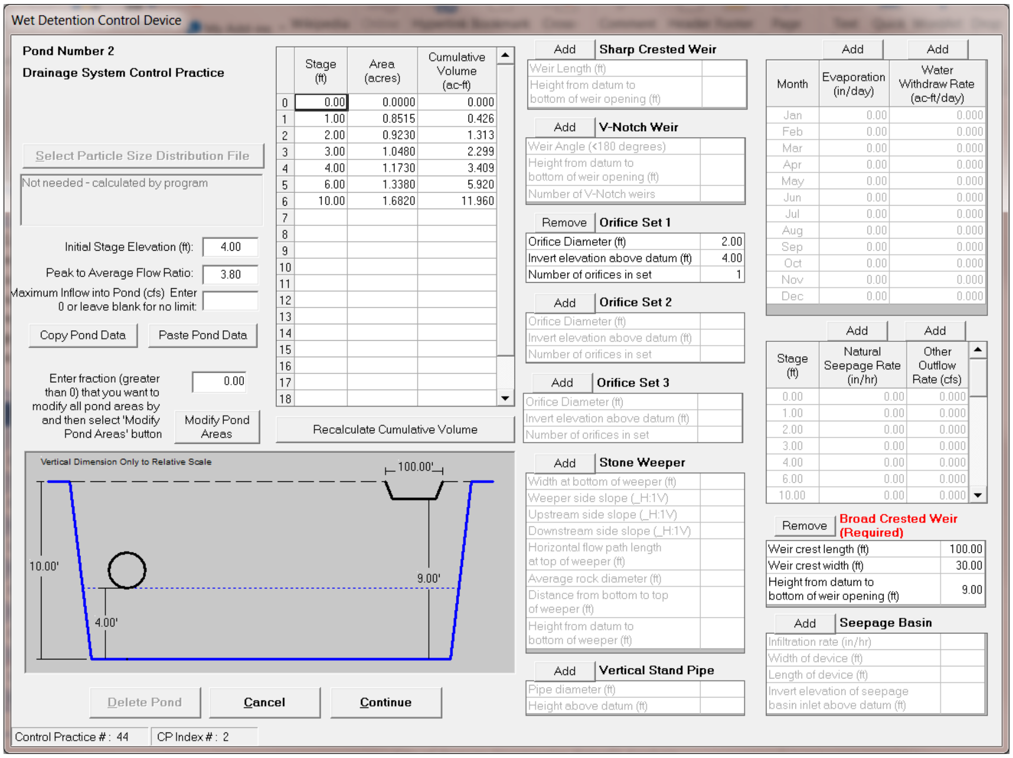

Figure 23: Stormwater pond (P34418) in MR-1 (WinSLAMM).

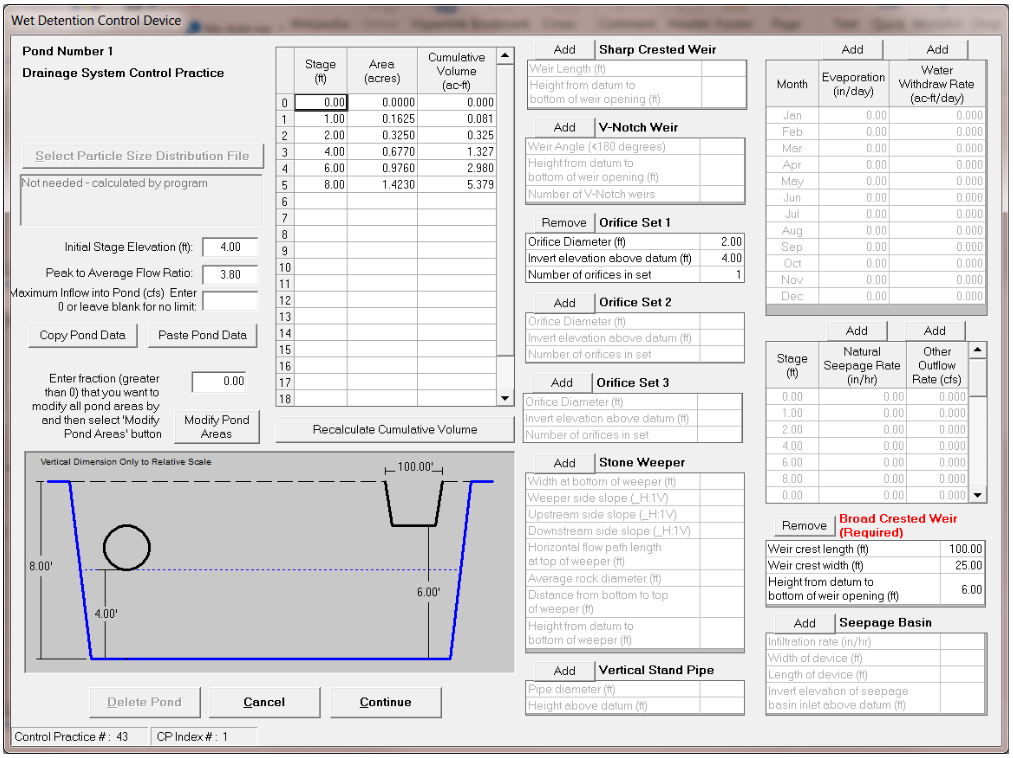

Figure 24: Stormwater pond (P34304) in MR-1 (WinSLAMM).

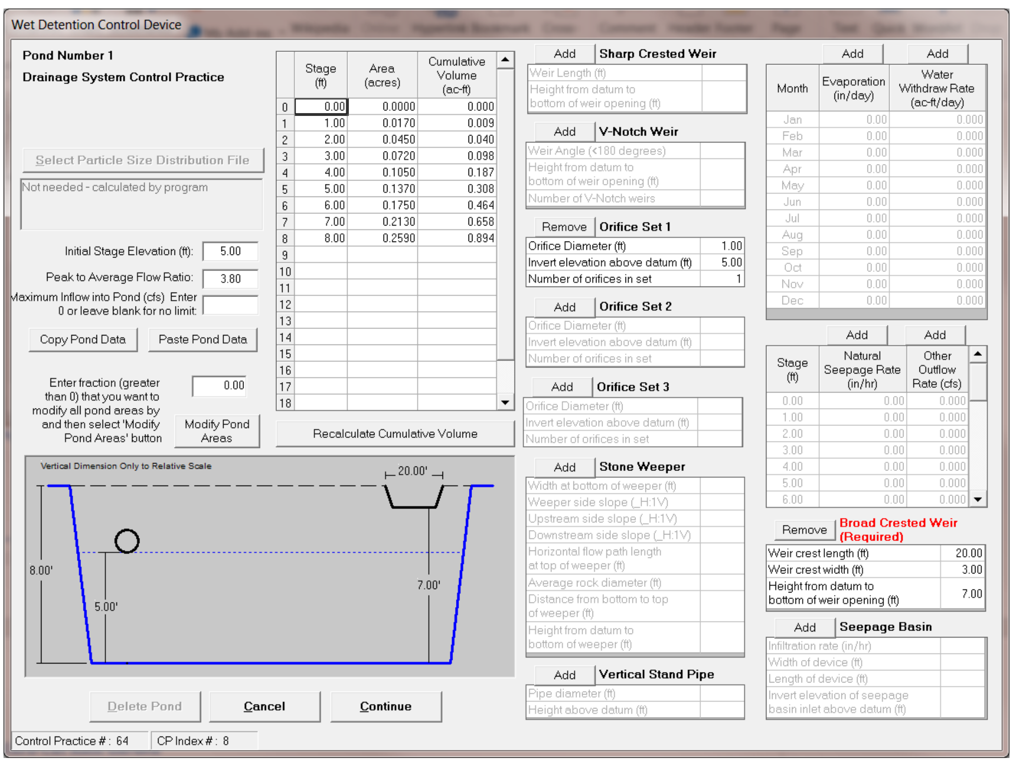

Figure 25: Stormwater pond (P34414) in MR-4 (WinSLAMM).

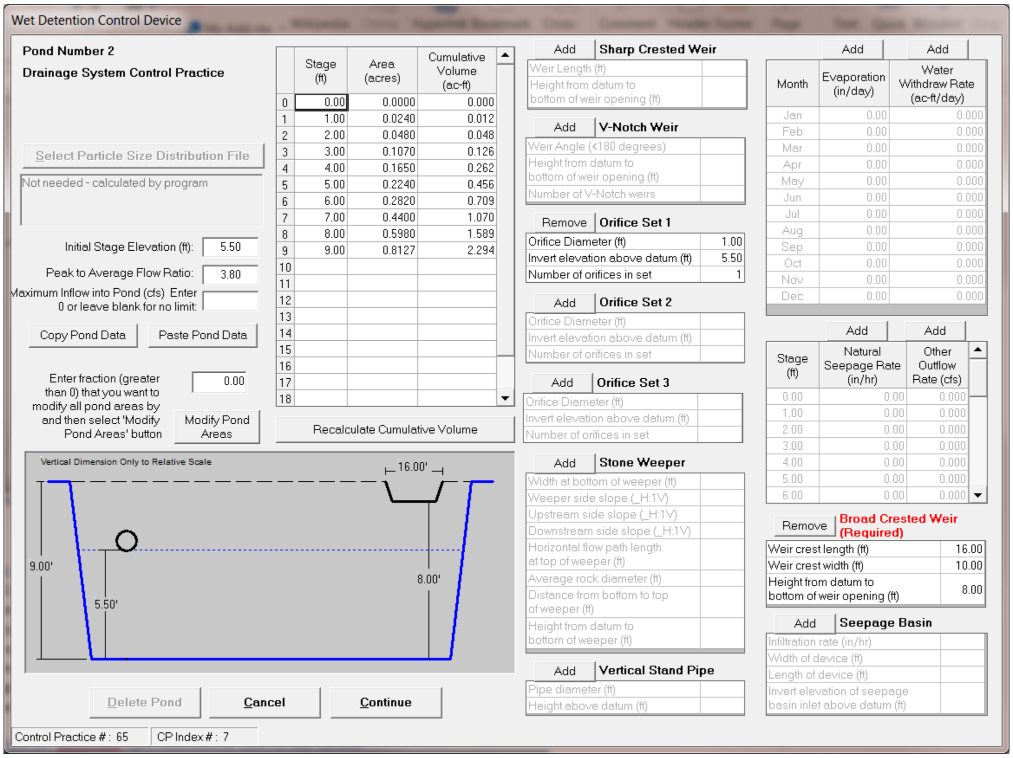

Figure 26: Stormwater pond (P34168) in MR-4 (WinSLAMM).

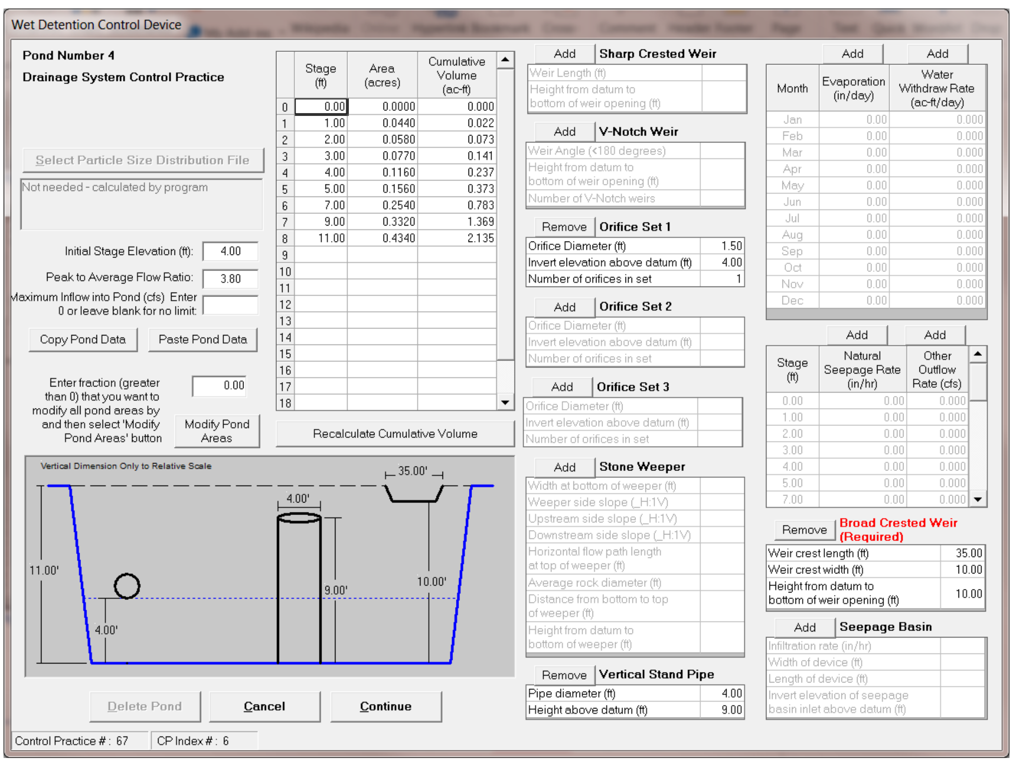

Figure 27: Stormwater pond (P34148) in MR-4 (WinSLAMM).

