BROOKLYN CENTER STORMWATER MANAGEMENT GUIDE

CITY OF BROOKLYN CENTER

February 2015

Wenck File #B1241-0053

West Mississippi Watershed Management Commission

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Engineers • Scientists
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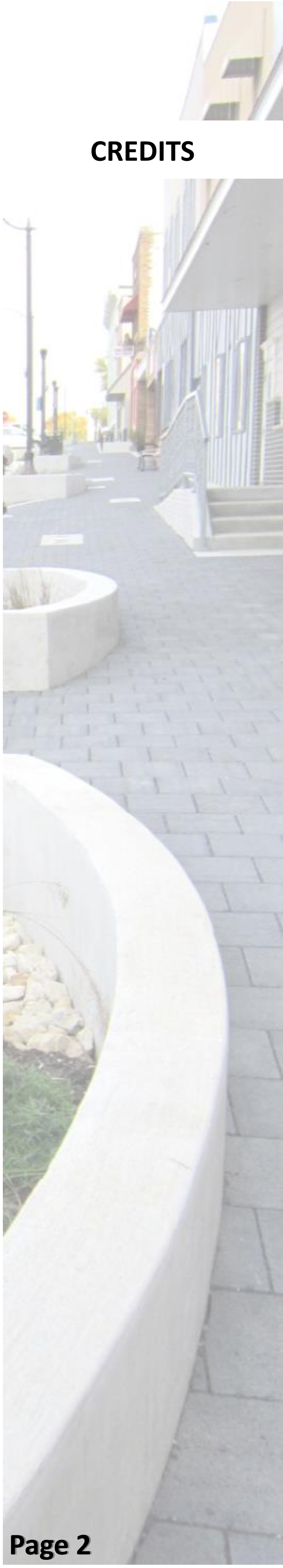

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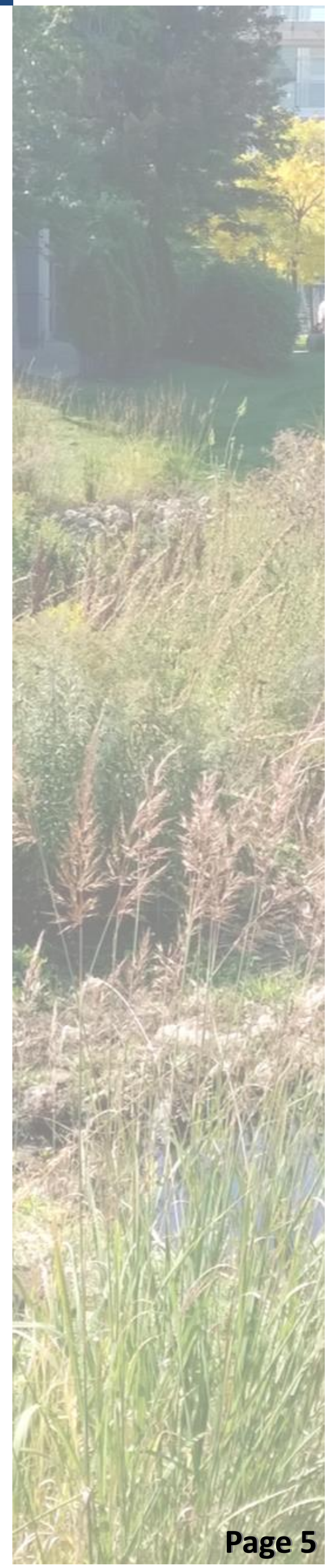
LIST OF ACRONYMS	TITLE
EPA	Environmental Protection Agency
GIS	Geographic Information System
LID	Low Impact Development
MIDS	Minimum Impact Design Standards
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
NURP	Nationwide Urban Runoff Program
ROW	Right of Way
SCM	Stormwater Control Measure
SCS	Soil Conservation Service
SSGI	Shared, Stacked-function Green Infrastructure
TMDL	Total Maximum Daily Load
TOD	Transit Oriented Development
TP	Total Phosphorus
TSS	Total Suspended Solids
WMWMC	West Mississippi Watershed Management Commission



The City of Brooklyn Center is an urban community on the Mississippi River located north of Minneapolis, Minnesota. The eastern portion of Brooklyn Center is located within the West Mississippi Watershed Management Commission (WMWMC). The WMWMC is comprised of a five-member board with representatives from each member city.

Working in collaboration with the Shingle Creek Watershed Management Commission, the WMWMC developed and adopted the Third Generation Watershed Management Plan in April 2013. This plan details the programs and projects the Commission will undertake over the next 10 years. The watershed plan details major goals and priorities that are implemented by and depend heavily on the dedication of member cities. Reducing the quantity of runoff, along with improving water quality, are the main goals of the watershed plan. The City of Brooklyn Center plans to meet these goals through effective planning and developing a cost effective capital improvement program. The City's planning effort identified stormwater control measures (SCMs) that can be utilized concurrently with street maintenance and reconstruction and/or as stand alone projects.

The Minnesota Pollution Control Agency (MPCA) is currently conducting a Total Maximum Daily Load (TMDL) study on the Upper Mississippi River for bacteria based on E. coli levels. The City of Brooklyn Center, working in collaboration with the WMWMC, has identified an area that discharges pullulated stormwater to the Upper Mississippi River. Stormwater runoff from this area has been suspected of having elevated bacteria concentrations. The Mississippi River is also impaired for turbidity. Stormwater management practices will be implemented in this area to meet the WMWMC's goals and TMDL requirements.

The City of Brooklyn Center has implemented practices to improve water quality including stormwater ponds, grit chambers, pervious pavement, and rain gardens. In addition to these stormwater management methods, this study includes SCMs purposed for multiple uses. "Shared, stacked-function" refers to situations where the infrastructure is intended to provide service for more than one parcel (public or private) and may include public interaction, art display, or water reuse. The designs use guidance from the MPCA Minimum Impact Design Standards (MIDS), a relatively new approach to stormwater management in Minnesota. Instead of using current watershed rules to design future stormwater management, designs focused on future water quality goals. The MPCA researched and developed MIDS over a number of years, and the agency has created a MIDS package of information that will allow individual communities to more easily implement MIDS principles and performance standards.

P8, a hydrology and water quality model, was used to analyze which of the Shared Stacked-Function Green Infrastructure (SSGI) practices were most feasible and effective. The model was also used to assess the overall water quality and runoff volume reduction possible with these SSGI retrofits. The SSGI were designed according to the MPCA's MIDS and have the potential to result in significant pollutant removal. If these practices are implemented the City of Brooklyn Center would reduce annual TSS loads by 32% and TP loads by 24%. Additionally these practices will help reduce bacteria levels and mitigate the effects of chloride.

This study identifies numerous opportunities to implement SSGI practices. Photos and renderings demonstrate how and where green infrastructure can be implemented and incorporated into the City's street reconstruction program. From stormwater planters to rain gardens to underground storage systems, the potential green infrastructure locations are a menu of practices that could be implemented over the foreseeable future as opportunities arise. The practices could be constructed as stand-alone projects and/or included as part of reconstruction projects.

PURPOSE

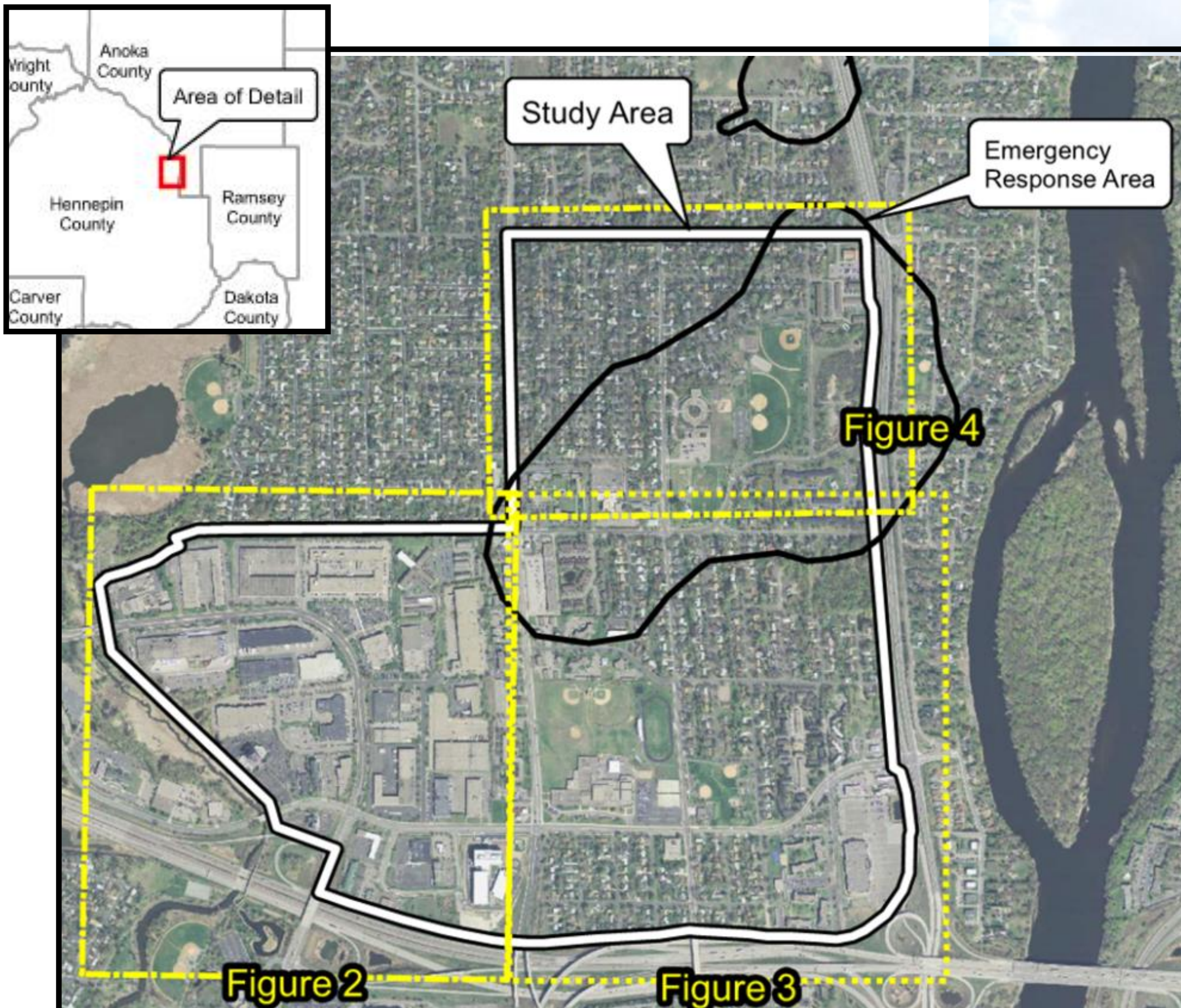
The purpose of this study is to provide a sample of options that can be used to improve stormwater management throughout the City of Brooklyn Center using SSGI. "Shared, stacked-function" refers to situations where the green infrastructure is intended to provide service for more than one parcel (public or private). The entire facility also functions to provide additional amenities beyond solely managing stormwater.

The goals of this study are to help the City of Brooklyn Center meet TMDL requirements and the goals of the WMWMC through implementation of SCMs. This is done by identifying options throughout the study area that ultimately reduce the quantity of runoff and improve the water quality to downstream waterbodies. Much of the identified area has been developed without SCMS so it presents exceptional opportunities for implementing green infrastructure. The "Shared, Stacked-Function Green Infrastructure" section of this study serves as a design guide for specific types of green infrastructure, and Appendix A provides sample green infrastructure layouts to consider.

The "Potential Locations" section should be viewed as a pallet of practices that can be constructed as stand-alone projects.

STUDY AREA

In order to promote the goals of the WMWMC Watershed Management Plan, the WMWMC provided funding for planning efforts in the City of Brooklyn Center. The area identified for potential improvement is shown below.