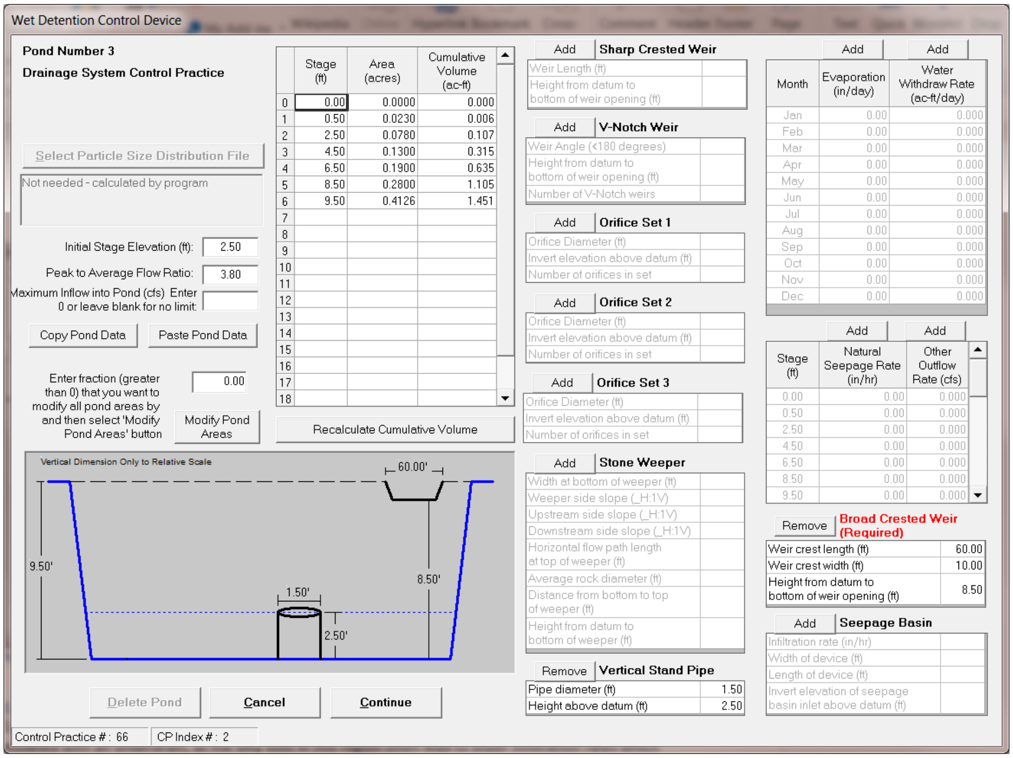

Figure 28: Stormwater pond (P35402) in MR-4 (WinSLAMM).

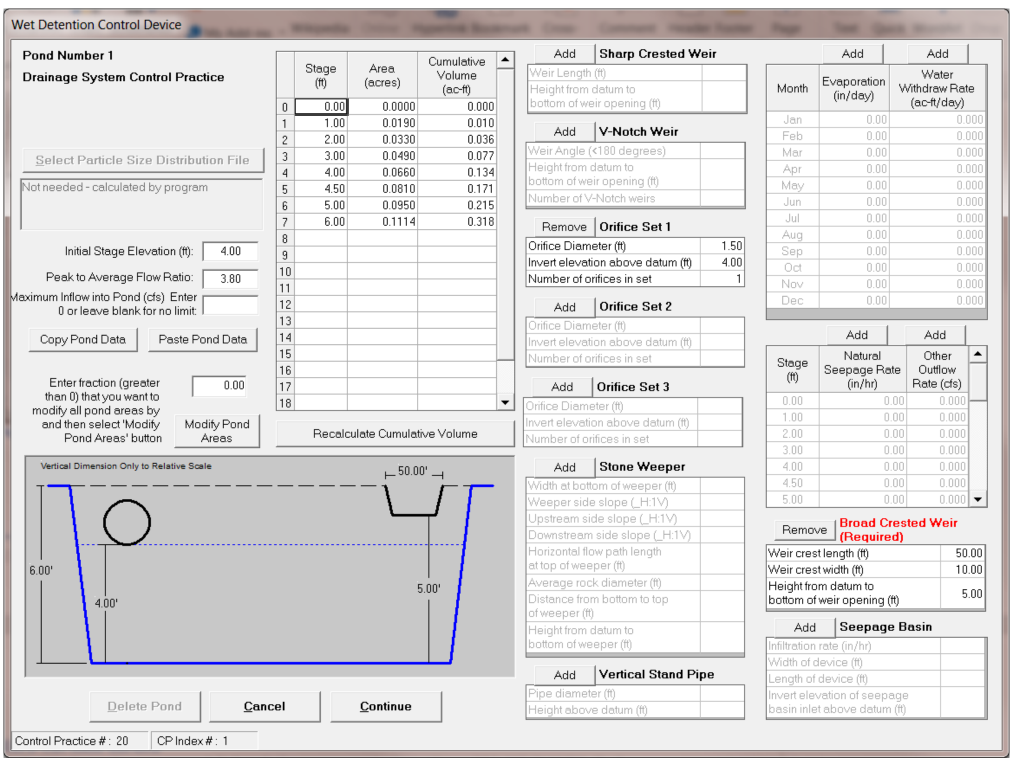

Figure 29: Stormwater pond (P19E304) in RR-1 (WinSLAMM).

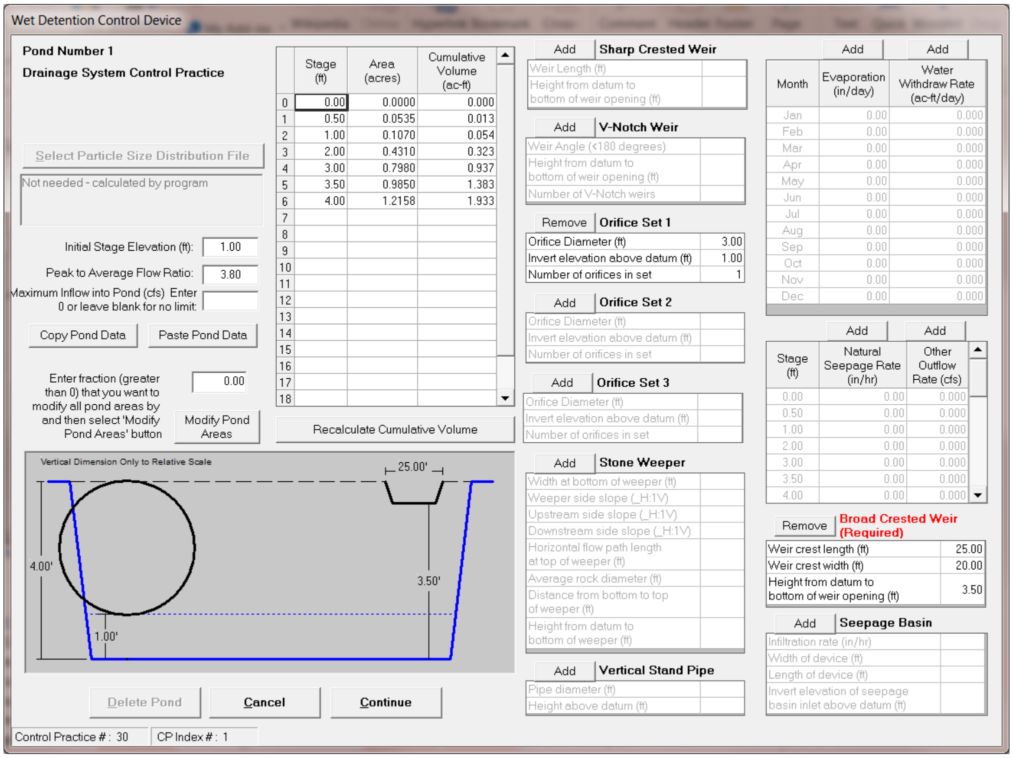

Figure 30: Stormwater pond (P25216) in RR-8 (WinSLAMM).

Street Cleaning

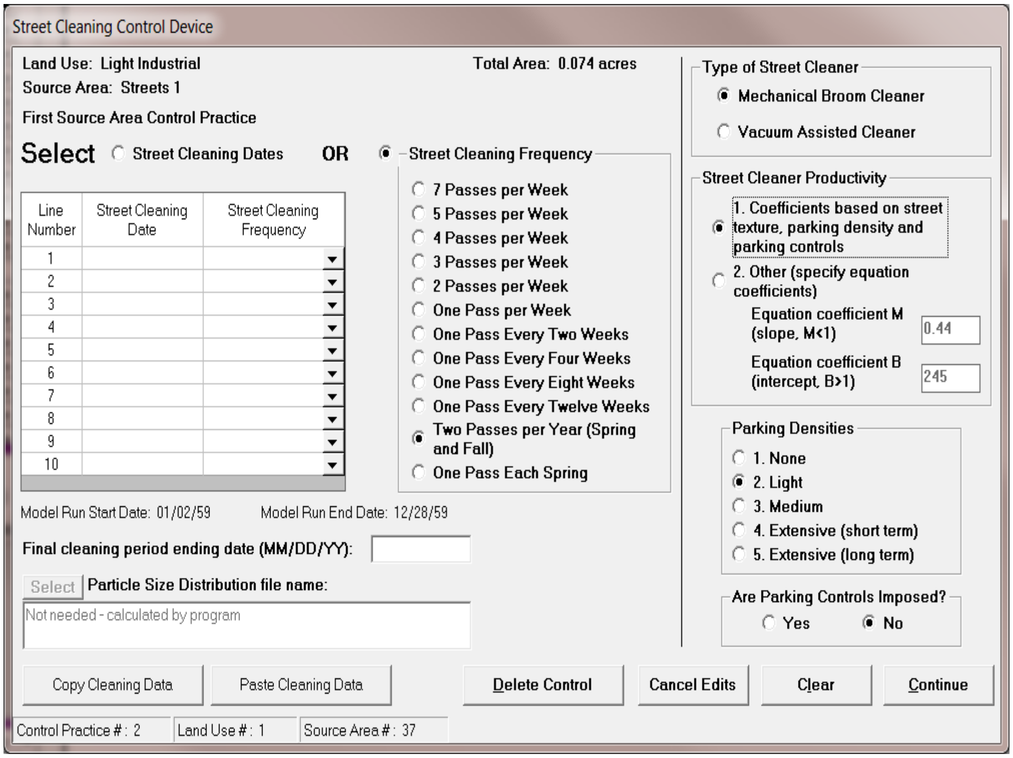

Figure 31: General street cleaning WinSLAMM model inputs.

Proposed Conditions

BMP Modifications

Ponds were scrutinized following guidance from the Minnesota Pollution Control Agency (MPCA, 2014), 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 contributing drainage area. Ponds that did not fit these criteria were considered for modifications.

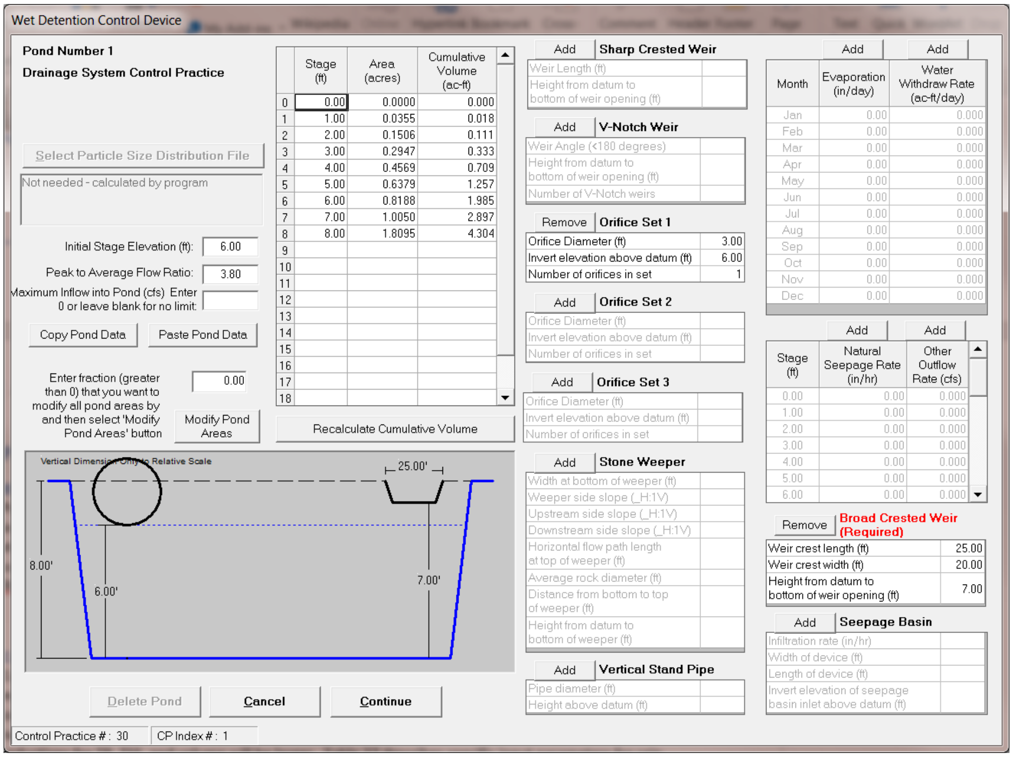

Figure 32: Stormwater pond (P25216) modification in RR-8 (WinSLAMM).

Boulevard Bioswales

Boulevard bioswales were modeled as a drainage area control practice in WinSLAMM. More specifically, the grass swale control practice was used with the parameters in Figure 33.

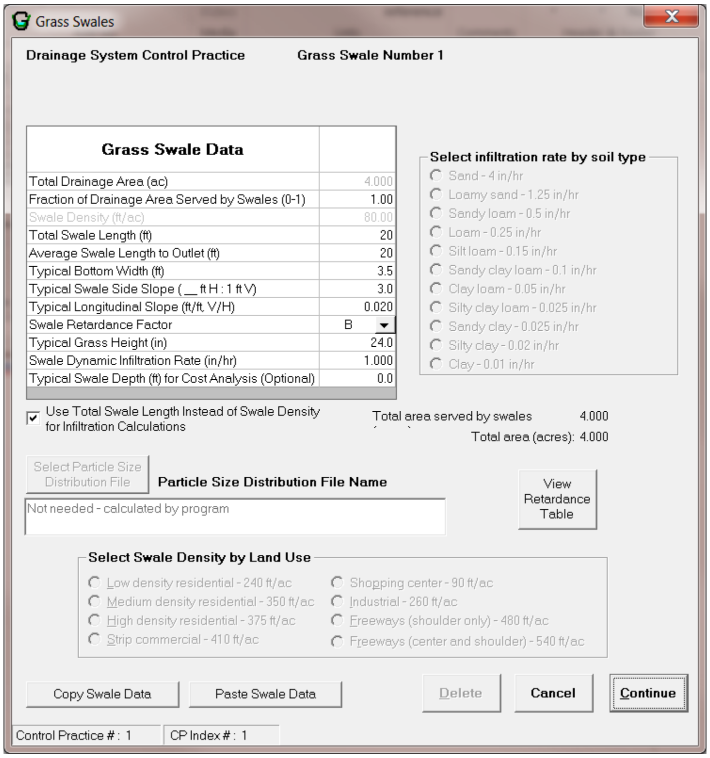

Figure 33: General boulevard bioswale (WinSLAMM).

Curb-Cut Rain Gardens

Curb-cut rain gardens were modeled as drainage area control practices within WinSLAMM. Each was modeled without an underdrain based on available soil information. If based on soil tests it is determined that an underdrain would be necessary, then estimated reductions for volume, TP, and TSS will be lower.

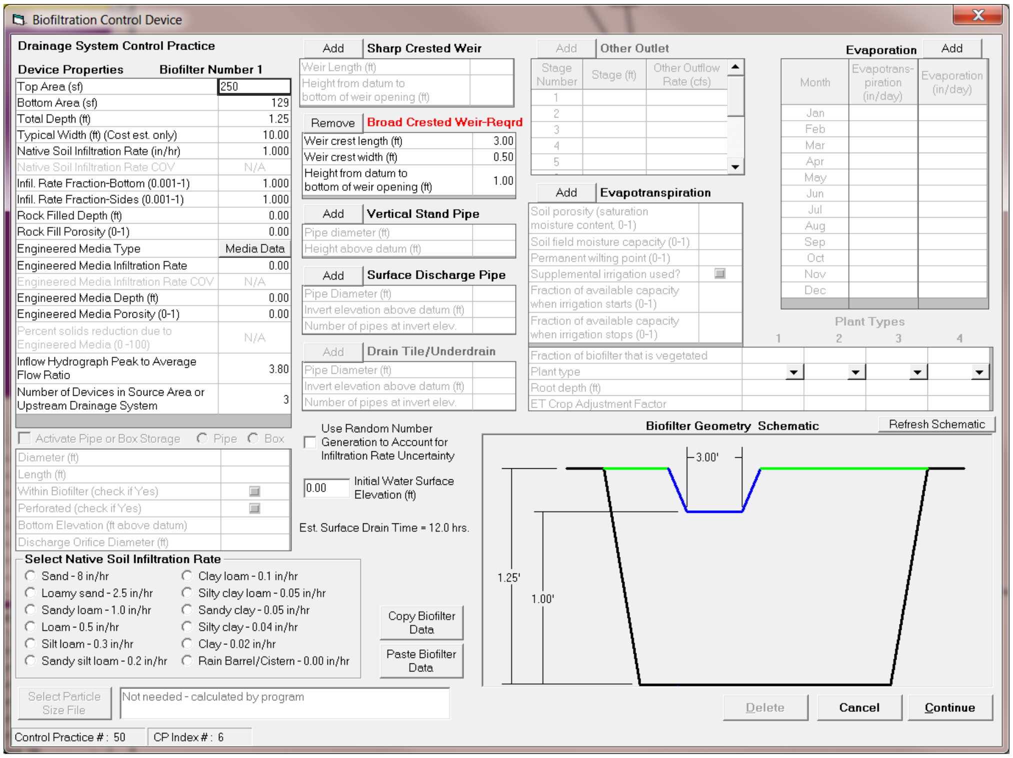

Figure 34: General curb-cut rain garden (WinSLAMM).

Infiltration Basins

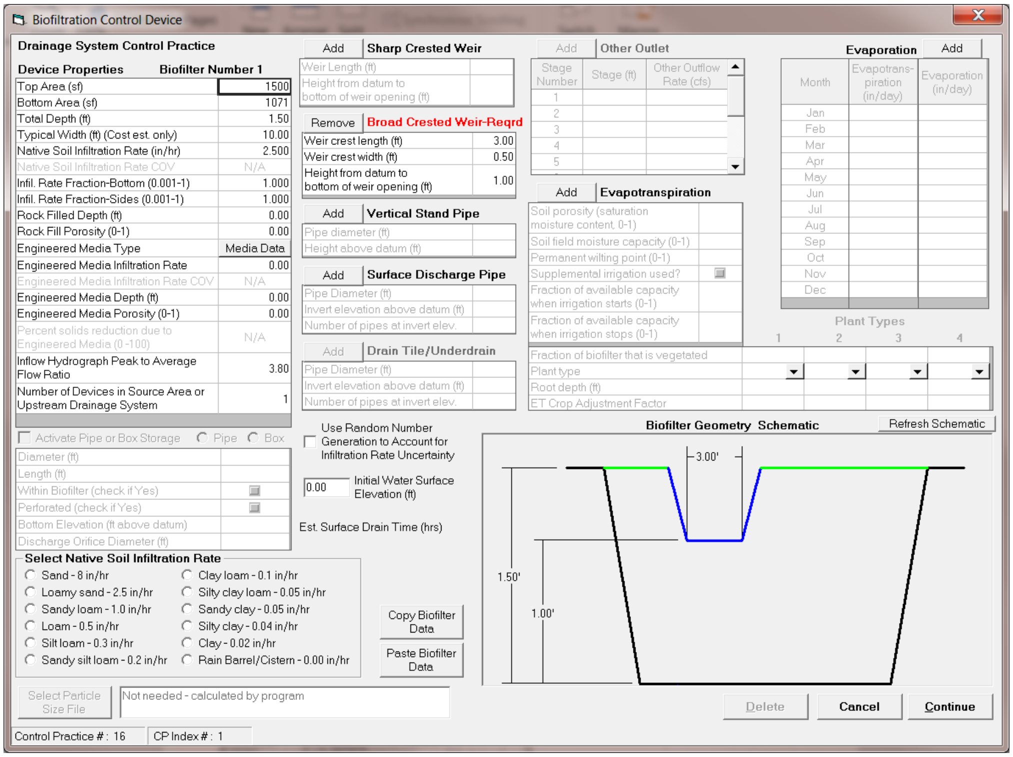

Figure 35: Infiltration basin (1,500 sq-ft) in MR-3 (WinSLAMM).

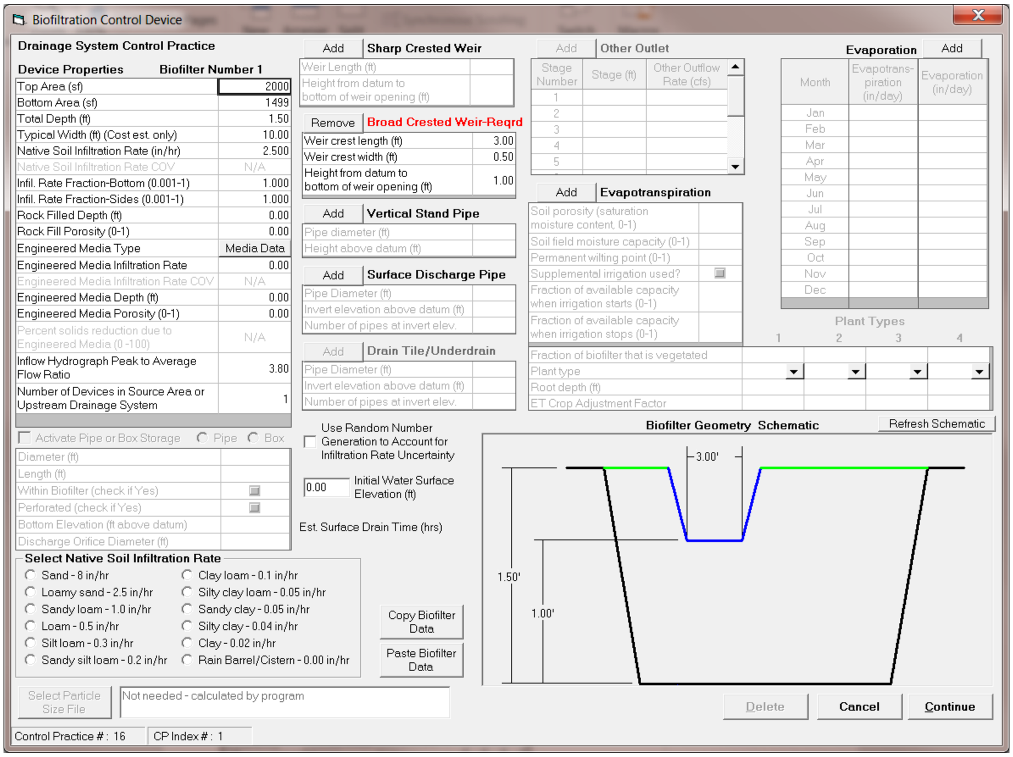

Figure 36: Infiltration basin (2,000 sq-ft) in MR-3 (WinSLAMM).

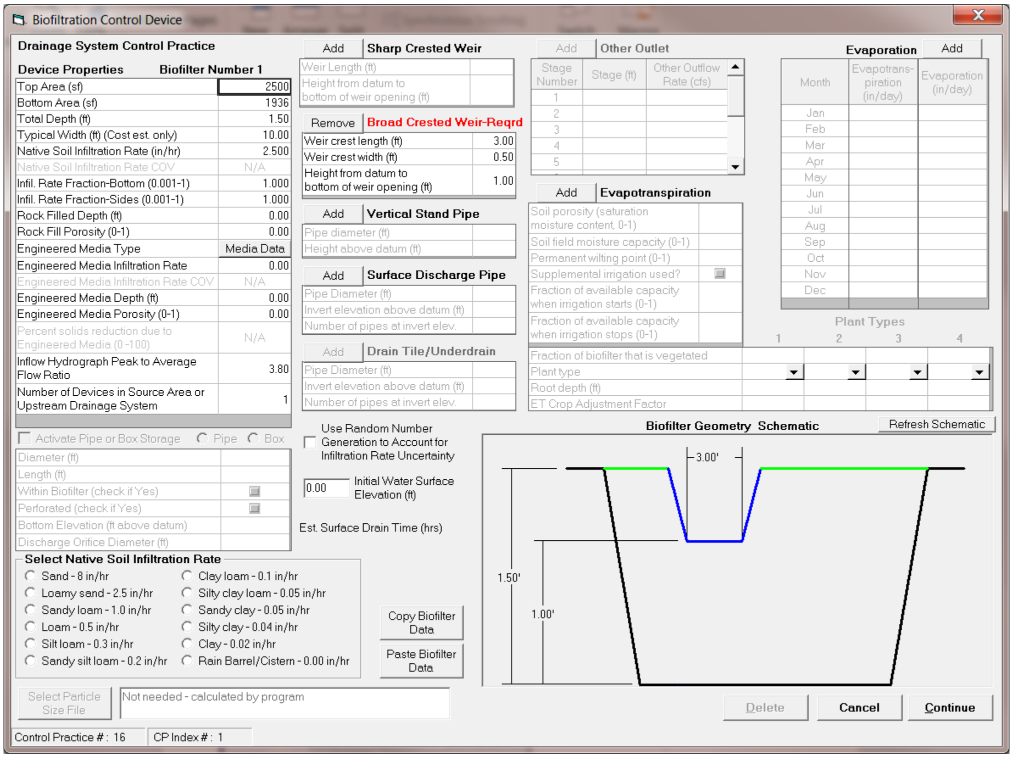

Figure 37: Infiltration basin (2,500 sq-ft) in MR-3 (WinSLAMM).

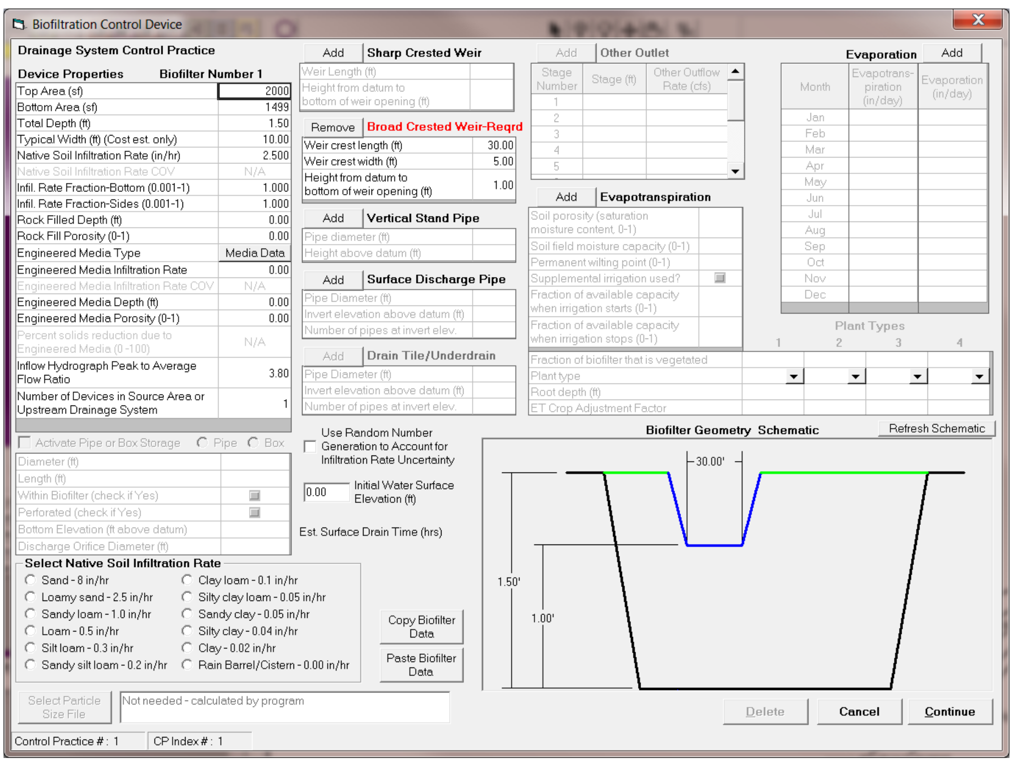

Figure 38: Infiltration basin (2,000 sq-ft) in MR-6 (WinSLAMM).