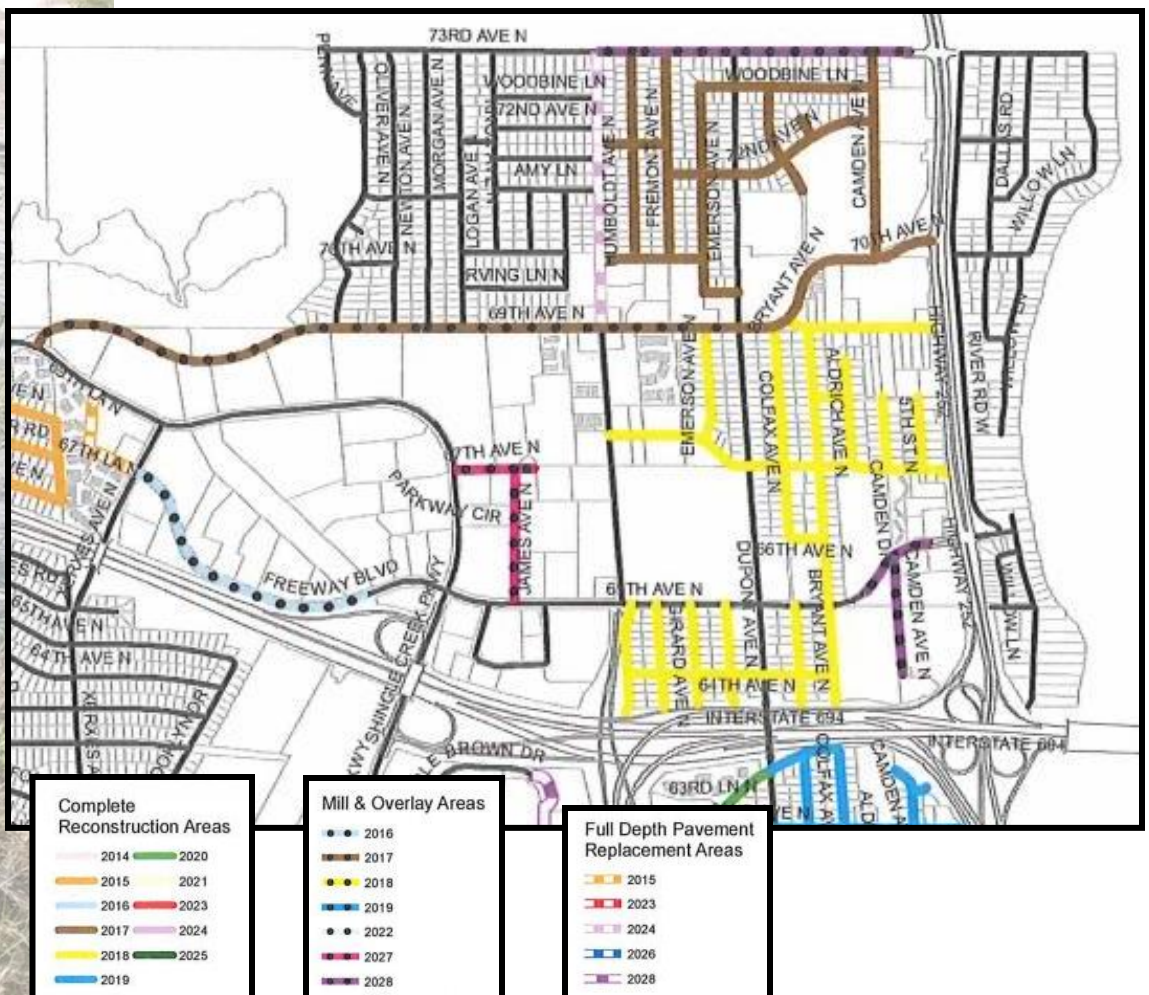
Map shows the study area (outlined in white), the Emergency Response Area (black), and several figures cutouts (yellow). The City is currently reviewing its Wellhead Protection Area and the Emergency Response Area may change in the near future.

The study area is roughly 680 acres. It is bound by Interstate 694 on the south and Highway 252 on the east. The area highlighted in red (left) is an 'emergency response area' and restricted from infiltration. Approximately 220 acres of the study area is an industrial park. Several stormwater ponds, meeting NPDES requirements, have been constructed to manage increased stormwater from development with the industrial park. The remaining 460 acres consists of light and medium residential lots, along with some schools and parks. Also included in this area are several stormwater ponds, pervious pavement, rain gardens, and infiltration basins.

BACKGROUND

STUDY AREA

The City of Brooklyn Center has identified streets for maintenance and reconstruction through 2028. As a part of this the street maintenance and reconstruction plan, the City would like to include stormwater management that meets WMWMC's stormwater management goals. Ideally, meeting these goals will parallel street reconstruction plans. The proposed reconstruction schedule for the study area is below.



Street reconstruction schedule for a portion of the City of Brooklyn Center, MN

SEEKING WATER QUALITY IMPROVEMENT

The City of Brooklyn Center has developed programs to improve water quality throughout the City. One program is the residential rain garden program. This program promotes green infrastructure and local stormwater management through education and sponsored development. The City has coordinated its efforts with Metro Blooms, a local organization.

Metro Blooms offers workshops that teach residents how to practice healthy and environmentally friendly management of yard products; the workshop focus on yard products such as waste, fertilizer, and salt. Participants are also guided through designing a rain garden for their property.

In the past, the City has coordinated with residents during street reconstruction to design and install rain gardens in neighborhoods; once installed, the rain gardens are maintained by residents. As a result, the City has coordinated the construction of seven rain gardens within the study area and many more throughout Brooklyn Center.

Curb Cut Rain Garden in Brooklyn Center , MN

FRAMEWORK

MINIMUM IMPACT DESIGN STANDARDS

- *MIDS represent the next generation of stormwater management*
- *A higher clean water performance goal for new development and redevelopment that will provide enhanced protection for Brooklyn Center's water resources.*
- *Retaining 1.1 inches of runoff on-site from all impervious surfaces will effectively reduce increases in runoff rate, volume and pollutant load to presettlement conditions.*

Stormwater management in urban areas has evolved substantially over the past 20 years. Historically, the goal was to move water off the landscape quickly to reduce or eliminate flooding. Now, stormwater professionals focus on keeping a raindrop where it falls to mimic natural hydrology and to minimize the amount of pollution reaching our lakes, rivers, and streams and to recharge groundwater.

In 2009, the Minnesota Legislature allocated funds to "develop performance standards, design standards or other tools to enable and promote the implementation of low impact development and other stormwater management techniques." Minimum Impact Design Standards (MIDS) represent the next generation of stormwater management and is based on low impact development (LID). LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product.

Island curb cut raingarden Maplewood Mall, MN

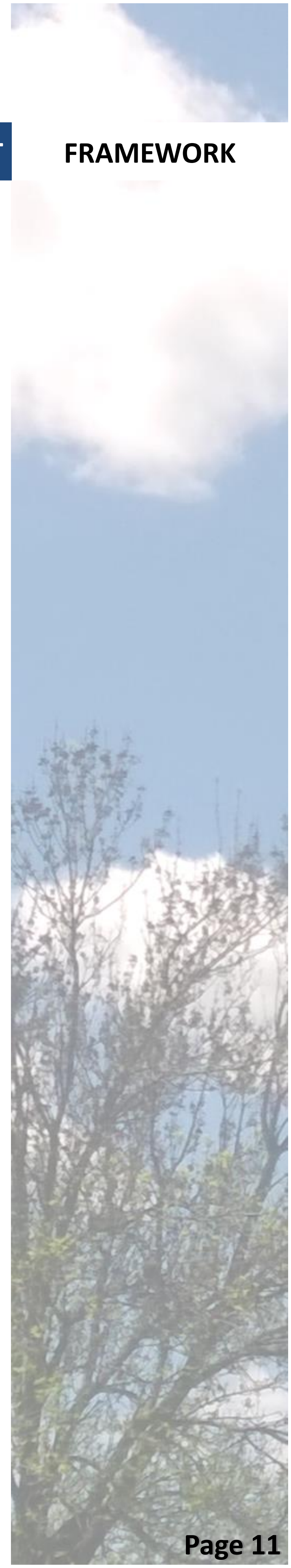
Many practices have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed to reduce the impact of built areas and promote the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

Using the LID approach, the MIDS study determined that retaining 1.1 inches of runoff on-site from all impervious surfaces will effectively reduce increases in runoff rate, volume and pollutant load to presettlement conditions.

NPDES MUNICIPAL PERMIT

The Municipal Separate Storm Sewer System Permit (MS4) was originally issued in 2006 to address the federal Phase II National Pollution Discharge Elimination System (NPDES) stormwater regulations for small MS4s. The MS4 permit has since been updated to further comply with and exceed the standards set forth in the NPDES. The municipal MS4 permit now requires no increase in runoff volume, total suspended solids (TSS), and total phosphorus (TP) for new development, and redevelopment must reduce runoff volume, TSS, and TP discharged from the site.

MIDS is more stringent than the NPDES requirements because it attempts to manage stormwater to presettlement conditions rather than existing conditions under the NPDES permit.



SSGI

Cistern

Stormwater planter

Tree trench

Bioretention

Underground infiltration

Infiltration trench

Pervious pavement

Minnesota filter

SHARED STACKED-USE GREEN INFRASTRUCTURE

Communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities using green infrastructure. Typically stormwater infrastructure serves only a single purpose: to dispose of runoff. Green infrastructure uses vegetation and soil to manage rainwater where it falls. Modern engineering practices can entwine natural processes with fabricated environments to provide stormwater management, flood mitigation, improved air quality, groundwater recharge, and improved downstream conditions.

A wide scale of options are available within the realm of green infrastructure. The Low Impact Development (LID) approach to stormwater management incorporates green infrastructure as well as traditional best management practices (BMP). “Shared, stacked -function” refers to designs that intend to provide service to more than one parcel (public or private) and the entire facility may function to provide additional amenities including artwork, public interaction, and green space. Examples of green infrastructure are presented below. Specific uses for these technologies are summarized in the “SSGI Locations” section.

SSGI

USE IN COLD CLIMATES

In Minnesota, stormwater management includes managing rainfall as well as snowmelt, whose characteristics are very different. Design criteria focusing on rainfall runoff may not work well during cold periods resulting in increased maintenance costs. In years when snowfall is high, this becomes a major concern because a substantial percentage of annual runoff volume and loading can come from snowmelt.

A thorough description of the science of snowmelt and recommended management approaches can be found in the Minnesota Stormwater Manual. This description includes and reports that the trend toward LID and SSGI shows a great deal of promise for snowmelt management. LID is effective because it relies on the natural interaction between runoff and soil biology. The manual discloses that SSGI such as permeable pavement, bioretention, and road drainage infiltration systems are effective under cold climate conditions with proper maintenance.

Road salt application is an ever-increasing challenge for stormwater managers. Shingle Creek, which flows through the City of Brooklyn Center, has an approved TMDL for chloride primarily due to winter road salt use. High chloride concentrations damage and kill vegetation planted in bioretention, stormwater planter and tree trench systems. Vegetation is a key ingredient to the performance of these systems. The following table from the Minnesota Stormwater Manual lists cold climate vegetation of the upper midwest with known salt tolerance (sorted by growth form). These species should be considered for stormwater planters and tree trenches exposed to high chloride concentrations.