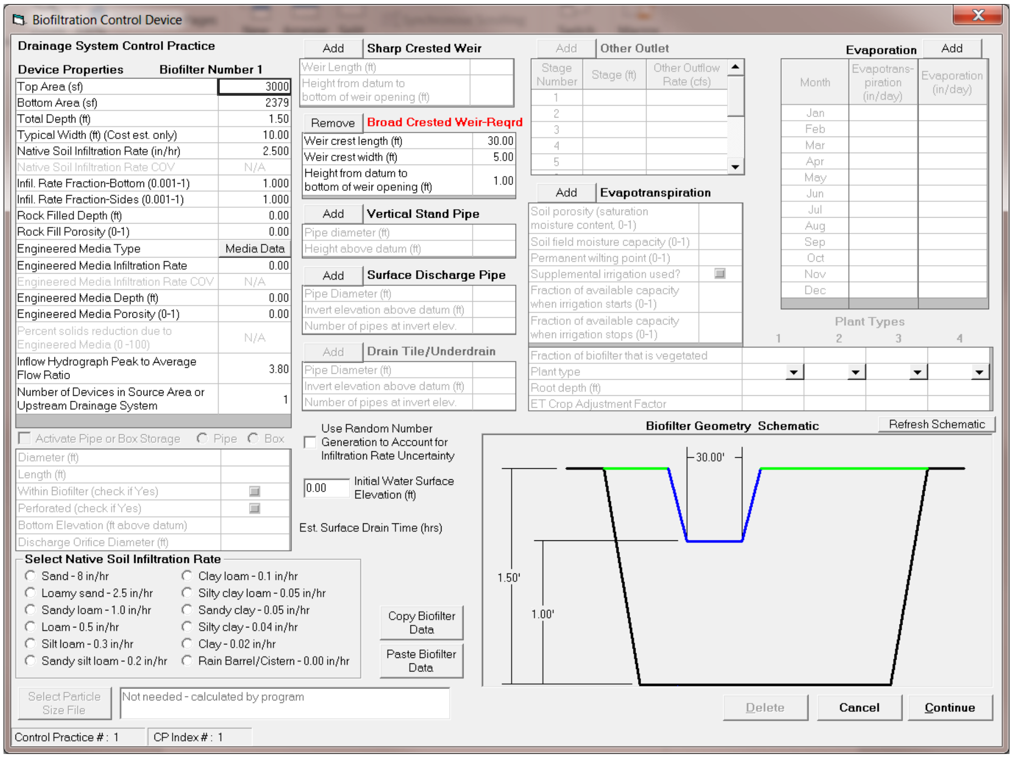

Figure 39: Infiltration Basin (3,000 sq-ft) in MR-6 (WinSLAMM).

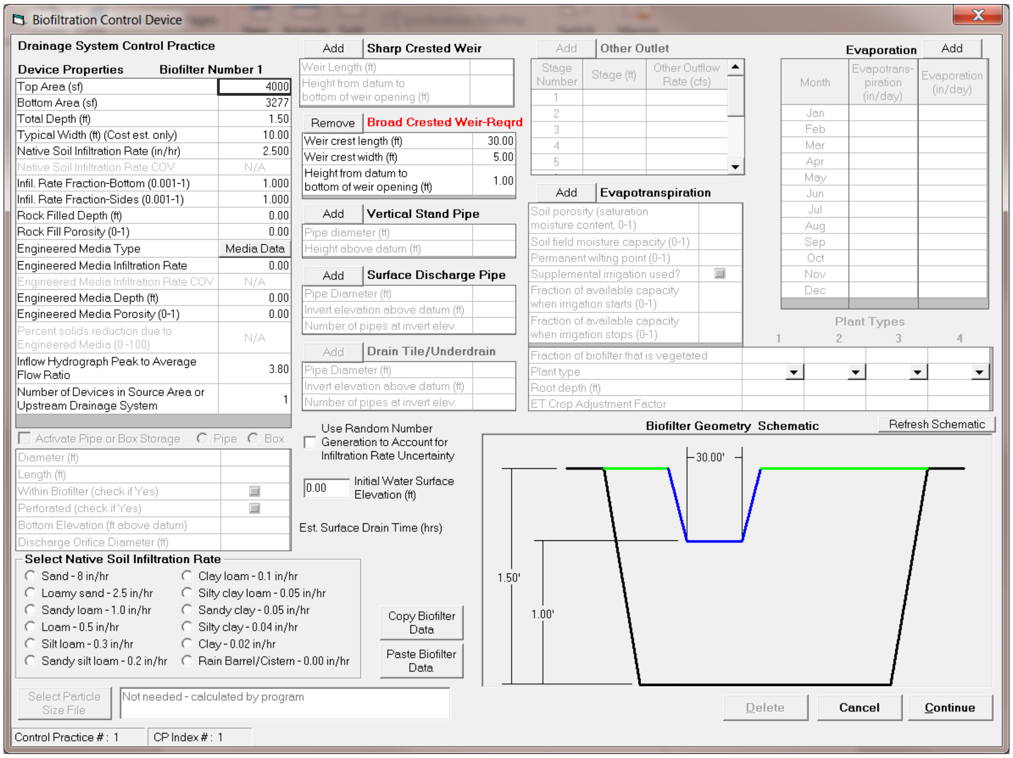

Figure 40: Infiltration Basin (4,000 sq-ft) in MR-6 (WinSLAMM).

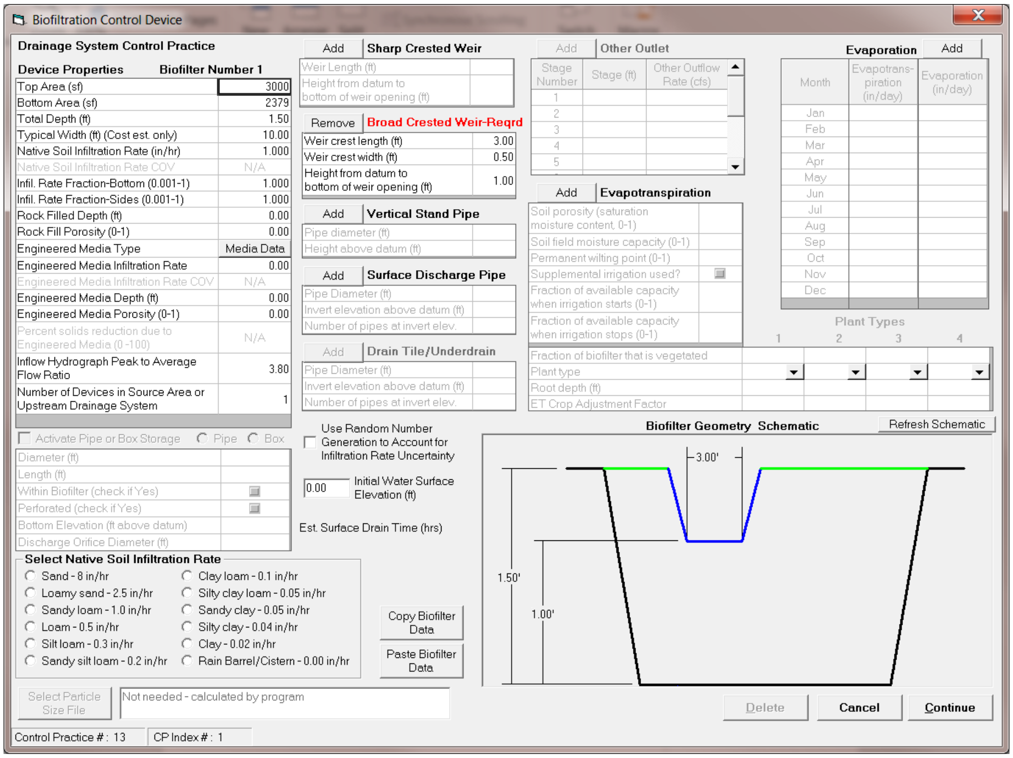

Figure 41: Infiltration basin (3,000 sq-ft) in RR-6 (WinSLAMM).

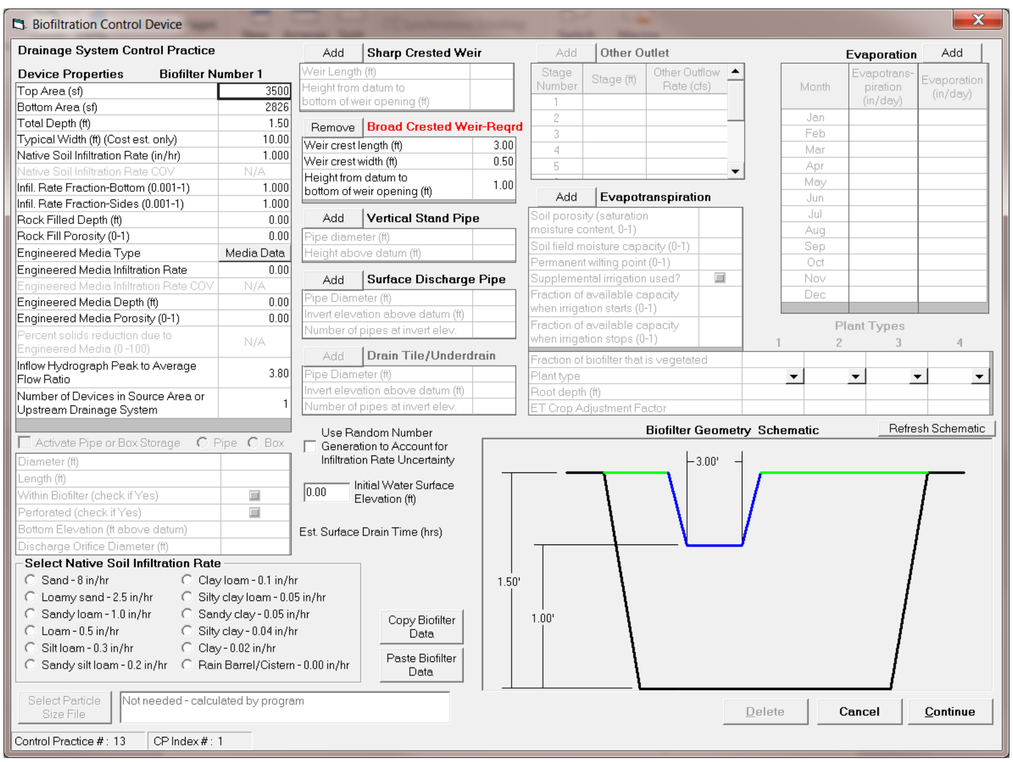

Figure 42: Infiltration basin (3,500 sq-ft) in RR-6 (WinSLAMM).

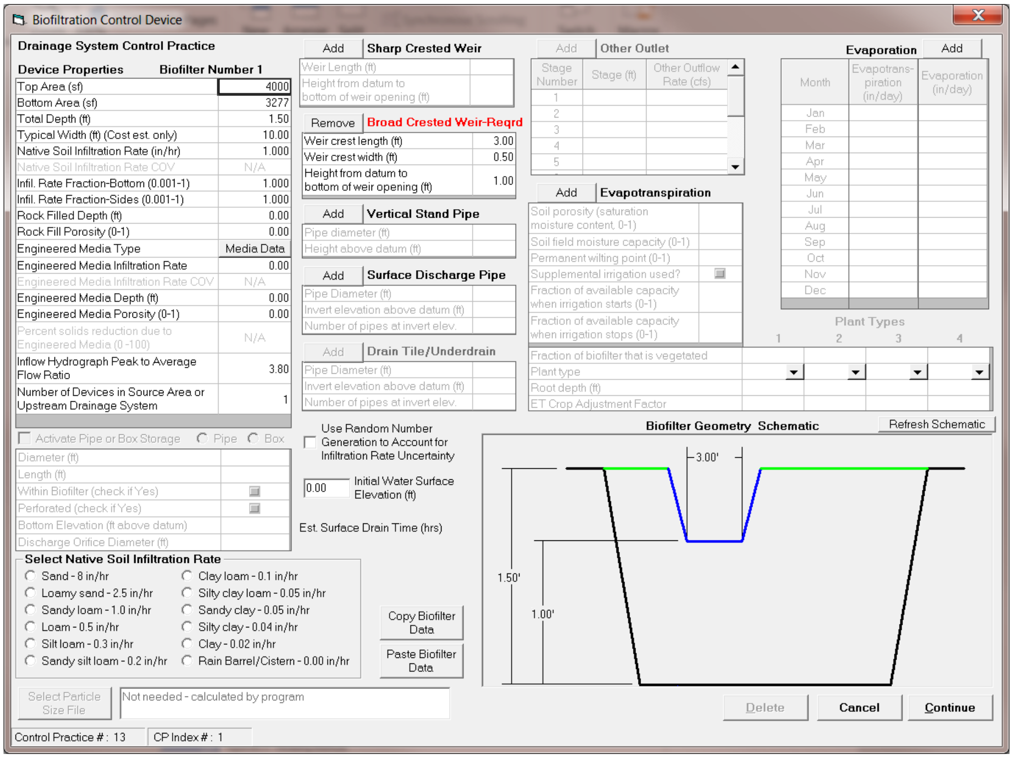

Figure 43: Infiltration Basin (4,000 sq-ft) in RR-6 (WinSLAMM).