Species	Soil Moisture	Salt Tolerance	Growth Form	Notes on Use
American Elm	Always Wet/Frequently	Medium/Low1	Tree	
Green Ash	Always Wet	Medium1	Tree	
Hackberry	Frequently Saturated/ Mostly Drained	Medium	Tree	
Jack Pine	Mostly Drained	High1	Tree	
Poplars	Frequently Saturated/ Mostly Drained	Medium1	Tree	Including aspen, cottonwood, black and silver-leaved poplar; fast growing; also provide good streambank stabilization; highly
White Ash	Frequently Saturated/ Mostly Drained	High1	Tree	
Cutleaf Sumac	Mostly Drained	High	Shrub	
Smooth Sumac	Mostly Drained	Medium	Shrub	Colonizes and spreads in high sun
Staghorn Sumac	Mostly Drained	High	Shrub	
Canada Wild Rye	Frequently Saturated	Medium	Herbaceous Grass	
Karl Foerster Reed Grass	Frequently Saturated/ Mostly Drained	High	Herbaceous Grass	This is a cultivar for landscaping
Alkali Grass	Mostly Drained	High	Herbaceous Grass	
Blue Gramma Grass	Mostly Drained	High	Herbaceous Grass	Selections being made for strongly salt-tolerant varieties; see
Little Bluestem	Mostly Drained	High	Herbaceous Grass	
Perennial Ryegrass	Mostly Drained	Medium	Herbaceous Grass	
Seed Mix: MN DOT Urban Prairie	Mostly Drained	High	Herbaceous Grass	
Seed Mix: MN DOT Western Tall	Mostly Drained	Medium	Herbaceous Grass	
Tall Wheatgrass	Mostly Drained	High	Herbaceous Grass	
Western Wheat Grass	Mostly Drained	High	Herbaceous Grass	

Underground Infiltration Basin

Infiltration Trench

Infiltration Manhole

Underground Filtration Basin

Filtration Trench

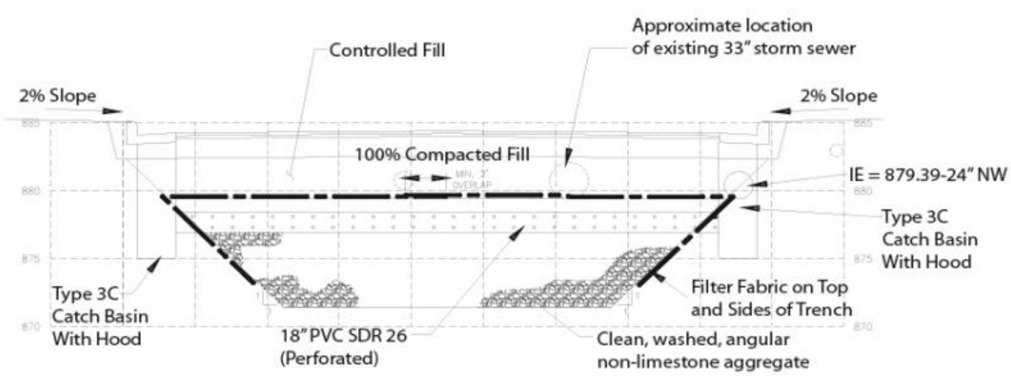
UNDERGROUND INFILTRATION/FILTRATION

Underground infiltration is a versatile stormwater management technique where space is limited, and is most suitable for highly urban areas or areas with large parking lots. Underground infiltration consists of perforated pipes or cisterns placed beneath a parking lot or open area. An example is shown below.

A cut view of an underground infiltration system. This system may be placed under a parking lot, park or other area to accommodate storage and infiltration of runoff.

Stormwater runoff is directed to this area via storm sewer for storage and infiltration. A manhole, filter, or hydrodynamic device provides pretreatment for runoff entering the storage area. In large storm events, the storage volume above the outlet reduces flow rates and discharge is directed into the storm sewer. Large angular rock (1-3 inches) surrounds the perforated pipes and provides additional storage capacity and structural stability for soils above. The design can be modified to include a filtration layer when infiltration is not practical. The system is designed to infiltrate within 48 hours.

Street replacement also provides an opportunity for this type of shared, stacked-function green infrastructure. Infiltration trenches can be placed beneath roads where no utilities are present. Runoff is directed to the underground system using perforated pipes, and when the system is saturated, runoff is conveyed back through the existing storm sewer (see cross section below). When a road is being replaced, the underground infiltration can be added to the project to reduce downstream pollutant loads. Maintenance includes periodic removal of sediment accumulated in the pretreatment devices. Sediment deposition should not be more than 1 foot in depth.



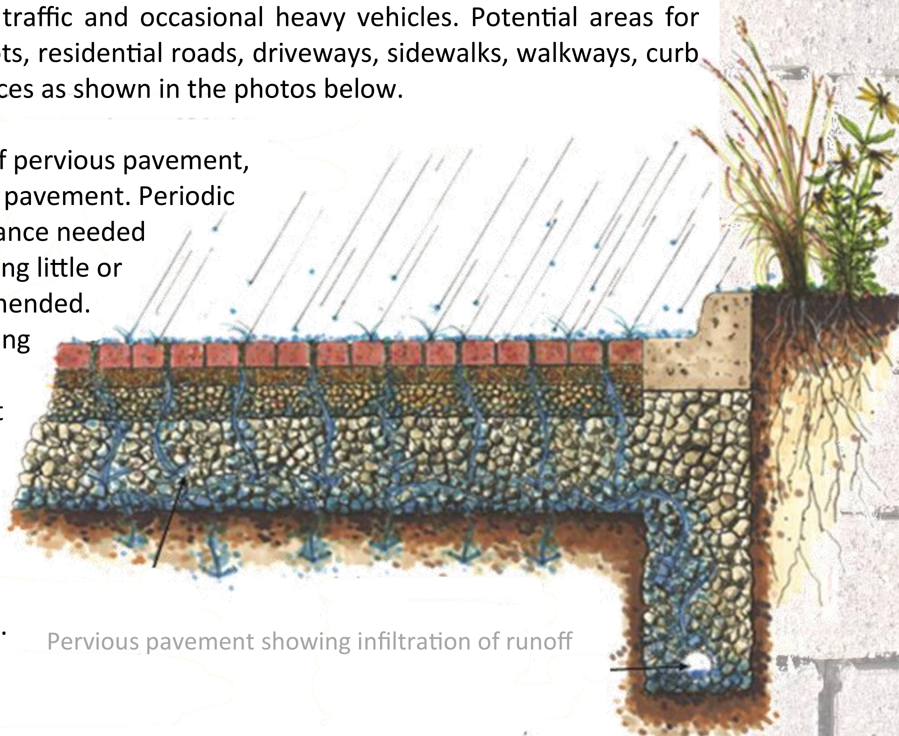
Cross section of an infiltration trench beneath the road.

PERVIOUS PAVEMENT

Pervious pavement has several different designs that follow the same general structure and result in reduced runoff volumes. Impervious pavement (concrete or asphalt) is replaced with a material that allows water to pass through to the sub-base. The subbase consists of an angular rock with large void spaces to temporarily store and infiltrate water that passes through the pervious pavement above. This method of pavement construction provides a means of infiltrating runoff from paved surfaces as well as any other contributing surface areas. The figure below is an illustration of pervious pavement and how water flows through it.

While pervious pavement remains unproven for heavy traffic, trucks, and high speeds, it is well-suited to handle light traffic and occasional heavy vehicles. Potential areas for implementation are parking lots, residential roads, driveways, sidewalks, walkways, curb islands and other similar surfaces as shown in the photos below.

To ensure long performance of pervious pavement, it is important to maintain the pavement. Periodic vacuuming is the key maintenance needed for pervious pavement and using little or no salt in the winter is recommended. Studies have shown that de-icing chemicals can be reduced or eliminated because snow-melt and ice infiltrates rather than refreezing. Maintenance of the surrounding landscaped areas will also ensure that the pavement does not become clogged with eroded sediment.



Pervious pavement showing infiltration of runoff

Images of pervious pavement in a parking lot (A) and low traffic areas (B).

PERVIOUS PAVEMENT

Pervious pavement has recently been shown to reduce the need for de-icing on roadways. In the images below, a section of porous asphalt is outlined in black. The image shows snow accumulating on the traditional pavement but not on the porous section. Snow and ice build-up is reduced substantially by pervious pavement, which allows municipalities to avoid applying salt as frequently. With recent increases in salt prices, pervious pavement in low traffic areas may be a valuable and a long-lasting alternative to salt application.

How snow accumulates on porous and traditional pavement in Robbinsdale, MN.

STORMWATER RESUSE

SSGI

Stormwater reuse is the practice of collecting rain water from impermeable surfaces and storing it for future use. There are a number of systems used for the collection, storage and distribution of rain water including rain barrels, cisterns, evaporative control systems, and irrigation.

Stormwater reuse facilities fit the shared, stacked-function mold by conserving groundwater, saving money through reduced groundwater pumping and treatment, and reducing pollutant loads to local lakes and rivers. Most commonly, these systems capture "free water" from a local pond and irrigate (after filtering) green space.

Recently implemented at the Maplewood Mall in Maplewood, MN (below), a large above-ground cistern was installed at the mall entrance to capture roof runoff. The Maplewood Mall cistern has a pump handle that, when pumped, cascades water down over a series of spinning gears and chimes and into an infiltration area. The system also serves to educate shoppers on stormwater management techniques and conservation. A tiled collage on the mall's wall provides an artistic background that illustrates an urban water cycle.

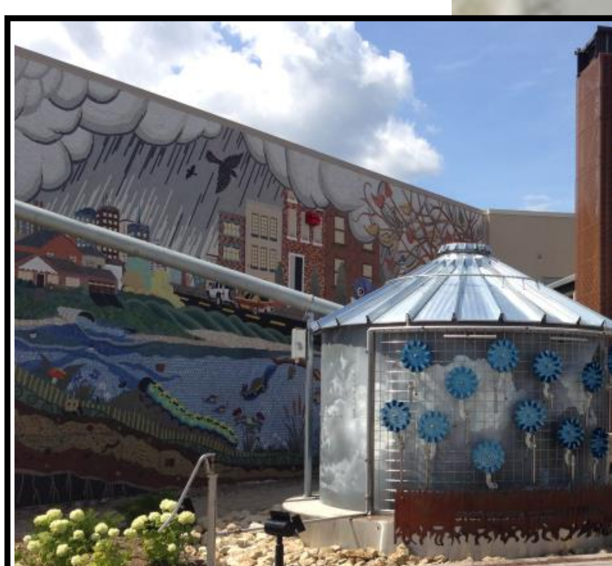
Cisterns are not always the most cost effective means of managing stormwater. However, many cities encourage residents to reuse water by providing rain barrels at reduced or no cost to the users. This can be especially effective at providing opportunities for public involvement and art.

Cisterns can be used in tandem with other SSGI

City opportunities to promote stormwater reuse with its residents

Public awareness and artwork

Cistern and artwork at the Maplewood Mall, MN



STORMWATER PLANTER (URBAN RAIN GARDEN)

Recommended vegetation for stormwater planters:

Flowers
- *Marsh Milkweed*
- *Iris variety*
- *Blue False Indigo*
- *Great Blue Lobelia*
- *Wild Bergamot*

Grasses & Rushes
- *Karl Foerster Reed Grass*
- *Soft Rush*
- *Hardstem Bulrush*
- *Little Bluestem*

Sedges
- *Tussock Sedge*
- *Hop Sedge*
- *Palm Sedge*

Shrubs
- *Red Osier Dogwood*
- *American Cranberry Bush*
- *Arrowwood*
- *Pussy Willow*
- *Nannyberry*

Trees
- *River Birch*
- *Hackberry*
- *Honey Locust (thornless)*
- *Swamp White Oak*

Stormwater planters (also referred to as urban rain gardens) are a familiar practice in urban areas to collect and infiltrate rainwater runoff. They are typically shallow depressions surrounded by poured concrete or landscaping block walls with soil engineered to quickly infiltrate water (within 48 hours).

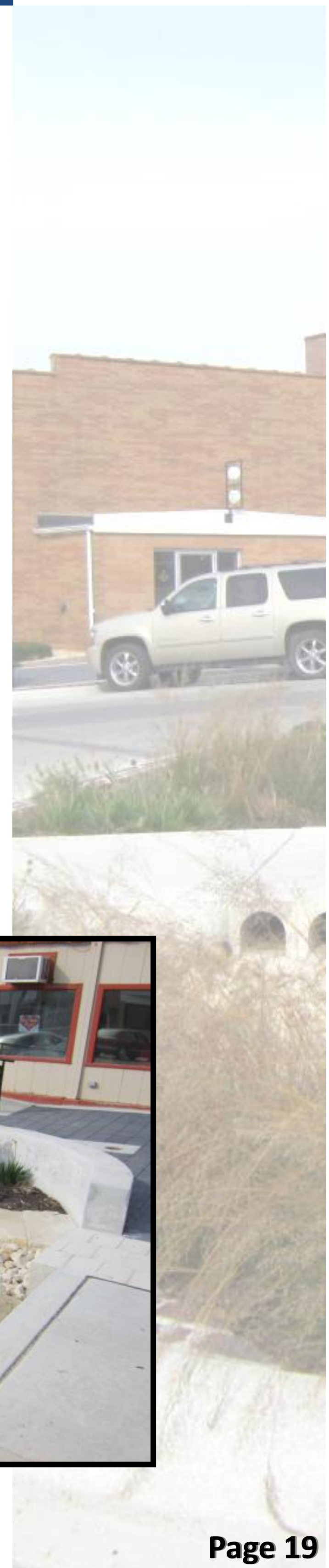
Effective stormwater planters have vegetation that is accustomed to changes in moisture availability and known to remove pollutants. Stormwater planters are placed along roads and with an opening in the curb, allowing runoff from parking lots, sidewalks, and roads to enter the planter to be treated and infiltrated. The sidebar photo and the photo below show stormwater planters from West Union, IA. Stormwater planters vary is size and shape but operate similarly. Runoff enters through the curb cut. When filled, runoff will bypass the planter and continue to the next downstream catch basin, pipe, or pond.

Pretreatment for stormwater planters is required by the Minnesota Pollution Control Agency (MPCA) to filter large debris and particles from runoff prior to entering the planter. Pretreatment options for stormwater planters include sumped catchbasins, forebays, or proprietary devices (i.e. Rain Guardian or Stauner sediment trap).

The design and maintenance of stormwater planters is similar to curb cut rain gardens. Stormwater planters can be located on or near storm sewer catch basins. Placing the curb cut upstream of the catch basin allows runoff to first enter and fill the stormwater planter before overflowing into the storm sewer. Maintenance includes mulch, trash removal, seasonal plant trimming, and plant replacement.

Stormwater planters have also been recently implemented on the Green Line between Minneapolis and St. Paul. The planters add needed green infrastructure into the 100% impervious corridor of University Avenue in St. Paul.

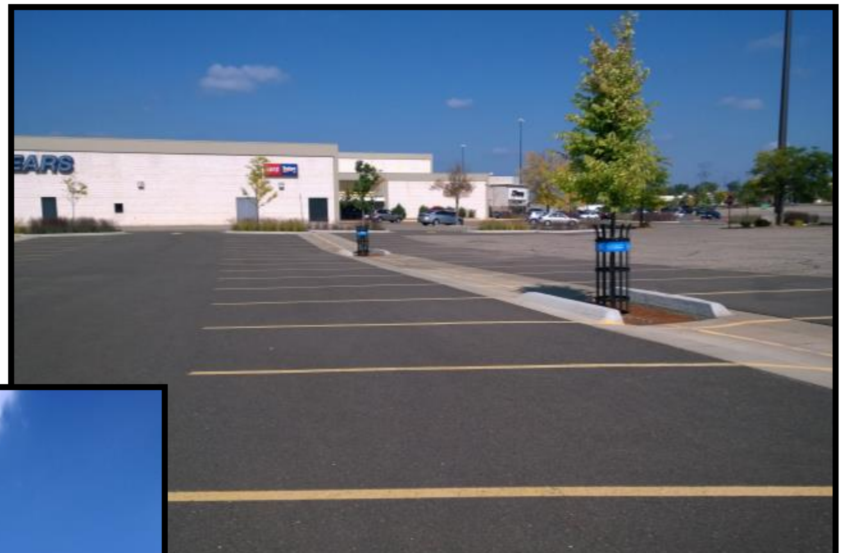
Stormwater Planter in West Union, IA



Stormwater Planters in West Union, IA

TREE TRENCH

Tree trenches provide underground storage for runoff while increasing green space on the surface. These practices are aesthetically pleasing and great for largely paved areas like roads, parking lots, and sidewalks. Below is an example of a fully functioning tree trench system in the Maplewood Mall parking lot. The trees spring up from the pavement while stormwater is directed underground.



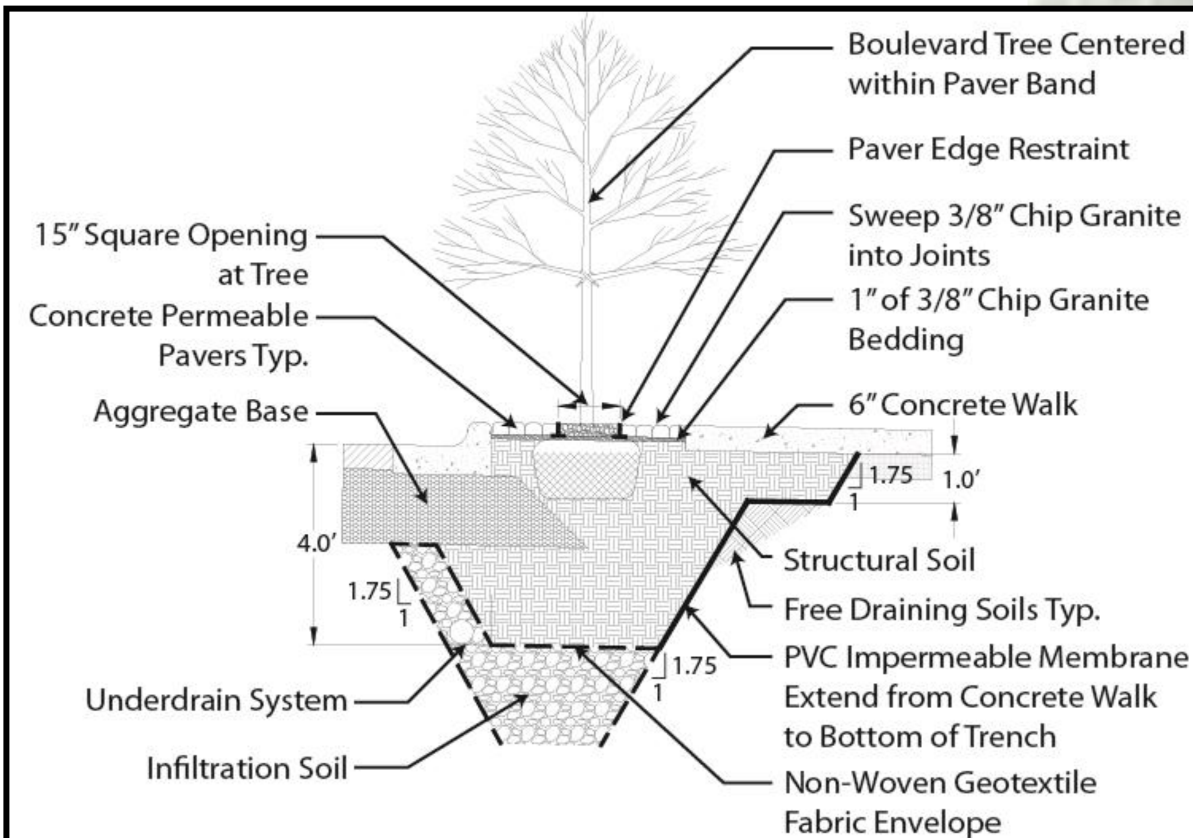
Tree Trenches installed in the Maplewood Mall parking lot.

The Ramsey Washington Metro Watershed District (RWMWD) installed this tree trench system in the Maplewood Mall parking lot as part of a redevelopment effort. In this application, the tree trench extends between parking lot islands and below drive lanes and parking stalls. Trench drains connect parking lot islands and collect runoff from the parking lot to be stored and infiltrated in the engineered media below the parking lot surface.

A common design in Europe is known as the Stockholm Tree Trench Method and was developed to provide suitable growing conditions for trees in highly urbanized environments. This method includes media with 2-4 inch angular rock layers that can support tree roots and provide storage for runoff .

To help sustain the growth of the trees in an urban environment, special measures are needed. The tree trenches installed by RWMWD used a patented structural soil developed by Cornell University. CU-Structural Soil™ (also known as CU-Soil™) was developed as a way to safely bear pavement loads after compaction and yet still allow root penetration and vigorous tree growth. The figures show healthy young trees in an entirely impervious landscape.

The Capitol Region Watershed District (CRWD), City of St. Paul and Metropolitan Council recently installed tree trenches on the Green Line in St. Paul. These trees are buried in a soil engineered to support the tree root system and collect runoff from the surrounding area. A cross-section of the design is shown below.



Example tree trench cross section used in St. Paul, MN

Maintenance of tree trenches is similar to other vegetated stormwater management. Newly planted trees need to be watered regularly. According to Johnson et al. 2008, trees need 1.5 gallons of water per inch of trunk diameter when soil is dry. This watering should be sustained for the first three years after planting. Young trees should also be protected from rodents by installing plastic tubing or mesh that extends 1 to 2 feet above the snow line. Trees should be pruned once (1) in each year 2 and 3, every three (3) years up to 10 years, and every five (5) years after that. Periodic removal of sediment from pretreatment sumps and removal of trash and debris will improve the longevity of the trenches.

BIORETENTION / INFILTRATION/FILTRATION BASIN

Recommended vegetation for bioretention:

Flowers
- *Cardinal Flower*
- *Daylily var.*
- *Iris variety*
- *Great Blue Lobelia*
- *Purple Conefl ower*
- *Wild Bergamot*
- *Purple Prairie Clover*

Grasses
- *Sideoats Gramma*
- *Little Bluestem*
- *Prairie Dropseed*
- *Karl Foerster Reed Grass*

Sedges
- *Palm Sedge*
- *Sun Sedge*

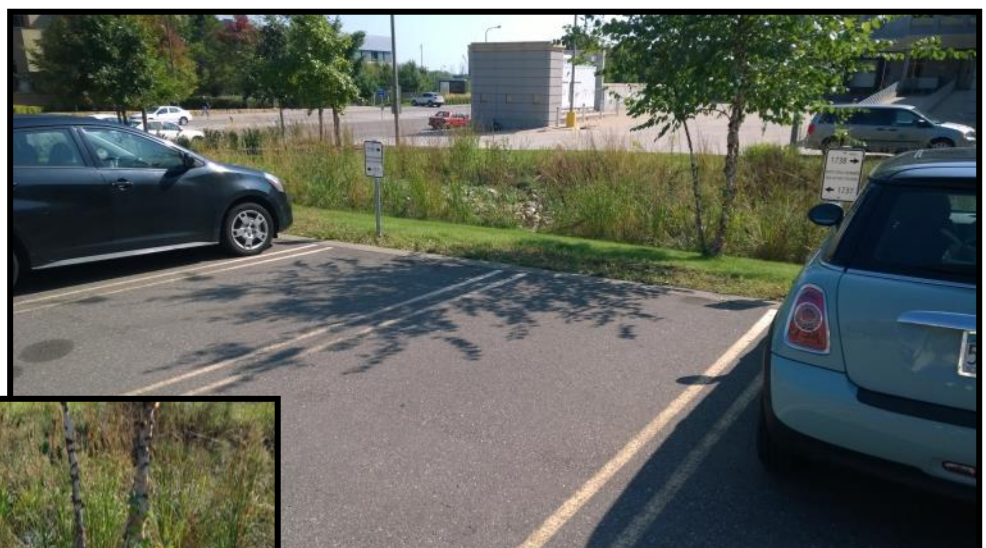
Shrubs
- *Dawrf-bush Honeysuckle*
- *Red Osier Dogwood*
- *American Cranberry Bush*
- *Arrowwood*

Trees
- *Sugar Maple*
- *River Birch*
- *Swamp White Oak*

Bioretention basins combine surface storage, infiltration, biological treatment, plant uptake, and evapotranspiration into a single green infrastructure. Stormwater is collected into the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic or mulch layer, planting soil, and plants. The bioretention system incorporates the more natural means of managing stormwater than any other treatment type.

Opportunities to include bioretention systems in the landscape include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and streetscapes (i.e., between the curb and sidewalk). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. Maintenance activities typically include sediment removal and maintenance of the vegetation. Invasive species need to be managed, dead vegetation must be removed, and dead plants must be replaced.