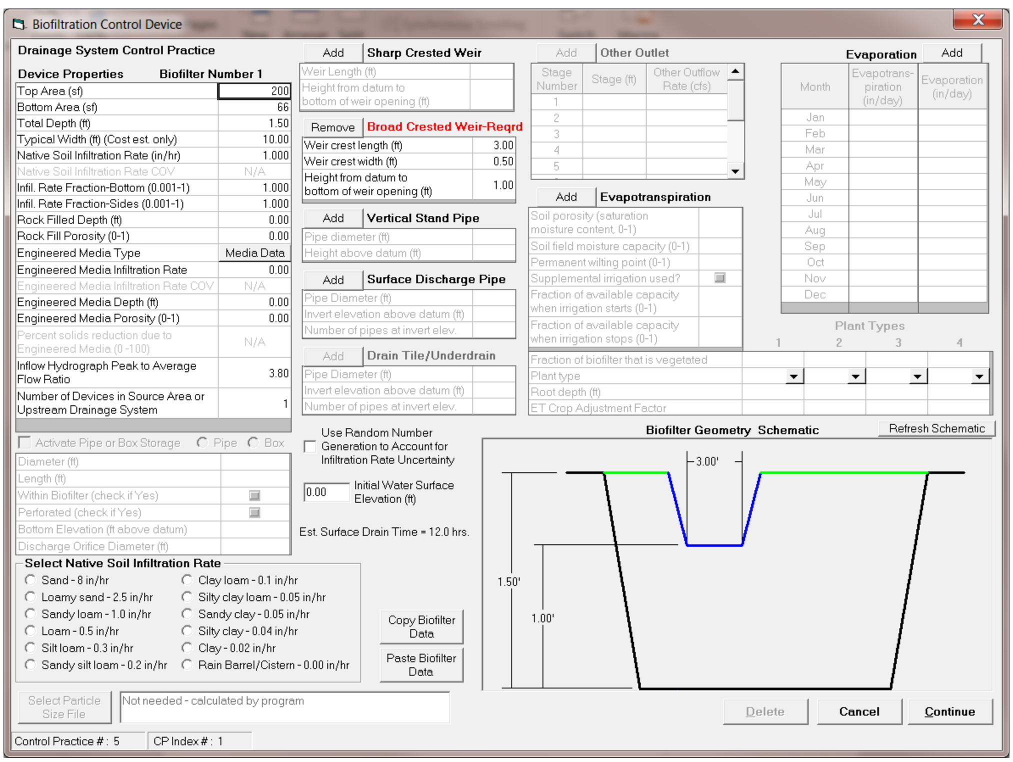

Figure 44: Infiltration basin (200 sq-ft) in RR-7 (WinSLAMM).

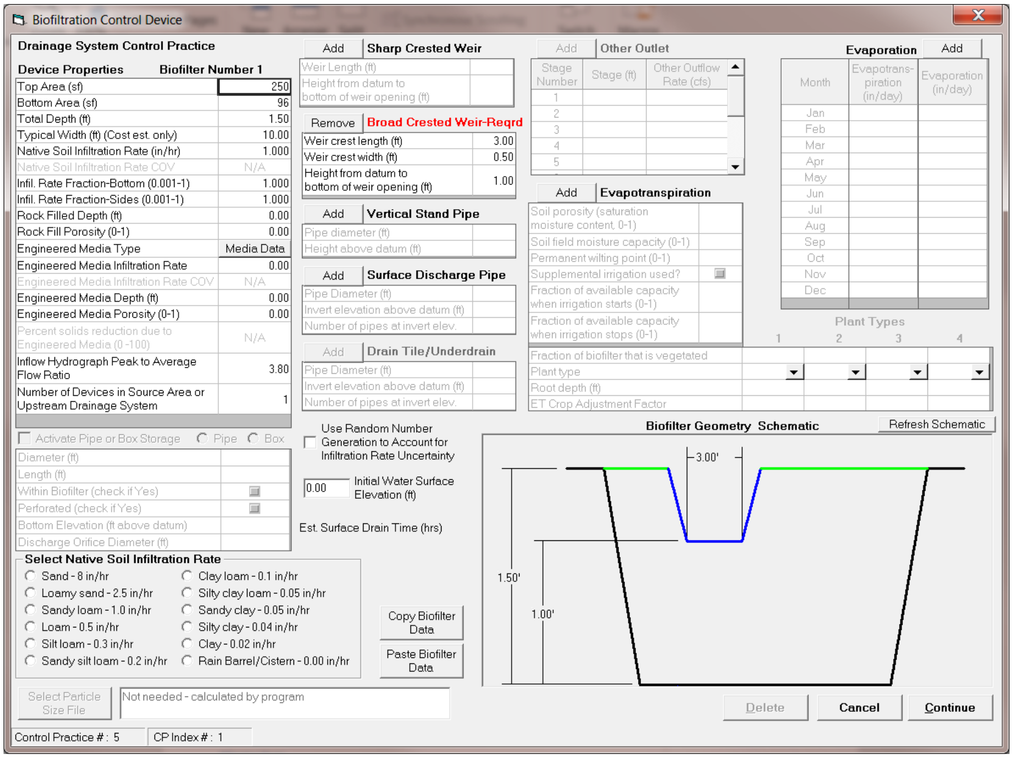

Figure 45: Infiltration basin (250 sq-ft) in RR-7 (WinSLAMM).

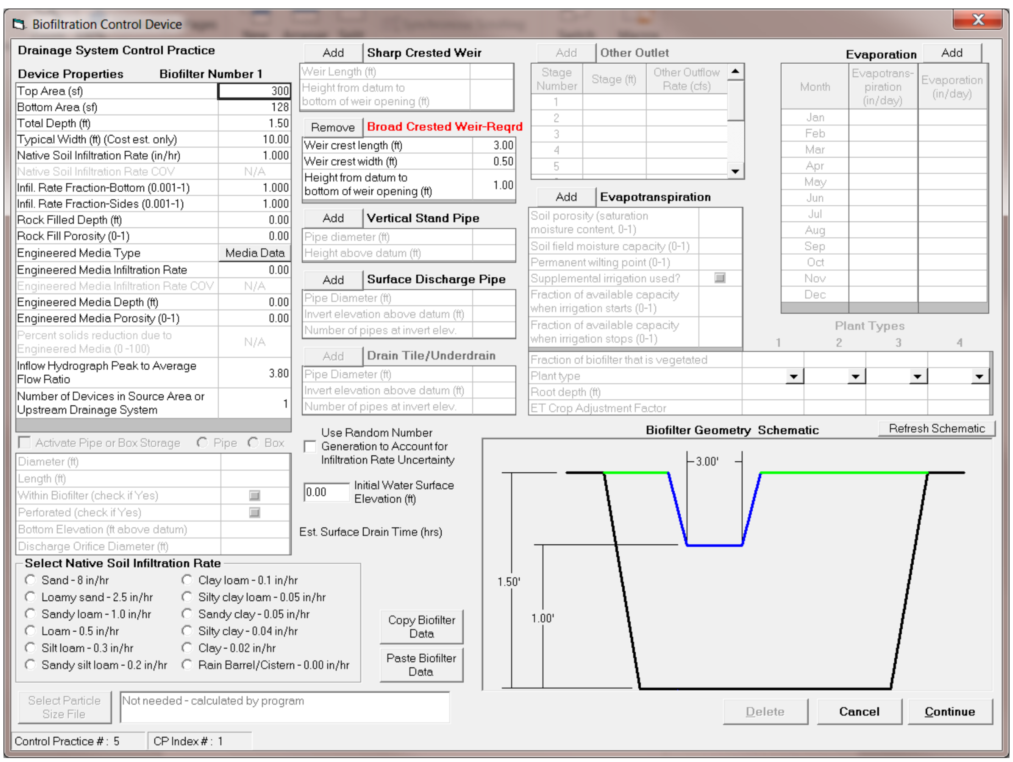

Figure 46: Infiltration basin (300 sq-ft) in RR-7 (WinSLAMM).

Hydrodynamic Devices

Table 9: 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

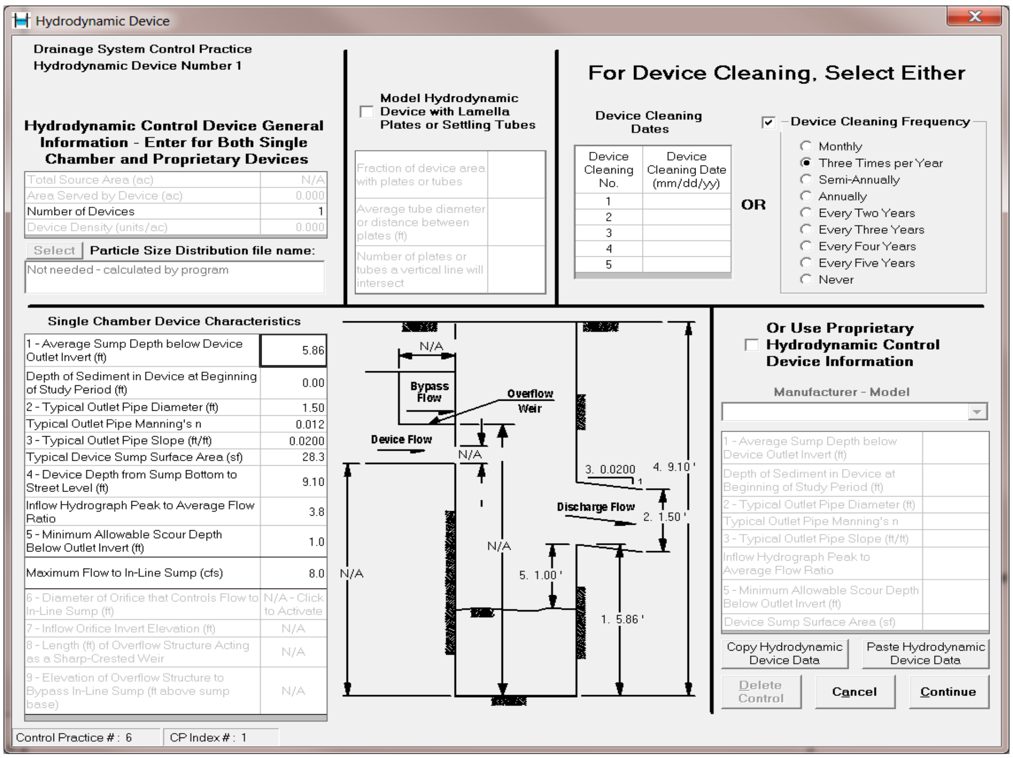

Figure 47: Hydrodynamic Device with 6' diameter (WinSLAMM).

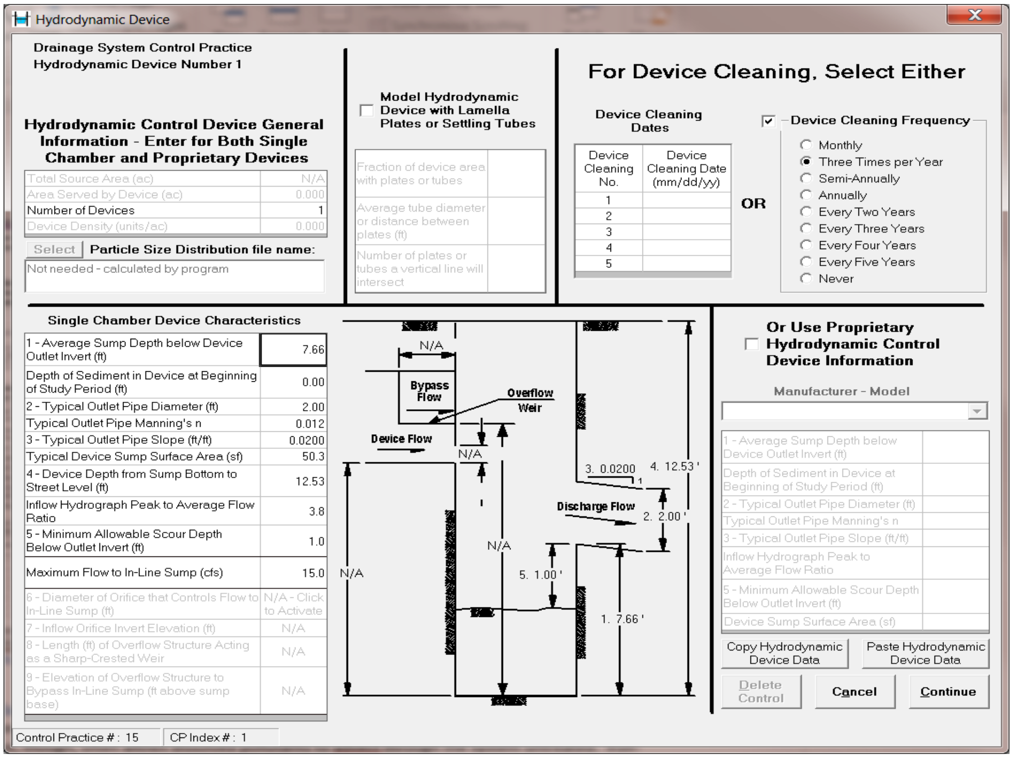

Figure 48: Hydrodynamic Device with 8' diameter (WinSLAMM).