The picture below shows a bioretention basin along the perimeter of a parking lot in downtown St. Paul. Note the ribbon curb that defines the edge of the pavement but also allows runoff to flow over the curb, through the vegetated buffer and into the bioretention basin.



Bioretention basin along a parking lot in St. Paul, MN

Similar to other green infrastructure, public art can be incorporated into bioretention practices. The picture below demonstrates how a bioretention basin in Oakdale, MN incorporated public art into the retaining walls and flow path. The decorative retaining walls create a “stepped” system that allows water to infiltrate or overflow to the next downstream step. The picture at the bottom of the page shows the circular pretreatment sump at the upstream end of the steps and the decorative concrete spheres in the concrete flume that carries concentrated flow from the overflow of each step.

Bioretention “steps” in Oakdale, MN

Pretreatment sump (at right) and concrete flume in Oakdale, MN

MINNESOTA FILTER

The Minnesota filter can be designed in two different ways; to improve the removal efficiency of ponds (filtration bench) or as filtration basins (filter layer). Both designs combine iron filings with sand to target the removal of dissolved phosphorous, organic material, and other contaminants. The images below show applications for the filtration basin design. The engineered media in the Minnesota filter contains oxidized iron filings which bind strongly with dissolved phosphorus and organics. By trapping organics, this technology may be specifically effective at reducing bacteria loads. As runoff passes through the filter media, those pollutants in the runoff bind to the iron thus removing the target contaminants. The removal efficiency of the filter varies with age. However, Minnesota filters remove an average of 60 percent of the total phosphorus in stormwater runoff. They are expected to have a lifespan of 35 years under regular maintenance, at which point the filter media would need to be replaced.

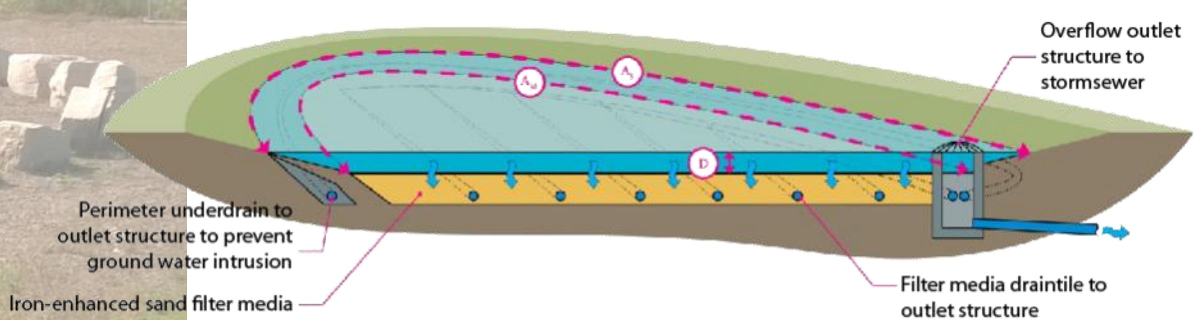
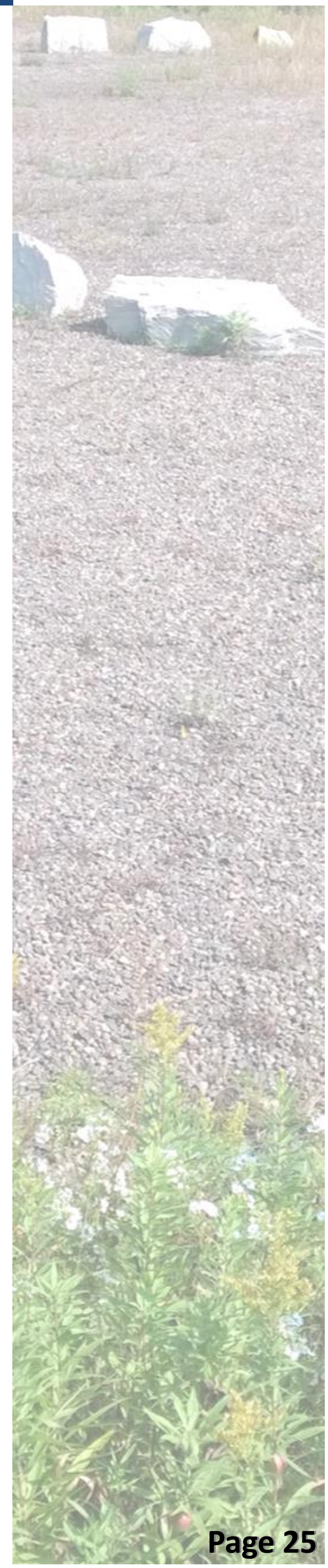


Image of Minnesota filter showing overflow structures and underdrain. This SSGI is able to remove pollutants like phosphorus and organic material.

Dry Minnesota filtration basin in the Ramsey -Washington Metro Watershed District

MINNESOTA FILTER



Minnesota filters can be implemented as a stand-alone filtration basin. The photos from the previous page are an example of a Minnesota filtration basin near the Maplewood Mall. The filtration basin design is ideal in locations where infiltration is either not practical or possible due to stormwater “hotspots”, existing contamination or high groundwater. Hotspots typically occur on commercial, industrial, institutional, municipal or transportation related sites that may produce higher levels of stormwater pollutants, and/or present a higher potential risk for spills, leaks, or illicit discharges.

Typical stormwater ponds are effective at removing particulate phosphorus and total suspended solids. One way to increase the dissolved phosphorus removal within a stormwater pond is to install a Minnesota filter in a treatment train with the stormwater pond as shown in figures below. In the treatment train system, runoff is collected in the pond, which acts as pretreatment. Suspended solids and debris settle out of the water while in the pond. As the pond fills, water is filtered through the media and exits the system through an underdrain. A secondary outlet above the filter provides rate control and prevents flooding.

The two images show a Minnesota filter bench system before and after a storm event. As the pond fills with water from a storm it begins to enter the iron filter.

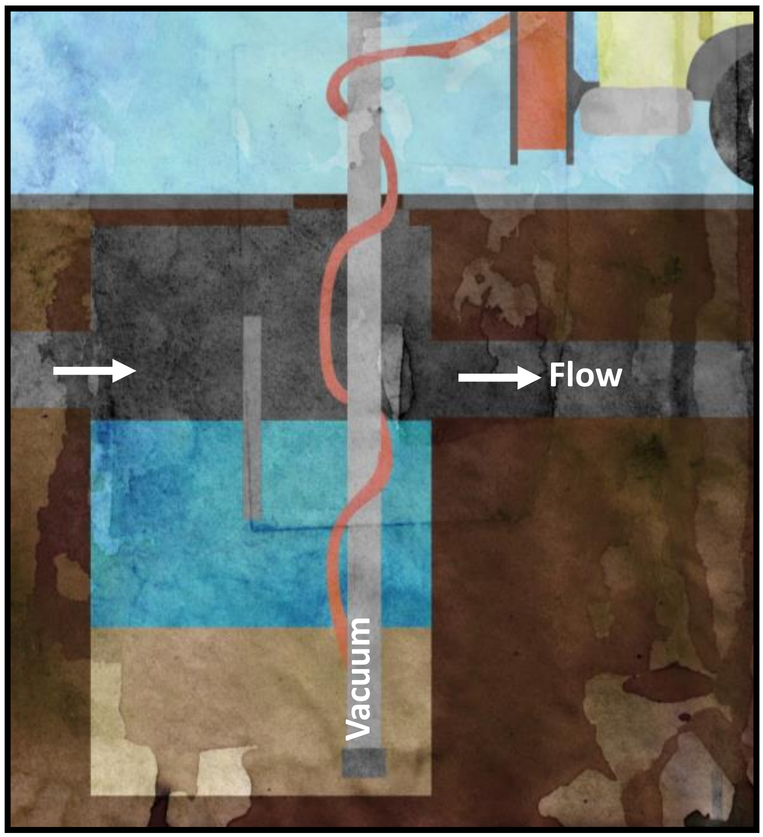
Regular weeding and removal of debris from the filter material will maintain functionality. When the effluent from the Minnesota Filter consistently exceeds 60 to 70 micrograms per liter the sand bed may need to be replaced. It is recommended that the filter material be tested at this point to determine if the iron is viable for trapping pollutants. The life expectancy of these systems can range from 5 to 20 years. Typical urban runoff will not cause the material to be “hot.” The filter material can be disposed on normally in most cases.

GRIT CHAMBER

A grit chamber is constructed in-line with the storm sewer and serves to trap sediment and debris. Grit chambers can be designed in many different ways including using prefabricated units. The City of Brooklyn Center has a large prefabricated Vortech grit chamber that receives diverted runoff from the storm sewer. Solids are separated in the system and water returns to the storm sewer.

One simple grit chamber design that is commonly used in Minnesota is a sumped catch basin or manhole. By adding a three foot sump (or deeper) and a device that prevents suspension, sediment and other debris settle to the bottom and can be removed suing a vacuum truck. These small, inline systems can be used in series to increase sediment removal.

There are a few proprietors that offer retrofit designs to sumped catchbasins and manholes. The SAFL Baffle, produced by Upstream Technologies, is one such technology. In this design, a steel plate with holes is added to the manhole perpendicular to the direction of flow. This is done to slow down flow and increase the time that water has to settle out particulates. This can further increase the sediment removal efficiency.



A sumped catch basin with a SAFL Baffle. Image from Upstream Technologies

Grit chambers need regular maintenance in order to be effective. A vacuum truck is needed to remove accumulated sediment. It is good practice to clean grit chambers during the spring thaw and throughout the summer season. Grit chambers that are not maintained properly may cause previously trapped sediment to re-suspend which acts to increases pollutant loads rather than decrease them.

CITY OF BROOKLYN CENTER METHODS

Wenck evaluated stormwater runoff in the study area by reviewing existing conditions using Geographic Information Systems (GIS) and data provided by the City. Wenck modeled the area hydrology and water quality using the computer program P8. A model was created for both existing conditions and with future possible green infrastructure. Green infrastructure was added to the existing condition model as an example of the potential for runoff volume and pollutant loading reductions in this area of Brooklyn Center.

P8 COMPUTER MODEL

P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds) is a computer model used for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. P8 is a useful diagnostic tool for evaluating and designing watershed improvements like green infrastructure. The model requires a user to input watershed characteristics, green infrastructure dimensions, local precipitation and temperature, and water quality parameters.

P8 calculates runoff separately from pervious and impervious areas. Calculations for pervious areas use the Soil Conservation Service (SCS) Curve Number (CN) method. Runoff from impervious areas begins once the cumulative storm rainfall exceeds the specified depression storage, with the runoff rate equal to the rainfall intensity.

The P8 model uses an hourly precipitation record (rain and snowfall) and daily temperature record. Precipitation and temperature data were obtained from the Minneapolis-St. Paul International Airport. Records from 2001 to 2010 were used for this study.

Wenck selected the NURP50 particle file for this study. The component concentrations in the NURP50 file represent the 50th percentile (median) values compiled in the EPA's Nationwide Urban Runoff Program (NURP).

EXISTING CONDITIONS

Wenck created the existing model to mimic the watershed as it is today by routing runoff through the storm sewer, stormwater ponds, and infiltration basins. However, the majority of the watershed is collected in storm sewer and discharged to the Mississippi River untreated. Green infrastructure with small watersheds such as rain gardens and pervious sidewalks were not included in the model. This smaller green infrastructure is valuable to the watershed but adds a level of detail that is not consistent with large scale models. The existing model also does not include the large grit chamber in the Cinema parking lot because swirl separators are not simulated by P8.

The majority of the watershed drains to the east and into the Mississippi River while a small portion drains west to Shingle Creek. The area can be broken into two distinct areas: the eastern portion is mostly residential and park land and the western portion of the site is an industrial park with large amounts of impervious area.

The study area existing condition generates approximately 211,000 pounds of TSS, and 750 pounds of TP annually. This estimate includes the expected removals due to larger existing green infrastructure in the study area comprised of twelve privately owned stormwater ponds. These ponds are located in subwatersheds N-01, S-01, two in S-06, two in S-11, S-12, S-13, S-18, S-20, S-22, and W-02. Subwatersheds with the highest annual pollutant loads tend to be those that do not have existing stormwater management in place. The untreated subwatersheds also offer the greatest margin for improvement.

The table on the next page (Page 29) shows the existing TSS load by subwatershed. A corresponding map of TSS loading is included in the Appendix (Figure 5). It is clear from this image that the industrial properties (west side of the map) contribute some of the largest TSS loads. The City may find industrial property owners open to coordinating on projects that help them achieve their required treatment level. The MPCA maintains an online tool to access environmental information called “What’s in My Neighborhood”. A link to the Website is included in the references section. Any individual with a computer can search a neighborhood, using an interactive map, for businesses with a NPDES Industrial Stormwater Permit (I-SW-Permit).

Some of the lowest loading rates are from parks and open green space. Most of these areas are owned by the City but don’t offer the best opportunity to improve stormwater management. In some areas, this green space can be used to divert storm sewer pipes into underground treatment systems.

The table on the next page (Page 29) also shows the existing TP load by subwatershed. A corresponding map of TP loading is included in the Appendix (Figure 6). Similar to the TSS loading map, green space contributes the lowest TP loading and the industrial properties (west) contribute higher loads. The TP loading varies slightly from the TSS loading for the residential properties. This may be due to the number of stormwater ponds that are used to treat runoff in this area. Stormwater ponds are very effective at removing TSS and phosphorus but approximately half of TP is dissolved phosphorus which is not trapped in stormwater ponds.

EXISTING CONDITIONS

Watershed Name	Watershed Area (Ac)	Percent Impervious	Existing TSS Load (lbs/ac/yr)	Existing TP Load (lbs/ac/yr)
N-01	12.0	64.8%	175	1.0
N-02	9.7	85.0%	523	1.8
N-03	6.4	90.0%	553	1.9
N-04	8.1	40.0%	247	0.8
N-05	15.5	40.0%	247	0.8
N-06	14.2	53.6%	330	1.1
N-07	11.0	53.6%	330	1.1
N-08	20.2	35.0%	216	0.7
N-09	32.2	28.3%	175	0.6
N-10	2.5	85.0%	522	1.8
N-11	30.7	16.0%	100	0.3
N-12	10.7	40.0%	247	0.8
N-13	67.7	40.0%	247	0.8
S-01	16.0	86.7%	82	0.8
S-02	53.2	64.8%	399	1.3
S-03	12.5	57.9%	357	1.2
S-04	46.7	65.0%	400	1.3
S-05	23.9	59.9%	369	1.2
S-06	12.5	44.6%	20	0.4
S-07	5.3	65.4%	402	1.3
S-08	15.5	65.4%	403	1.4
S-09	48.8	38.6%	238	0.8
S-10	5.0	37.1%	229	0.8
S-11	6.0	70.5%	142	0.8
S-12	11.0	64.6%	56	0.6
S-13	1.2	66.0%	31	0.6
S-14	15.0	80.0%	492	1.7
S-15	42.9	72.0%	443	1.5
S-16	8.5	72.0%	253	0.8
S-17	14.9	72.0%	776	2.6
S-18	4.2	72.0%	202	1.2
S-19	5.6	72.0%	443	1.5
S-20	8.4	72.0%	149	1.0
S-21	22.9	72.0%	443	1.5
S-22	7.4	60.0%	80	0.7
S-23	8.5	20.0%	124	0.4
W-01	6.4	85.0%	523	1.8
W-02	4.7	72.0%	277	1.3
W-03	35.8	80.0%	492	1.6
Total	**684**	**56.2%**	**309**	**1.1**

Existing TSS and TP loadings by subwatershed presented as pounds per acre per year.
Images of this data on a map are included in Appendix A.

ASSESSMENT

FUTURE POSSIBILITIES

The future possibilities model incorporates new green infrastructure in the existing conditions model to demonstrate what can be achieved in different applications. The new green infrastructure was designed to meet MIDS where practical. Potential SSGI locations are described on pages 32-38. The new stormwater management practices are placed strategically within the subwatersheds to capture the most runoff. If all of the proposed practices were developed, the City of Brooklyn Center would reduce TSS loads by 68,000 pounds per year and TP loads by 180 pounds per year. Subwatersheds where MIDS was met achieved greater than 80% TSS load reduction and greater than 50% TP load reduction annually. These subwatersheds include N-01, N-02, N-03, N-04, N-0, N-06, N-07, N-13, and S-08.

The table on the following page (Page 31) shows the TSS and TP reductions per subwatershed. Corresponding maps of TSS and TP loadings are included in the Appendix (Figures 7 and 8 respectively). White subwatersheds receive no additional treatment. This may be because there are existing BMPs in the watershed, treatment was not feasible, or space was limited.

LIMITATIONS AND ASSUMPTIONS

Due to limited information, potential SSGI locations shown in the following section require further investigation before they can be implemented. Topography, soil types, utilities, and future land use is needed to proceed with final design. The recommended SSGI designs were placed with the intention to fit the landscape and meet MIDS where possible. The results of a final design may vary slightly from what is proposed in this report.

Based on NRCS Web Soil Survey Wenck determined that soil types were mostly sandy. Consequently, Wenck assumed an infiltration rate of 1.0 inches per hour where infiltration appears feasible. A detailed soil investigation to determine soil type and groundwater elevations is needed before design of any infiltration practice. Infiltration is prohibited in wellhead protection areas and filtration techniques will be used. All of the proposed practices can be retrofitted with a sand filter and underdrain if infiltration is not feasible.

Watershed Name	Watershed Area (Ac)	Percent Impervious	TSS Load Reduction (lbs/ac/yr)	TSS Load Reduction (%)	TP Load Reduction (lbs/ac/yr)	TP Load Reduction (%)
N-01	12.0	64.8%	149	85.2%	0.3	33.3%
N-02	9.7	85.0%	445	85.2%	1.0	57.6%
N-03	6.4	90.0%	471	85.2%	1.4	73.8%
N-04	8.1	40.0%	210	85.2%	0.5	57.3%
N-05	15.5	40.0%	210	85.2%	0.5	57.3%
N-06	14.2	53.6%	281	85.2%	0.6	57.2%
N-07	11.0	53.6%	256	77.6%	0.6	52.4%
N-08	20.2	35.0%	0	0.0%	0.0	0.0%
N-09	32.2	28.3%	0	0.0%	0.0	0.0%
N-10	2.5	85.0%	0	0.0%	0.0	0.0%
N-11	30.7	16.0%	25	24.7%	0.1	22.5%
N-12	10.7	40.0%	0	0.0%	0.0	0.0%
N-13	67.7	40.0%	242	98.0%	0.8	90.5%
S-01	16.0	86.7%	57	70.0%	0.6	70.0%
S-02	53.2	64.8%	98	24.5%	0.2	14.3%
S-03	12.5	57.9%	0	0.0%	0.0	0.0%
S-04	46.7	65.0%	189	47.2%	0.4	27.5%
S-05	23.9	59.9%	5	1.5%	0.0	1.3%
S-06	12.5	44.6%	14	70.0%	0.3	70.0%
S-07	5.3	65.4%	393	97.7%	1.2	91.5%
S-08	15.5	65.4%	51	12.8%	0.2	12.4%
S-09	48.8	38.6%	6	2.7%	0.0	2.6%
S-10	5.0	37.1%	0	0.0%	0.0	0.0%
S-11	6.0	70.5%	0	0.0%	0.0	0.0%
S-12	11.0	64.6%	0	0.0%	0.0	0.0%
S-13	1.2	66.0%	0	0.0%	0.0	0.0%
S-14	15.0	80.0%	0	0.0%	0.0	0.0%
S-15	42.9	72.0%	0	0.0%	0.0	0.0%
S-16	8.5	72.0%	189	74.6%	0.5	58.7%
S-17	14.9	72.0%	538	69.4%	1.4	52.0%
S-18	4.2	72.0%	0	0.0%	0.0	0.0%
S-19	5.6	72.0%	0	0.0%	0.0	0.0%
S-20	8.4	72.0%	0	0.0%	0.0	0.0%
S-21	22.9	72.0%	179	40.4%	0.5	31.8%
S-22	7.4	60.0%	0	0.0%	0.0	0.0%
S-23	8.5	20.0%	0	0.0%	0.0	0.0%
W-01	6.4	85.0%	0	0.0%	0.0	0.0%
W-02	4.7	72.0%	0	0.0%	0.0	0.0%
W-03	35.8	80.0%	142	28.9%	0.3	16.9%
Total	**684**	**56.2%**	**107**	**34.6%**	**0.3**	**25.9%**

Potential TSS and TP load reductions by subwatershed presented as pounds per acre per year. Images of this data on a map are included in Appendix A.

LOCATIONS

POTENTIAL SSGI LOCATIONS

Wenck staff evaluated locations to implement new SSGI that could be coordinated with the City street reconstruction. Locations were selected to achieve the greatest treatment, to fit the landscape, and present a variety of options in different settings. The practices identified in this report should not be viewed as the full extent of stormwater improvement that can be achieved. Instead, the potential locations are presented as a menu of options that can be used interchangeably throughout the City. In addition green infrastructure was placed in an attempt to illustrate the potential for shared, stacked-function, green infrastructure to service multiple properties. The whole study area is within a Wellhead Protection Area which may limit infiltration. In the event that infiltration is not practicable, all of the proposed SSGI can be designed for filtration.

POTENTIAL LOCATIONS - NORTH

Figure 2 in the appendix shows the north portion of the study area and the proposed locations for SSGI. This area includes a groundwater sensitive area where infiltration is not allowed. The future site of the regional water treatment facility is also located within this area. These subwatersheds all direct runoff to the east and into the Mississippi River.

Subwatershed N-13 is a large residential district with no existing green infrastructure. The streets in this subwatershed are scheduled to be fully reconstructed in 2017. Full reconstruction of streets is a great opportunity to install practices like the infiltration trench (IT) shown in the street ROW of watershed N-13 (see page 14 for more details) . When the area is being designed for reconstruction, locations with minimal underground utilities should be identified. These places would be ideal for infiltration trenches. The infiltration trench would be installed in-line with the storm sewer or flow would be bypassed into a separate pipe system. If the infiltration trench cannot be placed outside of the 1-year Emergency Response Area, filtration will be used instead. Placing infiltration trenches in streets that are being reconstructed adds to the ease of maintenance and construction. The City does not need to acquire separate property rights and the trench can be maintained using equipment the City already regularly uses, like vacuum trucks. Wenck estimates this practice would remove 1,300 pounds of TSS per year and 4 pounds of TP per year.

This neighborhood (subwatershed N-13) should also be considered for additional rain garden installation. There is one existing curb cut rain gardens in this area but as the area is reconstructed, more opportunities may become available.

Large regional treatment facilities are proposed in two locations: one in each N-06 and N-08. Both of these facilities would be underground filtration (UG) basins that receive runoff by diverting runoff from the storm sewer. They are both located in the Emergency Response Area so infiltration is not practicable. Because the streets are scheduled to be reconstructed in 2017, these practices would be implemented when the storm sewer is replaced on the roads. The new storm sewer would include diversion pipes that route runoff into the underground infiltration basins.

POTENTIAL LOCATIONS - NORTH

The SSGI in N-06, labeled UG, is located under the parking lot of a local church. Implementing this design would require coordinating and negotiating with the church leadership. Including the replacement of the parking lot may increase the church's desire for this project to progress. The underground infiltration basin would treat runoff from the church, the neighboring apartment complex and the surrounding neighborhood. Wenck estimates that this system has the potential of removing 9,400 pounds of TSS and 29 pounds of TP per year.

The SSGI in N-08, labeled UG, would be located on property owned by the City of Brooklyn Center and is undeveloped. Implementation may be easier of this parcel and it is undeveloped. Similar to the one located in N-06, this underground infiltration basin would receive runoff from multiple pieces of property including neighborhoods, the Evergreen Park Elementary School, and streets. Wenck estimates this practice would remove 10,100 pounds of TSS and 31 pounds of TP per year. The orientation of the basin can be adjusted so that it is not located under any playing fields. Together, the three proposed practices in this area would meet MIDS for watersheds N-6, N-11, and N-13.