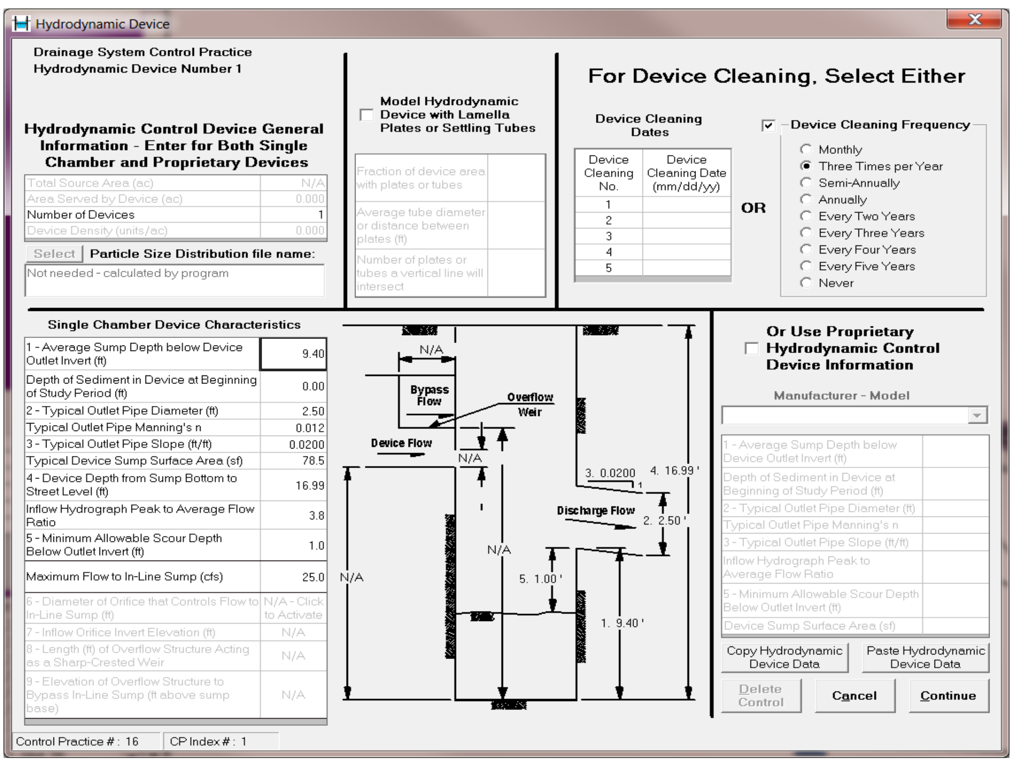

Figure 49: Hydrodynamic Device with 10' diameter (WinSLAMM).

Iron Enhanced Sand Filter Pond Bench

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.

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 80% of the DP load.

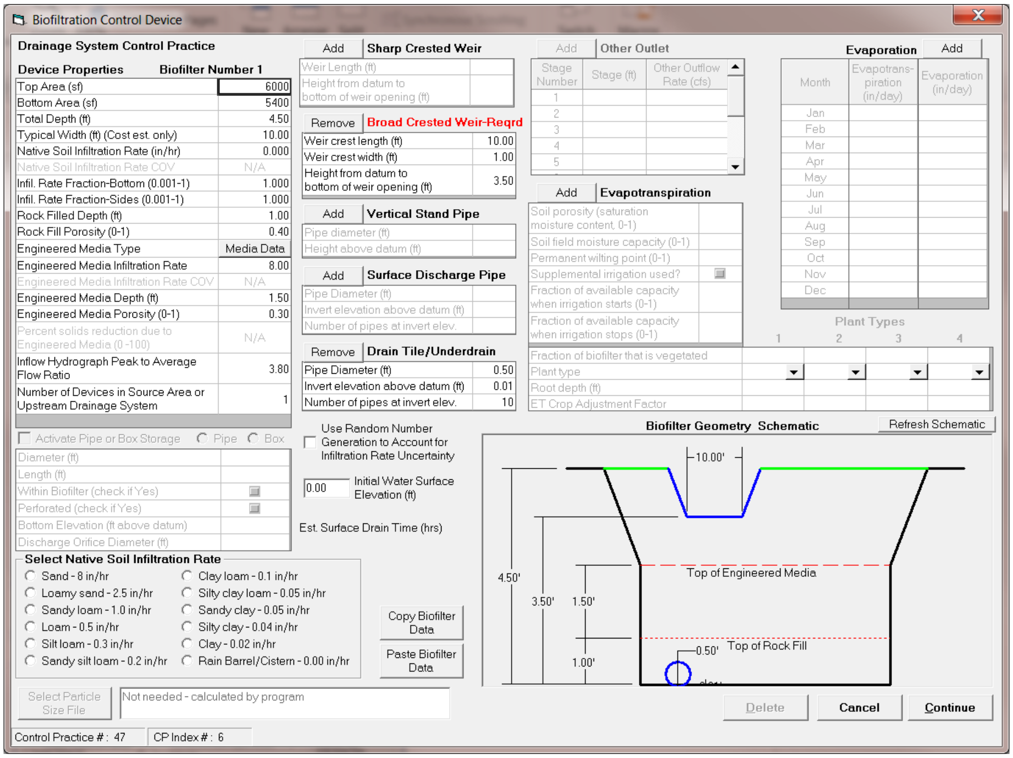

Figure 50: Iron-enhanced sand filter pond bench (P34304) in MR-1 (WinSLAMM).

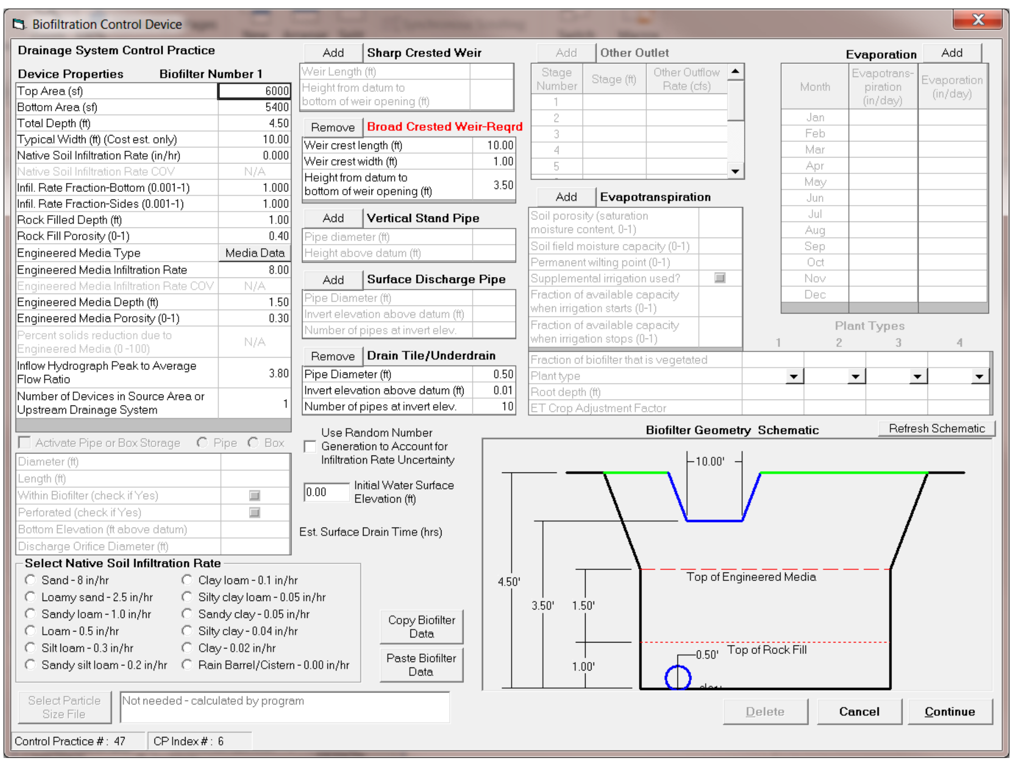

Figure 51: Iron-enhanced sand filter pond bench (P34418) in MR-1 (WinSLAMM).

Iron-enhanced Sand Filter Check Dam

With this BMP there are two processes that drive pollutant retention within the practice. First, the practice detains stormwater behind the dam, dropping particulate pollutants out of suspension. Secondly, any water that has been impounded by the dam can either pass through the dam (and its IESF) or be evapotranspired prior to passing through the dam. To mimic these processes within WinSLAMM two different models were created, each with the same land use, soil, and existing stormwater infrastructure conditions. Within both models a biofiltration drainage area control practice was installed.

To model the effect of detaining water behind the dam, a biofiltration control practice with the same ponding storage as the check dams was modeled. This practice did not have an underdrain and assumed very silty soils with no infiltration (Figure 52 and Figure 54). Volume, TSS, and particulate phosphorus retention were determined from this model. For water passing through the filter, a similarly sized biofiltration control practice was modeled, but in this case was modeled with an underdrain (Figure 53 and Figure 55). Dissolved phosphorus retention was determined from this model assuming that 80% of dissolved phosphorus flowing through the dam was retained (Erickson & Gulliver, 2010). Total phosphorus reduction was the summation of particulate and dissolved phosphorus reductions between the two models.

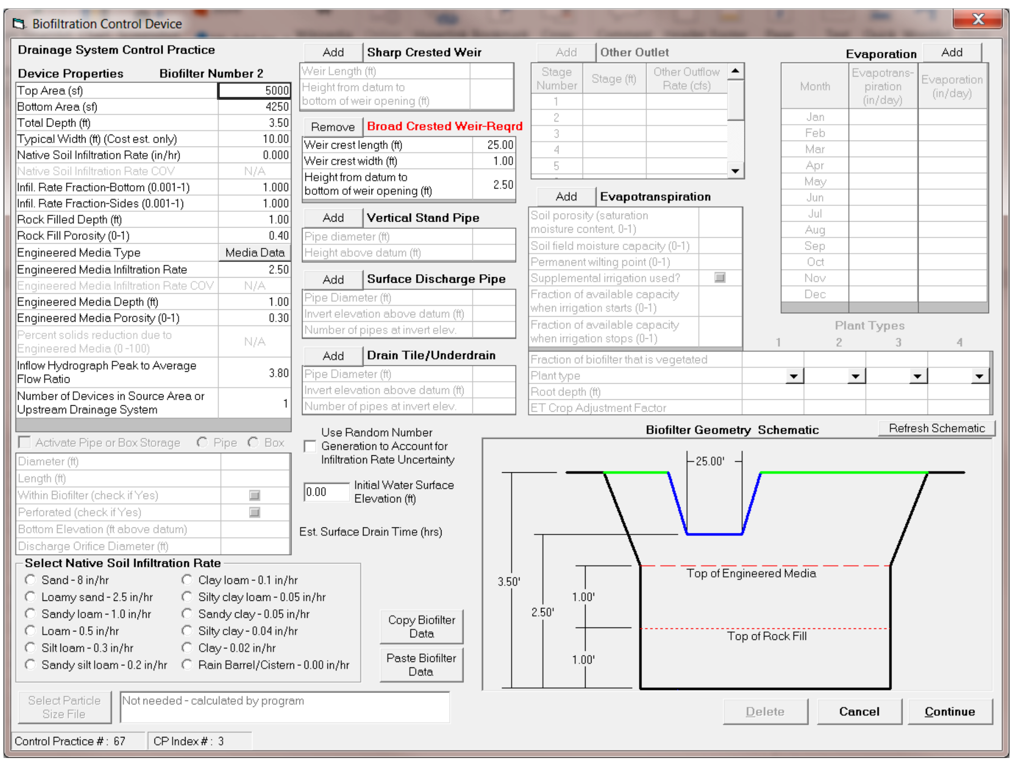

Figure 52: Iron-enhanced sand filter check dam (South Ditch W) in MR-4. Parameters model dam behind the iron-enhanced sand filter (WinSLAMM)

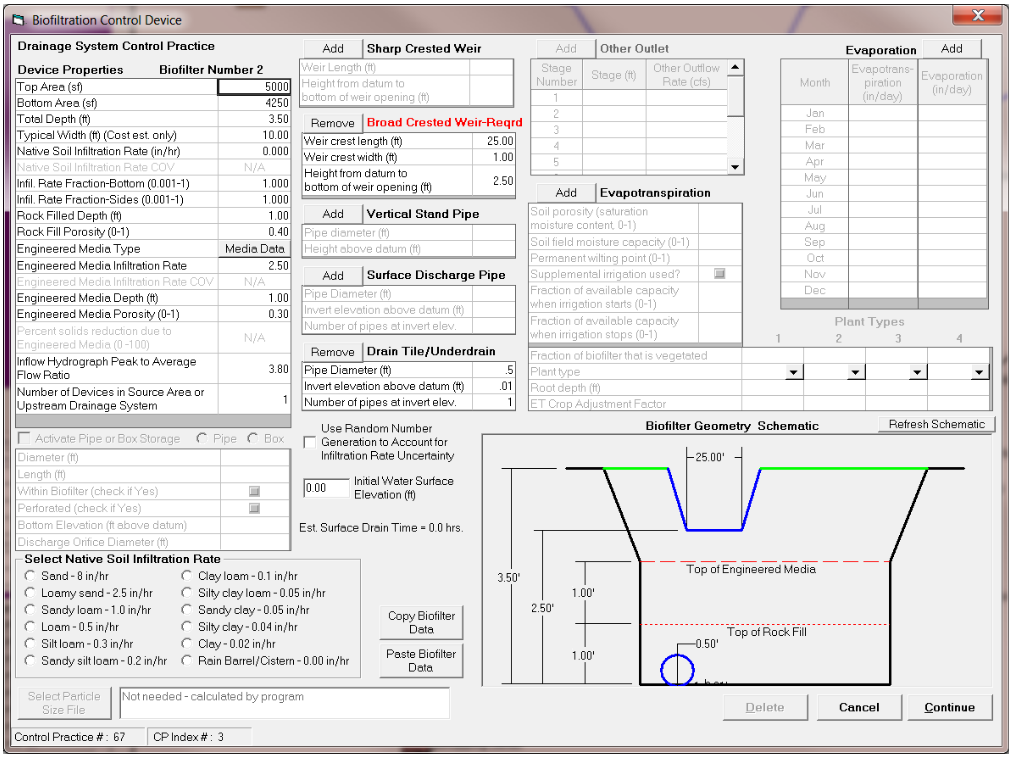

Figure 53: Iron-enhanced sand filter check dam (South Ditch W) in MR-4. Parameters model the iron-enhanced sand filter (WinSLAMM).