POTENTIAL LOCATIONS - WEST

Figure 3 in the appendix shows the west portion of the study area and the proposed locations for SSGI. This area is largely industrial and commercial which have high percentages of impervious area. Three watersheds in this area discharge to the west to Shingle Creek. The remaining portion discharges to the east to the Mississippi River.

Some of the streets in this area were recently reconstructed and don't offer a good opportunity for redevelopment. There is one section of street that is scheduled for mill and overlay in 2027, but this street is heavy in underground utilities which is not Ideal for implementing SSGI in the street right of way. However, these streets could be retrofitted with grit chambers to help improve TSS removal from multiple properties. The remaining options require that the City coordinate with private industries.

In Subwatershed N-01 an infiltration basin (IB) is proposed on green space owned by an apartment complex. This infiltration basin is designed to receive runoff from 69th Avenue North which is scheduled for mill and overlay in 2017. By reconstructing a portion of the street, stormwater would be diverted to the infiltration basin. The infiltration basin would treat runoff from the street and some of the adjacent apartment complex. Wenck estimates this SSGI would remove 2,000 pounds of TSS per year and 7 pounds of TP per year. This project would require an easement from the apartment complex. To entice the owner, the project could include a walking park for residents.

A filtration trench (FT) is proposed in the street right of way on Shingle Creek Parkway in subwatershed W-03 (See Page 14 for more information). Shingle Creek Parkway was recently reconstructed, so this practice should be viewed as an option if the opportunity presents itself or if it can be implemented elsewhere. Wenck assumed that the groundwater level is too high for infiltration due to its proximity to the creek so filtration

POTENTIAL LOCATIONS - WEST

would be necessary. The location of this practice allows the SSGI to treat runoff from two properties and the street. Wenck estimates this SSGI would remove 5,100 pounds of TSS and 10 pounds of TP annually.

An infiltration trench (IT) is proposed in each of the subwatersheds S-16, S-17, and S-21. These infiltration trenches are all similar in design but show the versatility of this practice where space is limited and property owners may be adverse to losing space to storm-water management. These projects illustrate that a joint effort could be mutually beneficial. These infiltration trenches would help the City meet the goals of the WMWMC and help the property owners meet WMWMC stormwater management requirements associated with future development. Property owners may be further convinced to participate in the future as NPDES permits become more stringent. The trenches would replace a section of storm sewer located in a private property. When designed to meet MIDS, Wenck estimates the trench in S-17 would reduce TSS loads by 2,800 pounds per year and TP loads by 7 pounds per year.

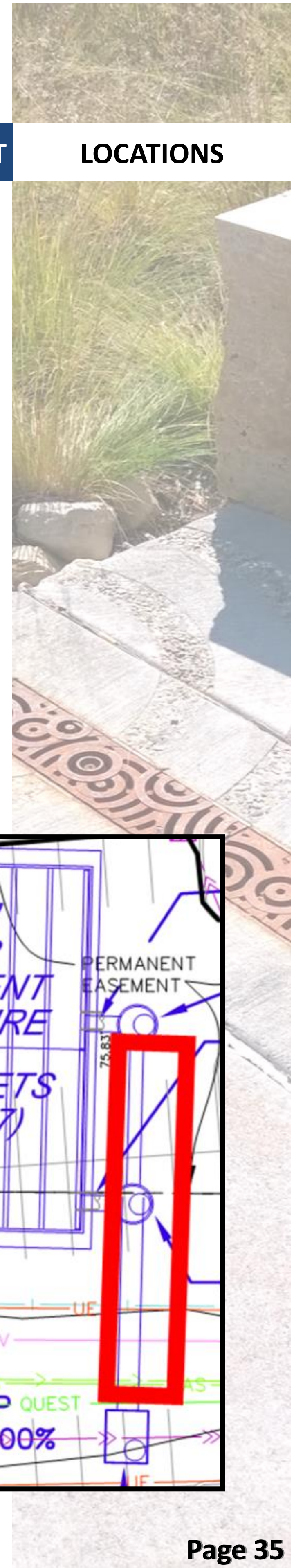
Two infiltration trenches are located on private roads in watersheds S-16 and S-21. Again, these trenches would replace the existing storm sewer and runoff collected by the storm sewer would flow to the infiltration trenches. The trench in S-21 would remove 4,100 pounds of TSS and 11 pounds of TP annually. The trench in S-16 would remove 4,600 pounds of TSS and 12 pounds of TP annually. These three infiltration trenches may need to be designed as filtration trenches if historical contamination proves to be a concern.

Finally, in S-08 a Minnesota Filtration Basin (FB) is proposed on a parcel that is currently green space. This basin would serve to treat runoff from the adjacent apartment complex and could be shared by other surrounding properties in the future. This project is in a prominent location and would manage stormwater and offer park space for the residents of the apartment complex. If treating only the apartment complex, Wenck estimates this basin would remove 300 pounds of TSS per year and 2 pounds of TP per year. As the surrounding area has need of stormwater management, this facility would be expanded to offer more treatment.

POTENTIAL LOCATIONS - EAST

The figure on the next page shows the east portion of the study area and the proposed locations for SSGI. This area includes Brooklyn Center High School and Firehouse Park. The majority of the east portion of the study area is residential with interspersed commercial land use. The entire area drains to the storm sewer along 65th Avenue North which discharges to the Mississippi River.

Two ponds are proposed with retrofits for Minnesota Filter Benches (MF) . One is proposed in watershed S-01 and one in S-06. The filter bench is ideal for stormwater ponds because it increases the efficiency of an existing system. Wenck estimates that the bench in S-01 would reduce TSS loads by 900 pounds and TP loads by 10 pounds per year; the one in S-06 would reduce TSS loads by 200 pounds and TP by 3 pounds per year. While both of these load reductions seem low, the Minnesota Filter has the added benefit of

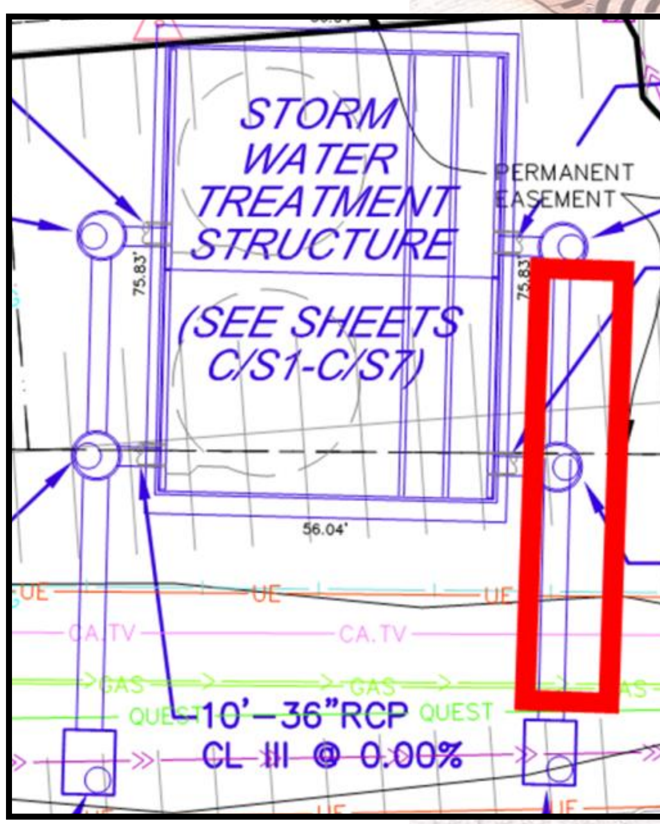


trapping organic material. The Minnesota Filter has not been specifically studied for removal of bacteria but it is known to trap organic material which may include bacteria. Watershed S-01 is a large parking lot which would accumulate food waste. Similarly, watershed S-06 is an open athletic field. Both of these subwatersheds would attract wildlife like birds and rodents whose waste would increase the bacteria load in runoff. By retrofitting these ponds with Minnesota Filters, Wenck hypothesizes the bacteria loads would also be reduced. The recommendations provide more detail on bacteria removal.

Pervious pavement (PP) is proposed in a parking lot in Firehouse Park or subwatershed S-05. The pervious pavement is designed to cover the western third of the parking lot. Runoff from the remaining portion of the parking lot would flow to the pervious pavement where it would infiltrate. Wenck estimates this practice would reduce TSS loads by 130 pounds per year and TP loads by 1 pound per year.

Flow from 65th Avenue North storm sewer is diverted into two large Vortech grit chambers, located in the Regal Cinema parking lot. This grit chamber was designed to manage runoff from a large watershed (approximately 410 acres). The City removed accumulated sediment from the grit chamber during the winter of 2014-2015. This maintenance may prove to reduce pollutant loads including bacteria. This grit chamber may be linked to high bacteria levels in runoff. Regular maintenance will help prevent the Vortech chambers from becoming a source of bacteria.

To further reduce the bacteria levels in runoff leaving the grit chamber, an infiltration trench (IT) has been designed as a retrofit (shown in detail - right). This is located in watershed S-01 on the Figure 4 of the Appendix. The red area in the figure to the right denotes where storm sewer pipe can be converted to a perforated pipe with an infiltration trench. The existing pipe has very little slope which makes it ideal for an infiltration practice and the perforated pipe will allow overflow to leave structure. This location has a number of other utilities which limit the size of the infiltration trench. The retrofit will mostly serve as a secondary treatment to infiltrate runoff and any bacteria it contains. That runoff would otherwise have passed through to the Mississippi River. The system would reduce TSS loads by 5,400 pounds per year and TP loads by 4 pounds per year.



Retrofit design for the grit chamber in the Regal Cinema parking lot.

Bacteria loadings vary greatly based on the wildlife present and activities taking place. A thorough investigation would be needed to evaluate the source of bacteria in order to effectively model loading rates. It is assumed that water passing through the grit chamber in S-01 has elevated levels of bacteria because it is tributary to the Mississippi outfall

POTENTIAL LOCATIONS - EAST

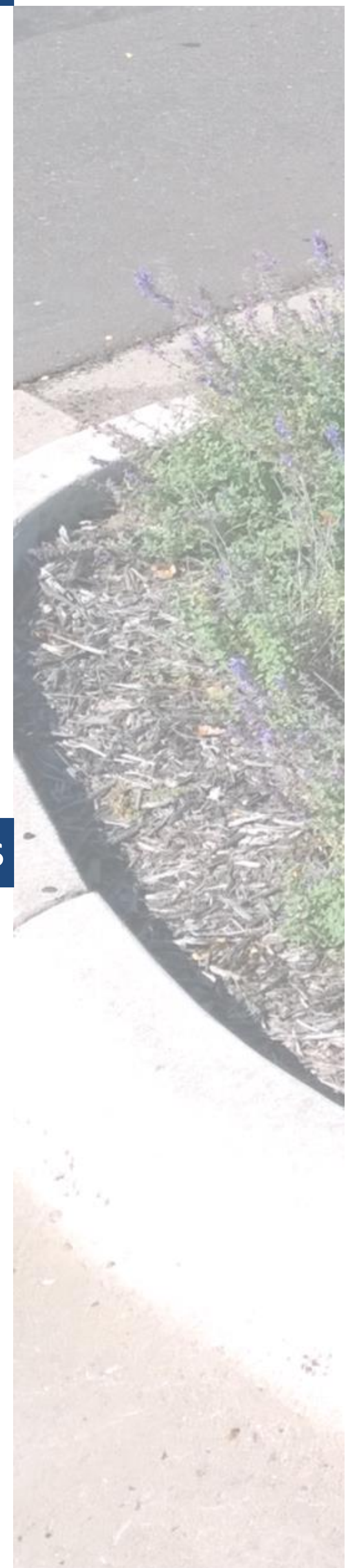
where sampling indicates bacterial contributions that exceed the desired water quality level. Recent maintenance of the grit chamber should reduce bacteria loads by trapping sediment. Recent research suggests enhanced survival of *E. Coli* in sediments including those in urban drainage systems (USEPA, 2001). Reducing TSS in turn has the effect of trapping bacteria like *E. Coli.*

Subwatershed S-04 is scheduled for street reconstruction in 2018. The storm sewer for this subwatershed is all routed down Bryant Avenue North where an infiltration trench (IT) would treat runoff for a large number of homes and streets. Bryant Avenue North has utilities in the street right of way, but there is green space available to the east. This property is owned by an apartment complex. If an easement were secured, Wenck estimates this practice would remove 8,800 pounds of TSS and 17 pounds of TP annually. A similar practice (IT) would be implemented in the neighborhoods of watershed S-02 which is also scheduled for reconstruction in 2018.

Tree trenches (TT) have been proposed along 65th Avenue North (watershed S-07) and Humboldt Avenue North (watershed S-09). Neither of these streets are scheduled for reconstruction in the foreseeable future. The tree trenches would be designed to capture runoff from the street before it enters the storm sewer. These tree trenches would also greatly enhance the aesthetics of two main streets in the City. This may be a good opportunity to incorporate the Stockholm Tree Trench design which is relatively new to the area and gaining traction. The tree trenches on 65th Avenue North would remove 800 pounds of TSS and 3 pounds of TP per year. The tree trenches on Humboldt Avenue North would remove 300 pounds of TSS and 1 pound of TP annually.

Finally, there is an undeveloped area at the north end of watershed S-23. This is privately owned property but has remained undeveloped due to wetlands in the area. It may be advantageous to coordinate with the land owner to develop a stormwater pond (STP) with Minnesota Filter Bench to treat all runoff passing through the storm sewer in 69th Avenue North. Flow in this storm sewer would be diverted into the stormwater pond where overflow would be filtered by the Minnesota Filter Bench before continuing east to the Mississippi River. The proposed design follows NURP guidelines and would remove 16,000 pounds of TSS per year and 36 pounds of TP per year.

RECOMMENDATIONS



The City of Brooklyn Center is planning for future street reconstruction and seeking to improve water quality in conjunction with that reconstruction. In collaboration with the WMWMC, the City is dedicated to implementing green infrastructure meant to improve stormwater management throughout the City. The City initiated this study to outline alternatives for the development of shared, stacked-function green infrastructure (SSGI) for stormwater management which will streamline the design process as projects become available. To help guide the design process, Wenck has created a menu of options that the City can choose to pursue.

The proposed SSGI were designed to fit the landscape and meet Minimum Impact Design Standards (MIDS). If all of the proposed practices were implemented the City would reduce TSS loads by 68,000 pounds per year and TP loads by 180 pounds per year. This green infrastructure should be viewed as opportunities as well as examples of how green infrastructure can be implemented elsewhere.

To help achieve final implementation of some of these designs, Wenck recommends that the City start forming relationships with as many, if not all, of the businesses in this area. Those partnerships could result in shared interests being met and larger goals being accomplished. Wenck also suggests that the City use this study as a starting point for future stormwater management development. The examples of SSGI demonstrated in this report would function in other parts of the City as well.

PHOSPHORUS AND SUSPENDED SOLIDS

The table on the following page is a priority list of practices that can be used to gauge the value of each proposed practice based on the cost to construct and the amount of phosphorus removed. Other factors affecting the priority of different options are herein discussed. The list notes projects that require easements or interaction with property owners with an asterisk (*).

Wenck recommends, based on a pollutant removal basins, the first priority should be given to the stormwater pond (STP) at the north end of watershed S-23. This practice treats the largest combined watershed, has a good cost to effectiveness ratio and removes a large amount of pollution annually. If an easement cannot be secured with the property owner, there may be an opportunity to coordinate with MnDOT to place the pond within the ROW of Highway 252.

Priorities 2, 3 and 4 are infiltration trenches that coordinate with City street reconstruction projects. The infiltration trenches in N-13 and S-02 are both within the street ROW and have a good cost to pollutant removal ratio. The trench in S-04 would require an easement which would increase the cost effectiveness of this project. However, the project coordinates with street reconstruction raises its priority level.

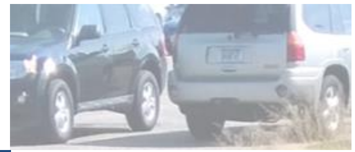
The remaining green infrastructure is prioritized by cost per pound of TP removed with the exception of FT-01. This filtration trench is given a low priority because it would require construction within Shingle Creek Parkway which was recently reconstructed.

Priority	Location Watershed	Practice Type (Map label)	Construction Cost	TP Removed (lb/yr)	Cost/ Pound TP	Practice Size (sf)	Retention Volume (cf)	Annual Maintenance Cost
1*	N-05	Stormwater Pond (STP)	$263,200	36.4	$7,231	73,500	350,900	$2,500
2	N-13	Infiltration Trench (IT)	$91,700	4.3	$21,326	2,300	9,100	$2,500
3	S-02	Infiltration Trench (IT)	$120,000	10.2	$11,765	3,000	12,000	$2,500
4*	S-04	Infiltration Trench (IT)	$159,900	17.3	$9,243	4,000	16,000	$2,500
5*	N-01	Infiltration Basin (IB)	$42,800	6.5	$6,585	10,400	13,100	$2,500
6*	S-16	Infiltration Trench (IT)	$120,000	11.5	$10,435	3,000	12,000	$2,500
7*	S-17	Infiltration Trench (IT)	$80,000	7.4	$10,811	2,000	8,000	$2,500
8*	S-21	Infiltration Trench (IT)	$120,000	10.8	$11,111	3,000	12,000	$2,500
9	N-08	Underground Infiltation (UG)	$624,600	31.3	$19,955	15,600	62,400	$5,000
10*	N-06	Underground Infiltation (UG)	$605,800	29.4	$20,605	15,100	60,500	$5,000
11	S-05	Pervious Pavement (PP)	$8,600	0.4	$21,500	400	860	$1,000
12	W-03	Filtration Trench (FT)	$91,700	10.0	$9,170	2,300	9,100	$2,500
13	S-07	Tree Trench (TT)	$197,700	2.6	$76,038	3,900	7,900	$5,000
14	S-09	Tree Trench (TT)	$131,800	1.0	$131,800	2,600	5,200	$5,000
15*	S-08	Filtration Basin (IB)	$205,400	0.3	$684,667	2,000	14,000	$2,500
16		Grit Chamber (GC)	$6,000	-	-	30		$300

Cost estimate for proposed practices and cost per pounds of TP removed. The proposed practices are identified by the watershed that they are located in. Column 3 shows the abbreviations used in Figures 2-4 in the Appendix. General sizing and retention volumes are included for design purposes. Asterisk (*) indicates a project requiring private property cooperation.

The City may find industrial property owners open to coordinating on projects that help them achieve their required treatment level.

The MPCA maintains an online tool to access environmental information called “What’s in My Neighborhood”. A link to the Website is included in the references section. Any individual with a computer can search an area, using an interactive map, for businesses with an NPDES Industrial Stormwater Permit (I-SW-Permit). When a business is permitted to discharge industrial activity impacted stormwater, the I-SW-Permit may require



PHOSPHORUS AND SUSPENDED SOLIDS

sampling of the stormwater at a outfall location. The parameter(s) a business must collect samples for, varies by the industrial activities conducted at the facility as defined in the I-SW-Permit. If the stormwater is sampled and exceeds the annual average benchmark limit, then the facility must make improvements (BMPs, non-structural, or/ and structural) to reduce the discharge of a particular water quality parameter.

By reviewing sites' monitoring the City could identify which properties must make improvements. The City could then implement a program that offers funds for structural stormwater treatment based on quantity of TSS, TP, and/or bacteria load reduction. These practices may exceed the requirements of the requirements of the I-SW-Permit in which case the City may need to increase cost sharing. To monitor the benefit of the stormwater management, the applicant would need to establish a sampling plan that demonstrates effective use of funding.

BACTERIA

In the goal of reducing bacteria loads, it is important to understand that improvements to other water quality parameters can achieve reduced bacteria loads. Trapping particulate matter in stormwater runoff has the added benefit of trapping bacteria. Recent research suggests enhanced survival of *E. Coli* in sediments including those in urban drainage systems (USEPA, 2001). Bacteria like *E. Coli* tend to grow on surfaces like particulates that runoff in storm events. When these particulates (TSS) are trapped, any attached bacteria are trapped as well. Quantifying the reduction of bacteria loads due to trapped sediment would require knowledge of the source and loading rates which are very site/situation specific.

Wenck is committed to helping the City achieve bacteria removals and will continue to seek options for bacteria removal from stormwater. In order to take more measurable steps toward meeting the bacteria TMDL, Wenck proposes several practical options that will have a measurable impact on bacteria levels in the City. The following is a list of steps the City can take to start improving bacteria levels in the City.

- *Source Assessment* - The first step in reaching the goal of reducing bacteria concentrations in stormwater discharge is to understand where issue starts. Source assessment is important for establishing goals, learning where to focus the City's efforts, and how to best meet established goals. Sources of bacteria in urban runoff can be very broad including wildlife, pets, sewer overflow, sediment, and/or drainage lines. Recent studies have demonstrated that subsurface concrete and PVC drainage lines can be sources of enterococcus to storm water (Schultz-Fademrecht et. al 2010).

- *Reduce I&I* - Inflow and Infiltration (I&I) can cause bacteria from surface soils to enter the storm sewer. Continued improvement of the City's sewer infrastructure will help limit the amount of bacteria entering the storm sewer.

- *Doggy Bags* - A capital improvement project geared toward reducing animal and pet waste left in the open would reduce fecal matter as a source of bacteria.

This project could include placing trash bins and plastic waste bags throughout public walking areas. This will promote pet and animal owners to place waste in the trash rather than leaving it in the open where it could runoff in a storm event and elevate bacteria loads.

- *Active Treatment* - Traditional treatment options of bacteria and pathogens in wastewater can be implemented on a smaller scale to help improve water quality. While dosing stormwater with chlorine is not ideal, ultraviolet (UV) light systems may help kill harmful bacteria in runoff. Further investigation is needed, but a solar powered UV system could be installed in the grit chamber in watershed S-01 to treat runoff as it passes through.

- *Research* - This study also offers passive stormwater management options that have the potential to reduce bacteria loads in runoff. These practices are not proven and would require continued monitoring to determine their effect. The following table lists options by priority level that could have a positive impact on bacteria loads.

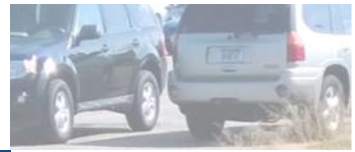
Priority	Watershed	Practice Type	Construction Cost	Practice Size (sf)	Retention Volume	Annual Maintenance Cost
1	S-01	Infiltration Trench (IT)	$64,000	800	3,200	$2,500
2*	S-06	Minnesota Filter (MF)	$49,000	1,900	-	$2,500
3	S-01	Minnesota Filter (MF)	$476,000	18,000	-	$2,500

Cost estimate for proposed practices that have the potential for bacteria reduction. The proposed practices are identified by the watershed that they are located in. Column 3 shows the abbreviations used in Figures 2-4 in the Appendix. General sizing and retention volumes are included for design purposes. Asterisk (*) indicates a project requiring private property cooperation.

The retrofit to the grit chamber in the Regal Cinema parking lot should be given the highest priority. This practice would have one of the most immediate impacts on bacteria loads in the City because it treats a very large watershed. The design would convert a concrete pipe into a perforated pipe that allows infiltration. By infiltrating runoff, associated bacteria and phosphorus loads would be reduced as well. Research has suggested that bacteria in groundwater have a maximum survival of 1 year (Gerba and Bitton, 1994). As a result, infiltration of runoff containing bacteria would not effect drinking water supply as long as it occurred outside of the 1-yr Emergency Response Area (Figure 1).

Two Minnesota Filtration Benches should be given the next highest priority. Again, they are not the most cost effective options in regards to other pollutants, but they may help meet the bacteria TMDL. A cheaper alternative would be to install the draintile but allow the native soil to filter stormwater. This may have a similar result.

As the City becomes aware of another bacteria sources, technologies in this report may be effective means of reducing bacteria loads.



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APPENDIX A SUPPORTING FIGURES