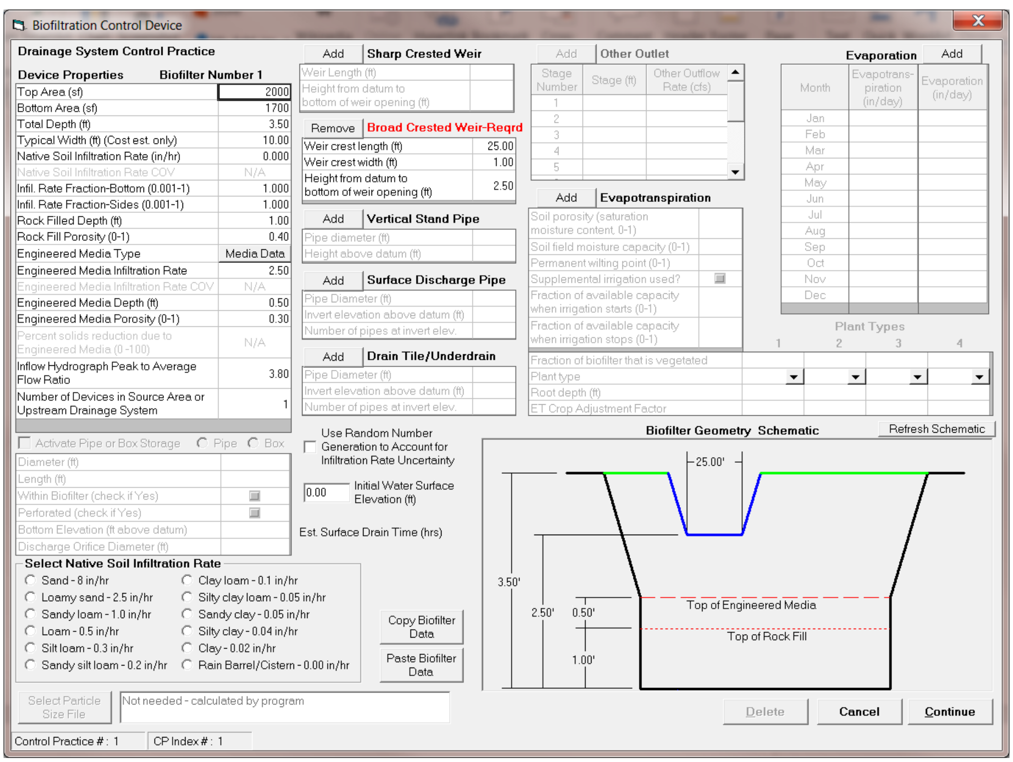

Figure 54: Iron-enhanced sand filter check dam (South Ditch) in MR-7. Parameters model dam behind the iron-enhanced sand filter (WinSLAMM).

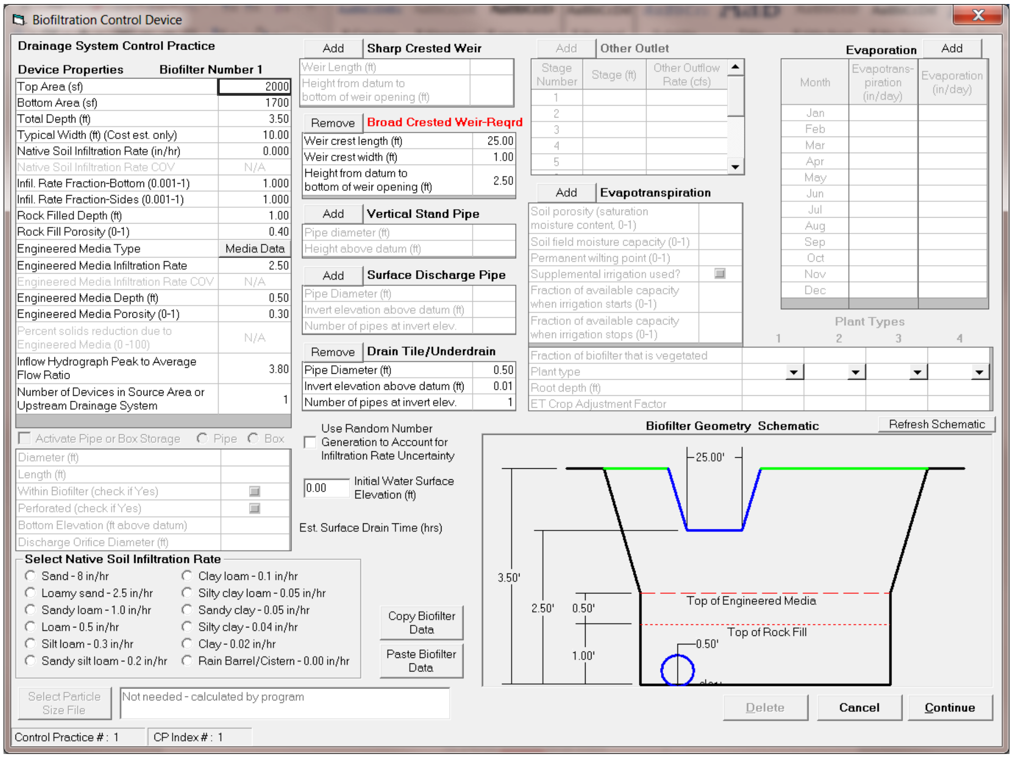

Figure 55: Iron-enhanced sand filter check dam (South Ditch) in MR-7. Parameters model the iron-enhanced sand filter (WinSLAMM).

Appendix B – Project Cost Estimates

Introduction

The 'Cost Estimating' section on page 10 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 check dams, iron enhanced sand filters, and ponds.

Check Dam

Table 10: Catchment MR4 - IESF Check Dam in US-10 southern ditch

Activity	Units	Unit Price	Quantity	Unit Price
Design	each	$3,000.00	1	$3,000.00
Mobilization and Site Preparation	each	$3,000.00	1	$3,000.00
Land Acquisition - owned by MNDOT	N/A	N/A	N/A	$0.00
Engineered Soil Mix (5% iron by weight)	cu-yards	$275.00	3.1	$852.50
Rocks	cu-yards	$125.00	4.6	$575.00
Permeable Liner	per dam	$100.00	1	$100.00
Installation	per dam	$5,000.00	1	$5,000.00
			Total for Project =	$12,527.50

Table 11: Catchment MR7 - IESF Check Dam in US-10 southern ditch

Activity	Units	Unit Price	Quantity	Unit Price
Design	each	$3,000.00	1	$3,000.00
Mobilization and Site Preparation	each	$3,000.00	1	$3,000.00
Land Acquisition - owned by MNDOT	N/A	N/A	N/A	$0.00
Engineered Soil Mix (5% iron by weight)	cu-yards	$275.00	3.1	$852.50
Rocks	cu-yards	$125.00	4.6	$575.00
Permeable Liner	per dam	$100.00	1	$100.00
Installation	per dam	$5,000.00	1	$5,000.00
			Total for Project =	$12,527.50

Iron Enhanced Sand Filters

Table 12: Catchment MR1 – IESF Bench at P34418

Activity	Units	Unit Price	Quantity	Unit Price
Design/Bidding/Construction Oversight	Each	$ 40,000.00	1	$ 40,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Land Acquisition	acres	$ -	0	$ -
Clearing, Removal of Existing Infrastructure, and Pond Dewatering	Each	$ 12,000.00	1	$ 12,000.00
Common Excavation & Disposal	cu-yards	$ 40.00	300	$ 12,000.00
IESF Materials and Installation	sq-ft	$ 17.00	2,000	$ 34,000.00
Outlet/Inlet Control Structures	Each	$ 20,000.00	1	$ 20,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
		Total for project =		$ 138,000.00

Table 13: Catchment MR1 – IESF Bench at P34304

Activity	Units	Unit Price	Quantity	Unit Price
Design/Bidding/Construction Oversight	Each	$ 40,000.00	1	$ 40,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Land Acquisition	acres	$ -	0	$ -
Clearing, Removal of Existing Infrastructure, and Pond Dewatering	Each	$ 12,000.00	1	$ 12,000.00
Common Excavation & Disposal	cu-yards	$ 40.00	889	$ 35,560.00
IESF Materials and Installation	sq-ft	$ 17.00	6,000	$ 102,000.00
Outlet/Inlet Control Structures	Each	$ 20,000.00	1	$ 20,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
		Total for project =		$ 229,560.00

Ponds

Table 14: RR8 – Pond Modification at River Bend Park

Activity	Units	Unit Price	Quantity	Unit Price
Feasibility Study and Project Design	Each	$ 15,000.00	1	$ 15,000.00
Mobilization	Each	$ 10,000.00	1	$ 10,000.00
Land Acquisition - Public				$ -
Site Prep	Each	$ 10,000.00	1	$ 10,000.00
Brush Removal	Each	$ 15,000.00	1	$ 15,000.00
Sediment Testing	Each	$ 10,000.00	1	$ 10,000.00
Existing Infrastructure Retrofit	Each	$ 5,000.00	1	$ 5,000.00
Outlet Control Structure	Each	$ 10,000.00	1	$ 10,000.00
Site Restoration	Each	$ 10,000.00	1	$ 10,000.00
	Project Total Before Excavation =			$ 85,000.00

	Management Levels		
Activity	1	2	3
Soil To Excavate (cu-yds)	3,100	3,100	3,100
Cost To Excavate ($/cu-yd)	$20	$35	$50
Cost To Excavate (Total $)	$62,000	$108,500	$160,000
Other Construction Costs ($)	$85,000	$85,000	$85,000
Total Project Cost ($)	$147,000	$193,500	$245,000

Appendix C – Volume Reduction Ranking Tables

Introduction

Volume reduction was not identified as a primary reduction target 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 15: Mississippi River Network. Cost-effectiveness of retrofits with respect to volume reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ ac-ft Vol./year (30-year)
1	MR6-A	57	Infiltration Basin	Southeastern Portion of MR6	MR6	3.6 - 4.9	2,110 - 2,836	3.8 - 5.4	$43,796 - $83,796	$225	$440 - $562
2	MR3-A	44	Infiltration Basin	Riverdale Dr.	MR3	2.5 - 3.0	867-1,034	2.2-2.7	$33,796 - $53,796	$225	$602 - $735
3	MR5-A	52	Curb-Cut Rain Garden	Tungsten St. and Rivlyn Ave.	MR5	0.4-0.5	155-249	0.4-0.6	$8,982	$225	$950 - $1,380
4	MR1-A	34	Curb-Cut Rain Garden	Various locations in MR1	MR1	0.8-2.3	166-493	1.5-3.3	$32,348 - $81,860	$675 - $2,025	$1,140 - $1,448
5	MR2-A	40	Curb-Cut Rain Garden	Ebony St. and 137th Ave.	MR2	0.4-1.2	112-336	0.3-0.9	$8,982 - $26,946	$225 - $675	$1,853
6	MR5-B	53	Boulevard Bioswales	Riverdale Dr.	MR5	0.1	61	0.1	$8,526	$225	$2,714
7	MR2-B	41	Boulevard Bioswales	Riverdale Dr. and Ebony St.	MR2	0.1	61	0.1	$8,526	$225	$3,512
13	MR1-B	35	IESF Bench	Feldspar St. and Garnet St.	MR1	2.4	0	0.0	$143,475	$459	N/A
13	MR1-C	36	IESF Bench	Hematite Cir. and Garnet St.	MR1	7.6	0	0.0	$235,035	$1,377	N/A
13	MR3-B	45	Hydrodynamic Device	Riverdale Dr.	MR3	0.4	211	0.0	$109,752	$630	N/A
13	MR4-A	49	IESF Check Dam	US-10	MR4	0.2	15	0.0	$15,448	$365	N/A
13	MR5-C	54	Hydrodynamic Device	Tungsten St. and Rivlyn Ave.	MR5	0.9	682	0.0	$109,752	$630	N/A
13	MR7-A	60	IESF Check Dam	US-10	MR7	0.2	15	0.0	$15,448	$365	N/A

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

Table 16: Rum River Network. Cost-effectiveness of retrofits with respect to volume reduction. 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	Estimated Annual Operations & Maintenance	Estimated cost/ ac-ft Vol./year (30-year)
1	RR1-A	64	Curb-Cut Rain Garden	Oneida St.	RR1	0.4 - 0.5	111 - 118	0.6 - 0.7	$8,982	$225	$763 - $899
2	RR6-A	83	Infiltration Basin	142nd LN.	RR6	4.2 - 4.8	1,139 - 1,267	2.6 - 2.9	$63,796 - $83,796	$225	$901 - $1,036
3	RR4-A	75	Curb-Cut Rain Garden	Waco St.	RR4	0.4 - 0.5	122 - 155	0.3 - 0.4	$8,982	$225	$1,380 - $1,846
4	RR2-A	67	Curb-Cut Rain Garden	Various locations in RR2	RR2	0.5 - 5.0	155 - 1,551	0.4 - 3.8	$15,844 - $90,112	$225 - $2,250	$1,384 - $1,982
5	RR3-A	71	Curb-Cut Rain Garden	Waco St.	RR3	0.6 - 0.7	188 - 204	0.5	$15,844	$225	$1,525 - $1,652
6	RR5-A	79	Curb-Cut Rain Garden	142nd LN.	RR5	0.37 - 0.43	110 - 129	0.26 - 0.30	$8,982	$225	$1,725 - $2,017
7	RR7-A	86	Infiltration Basin	Rivers Bend Park Parking Lot	RR7	0.20 - 0.32	59 - 72	0.12 - 0.15	$7,796 - $9,796	$225	$3,727 - $4,007
15	RR2-B	68	Hydrodynamic Device	Xkimo St.	RR2	0.8	322	0.0	$109,752	$630	N/A
15	RR3-B	72	Hydrodynamic Device	Waco St.	RR3	0.4	167	0.0	$55,752	$630	N/A
15	RR4-B	76	Hydrodynamic Device	Waco St.	RR4	0.5	200	0.0	$55,752	$630	N/A
15	RR5-B	80	Hydrodynamic Device	142nd LN.	RR5	0.3	111	0.0	$28,752	$630	N/A
15	RR8-A	89	Pond Modification	Rivers Bend Park	RR8	7.7	3,672	0.2	$140,840 - $215,840	$900	N/A
15	RR8-B	90	Hydrodynamic Device	142nd Ave.	RR8	0.2	108	0.0	$28,752	$630	N/A
15	RR8-C	91	Hydrodynamic Device	Xkimo St.	RR8	0.5	220	0.0	$109,752	$630	N/A
15	RR9-A	94	Hydrodynamic Device	St. Francis Blvd. and Bunker Lake Blvd.	RR9	0.7	364	0.0	$55,752	$630	N/A

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

Appendix D – Soil Information

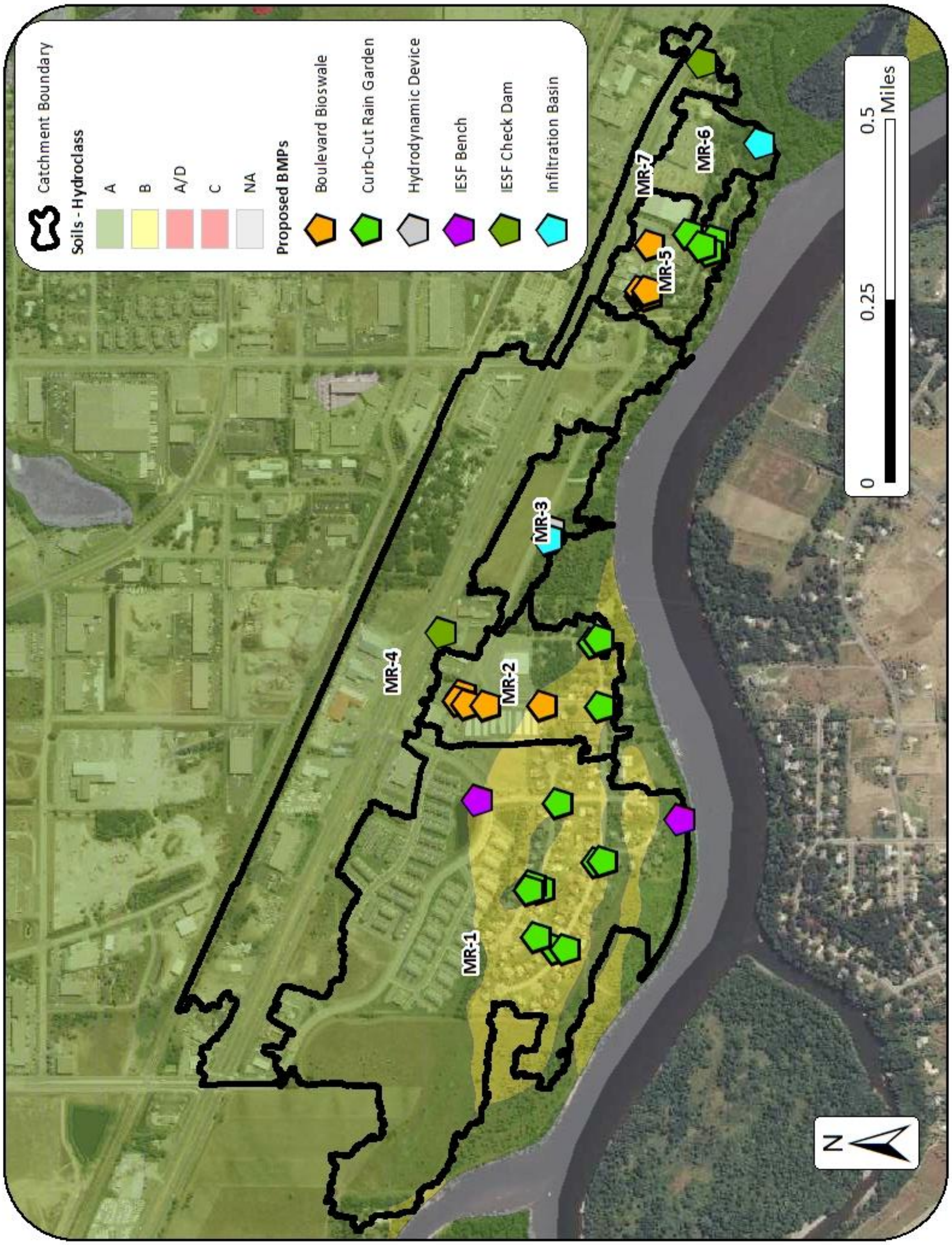

Figure 56: Soil hydroclass and proposed retrofit locations in the Mississippi River network.

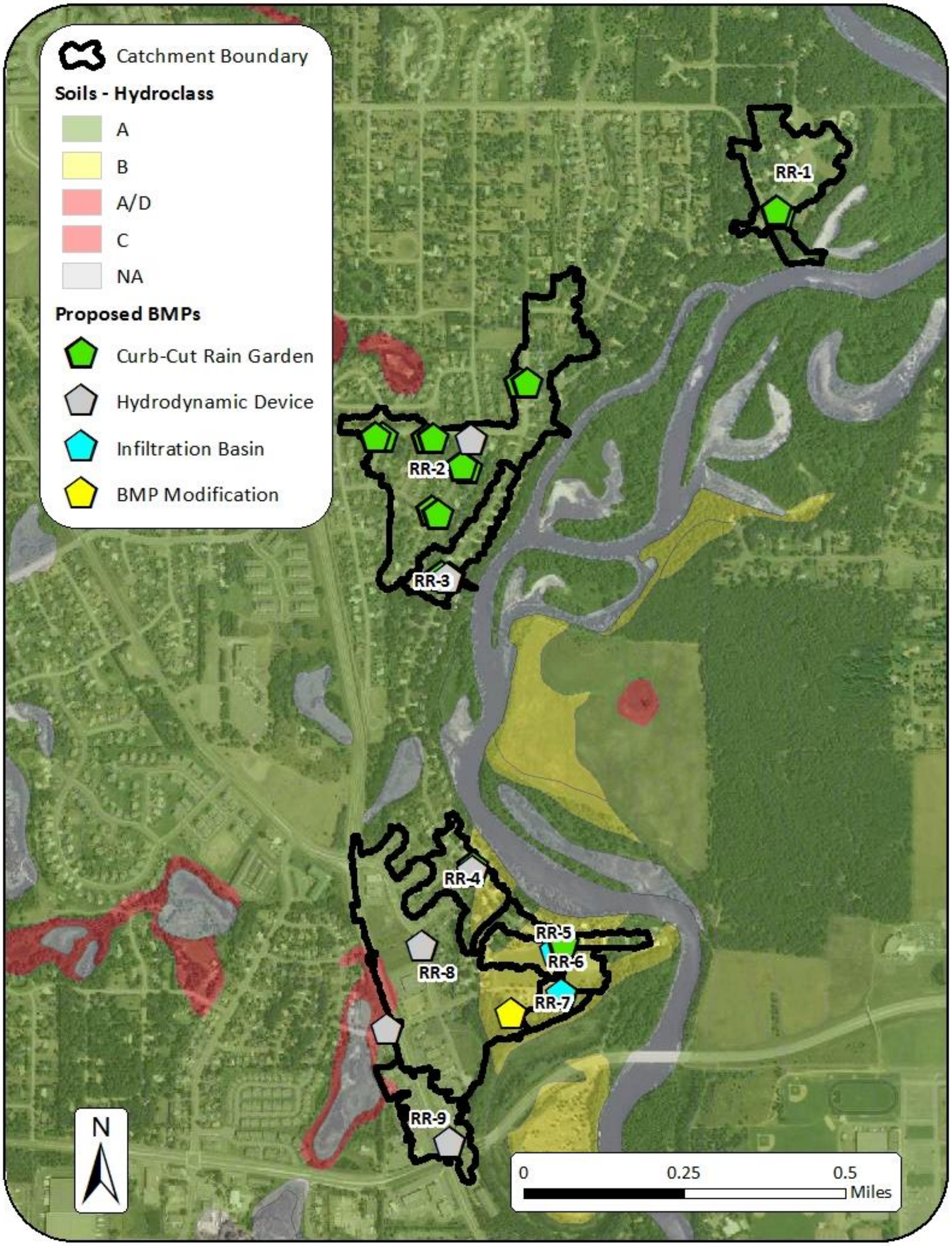

Figure 57: Soil hydroclass and proposed retrofit locations in the Rum River network.

Appendix E – Wellhead Protection Areas

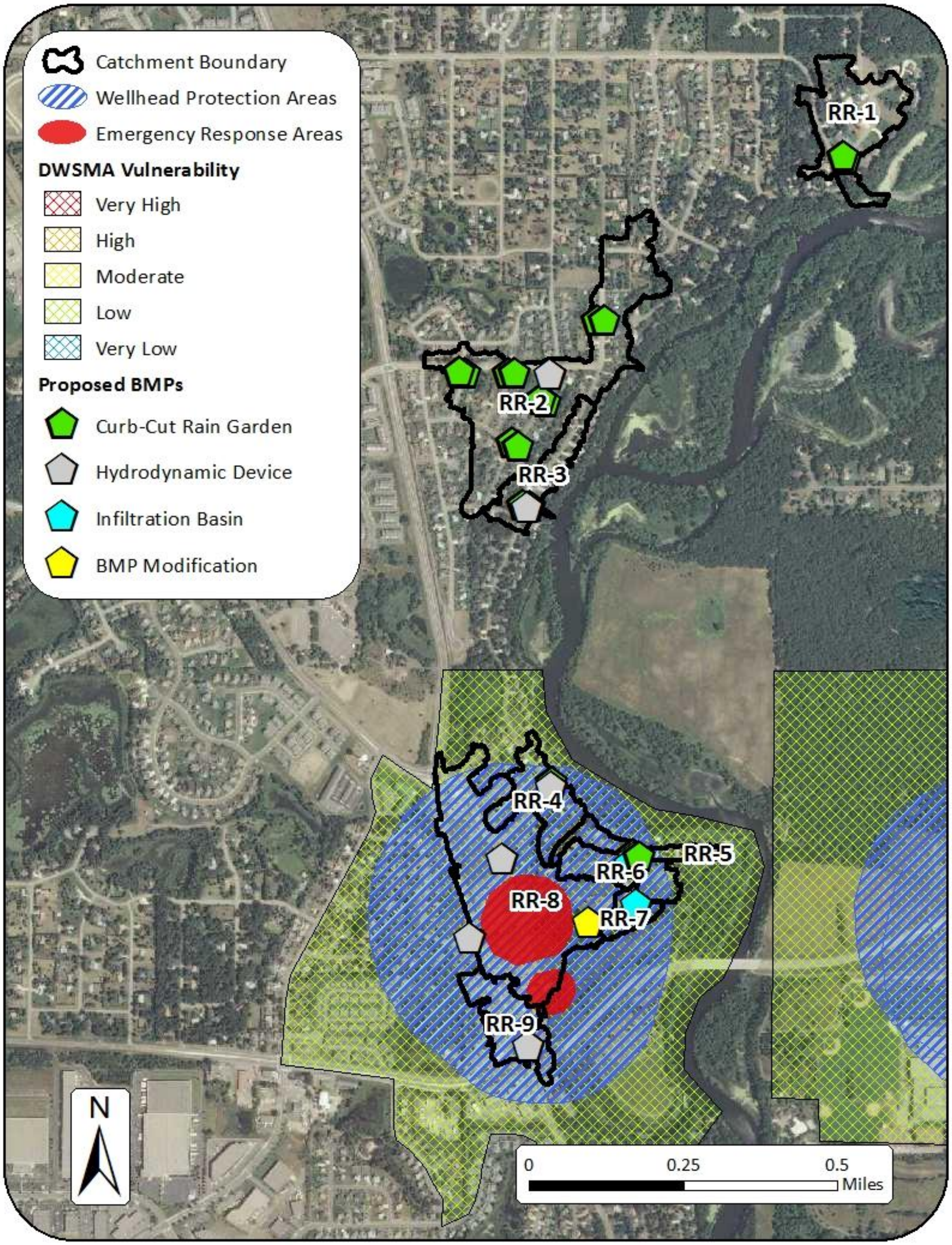

Figure 58: Wellhead protection areas and proposed retrofit locations in the Rum River network. The Mississippi River network did not overlap with any wellhead protection areas.